IPC-9850

Surface Mount Equipment Characterization

Assembly Equipment Sub-Committee (5-41)

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1 Introduction

1.1 Scope

This standard establishes the procedures to characterize machine placement capability of surface mount assembly equipment in specification documents, as well as in documentation used to verify a specific machine's placement capability conformance to the specification, while maintaining a placement accuracy to placement speed 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 characterization parameters. These standardized tools **shall** be used to develop and report the information called out in this standard.

1.3 Background

With the proliferation of Surface Mount Technology (SMT), placement equipment users have struggled with the question of which machine will perform best in a given manufacturing environment. The advantage of the SMT assembly process to rapidly place components in precise alignment to the land patterns on the printed wiring board (PWB) was the initial yardstick by which machines were selected. Machines that could place components the quickest and with the least amount of scrap were considered the best.

Initially, the most common evaluation method was placement yield. For this evaluation, a machine is made to populate a large number of the user product where visible placement errors are counted as defects. Machines with the least defects and the most robust operation were considered best. The high yield and reliability of modern SMT placement systems require that very large amounts of data be collected to meaningfully assess yield and reliability. This standard provides new tools for gauging the yield and reliability of placement equipment yet presents performance results in the traditional metrics.

In addition to the high yield and reliability expected of modern placement equipment, the SMT assembly process has become significantly more demanding. Components have decreased in size, component terminations are smaller, and placement locations have moved closer together. All this while the number of components on the PWB and product volumes have increased significantly. Placement equipment must now place components more rapidly and with extreme precision to be financially viable. This has made requirements on placement machines more demanding.

Historically, placement equipment vendors have selected their own parameters and methodologies to present the specification of their machines' throughput and placement capabilities. The many representations of this information have made the comparison between similar types of placement machines very difficult. To obtain comparable data, users have been forced to conduct on-location evaluations of various machines under the same conditions. This type of methodology is very time consuming for users and very capital intensive for suppliers.

This standard simplifies the evaluation process by standardizing the performance parameters that describe the placement machines' capabilities. It also couples placement throughput and placement quality so speed and accuracy parameters are dependent on each other. This standard also specifies the methodologies by which the capability parameters are measured. This reduces potential user-vendor friction created when the user believes the equipment is not functioning properly. The methodologies specified herein are consistent and verifiable, thus providing common-ground-methodologies between users and vendors.

These methodologies were achieved by separating machine performance from the rest of the SMT process variables, which include paste printing, component quality, packaging type and PWB quality. The speed and quality 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 information that can be utilized to perfectly predict production quality, this methodology was selected in order to remove as much of the variation as possible between facilities, products, process, and operators.

While the ultimate goal is to evaluate a machine's capability to place components in paste on actual PWBs, it is not currently possible to make such measurements at the required precision and speed. It is anticipated that future in-line inspection systems will improve in their ability to measure component location and orientation. In the future it may become possible to use in-line post-placement (pre-reflow) automatic optical inspection (AOI) systems to measure the placement machine capabilities.

Due to the convergence of high-speed and fine pitch machines, this standard makes no attempt to separate the two types of machines. The user is empowered to decide if a particular model is the best solution for the application based upon the data reported by the supplier.

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 is 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.

1.4.3 Test Components Five component types --QFP-100, QFP-208, BGA-228, 1608C capacitor, and SOIC-16 --were selected to represent the range of component types placed by surface mount equipment. See Table 3-1 and section 6 for more precise documentation of these component types.

During the verification of a placement machine, one of the goals is to assess the error induced by the placement machine. To isolate the contribution of the surface mount equipment to the placement error, which is what this standard intends to hold suppliers accountable for, it is desirable to reduce other effects that may contribute to the placement error evaluation process. Using nearly perfect components can best reduce the effect of components on placement error evaluation. Such components minimize the error associated with SMT component-to-component variation. For instance, 1608C chip capacitors were chosen as test components because the sides of the capacitors are very precisely and squarely fabricated. Chip resistors were not selected because they are fabricated in a way that the top edges of the component seen by the vision CMM may not be in good registration with the side or bottom features of the component used by the placement machines. The electrodes of ceramic chip capacitors are somewhat problematic because of their bulbous shape.

SOIC-16 integrated circuits were selected as a standard component because of their relatively low cost and sturdy construction. SOIC-16 components are believed to be representative of a broad class of coarse pitch leaded components. Almost all SMT placement machines are capable of processing SOIC-16 devices, so this component makes it possible to compare the performance of the various machine models. Additionally, 1608C Chip capacitors and SOIC-16s are economically available in tape packaging, which is how most users feed them because it enables most machines to maximize the placement speed. Both 1608C and SOIC-16 component types must meet the Joint Electron Device Engineering Council standard (JEDEC Solid State Technology Association, also known as JEDEC).

Glass slugs are used to present placement machine vision systems with perfect component images that are free of bent leads and other part imperfections. The glass slugs also allow the inclusion of fiducial markings that the coordinate measurement machines (CMMs) use to speed up measurements. The slug fiducial markings are measured by the CMM, instead of the actual slug component features, to represent the location of the slug component feature. The slug fiducial markings can only be used to represent the position of the slug component feature if the slug has been United States National Institute of Standards (NIST) certified to that effect. The slug fiducial markings **shall** not be processed by the placement machines during the test and are not known to interfere with the normal operation of the placement machine's vision systems. The clearly defined slug fiducial markings have the benefit of minimizing the measurement-induced portion of the total error observed by the measurement machine, and are particularly important because the specification limits for fine pitch components (QFP and BGA) are so tight.

For this standard, two QFP and one BGA slugs represent component types. Specifically, the QFP-100, QFP-208, and BGA-228 component types permit the comparison of an extended range of chip-shooters with that of specialized IC-placers and multi-functional placement systems. To maintain consistency when utilizing slugs, all slugs in the pickup trays **shall** have the same orientation.

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 that suppliers or users may wish to consider. Rules for adding claims about additional component types are presented later in this standard.

1.4.4 Test Panels The evaluation methods of this standard specify component placement into sticky media dispensed 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 PWB materials that are much more susceptible to shrinking and wrapping. The second reason is that it permits use of a standard Optical Coordinate Measurement Machine (CMM) to illuminate the outline of the components. 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 component groups (one component group at a time) for this standard:

a. 36 QFP-100,
b. 30 QFP-208
c. 100 BGA-228
d. 80 SOIC16
e. 400 1608C (Capacitors)

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 back light intensity. 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 vendor claims. They also assure the vendor that the customer is properly evaluating the machine performance. For an Optical CMM to be a capable gauge for evaluating the surface mount process, its accuracy and repeatability must be significantly higher that the accuracy and repeatability of the surface mount equipment. The measurement capabilities required by the CMM depend on the type of components being evaluated and on the specification limits that the supplier is committing to.

The accepted method for evaluating measurement system performance is called Gauge Repeatability and Reproducibility (GR&R). This methodology determines the measurement system’s ability to consistently measure the same product over and over again. The methodology requires that the measurement uncertainty (6x the 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 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 Equipment Measurement equipment that meets or exceeds the required GR&R and accuracy specification limits under the specified evaluation procedures for a specified component type is acceptable.

Automated Optical CMM machines are currently favored by many placement equipment vendors and users due to their measurement speed. The rapid measurement speed is required due the large number of measurements required to attain statistically meaningful characterization results. Although this method has been demonstrated to work well, significant limitations are recognized. The limitations restrict interpretation of the results to the actual SMT process.

Since CMMs were originally developed for a machine shop environment, their lighting systems and measurement tools are not optimized for measuring surface mount components. The machines are applied to the placement evaluation process by utilizing clear PVPs that make available high quality images on the CMM. The components are mounted onto the PVP, are illuminated, and then their positions are measured.

Limitations of the CMMs are their cost and lack of mobility. CMMs are expensive since they utilize many features that provide structural rigidity, precise position, and high quality imaging. They require delicate calibration and are sensitive to changes in the environmental conditions, which makes them non-portable.

1.4.5.2 Reporting Measurement results are recorded on standardized forms. The Placement Performance Metric is form IPC-9850-F1. This form serves two distinct functions. The first is to report the general performance by machine model type and the second is to validate the performance of a specific machine by serial number. Values for speed and accuracy that are simultaneously achievable are listed. 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.

The Reliability Performance form (IPC-9850-F2) provides an indication of typical results determined from values reported by users. Unlike the Placement Performance Metric, which cites guaranteed performance, the Reliability Performance form merely conveys typical reliability levels for the machine model type based upon a nominal amount of data collected by the placement machine supplier’s customers in their factories. But this reliability performance form does establish a foundation upon which the industry can raise the reliability, availability and maintainability of the surface mount equipment infrastructure.

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

1.6 Data Methods

With regards to the statistical treatment of placement deviation data, we have 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 limits at the two prescribed Cpk limits (1.33 and 2.0) contain some percentage of data less than the 99.9968% and 99.9999% percentages normally associated with these Cpk limits. 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 Cpks of 1.33 or 2.0.

1.7 Terms and Definitions

Additional terms and definitions are provided in Table 4-4 and 4.1.1 through 4.1.11.

Fiducials are markings on substrate materials --such as PWBs or glass-- that are utilized by the placement equipment vision systems to locate the position and orientation of the substrate.

Component refers to surface mount parts which are utilizes in the construction of electronic devices.

Placement Error is defined as 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 refers to a NIST certified glass panel with etched image of a single Component and reference fiducials.

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

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

$\mathbf{q_{dev}}$ refers to the rotational placement error (about the component’s X-Y area centroid location).

Overhang refers to the portion of the lead’s width, at the lead’s tip, that extends off of the land’s edge. Overhang I is due to placement error jointly caused by the X, Y, and θ deviations.

Assist is defined as an unplanned interruption that occurs during an equipment cycle where all three of the following conditions apply:

- The interrupted equipment cycle is resumed through external intervention (e.g., by an operator or user, either human or host computer).
- There is no replacement of a machine part (defined specifically to distinguish from component parts being placed by the machine), other than vendor specified machine consumable parts.
- There is no further variation from specifications of equipment operations.

Build Time - The amount of time it takes the machine to pick and place all the components. This time period includes fiducial read time and nozzle change time if any.

Failure is defined as any unplanned interruption or variance from the specifications of equipment operation other than assists. Specifically, some part of the placement machine has to be replaced or the machine had to be turned off and then back on in order to continue production.

Net Throughput - The number of Components Per Hour (CPH) the machine can place on the verification PVP.

Preventive Maintenance (PM) is a machine stop required by the supplier's published PM schedule.

Repeatability is defined as one standard deviation of the placement error when placing multiple components upon multiple boards.

Tact Time - The average time required to place a single component while maintaining the specified placement process capability. Excludes transfer time, fiducial time and nozzle change time.

Total Tact Time - The time required to place all components on verification glass verification panel while maintaining the specified placement process capability. Excludes Transfer Time, Fiducial Time and Nozzle Change Time.

Transfer time – The total transport time in and out of the machine, excluding the time the panel spends in the work-area.

- Movement in and out of work area
- Time to clamp/release the board in the work area

Land The termination areas on the PWB 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.

1.8 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. 1608C is equivalent to the 0603 (60milx30mil) component type.

2. Referenced Documents

IPC-A-610 Acceptability of Electronic Assemblies

IPC-SM-782 Surface Mount Design and Land Pattern Standard

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

SEMI E10-0699E Standard for Definition and Measurement of Equipment Reliability (Semiconductor Equipment and Materials International 805 East Middlefield Road Mountain View, CA 94043-4080)

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

IPC/EIA J-STD-001 Soldered Electrical and Electronic Assemblies standard (sometimes called the National Soldering Standard)

3 Placement Performance Metric

3.1 Machine Performance Form IPC-9850-F1

This form (see 7 Forms) serves two distinct functions. One is to report the general performance by machine model type. The second is to validate the performance of each machine shipped, as identified by serial number.
The top of the form is divided into two sections. At the top left is a region for identifying the vendor and machine model. At the top right there is a region for use only when the form is utilized for performance validation:

- Serial Number
- Build Date and Time

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

Section I informs of the Test Conditions during the build that generated the data reported in form Sections II, III and IV. The conditions are:

- Number of Heads/Spindles
- Type of Heads/Spindles
- Type of Camera
- Number of Feeders/Trays
- Type of Nozzles
- Number of Nozzles
- Number of Panels Built
- Number of Parts Per Panel

and describe the hardware and software setup of the equipment for the reported results.

Section II presents the time-based parameters measured during the build cycle as components are placed. The parameters are

- Build Time, seconds
- Transfer Time, seconds
- Tact Time, seconds

The Net Throughput (in CPH) also is attained from the time-based parameters.

Section III and IV present CMM measured and analyzed performance parameters attained for the panels populated during the data collection for Section II while under the equipment setup of Section I:

- Repeatability (one standard deviation)
- Accuracy Spec. Limits for Cpk=1.33 for
- Accuracy Spec. Spec. Limits for Cpk=2.0
- Cpk for Termination-to-Land 50% Coverage
- Cpk for Termination-to-Land 75% Coverage

The Repeatability and Accuracy parameters are individually calculated for the X-axis, Y-axis, and θ rotation, while the Termination-to-Land calculations integrate the X-axis, Y-axis, and θ rotation placement errors. See Section 3.4.3.2.2 (Cpk for Termination-to-Land Coverage) 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. Completed copies of this form **shall** be used as part of a placement machine model's documentation and performance package (i.e. it applies to all machines of the model type listed).

3.1.2 Performance Validation Form IPC-9850-F1 **shall** be used to validate the performance of a specific individual machine prior to customer delivery. The vendor **shall** provide the customer form IPC-9850-F1 with data for at least one component type placed by that specific machine and derived using the methodologies of this standard. The vendor **shall** provide data for the most representative component placed by that machine, or as otherwise agreed upon between the customer and the supplier. When form IPC-9850-F1 is used to validate a specific machine, the serial number of the machine and the date of the build **shall** be provided.

A specific exception is provided for the performance verification using the 1608C component type only. The exception is that the supplier may choose to measure only rows 1, 5, 9, 13, 17, and 20 (where row 1 is defined to be the first horizontal line of components above the 'IPC 9850 Verification Panel' text) per panel when verifying the performance of the shipping machine. This exception is granted in order to reduce the time suppliers spend in preparation to ship a machine, specifically to reduce the CMM measurement time and to reduce the amount of tape stretch the components on the panels waiting to be measured are exposed to after placement but prior to measurement. However, the panel must still be populated with all 400 components in according to the procedures of this standard.

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 vendor discretion. If this is done, these guidelines **shall** be followed:
1) at least 30 components/ slugs, or as many as will fit on the 8" x 8" Placement Verification Panel.
2) All 4 orientations must 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 should be used.
4) The placement pattern should be reasonably balanced, density-wise, from left-to-right and top-to-bottom.
5) For boards shall be run.
6) If the pattern contains less than 100 parts, all parts shall be measured.
7) If the pattern contains at least 100 parts, then if orientation is identical throughout a row, a systematic sample of columns must be measured for accuracy, while if orientation is identical throughout a column, then a systematic sample of rows must be measured for accuracy.

3.2 Characterization Methodology

3.2.1 Background Many methods for evaluating the performance capabilities of placement equipment have been employed in the past. The preferred method for this standard utilizes a non-contact optical CMM for measuring the location of components with respect to panel fiducials. This method was selected because many vendors and users have extensive knowledge of the method and have already developed evaluation and diagnostic tools utilizing optical CMM equipment.

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 (see 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 by the machine, as though they were four adjacent PWBs in a production environment. Machines that buffer PWBs 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 vendor'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, QFP-208 and BGA-256 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 SOIC-16 and 1608C components that are specified in Section 6.5.

3.2.1.2 Machine's Component Accommodation While the standard PVP is designed to accept a variety of component types, placement patterns are prescribed only for a single type of component per PVP. This is done to avoid a situation where certain machines are not capable of placing all of the specified components. Specific examples include high-speed placement machines that are not designed to place QFP or BGA components and fine-pitch machines that are not designed to rapidly place 1608C components. See Appendix E for the placement locations to be used for each component type.

Each supplier may apply placement optimization procedures to the order by which components are placed, which nozzle places a specific component, and which camera is utilized. However, it is expected that all spindles/ nozzles **shall** be utilized as equally as possible, and that within the placements made by a particular spindle /nozzle, all nozzle & rotation combinations **shall** be used as equally as possible (e.g. no manual manipulation to optimize the pattern to exclude certain nozzles is permitted). At the very minimum, the population of the panel only requires the use of one head and camera combination. The user has the responsibility to determine whether single or multiple head and camera combinations optimize the balance between speed and accuracy results for a model type.

3.2.1.3 Panel-to-Panel Variability To captures both "within board" and "between boards" sources of variability for each component, four-PVP 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 Test Conditions The Test Condition parameters section of IPC-9850-F1 report the machine conditions during the execution of the speed and repeatability/ accuracy procedures. These conditions are selected to provide sufficient information for a user to interpret and reproduce the documented performance.

3.3.1.1 Number of Heads/Spindles For this standard, this is the number of heads/spindles utilized by the machine during the evaluation of performance. Each head/spindle should be used approximately equally. The placement program is not to be manually optimized to avoid certain spindles or rotations. (A spindle moves up and down to pick and place components. Nozzles are attached to the end of spindles and adapt spindles to a particular range of component types. Some machines have multiple nozzle spindles. Some machines have multiple spindle heads. Other machines have multiple heads.) Report the total number of heads/spindles used.

3.3.1.2 Type of Heads/Spindles This refers to kind of heads/spindles used to align the components. (Some machines use one kind of head/spindle for fine pitch components and another kind for other components.) Report the type of heads/spindles used.

3.3.1.3 Type of Camera

For this standard, this refers to the kind of camera used to align the components. (Some machines use one kind of camera for fine pitch components and another kind for other components. Others are capable of aligning a particular component type with more than one kind of camera.)

3.3.1.4 Number of Feeders/Trays

For this standard, this refers to the number of component feeders or matrix trays utilized by the machine during the performance evaluation. (The number of feeders used affects the speed of some types of machines. Sometimes multiple feeders per part number are required to maximize the throughput.)

3.3.1.5 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.)

3.3.1.6 Number of Nozzles

For this standard, this refers to the number of nozzle utilized by the heads/spindles during the performance evaluation.

3.3.1.7 Number of Panels Built

For this standard, this refers to the number of panel populated during the evaluation of performance parameters.

Calculation Method - The number of panels is specified in the procedure to be four.

3.3.1.8 Number of Parts Per Panel

For this standard, this refers to the number of components placed on each panel during the evaluation Performance parameters.

Calculation Method - The number of component placed on each panel is specified by the placement program corresponding to the specific part type.

3.3.2 Time-Based Parameters

These parameters describe the defined time periods that a board endures during a complete cycle of placing components on a PWB (glass verification panel in this instance). Figures 3-1 and 3-2 show how these parameters are defined.

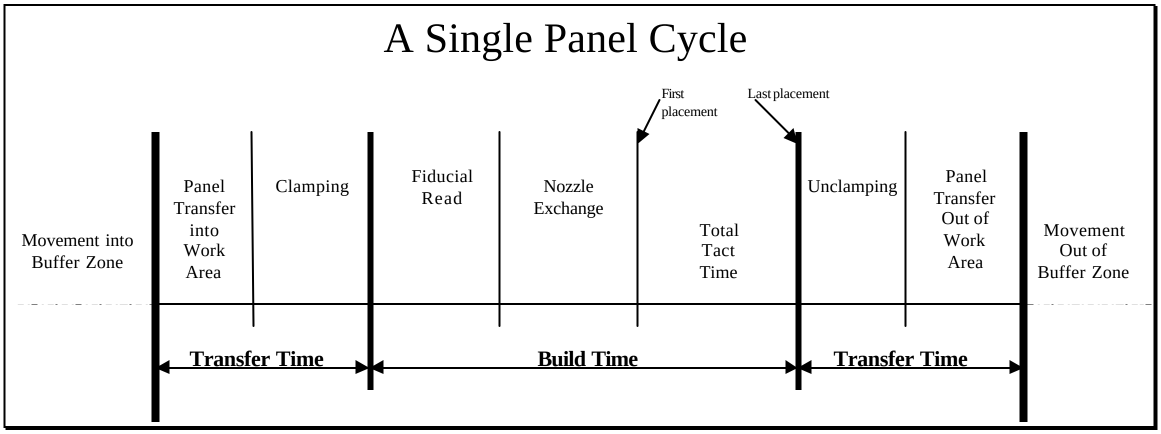

A Single Panel Cycle
First placement
Last placement
Movement into Buffer Zone
Panel Transfer into Work Area
Clamping
Fiducial Read
Nozzle Exchange
Total Tact Time
Unclamping
Panel Transfer Out of Work Area
Movement Out of Buffer Zone
Transfer Time
Build Time
Transfer Time

Figure 3-1: Performance Parameter Description for a Single Panel

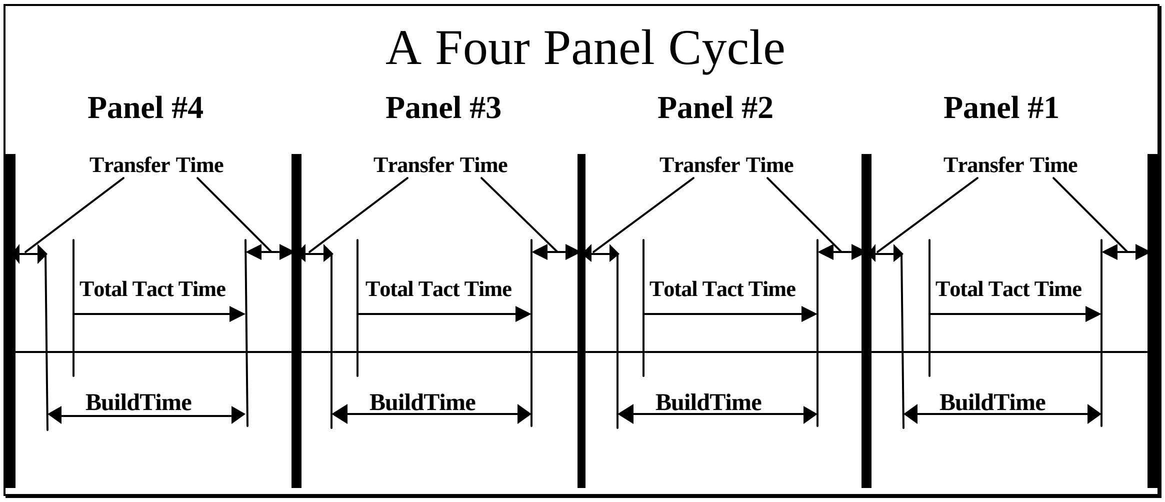

A Four Panel Cycle
Panel #4
Panel #3
Panel #2
Panel #1
Transfer Time
Transfer Time
Transfer Time
Transfer Time
Total Tact Time
Total Tact Time
Total Tact Time
Total Tact Time
BuildTime
BuildTime
BuildTime
BuildTime

Figure 3-2: Performance Parameter Description for a Four-Panel Build

These measured parameters -- build time, transfer time and tact time -- must be obtained for the same panel population build for which the repeatability and accuracy performance values are obtained.

The measurement procedures for these measured time-based parameters require the use of a stopwatch and/or an oscilloscope. Stopwatches are utilized to measure the duration of a cycle. Oscilloscopes are usually utilized to monitor hardware transitions in order to identify the start and end of a cycle for transitions that are not be easily (i.e. repeatable and/or accurately) detectable with the naked eye.

The ability to measure a time-based parameter must be examined by the user to assure that measurements are precise, i.e. both repeatability and accuracy are acceptable. The stopwatch and/or oscilloscope must have resolution of at least 0.01 second or better. A GR&R study must be performed to verify that the repeatability of the measurement is less than 0.01 seconds at a precision/tolerance ratio of better than 25% (see GR&R Discussion Appendix G)

3.3.2.1 Build Time

Build time for this standard is the average time required to assemble each standard panel. It includes the time required to align the panels as well as the time to place the components and change nozzles. Build time excludes the time required to transfer the board into and out of the workstation. Some machines overlap the fiducial alignment operation with the placement operation. Other machines overlap nozzle changing and pickups with the transfer operation. The build time ignores these factors.

Measurement Procedure - Use a oscilloscope or stopwatch to measure the amount of time a panel is in the work-area. Start the timing cycle when the clamp closes. Stop the timing cycle when the clamp opens. Populate four panels and average the four measurements to obtain the build time.

Calculation Method - Build four panels and average the four measurements to compute the value of the build time metric.

3.3.2.2 Transfer Time (T_t)

Transfer time for this standard includes the time required to move the board into the workstation, clamp the board, release the board and move the board out of the workstation. It represents the overhead associated with transporting the board when production is flowing normally.

Measurement Procedure - Use a oscilloscope or stopwatch to measure the time from the entry of the first panel to entry of the fifth panel (not required to be a verification glass verification panel), less the entire Build Time of the four panels. To minimize measurement error, some easily detectable and clearly defined point in the cycle should be utilized. Machines that buffer PWB's pre and post population may utilize additional panels to obtain a sustainable pulse rate, but only the set of four consecutive glass verification panels is acceptable for a proper characterization procedure.

Calculation Method - Take the time from the entry of the first panel to entry of the fifth panel (not required to be a verification glass verification panel) minus the entire build time of the four panels divided by four to compute the transfer time.

3.3.2.3 Total Tact Time

For this standard, Total Tact Time is the required time to place all components on verification glass verification panels while maintaining the specified placement process capability. It excludes transfer time, fiducial time and nozzle change time.

Measurement Procedure – Start the oscilloscope or stopwatch to measure the time at which the first component is placed, and stop the oscilloscope or stopwatch at the time the last component is placed for each of the four panels.

3.3.2.4 Tact Time

For this standard, tact time is the average time required to place each of the standard components at the standard CAD coordinates on four standard glass verification panels. Tact time excludes the time during which the board is being moved into position, clamped and aligned as well as the time required for the machine to change nozzles. The standard CAD coordinates cause the machines to place components across the surface of a 200-mm2 board and preclude tact times where components are placed artificially close together to minimize motion time. To the extent that a machine is able to overlap pickup operations with board transfer operations, the tact time of this standard is somewhat optimistic. This standard permits the supplier to define the feeder configuration and the pick and place sequence used during the measurement. The number of feeders and heads are reported so the reviewers of the standard tact time data understand the conditions required to attain it. The tact time is measured during the same runs used to gather the process capability data. This ensures that placement process parameters are optimized to achieve the best balance of speed and accuracy.

Calculation Method - Average the four total tact time measurements and divide by the number of components minus one on a single panel to compute the tact time.

3.3.2.5 Net Throughput

For this standard, it is the number of components per hour (CPH) the machine can place on the verification PVPl. This definition is implemented to provide a measure of equipment capability in a term that is common in the industry. Although the value obtained for this parameters does not correlate to a production PWB throughput (since each panel only has one type of component), it is a useful parameter for the comparison between equipment types.

Calculation Method – The number of components placed on a single glass verification panel, divided by the sum of the build time and the transfer time parameters divided by 3600.

Example for QFP-100:

$$\text{Net Throughput} = \frac{36 * 3600}{(\text{Build Time} + \text{Transfer Time})}$$

3.3.3 CMM Measured Parameters

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 Measurement Capability Evaluation Section 5.

3.3.3.1 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 Xdev 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 . θdev refers to the rotational placement error (about the component’s X-Y area centroid).

Calculation Method

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

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, when the placement of QFP-100 or BGA-228 slugs is evaluated, 36 slugs are placed per PVP on a total of 4 panels; thus *n*=36*4 = 144.

3.3.3.2 Accuracy

In industry, many suppliers specify performance against their own unique specification limits and capability index values (e.g. ±40 um with Cpk ≥ 1.5). One of the aspects of this IPC-9850 standard is that, instead of having a different specification limit and a different sigma level for each supplier, results from each **shall** be provided in terms the specification limits required to sustain Cpk's of 1.33 and 2.0. Specification limits are directly comparable from one machine to another when machines are reported at the same Cpk levels.

As long as surface mount placement equipment has been on the market, the manufacturers' claims and guarantees regarding placement accuracy levels have been cited in terms of X, Y, and θ (rotational) axes, separately. This traditional method of reporting performance, where performance is considered individually per axis considered, is covered in Sections 3.4.3.1 and 3.4.3.2.

A relatively recent method that considers the collective effect of all axes is also included in this standard (see Section 3.4.3.2.2). 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.

3.3.3.2.1 Spec limits for Cpk

For this standard, spec limits for Cpk 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, Cpk. Limit for a Cpk of 1.33 implies a capability of 64 PPM, and a Cpk of 2.0 implies a capability of 0.002 PPM. Users who wish to use some other level of defect rate (besides Cpk's of 1.33 or 2.0) can easily convert the information provided here to evaluate machine performance against the preferred capability level.

Calculation Method -

$$SL = 3S \text{ x } Cpk + |avg|$$

See Appendix A for discussion of Capability indices and Appendix B for discussion of the Specification Limits associated with Cpk Values and an example of this calculation.

3.3.3.2.2 Cpk for Termination-to-Land Coverage

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 overhang. Overhang is utilized to determine the amount of overlap between the termination shape and the land pattern. In a broader definition, termination refers to lead, end-cap, ball, or column (to name a few common terminations), depending upon the type of component being placed.

Two performance parameters chosen for Form IPC-9850-F1 evaluate the termination-to-land percentage. These two parameters are the machine's Cpk against the class 1 and 2 specification limits (50% max overhang of lead's width), as well as class 3 (25% max overhang of lead's width), based on IPC-SM-782 and IPC A-610. These parameters are evaluated with mathematical equations that quantify total error, i.e. the combined impacts of the X, Y, and θ deviations. The ‘Termination-to-Land Calculations.xls’ spreadsheet provides an instruction guide and a sample lead-to-land spreadsheet that supports these equations.

For leaded components, total error 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 3-3. 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). For area array components, total error is referred to as maximum ball error (MBE). Total error is then used to calculate termination-to-land. Termination-to-land evaluation for the 1608 component is not performed, since the end-cap to land proportions do not necessarily provide meaningful results. In this standard, the widely embraced IPC/EIA J-STD-001 and IPC-A-610 standards are utilized.

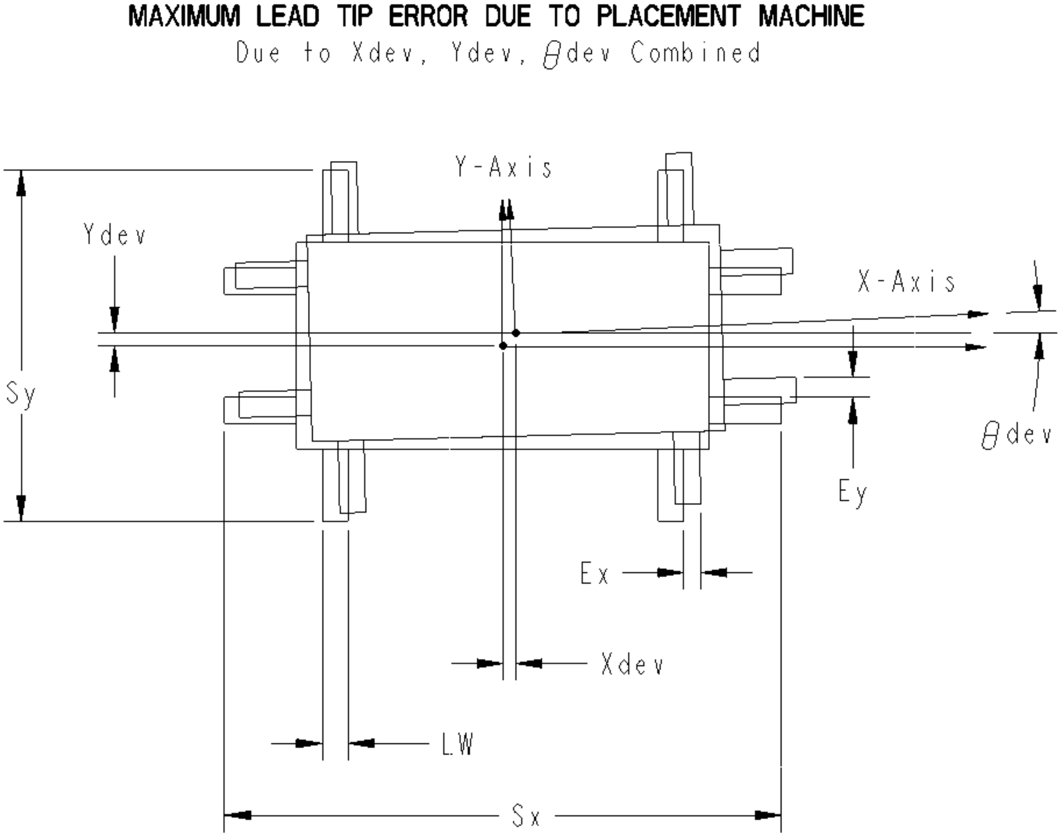

MAXIMUM LEAD TIP ERROR DUE TO PLACEMENT MACHINE
Due to Xdev, Ydev, θdev Combined
Y-Axis
Ydev
X-Axis
Sy
θdev
Ey
Ex
Xdev
LW
Sx

Figure 3-3

Total error (for leaded and area array components) is then used to calculate termination-to-land, based on the nominal component dimensions and the minimum land dimensions (IPC-SM-782). For leaded devices, termination-to-land is based on the width of the lead. For area array components, termination-to-land is based on the percentage of the land’s area that is in contact with the ball or column based on a two-dimensional mathematical model (not the percentage of the ball that is on land since the land typically is designed to have a smaller surface than the ball). The mean and standard deviation of these values for a group of placements are computed. The mean and standard deviation are used to attain the Cpk’s values.

For this standard, Cpk for termination-to-land coverage is the parameter that quantifies the placement machine’s capability of placing the component terminations on the associated lands. That is lead-to-land (LTL), ball-to-land (BTL), depending upon the component type, in terms of the amount of termination that ends up on the land as a result of the machine’s placement.

Land sizes are defined by IPC-SM-782. Termination sizes used here are the nominal values (average of the minimum and maximum values) (see Table 3-1). The Cpk is calculated relative to the 50% and 75% coverage called for in the assembly standards.

Table 3-1 NEEDS TITLE

Component Type	Component Length x Width	Termination Width	Land Length x Width	Spec Limits for Total Error (Class 1,2)	Spec Limits for Total Error (Class 3)
SOIC-16	8.89 x 6.0	0.42	NA x 0.60	0.300[1]	0.195[1]
QFP-100	16.0 x 16.0	0.20	NA x 0.30	0.150[2]	0.100[2]
QFP-208	32.0 x 32.0	0.20	NA x 0.30	0.150[2]	0.100[2]
BGA-228	15.0 x 15.0	0.50 (Dia.)	0.45 (Dia.)	0.207[3]	0.114[3]

Notes

1. Requiring Total Error (for leaded this is MLTE) to be ≤ 0.195 for this SOIC is equivalent to requiring Lead-to-Land to be ≥ 75%. The Total Error limit of 0.3 corresponds to LTL ≥ 50%.
2. Requiring Total Error (for leaded this is MLTE) to be ≤ 0.100 for this QFP is equivalent to requiring Lead-to-Land to be ≥ 75%. The Total Error limit of 0.15 corresponds to LTL ≥ 50%.
3. Requiring Total Error (for area array this is MBE) to be ≤ 0.114 is equivalent to requiring Lead-to-Land to be ≥ 75%. The Total Error limit of 0.207 corresponds to LTL ≥ 50%.

Calculation Method Calculation methods are provided for three component types: two leaded, one area array. Termination-to-land calculations are based on IPC-SM-782 designed termination and designed land dimensions, rather than actual ones. At time of publication of this standard, there is no standard for ball to land ratios for area array components. A 0.5 mm diameter ball with a 0.45 mm land for the BGA228 was selected for calculation of this metric.

Lead-to-land (LTL): is based on the percentage of the lead's width that is placed on land. This measurement quantifies the error for a component's lead that experiences the most offset (of all the leads) due to the joint x, y, and θ errors.

Calculation for a component with leads on four sides is shown here:

LTL= $100-\left(\frac{\left(MLTE-\frac{LandWidth-LeadWidth}{2}\right)}{LeadWidth}\cdot 100\%\right)$, where MLTE is defined below:

For a rectangular or square component with leads on **four** sides:

Maximum Lead Tip Error (MLTE) = $\max\begin{bmatrix} \left|ydev\right|+\left|\frac{S_x}{2}\cdot\sin(\theta dev)\right| \\ \left|xdev\right|+\left|\frac{S_y}{2}\cdot\sin(\theta dev)\right| \end{bmatrix}$

For a rectangular or square component with leads on its two longest sides:

If the component is placed so that the long sides are along the board's X-axis,

Maximum Lead Tip Error (MLTE) = $\left|xdev\right|+\left|\frac{\max(S_x,S_y)}{2}\cdot\sin(\theta\text{dev})\right|$

If the component is placed so that the long sides are along the board’s Y-axis,

$$\text{Maximum Lead Tip Error (MLTE)} = \left|ydev\right| + \left|\frac{\max(S_x, S_y)}{2} \cdot \sin(\theta dev)\right|$$

Ball-to-Land (BTL) refers to the percentage of the BGA ball or column of an area array components that is placed on its (round) land. BTL quantifies the error for the “ball” that experiences the most offset (of all the balls) due to the joint x, y, and θ errors.

$$\text{BTL} = \left(1 - \frac{\text{A}}{\pi \text{R}_1^2}\right) \bullet 100 \text{ , where}$$

$$\text{A} = 2\left[\frac{\text{R}_1^2}{2}\text{Sin}^{-1}(1) - \left\{\left(\frac{\text{c}-\Delta\text{r}}{2}\right)\sqrt{\text{R}_1^2 - (\text{c}-\Delta\text{r})^2} + \left(\frac{\text{R}_1^2}{2}\right)\sin^{-1}\left(\frac{\text{c}-\Delta\text{r}}{\text{R}_1}\right)\right\}\right] - 2\left[\frac{\text{R}_2^2}{2}\sin^{-1}(1) - \left\{\frac{\text{c}}{2}\sqrt{\text{R}_2^2 - \text{c}^2} + \frac{\text{R}_2^2}{2}\sin^{-1}\left(\frac{\text{c}}{\text{R}_2}\right)\right\}\right]$$

where:

$$\Delta\text{X} = |\text{Xdev}| + \left|\frac{S_x}{2} - \left(\frac{S_x}{2}\cos(\theta\text{dev}) - \frac{S_y}{2}\sin(\theta\text{dev})\right)\right|$$

$$\Delta\text{Y} = |\text{Ydev}| + \left|\frac{S_y}{2} - \left(\frac{S_y}{2}\cos(\theta\text{dev}) + \frac{S_x}{2}\sin(\theta\text{dev})\right)\right|$$

$$\Delta r = \sqrt{\Delta\text{X}^2 + \Delta\text{Y}^2}$$

$$\mathbf{c} = \frac{\text{R}_\text{L}^2 + \Delta\text{r}^2 - \text{R}_\text{B}^2}{2\Delta\text{r}}$$

R_L= radius of the land
R_B= radius of the ball
R_1= min(Radius of Ball, Radius of Pad)
R_2= max(Radius of Ball, Radius of Pad)
Xdev = Offset of component along the X-axis from the target placement
Ydev = Offset of component along the Y-axis from the target placement
θdev = Rotational offset of component from the target placement
ΔX = Maximum offset along the X-axis of the ball from its target placement
ΔY = Maximum offset along the Y-axis of the ball from the target placement
Δr = Radial offset of ball center to pad center. Synonymous with MBE in this document.

Computational note: the values of Sin^{-1} (x) need to be expressed in radians (rather than degrees).

Example of Computing Cpk limits for Termination-to-Land Coverage: After the x,y, and theta errors have been determined by the CMM (for a four board run using one particular component type), and the individual components’ Termination-to-Land computations have been made as well (using the equations above), the next step is to calculate the mean and standard deviation of this group of Termination-to-Land values. The Cpk equation should then be applied, using first the 50% specification limit and then the 75% limit. These 2 Cpk values then go in the Performance Reporting Form. Suppose the mean of the 144 Termination-to-Land values in a QFP100 run is 85% and the standard deviation of these values is 5%. Then Cpk versus 50% requirement is $\frac{85-50}{3 \bullet 5} = 2.33$.

4 Attribute Defect Rate and Reliability Performance Metric-- Form IPC-9850-F2

Complete evaluation of an SMT placement system must not only consider placement capability performance covered by Form IPC-9850-F1, but also include information about the yield and reliability of the system. Like the general performance use of Form IPC-9850-F1, Form IPC-9850-F2 **shall** be used to present the expected attribute defect rate and reliability of a specific machine model. However, unlike Form IPC-9850-F1 there **shall** be no requirement for a validation for a specific individual machine and there **shall** be no guarantee for the warranty period associated with IPC-9850-F2.

The selected reliability metric parameters for this standard fall into three categories -- reliability, availability, and maintainability. With the exception of Attribute Defect Rate, parameters are based on the SEMI E10-0699E standard.

The information presented in this form **shall** be gathered and reported according to this standard, and **shall** reflect the performance of the same machine model as in the Placement Performance Metric. The following information is reported on this form:

1. Manufacturer Name, Machine Model
2. Attribute Defect Rate (ppm)
3. Mean Placements Between Assists (MPBA)
4. Mean Time To Recover from assists ($MTTR_a$)
5. Mean Placements Between Failures (MPBF)
6. Mean Time To Repair failures ($MTTR_f$)
7. Equipment Dependent Uptime
8. Amount of Preventative Maintenance per 6000 Hours
9. Mispick Rate (ppm)
10. Data Collected From:
    a. Number of Factories
    b. Number of Machines
    c. Total Number of Placements

4.1 Attribute Defect Rate

Although production yield depends on the solder paste printing quality of the PWBs, sticky media is used for this procedure instead solder paste. It is recognized that the attribute defect level from placement operations on sticky tape are likely to be lower than defect levels from placement on solder paste or conductive adhesives in production runs. However use of solder paste introduces many additional variables such as paste viscosity, tackiness and height. The use of sticky tape provides a method to compare machines with a minimum number of variables. In addition, it eliminates the need for vendors to have costly screen-printing equipment and expertise in utilizing stencil printing, board cleaning processes, and controlled disposal of residual solder paste.

Since products assembled by surface mount equipment vary greatly by the type of component mix and size of the PWB, a special kit is provided. This kit is designed to be representative of the product of a ‘typical user’. This ‘typical user’ kit is made of 4400 components and **shall** be mounted onto the PWB with sticky media. Table 4-1 provides a list of the 4400 component types and quantities. Because some equipment is not designed to place all SMT parts, it may not capable of placing this specific set of components. If it is necessary to change the mix of components, the test **shall** be run using a similar mix of component types that are within the machine’s capability. The selected mix of components **shall** be clearly stated on form IPC-9850-F2. The components **shall** be presented to the machine using standard feeders or trays manufactured by a vendor-approved supplier.

Table 4-1 Component Types and Quantities for 'Typical kit'

Quantity	Component Type
440	SOT-23
440	SOIC-8
880	1608C
880	1608R
880	1005C
880	1005R

The components are to be placed onto an adhesive laminated PWB. The land pads for the PWB **shall** meet IPC-SM-782. (Specific board size and layout are not defined by this standard.) After the parts have been placed on the sticky PWB, a manual visual inspection is made to determine how many placement defects have occurred. While manual inspection is less than ideal due to its subjectivity, the investment in Automated Optical Inspection (AOI) equipment for such a limited application cannot be justified.

In this standard, attribute defect rate information differs significantly from the performance metric defined by the repeatability and accuracy parameters. Whereas the repeatability and accuracy performance parameters are defined through continuous data -i.e. numerically how much is the component placement error-, the attribute defect rate parameter is only a function of discrete defects i.e. components which are known to be placed such that a proper solder joint will not form. Generally these discrete defects occur at such small rates that they are not measured in percentages of the total number of placements but in defective parts per million (PPM) placements. These discrete defects are referred to as Attribute Defects, and the anticipated frequency of their appearance is referred to as the Attribute Defect Rate.

Attribute defects are defined as components placed upside down, tombstone, on side, missing, extra part, damaged lead(s), damaged part, completely off land, and wrong polarity. An exception is that upside down components are not to be counted as defects when using bulk feeders. Partially off-land and askew type placement defects are not included, since the performance level for these types of defects is accounted for by the repeatability and accuracy parameters. For this parameter evaluation, each component equals one opportunity for a defect and can have a maximum of only one defect, regardless of the associated anomalies –such as the number of leads, etc. Things other than the placement machine can cause attribute defects, but they **shall** be attributed to the machine in the absence of any other clear cause, such as poor board fiducials, etc.

Estimating the average number of defects that will occur in each million placements is no small task. Estimating defect rates less than 50 PPM requires very large sample sizes. Different sampling plans exist, each with it's own set of characteristics and sample sizes.) This standard requires the placement of 88,000 parts. Due to the time and cost associated with a machine supplier placing this many actual components with each machine manufactured, the 88,000 placements may be spread out over 20 consecutive machines in builds of 4,400 components. As a result, the confidence level applies only to that group of machines rather than any specific member of that group of machines. The data may be used as an estimate of the performance of the model type. When a new model machine is launched, where only a single machine of its kind is available for testing, this single machine **shall** be utilized for the 88,000 placements.

Calculation Method The PPM level is the total number of observed attribute defects during 88,000 placements of various component types, divided by 88,000, multiplied by 1,000,000. A minimum total of 88,000 components is to be placed over 20 tests, where each test run places a component mix of at least 4400 components. The number of defects is then calculated as a moving average of the last 20 tests.

$$\text{Attribute Defect Rate} = (1{,}000{,}000/88{,}000) * \sum_{test=i}^{i+20} AttributeDefects_i$$

The following example refers to Table 4-3 where two defects over the 88K parts yields Attribute Defect Rate of 23 ppm. For the first and second machines, the attribute defect rate is obtained by dividing the three attribute defects – found during run series 2, 7, and 17-- divided by 88K parts, for a 34 PPM. Once the third machine is shipped, the attribute defect level is reduced to 23 PPM, since the single attribute defect of run series 2 is replaced by the zero attribute defect of machine 3, run series 22.

Table 4-3 Calculation Example

Machine Number	1 (Note 1)																				2	3
Run Series 1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
Run Series 2		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
Run Series 3			3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Number of Attribute Defects	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0

Note 1: The first machine built will have 20 runs of 4400 components.

4.2 Reliability Parameters

In contrast to the machine placement performance parameters that specify worst case performance, this standard uses reliability parameters to describe typical performance. Reliability metrics are difficult for a supplier to specify because there is no reasonable way to verify these parameters for an individual machine prior to shipment, without rigorously exercising the machine for thousands of hours. Not only would this be costly, it would result in a new machine becoming a used machine. Since it is not reasonable to expect all suppliers to dedicate machines for reliability tests, in this standard the suppliers **shall** use reliability information collected by users of their equipment.

The problem of specifying reliability metrics is now compounded by the fact that users are collecting the data with which reliability estimates are made by the suppliers. Each user has its own set of understanding and ability to track reliability metrics amidst the pressures of daily production. The application of the equipment and skill of its operators and technicians are believed to be significant factors that contribute to the final observed reliability and maintainability. In this standard, terminology and metrics have been developed that help suppliers and users collect and exchange reliability data.

The high yield and reliability of modern SMT placement systems requires very large amounts of data in order to estimate these metrics. The desire for large data sets having fairly precise estimates of reliability performance must be balanced with the desire to report reliability as early as possible. Confidence intervals for many machine parameters can be made on the basis of what is observed in a sample because the underlying statistical distributions associated with those parameters are fairly well understood. However, at the initiation of this standard, some suppliers indicate that they do not have a complete enough understanding of the statistical distributions associated with one or more of the reliability metrics in this standard.

Some types of placement machines produce failure data with χ^2 distributions. At first glance, somewhere around half the machines would have somewhat better than the reliability levels experienced during the field studies, while the rest of the machines would experience somewhat worse reliability levels. In fact, if the machines have constant failure rates, 63% of the machines will have assists and failures more frequently than the observed MPBF and MPBA. This is due to the fact that most reliability distributions (such as χ^2) are skewed to the right, causing their median to be smaller than their mean.

Performance similar to the typical MPBF and MPBA performance of the equipment should be enjoyed when the recommended preventive maintenance (PM) activities are completed in a regular and timely manner. When preventive and corrective maintenance is not performed in accordance with the maintenance manual, reliability may be degraded.

To address confidence interval concerns, equipment suppliers **shall** only complete the reliability parameters with data based on at least 3 times as many placements as the reported mean placements between failures (MPBF) parameter (see 4.2.3). For example, it is not proper to claim MPBF of 1 million placements, without observing that level of performance over 3 million placements. The same is also true for the mean placements between assists (MPBA) parameter (see 4.2.1), were at least 3 times as many placements as is reported for MPBA need to be made.

Since several machines **shall** be utilized for the collection of data for the reliability metric on multiple machines, the following method **shall** be utilized for merging the data sets. For example, assume a supplier has data for two machines of a particular model type. The first machine was observed for 300,000 placements and experienced 2 assists while the second machine was observed for 500,000 placements and experienced 3 assists. The calculation for MPBA for the model type would be the total number of cycles divided by the total number of assists. In this case, MPBA would be

$$\frac{300{,}000 + 500{,}000}{2 + 3} = 160{,}000 \text{ cycles.}$$

Other metrics **shall** also be calculated this way when multiple machines have been observed.

An assist is defined as an unplanned interruption that occurs during an equipment cycle where all three of the following conditions apply:

- ➢ The interrupted equipment cycle is resumed through external intervention (e.g., by an operator or user, either human or host computer).
- ➢ There is no replacement of a machine part (defined specifically to distinguish from component parts being placed by the machine), other than vendor specified machine consumable parts.
- ➢ There is no further variation from specifications of equipment operations.

This definition was clarified not to include replenishment of components since it is tied to the type of feeders and tape capacity choices made by the user. It was agreed that replenishment is to be specified as a scheduled downtime.

A failure is defined as any unplanned interruption or variance from the specifications of equipment operation other than assists.

Preventive Maintenance (PM) is a machine stop required by the supplier's published PM schedule.

See table for 4-4, below, for examples of the terms ‘Assist’, ‘Failure’, and ‘Preventive Maintenance” as applicable to this standard:

Table 4-4 Terms Definition

Feeder assist time:	A machine stop required to recover/replace a damaged feeder or "un-jam" a feeder. Excludes parts replenishment. Measured from the time the operator starts assisting the feeder until the time that the machine starts running. Excludes operator latency. Excludes out of spec materials --such as sticking components in tape, delaminated cover tape, etc.
Software assist time:	The machine stops due to a program sequence error, but excludes operator-programming mistakes.
Fiducial assist time:	A machine stop required to find a fiducial that is unrecognizable or outside of the capture range. Measured from the time the machine stops until the machine starts running. Excludes operator latency.
Transport assist time:	A machine stop required to correct a board jam. Measured from the time the machine stops until the time the machine starts running. Excludes operator latency. Excludes assists caused by a board that has been loaded into the machine upside down or rotated.
Software failure time:	A machine stop required by a software defect. Includes the time needed to abort current operations, reboot (if required) and to restore all data and material to a production ready condition. Measured from the time the machine stops until the time the machine is ready to resume normal operation. Excludes operator (and supplier) latency.
Hardware failure time:	A machine stop required by a hardware failure of a factory approved part. Includes all unscheduled calibrations, adjustments, troubleshooting and part replacements. Excludes replacement of consumable or wear parts identified in the machine's manual. Measured from the time the machine stops until the time the machine is ready to resume normal operation. Excludes operator (and supplier) latency. Excludes preventive maintenance time. Excludes failures of unauthorized third party parts or materials.
Preventive maintenance time:	Includes all inspections, cleaning, lubrication, adjustment, calibrations and part replacements. Includes time required to replace all consumable and wear parts identified in the machine's manual. Measured from the time preventive maintenance activity begins until the machine is ready to resume normal operation. Excludes operator (and supplier) latency. Excludes repair time.

4.2.1 Mean Placements Between Assists (MPBA) –This is the average number of component placements between assists.

Calculation Method The total component placements divided by the number of assists during those component placements.

$$MPBA = \frac{\text{Total Equipment Placements}}{\text{\# of Assists}}$$

4.2.2 Mean Time To Recover from Assists (MTTR$_a$) –This is the average time to correct an assist and return the equipment to a condition where it can perform its intended function.

Calculation Method The sum of all assist recovery time (elapsed time, not necessarily total man hours) incurred during a specified period (including equipment and process test time, but not including maintenance delay), divided by the number of assists during that period.

$$MTTR_a = \frac{\text{Total Recovery Time}}{\text{\# of Assists}}$$

4.2.3 Mean Placements Between Failures (MPBF) –This is the average number of component placements between failures.

Calculation Method The total component placements divided by the total number of failures during those component placements.

For statistical credibility, the MPBF claim must be no higher than one third of the number of placements completed.

$$MPBF = \frac{\text{Total Equipment Placements}}{\text{\# of Failures}}$$

4.2.4 Mean Time To Repair Failures (MTTR$_f$) –This is the average time to correct a failure and return the equipment to a condition where it can perform its intended function

Calculation Method The sum of all repair time (elapsed time, not necessarily total man hours) incurred during a specified period (including equipment and process test time, but not including maintenance delay), divided by the number of failures during that period.

$$MTTR_f = \frac{\text{Total Repair Time}}{\text{\# of Failures}}$$

4.2.5 Total Time- This is all time (at the rate of 24 hours/day, 7 days/week) during the period being measured.

4.2.6 Non-Scheduled Time - This is a period when the equipment is not scheduled to be utilized in production.

4.2.7 Operations Time - This is total time minus non-scheduled time.

4.2.8 Equipment Dependent Uptime –This is the percentage of operations time when a machine is in a condition to perform its intended function. It includes productive, standby, and engineering time, and does not include any portion of non-scheduled time.

Calculation Method The Equipment Dependent Uptime multiplied by 100 and divided by operations time.

4.2.9 Preventative Maintenance (PM) Time

This is the amount of time required for preventative maintenance as specified by the machine supplier. This metric will be based on the maintenance routines that are required each year in order to keep the machine in a warranted condition and how long those routines take for a 6000 hour period.

Calculation Method Multiply the amount of time required for each PM procedure by the number of times it is required in 6000 hours and add these up for a grand total.

4.2.10 Mispick Rate (in PPM) This is the frequency with which a component was not picked or picked incorrectly, even if recovery handled the problem. Mispicks include both pickup failures and vision failures, but excludes components exhaust.

Pickup defects will be handled in a manner similar to placement defects. Pickup defects are categorized as vacuum failures or vision failures. While many suppliers have various auto-recovery routines that prevent a pickup defect from resulting in a missing component placement defect, this type of defect has still been deemed worthy of tracking and reporting due to its impact on the assembly process. Pickup defects cause a reduction in net CPH and the unnecessary rejection and scrapping of good parts.

The number of mispicks that occur during the 4400 part placements made to determine placement defect rate will be recorded on Form IPC-9850-F2. The number of pickup defects made during this process for the past 20 machines will be reported, from which a point estimate for pickup defects in PPM can be made.

Measurement Procedure Clear the Mispick counters in the machine. Empty the reject bin. Record the relative humidity. Run the attribute defect test (place 4,400 components). Record the vacuum failure, and vision failure counter values. Examine the components found in the reject bin and count the defective components.

Calculation Method The total pickup attempts minus total number of placements minus the number of defective components divided by total pickup attempts minus defective components, multiplied by one million to obtain ppm.

$$\text{Mispick Rate} = 1{,}000{,}000 * \frac{\text{(Total Pickup Attempts)- (Total Number of Placements) –(Number of Defective Components)}}{\text{(Total Pickup Attempts) –(Number of Defective Components)}}$$

4.3 Reporting Sites This is the number of machine sites included in the reliability metric calculations.

4.3.1 Number of Machines This is the number of individual machines included in the reliability metric calculations.

4.3.2 Total Number of Placements This is the number of individual machine placements included in the reliability metric calculations.

4.3.3 Total Pickup Attempts This is the number of times the nozzles attempted to pick components.

5 Measurement Capability Verification –Form IPC-9850-F3

Form IPC-9850-F3 functions as a tool for demonstrating the measurement capability of the measurement equipment used to generate the parameter values 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, and **shall** reflect the performance of the measurement equipment used in the machine performance analysis. The reported information should be acquired no more than 90 days prior to the machine performance study.

The parameters of this metric **shall** evaluate the measurement system’s ability to accurately 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 and yields results about the measurement capabilities of the CMM along the same axes as reported by the placement performance metric. exceed The specification limits reported in the performance reporting form **shall** never be smaller than the larger of the GR&R and accuracy CMM specification limits per component type. Suppliers that add additional component types to the Placement Performance Metric **shall** also report their measurement capabilities for the same component types.

Suppliers may include procedures to measure placements with the placement machine itself. This is acceptable for a particular placement machine as long as that particular machine (not just a sample machine from that particular model type) passes the gauge requirements laid out in this section which determine whether or not its measurement capability is acceptable.

5.1 Gauge Repeatability and Reproducibility Capability

This verification procedure determines the CMM's ability to repeat and reproduce the component location and rotation mounted onto the PVP. This evaluation **shall** be made for each component type.

While multiple GR&R methodologies are available, this standard uses the traditional average-range method and recommends the use of the spreadsheet discussed in Appendix H. The results are reported in terms of the upper and lower specification limits that yield a precision-to-tolerance ratio of better than 25%.

Although a precision-to-tolerance (P/T) ratio of less than 20% is usually considered acceptable, 25% is utilized in this standard to accommodate existing CMM machines. However this reduced P/T ratio specification if somewhat offset by the fact that the analysis is performed using a more stringent requirement of six sigma (+/-3 sigma or 99.7%) versus the customary value of 5.15 sigma (+/- 2.575 sigma or 99%) recommended by the Automotive Industry Action Group (AIAG).

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, Section 3. Measure the populated PVP three consecutive times. The PVP is to be completely removed and replaced from the CMM for each run. Only 36 components need to be measured for each run. Appendix F outlines the component locations for the specific component panel layout. After the three measurements are obtained the CMM must be shutdown and restarted.

The same PVP plate **shall** be subjected to two additional measurement cycles (two more sets of 3 measurements) 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.

For the SOIC-16 and 1608C components, the center of the component **shall** be measured using the lead outline and component outline, respectively. The same measurement procedure applies to the PVP populated with slugs. However, since the CMM utilizes the fiducial markings on all glass slugs, regardless of the specific component image, it is only necessary to evaluate the CMM’s ability to measure the slugs using the fiducial markings and not individually for the QFP and BGA component types. Appendix D provides suggested methods for measurement methods.

5.2 Accuracy Capability

This verification procedure determines the Optical CMM's ability to accurately measure the placement of components on the glass verification panel. This is accomplished by evaluating the CMM’s ability to measure the NIST certified glass verification panel specified in Figure 5-1. This accuracy verification panel (AVP) was designed to evaluate the CMM’s ability to measure three component types required for compliance with Section 3.

To evaluate the measurement capabilities of the 1608C and SOIC-16 components, their images have been etched onto the AVP. Since slugs are utilized for the QFP and BGA components, only slug fiducials marking are etched onto the AVP. Some of the etched images are translated and rotated from their specified CAD location, in order to test the CMM’s ability to measure components with measurement error. Some of the 1608C and SOIC-16 component images on the AVP are translated in a range of ± 50 micrometers, and rotated in a range of ±3° range. Some of the four fiducial image sets will be translated in a range of ± 25 micrometers, and rotated in a range of ±1° range. The ‘CMM Accuracy Eval.xls’ file provides an instruction guide and a sample CMM accuracy evaluation spreadsheet.

This methodology is implemented using a measurement program on the CMM, which searches for the components on the glass panel at their CAD locations. These CAD locations are the centers of the components as if no translation or rotations were applied to the images on the glass panel. The CAD locations of the images can be found in Appendix F. The CMM measurement results are compared to the locations and rotations of the component images provided by the NIST certification for the unique glass panel utilized. The closer the CMM measurement values are to the certified locations the better the measurement capability of the CMM.

The results are reported in terms of the upper and lower specification limits that yield process capability indexes equal to 2.0. See Appendix B for discussion.

Measurement Procedure Measure the center location and orientation of the component images on the certified accuracy verification panel a single time. Measure the center location and orientation of each group of four fiducials that represent the slug component types. Use the same image analysis procedures that are utilized for the Placement Performance Metric evaluation. Appendix D provides a guide for the proper methods of measuring the center locations of the components.

Calculation Method Subtract the CMM measured image locations from the NIST certified image locations along the X, Y and θ axes, for each of the 1608C, SOIC-16, and slug features. This provides a distribution of the measurement errors of the CMM. Use these distributions to calculate the average and standard deviation for each axis. Calculate the process specification limits for each axis using the following equations, when Cpk = 2.0. See Appendix B for a discussion of these equations.

$SL=3*SD_{Error}*Cpk+|Avg_{Error}|$

where $Avg_{Error}, = \frac{1}{18}\sum_{i=1}^{18}(MeasuredLocation_i - CertifiedLocation_i)$

and $SD_{Error}, \sqrt{\frac{1}{18-1}\sum_{i=1}^{18}(MeasuredLocation_i - CertifiedLocation_i)^2}$,

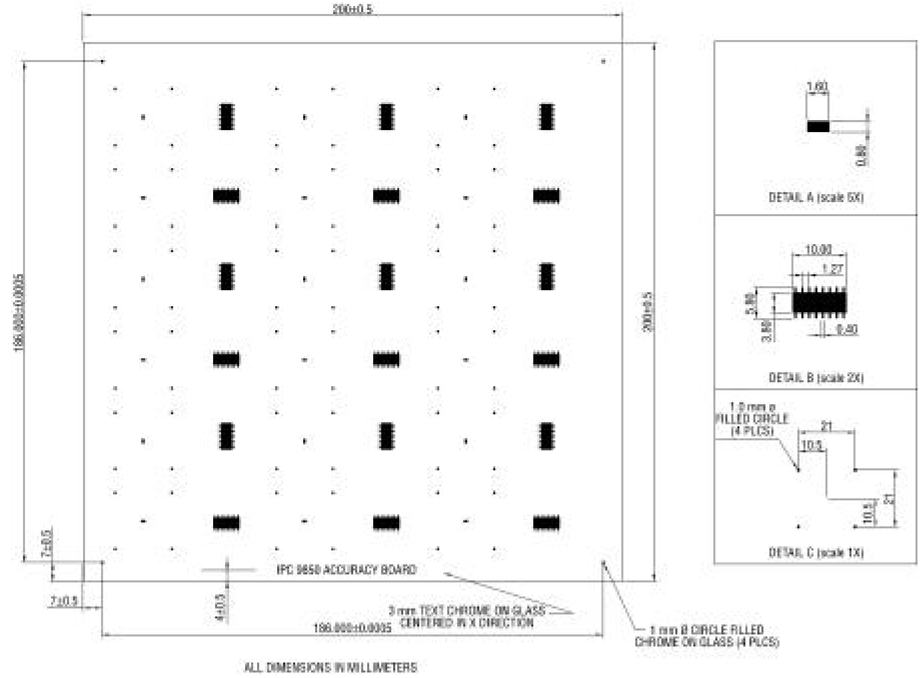

200±0.5
186.000±0.0005
200±0.5
7±0.5
7±0.5
4±0.5
IPC 9850 ACCURACY BOARD
3 mm TEXT CHROME ON GLASS CENTERED IN X DIRECTION
186.000±0.0005
1 mm Ø CIRCLE FILLED CHROME ON GLASS (4 PLCS)
ALL DIMENSIONS IN MILLIMETERS
1.60
0.80
DETAIL A (scale 5X)
10.00
1.27
3.80
3.80
0.40
DETAIL B (scale 2X)
1.0 mm ø FILLED CIRCLE (4 PLCS)
21
10.5
21
10.5
DETAIL C (scale 1X)

Figure 5-1 Accuracy Verification Panel

6 Test Vehicles

Users of this standard **shall** utilize standardized materials and methods to ensure that users and suppliers of SMT placement equipment are able to observe the same placement performance results within the tolerance of their measurement gauge's repeatability, reproducibility and accuracy.

Table 6-1 is the material list for the execution of the placement performance evaluation. Check the IPC website for suggested suppliers of evaluation material.

Table 6-1 Tool Kit Materials List For Performance Evaluation

Quantity	Material
4	Placement Verification Panel (see Figure 6-2)
1	CMM Measurement Verification Panel
150	QFP-100 slugs with no background or with white background
130	QFP-208 slugs with no background or with white background
150	BGA-228 slugs with no background or with white background
1600+	1608C Components
240+	SOIC 16 Components
	Optional
4	PVPl Carrier
-	Sticky tape

6.1 Placement Verification Panel Specifications

Glass verification panels with anti-reflective chrome metallization are used because they are dimensionally stable and can be made very accurately. The glass board fiducials create stable high-contrast images on both placement machines and CMMs. The transparent glass allows the use of back lighting on the CMM to increase the gauge repeatability of the measurements.

The IPC-9850-P1 placement verification panel (Figure 6-1) was designed to be small enough to measure on relatively affordable vision CMMs and large enough to represent a typical sized PWB.

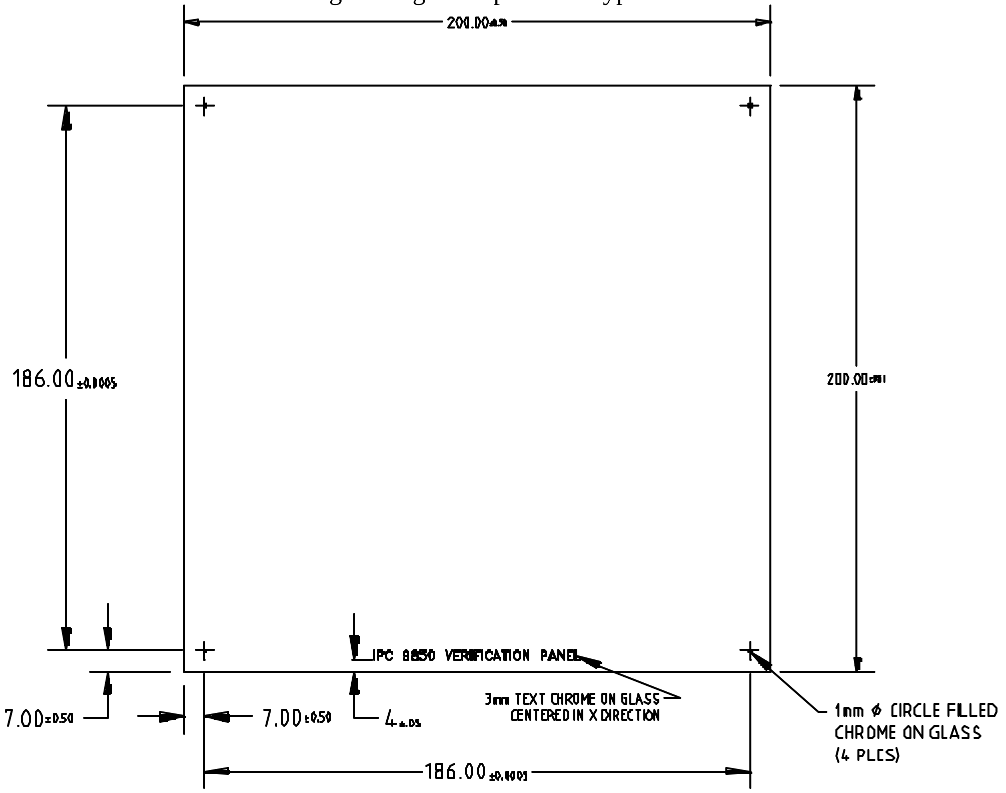

200.00±.50
186.00±0.0005
200.00±.01
IPC 9850 VERIFICATION PANEL
3mm TEXT CHROME ON GLASS
CENTERED IN X DIRECTION
1mm ø CIRCLE FILLED
CHROME ON GLASS
(4 PLCS)
7.00±0.50
7.00±0.50
4±.05
186.00±0.0005

Figure 6-1 Placement Verification Panel

6.2 Placement Verification Panel Carrier Specifications

The standard does not specify or require the use of a carrier for the PVP. A recommended carrier design is shown in Appendix I.

6.3 Glass Slug Specifications

Slugs must meet the dimensional specifications of Figures 6-2, 6-3, 6-4, 6-5, 6-6, and 6-7.

Implication of the glass slug weight on placement acceleration and speed was considered. While there may be cases where the machine performance will need to be adjusted to accommodate the slug, this type of slugs are currently being used by most vendors without performance issues.

The patterns on the slugs will be made of black chrome. Since some suppliers use front lighting and some use back lighting the slugs may be either white background for leads on chrome background or chrome leads with no background.

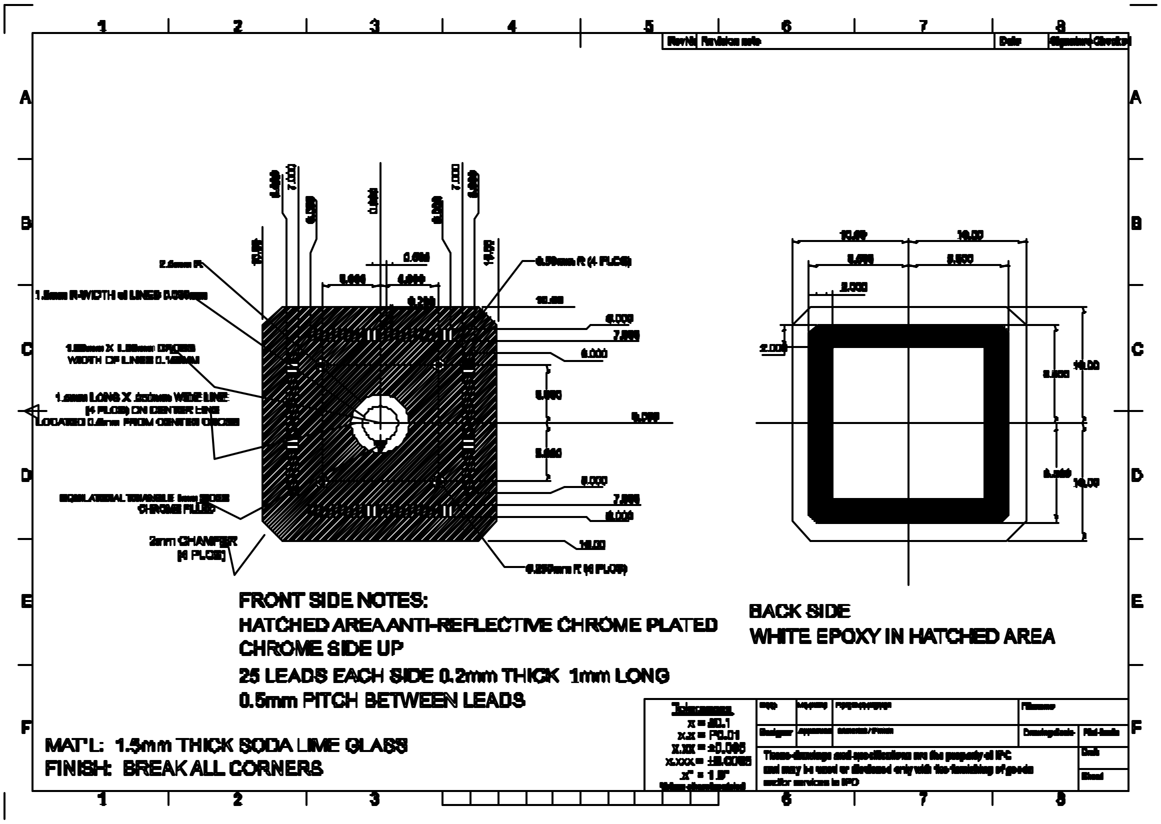

1
2
3
4
5
6
7
8
A
B
C
D
E
F
2.5mm R
1.5mm R-WIDTH of LINES 0.050mm
1.50mm X 1.50mm CROSS
WIDTH OF LINES 0.150MM
1.0mm LONG X .050mm WIDE LINE
(4 PLCS) ON CENTER LINE
LOCATED 0.5mm FROM CENTER CROSS
EQUILATERAL TRIANGLE 1mm SIDES
CHROME FILLED
2mm CHAMFER
(4 PLCS)
0.50mm R (4 PLCS)
0.250mm R (4 PLCS)
7.000
6.000
5.000
4.000
10.00
FRONT SIDE NOTES:
HATCHED AREA ANTI-REFLECTIVE CHROME PLATED
CHROME SIDE UP
25 LEADS EACH SIDE 0.2mm THICK 1mm LONG
0.5mm PITCH BETWEEN LEADS
BACK SIDE
WHITE EPOXY IN HATCHED AREA
MAT'L: 1.5mm THICK SODA LIME GLASS
FINISH: BREAK ALL CORNERS
Tolerances
x = ±0.1
x.x = ±0.01
x.xx = ±0.005
x.xxx = ±0.0005
x° = 1.5°
Filename
Sheet

Figure 6-2 QFP 100 Slug for White Background for Leads on Chrome Background (Negative)

Drawing File Name: ipc_100QFP_glass_NEGATIVErevb.eps

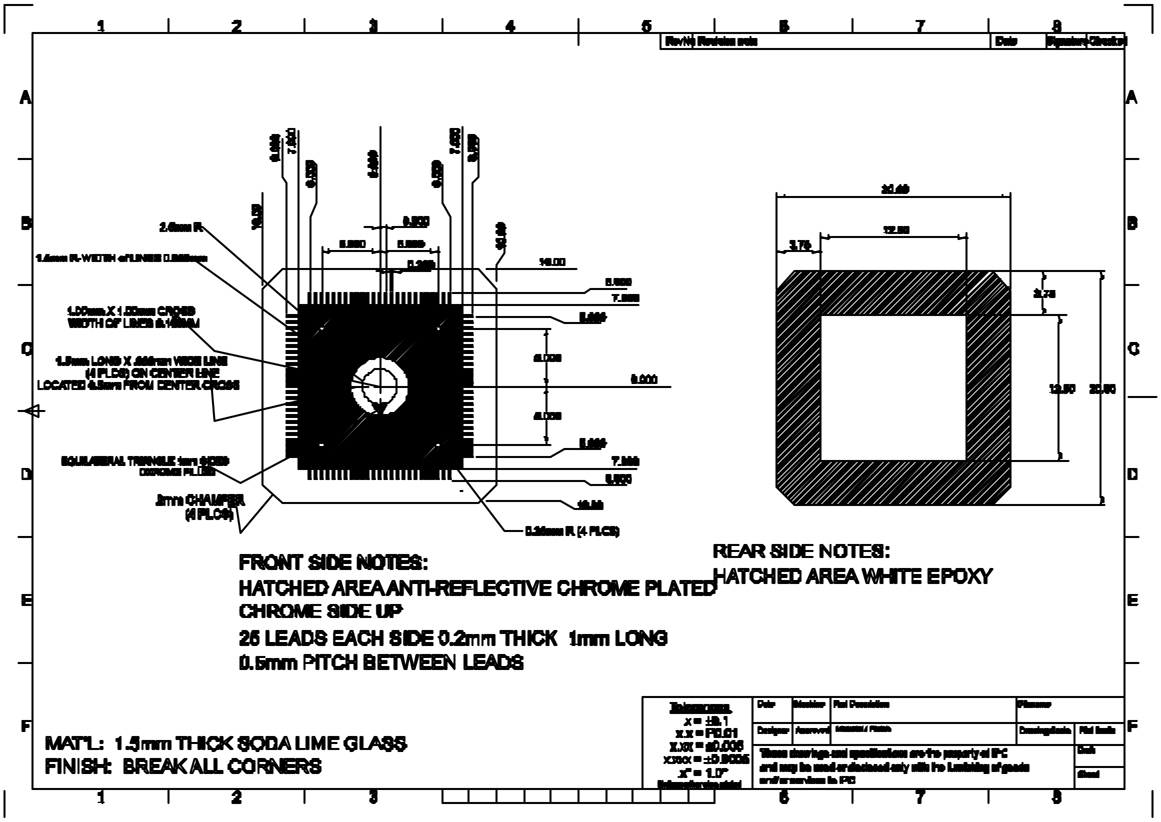

1
2
3
4
5
6
7
8
A
B
C
D
E
F
Rev/Nr Revision note
Date
Signature Checked
2.5mm R
10.00
20.40
12.50
3.75
12.50
20.50
5.000
7.500
6.000
0.200
0.500
FRONT SIDE NOTES:
HATCHED AREA ANTI-REFLECTIVE CHROME PLATED
CHROME SIDE UP
25 LEADS EACH SIDE 0.2mm THICK 1mm LONG
0.5mm PITCH BETWEEN LEADS
REAR SIDE NOTES:
HATCHED AREA WHITE EPOXY
MAT'L: 1.5mm THICK SODA LIME GLASS
FINISH: BREAK ALL CORNERS
2mm CHAMFER
(4 PLCS)

Figure 6-3 QFP 100 Slug for Chrome Leads With No Background (Positive)
Drawing File Name: ipc_100QFP_glass_POSITIVErevb.eps

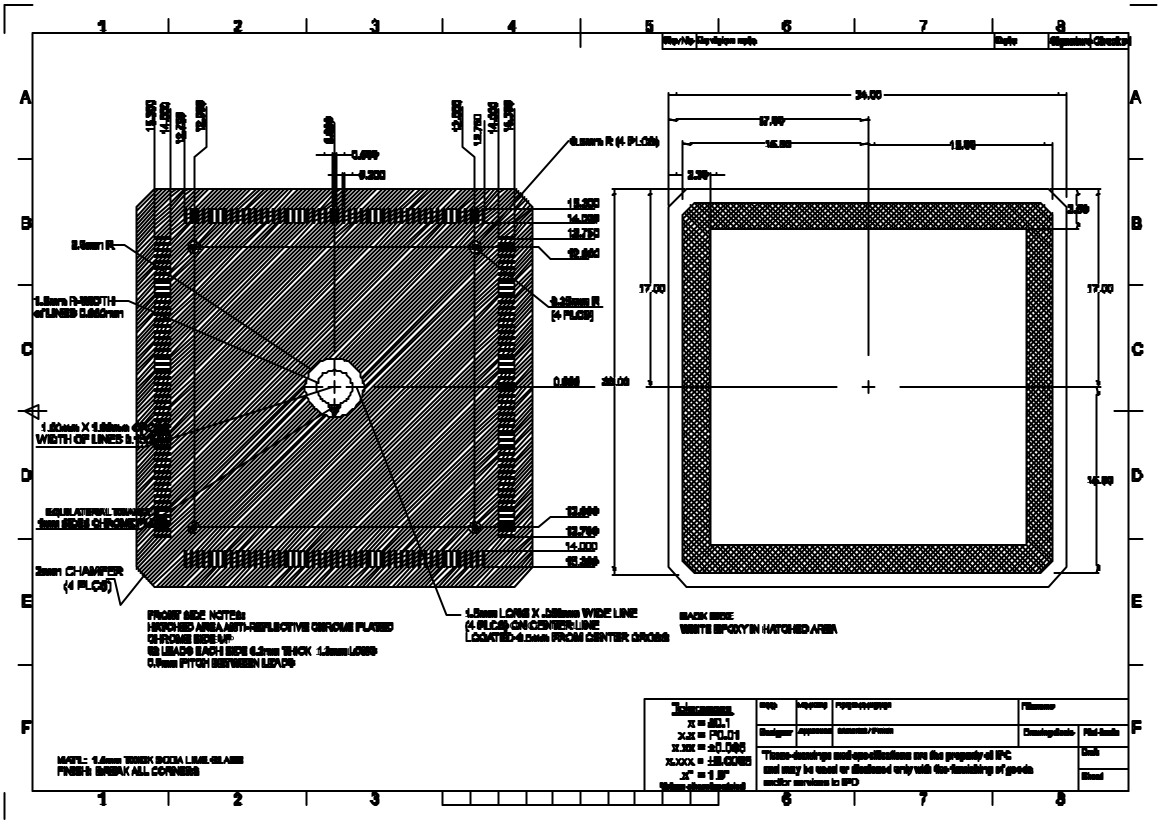

1
2
3
4
5
6
7
8
A
B
C
D
E
F
2.5mm R
15.300
14.000
12.750
12.600
12.600
12.750
14.000
15.300
17.00
34.00
2.50
2mm CHAMFER
(4 PLCS)
FRONT SIDE NOTES:
HATCHED AREA ANTI-REFLECTIVE CHROME PLATED
CHROME SIDE UP
52 LEADS EACH SIDE 0.2mm THICK 1.2mm LONG
0.5mm PITCH BETWEEN LEADS
1.5mm LONG X .300mm WIDE LINE
(4 PLCS) ON CENTER LINE
LOCATED 4.5mm FROM CENTER CROSS
BACK SIDE
WHITE EPOXY IN HATCHED AREA
MAT'L: 1.5mm THICK SODA LIME GLASS
FINISH: BREAK ALL CORNERS

Table 6-4 QFP 208 Slug for White Background for Leads on Chrome Background (Negative)
Drawing File Name: ipc_QFP208_glass_NEGATIVE.eps

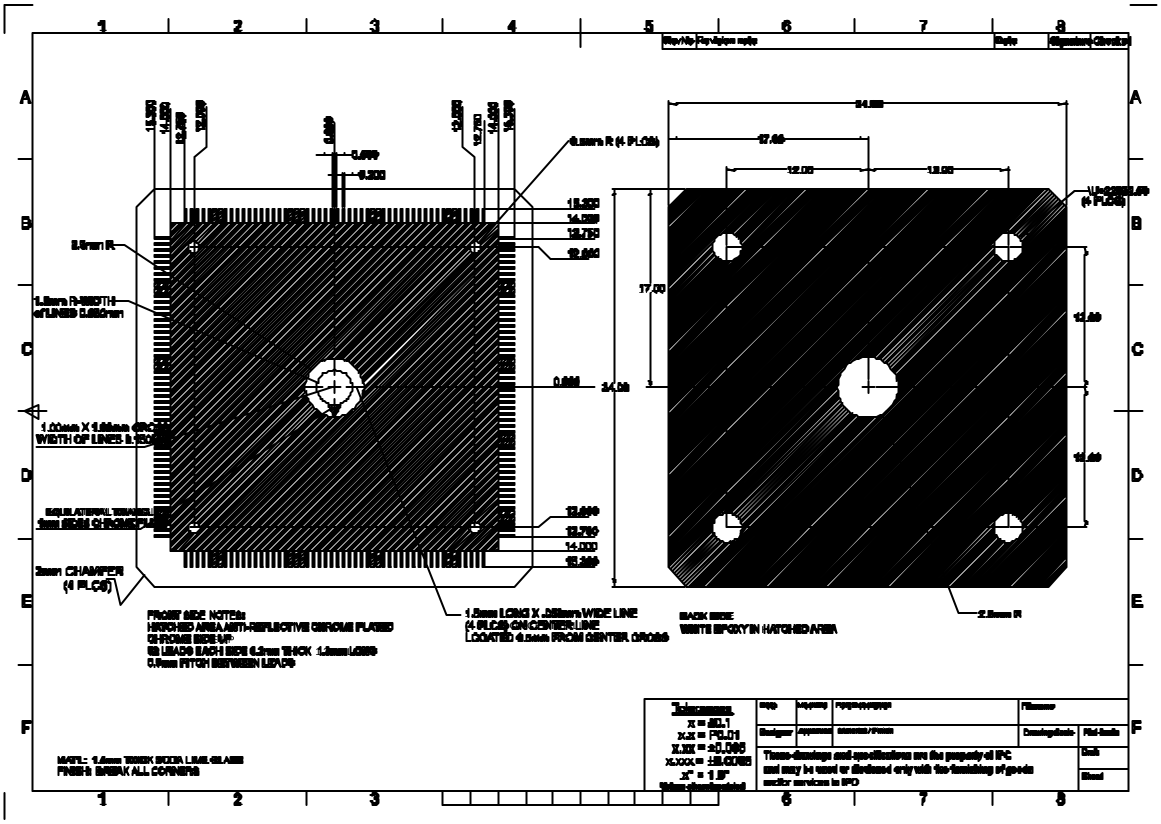
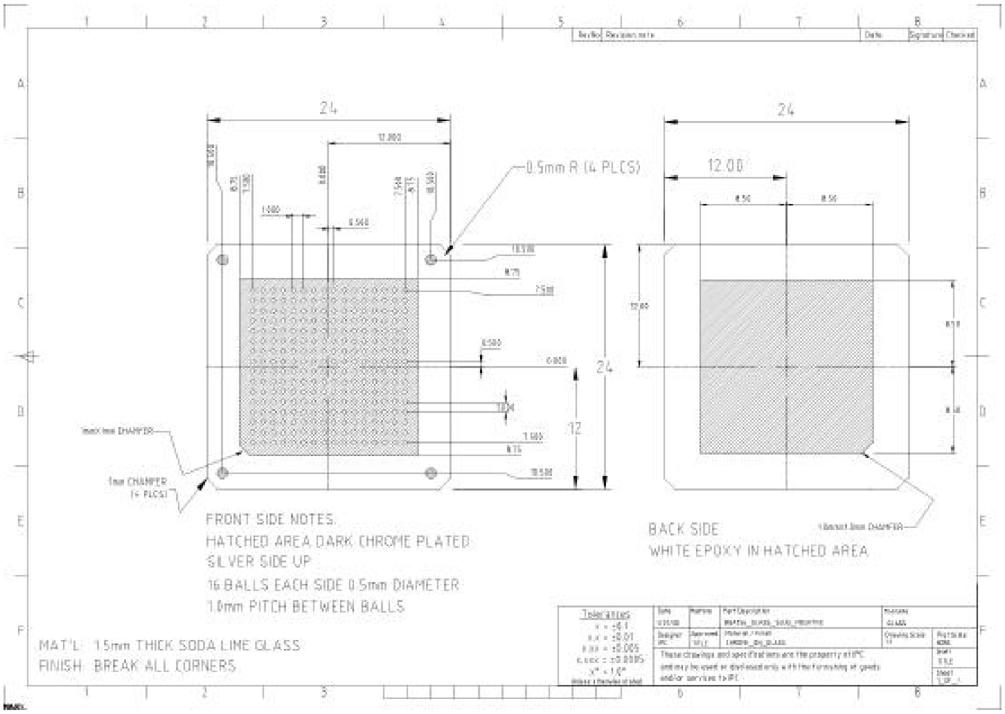

1
2
3
4
5
6
7
8
A
B
C
D
E
F
Rev No Revision note
Date
Signature Checked
0.5mm R (4 PLCS)
24.00
17.00
12.00
12.00
15.300
14.000
12.750
12.650
0.000
12.650
12.750
14.000
15.300
17.00
24.00
12.00
12.00
2.5mm R
2mm CHAMFER
(4 PLCS)
FRONT SIDE NOTES:
HATCHED AREA ANTI-REFLECTIVE CHROME PLATED
CHROME SIDE UP
52 LEADS EACH SIDE 0.3mm THICK 1.3mm LONG
0.5mm PITCH BETWEEN LEADS
1.5mm LONG X .05mm WIDE LINE
(4 PLCS) ON CENTER LINE
LOCATED 4.5mm FROM CENTER CROSS
BACK SIDE
WHITE EPOXY IN HATCHED AREA
MAT'L: 1.5mm THICK SODA LIME GLASS
FINISH: BREAK ALL CORNERS
Tolerances
x = ±0.1
x.x = ±0.01
x.xx = ±0.005
x.xxx = ±0.0005
x° = 1.0°
Designer
These drawings and specifications are the property of IPC
and may be used or disclosed only with the furnishing of goods
and/or services to IPC
Filename
Drawing Scale
Sheet

Table 6-5 QFP 208 Slug for Chrome Leads With No Background (Positive)

Drawing File Name: ipc_QFP208_glass_POSITIVE.eps


1
2
3
4
5
6
7
8
A
B
C
D
E
F
Rev No Revision note
Date
Signature Checked
24
24
12.000
12.00
0.5mm R (4 PLCS)
8.50
8.50
12.00
24
12
1mm CHAMFER
(4 PLCS)
FRONT SIDE NOTES:
HATCHED AREA DARK CHROME PLATED
SILVER SIDE UP
16 BALLS EACH SIDE 0.5mm DIAMETER
1.0mm PITCH BETWEEN BALLS
BACK SIDE
WHITE EPOXY IN HATCHED AREA
MAT'L: 1.5mm THICK SODA LIME GLASS
FINISH: BREAK ALL CORNERS
Tolerances
x = ±0.1
x.x = ±0.01
x.xx = ±0.005
x.xxx = ±0.0005
x° = 1.0°
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and/or services to IPC

Figure 6-6 BGA228 Slug for White Background for Leads on Chrome Background

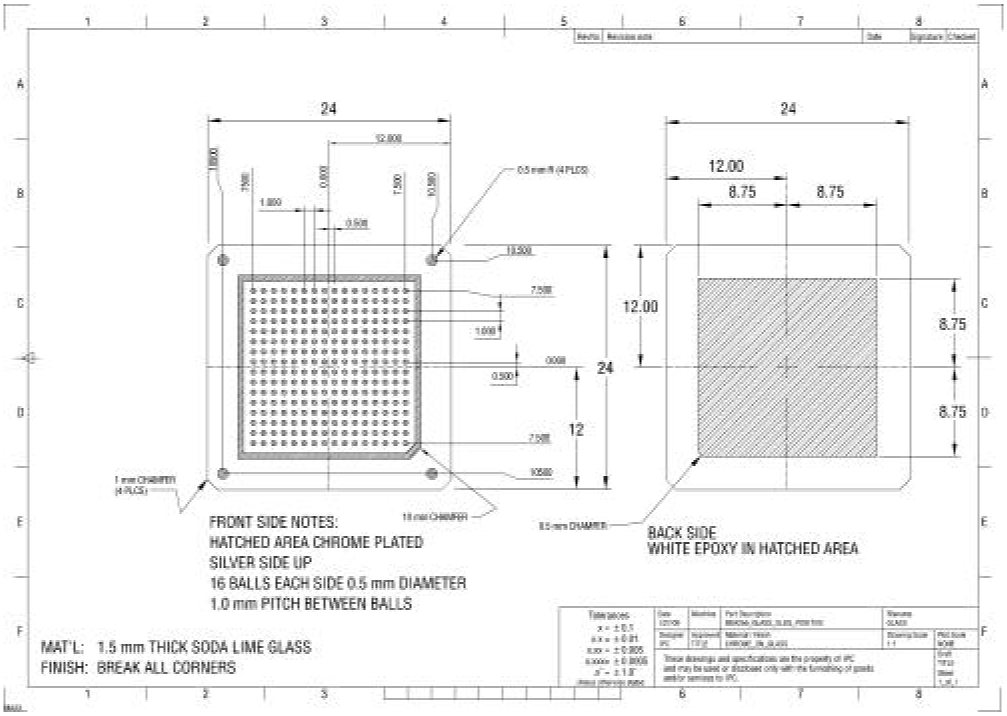

24
12.000
1.000
0.500
7.500
0.000
10.500
0.5 mm R (4 PLCS)
1.000
0.000
0.500
12
24
1 mm CHAMFER (4 PLCS)
1.5 mm CHAMFER
FRONT SIDE NOTES:
HATCHED AREA CHROME PLATED
SILVER SIDE UP
16 BALLS EACH SIDE 0.5 mm DIAMETER
1.0 mm PITCH BETWEEN BALLS
MAT'L: 1.5 mm THICK SODA LIME GLASS
FINISH: BREAK ALL CORNERS
24
12.00
8.75
8.75
12.00
8.75
8.75
0.5 mm DIAMETER
BACK SIDE
WHITE EPOXY IN HATCHED AREA
Tolerances
x = ± 0.1
x.x = ± 0.01
x.xx = ± 0.005
x.xxx = ± 0.0005
x° = ± 1.0°
Part Description
Drawing Scale
1:1
These drawings and specifications are the property of IPC
and may be used or disclosed only with the furnishing of goods
and/or services to IPC.

Figure 6-7 BGA228 Slug for Chrome Leads With No Background

6.4 Sticky Media Application

To maintain the components in location on the glass panel, a double-sided sticky media adhesive is applied to the glass verification panel area between the fiducial markings. There are two important requirements for the sticky media. The first is the consistency by which the sticky material is applied to the glass verification panel surface. It is important that the adhesive be applied evenly across the entire surface of the glass while providing sufficient clarity for the CMM back light. The second requirement is the stability of the sticky material once it is applied to the glass media. The adhesive must maintain the components in position during the placement cycle, where the glass verification panel may be exposed to rapid accelerations. It must also keep the components in position throughout the evaluation procedure as time and environmental conditions change from the placement machine location to the CMM location.

The application of the sticky media to the glass verification panel requires significant care and experience. The application procedure of the sticky media is not specified (it is not possible to improve test results by improper application--only worse results). It is left up to the user to determine the proper application of the adhesive.

Details and suggestions are provided in Appendix C.

6.5 Placement Program

6.5.1 1608C Component

The placement layout for 1608C components was designed to exercise the placement machine's capability at placing components at various distances from each other, so all machine axis are exercised, see Figure 6-8. The components are placed at the four most common placement angles -- 0, 90, 180 270 degrees -- and the placement order and the number of supporting feeders is to be determined by each individual machine vendor with the goal of optimizing placement rate and accuracy for a specific machine type. Appendix E presents the positions of the components with respect of the fiducials in numeric format.

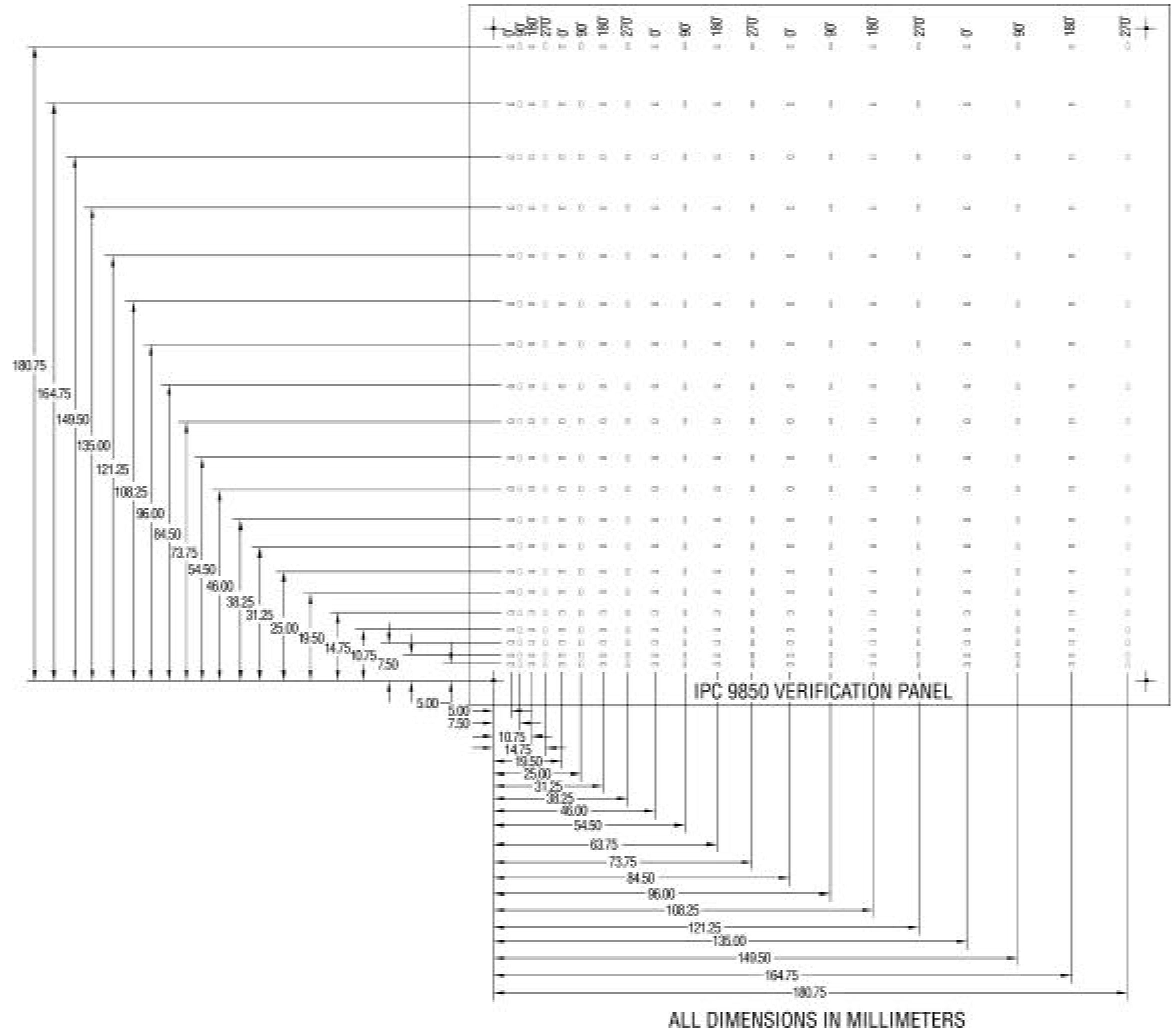

0°
90°
180°
270°
180.75
164.75
149.50
135.00
121.25
108.25
96.00
84.50
73.75
54.50
46.00
38.25
31.25
25.00
19.50
14.75
10.75
7.50
5.00
63.75
IPC 9850 VERIFICATION PANEL
ALL DIMENSIONS IN MILLIMETERS

Figure 6-8 Component Location Layout for 1608C Components

6.5.2 SOIC-16 Component

Figure 6-9 presents the placement layout for the SOIC-16 component on the PVP. Appendix E presents the positions of the components with respect of the fiducials in numeric format.

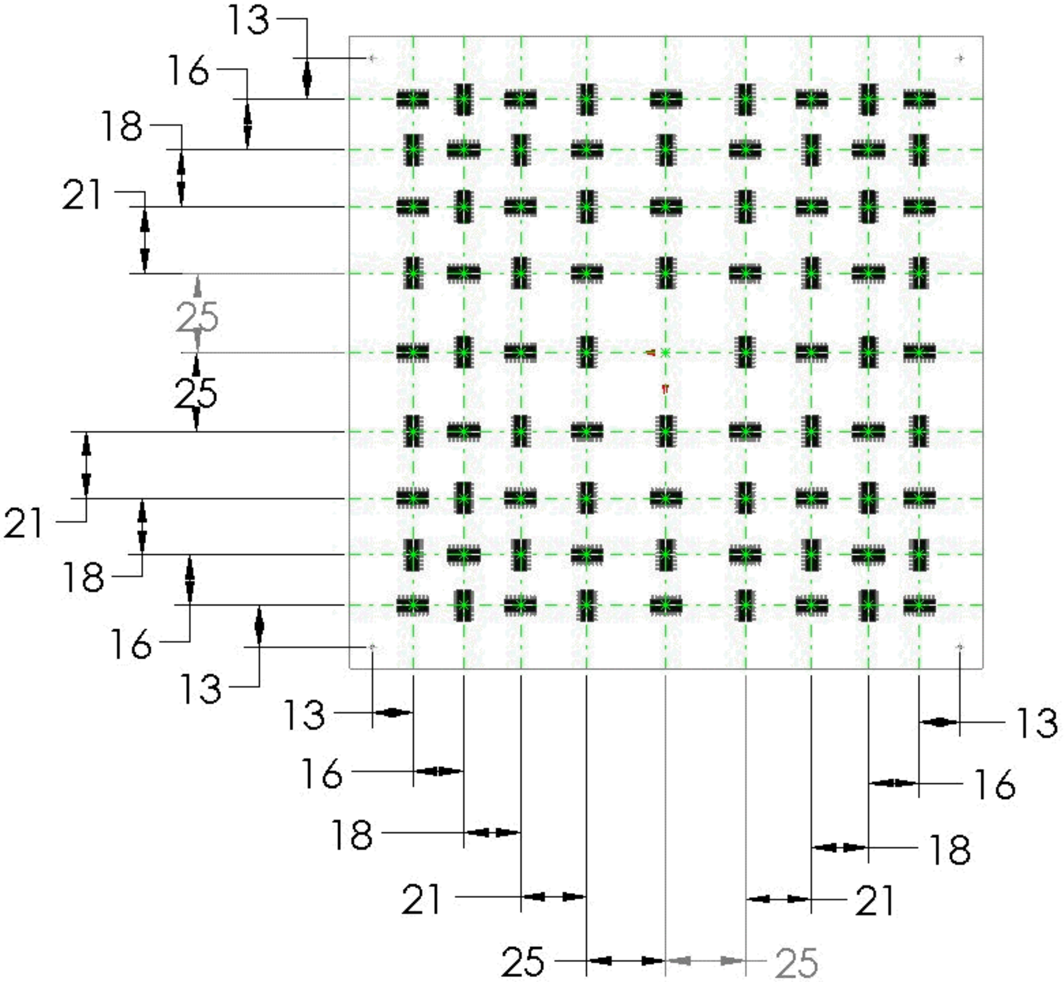
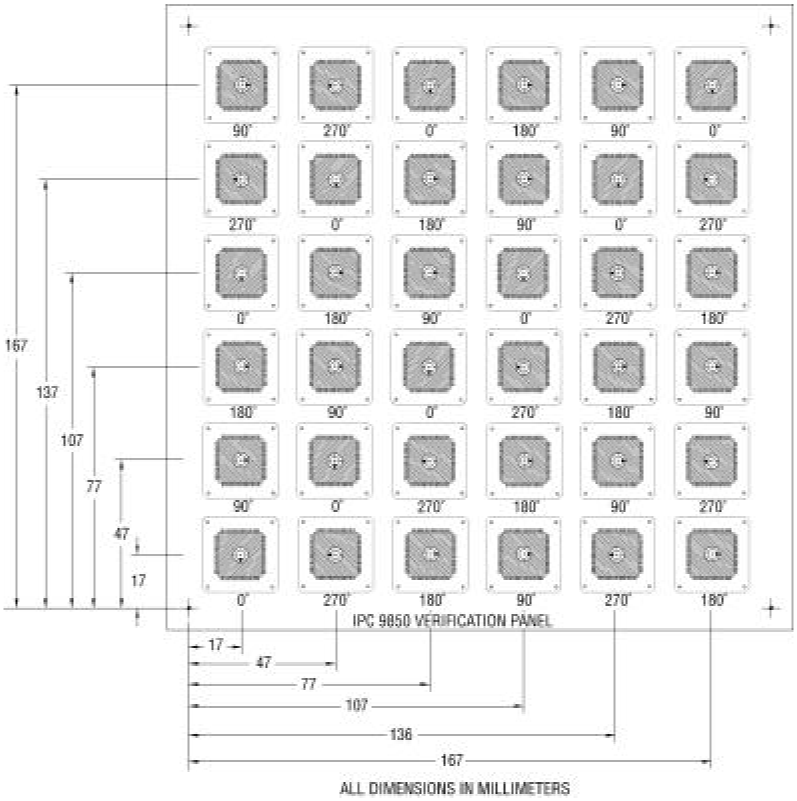

13
16
18
21
25
25
21
18
16
13
13
16
18
21
25
25
21
18
16
13

Figure 6-9 Component Location Layout for SOIC 16 Components
File Name: SOIC-16 Placement Layout.pcx

6.5.3 QFP-100 and BGA-228 Slugs

The panel is populated with glass slugs for the corresponding component type. Fine pitch placement programs for the QFP-100, and BGA-228 have the position and angular rotation pattern shown in Figure 6-10. Appendix E presents the positions of the components with respect of the fiducials in numeric format.


90°
270°
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90°
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167
137
107
77
47
17
IPC 9850 VERIFICATION PANEL
17
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77
107
136
167
ALL DIMENSIONS IN MILLIMETERS

Figure 6-10 Component Location Layout for QFP-100 and BGA 228 Slug Components

6.5.4 QFP-208 Slug

Figure 6-11 presents the placement layout for the QFP-208 slug component on the PVP. Appendix E presents the positions of the components with respect of the fiducials in numeric format.

[new drawing pending]

Figure 6-11 Component Location Layout for QFP-208 Slug Components

7 Forms and Diagrams

The forms and diagrams on the following pages may be freely copied and reproduced. Contact IPC for electronic copies of the forms. [web download after this is published]

Placement Performance Form
IPC-9850-F1

Manufacturer Name	
Machine Model	

When form is used for ship verification	
Serial Number	
Build Date and Time	

Component Type		QFP-100	QFP-255	BGA-228		1608C	SOIC-16
Test Conditions During Build							
Number of Heads/Spindles							
Type of Heads/Spindles							
Type of Camera							
Number of Feeders/Trays							
Type of Nozzles							
Number of Nozzles							
Number of Panels Built		4	4	4		4	4
Number of Parts Per Panel		36	30	36		400 (120 for CMM meas. validation)	80
Test Results							
Build Time, seconds							
Transfer Time, seconds							
Tact Time, seconds							
Net Throughput, CPH							
Repeatability (One Standard Deviation)							
Axis	X, micrometers						
	Y, micrometers						
	θ, degrees						
Accuracy							
Spec. Limits[1] for Cpk=1.33	+X, micrometers						
	+Y, micrometers						
	+θ, degrees						
Spec. Limits[1] for Cpk=2.0	+X, micrometers						
	+Y, micrometers						
	+θ, degrees						
Cpk for Termination-to-Land	50% Coverage					N/A[2]	
	75% Coverage					N/A[2]	

Note 1 : To be valid, reported Spec. Limits must not exceed the Spec. Limits of the CMM capability reported in form IPC-9850-F3.
Note 2: Termination-to-Land evaluation for 1608 components is not required. See Section 3.4.3.2.2 for details.

Form 9850-F1 Performance, issue date

Reliability Performance Form
IPC-9850-F2

Attribute defect rate and Reliability numbers are not to be construed as guarantees in any way. They simply indicate actual levels of reliability for this equipment achieved at customer locations.

Manufacturer Name	
Machine Model	

Attribute Defect Rate (ppm)	

Specified Components		Alternate Components Used	
Component Type	Quantity	Component Type	Quantity
SOT-23	440		
SOIC-8	440		
1608C	880		
1608R	880		
1005C	880		
1005R	880		

Mean Placements Between Assists (MPBA)	
Mean Time To Recover from assists ($MTTR_a$), minutes	
Mean Placements Between Failures (MPBF)	
Mean Time To Repair failures ($MTTR_f$), hours	
Equipment Dependent Uptime, %	
Amount of Preventative Maintenance per 6000 Hours, hours	
Mispick Rate (ppm)	

Data Collected From:

Number of Factories	
Number of Machines	
Total Number of Placements	

Form 9850-F2 Reliability, issue date

CMM Capability to Evaluate Metric Parameters
IPC-9850-F3

Date of GR&R Study	Machine Axis	Repeatability & Reproducibility, GR&R Limits[1]			Accuracy, Spec. Limits[1]		
__________		Glass Slugs[2]	1608 Cap	SOIC-16	Glass Slugs[2]	1608 Cap	SOIC-16
Placement Verification Glass Panel	X, micrometers						
	Y, micrometers						
	θ, deg						
Measurement Capability Glass Panel	X, micrometers						
	Y, micrometers						
	θ, deg						

Note 1: To be valid, reported Spec. Limits in form IPC-9850-F1 must not exceed worse case Spec. Limits of the CMM capability per component type.

Note 2: Since the CMM utilizes the fiducial markings on all glass slugs, regardless of the specific component image, it is only necessary to evaluate the CMM's ability to measure the slugs using the fiducial markings.

Form 9850-F3 CMM Capability, issue date

Appendix A: Capability Indexes.

Cp can be computed when a process specification limit is stated:

$$Cp = \frac{\text{UpperSpecLimit} - \text{Lower SpecLimit}}{6 \cdot s}$$

For a process with target of zero, the upper and lower specs have the same magnitude, the equation can be rewritten as:

$$Cp = \frac{\text{UpperSpecLimit}}{3 \cdot s}$$

Cpk quantifies how many sets of 3 standard deviations lie (fit) between the process mean and the closest specification limit. Cpk is intended for use with distributions that are normal or near normal, and is valuable because it can be used to quantify the number of placements per million that will occur outside of the specification limits due to the lack of accuracy or repeatability of the placement machine.

$$\text{Cpk} = \frac{\min\left(\bar{x} - \text{Lower Spec Limit}, \text{ Upper Spec Limit} - \bar{x}\right)}{3 \cdot s} = \frac{\text{Distance between the mean and the nearest spec}}{3 \cdot s}$$

where s = the standard deviation of the sample.

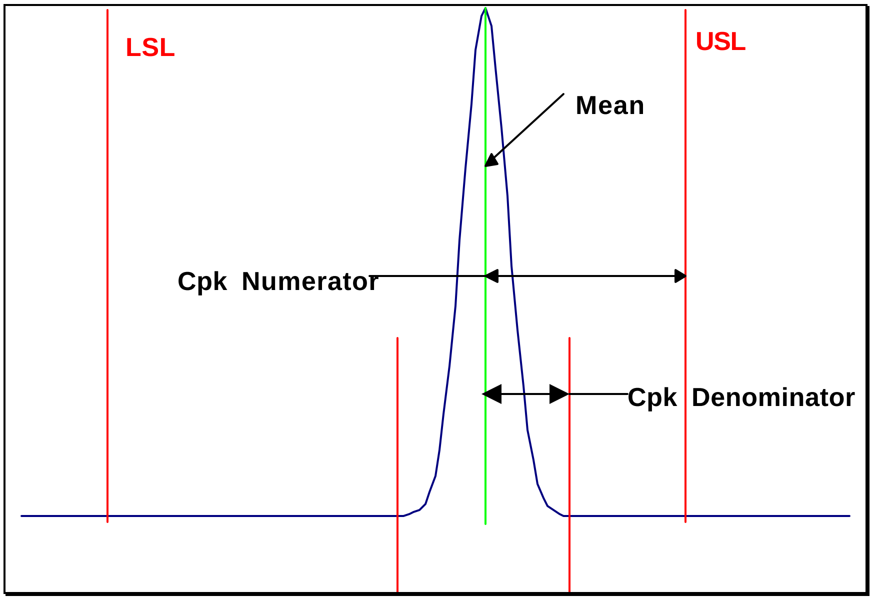


Figure A-1, title

For a centered process the Specification Limits (SL) are obtained by using the following equation, where SD is the standard deviation and Avg is the average of the data set.

Appendix B: Specification Limits for Cpk Values

Definitions:

Process Spread = Standard Deviation of Data Set = SD
Process Mean Average of Data Set = Avg
Process Target = Target
Upper Specification Limit =USL
Lower Specification Limit =LSL

For a centered process Target =0 and thus USL=LSL

Define Specification Limit for a Centered Process = SL = USL=-1*LSL.

Define Specification Width SW = USL-LSL, thus for a Centered Process

SW=SL-(-1*SL)= 2*SL

Define a General Process Capability Index Cp and Cpk as

Cp= SW/(6*SD)

and

Cpk=Cp*(1-K)

Where,

K= (Target-Avg)/(SW/2)

For a centered Process

Cp=2*SL/(6*SD)=SL/(3*SD)

Cpk=(SL/(3*SD))*(1-K) Where K=(0-Avg)/(2*SL/2))=-Avg/SL

Substituting for Cp and K in the Cpk expression yields

Cpk=(SL/(3*SD))*(1--Avg/SL)=SL/(3*SD)+SL*Avg/(3*SD*SL)=SL/(3*SD)+Avg/(3*SD)

Solving for the SL in the Cpk expression yields

SL=3*SD*(Cpk-Avg/(3*SD))=3*SD*Cpk+|Avg|

Example:

X Average=-9.7 micrometers
X Std Dev = 15.9 micrometers

Y Average = 7.6 micrometers
Y Std Dev = 21.7 micrometers

Thus for a Cpk of 2 the SL for the X-axis is

SL=3*15.9*2+|9.7|=105 micrometers

And the SL for the Y-axis is 122 micrometers.

Appendix C

Guidelines for Adhesive Used for Machine Capability Testing (Selection and Application)

C-1 Background

Based on experience by the participating members of the IPC Assembly Equipment Subcommittee, it was recommended that a guideline be written for the selection and application of adhesive used for machine capability testing. It was the Subcommittee's preference to not specify the exact adhesive to use but to establish a guideline that would give some direction for users to select and apply adhesive while performing machine capability tests. Improper selection and application of adhesive could result in a machine performance to be misrepresented. In other words, the data will show a machine to look worse than it actually is.

C-2Purpose

The purpose of this guideline is to provide a user wishing to perform a machine capability test some direction for the selection and application of adhesive. The adhesive is used to hold the test parts onto the glass plate during machine placement. The adhesive also holds the parts in place until an accurate measurement can be taken using a verified CMM (Coordinate Measurement Machine). The adhesive should perform such that the parts do not move more dm a specified amount in actual conditions in which the glass plate is subjected to. The actual conditions being time, temperature and movement of the glass plate.

C-3 Materials / Equipment

It is the intent of the Subcommittee not to specify the adhesive to be used. Based on experience of the members of this Subcommittee, a spray adhesive is not stable enough and can be very inconsistent. This guideline is intended for use with tape or sheet adhesive. This guideline will provide information to select an adequate adhesive and instructions on how to best apply it. At some point in the future, the Subcommittee may elect to set up a process or system to acquire a specific adhesive through IPC if the members see benefit to do so and EPC is in agreement.

The CMM to be used is assumed to be calibrated and in proper working order. The CMM must have been verified to be acceptable using the GR & R procedure that this Subcommittee has set forth. The procedure specifies the glass plate, parts, placement patterns and conditions for performing the GR&R study.

The glass plate and parts that are used to test a particular adhesive should be the same glass plate and part types that will be used to conduct the placement tests needed to report machine capability per the IPC specification.

C-4 Procedure

1. Clean the glass plate and parts (if applicable) using alcohol free glass cleaner and lint free cloth.

2. Tape the area of placement with the double side adhesive. It is recommended that the adhesive be pre-cut to size. The biggest problem with applying adhesive is stretching the adhesive and applying is under stress. The adhesive then moves after the parts have been placed. To avoid this, purchase the adhesive pre-cut or dispense and cut the adhesive avoiding stretch instead of pulling and tearing.

3. For test parts other that chips, strips of adhesive smaller than the test parts should be used versus a full sheet. This will promote removal of test parts, particularly, glass test parts.

4. While applying tape, ensure minimal air bubbles.

5. After the adhesive is applied, verify it is in the correct position and flat.

6. Carefully remove the backing from the adhesive so as not to lift the adhesive from the glass board.

7. Run the glass plate using the same glass plate and part types that will be used to conduct the placement tests. The placement tests are those which have been defined by the Subcommittee.

8. Take the glass plate with parts placed to the CMM for measurement immediately. The glass plate should be transported in a horizontal position. Movement should be minimized as well as conditions such as temperature.

9. Measurements should be taken and output generated for later comparison.

10. The glass plate should be re-measured at some time period after the first measurement. It is recommended that the glass plate be re-measured for comparison at worst case intervals at which are expected by the user. The worst case scenario would be the longest period at which would be expected to elapse between placement and measurement. As a minimum, two hours should elapse between the first measurement and re-measurement.

II. Other re-measurements can be taken after simulating movement conditions or temperature changes.

12. Some adhesives are capable of being re-used. If this is planned for the application, Ns same series of tests should be repeated for each re-use of the adhesive to establish the frequency at which the adhesive should be re-applied. The obvious best case would be to re-apply after each test. As a reminder, poor adhesive will only worsen end results.

13. Measurements should be compared from the initial measurement to all subsequent measurements to look for changes or movement of parts after placement.

14. For the adhesive to be acceptable, the maximum movement that can be observed between the initial measurement and re-measurements should be a maximum of two (2) microns.

C-5 Results / Summary

Poor adhesive, improper application of adhesive, poor measurement re-use of adhesive and many other factors affect test results for machine capability measurement. By following these guidelines, only better results can be obtained. Failure to do so may degrade the perceived performance of a placement machine.

Appendix D
Suggested Methodologies for Measuring Components using an Optical CMM

D-1 Introduction

In the IPC-9850 standard the following components are used to prove the accuracy of placement machines:

- Glass QFP-100, QFP-208
- Glass BGA-228
- Real 1608C
- Real SOIC16

However it is not described how those components must be measured on the CMM machine. The center of the components can be constructed in different ways. Every method has its own accuracy.

This report investigates the different methods to measure the components and the sensitivity of the estimate of the center location of the component to measuring and component variances.
Finally a recommendation is given how the components should be measured.

D-2 Slugs (glass components)

The glass QFP-100, QFP-208 and BGA-228 are provided with 4 fiducials, one at each corner of the component. There are several ways to construct the center and the angle of the component using 2 or all 4 fiducials.

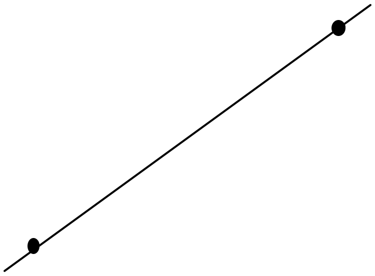
D-2.1 Methods to measure the X- and Y-location of the slug

The different methods to measure the center location of the component are described below.

D-2.1.1 Using 2 fiducials
Measure two diagonal fiducials and take the average x and y

$$x_{component} = \frac{x_1 + x_2}{2}$$

$$y_{component} = \frac{y_1 + y_2}{2}$$

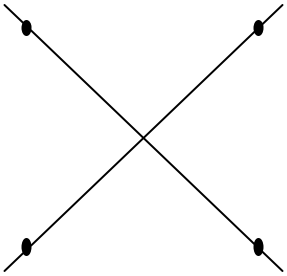


D-2.1.2 Using 4 fiducials
Method 1

Measure all fiducials and take the average x and y:

$$x_{component} = \frac{x_1 + x_2 + x_3 + x_4}{4}$$

$$y_{component} = \frac{y_1 + y_2 + y_3 + y_4}{4}$$



Method 2
Take the intersection point of two diagonal lines through the fiducials

D-2.2 Methods to measure the angle of the slug

The different methods to measure the angle of the component are described below.

D-2.2.1 Using 2 diagonal fiducials

Take the angle of the line through the 2 diagonal fiducials and subtract the nominal angle (in this case the component is square so the nominal angle is 45 degrees).

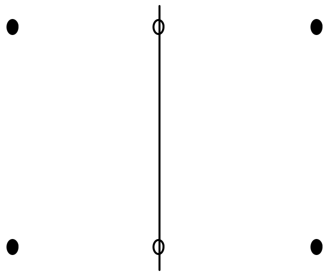
D-2.2.2 Using 4 fiducials

Method 1

Take the average of the angle of the two diagonal lines through the fiducials

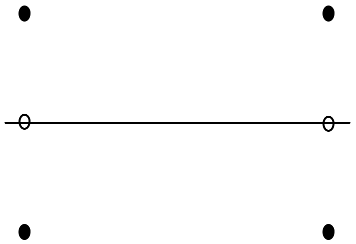
Method 2

Take the angle of the line through the vertical midpoints minus 90 degrees:



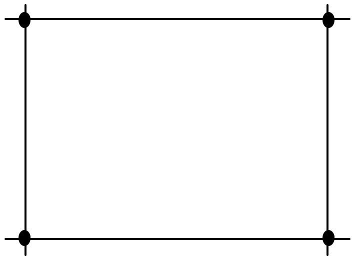
Method 3

Take the angle of the line through the horizontal midpoints:



Method 4

Take the average angle of all "sides" of the component:



Method 5: Take the average of the angles of method 2 and 3

D-2.3 Simulation

By simulating measurement errors on the X- and Y-locations of the fiducials, the sensitivity of the methods above is determined.

The measurement errors on the fiducials are assumed to be distributed with a standard deviation of 0.0005 mm. Then 1000 measurements are simulated (using MS Excel). With those measurements, the x, y, and theta locations of the component are calculated with the different methods above. The mean and standard deviation of the center location using the different methods is given in the tables below.

Using 2 fiducials

Table D-1 Mean and stdev using 2 fiducials (nominal means are: x=0, y=0, theta=0)

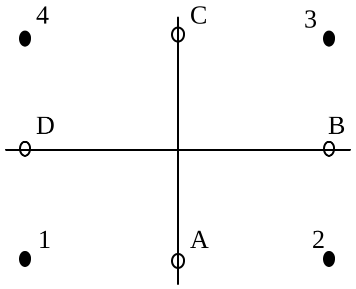
	x (mm)	y (mm)	theta (mm)
Mean	0.000	0.000	0.000
Stdev	62.10^{-5}	61.10^{-5}	243.10^{-5}

Using 4 fiducials

Table D-2 Mean and stdev per method using 4 fiducials (nominal means are: x=0, y=0, theta=0)

	Method 1		Method 2		Method 1	Method 2	Method 3	Method 4	Method 5
	x (mm)	y (mm)	x (mm)	y (mm)	theta (mm)	theta (mm)	theta (mm)	theta (mm)	theta (mm)
Mean	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Stdev	42.10^{-5}	44.10^{-5}	62.10^{-5}	60.10^{-5}	174.10^{-5}	228.10^{-5}	230.10^{-5}	167.10^{-5}	166.10^{-5}

D-2.4 Conclusion



From the results above can be concluded that using 4 fiducials to estimate the center location of the component is more reliable. From table 2 is concluded that the best methods to calculate x,y and theta are method 1 for x,y and method 5 for theta.

So the glass QFP and BGA are recommended to be measured as follows:
Measure the X- and Y-location of the 4 (black) fiducials. Construct with these results 4 (white) midpoints at each side of the component. The theta of the component is constructed by taking the average angle of the 2 lines. Taking the average x and y of the measured fiducials determine the X- and Y-location of the component. Beware that this is NOT the same as taking the intersection point of the 2 lines through the midpoints.

In formulas:

$$x_{component} = \frac{x_1 + x_2 + x_3 + x_4}{4}$$

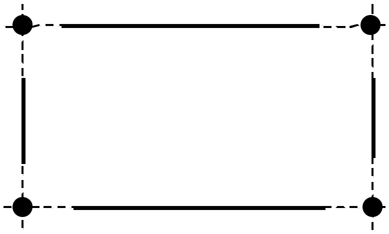
$$y_{component} = \frac{y_1 + y_2 + y_3 + y_4}{4}$$

$$theta_{component} = \frac{theta_{line1} + theta_{line2} - 90}{2} = \frac{\tan^{-1}\left(\frac{y_2+y_3-y_1-y_4}{x_2+x_3-x_1-x_4}\right) + \tan^{-1}\left(\frac{x_1+x_2-x_3-x_4}{y_1+y_2-y_3-y_4}\right)}{2}$$

D-3 1608C component

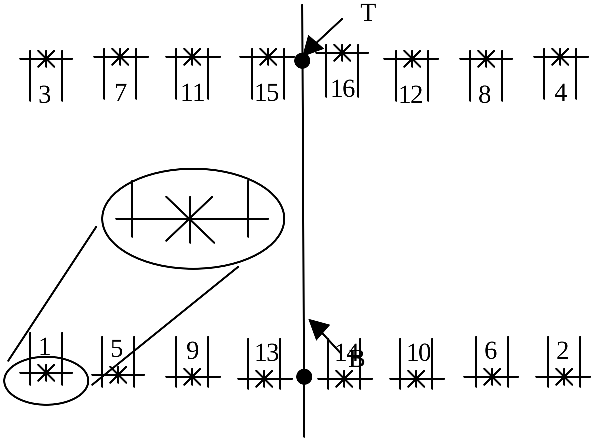
The methods to measure the 1608C component are almost the same as is described for the slugs.
First all four sides of the component are measured (black lines). With these lines, the intersection points are constructed (black points). Now the same methods as described for the 4 fiducials of the slugs can be applied. Therefore also for the 1608C component it is recommended to use method 1 and 5 for the component- x, y and theta respectively.

D-4 SOIC16 component



Method 1

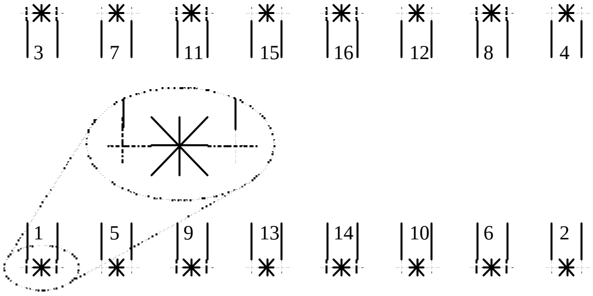
The leads of the SOIC-16 component are measured as follows. The right, left and bottom sides of the lead are measured. Two intersection points are constructed from these measurements. The average x and y of intersection points are the coordinates of the lead.



This can be done for all leads, but also for only a few leads. In the section below, measurements are simulated to determine the influence of the number of measured leads on the center-estimate of the component. Notice that always the most outer leads are measured to get a correct and reliable calculation of the x,y and angle (e.g. Using 8 leads, at both sides the two outer leads are measured).
The position of the center of the component is the average x and y of all measured leads.

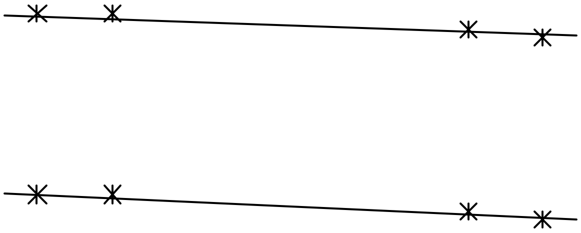
The theta of the component is
1, Average the location for both X_T and Y_T on the top side leads of the component
2, Average the location for both X_B and Y_B on the bottom side leads of the component
3. Use the points (X_T,Y_T) and (X_B,Y_B) to determine a line
4, Then measure the angle of this line minus 90 degrees to determine the angle of the component.

Method 2



The leads of the SOIC16 component are measured as follows. The right, left and bottom sides of the lead are measured. Two intersection points are constructed from these measurements. The average x and y of those intersection points are the coordinates of the lead.

This can be done for all leads, but also for only a few leads. In the section below, measurements are simulated to determine the influence of the number of measured leads on the center-estimate location of the component. Notice that always the most outer leads are measured to get a correct and reliable calculation of the x,y and theta location (e.g. Using 8 leads, at both sides the two outer leads are measured).



The position of the center location of the component is the average X- and Y-location of all measured leads. The theta of the component is determined by fitting a line through the leads at the north side and one through the leads at the south side. The average angle of those two lines is the estimated theta location of the component.

In formulas:

$$x_{comp} = \frac{\sum_{i=1}^{n} x_i}{n}$$

$$y_{comp} = \frac{\sum_{i=1}^{n} y_i}{n}$$

$$theta_{comp} = \frac{\tan^{-1}\left(\frac{\frac{n}{2}\sum\limits_{\text{southleads}} x_i y_i - \left(\sum\limits_{\text{southleads}} x_i \sum\limits_{\text{southleads}} y_i\right)}{\frac{n}{2}\sum\limits_{\text{southleads}} x_i^2 - \left(\sum\limits_{\text{southleads}} x_i\right)}\right) + \tan^{-1}\left(\frac{\frac{n}{2}\sum\limits_{\text{north leads}} x_i y_i - \left(\sum\limits_{\text{north leads}} x_i \sum\limits_{\text{northleads}} y_i\right)}{\frac{n}{2}\sum\limits_{\text{north leads}} x_i^2 - \left(\sum\limits_{\text{northleads}} x_i\right)}\right)}{2}$$

D-4.1 Simulation

The variation on the intersection points of the leads comes from two error causes:

1. The measurement error, distribution assumed with stdev of 0.0005
2. The component variation, distribution assumed with stdev of 0.0017 in x and 0.0127 in y

With these estimates of the intersection points the lead location is calculated. And with those leads, the center- and angle location of the component is estimated, using 4,8,12 or 16 leads.
In this way ten thousand measurements are simulated. In the table below are given the estimates of the center- and angle location of the component using 4,8,12 or 16 leads.

Nr. of leads used	Mean			Stdev		
	x	y	theta	x	y	theta
4	0.000	0.000	0.000	0.0014	0.0081	1.0325
8	0.000	0.000	0.005	0.0010	0.0057	0.8420
12	0.000	0.000	0.000	0.0008	0.0047	0.8028
16	0.000	0.000	0.001	0.0007	0.0040	0.7989

Table D-3: ***Mean and stdev vs. nr. of measured leads (nominal means are: x=0, y=0, theta=0)***

D-4.2 Conclusion

From the results above, can be concluded that using all 16 leads, gives the best estimate of the center- and angle location of the component.

D-5 Recommendations

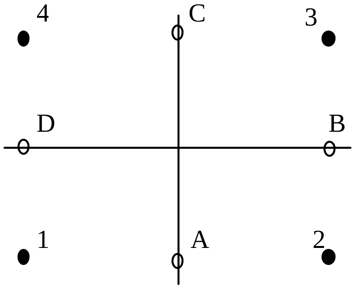
The results in this report show that the way the center- and angle location of a component are measured influences the accuracy. Therefore it is recommended to include general directions for measuring the components which are used in the IPC-9850 standard.

In the figures below, the measurement recommendations given in this Appendix are summarized.

Glass QFP-100, QFP-208 and BGA-228

Measure the fiducials (1,2,3,4)
Construct intersection points (A,B,C,D)

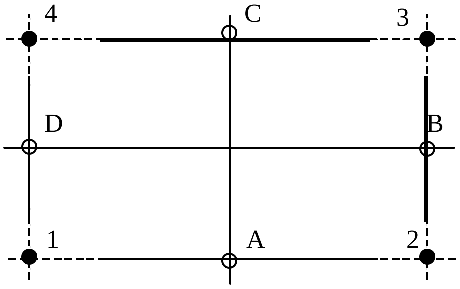
x,y: Average of x resp. y of the fiducials (1,2,3,4)
theta: Average angle of lines AC and BD



1608C

Measure sides of component (thick lines)
Construct intersection points (1,2,3,4)
Calculate midpoints (A,B,C,D)

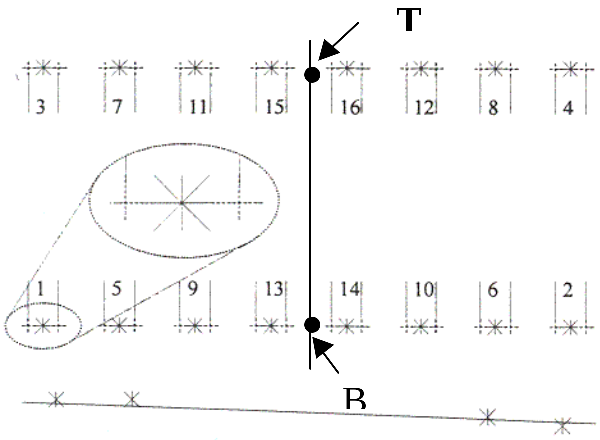
x,y: Average of x resp. y of the fiducials (1,2,3,4)
theta: Average angle of lines AC and BD



SOIC16

Measure left, right and bottom of lead.
Construct intersection points.
Construct midpoint (*).
Draw fines through northern and southern midpoints.

x,y. Average of all leads



Method 1

The theta of the component is
1, Average the location for both X_T and Y_T on the top side leads of the component
2, Average the location for both X_B and Y_B on the bottom side leads of the component
3. Use the points (X_T, Y_T) and (X_B, Y_B) to determine a line
4, Then measure the angle of this line minus 90 degrees to determine the angle of the component.

Method 2

theta: Average of angles of northern and southern line.

Appendix E
Component Locations for Panel Population

IPC 9850 1608C CHIP GRID LAYOUT

		X_1 5			X_2 7.5			X_3 10.75			X_4 14.75			X_5 19.5			X_6 25			X_7 31.25			X_8 38.25			X_9 46			X_{10} 54.5		
		X	Y	θ	X	Y	θ	X	Y	θ	X	Y	θ	X	Y	θ	X	Y	θ	X	Y	θ	X	Y	θ	X	Y	θ	X	Y	θ
Y_1	5	5	5	0	7.5	5	90	10.75	5	180	14.75	5	270	19.5	5	0	25	5	90	31.25	5	180	38.25	5	270	46	5	0	54.5	5	90
Y_2	7.5	5	7.5	0	7.5	7.5	90	10.75	7.5	180	14.75	7.5	270	19.5	7.5	0	25	7.5	90	31.25	7.5	180	38.25	7.5	270	46	7.5	0	54.5	7.5	90
Y_3	10.75	5	10.75	0	7.5	10.75	90	10.75	10.75	180	14.75	10.75	270	19.5	10.75	0	25	10.75	90	31.25	10.75	180	38.25	10.75	270	46	10.75	0	54.5	10.75	90
Y_4	14.75	5	14.75	0	7.5	14.75	90	10.75	14.75	180	14.75	14.75	270	19.5	14.75	0	25	14.75	90	31.25	14.75	180	38.25	14.75	270	46	14.75	0	54.5	14.75	90
Y_5	19.5	5	19.5	0	7.5	19.5	90	10.75	19.5	180	14.75	19.5	270	19.5	19.5	0	25	19.5	90	31.25	19.5	180	38.25	19.5	270	46	19.5	0	54.5	19.5	90
Y_6	25	5	25	0	7.5	25	90	10.75	25	180	14.75	25	270	19.5	25	0	25	25	90	31.25	25	180	38.25	25	270	46	25	0	54.5	25	90
Y_7	31.25	5	31.25	0	7.5	31.25	90	10.75	31.25	180	14.75	31.25	270	19.5	31.25	0	25	31.25	90	31.25	31.25	180	38.25	31.25	270	46	31.25	0	54.5	31.25	90
Y_8	38.25	5	38.25	0	7.5	38.25	90	10.75	38.25	180	14.75	38.25	270	19.5	38.25	0	25	38.25	90	31.25	38.25	180	38.25	38.25	270	46	38.25	0	54.5	38.25	90
Y_9	46	5	46	0	7.5	46	90	10.75	46	180	14.75	46	270	19.5	46	0	25	46	90	31.25	46	180	38.25	46	270	46	46	0	54.5	46	90
Y_{10}	54.5	5	54.5	0	7.5	54.5	90	10.75	54.5	180	14.75	54.5	270	19.5	54.5	0	25	54.5	90	31.25	54.5	180	38.25	54.5	270	46	54.5	0	54.5	54.5	90
Y_{11}	63.75	5	63.75	0	7.5	63.75	90	10.75	63.75	180	14.75	63.75	270	19.5	63.75	0	25	63.75	90	31.25	63.75	180	38.25	63.75	270	46	63.75	0	54.5	63.75	90
Y_{12}	73.75	5	73.75	0	7.5	73.75	90	10.75	73.75	180	14.75	73.75	270	19.5	73.75	0	25	73.75	90	31.25	73.75	180	38.25	73.75	270	46	73.75	0	54.5	73.75	90
Y_{13}	84.5	5	84.5	0	7.5	84.5	90	10.75	84.5	180	14.75	84.5	270	19.5	84.5	0	25	84.5	90	31.25	84.5	180	38.25	84.5	270	46	84.5	0	54.5	84.5	90
Y_{14}	96	5	96	0	7.5	96	90	10.75	96	180	14.75	96	270	19.5	96	0	25	96	90	31.25	96	180	38.25	96	270	46	96	0	54.5	96	90
Y_{15}	108.25	5	108.25	0	7.5	108.25	90	10.75	108.25	180	14.75	108.25	270	19.5	108.25	0	25	108.25	90	31.25	108.25	180	38.25	108.25	270	46	108.25	0	54.5	108.25	90
Y_{16}	121.25	5	121.25	0	7.5	121.25	90	10.75	121.25	180	14.75	121.25	270	19.5	121.25	0	25	121.25	90	31.25	121.25	180	38.25	121.25	270	46	121.25	0	54.5	121.25	90
Y_{17}	135	5	135	0	7.5	135	90	10.75	135	180	14.75	135	270	19.5	135	0	25	135	90	31.25	135	180	38.25	135	270	46	135	0	54.5	135	90
Y_{18}	149.5	5	149.5	0	7.5	149.5	90	10.75	149.5	180	14.75	149.5	270	19.5	149.5	0	25	149.5	90	31.25	149.5	180	38.25	149.5	270	46	149.5	0	54.5	149.5	90
Y_{19}	164.75	5	164.75	0	7.5	164.75	90	10.75	164.75	180	14.75	164.75	270	19.5	164.75	0	25	164.75	90	31.25	164.75	180	38.25	164.75	270	46	164.75	0	54.5	164.75	90
Y_{20}	180.75	5	180.75	0	7.5	180.75	90	10.75	180.75	180	14.75	180.75	270	19.5	180.75	0	25	180.75	90	31.25	180.75	180	38.25	180.75	270	46	180.75	0	54.5	180.75	90

		X_{11} 63.75			X_{12} 73.75			X_{13} 84.5			X_{14} 96			X_{15} 108.25			X_{16} 121.25			X_{17} 135			X_{18} 149.5			X_{19} 164.75			X_{20} 180.75		
		X	Y	θ	X	Y	θ	X	Y	θ	X	Y	θ	X	Y	θ	X	Y	θ	X	Y	θ	X	Y	θ	X	Y	θ	X	Y	θ
Y_1	5	63.75	5	180	73.75	5	270	84.5	5	0	96	5	90	108.25	5	180	121.25	5	270	135	5	0	149.5	5	90	164.75	5	180	180.75	5	270
Y_2	7.5	63.75	7.5	180	73.75	7.5	270	84.5	7.5	0	96	7.5	90	108.25	7.5	180	121.25	7.5	270	135	7.5	0	149.5	7.5	90	164.75	7.5	180	180.75	7.5	270
Y_3	10.75	63.75	10.75	180	73.75	10.75	270	84.5	10.75	0	96	10.75	90	108.25	10.75	180	121.25	10.75	270	135	10.75	0	149.5	10.75	90	164.75	10.75	180	180.75	10.75	270
Y_4	14.75	63.75	14.75	180	73.75	14.75	270	84.5	14.75	0	96	14.75	90	108.25	14.75	180	121.25	14.75	270	135	14.75	0	149.5	14.75	90	164.75	14.75	180	180.75	14.75	270
Y_5	19.5	63.75	19.5	180	73.75	19.5	270	84.5	19.5	0	96	19.5	90	108.25	19.5	180	121.25	19.5	270	135	19.5	0	149.5	19.5	90	164.75	19.5	180	180.75	19.5	270
Y_6	25	63.75	25	180	73.75	25	270	84.5	25	0	96	25	90	108.25	25	180	121.25	25	270	135	25	0	149.5	25	90	164.75	25	180	180.75	25	270
Y_7	31.25	63.75	31.25	180	73.75	31.25	270	84.5	31.25	0	96	31.25	90	108.25	31.25	180	121.25	31.25	270	135	31.25	0	149.5	31.25	90	164.75	31.25	180	180.75	31.25	270
Y_8	38.25	63.75	38.25	180	73.75	38.25	270	84.5	38.25	0	96	38.25	90	108.25	38.25	180	121.25	38.25	270	135	38.25	0	149.5	38.25	90	164.75	38.25	180	180.75	38.25	270
Y_9	46	63.75	46	180	73.75	46	270	84.5	46	0	96	46	90	108.25	46	180	121.25	46	270	135	46	0	149.5	46	90	164.75	46	180	180.75	46	270
Y_{10}	54.5	63.75	54.5	180	73.75	54.5	270	84.5	54.5	0	96	54.5	90	108.25	54.5	180	121.25	54.5	270	135	54.5	0	149.5	54.5	90	164.75	54.5	180	180.75	54.5	270
Y_{11}	63.75	63.75	63.75	180	73.75	63.75	270	84.5	63.75	0	96	63.75	90	108.25	63.75	180	121.25	63.75	270	135	63.75	0	149.5	63.75	90	164.75	63.75	180	180.75	63.75	270
Y_{12}	73.75	63.75	73.75	180	73.75	73.75	270	84.5	73.75	0	96	73.75	90	108.25	73.75	180	121.25	73.75	270	135	73.75	0	149.5	73.75	90	164.75	73.75	180	180.75	73.75	270
Y_{13}	84.5	63.75	84.5	180	73.75	84.5	270	84.5	84.5	0	96	84.5	90	108.25	84.5	180	121.25	84.5	270	135	84.5	0	149.5	84.5	90	164.75	84.5	180	180.75	84.5	270
Y_{14}	96	63.75	96	180	73.75	96	270	84.5	96	0	96	96	90	108.25	96	180	121.25	96	270	135	96	0	149.5	96	90	164.75	96	180	180.75	96	270
Y_{15}	108.25	63.75	108.25	180	73.75	108.25	270	84.5	108.25	0	96	108.25	90	108.25	108.25	180	121.25	108.25	270	135	108.25	0	149.5	108.25	90	164.75	108.25	180	180.75	108.25	270
Y_{16}	121.25	63.75	121.25	180	73.75	121.25	270	84.5	121.25	0	96	121.25	90	108.25	121.25	180	121.25	121.25	270	135	121.25	0	149.5	121.25	90	164.75	121.25	180	180.75	121.25	270
Y_{17}	135	63.75	135	180	73.75	135	270	84.5	135	0	96	135	90	108.25	135	180	121.25	135	270	135	135	0	149.5	135	90	164.75	135	180	180.75	135	270
Y_{18}	149.5	63.75	149.5	180	73.75	149.5	270	84.5	149.5	0	96	149.5	90	108.25	149.5	180	121.25	149.5	270	135	149.5	0	149.5	149.5	90	164.75	149.5	180	180.75	149.5	270
Y_{19}	164.75	63.75	164.75	180	73.75	164.75	270	84.5	164.75	0	96	164.75	90	108.25	164.75	180	121.25	164.75	270	135	164.75	0	149.5	164.75	90	164.75	164.75	180	180.75	164.75	270
Y_{20}	180.75	63.75	180.75	180	73.75	180.75	270	84.5	180.75	0	96	180.75	90	108.25	180.75	180	121.25	180.75	270	135	180.75	0	149.5	180.75	90	164.75	180.75	180	180.75	180.75	270

IPC 9850 SOIC16 GRID LAYOUT

left to right

top to bottom

	13	29	47	68	93	118	139	157	173
13	X	X	X	X	X	X	X	X	X
29	X	X	X	X	X	X	X	X	X
47	X	X	X	X	X	X	X	X	X
68	X	X	X	X	X	X	X	X	X
93	X	X	X	X		X	X	X	X
118	X	X	X	X	X	X	X	X	X
139	X	X	X	X	X	X	X	X	X
157	X	X	X	X	X	X	X	X	X
173	X	X	X	X	X	X	X	X	X

80 points in a 9 x 9 grid with no center point.

0	90	180	270	0	90	180	270	0
90	180	270	0	90	180	270	0	90
180	270	0	90	180	270	0	90	180
270	0	90	180	270	0	90	180	270
0	90	180	270		90	180	270	0
270	0	90	180	270	0	90	180	270
180	270	0	90	180	270	0	90	180
90	180	270	0	90	180	270	0	90
0	90	180	270	0	90	180	270	0

IPC 9850 QFP-100 & BGA-228 GRID LAYOUT

		X_1		17	X_2		47	X_3		77	X_4		107	X_5		137	X_6		167
		X	Y	θ	X	Y	θ	X	Y	θ	X	Y	θ	X	Y	θ	X	Y	θ
Y_1	17	17	17	90	47	17	270	77	17	0	107	17	180	137	17	90	167	17	0
Y_2	47	17	47	270	47	47	0	77	47	180	107	47	90	137	47	0	167	47	270
Y_3	77	17	77	0	47	77	180	77	77	90	107	77	0	137	77	270	167	77	180
Y_4	107	17	107	180	47	107	90	77	107	0	107	107	270	137	107	180	167	107	90
Y_5	137	17	137	90	47	137	0	77	137	270	107	137	180	137	137	90	167	137	270
Y_6	167	17	167	0	47	167	270	77	167	180	107	167	90	137	167	270	167	167	180

Rotation Chart

90	270	0	180	90	0
270	0	180	90	0	270
0	180	90	0	270	180
180	90	0	270	180	90
90	0	270	180	90	270
0	270	180	90	270	180

IPC 9850 QFP-208 GRID LAYOUT

Appendix F- Component Location for Accuracy Verification Panel
(to be developed)

Appendix G- How to Perform a GR&R Test
Instruction for Using the Gauge R&R Spreadsheet

G-1 Purpose Gauge R&R is performed to determine the reliability of the measurement process. The Gauge R&R test sums all the possible sources of error related to having repeatable and reproducible measurements. A list of possible sources of error are:

G-2 Inspection Measurement Machine – all inspection machines are specified to have limits on how accurately and repeatably they can measure. This is due mostly to machine design and will vary depending quality and price of CMM used.

G-3 Inspection Program – the user will write a program for the CMM machine that will measure different components and different boards. These programs could possibly be a big source of error if they are not written properly. Every program written will need to have a GR&R test done to ensure its accuracy. For this standard there needs to be a minimum of 3 different GR&R tests:

- 1608 Capacitor Board
- SOIC16 Board
- Glass Part Board (Assumes the same program is run for both BGA and QFP part)

G-4 Error Contributed by Fixture – When the board is mounted on the CMM during measurement any movement will cause an error. The goal of the fixture is to hold the board securely every time it is measured.

G-5 Operator Error – If different operators run the same test they should get the same results. Any variation between the different operators is error. Note: The goal of a good inspection program and fixturing system is to reduce this variable. If operator error is high the inspection program and/or the fixtures need to be changed.

G-6 Error Contributed by the Component

Glass Component **-** measurement uncertainty
Live Components
Chips **-** Resisters, the die cutting process. Capacitors cut with a die saw
Leaded - plastic package forming, lead finish etc.

G-7 Equipment Needed:

- CMM
- 1 Measurement Verification Panel and mounting fixture
- Parts (one of the following)
    - 36 glass QFP-100 slugs
    - 30 glass QFP-208 slugs
    - 36 glass BGA slugs
- 80 SOIC16
- 400 1608C

G-8 Procedure:

1. Run one Measurement Verification Panel on any piece of equipment.

Note: This test is not testing the placement equipment in any way, so the machine that places the placement does not matter; but the components should be placed on the board with a average amount of deviation.

2. Operator 1 then takes this board and places it on the inspection machine, run the board and logs the results. These results are copied into the Operator 1; Test 1 area of the spreadsheet.
3. Operator 1 then removes the board from the inspection machine.
4. Operator 1 then places the board back onto the inspection machine, runs the board and gets the results. These results are copied into the Operator 1; Test 2 area of the spreadsheet.
5. Operator 1 then removes the board from the inspection machine.
6. Operator 1 then places the board back onto the inspection machine, runs the board and gets the results. These results are copied into the Operator 1; Test 3 area of the spreadsheet.
7. Operator 1 then removes the board and gives to Operator 2.
8. Operator 2 then runs steps 2 though 6 placing their data into the Operator 2 section of the spreadsheet.
9. When all of the data has been entered into the spreadsheet, switch screens to the analysis sheet. Press the get data button. This will enter the data into the correct columns of the spreadsheet and calculate the result.

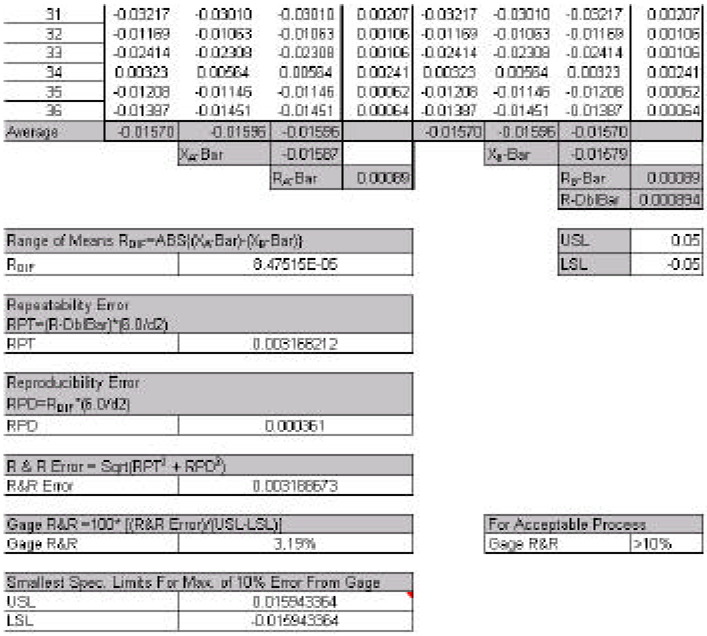
The calculation that is performed is the Average & Range method.

Appendix H- Instruction for Using the Gauge R&R Spreadsheet

G-9 Calculation Method: Average and Range Method

G-10 Definitions

X_A-Bar = Average of all the points measured by operator A
R_A-Bar = The average of ranges measured by operator A
X_B-Bar = Average of all the points measured by operator B
R_B-Bar = The average of ranges measured by operator B
*R-DblBar = **The average of the ranges from operator A and B***
R_{DIF} = This is the range between the averages for operators A and B
d_2 = 1.693



31	-0.03217	-0.03010	-0.03010	0.00207	-0.03217	-0.03010	-0.03217	0.00207
32	-0.01169	-0.01063	-0.01063	0.00106	-0.01169	-0.01063	-0.01169	0.00106
33	-0.02414	-0.02309	-0.02308	0.00106	-0.02414	-0.02309	-0.02414	0.00106
34	0.00323	0.00564	0.00564	0.00241	0.00323	0.00564	0.00323	0.00241
35	-0.01208	-0.01146	-0.01146	0.00062	-0.01208	-0.01146	-0.01208	0.00062
36	-0.01397	-0.01451	-0.01451	0.00064	-0.01397	-0.01451	-0.01397	0.00064
Average	-0.01570	-0.01596	-0.01596		-0.01570	-0.01596	-0.01570	
		X_A-Bar	-0.01587			X_B-Bar	-0.01579	
			R_A-Bar	0.00089			R_B-Bar	0.00089
							R-DblBar	0.000894

Range of Means R_{DIF}=ABS{(X_A-Bar)-(X_B-Bar)}	
R_{DIF}	8.47515E-05

USL	0.05
LSL	-0.05

Repeatability Error RPT=(R-DblBar)*(6.0/d2)	
RPT	0.003168212

Reproducibility Error RPD=R_{DIF}*(6.0/d2)	
RPD	0.000361

R & R Error = Sqrt(RPT^2 + RPD^2)	
R&R Error	0.003188673

Gage R&R =100* [(R&R Error)/(USL-LSL)]	
Gage R&R	3.19%

For Acceptable Process	
Gage R&R	>10%

Smallest Spec. Limits For Max. of 10% Error From Gage	
USL	0.015943364
LSL	-0.015943364

G-11 Formulas (As seen in the spreadsheet above)

G-11.2 Range of Means

R_{DIF} = ABS{(X_A-Bar)-(X_B-Bar)}

G-11.3 Repeatability Error

RPT = (R-DblBar)*(6.0/d2)

G-11.4 Reproducibility Error

RPD = (R_{DIF})*(6.0/d2)

G-11.5 Total Error

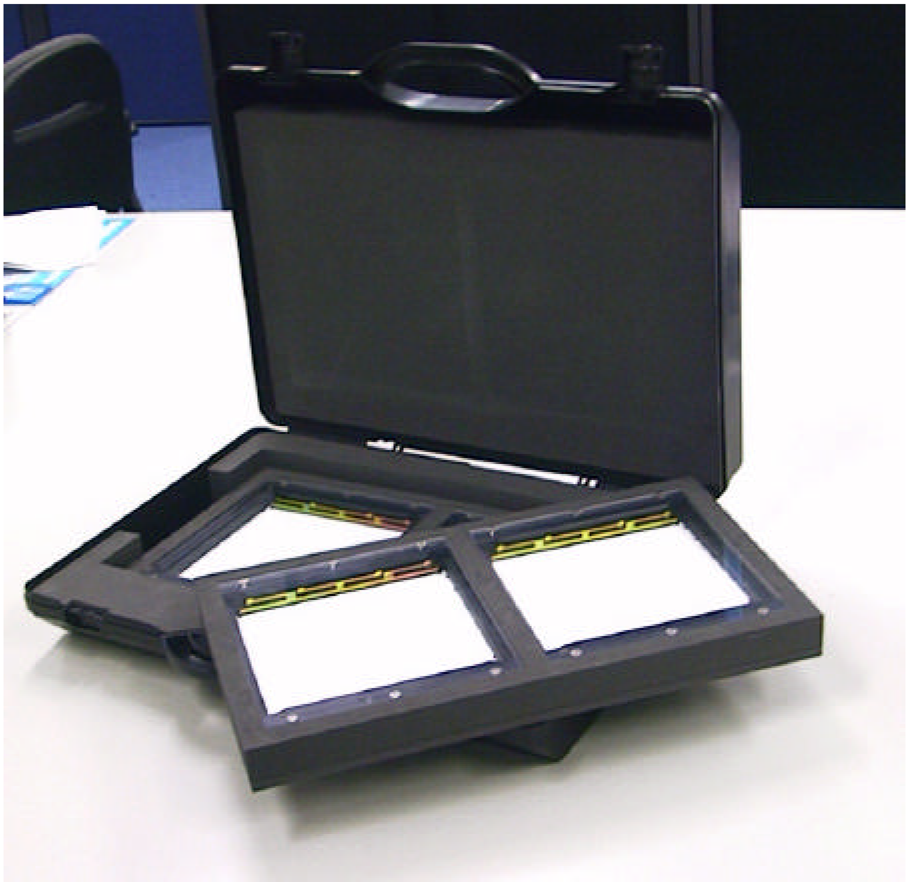
R&R Error = SQRT(RPT^2+PRD^2)

Gage R&R =100*[(R&R Error)/(USL-LSL)]
(Must be less then 10% for gage to be valid)

Lowest Specification Limits possible with current gage error.
+/-Specification Limits = ABS{(1/2)*(10)*R&R Error}

Appendix I - Placement Verification Panel Carrier

A photograph of a suggested suitcase for the Placement Verification Panel carrier. The suitcase is the packaging for the set of 4 separate carriers. See ‘CarrierDocuments.zip’ for design details of the carrier.

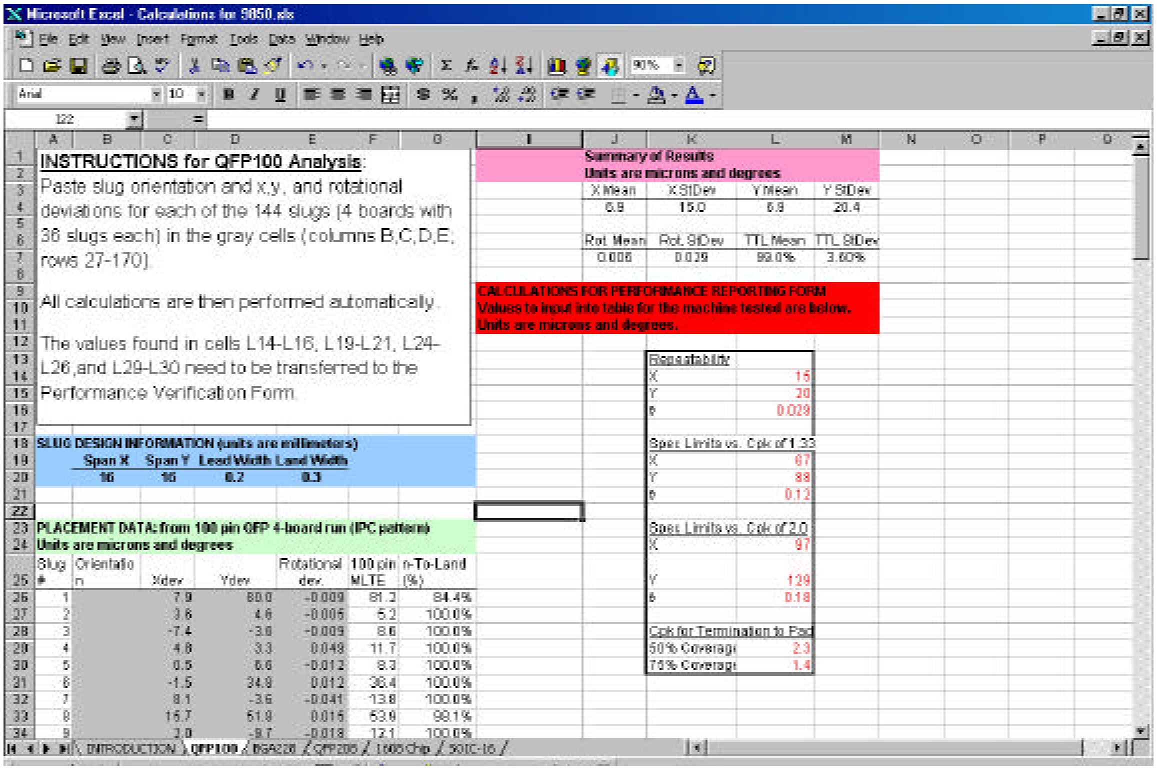


Appendix J- Instruction for Using The 'Termination-to-Land Calculations.xls' spreadsheets

The workbook contains a spreadsheet for each of the 5 component types. In each worksheet, instructions are included that explain where to place the x, y, and theta errors that were established by the CMM for all components on the 4 boards. A workbook with termination-to-land calculation spreadsheets for each of the five component types may be downloaded from the IPC web site. (Document reviewers contact Jack Crawford at IPC for this file.)

The spreadsheet automatically calculates the summary information that needs to be put into the Performance Reporting Form when it is being used to verify specification compliance.

As an example, here is what the QFP100 spreadsheet looks like:


Microsoft Excel - Calculations for 9850.xls
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Arial
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INTRODUCTION
QFP100
BGA228
QFP208
1608 Chip
SOIC-16

INSTRUCTIONS for QFP100 Analysis:
Paste slug orientation and x,y, and rotational deviations for each of the 144 slugs (4 boards with 36 slugs each) in the gray cells (columns B,C,D,E; rows 27-170).

All calculations are then performed automatically.

The values found in cells L14-L16, L19-L21, L24-L26, and L29-L30 need to be transferred to the Performance Verification Form.

Summary of Results
Units are microns and degrees

X Mean	X StDev	Y Mean	Y StDev
6.9	15.0	6.9	20.4
Rot. Mean	Rot. StDev	TTL Mean	TTL StDev
0.006	0.029	99.0%	3.60%

CALCULATIONS FOR PERFORMANCE REPORTING FORM
Values to input into table for the machine tested are below.
Units are microns and degrees.

Repeatability	
X	16
Y	30
θ	0.029
Spec Limits vs. Cpk of 1.33	
X	67
Y	88
θ	0.12
Spec Limits vs. Cpk of 2.0	
X	97
Y	129
θ	0.18
Cpk for Termination to Pad	
50% Coverage	2.3
75% Coverage	1.4

SLUG DESIGN INFORMATION (units are millimeters)

Span X	Span Y	Lead Width	Land Width
16	16	0.2	0.3

PLACEMENT DATA: from 100 pin QFP 4-board run (IPC pattern)
Units are microns and degrees

Slug #	Orientation	Xdev	Ydev	Rotational dev.	100 pin MLTE	n-To-Land (%)
1		7.9	80.0	-0.009	81.2	84.4%
2		3.6	4.6	-0.005	5.2	100.0%
3		-7.4	-3.0	-0.009	8.6	100.0%
4		4.8	3.3	0.049	11.7	100.0%
5		0.5	6.6	-0.012	8.3	100.0%
6		-1.5	34.9	0.012	36.4	100.0%
7		8.1	-3.6	-0.041	13.8	100.0%
8		15.7	51.9	0.016	53.9	98.1%
9		2.0	-9.7	-0.018	12.1	100.0%

The equations used are identical to those presented in the body of this standard.