



ASSOCIATION CONNECTING
ELECTRONICS INDUSTRIES

IPC-2615

Printed Board Dimensions and Tolerances

IPC-2615

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A standard developed by IPC

2215 Sanders Road, Northbrook, IL 60062-6135

Tel. 847.509.9700 Fax 847.509.9701

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Printed Board Dimensions and Tolerances

Developed by the Dimensioning and Tolerancing Task Group (1-10a) of
the Printed Board Design Committee (1-10)

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

Contact:

IPC
2215 Sanders Road
Northbrook, Illinois
60062-6135
Tel 847 509.9700
Fax 847 509.9798



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Any Standard involving a complex technology draws material from a vast number of sources. While the principal members of the Dimensioning and Tolerancing Task Group (1-10a) of the Printed Board Design Committee (1-10) are shown below, it is not possible to include all of those who assisted in the evolution of this standard. To each of them, the members of the IPC extend their gratitude.

Printed Board Design Committee

Chairman
Rick Hartley
Applied Innovation

Dimensioning and Tolerancing Task Group

Chairman
John A. Sabo, C.I.D.
Rockwell Automation/
Allen Bradley

Technical Liaisons of the IPC Board of Directors

Stan Plzak	Peter Bigelow
Pensar Corp.	Beaver Brook
	Circuits Inc.

Dimensioning and Tolerancing Task Group

Leon Cohen
C. Don Dupriest, Lockheed Martin Corporation
Will J Edwards, Lucent Technologies Inc.
Joe Fjelstad, Pacific Consultants LLC

Pierre Gadoua, Bae Systems Canada, Inc.
John H. Morton, C.I.D., Lockheed Martin Corporation
Deepak K. Pai, C.I.D., General Dynamics Information Sys. Inc.

John A. Sabo, C.I.D., Rockwell Automation/Allen-Bradley
Margaret Terpening, Boeing Phantom Works
Wally Younger, Nelco Technology, Inc.

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Printed Board Dimensions and Tolerances

1 PURPOSE

The purpose of this Standard is to establish acceptable principals and practices for dimensioning and tolerancing used to define end-product requirements for printed boards and printed board assemblies.

1.1 Scope This Standard covers dimensioning and tolerancing of electronic packaging as it relates to printed boards and the assembly of printed boards. The concepts defined in this Standard are derived from ASME Y14.5M-1994. Printed boards have such wide applications that there may be times where this standard does not address a specific case. In those cases, the user is referred to ASME Y14.5M 1994 for use of additional dimensioning and tolerancing concepts.

1.2 General This Standard covers dimensioning, tolerancing, and related practices for use on printed board drawings and in related documents. Uniform practices for stating and interpreting these requirements are established herein.

1.2.1 Units The International System of Units (SI) is featured in this Standard.

1.2.2 Reference to This Standard Where drawings are based on this Standard, this fact shall be noted on the drawings or in a document referenced on the drawings. References to this Standard shall state "IPC-2615 or per IPC-2615."

1.2.3 Figures The figures in this Standard are intended only as illustrations to aid the user in understanding the principles and methods of dimensioning and tolerancing described in the text. The absence of a figure illustrating the desired application is neither reason to assume inapplicability nor basis for drawing rejection. In some instances figures show added detail for emphasis, in other instances figures are incomplete by intent. Numerical values of dimensions and tolerances are illustrative only.

1.2.4 Notes Notes herein in capital letters are intended to appear on finished drawings. Notes in lower case letters are explanatory only and are not intended to appear on drawings.

1.2.5 Reference to Gauging This document is not intended as a gauging standard. Any reference to gauging is included for explanatory purposes only.

1.3 References

1.3.1 IPC Specifications¹

IPC-T-50 Terms and Definitions

IPC-D-310 Guidelines for Phototool and Artwork Generation

IPC-D-325 Documentation for Printed Boards and Printed Board Assemblies

IPC-D-330 Design Guide for Printed Boards and Printed Board Assemblies

IPC-2220 Design Standard Series for Printed Boards

IPC-6010 Performance Specification Series for Printed Boards

1.3.2 ANSI Standards² When the following American National Standards referred to in this Standard are superseded by a revision approved by the American National Standards Institute, Inc., the latest revision shall apply.

ANSI Y14.1-1980, Drawing Sheet Size and Format

ANSI Y14.2M-1979, Line Conventions and Lettering

ASME Y14.5M-1994, Geometric Dimensioning and Tolerancing

ANSI Z210.1-1976, Metric Practice

2 TERMS AND DEFINITIONS

The definition of terms shall be in accordance with IPC-T-50 and the following.

2.1 Actual Size The measured size.

2.2 Basic Dimension A numerical value used to describe the theoretically exact size, profile, orientation, or location of a feature or datum target. It is the basis from which permissible variations are established by tolerances on other dimensions, in notes, or in feature control frames (see 3.4.1).

2.3 Bilateral Tolerance A tolerance in which variation is permitted in both directions from the specified dimension.

2.4 Cumulative Tolerances The summation of all tolerances permitted between functionally related features:

1. IPC, 2215 Sanders Road, Northbrook, IL 60062

2. ANSI, 655 15th Street N.W., Suite 300, Washington, DC 20005-5794

- a) **Chain Dimensioning** The maximum variation between two features is equal to the sum of the tolerances on the intermediate distances; this results in the greatest tolerance accumulation.
- b) **Base Line Dimensioning** The maximum variation between two features is equal to the sum of the tolerances on the two dimensions from their origin to the features; this results in a reduction of tolerance accumulation.
- c) **Basic Dimensioning** The maximum variation between two features is controlled by the positional tolerance on the two features; this results in zero tolerance accumulation.

2.5 Datum A theoretically exact point, axis, or plane derived from the true geometric counterpart of a specified datum feature. A datum is the origin from which the location or geometric characteristics of features of a printed board are established.

2.6 Datum Feature An actual feature of a printed board that is used to establish a datum.

2.7 Datum Axis The theoretical axis derived from the true geometric counterpart of a specified feature (i.e., tooling hole, fiducial) as established by the extremities of contacting points of the actual datum feature.

2.8 Datum Target A specified point or area on a printed board used to establish a datum.

2.9 Dependent of Size The concept that permits tolerances of form or position to vary in proportion to, and dependent on, the size of the feature.

2.10 Dimension A numerical value expressed in appropriate units of measure and indicated on a drawing and in other documents along with lines, symbols and notes to define the size, location or geometric characteristic of a printed board or printed board feature.

2.11 End Product (End Item) An end product is the individual printed board or assembly in its final or completed state.

2.12 Fabrication Allowance An amount added to a printed board feature, e.g., the diameter of a land, which is an accumulation of manufacturing variation. The fabrication allowance is intended to assure that manufacturing variation does not allow certain performance characteristics to be exceeded, such as minimum annular ring.

2.13 Feature The general term applied to a physical portion of a printed board or printed board assembly, such as a surface, hole, slot, or surface mount land.

2.14 Feature of Size One cylindrical surface or a set of two plane parallel surfaces, each of which is associated with a size dimension.

2.15 Fiducial A printed board artwork feature (or features) that is created in the same process as the printed board conductive pattern and that provides a common measurable point for component mounting with respect to a land pattern or land patterns.

2.16 Geometric Tolerance The general term applied to the category of tolerances used to control form, profile, orientation, and location.

2.17 Limits of Size The specified maximum and minimum sizes.

2.18 Least Material Condition (LMC) The condition in which a feature of size contains the least amount of material within the stated limits of size - for example, maximum hole diameter, or minimum printed board size.

2.19 Maximum Material Condition (MMC) The condition in which a feature of size contains the maximum amount of material within the stated limits of size; for example, minimum hole diameter, maximum printed board size.

2.20 Positional Tolerance The amount that a feature is permitted to vary from the location of true position.

2.21 Reference Dimension A dimension, usually without tolerance, used for information purposes only. It is considered auxiliary information and does not govern production or inspection operations. A reference dimension is a repeat of a dimension or is derived from other values shown on the drawing or on related drawings.

2.22 Regardless of Feature Size (RFS) The term used to indicate that a geometric tolerance or datum reference applies at any increment of size of the feature within its size tolerance. Regardless of feature size permits no additional positional, form, or orientation tolerance other than that stated in the applicable feature control frame. RFS can only be applied to features of size.

2.23 Simulated Datum A point, axis, or plane established by processing or inspection equipment.

2.24 Tolerance The total amount by which a specific dimension is permitted to vary. The tolerance is the difference between the maximum and minimum limits.

2.25 Tolerance, Statistical A tolerance that is based on statistical models, usually combining a variety of specific tolerances i.e., Root Mean Square (RMS) value.

2.26 Toleranced Dimension A dimension with a directly applied tolerance as opposed to a basic dimension that specifies the exact size or location of a feature.

2.27 True Position The theoretically exact location of a feature established by basic dimensions.

2.28 Undimensioned Drawing An undimensioned drawing depicts to a precise scale on environmentally stable material a template or a pattern for which dimensioned detail drawings would be impractical.

2.29 Unilateral Tolerance A tolerance in which variation is permitted in one direction from the specified dimension.

2.30 Virtual Condition The boundary generated by the collective effects of the specified MMC or LMC limit of size of a feature and any applicable geometric tolerances.

3 GEOMETRIC CHARACTERS AND SYMBOLS

3.1 General This Section establishes the symbols for specifying geometric characteristics and other dimensional requirements typically used on PCB engineering drawings.

Symbols should be of sufficient clarity to meet the legibility and reproducibility requirements of ANSI Y14.2M. For symbols not described in the following, refer to ASME Y14.5M-1994.

3.2 Use of Notes to Supplement Symbols Situations may arise where the desired geometric requirement cannot be completely conveyed by symbology. In such cases, a note may be used to describe the requirement, either separately or supplementing a geometric tolerance. See 6.3.5.2.

3.3 Symbol Construction Information related to the construction, form, and proportion of individual symbols described herein is contained in ASME Y14.5M-1994 Appendix C.

3.3.1 Geometric Characteristic Symbols The symbols denoting central geometric characteristics are shown in Table 3-1. Table 3-2 shows other symbols used in special applications.

3.3.2 Datum Feature Symbol The datum feature symbol consists of a capital letter enclosed in a square frame with a leader line extending from the frame to the concerned feature, terminating with a triangle (see Figure 3-1). The

CHARACTERISTIC	SYMBOL	TYPE OF TOLERANCE	USES
POSITION		LOCATION	HOLE AND LAND LOCATION
PROFILE OF SURFACE		PROFILE	BOARD EDGES
FLATNESS		FORM	BOW & TWIST

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Table 3-1 General Geometric Characteristic Symbols

CHARACTERISTIC	SYMBOL	TYPE OF TOLERANCE	USES
STRAIGHTNESS		FORM	BONDING OF HEATSINK
CIRCULARITY		FORM	ROUND PRINTED BOARD, TIGHT FITTING CASE
ANGULARITY		ORIENTATION	SPECIAL SLOT OF FEATURE CONTROL
PERPENDICULARITY		ORIENTATION	HOLE TO THICK BOARD RELATIONSHIP
PARALLELISM		ORIENTATION	EDGES TO TIGHT FITTING CASE
CONCENTRICITY		LOCATION	METAL CORE BOARD HOLES, TEST FEATURE

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Table 3-2 Special Application Symbols

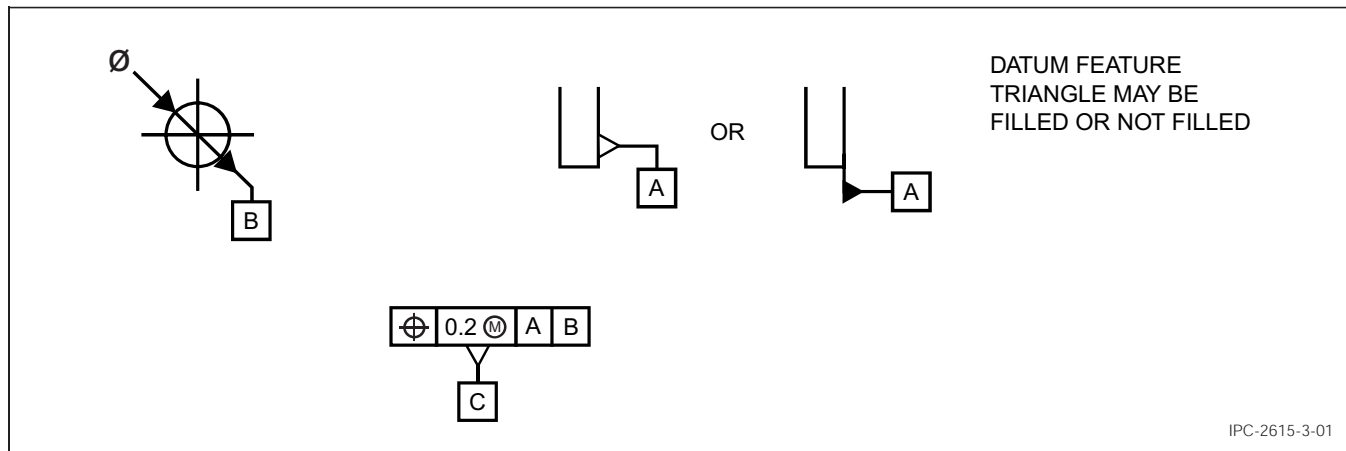


Figure 3-1 Datum Feature Symbol

triangle may be filled or not filled. The datum feature symbol is applied to the concerned feature surface outline, extension line, dimension line, or feature control frame as shown in Figure 3-2. The symbol frame is related to the datum feature by one of the methods prescribed in 3.5.

3.3.2.1 Letters of the Alphabet Letters of the alphabet (except I, O, and Q) are used as datum identifying letters. Each datum feature requiring identification shall be assigned a different letter.

3.3.2.2 Repeated Datum Feature Symbols Where the same datum feature symbol is repeated to identify that same feature in other locations on a drawing, it need not be identified as a reference.

3.3.3 Basic Dimension Symbol A basic dimension states only half of the requirement; a tolerance must be associated with the feature to complete the requirement.

The symbolic means of indicating a basic dimension is shown in Figure 3-3.

3.3.4 Material Condition Symbols The symbols used to indicate “at maximum material condition,” “regardless of feature size,” and “at least material condition” are shown in Table 3-3. The use of these symbols in local and general notes is prohibited. When no material modifier is used, RFS is assumed.

The use of MMC permits greater possible tolerance as the part feature deviates from its maximum material condition. It also assures interchangeability and permits functional gauging techniques. The maximum material condition principle is normally valid only when both of the following conditions exist.

Two or more features are interrelated with respect to location or orientation (e.g., a hole and an edge or surface, two holes, etc.). At least one of the related features is a feature

of size. The feature (or features) to which the MMC principle is to apply must be a feature of size (e.g., a hole, slot, conductor, etc.) with an axis or center plane.

Least material condition applies when special design requirements will not accommodate MMC or when RFS is too strict. It can be used to maintain critical center locations of features for which the positional tolerance can be increased as the size of the feature departs from its least material condition. The amount of increase in positional tolerance permissible is equal to the feature size departure from LMC.

3.3.5 Diameter and Radius Symbols The symbols used to indicate diameter and radius are shown in Table 3-3. These symbols precede the value of a dimension or tolerance given as a diameter or radius, as applicable.

3.3.6 Reference Symbol A reference dimension (or reference data) is identified by enclosing the dimension (or data) within parentheses. See Table 3-3.

3.4 Geometric Tolerance Symbols Geometric characteristic symbols, the tolerance value, and datum reference letters, where applicable, are combined in a feature control frame to express a geometric tolerance.

3.4.1 Feature Control Frame A geometric tolerance for an individual feature is specified by means of a feature control frame divided into compartments containing the geometric characteristic symbol followed by the tolerance (see Figure 3-4). Where applicable, the tolerance is preceded by the diameter symbol and followed by a material condition symbol.

3.4.2 Feature Control Frame Incorporating Datum References Where a geometric tolerance is related to a datum, this relationship is indicated by entering the datum reference letter in a compartment following the tolerance.

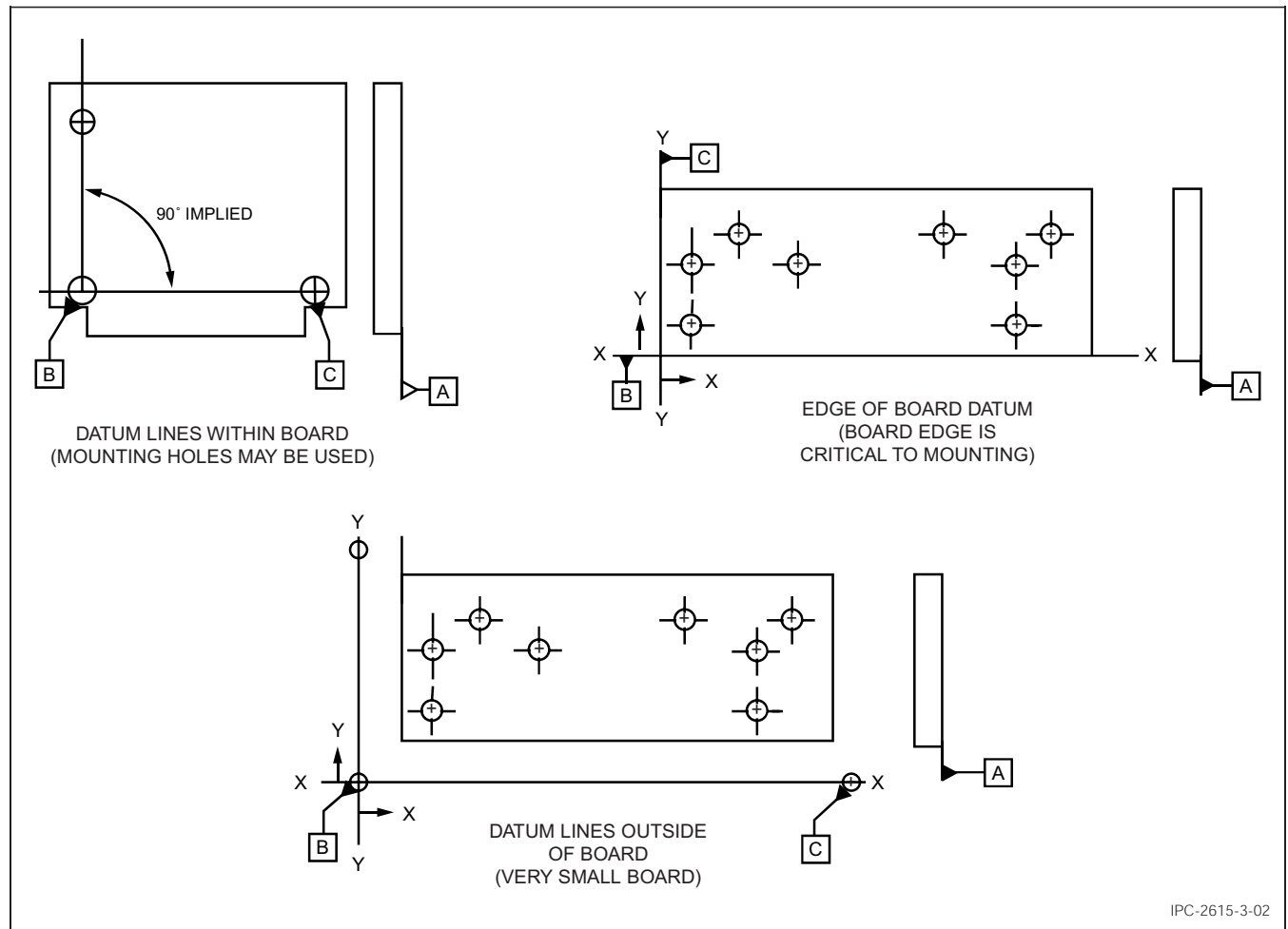


Figure 3-2 Examples of Datum Identification

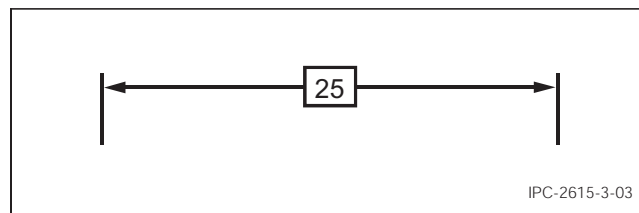


Figure 3-3 Basic Dimension Symbol

(see Figure 3-5). Where applicable, the datum reference letter is followed by a material condition symbol.

3.4.2.1 Multiple Datum Requirements Where more than one datum is required, the datum reference letters (followed by a material condition symbol, where applicable) are entered in separate compartments in the desired order of precedence, from left to right (see Figure 3-6). Datum reference letters need not be in alphabetical order in the feature control frame.

3.4.2.2 Composite Feature Control Frame A composite feature control frame is used where more than one tolerance is specified for the same geometric characteristic of a

feature or features having different datum requirements. The composite frame contains a single entry of the geometric characteristic symbol followed by each tolerance and datum requirement, one above the other (see Figure 3-7 and 6.4.1).

3.4.2.3 Common Profile Tolerance Symbol The symbol used to indicate that a profile tolerance applies to surfaces all around the printed board is a circle located at the junction of the leader from the feature control frame (see Figure 3-8).

3.4.3 Combined Feature Control Frame and Datum Feature Symbol Where a feature or pattern of features controlled by a geometric tolerance also serves as a datum feature, the feature control frame and datum feature symbol are combined (see Figure 3-9).

3.4.3.1 Control Frame and Datum Feature Symbol Combinations Wherever a feature control frame and datum feature symbol are combined, datums referenced in the feature control frame are not considered part of the datum feature symbol. In the positional tolerance example, Figure

TERM	SYMBOL
MAXIMUM MATERIAL CONDITION	(M)
LEAST MATERIAL CONDITION	(L)
DIAMETER	Ø
RADIUS	R
REFERENCE	()
ARC LENGTH	()
STATISTICAL TOLERANCE	ST
BETWEEN	↔
REGARDLESS OF FEATURE SIZE	(S)

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Table 3-3 Modifying Symbols

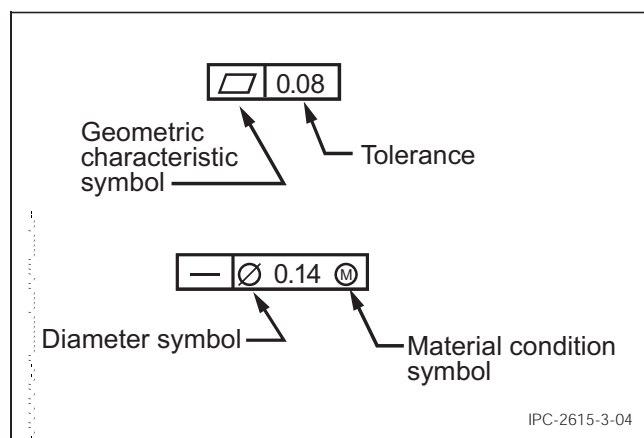


Figure 3-4 Feature Control Frame

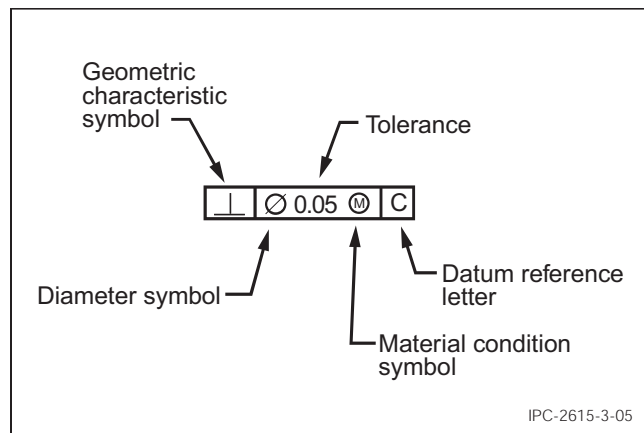


Figure 3-5 Feature Control Frame Incorporating Datum Report

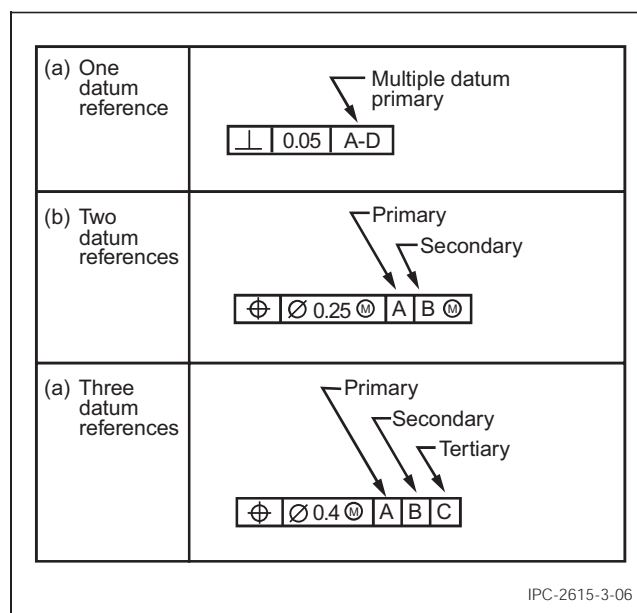


Figure 3-6 Order of Precedence of Datum Reference

3-9, a feature is controlled for position in relation to datums A and B, and identified as datum C. Whenever datum C is referenced elsewhere on the drawing, the reference applies to datum C not to datums A and B.

3.5 Feature Control Frame Placement The feature control frame is related to the considered feature by one of the following methods as depicted in Figure 3-10.

- locating the feature control frame below or attached to a leader-directed callout or dimension pertaining to the feature;

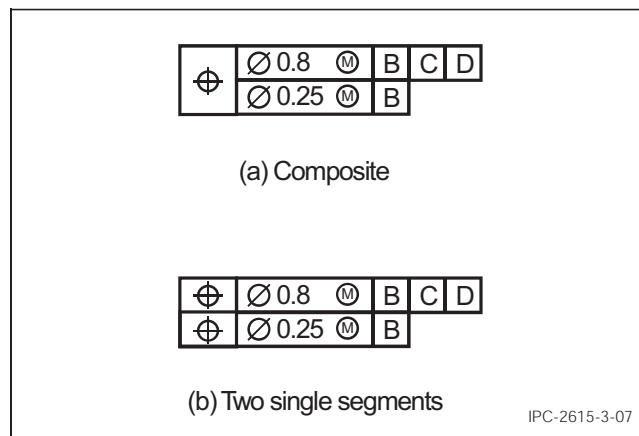


Figure 3-7 Multiple Feature Control Frames

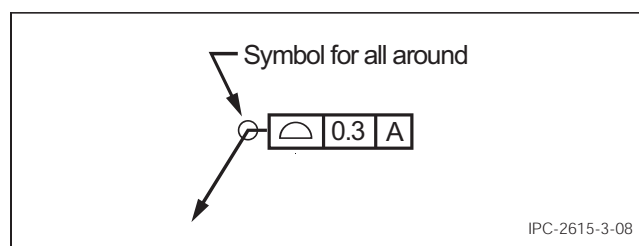


Figure 3-8 Symbol for All Around

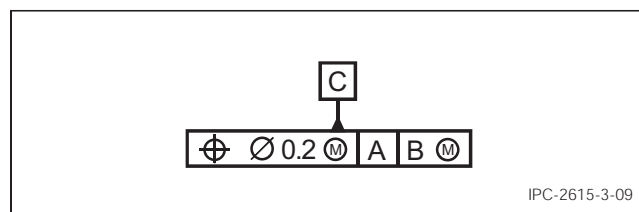


Figure 3-9 Combined Feature Control Frame and Datum Feature Symbol

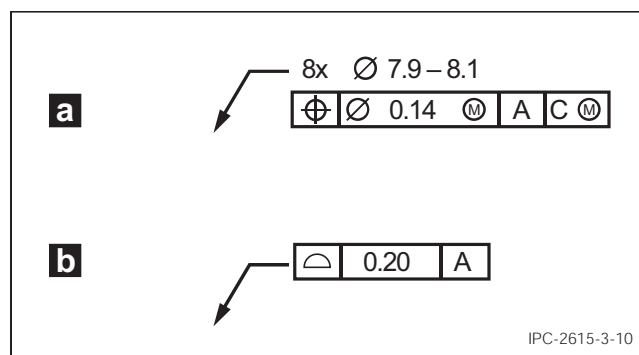


Figure 3-10 Feature Control Frame Placement

- b) running a leader from the frame to the feature;
- c) attaching a side or an end of the frame to an extension line from the feature, provided it is a plane surface;
- d) attaching a side or an end of the frame to an extension of the dimension line pertaining to a feature of size.

4 GENERAL RULES

The following rules apply to the use of material condition modifiers.

4.1 Maximum Material Condition Principle (MMC) Effect of MMC. Where a geometric tolerance is applied on an MMC basis, the specified tolerance is interdependent on the size of the considered feature. The tolerance is limited to the specified value if the feature is produced at its MMC limit of size. Where the actual size of the feature has departed from MMC, an increase in the tolerance is allowed equal to the amount of such departure. The total permissible variation in the specific geometric characteristic is maximum when the feature is at LMC (see Figure 4-1). Referencing a datum feature on an MMC basis means the datum is the axis or center plane of the feature at the MMC limit. Where the actual size of the datum feature has departed from MMC, a deviation is allowed between its axis or center plane and the axis or center plane of the datum (see Table 4-1).

4.2 Regardless of Feature Size Where a geometric tolerance is applied on an RFS basis, the specified tolerance is independent of the size of the considered feature. The tolerance is limited to the specified value regardless of the actual size of the feature. Likewise, referencing a datum feature on an RFS basis means that a centering about its axis or center plane is necessary, regardless of the actual size of the feature (see Table 4-2).

4.3 Least Material Condition Principle Where a positional tolerance is applied on an LMC basis, the specified tolerance is interdependent on the size of the considered feature. The tolerance is limited to the specified value if the feature is produced at its LMC limit of size. Where the actual size of the feature has departed from LMC, an increase in the tolerance is allowed equal to the amount of such departure. The total permissible variation in position is maximum when the feature is at MMC. Likewise, referencing a datum feature on an LMC basis means the datum is the axis or center plane of the feature at the LMC limit. Where the actual size of the datum feature has departed from LMC, a deviation is allowed between its axis or center plane and the axis or center plane of the datum (see Table 4-3).

4.4 Limits of Size Unless otherwise specified, the limits of size of a feature prescribe the extent within which variations of geometric form, as well as size, are allowed. This control applies solely to individual features of size as defined in 2.14.

4.4.1 Individual Feature of Size (Rule #1) Where only a tolerance of size is specified, the limits of size of an individual feature prescribe the extent to which variations in its geometric form, as well as size, are allowed.

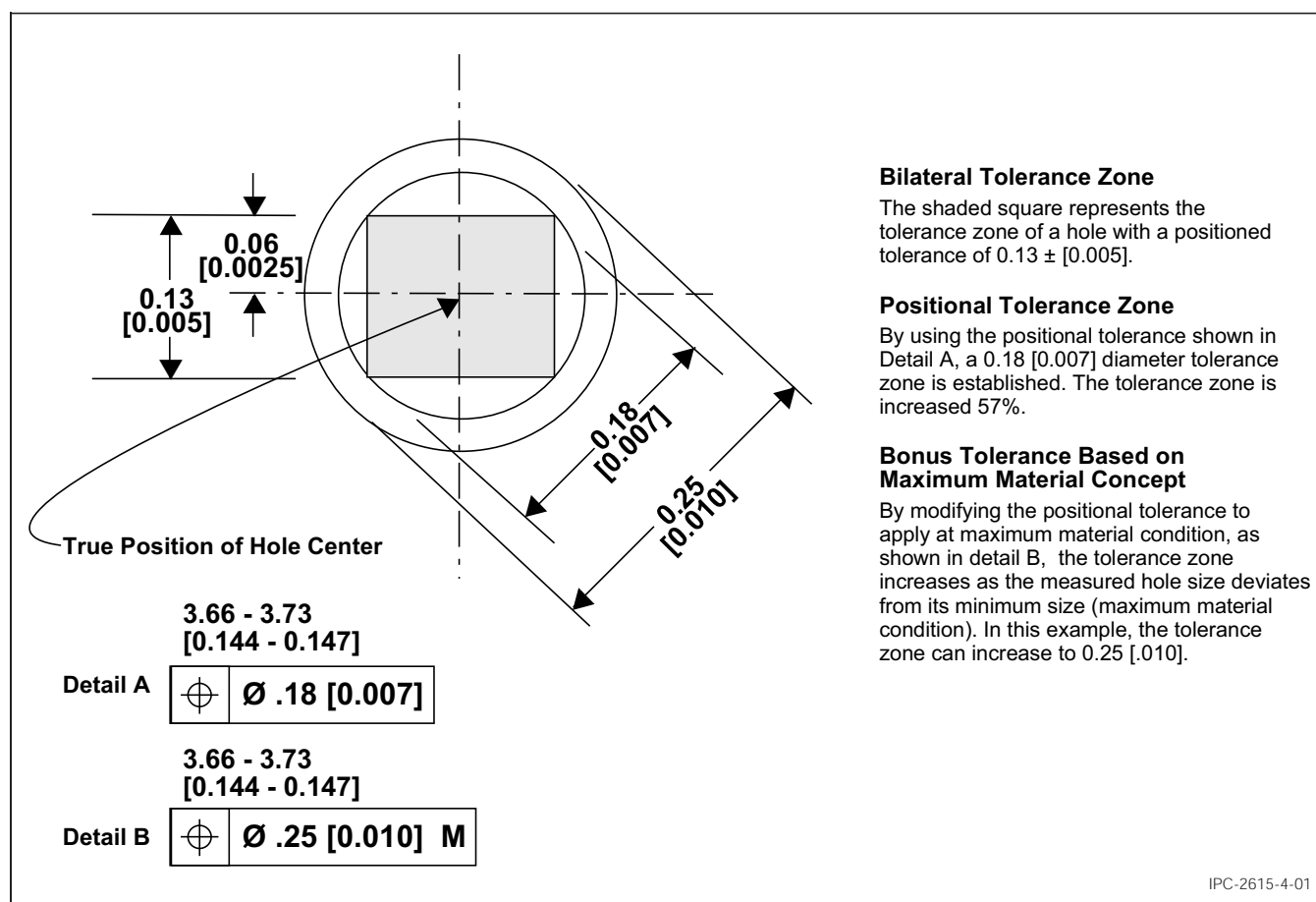


Figure 4-1 Positional Tolerancing at MMC

$\varnothing .78$ $\varnothing .85$ $\varnothing .01 M$		
LMC	size	tolerance
	.85	.07
	.84	.06
	.83	.05
	.82	.04
	.80	.03
	.79	.02
MMC	.78	.01

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Table 4-1 Maximum Material Condition Range

4.4.1.1 Variations of Size The actual size of an individual feature at any cross section shall be within the specified tolerance of size.

4.4.1.2 Variations of Form (Envelope Principle) The form of an individual feature is controlled by its limits of

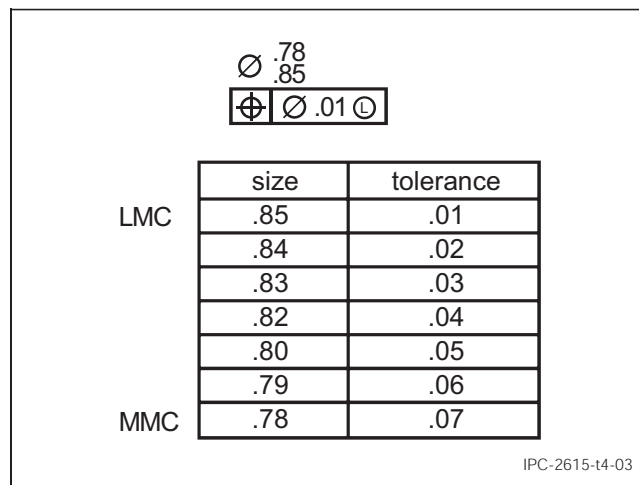
$\varnothing .78$ $\varnothing .85$ $\varnothing .01$		
LMC	size	tolerance
	.85	.01
	.84	.01
	.83	.01
	.82	.01
	.80	.01
	.79	.01
MMC	.78	.01

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Table 4-2 Regardless of Feature Size Range

size to the extent prescribed in the following paragraphs and illustrated in Figure 4-2.

- a) The surface or surfaces of a feature shall not extend beyond a boundary (envelope) of perfect form at MMC. This boundary is the true geometric form



	size	tolerance
LMC	.85	.01
	.84	.02
	.83	.03
	.82	.04
	.80	.05
	.79	.06
MMC	.78	.07

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Table 4-3 Least Material Condition Range

represented by the drawing. No variation in form is permitted if the feature is produced at its MMC limit of size.

- Where the actual size of a feature has departed from MMC toward LMC, a variation in form is allowed equal to the amount of such departure.
- There is no requirement for a boundary of perfect form at LMC. Thus, a feature produced at its LMC limit of size is permitted to vary from true form to the maximum variation allowed by the boundary of perfect form at MMC.

4.4.2 Relationship Between Individual Features The limits of size do not control the orientation or location relationship between individual features. Features shown perpendicular, coaxial, or symmetrical to each other must be controlled for location or orientation to avoid incomplete drawing requirements.

4.5 Applicability of MMC, RFS, and LMC Applicability of RFS, MMC, and LMC is limited to features subject to

variations in size. They may be datum features or other features whose axes or center planes are controlled by geometric tolerances. In such cases, the following practices apply.

- Tolerances of Position (Rule #2) RFS, MMC or LMC must be specified on the drawing with respect to the individual tolerance, datum reference, or both, as applicable.*

* Retained for explanation purposes on older drawings. Per ASME Y14.5M-1994, RFS is assumed unless otherwise indicated

- All Other Geometric Tolerances (Rule #3). RFS applies, with respect to the individual tolerance, datum reference, or both, where no modifying symbol is specified. MMC must be specified on the drawing where it is required.

5 DATUM REFERENCING

5.1 General This section establishes the principle of datum referencing used to relate features of a printed board to an appropriate datum or datum reference frame. It contains the criteria for selecting, designating, and using features of a printed board as the basis for dimensional definition. A datum indicates the origin of a dimensional relationship between a toleranced feature and a designated feature or features on a printed board. The designated feature serves as a datum feature, whereas its true geometric counterpart establishes the datum.

5.1.1 Application Because a datum is theoretical, measurements cannot be made from a true geometric counterpart. A datum is assumed to exist in and be simulated by the associated processing equipment. For example, machine tables and surface plates, though not true planes, are of such quality that they are used to simulate the datums from which measurements are taken and dimensions verified. The flat surfaces of manufactured printed

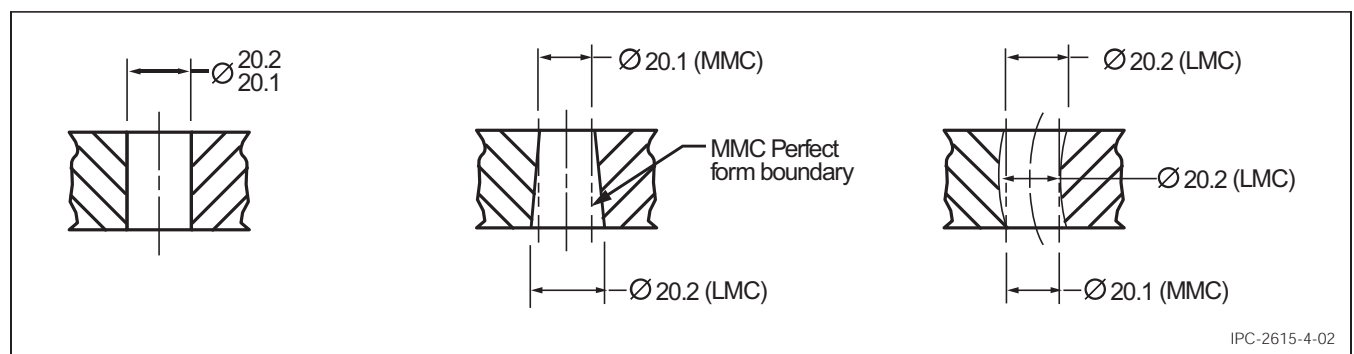


Figure 4-2 Variations of Form Allowed By Size Tolerance

board are seen to have irregularities due to both the circuitry and the variation in the laminate surface. Contact is made with a datum plane at a number of surface extremities or high points.

5.1.2 Datum Reference Frame Sufficient datum features, those most important to the design of a printed board, are chosen to position the printed board in relation to a set of three mutually perpendicular planes, jointly called a datum reference frame. This reference frame exists in theory only and not on the printed board. Therefore, it is necessary to establish a method for simulating the theoretical reference frame from the actual features of the printed board. This simulation is accomplished by positioning the printed board on appropriate datum features to adequately relate the printed board to the reference frame and to restrict motion of the printed board in relation to it (see Figure 5-1).

5.1.2.1 Plane Simulation Relationship These planes are simulated in a mutually perpendicular relationship to provide direction as well as the origin for related dimensions and measurements. Thus, when the printed board is positioned on the datum reference frame (by physical contact between each datum feature and its counterpart in the associated processing equipment), dimensions related to the datum reference frame by a feature control frame or note are thereby mutually perpendicular. This theoretical reference frame constitutes the three plane dimensioning system used for datum referencing.

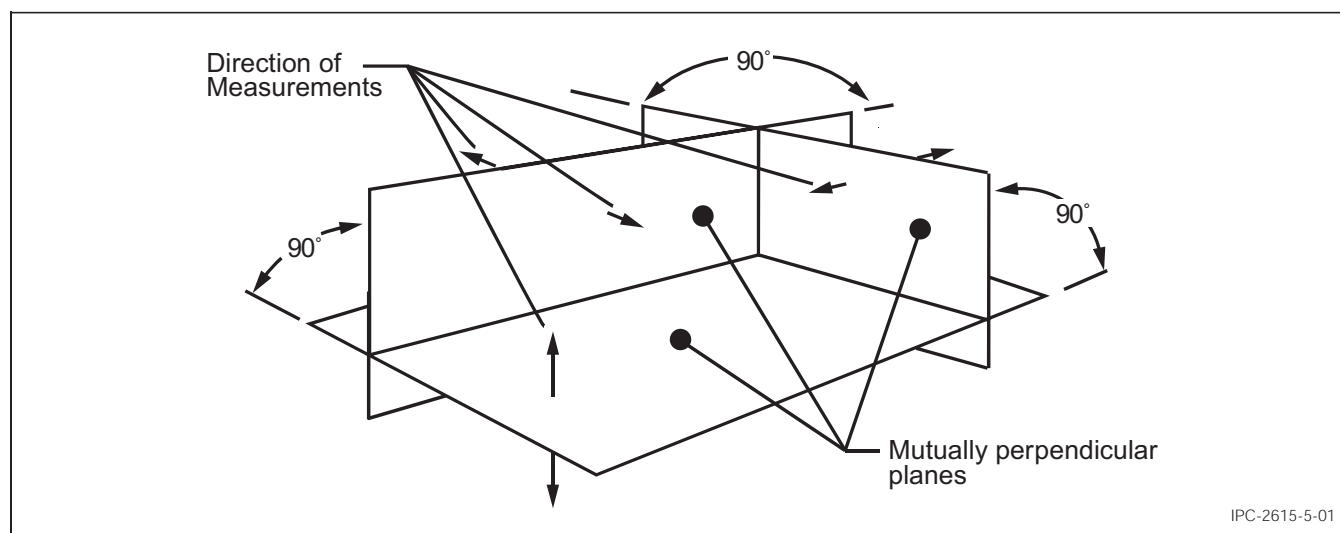
5.1.2.2 Datum Options In the case of a printed board profile or a secondary datum feature of size position, a single datum reference frame will suffice. In others, additional datum reference frames may be necessary where physical separation or the functional relationship of

features require that datum reference frames be applied at specific locations on the printed board. In such cases, each feature control frame must contain the datum feature references that are applicable. Any difference in the order of precedence or in the material condition of any datums referenced in multiple feature control frames requires different datum simulation methods and, consequently, establishes a different datum reference frame. See 5.3.9.

5.2 Datum Features A datum feature is selected on the basis of its geometric relationship to the toleranced feature and the requirements of the design. To ensure proper printed board interface and assembly, corresponding features of mating parts are also selected as a datum feature where practical. Datum features must be readily discernible on the printed board. A datum feature should be accessible on the printed board. For printed boards, the primary datum features will normally be the plane of the board, and typically the mounting (nonplated-through) holes used as secondary and tertiary datum features (see Figure 5-2). However, there may be occasions when the edges of the printed board, slots, or fiducials may serve as secondary and tertiary datum features (see Figures 5-3, 5-4, and 5-5, respectively). Using fiducials as datum features means that the profile is controlled in relation to the circuit pattern as opposed to the hole pattern, as is normally the case.

5.2.1 Datum Feature Symbols Datum features are identified on the drawing by means of symbols (see 3.3.2). The datum feature symbol is applied to the concerned feature surface outline, extension line, dimension line or feature control frame.

5.2.2 Datum Feature Control Measurements made from a datum plane do not take into account any variations of



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Figure 5-1 Datum Reference Frame

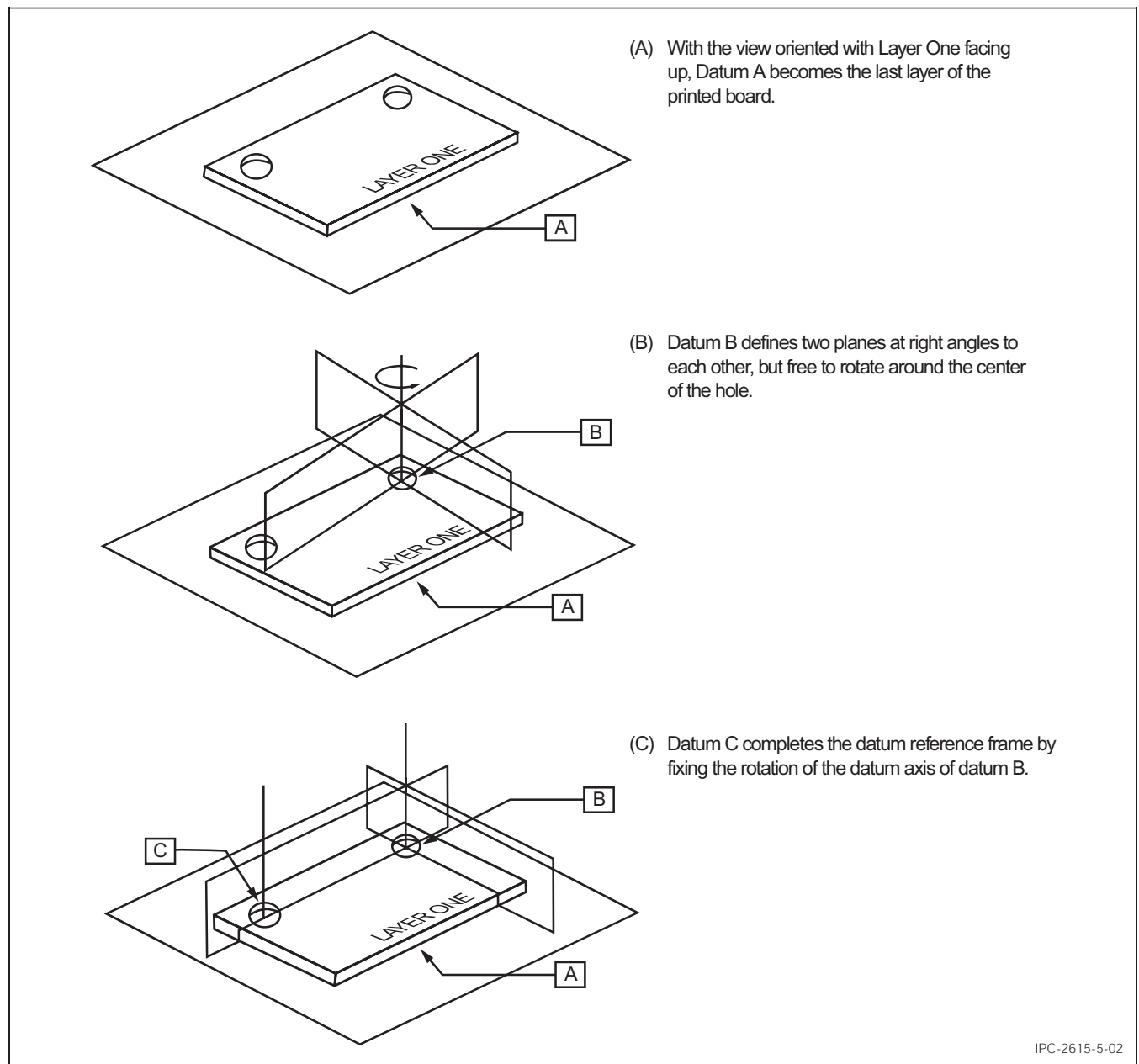


Figure 5-2 Datum Reference Frame to Printed Board Relationships

the datum surface from the datum plane. This can happen with a warped printed board lying on a surface plate. Consideration shall be given to the desired accuracy of datum features relative to design requirements and the degree of control necessary for the tolerated features related to them. If not sufficiently accurate, datum features may need to be controlled by specifying appropriate geometric tolerances. Where control of the entire feature becomes impractical, use of datum targets may be considered. Datum targets are used for assemblies only; not for unassembled printed wiring boards. See 5.4.

5.2.3 Specifying Datums in Order of Precedence To properly position a printed board on the datum reference

frame, datums must be specified in an order of precedence in the feature control frame. Figure 5-6 illustrates a printed board where the datum features follow the preferred convention for noncircular printed boards. The desired order of precedence is indicated by entering the appropriate datum reference letters, from left to right, in the feature control frame. In Figure 5-6, the datum features are identified as surface A, and features (nonplated-through holes) B, and C. These features are most important to the design and function of the printed board. Features A, B, and C are the primary, secondary, and tertiary datum features, respectively, since they appear in that order in the feature control frame. Typically, the printed board is oriented with the component side or the designated Layer 1 facing up. The resultant

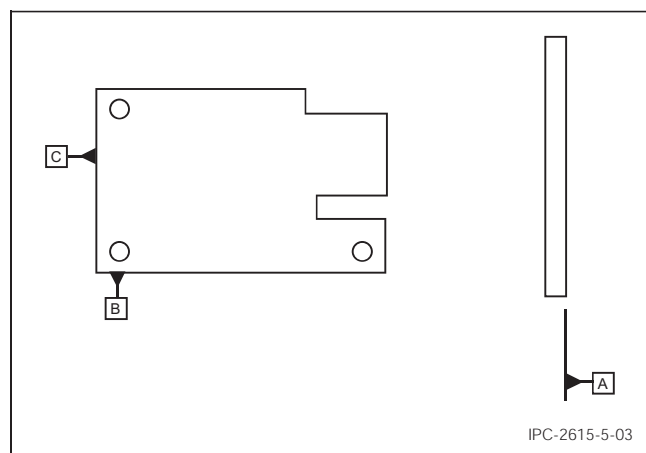


Figure 5-3 Datum Reference Using Printed Board Edges

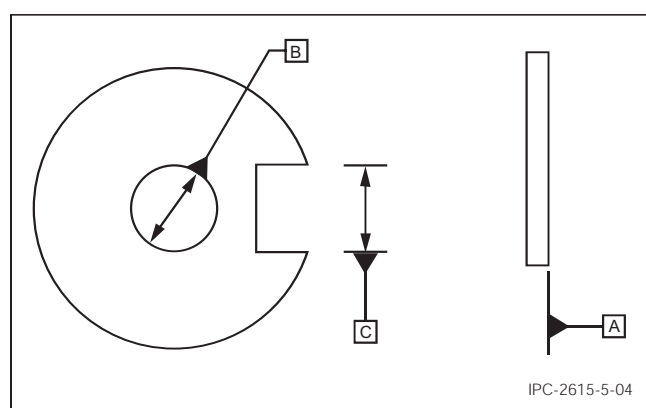


Figure 5-4 Hole and Slot Establishing Secondary and Tertiary Datums

establishes the opposite side of the printed board as the primary datum feature. The other two datum planes are established by either two holes, etched features or edges of the printed board. Coordinate zero for measurement should originate at the secondary datum feature. All datum features should either be located on grid or establish grid criterion. All datum features shall be located within the board profile or on the board profile itself.

5.2.3.1 Positioning Part on Datum Reference Frame

Figure 5-2 illustrated the typical sequence for positioning the printed board shown in Figure 5-6 on a datum reference frame as simulated by the processing equipment. The primary datum feature relates the printed board to the datum reference frame by bringing a minimum of three points on the surface into contact with the first datum plane (see Figure 5-2a). The printed board is further related to the frame by bringing at least two points of the secondary datum feature into contact with the second datum plane as simulated by a pin in a drill press (see Figure 5-2b and Figure 5-7). The relationship is completed by bringing at least one point of the tertiary datum feature into contact with the third datum plane (see Figure 5-2c). As measurements are made

from datum planes, positioning of the printed board on a datum reference frame in this manner ensures a common basis for measurements.

5.3 Establishing Datums The following paragraphs define the criteria for establishing datums from datum features.

5.3.1 Primary Datum Feature The primary datum feature for a printed board will usually be the plane surface of the board and may be either the first or last layer of the printed board. Most often, it will be the surface opposite Layer 1, but there may be cases where Layer 1 is an appropriate choice for the primary datum. The primary datum is simulated by a plane contacting the high points of that surface (see Figure 5-8). If irregularities on the surface of a primary or secondary datum feature are such that the printed board is unstable (that is, it wobbles) when brought into contact with the corresponding surface of a fixture, the printed board may be adjusted to an optimum position, if necessary, to simulate the datum. Unless otherwise specified on the drawing, it is understood that the contact points could be circuitry or the base laminate, depending on the flatness of the printed board.

5.3.2 Secondary and Tertiary Datum Features Not Subject to Size Variations The sequence for establishing the datum reference frame is illustrated in Figure 5-3 when the edges of a printed board are specified as secondary and tertiary datum features. The primary datum feature relates the part to the datum reference frame by bringing a minimum of three points on the surface into contact with the first datum plane. The secondary datum is established by bringing at least two points of the secondary datum feature into contact with the second datum plane. The relationship is completed by bringing at least one point of the tertiary datum into contact with the third datum plane. Measurements on the printed board are made from the datum planes. This method of establishing a datum reference frame is recommended when the edges are the most critical locating features of the printed board.

5.3.3 Secondary and Tertiary Datum Features Subject to Size Variations Datum features such as diameters and widths (e.g., slots) are subject to variations in size as well as form. Because variations are allowed by the size dimension, it becomes necessary to determine whether RFS or MMC applies in each case (see 4.1, 4.2, and 4.3). For a tolerance of position, the datum reference letter is always followed by the appropriate modifying symbol in the feature control frame. For all geometric tolerances, RFS is implied unless otherwise specified.

5.3.4 Specifying Datum Features RFS Where a datum feature of size is applied on an RFS basis, the datum is established by physical contact between the feature and the

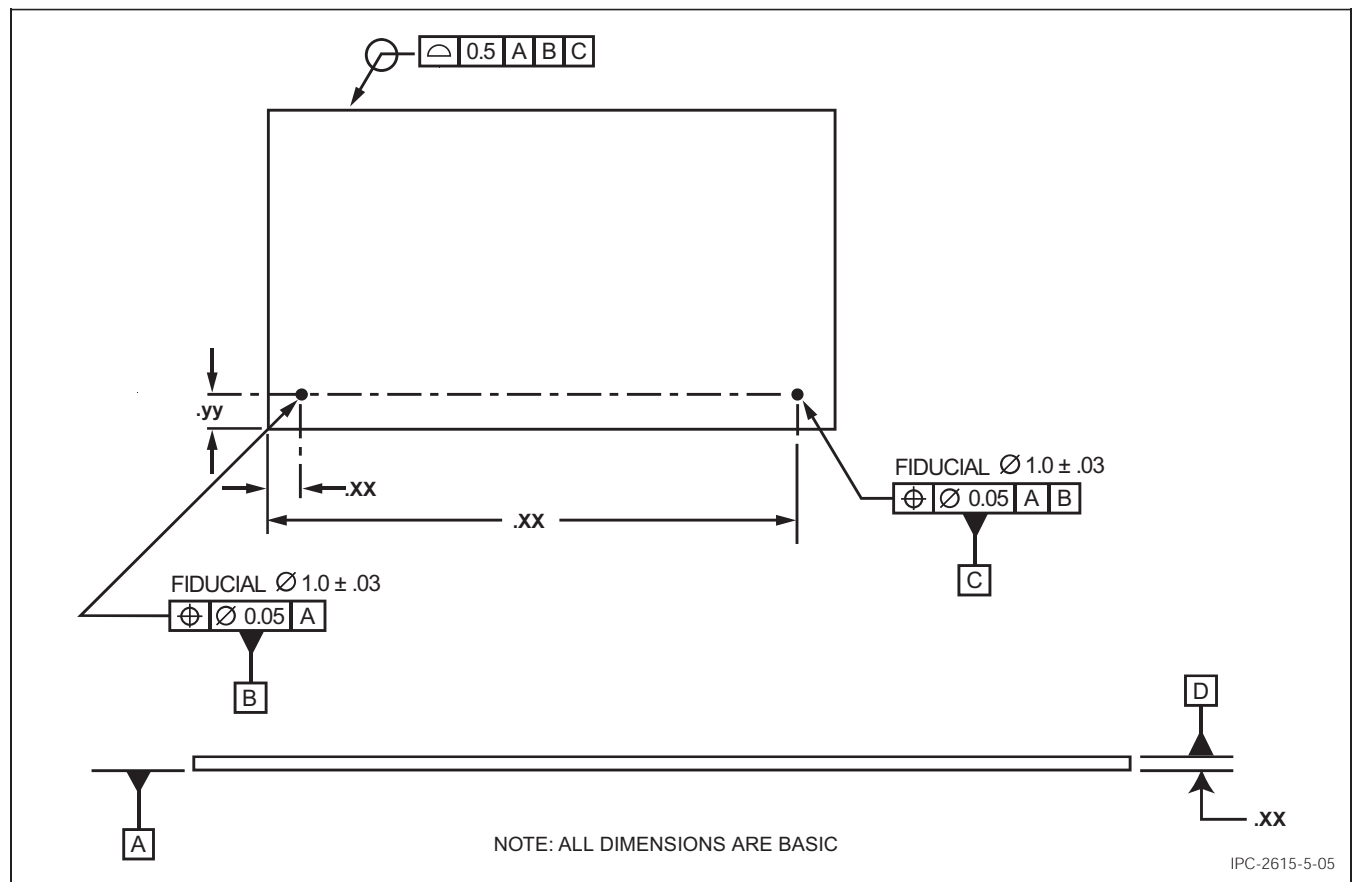


Figure 5-5 Additional Datum Example

or surfaces and surfaces of the processing or inspection equipment. Machine elements which are variable in size (such as tooling pins, surface plates, or guide rails) are used to simulate a true geometric counterpart of the feature and to establish the datum.

- a) **Secondary Datum Feature – Diameter** For an external feature, the secondary datum (axis or center plane) is established by the axis of the smallest circumscribed, perfect cylinder which contacts the profile surface of the printed board. For an internal feature (a hole), the datum is the axis of the largest inscribed, perfect cylinder which contacts the hole surface. The contacting cylinder must be oriented perpendicular to the primary datum. Datum B in Figure 5-7 illustrates this principle.
- b) **Secondary Datum Feature – Width** For an external feature, the secondary datum (axis or center plane) is established by the center plane between two parallel planes which, at minimum separation, contact the corresponding surfaces of the feature. For an internal feature (a slot), the datum is the center plane between two parallel planes which at maximum separation contact the corresponding surfaces of the slot. The contacting parallel planes must be oriented perpendicular to the primary datum.

5.3.5 Specifying Datum Features at MMC Where a datum feature of size is applied on an MMC basis, machine and gauging elements in the processing equipment, which remain constant in size, may be used to simulate a true geometric counterpart of the feature and to establish the datum. In each case, the size of the simulated datum is determined by the specified MMC limit of size of the datum feature or its virtual condition, where applicable.

5.3.5.1 Datum Feature Size Control Where a datum feature of size is controlled by a specified tolerance of form (profile), the size of the simulated datum is the MMC limit of size.

5.3.5.2 Secondary or Tertiary Datum Features of Size Where secondary or tertiary datum features of size in the same datum reference frame are controlled by a specified tolerance of location or orientation with respect to each other, the size of the simulated datum is the virtual condition of the datum feature (see Figure 5-9). This example illustrates both secondary and tertiary datum features specified at MMC but simulated at virtual condition.

5.3.6 Cylindrical Datum Features Cylindrical datum features can be holes or the profile of a circular shaped printed board. A cylindrical datum feature is always associated with two theoretical planes intersecting at right

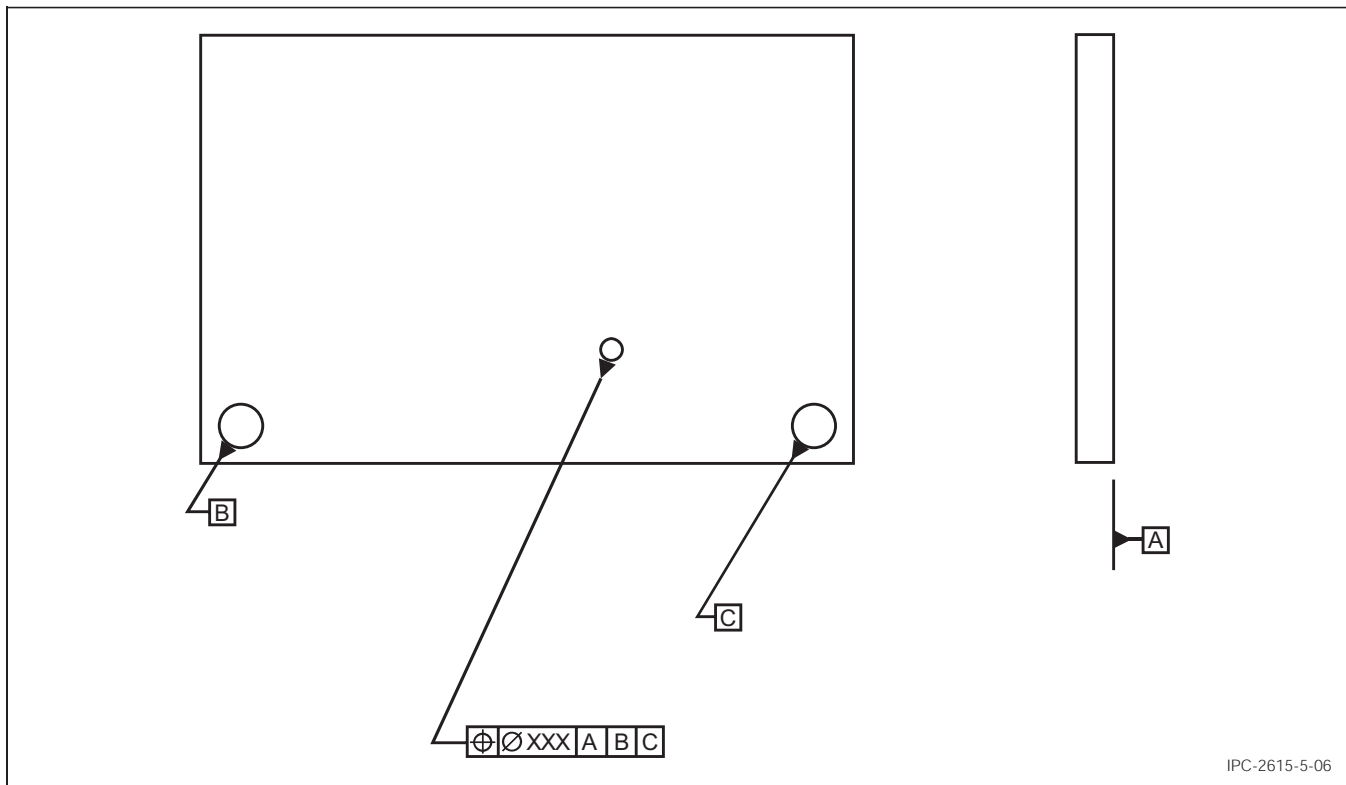


Figure 5-6 Datum Feature Identification and Reference

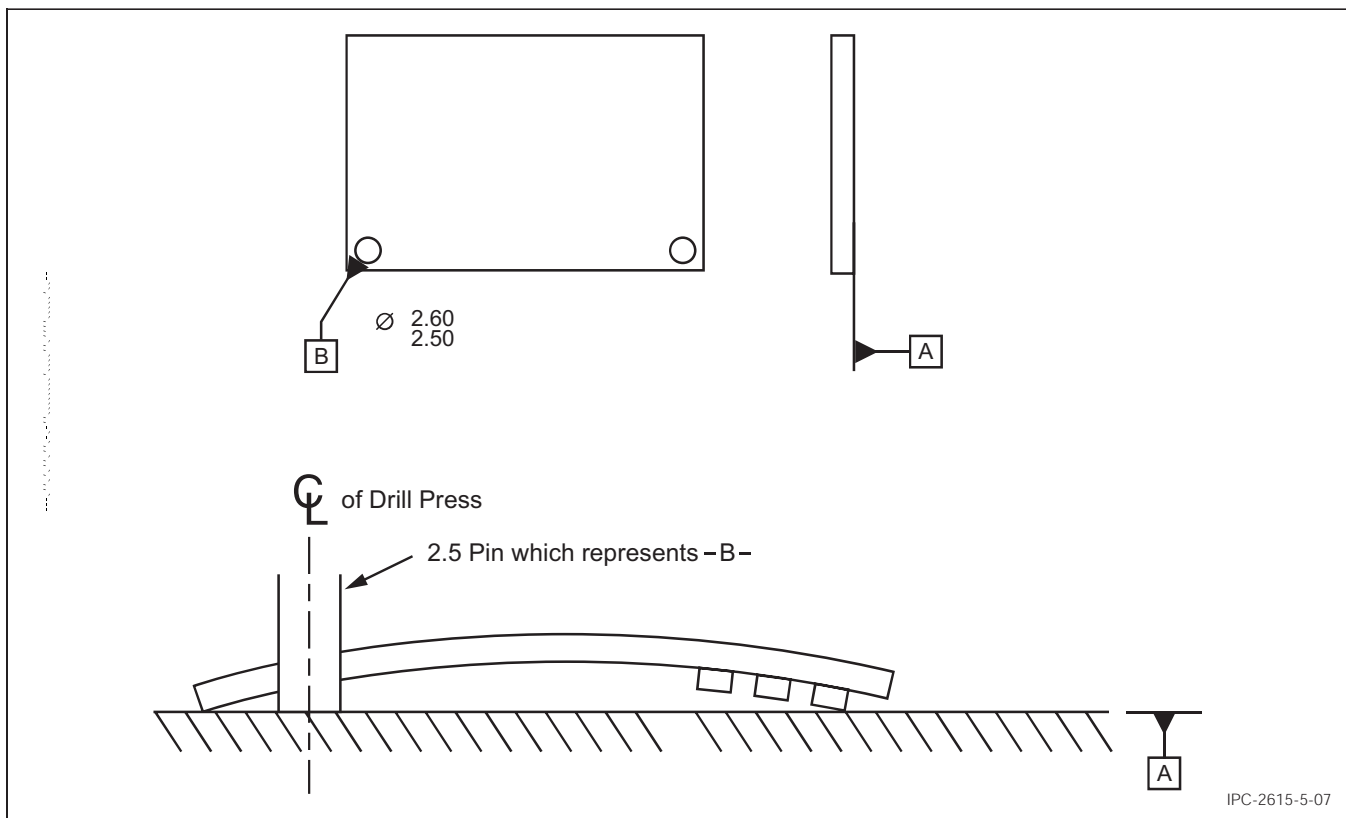


Figure 5-7 Secondary Datum Established By Internal Feature

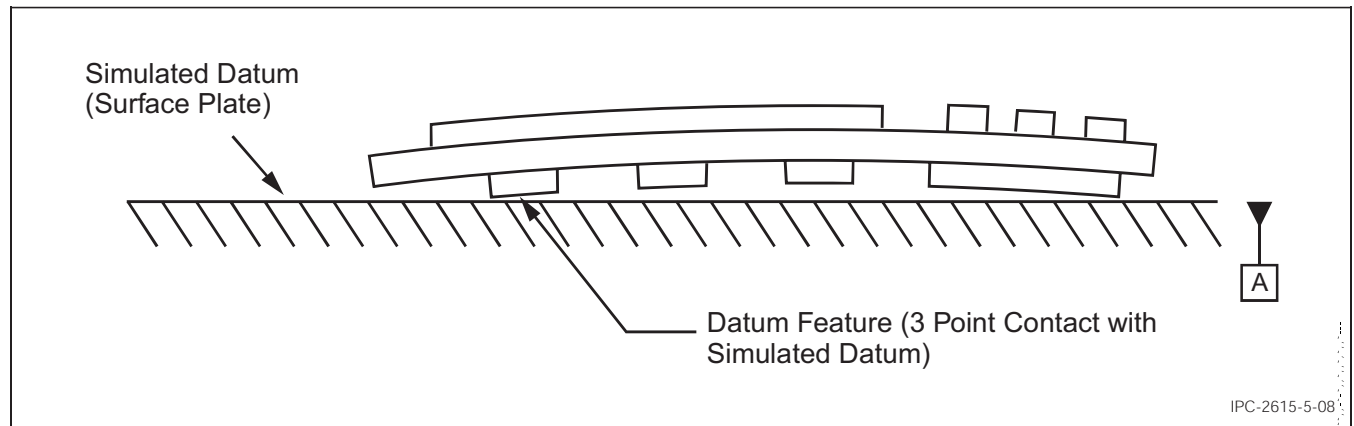


Figure 5-8 Datum Feature and Simulated Datum

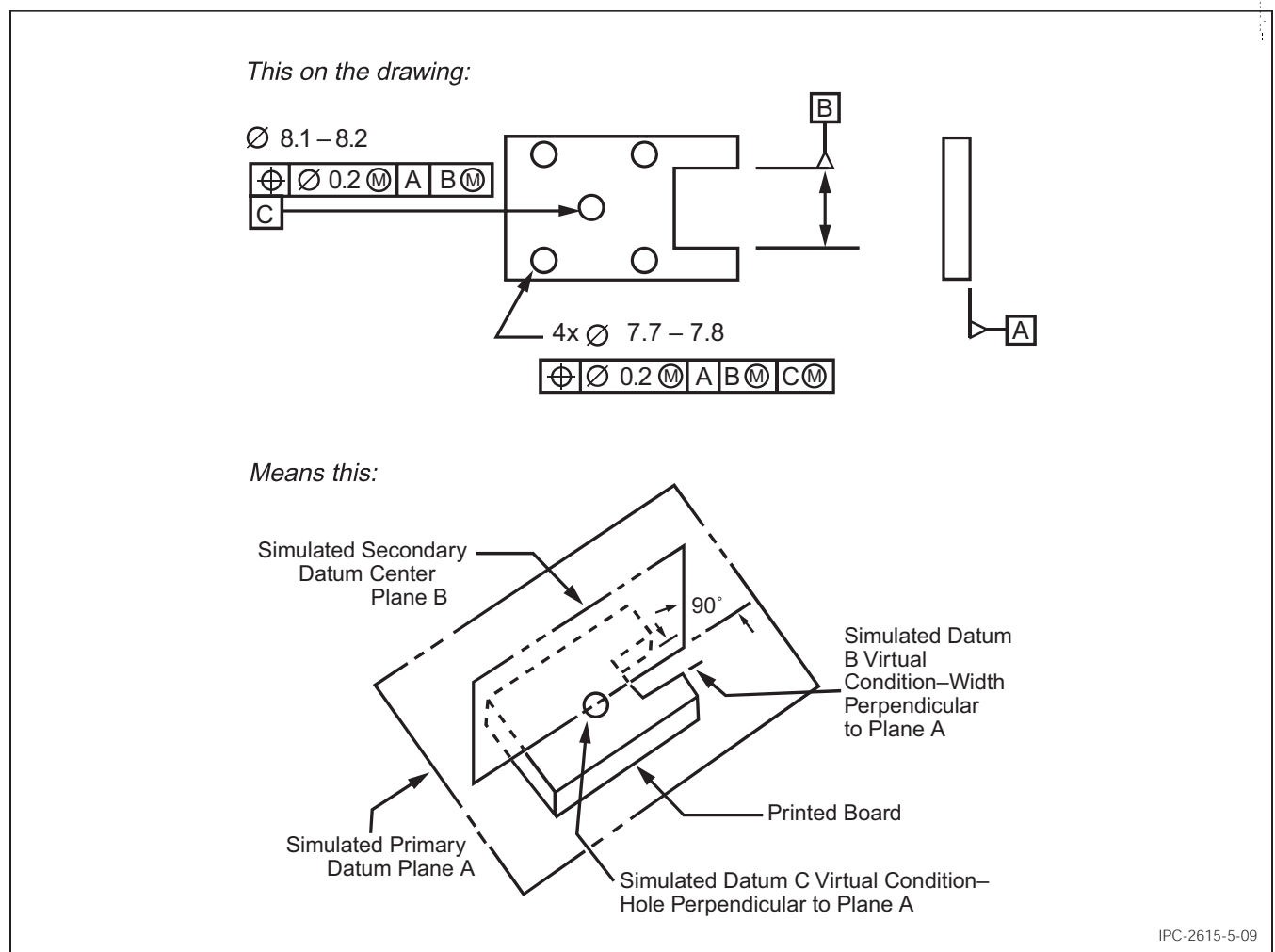


Figure 5-9 Virtual Condition of Datum Feature