IEC PAS 61182-12

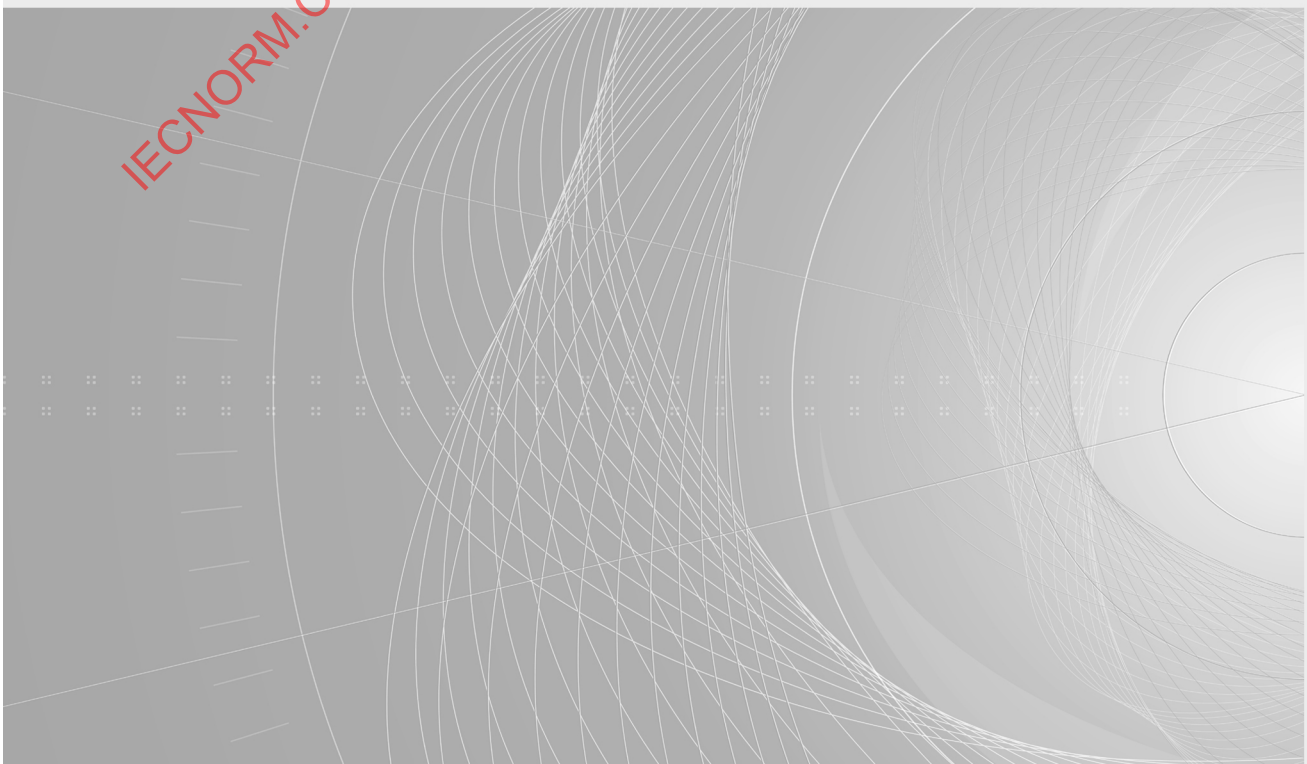
Edition 1.0 2014-08

PUBLICLY AVAILABLE SPECIFICATION

PRE-STANDARD

colour inside

Generic requirements for printed board assembly products manufacturing description data and transfer methodology



IEC PAS 61182-12:2014-08(en)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

GENERIC REQUIREMENTS FOR PRINTED BOARD ASSEMBLY PRODUCTS MANUFACTURING DESCRIPTION DATA AND TRANSFER METHODOLOGY

FOREWORD

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IEC PAS 61182-12, submitted by IPC has been processed by IEC technical committee 91: Electronics assembly technology. It is based on IPC-2581B. It is published as a double-logo PAS. The structure and editorial rules used in this PAS reflect the practice of the organization which submitted it.

The text of this PAS is based on the following document:

This PAS was approved for publication by the P-members of the committee concerned as indicated in the following document

Draft PAS	Report on voting
91/1182/PAS	91/1192/RVD

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This PAS shall remain valid for an initial maximum period of 3 years starting from the publication date. The validity may be extended for a single period up to a maximum of 3 years, at the end of which it shall be published as another type of normative document, or shall be withdrawn.

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Generic Requirements for Printed Board Assembly Products Manufacturing Description Data and Transfer Methodology

1 SCOPE

This standard specifies the XML schema that represents the intelligent data file format used to describe printed board and printed board assembly products with details sufficient for tooling, manufacturing, assembly, and inspection requirements. This format may be used for transmitting information between a printed board designer and a manufacturing or assembly facility. The data is most useful when the manufacturing cycle includes computer-aided processes and numerical control machines.

The data can be defined in either English or International System of Units (SI) units. The format is a convergence of the IPC-2511 “GenCAM” and the Valor Computerized Systems “ODB-X” format structure.

1.1 Focus and intent

The generic format requirements are provided in a series of standards focused on printed board manufacturing, assembly, and inspection testing. This standard series consists of a generic standard (IPC-2581) that contains all the general requirements. There are seven sectional standards that are focused on the XML details necessary to accumulate information in the single file, that addresses the needs of the manufacturing disciplines producing a particular product.

The sectional standards (IPC-2582 through 2588) paraphrase the important requirements and provide suggested usage and examples for the topic covered by the sectional standard.

1.2 Notation

Although the data would be contained in a single file, the file can have different purposes as described in Section 4. The XML schema used for this standard follows the notations set forth by the W3C and is as follows:

element – Element appears exactly one time

element? – Element may appear 0 or 1 times

element* – Element may appear 0 or more times

element+ – Element may appear 1 or more times

Any IPC-258X file is composed of a high level element (IPC-2581) that contains up to six sub-elements:

Content – information about the contents of the 258X file

LogisticHeader – information pertaining to the order and supply data

HistoryRec – change information of the file

Bom – Bill of Materials (Material List) information

Ecad – Computer Aided Design (engineering) information

Avl – Approved Vendors List information

2 APPLICABLE DOCUMENTS

The following documents contain requirements which, when referenced, constitutes provisions of IPC-2581. At the time of publication, the editions indicated were valid. All documents are subject to revision and parties entering into agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the documents indicated below.

The revision of the document in effect at the time of solicitation **shall** take precedence.

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

IPC-2501 *Definition for Web-Based Exchange of XML Data*

IPC-2524 *PWB Fabrication Data Quality Rating System*

IPC-2511 *Generic Requirements for Implementation of Product Manufacturing Description Data and Transfer XML Schema Methodology*

IPC-2571 *Generic Requirements for Electronics Manufacturing Supply Chain Communication - Product Data eXchange (PDX)*

IPC-2576 *Sectional Requirements for Electronics Manufacturing Supply Chain Communication of As-Built Product Data - Product Data eXchange*

IPC-2577 *Sectional Requirements for Supply Chain Communication of Manufacturing Quality Assessment - Product Data eXchange (PDX)*

IPC-2578 *Sectional Requirements for Supply Chain Communication of Bill of Material and Product Design Configuration Data - Product Data eXchange*

IPC-7351 *Generic Requirements for Surface Mount Design and Land Patterns*

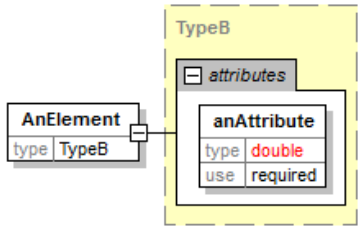
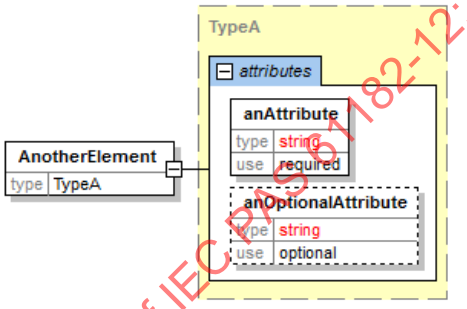
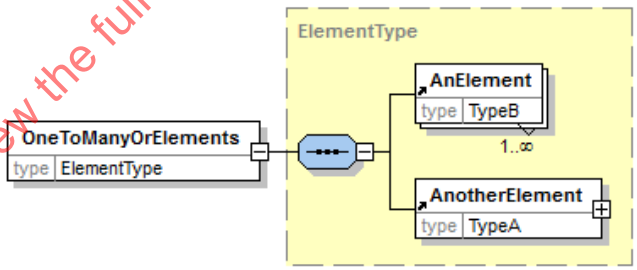
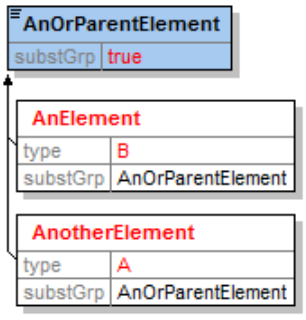
2.1 Documentation conventions

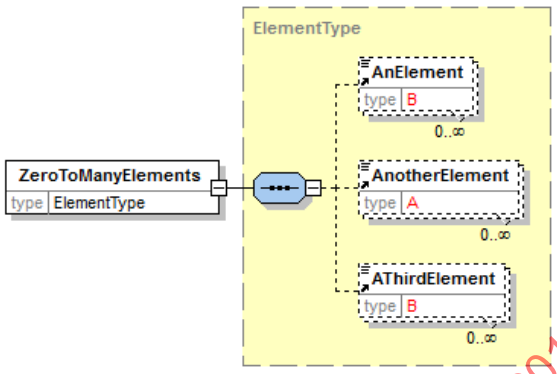
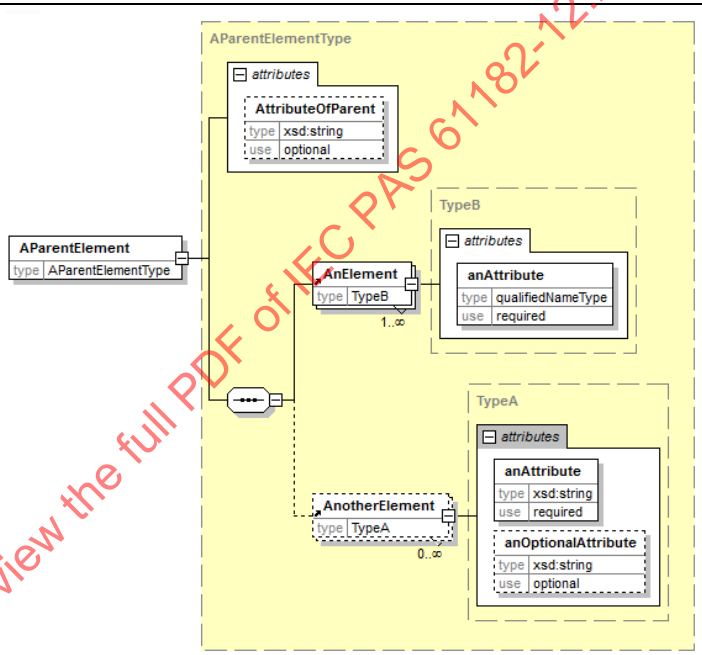
The XML file format standard and the XML Schema definition language standard, as defined the by World Wide Web Consortium (W3C), have been adopted by IPC for use in the IPC-2500 series of standards.

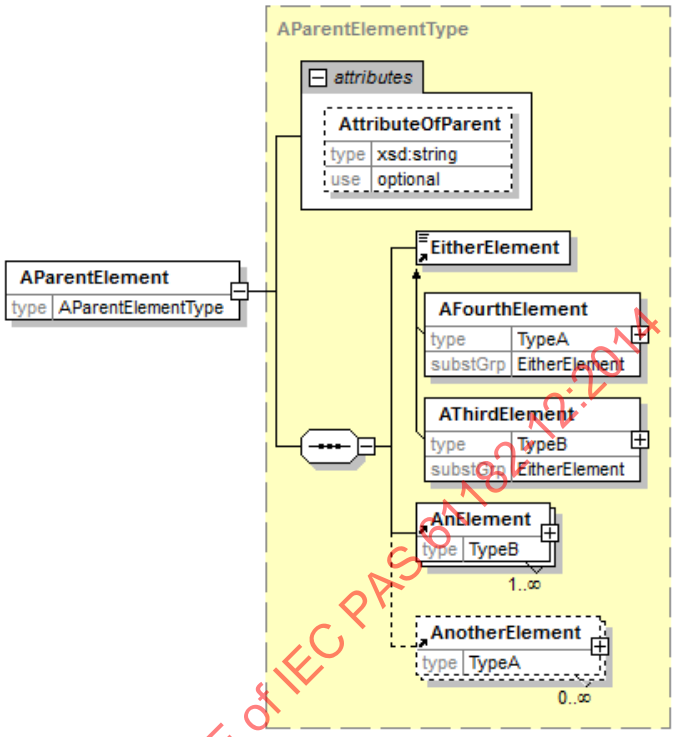
In addition to the text based schema notation, this document provides graphical representation of the structure of the file format. The XML diagrams are designed to effectively illustrate the structure and cardinality of elements and attributes that make up any IPC-258X file. The notation in the graphics does not provide a complete visualization of the schema definition for the file format, but it does provide a good top down overview. Should there be any conflict between the graphical notation and the schema notation, the authoritative definition is the schema notation.

Table 1 provides an overview of the graphical notation used in the document.

Table 1 Graphical Notation Overview

<table>
<tr><td>This diagram depicts an element named AnElement that is of type TypeB. There is one attribute, named anAttribute, that is of type double. The attribute is required.</td><td> 
</td></tr>
<tr><td colspan="2">Example:
<AnElement anAttribute=”14.44e-3”/>
Note that all attribute values must be enclosed in quotes, regardless of type.</td></tr>
<tr><td>This diagram depicts an element named AnotherElement that is of type TypeA with two attributes. The attribute anAttribute is required. The second attribute, anOptionalAttribute, is optional. Both attributes are of type string.</td><td> 
</td></tr>
<tr><td colspan="2">Examples:
<AnotherElement anAttribute=”red” anOptionalAttribute=”a string” />
<AnotherElement anAttribute=”blue” /></td></tr>
<tr><td>The ElementType OneToManyOrElements is the parent of an unordered list of one or more instances of the elements AnElement and AnotherElement. The type TypeA occurs only once while TypeB can occur many times.</td><td> 
</td></tr>
<tr><td>The arrow indicates a substitution of the element named AnOrParentElement. The substitution declares that one and only one occurrence is allowed. The AnOrParentElement can have one of AnElement or AnotherElement as a child element.</td><td> 
</td></tr>
</table>

The optional indication for the three element children shows that none may be present or many versions of all three are possible.	
This diagram depicts an element, AParentElement, of type AParentElementType. This element has one attribute, attributeOfParent, which is optional. The lines indicate that occurrences of AnElement and AnotherElement appear in the order with AnElement indicated as required while AnotherElement is optional. Both elements have a required attribute; however, if AnotherElement is instantiated, anOptionalAttribute is also possible.	

This diagram depicts a type, AParentElementType, that contains a sequence starting with one of AThirdElement or AFourth element followed by 1-n AnElement and an optional final AnotherElement. The AParentElement also has an optional attribute.	

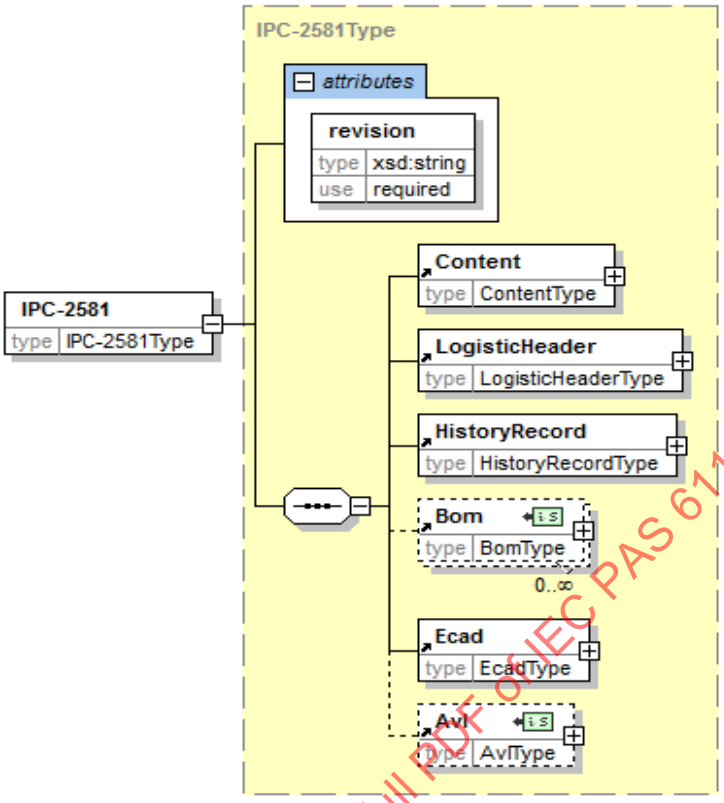
3 REQUIREMENTS

The XML schema contained in this document describes the structure of a generic computer-aided manufacturing 258X exchange format. The document specifies data elements specifically designed to establish the information exchange related to the data needed by printed board manufacturing, and assembly including inspection of those products.

The XML schema defines the configuration of mandatory and optional elements, as well as mandatory and optional attributes. The Top Level (TopElement) of the schema contains six major elements. The schema notation specifies that the 6 top-level elements are required to appear in the order shown in Figure 1. The order of appearance in the file is significant. For instance, the appearance of graphics on a layer is dependent on the order of appearance in the file. The order is also important because elements often reference information that is defined elsewhere in the file in order to eliminate redundancy within the file. The file is structured to allow all references to be resolved in one pass.

An implementation of the XML schema must be able to facilitate the reading and/or writing of all characteristics defined within the requirements stated in the `Mode` function of this standard. Some tools may have only read capability; some may have only write capability. Some tools may have both read/write capability. All schema defined in the standard as mandatory (1-1, 1-n occurrences) **shall** be executed as appropriate. Tool providers **shall** identify their capability by Mode Level (USERDEF 1, Design 1, 2 or 3, Fabrication 1, 2, or 3 etc.) plus 2581R; 2581W; or 2581RW.

Each element has a specific function or task. Accordingly, the information interchange for a specific purpose is possible only if that element is populated. The ability to select those characteristics that are appropriate for a given task makes the schema a robust methodology for defining only those areas and characteristics that are necessary to produce a given product. Figure 1 shows the potential children elements of the Top Element (IPC-2581).



Attribute / Element Name	Attribute / Element Type	Description	Occur-rence
IPC-2581	IPC-2581Type	The generic name of the file used to describe Design, Fabrication, Assembly, and Test information in accordance with the IPC-2581 standard.	1-1
revision	string	The status of the IPC-2581 file content.	1-1
Content	ContentType	The `Content` element defines the function of the file, and references the major sections of the product description (i.e., Step, Layer, Bom and Avl). In addition, there are six dictionaries indicated in Content that would contain the pre-described information needed for the file details.	1-1
LogisticHeader	LogisticHeaderType	The `LogisticHeader` describes information pertaining to ordering and delivery, by identifying individuals and locations responsible for these functions.	1-1
HistoryRecord	HistoryRecordType	The `HistoryRecord` element provides a sequential change number for the IPC-2581 file. The number is changed every time the controlled version of the IPC-2581 file is modified. Also identified are the change approval conditions.	1-1
Bom	BomType	The Bill of Materials for the board is a list of all the different components to be used for the assembly of the board, arranged by their OEM Design Number (ODN) and the materials used to fabricate the printed board.	0-n
Ecad	EcadType	The `Ecad` section describes the Computer Aided Design data of the job, including all the graphical description of the layers, component location, panel design, etc.	1-1
Avl	AvlType	The `AVL` element contains the list of matching manufacturer's part numbers (MPNs) and vendor information of a certain component parts. Approved vendors of printed board materials may also be included.	0-1

Figure 1 IPC-258X Children Element

3.1 Rules concerning the use of XML and XML Schema

The rules required to define syntax and semantics of the 258X file format notation have been simplified by the adoption of the W3C standards for XML Schema and XML file formats. These two standards are well specified by the W3C. The popularity of these standards has lead to the development of many commercial and open source software tools and libraries that conform to the W3C standards.

A 258X file begins with the notation of the revision of the generic standard and the latest revision letter followed by the software revision of the released XML schema. i.e., <IPC-2581A revision = _"2.0"> tag and ends with the <IPC-2581A> tag. The content between these tags must match the .xsd definition of the 258X schema as defined by the IPC-2581 through IPC-2588 XML. The latest software release is found at: http://webstds.ipc.org/standards.htm#x2580.

3.1.1 File readability and uniformity

A valid 258X file must conform to the W3C Canonical XML format. The format is defined by the http://www.w3.org/TR/xml-c14n specification. Software tools exist that will take malformed XML and automatically generate Canonical XML.

3.1.2 File markers

An optional checksum can be appended following the </258X> tag. The checksum is an MD5 message digest algorithm (see Internet RFC 1321: http://www.ietf.org/rfc/rfc1321.txt) that is base64 encoded. The checksum starts with the "<" character of the <258X> tag and ending with the ">" character of the closing </258X> tag. The checksum follows immediately after the ">" character of the closing </258X> tag.

The digest provides a 128-bit checksum of the 258X file contents. The MD5 signature must be base64 encoded (see IETF RFC 1421 for the base64 algorithm) to convert the MD5 signature to a US-ASCII, base64 string. An end of line character will indicate the end of the base64 encoded MD5 signature.

3.1.3 File extension

The file extension for a 258X file is .xml.

3.1.4 File remarks

The 258X format permits file remarks using the standard XML commenting notation. They are only to be used to support debugging software. A parser may ignore and discard remarks when reading a 258X file. File remarks are never to be used to represent design or manufacturing information.

3.1.5 Character set definition

The XML standard uses the Unicode character set. This character set covers the characters used in hundreds of written languages. The XML standard allows several of the Unicode encoding formats to be used in an XML file. IPC-2581 through IPC-2588 requires the use of the UTF-8 character encoding of the Unicode character set. Although comments and user assigned names may be in any language of choice, all qualified names or enumerated string names **shall** be in English only.

3.2 Data organization and identification rules

The 258X standards use a namespace mechanism for XML instance files that is similar to the XML namespace mechanism that was created for managing XML meta-data namespaces. The instance file namespace mechanism prevents collisions between the names used by the different products within a single file. This partitioning of namespaces is necessary because any of the 258X files may contain information describing an arbitrary collection of products. (Boards, assemblies, or panels that are products allowed in an IPC-258X file.) For example, a file could contain descriptions for building multiple electronic assemblies that are manufactured on separate panels. This mechanism also prepares the way for a distributed database of 258X design data in which the data can be trusted to be universally unambiguous.

3.2.1 Naming elements within a 258X File

The capability of Unique namespaces was created to allow a panel to be defined in the single 258X file that contains multiple unique boards. Since two boards may reuse the same identifier, e.g., “U1”, “R1”, it must be possible to separate names in the file into namespaces. The 258X namespace implementation borrows the notation used by XML namespaces and makes the 258X standard format consistent with conventional XML usage.

There are two types of names used to name top-level objects (element instances) in a 258X file. The first type of name is a `qualifiedName` type. This type includes a prefix in the name that corresponds to a namespace within the 258X file. The prefix and the globally unique identity of the `Namespace` are declared in the `Namespace` element. The second type of name is a `shortName` type. This type is required to be unique within the 258X file. The syntax restrictions on short names and qualified names assure that all names will be unique as top-level names within 258X file.

3.2.2 The Use of XML elements and types

A comprehensive overview of XML Schema can be found in the W3C XML Schema Primer. This section briefly describes the decisions that were made in the development of the 258X schema. Reviewing the Primer is recommended prior to reading this section.

The XML Schema defines a namespace mechanism that can be used when defining element names. The W3C also provides a set of general purpose element and attribute types, such as xsd:string, xsd:double, and xsd:datetime. The 258X format uses these standard types, however the documentation of the 258X standard has been defined without the use of a namespace prefix for element names within a 258X file.

Each of the schema elements has a prefix, “xsd:”, which is associated with the XML Schema namespace through the declaration, xmlns:xsd=”http://www.w3.org/2000/08/XMLSchema”, that appears in the schema element. The prefix xsd: is used by convention to denote the XML Schema namespace, although any prefix can be used. The same prefix, and hence the same association, also appears on the names of built-in simple types, e.g. xsd:string. The purpose of the association is to identify the elements and simple types as belonging to the vocabulary of the XML Schema language rather than the vocabulary of the schema author.

In XML Schema, there is a basic difference between complex types that allow elements in their content and may carry attributes, and simple types that cannot have element content and cannot carry attributes. There is also a major distinction between definitions that create new types (both simple and complex), and declarations that enable elements and attributes with specific names and types (both simple and complex) to appear in document instances.

New complex types are defined using the `complexType` element and such definitions typically contain a set of element declarations, element references, and attribute declarations. The declarations are not themselves types, but rather an association between a name and constraints that govern the appearance of that name in documents governed by the associated schema. Elements are declared using the “element,” and attributes are declared using the “attribute.”

3.2.3 Attribute base types (governing templates)

The attribute basic types (SimpleTypes) provided by XML Schema are defined by the W3C. They are easy to distinguish from the IPC-258X types because the W3C type is always prefixed with “xsd:”. The W3C datatypes are defined in http://www.w3.org/2000/10/XMLSchema (XML Schema Part 2).

Table 2 defines those W3C basic types that are used to define attributes in the 258X schema. The xsd:string type is constrained to create specific base types for special purpose strings, such as qualifiedName and shortName. The rules for special number types and the date format are also defined. Table 3 defines those basic types that have been standardized for use within the IPC-258X format.

Table 2 Governing Template Basic Types Defined by W3C

xsd:string	A W3C standard data type for a Unicode character string. The characters are from the UTF-8 character set as defined in http://www.ietf.org/rfc/rfc2279.txt.
xsd:double	A W3C standard data type for a binary floating-point number. The W3C definition of xsd:double is in http://www.w3.org/TR/xmlschema-2/. The xsd:double is a number where the value can be positive, negative, integer or floating point, with at least 7 digits of precision. Numbers are assumed to be positive but can be explicitly designated as positive by preceding the number with a '+' (ASCII decimal 43) character. Negative numbers must be explicitly designated as negative by a preceding '–' (ASCII decimal 45) character. An internal representation of an IEEE double precision floating-point number is assumed. This range of values for IEEE doubles is defined as 3.4x10-38 ≤ value ≤ 3.4x10+38. The format for representing a double is the same as the format used in the computer languages C, Perl, Python, or TCL. For example, all the following are legal numbers: 1.005 ; 0.01; .01; -2.334e-33; .224e-2
xsd:nonNegativeInteger	A W3C standard data type for non-negative integer numbers. The W3C definition of xsd:nonNegativeInteger is in http://www.w3.org/TR/xmlschema-2/. The range of values allowed are 0 ≤ value ≤ 2147483647 (the non-negative values that fit in a 32 bit signed integer).
xsd:positiveInteger	A W3C standard data type for positive integer numbers. The W3C definition of xsd:positiveInteger is in http://www.w3.org/TR/xmlschema-2/. The range of values allowed are 1 ≤ value ≤ 2147483647 (the positive values that fit in a 32 bit signed integer).
xsd:dateTime	The W3C standard data type for the current date and time is xsd:dateTime. (See http://www.w3.org/TR/NOTE-datetime-970915.html.) The following formats from the W3C specification are recommended for 258X files: Complete date plus hours, minutes and seconds: YYYY-MM-DDThh:mm:ssTZD (e.g. 1997-07-16T19:20:30.4536+01:00) Complete date plus hours, minutes, seconds and a decimal fraction of a second: YYYY-MM-DDThh:mm:ss.sTZD (e.g. 1997-07-16T19:20:30.45+01:00) where: YYYY = four-digit year MM = two-digit month (01=January, etc.) DD = two-digit day of month (01 through 31) hh = two digits of hour (00 through 23) (am/pm NOT allowed) mm = two digits of minute (00 through 59) ss = two digits of second (00 through 59) s = one or more digits representing a decimal fraction of a second TZD = time zone designator (Z or +hh:mm or –hh:mm)
xsd:anyURI	A W3C standard data type for hyperlinks. The W3C definition of xsd:anyURI is in http://www.w3.org/TR/xmlschema-2/.
xsd:unsignedByte	The W3C standard for an unsigned byte (an unsigned 8 bit integer with a value between 0-255.) The W3C definition of xsd:unsignedByte is in http://www.w3.org/TR/xmlschema-2/.
xsd:base64Binary	The data is encoded using base64. (see IETF *RFC 1421* for the base64 algorithm and http://www.w3.org/TR/xmlschema-2/#base64Binary)

Table 3 Governing Template Basic Types Defined by IPC

qualifiedName	The `qualifiedName` data type is a data type defined for the 258X series. The type is a restricted xsd:string data type where the pattern of the string must match the regular expression "[a-zA-Z][a-zA-Z0-9_\-#]*:.+". The definition of the qualifiedName data type is: <xsd:simpleType name = "qualifiedName"> <xsd:restriction base = "xsd:string"> <xsd:pattern value = "[a-zA-Z][a-zA-Z0-9_\#-]*:.+"/> </xsd:restriction> </xsd:simpleType> An example of a string that matches the pattern is: "prefix:name". The "prefix" is a `Namespace` name. The "name" is the name of an object within the Namespace.
nonNegativeDouble	The `nonNegativeDouble` data type is defined for the 258X series. The type restricts an xsd:double to positive numbers, inclusive of 0. The non-negative range of values for IEEE doubles is defined as $0.0 \leq$ value $\leq 3.4 \times 10^{38}$.
shortName	The `shortName` data type is a data type defined for the 258X series. The type is a restricted xsd:string data type where the pattern of the string must match the regular expression "[a-zA-Z][a-zA-Z0-9_-]*". The xsd definition of the shortName data type is: <xsd:simpleType name = "shortName"> <xsd:restriction base = "xsd:string"> <xsd:pattern value = "[a-zA-Z][a-zA-Z0-9_-]*"/> </xsd:restriction> </xsd:simpleType> An example of a string that matches the pattern is "bob_24"

3.2.3.1 Qualified name convention

The IPC-258X file supports two types of qualified names. One is a basic qualifiedName; the second is a complete qualifiedName as shown in Table 3.

A basic qualifiedName is composed of at least one letter, followed by any number of letters, numbers, underscores, or hyphens. To form a complete qualifiedName, one can optionally prefix a basic qualifiedName with a colon delimited path, where each step along the path is constructed the same way as the basic qualified name. This permits sorting of sort names into a hierarchy (see Table 3).

Examples of basic qualified names are:

"KarenSingleBoard"
"MultilayerStrategy"
"StandardPrimitiveShapes"

Examples of complete qualified names are:

"Set1:KarenSingleBoard"
"Set1:MultilayerStrategy"
"Set1:StandardPrimitiveShapes"

3.2.4 Coordinate system and transformation rules

Any geometry defined in a 258X file is defined in a Cartesian coordinate system. The x coordinates become more positive going from left to right (west to east). The y coordinates become more positive going from bottom to top (south to north). The primary side (TOP) of the board, coupon, or panel is in the x-y plane of the coordinate system with the primary side facing up.

The illustration in Figure 2 provides a perspective drawing of a board and a coordinate system. Each product in a 258X file is defined relative to a local coordinate system for the product. The point of origin of the product is located at (0,0) in the local coordinate system.

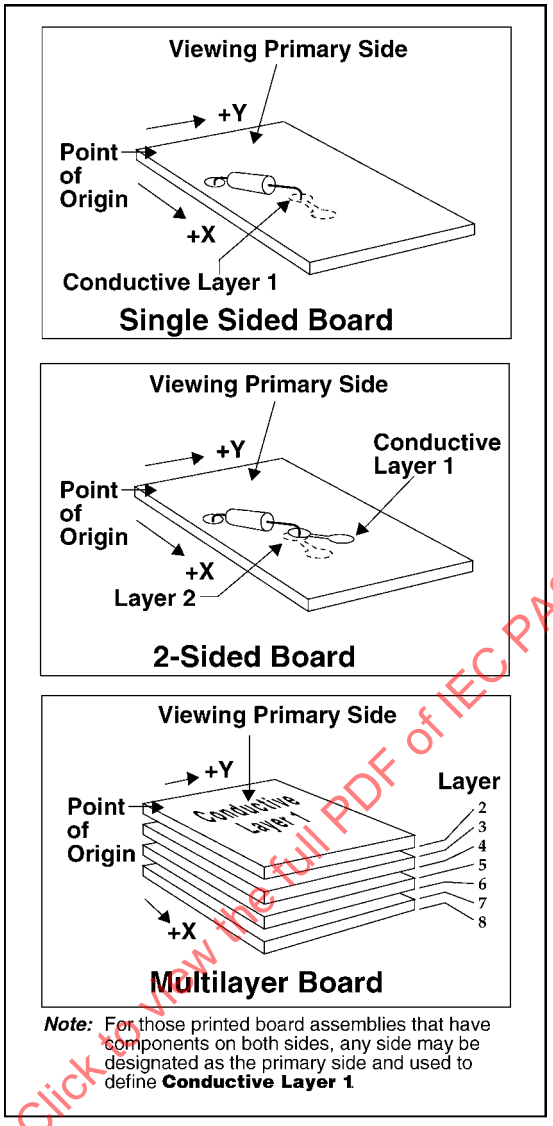


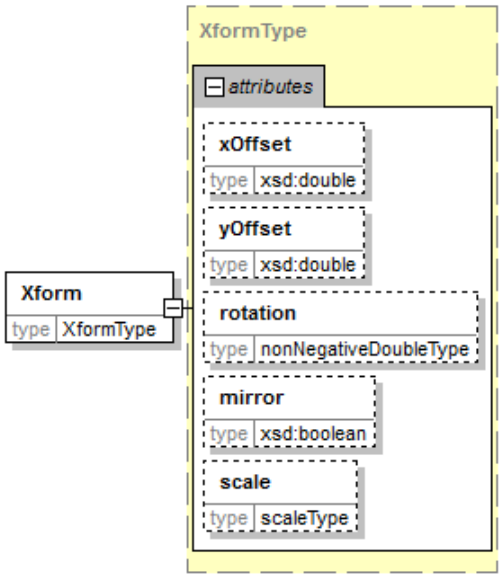
Figure 2 Printed Board Viewing

3.3 Transformation characteristics (Xform)

The `Xform` element defines a transformation that may be used throughout this specification to define a modification of the original stored data in the Dictionaries, the location and orientation of physical features. `Features`, `Shapes`, `Primitives` or other graphics in the file may manipulated relative to their local Cartesian coordinate system by the values set in the transform. The `Xform` element can define a modification of the pre-defined feature's point of origin, and then apply rotation, mirroring, scaling and location (x and y) of the image.

The units of measure are defined in the `CadHeader` as an attribute that describes the details of all the features in the `Ecad` section. In addition, units of measure are also defined in each of the Dictionaries that contain graphical information. These are `DictionaryStandard`, `DictionaryUser`, `DictionaryFont`, and `DictionaryLineDesc`. When a pre-defined image from one of the dictionaries is used in the `Ecad` section, the units of measure must match.

The order of the transformation **shall** always follow the order of the fields in the description. This would be to 1) modify the origin; 2) apply rotation; 3) mirror image; and 4) scale.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Xform	XformType	An element that provides the ability to reset the point of origin of a predefined target that can be scaled, mirror imaged or rotated.	0-1
xOffset	double	The x offset of a previously defined shape relative to its original point of origin in order to define a new origin used for rotation, mirroring, scaling and location. The `CadHeader` defines the units of measure.	0-1
yOffset	double	The y offset of a previously defined shape relative to its original point of origin in order to define a new origin used for rotation, mirroring, scaling and location. The `CadHeader` defines the units of measure.	0-1
rotation	nonNegativeDouble Type	Defines the rotation of a shape about the local origin in degrees. Positive rotation is always counter-clockwise as viewed from the board TOP (primary side). Degree accuracy is expressed as a two place decimal i.e., 45.15; 62.34	0-1
mirror	boolean	An enumerated string as either TRUE or FALSE (part of the 3WC standard). TRUE equals that the image is mirrored; FALSE indicates that it is not. Mirror is implemented as FALSE by default and MUST be set to True if the features/components are to be inverted.	0-1
scale	scaleType	An attribute that defines a “double” dimension whose minExclusiveValue=0.0 representing the multiplication factor of all x and y dimensions. The scale factor does not apply to angular values.	0-1

3.3.1 The x and y Offset attributes

The `xOffset` and `yOffset` attributes are of type xsd:double. They define the x and y offset of a shape relative to the origin of a Cartesian coordinate system. The definition of shapes can be nested and the x and y attributes are always interpreted relative to the local coordinate system of the shape to which the transformation applies. The default value for x and y is 0.0.

3.3.2 The rotation attribute

The `rotation` attribute is of type `nonNegativeDouble` that defines the rotation of a shape about the local origin. The interpretation of the value is set globally in the file to units of degrees. The range of the rotation parameter for DEGREES is 0.00 to 360.00 expressed as a `nonNegativeDouble` with an accuracy of a two place decimal. Positive rotation is always counter-clockwise as viewed from the board TOP (primary side), even if the component that is being rotated is on the board BOTTOM (secondary side). Rotation defaults to 0.0, and can be applied to text, or any physical shape.

3.3.3 The mirror attribute

The `mirror` attribute is of data type `boolean`. This type is an enumerated string indicating TRUE or FALSE. The default value for MIRROR is FALSE. When mirror is set to TRUE it indicates that all x dimensions are set to a –x value. The proper interpretation of the mirror and rotate attributes are shown in Figure 3. The example shows a unique artwork (14-pin DIP device) placed on the top and bottom of a board at 90.00° rotations.

3.3.4 The scale attribute

The `scale` attribute is of data type `scaleType`. The `scale` attribute is a “double” that must have a value greater than zero. All x and y dimensions of a geometry are multiplied by the scale attribute. The scale factor does not apply to angular values. The default value is 1.0.

3.3.5 The x and y Location attributes

The `xLocation` and `yLocation` attributes are of type xsd:double. They define the x and y position where a feature, component, text or other shape is placed. The `xLocation` and `yLocation` coordinate positions a shape by its original origin or its modified origin (x and y Offset) relative to the origin of the image upon which the feature, component etc. is to be located. Mirroring, rotating, and scaling may all apply to the location of the shape as indicated by the `Xform`.

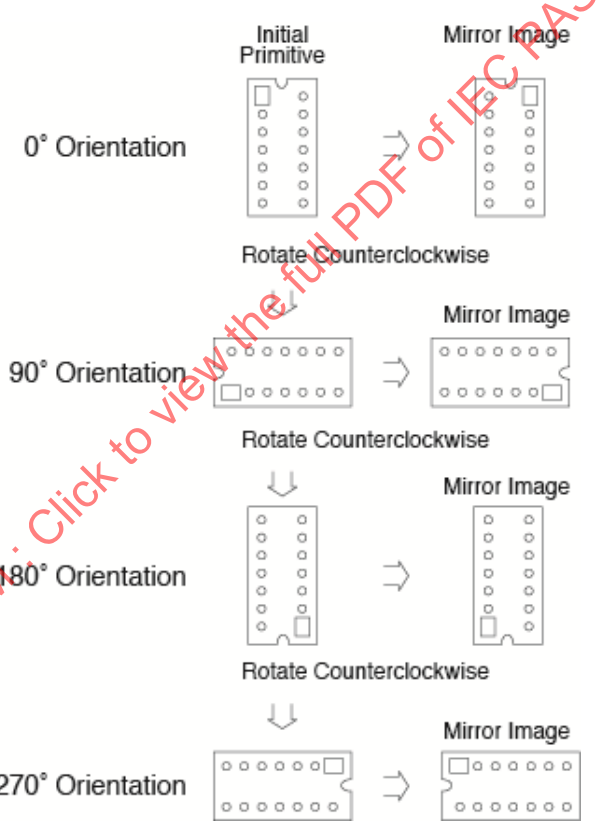


Figure 3 Rotation and Mirror Diagram

3.4 Substitution groups

The IPC-2581 uses the concept of substitution within the XML schema. Various groups of elements have been identified in the body of the standard and have been designated as having a specific focus or purpose. Within the schema, these substitution groups are provided with a name. When a group exists and if they are required according to the instances of the schema, it is mandatory that the substitution name be replaced by one of the acceptable descriptions identified within the group.

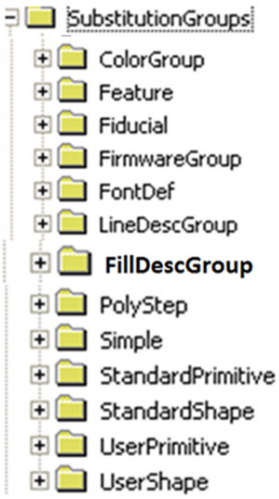
Often a schema needs to specify that one of several different XML Elements can be used with equal validity. For example, in every case where a `Triangle` can be used, it is also permissible to use a `Diamond`, `Hexagon`, `Octagon`, `Oval`, or one of several others: even though these shapes are quite different, they are equivalent as far as the schema is concerned. IPC-2581 handles this by using "substitution groups."

A substitution group consists of two types of elements: a "head" and elements which may substitute for the head. Furthermore, when the head is denoted as ABSTRACT, the substitution is required, rather than optional. In IPC-2581, the heads of all substitution groups are ABSTRACT. Thus, it means that a valid instance document is not allowed to contain a `StandardPrimitive` element, but instead, (where `StandardPrimitive` is called for in the schema) a `Triangle`, `Diamond`, `Hexagon`, etc. must be used.

It should be noted that the head of one substitution group may be used within a different substitution group. As an example, the `StandardPrimitive` element is part of the `StandardShape` substitution group, which in turn is part of the `Feature` substitution group. This means that a `Triangle`, `Diamond`, `Hexagon`, etc. may be used wherever a `Feature` or `StandardShape` is called for, as well as wherever a `StandardPrimitive` is called for.

IPC-2581 features several dictionaries that permit specifying some type of information (such as a `StandardPrimitive` or a `LineDesc`) one time, and to reuse that definition as often as necessary. Some substitution groups in IPC-2581 are present to enable specifying either a dictionary entry or the same kind of information defined in specific detail within the body of the file. Any predefined image contained in the Dictionaries must have a unique "id". It is the "id" name that is used to instantiate information from any of the dictionaries.

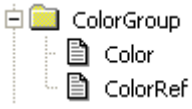
There are 13 substitution groups within the IPC-2581 schema. These are shown in the following table.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
ColorGroup	ABSTRACT	A substitution group that permits the substitution of the `Color` element when it is a child of the parent `Set`, or `Text` Elements.	3
Feature	ABSTRACT	A substitution group that permits the substitution of the `Feature` element when it is a child of the parent `Set` element.	1
Fiducial	ABSTRACT	A substitution group that permits the substitution of the `Fiducial` element when it is a child of the parent `Set` element.	1
FirmwareGroup	ABSTRACT	A substitution group that permits the substitution of the `FirmwareGroup` element when it is a child of the parent `Firmware` element.	1
FontDef	ABSTRACT	A substitution group that permits the substitution of the `FontDef` element when it is a child of the parent `EntryFont` element.	1
LineDescGroup	ABSTRACT	A substitution group that permits the substitution of the `LineDescGroup` element when it is a child of the parent of most `StandardPrimitives`, `Outline`, `Polyline`, or `Set` elements.	16
FillDescGroup	ABSTRACT	A substitution group that permits the substitution of the `FillDescGroup` element when it is a child of the parent of most `StandardPrimitives`, `Outline`, `Polyline`, or `Set` elements.	16
PolyStep	ABSTRACT	A substitution group that permits the substitution of the `PolyStep` element when it is a child of the parent `Polyline` or `Polygon` elements.	2
Simple	ABSTRACT	A substitution group that permits the substitution of the `Simple` element when it is a child of the parent `DfxMeasurement`, `Glyph`, or `Slot` elements.	3
StandardPrimitive	ABSTRACT	A substitution group that permits the substitution of the `StandardPrimitive` element when it is a child of the parent `EntryStandard` element.	1
StandardShape	ABSTRACT	A substitution group that permits the substitution of the `StandardShape` element when it is a child of the parent `LayerPad` or `Pad` elements.	2
UserPrimitive	ABSTRACT	A substitution group that permits the substitution of the `UserPrimitive` element when it is a child of the parent `EntryUser` element.	1
UserShape	ABSTRACT	A substitution group that permits the substitution or classification of a higher level substitution group. The `UserShape` element may be used to further classify `Feature`. In so doing, `UserShape` can be substituted by a `UserPrimitive` or `UserPrimitiveRef`.	0

3.4.1 ColorGroup

The `ColorGroup` substitution group consists of various colors that may be used within the body of the IPC-2581 standard. Color may be predefined and named in the `DictionaryColor`. `Color` is used by the `FinishType`, `Set`, or `Text` elements. It is referred to in the body of the file by its "Color ID" or by the three attributes that make up color (red, green, blue).



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Color	ColorType	The description of a specific color using the three attributes of red, green, and blue.	0-n
ColorRef	ColorRefType	The id of a previously defined color stored in the DictionaryColor.	0-n

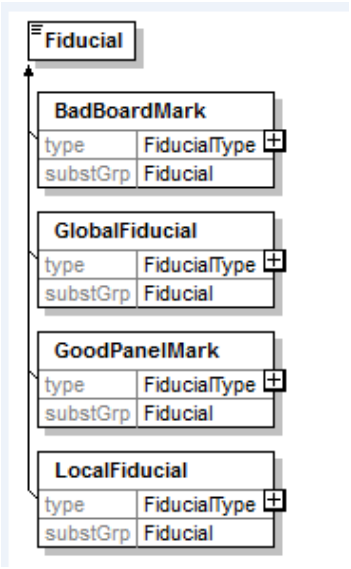
3.4.2 Feature

The `Feature` substitution consists of two major substitution groups. Where `Feature` is called for, an instance must substitute a graphic allowed by either the `StandardShape` or `UserShape` substitution groups.

Attribute / Element Name	Attribute / Element Type	Description	Occurrence
StandardShape	ABSTRACT	A substitution group that occurs in the IPC-2581 schema and permits the substitution of the `StandardShape` element when it is a child of the parent `LayerPad` or `Pad` elements.	0-n
UserShape	ABSTRACT	A substitution group that occurs in the IPC-2581 schema and permits the substitution or classification of a higher level substitution group. The `UserShape` element may be used to further classify `Feature`. In so doing `UserShape` can be substituted by a `UserPrimitive` or `UserPrimitiveRef`.	0-n

3.4.3 Fiducial

The `Fiducial` substitution group consists of four elements that may be used to replace the `Fiducial` element. When the `Fiducial` element is substituted, it **shall** be by either a `BadBoardMark`, `GlobalFiducial`, `GoodPanelMark`, or `LocalFiducial` fiducial type. The `Fiducial` elements contain an Xform and a substitution capability to a `StandardShape`. An optional `Pin` attribute allows reference to a component pin.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
BadBoardMark	FiducialType	A set of Standard Shapes used as an aid to the board assembler by defining those boards in a panel that did not pass inspection or electrical test. The fiducial shape is positioned near each board in the assembly panel array and covered over to signify that the board is defective.	0-n
GlobalFiducial	FiducialType	A set of Standard Shapes used in the description, arrangement or positioning of a group of features on an individual board, assembly, or panel.	0-n
GoodPanelMark	FiducialType	A single Standard Shape used to define a panel where all boards on the panel are good. The fiducial is positioned once on the panel and enables reduction in inspection time.	0-n
LocalFiducial	FiducialType	A set of fiducials (usually a pair) used in the description and arrangement of features related to a specific component on a board, assembly, or panel which aide in the location/positioning process.	0-n

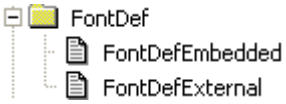
3.4.4 FirmwareGroup

The `FirmwareGroup` substitution group consists of the description element for the firmware that defines the data to be added to a component through the `RefDes` element of a particular `BomItem`. The information may be provided as a `CachedFirmware` element or as a reference to the firmware which has been stored and identified with an “id” in the `DictionaryFirmware`.

Attribute / Element Name	Attribute / Element Type	Description	Occurrence
CachedFirmware	CachedFirmwareType	An element that identifies the firmware needed for a particular component in the Bill of Material. The information is in a `hexEncodeBinary` format.	0-n
FirmwareRef	FirmwareType	An element that references `CachedFirmware` stored in the `DictionaryFirmware` through the callout of the firmware “id”	0-n

3.4.5 FontDef

The `FontDef` substitution group consists of the description of a font that is different than the standard Helvetica and which is contained in the `DictionaryFont`. Fonts in the dictionary have an “id” which is called out when a `FontRef` is instantiated. `FontRef` is used by the element `Text`, which is called for in `SilkScreen` and `AssemblyDrawing`. `Text` can also be substituted whenever a `UserPrimitive`, `UserShape` or `Feature` is called for.

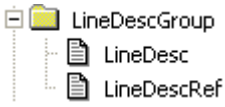


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
FontDefEmbedded	FontDefEmbedded Type	A description of a font using individual characters that are defined in accordance with the `Glyph` element and are contained in the `DictionaryFont`. Fonts must be predefined and may not be instantiated as part of the data in the file.	0-n
FontDefExternal	FontDefExternal Type	A reference to an external font description through the instantiation of a URN. The font is named and the reference is contained in the `DictionaryFont`. The appropriate character set is defined by the URN. External Fonts must be predefined and may not be instantiated as part of the data in the file.	0-n

The term "Uniform Resource Name" (URN) refers to the subset of URI that are required to remain globally unique and persistent even when the resource ceases to exist or becomes unavailable. A URI can be further classified as a locator, a name, or both. The term "Uniform Resource Locator" (URL) refers to the subset of URI that identify resources via a representation of their primary access mechanism (i.e., their network "location"), rather than identifying the resource by name or by some other attribute(s) of that resource.

3.4.6 LineDescGroup

The `LineDescGroup` substitution specifies the `LineDesc or LineDescRef`. The LineDesc specifies the `LineWidth, LineEnd and LineProperty` characteristics of any feature that requires that definition. Line descriptions are a part of the `Outline, Polyline` and `Set` element definitions. The substitution is also instantiated by the substitution group `Simple` which calls for `Arc`, `Line`, `Outline` and `Polyline`. In addition to the UserPrimitives the StandardPrimitives also make use of the line descriptions when required. The `LineDescRef` requires an “id” that must be unique within the 2581 file.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
LineDesc	LineDescType	An element that identifies the `LineEnd`, `LineWidth and LineProperty` characteristics	0-n
LineDescRef	LineDescRefType	A reference to a `LineDesc` that is contained in the `DictionaryLineDesc` and identified by its unique “id”. The units for the dictionary are defined and must be consistent with the units of the `CadHeader` when referenced from the `Ecad` section.	0-n

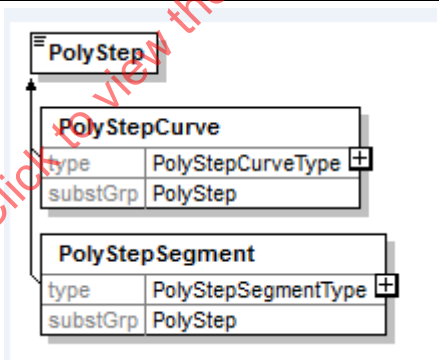
3.4.7 FillDescGroup

The `FillDescGroup` substitution specifies the `FillDesc` or `FillDescRef`. The `FillDesc` element provides the `FillProperties, LineDesc` and `Color` characteristics of any feature that requires that definition. Fill descriptions are a part of the `StandardPrimitives`, any `UserPrimitive` closed shape and `Set` element definitions. The `FillDescRef` requires an "id" that must be unique within the 2581 file

Attribute / Element Name	Attribute / Element Type	Description	Occurrence
FillDesc	FillDescType	An element that identifies the `FillProperties, LineDesc and Color` characteristics	0-n
FillDescRef	FillDescRefType	A reference to a `FillDesc` that is contained in the `DictionaryFillDesc` and identified by its unique "id". The units for the dictionary are defined and must be consistent with the units of the `CadHeader` when referenced from the `Ecad` section.	0-n

3.4.8 PolyStep

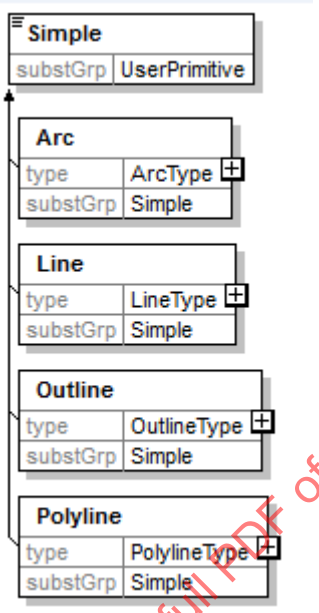
The `Polystep` substitution consists of defining either a `Line` or an `Arc` as the continuation of a `Polyline` or `Polygon` description. The location information is interpreted as being the point to which the curve (`Arc`), or segment (`Line`) is drawn. The substitution may take place anywhere within the file where the elements `Polyline` and `Outline` occur. This action includes the dictionaries where graphic descriptions are predefined. The `Units` of measure must be consistent with the `Units` parameter of the three dictionaries where this substitution can take place; `DictionaryStandard`, `DictionaryUser`, and `DictionaryFont`.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
PolyStepCurve	PolyStepCurveType	The continuation of the linear description of a `Polyline` or `Polygon` if the next portion to be defined is an arc. The end point of the arc is defined as well as the location of the radius. `CounterClockwise` is the default direction	0-n
PolyStepSegment	PolyStepSegmentType	The continuation of the linear description of a `Polyline` or `Polygon` if the next portion to be defined is a line segment. The end point of the line is defined.	0-n

3.4.9 Simple

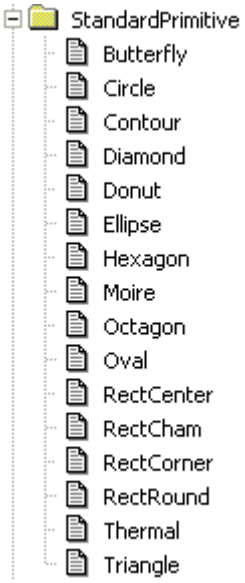
The `Simple` substitution consists of defining an `Arc`, `Line`, `Outline` or `Polyline`. The `Simple` substitution is called for in the `DfxMeasurement`, `Glyph`, and `Slot` elements. `Simple` is also identified as a `UserPrimitive`, `UserShape`, or `Feature` and the four elements may be substituted when called for in conjunction with those descriptions. When predefined in the `DictionaryUser`, or `DictionaryFont` the `Units` must match those of the dictionary.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Arc	ArcType	`Arc` elements are curves (defined by three sets of coordinates: `startX`, `startY`, `endX`, `endY` and `centerX`, `centerY`. The width of the arc is applied when the arc is instantiated or predefined.	0-n
Line	LineType	`Line` elements are individual line segments. The `lineWidth` and `lineEnd` conditions are defined when the line is instantiated or pre-defined. The `lineEnd` default is ROUND.	0-n
Outline	OutlineType	`Outline` has `Polygon` and `LineDesc` as children elements. The characteristics of the `Polygon` must be a closed shape. The point of origin of the shape is identified as the 0:0 coordinate. The element includes the start of the polygon definition (`PolyBegin`) and the appropriate number of PolySteps to complete the closed shape. The `lineWidth` is defined at a time when the `Outline` is instantiated or predefined.	0-n
Polyline	PolylineType	The `Polyline` element consists of a series of lines that define a particular grouping configuration. These line segments do NOT result in a closed shape, however they can be pre-defined and re-used as needed. The `lineWidth` and `lineEnd` of the `Polyline` are defined at the time the `Polyline` is instantiated or predefined.	0-n

3.4.10 StandardPrimitive

There are sixteen Standard Primitives defined in the IPC-2581 structure. Any of the primitive shapes may be a candidate for substitution when `StandardPrimitive` is called for in the schema. The names of the various shapes indicate their type; each has its attributes that identify the physical requirements. Any `StandardPrimitive` may be predefined, provided a unique “id”, and contained in the `DictionaryStandard`. All `StandardPrimitive` shapes are developed in accordance with their description requirements in the preferred orientation of this standard.

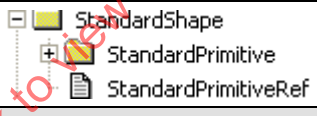


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Butterfly	ButterflyType	A primitive shape (either ROUND or SQUARE) that has two quadrants of the Cartesian coordinate system removed (0 to 90° and 180 to 270°).	0-n
Circle	CircleType	A primitive shape that defines a round object where the circular shape consists of a diameter.	0-n
Contour	ContourType	A closed primitive shape that has as its children a polygon and optional cutout(s) The sequence of connected edges that form the polygon may be straight or circular.	0-n
Diamond	DiamondType	A primitive shape with four equal sides that are extended from its horizontal center to its vertical center. The lines converge into a point both horizontally and vertically. The overall description of the shape is controlled by the width (distance between vertical point) and the height (distance between horizontal point).	0-n
Donut	DonutType	A round, square, hexagon, or octagon shaped primitive consisting of an outer diameter and inner diameter that define physical characteristics of the donut.	0-n
Ellipse	EllipseType	An elliptical primitive shape that follows the standard ellipse characteristics and is defined by a width and height dimension, establishing the overall limits of the feature.	0-n
Hexagon	HexagonType	A six-sided primitive shape with all sides being equal in length and with all angles between adjacent sides being equal. The orientation of the Hexagon is with one of its points facing North. Only the dimension across the points is required.	0-n
Moire	MoireType	A series of circles, each consisting of a smaller diameter than the previous. The details of the `Moire` is defined by the number of rings, their center line spacing, and the ring width. The pattern may also contain a crosshair representing its point of origin. Restrictions apply so that `ringWidth` is smaller than `ringGap`.	0-n
Octagon	OctagonType	An eight-sided primitive shape with all sides being equal in length and with all angles between adjacent sides being equal. The orientation of the `Octagon` is with one of its points facing north. Only the dimension across the points is required.	0-n
Oval	OvalType	A rectangular primitive shape with a complete radius (180° arc) at each end. The limits of the feature are controlled by the length and width of the oval across the outer extremities.	0-n

RectCenter	RectCenterType	The characteristics of a rectangle defined by a width and height dimension consistent with a horizontal position on the Cartesian coordinate system. The center point is the point of origin and is used to locate the `RectCenter`. A "`square`" is a `RectCenter` with the width and height equal.	0-n
RectCham	RectChamType	A rectangle with one or more corners chamfered. The user has the option to define any of the corners as containing the chamfer as well as the chamfered dimensions. All chamfers (or opportunities for chamfers) must be identical in size.	0-n
RectCorner	RectCornerType	A constraining rectangular area (bounding box) that describes a rectangle consistent with a horizontal position on the Cartesian coordinate system. The point of origin is the lower left corner. A Square positioned by its corners is a `RectCorner` that is defined by having the X and Y offset be equal.	0-n
RectRound	RectRoundType	A rectangle with one or more corners rounded. The user has the option to define any of the corners as containing the radius as well as the radiused dimensions. All corners (or opportunities for corners) must be identical in size.	0-n
Thermal	ThermalType	A primitive shape consisting either of ROUND, SQUARE, HEXAGON, or OCTAGON configuration that historically defines the removal of material from a plane or conductive fill area in accordance to the shape attribute description.	0-n
Triangle	TriangleType	A primitive isosceles triangular shape that has two equal sides and a base. The feature is defined by a base and height dimension.	0-n

3.4.11 StandardShape

The `StandardShape` substitution group permits the substitution of any of the `StandardPrimitive` shapes in accordance with their individual descriptions. A predefined `StandardPrimitive` may also be instantiated by its unique "`id`" when the feature is contained in the `DictionaryStandard`. When a reference is made to the dictionary predefined primitive, the `Units` must match.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
StandardPrimitive	ABSTRACT	A substitution group that permits the substitution of the `StandardPrimitive` element with any of the sixteen standard primitive types.	0-n
StandardPrimitiveRef	StandardPrimitiveRefType	A reference to a predefined `StandardPrimitive`, contained in the `DictionaryStandard`. The reference is by its unique "id". The units of the referenced predefined primitive and the `Ecad` section where it is to be instantiated must match.	0-n

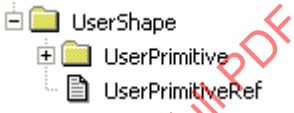
3.4.12 UserPrimitive

The `UserPrimitive` substitution group consists of any simple graphic feature (`Arc`, `Line`, `Outline` or `Polyline`), as well as `text` or `UserSpecial` shapes. The `UserSpecial` element is a collection of `Features` (which are any of the permitted graphics used in the 2581 file). `UserSpecial` permits the definition of logos, special targets, drawing formats or other graphics needed by a particular design. `UserPrimitives` can be predefined, assigned a unique "id" and contained in the `DictionaryUser`. The `DictionaryUser` defines the `Units` used to describe the graphic shapes.

Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Simple	ABSTRACT	A substitution consists of defining an `Arc, Line, Outline or Polyline`. The `Simple` substitution is called for in the schema in `DfxMeasurement`, `Glyph`, and `Slot` elements and may be defined in any other graphics.	0-n
Text	TextType	The text element defines text strings, fonts, and the bounding box containing the text. Also included are Xform to position, mirror or rotate the text.	0-n
UserSpecial	UserSpecialType	The `UserSpecial` element has all the capabilities allowed by the standard. The characteristic uses the substitution group “Feature” and may develop any combination of graphical shapes.	0-n

3.4.13 UserShape

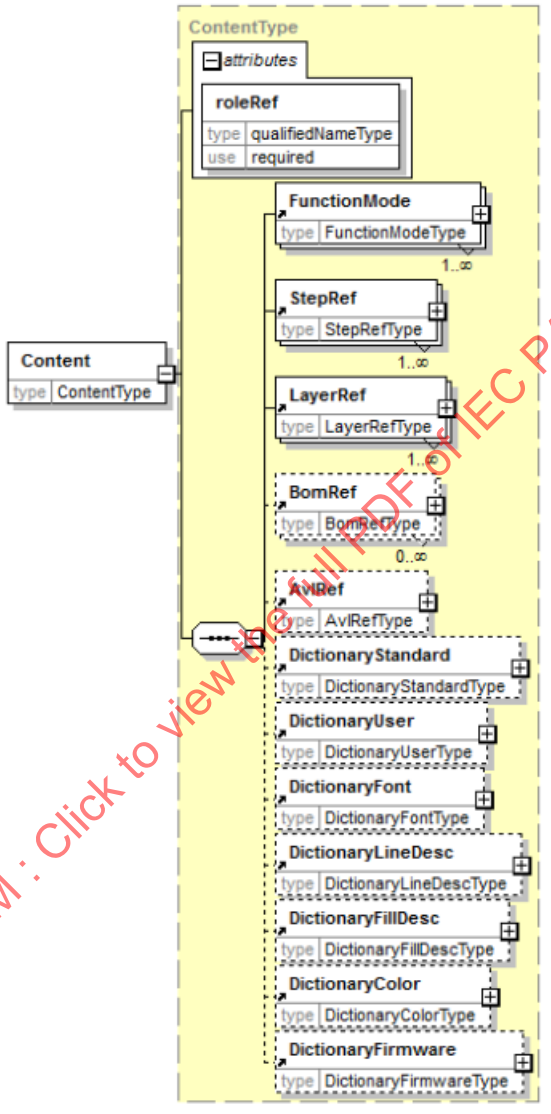
The `UserShape` substitution group permits the substitution of any of the `UserPrimitive` shapes in accordance with their individual descriptions. A predefined `UserPrimitive` may also be instantiated by its unique “id” when the feature is contained in the `DictionaryUser`. When a reference is made to the dictionary predefined primitive, the `Units` must match.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
UserPrimitive	ABSTRACT	A substitution group that occurs in the IPC-2581 schema and permits the substitution of the `UserPrimitive` element with any of the user primitive description or types.	0-n
UserPrimitiveRef	UserPrimitiveRefType	A reference to a predefined `UserPrimitive` contained in the `DictionaryUser`. The reference is by its unique “id”. The units of the referenced predefined primitive and the Ecad section where it is to be instantiated must match.	0-n

4 CONTENT

The `Content` sub-element provides the information about the contents of the IPC-258X file. The `Content` schema identifies the depth and breadth of information in the file. The `Content` sub-elements include references to the `FunctionMode`, `StepRef`, `LayersRef`, `BomRef`, and `AvlRef` included in the file, plus six Dictionaries: `DictionaryStandard`, `DictionaryUser`, `DictionaryFont`, `DictionaryLineDesc`, `DictionaryColor`, and `DictionaryFirmware`.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Content	ContentType	The `Content` element defines the function of the file, and references the major sections of the product description (i.e., Step, Layer, Bom and Avl). In addition, there are six dictionaries indicated in Content that would contain the pre-described information needed for the file details.	1-1
roleRef	qualifiedNameType	A reference to a globally unique name that identifies the role responsibility associated with the specific role at the time the file is transferred or archived.	1-1

FunctionMode	FunctionModeType	The function that the file is intended to perform between trading partners.	1-n
StepRef	qualifiedNameType	The names of all Step elements that are included in the IPC-258X file through the reference of their unique name.	1-n
LayerRef	qualifiedNameType	The names of all Layer elements that are included in the IPC-258X file through the reference of their unique name.	1-n
BomRef	qualifiedNameType	The names of all Bom elements that are included in the IPC-258X file through the reference of their unique name.	0-n
AvlRef	qualifiedNameType	A reference to the he `Avl` name established in the file. This file contains the approved vendor list for all items contained in the `BomData`.	0-1
DictionaryStandard	DictionaryStandard Type	An element that contains substitution group information using predefined descriptions of standard primitives identified by the 2581 standard and described by the user for reuse in the file.	0-1
DictionaryUser	DictionaryUserType	An element that contains substitution group information using predefined descriptions of user primitives identified by the 2581 standard and described by the user for reuse in the file.	0-1
DictionaryFont	DictionaryFontType	An element that contains substitution group information regarding font descriptions as predefined Glyphs or references to external URN's for character sets that differ from the Helvetica standard.	0-1
DictionaryLineDesc	DictionaryLineDesc Type	An element that contains substitution group information using line description criteria, predefined by the user for reuse in the file.	0-1
DictionaryFillDesc	DictionaryFillDescType	An element that contains substitution group information using fill description criteria, predefined by the user for reuse in the file.	0-1
DictionaryColor	DictionaryColorType	An element that contains substitution group information using color description criteria, predefined by the user for reuse in the file.	0-1
DictionaryFirmware	DictionaryFirmware Type	An element that contains substitution group information using firmware description criteria, predefined by the user for reuse in the file.	0-1
The XML schema will have a restriction that requires the reference for `StepRef`, `LayerRef`, `BomRef`, and `AvlRef` be by the globally unique "name." The intent of the Content Element is to act as a table of contents for the 2581 file.			

4.1 Content: FunctionMode

The `FunctionMode` element defines the global mode of the file (see Table 4). There are five valid values for the `mode` attribute. These are:

USERDEF (User Defined) – Anything that may be included in the IPC-2581 standard job is possible even to being completely Full. A Comment attribute is required for USERDEF (user defined) Mode.

DESIGN – file carries mostly Design start or complete description

FABRICATION – file carries mostly Fabrication information

ASSEMBLY – file carries mostly Assembly information

TEST – file carries mostly testing information for bare board or assembly

Table 4 File Segmentation and Function Apportionment

Name	User Def	Design			Fabrication			Assembly			Test		
		1	2	3	1	2	3	1	2	3	1	2	3
Hierarchical layer/stack instance files	O	N	Y	N	N	N	N	N	N	N	N	N	N
Hierarchical conductor routing files	O	N	Y	N	N	N	N	N	N	N	N	N	N
BOM (Components and Materials)	O	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y
AVL (Components and Materials)	O	N	Y	Y	N	Y	Y	Y	Y	Y	N	N	Y
Component Packages	O	Y	Y	Y	N	N	Y	Y	Y	Y	N	Y	Y
Land Patterns	O	N	Y	Y	N	N	Y	N	Y	Y	N	Y	Y
Device Descriptions	O	Y	Y	Y	N	N	N	N	N	Y	N	N	Y
Component Descriptions	O	Y	Y	Y	N	N	N	Y	Y	Y	N	Y	Y
Soldermask; Solder Paste Legend Layers	O	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Drilling and Routing Layers	O	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Documentation Layers	O	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Net List	O	Y	Y	Y	N	Y	Y	N	Y	Y	Y	N	Y
Outer Copper Layers	O	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Inner Layers	O	N	N	Y	Y	Y	Y	N	Y	Y	N	N	Y
Miscellaneous Image Layers	O	N	Y	Y	N	Y	Y	N	Y	Y	N	Y	Y
DFX Analysis	O	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

O = User Defined so Data is Optional N=Data is Not Included Y=Data is Included

Each `FunctionMode` has a specific purpose defined for the industry. The `FunctionMode` element has three attributes. The first is `mode`, which can be the enumerated strings of DESIGN, FABRICATION, ASSEMBLY, TEST and USERDEF. The USERDEF mode provides the opportunity for a unique data arrangement with the Option to contain or not contain the specific information based on need or restrictions. In many instances, the testing function is already included in fabrication and assembly modes consisting of bare board testing for fabrication, and in-circuit testing for assembly. Nevertheless, there are times when companies wish to outsource the testing activity. Therefore it is important to identify the various testing modes.

In order to define additional granularity, `FunctionMode` has a second attribute, `level`, that defines the data complexity needed for each of the mode condition. The attribute `level` is a positive integer however only the numbers 1, 2 or 3 are presently allowed since each mode has only three levels. When identifying USERDEF as the mode, the level should be set at 1. The levels encompass their own file details in order to identify that they are associated with an individual mode. Thus, the required file content for level 1 of the DESIGN mode is not the same as a level 1 for the ASSEMBLY mode.

The `FunctionMode` element has a third attribute. The attribute is `comment` which, as string data, permits the users of the 2581 file to enhance the `FunctionMode` descriptions with additional information.

4.1.1 USERDEF mode

The `USERDEF` mode identifier is optional and may incorporate some or all of the total of the fifteen functions. Each function may be represented and available in the file. The order of the details in the file is not significant as several elements may be used to address any given function. Hierarchical padstack and route information reflects original design intent that may be altered in the representation of the flattened fabrication data. For FABRICATION and ASSEMBLY, flattened data **shall** be used. A Comment noting which functions are included is required.

4.1.2 DESIGN mode

The `DESIGN` mode consists of three levels of complexity. Each level performs a different function consisting of an original design starting from scratch to completed design that had already been converted to manufacturing data, or a completed design that is still in the CAD format structure. See IPC-2582 and IPC-2583 for sectional data descriptions.

4.1.3 FABRICATION mode

The `FABRICATION` mode consists of three levels of complexity. Each level describes information in a layered format, from very simplistic data to that where the customer has dictated very specific materials and material stack-up structures. See IPC-2584 and IPC-2588 for sectional data descriptions.

4.1.4 ASSEMBLY mode

The `ASSEMBLY` mode consists of three levels of complexity. Each level describes a concept of more complete information. The simplest level is mainly bill of material data as well as external copper layers. In its most complete form, the assembly information describes the component approved vendor listing for aliases and substitution in sufficient detail to ensure proper assembly. See IPC-2586 and IPC-2588 for sectional data descriptions.

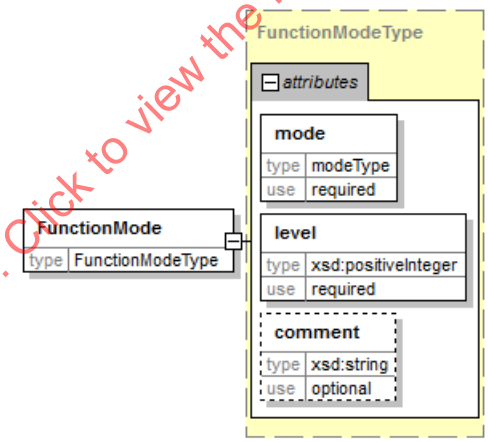
4.1.5 TEST mode

The `TEST` mode consists of three levels of complexity. Each level describes a specific function for testing information that must be contained within a file. In its simplest mode, the data describes information to allow bare board testing. In its most complex mode, there is information on in-circuit test, impedance control, and dielectric withstanding voltage conditions. See IPC-2585 and IPC-2587 for sectional data descriptions.

4.2 Function levels

The IPC-258X is limited to be organized as one of thirteen function levels. The `level` attribute, when associated with the `mode` attribute, defines the complexity and detail of the file content.

The `level` attribute consists of a positive integer and identifies complexity with respect to the characteristics for mode-DESIGN, mode-FABRICATION, mode-ASSEMBLY and mode-TEXT. A mode-USERDEF mode may consists of all or any number of the elements for an IPC-258X file and has only one (1) level value. For all other modes, the `level` attribute relates to the type of mode and is apportioned as one of three levels.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
FunctionMode	FunctionModeType	The function that the file is intended to perform between trading partners.	1-1
mode	modeType	An enumerated string, either USERDEF | DESIGN | FABRICATION | ASSEMBLY | TEST, that defines the type of mode that the file is intended to serve.	1-1
level	positiveInteger	A numerical value of 1, 2, or 3 used to define the complexity of the mode.	1-1
comment	string	Any appropriate comment to help clarify the intended use of the file.	0-1

4.2.1 USERDEF Mode Level 1

The USERDEF mode level 1 requirements are shown as follows. The characteristics represent the most complete state possible, however their inclusion in the file is optional. A comment should indicate which characteristics are available to assist the communication between users of the data.

Layer Stack: Instances of multilayer structure at a single point site defining the characteristics that exist at a particular point including land description or reference, non-pad description or reference, thermal connections or reference, and holes (through-hole, buried, blind, and microvias). LayerStacks are for reference to the construction of the original design.

Conductor Route: Original CAD data files describing conductive patterns and features used to interconnect electronic components in accordance with the original schematic capture file and component library descriptions.

Bom: Bill of Material information that describes, in sufficient detail, the component descriptions of the printed board, as well as the materials used for board fabrication, assembly, and test.

Avl: An approved vendor list for each item as defined by the OEM and modified accordingly by the board fabricator and the board assembler to reflect the materials and components used in the final electronic assembly.

Component Packages: Physical outlines of mechanical dimensions for electronic and mechanical components, their pins, (lands), and their relation to their logical net description.

Land Patterns: Combinations of lands used on outer layers that are grouped into a pattern so that they coincide with the mounting pins (IO's) of electronic or electromechanical components. The information is through a reference to the individual land for each pin of a device. Land patterns are for reference only to provide a grouping of lands related to a particular component.

Device Descriptions: Device characterization including the electronic or electromechanical part number, as well as its value, tolerance, and pin ID consisting of a name and function.

Component Descriptions: Consists of the components and their instances on the electronic assembly, including a reference to a specific land pattern, a component package style, and a device if the component is electronic.

Masking Layer: Images for solder mask on external layers of a printed circuit board (top and bottom) as well as legend marking to be incorporated on top of solder mask material.

Drilling Routing: Information on hole forming, either through mechanical drilling, laser ablation, or chemical mechanism and the relationship of the conductor routing layer.

Documentation Layers: Information on the details for finishes, tolerances, and other details necessary to complete the full disclosure of the printed board structure and/or assembly.

Net List: A list of physical nets that includes the physical net points, the location, side, as well as additional information required for bare board electrical testing.

Outer Conductive: External copper geometries and features used for electronic probing or component attachment. They may be defined as positive or negative.

Inner Layers: Image description for innerlayers of multilayered PCB's where the description indicates the conductive pattern as well as plated-through holes contained within a layerset. These characteristics are also used to describe embedded passive layers.

Image Layers: Miscellaneous image layers that may be extracted from the originating CAD system that provide supplementary details for either printed circuit board fabrication or printed circuit board assembly processes and testing.

Analysis: Any of the CAD data can have Design for Manufacturing processes run against it. The results of these are referenced in the `Analysis` element.

4.2.2 Design Levels

The Design Level requirements have a variety of element combinations. Each combination is identified by its `mode` and `level` in combination. There are three Design Level descriptions starting with Design Level 1, Design Level 2 and Design Level 3. The following sections show the content of each of the three design levels. It should be noted that when the elements that represent the design mode are available in any of the fabrication or assembly file structures, the information should be treated as original input and reference and can be used for analysis and checking; however, ASSEMBLY and FABRICATION elements take precedence.

4.2.2.1 Design Level 1

This level represents the original OEM design as was used to lay out a PCB from the design schematic, layout design rules, and component information. The characteristics represent designing from scratch, taking OEM input and developing the board. Design Level 1 requirements are shown as follows:

Bom: Bill of Material information that describes, in sufficient detail, the component descriptions of the printed board, as well as the materials used for board fabrication, assembly, and test.

Component Packages: Physical outlines of mechanical dimensions for electronic and mechanical components and their relation to their logical net description.

Device Descriptions: Device characterization including the electronic or electromechanical part number, as well as its value, tolerance, and pin ID consisting of a name and function.

Component Descriptions: Consists of the components and their instances on the electronic assembly, including a reference to a specific land pattern, a component package style, and a device if the component is electronic.

Documentation Layers: Information on the details for finishes, tolerances, and other details necessary to complete the full disclosure of the printed board structure and/or assembly.

Net List: A list of logical nets that includes the physical net points of the components, the location, side, as well as additional information required for bare board electrical testing.

Analysis: Any of the CAD data can have Design for Manufacturing processes run against it. The results of these are referenced in the Analysis element.

4.2.2.2 Design Level 2

This level provides information that is used to modify an existing design using the original CAD data information since the changes impact the electrical characteristics that should be maintained. The characteristics represent modifying a design where the Fabrication and Assembly file has been archived by the OEM. Design Level 2 requirements are shown as follows:

Layer Stack: Instances of multilayer structure at a single point site defining the characteristics that exist at a particular point including land description or reference, non-pad description or reference, thermal connections or reference, and holes (through-hole, buried, blind, and microvias). LayerStacks are for reference to the construction of the original design.

Conductor Route: Original CAD data files describing conductive patterns and features used to interconnect electronic components in accordance with the original schematic capture file and component library descriptions.

Bom: Bill of Material information that describes, in sufficient detail, the component descriptions of the printed board, as well as the materials used for board fabrication, assembly, and test.

Avl: An approved vendor list for each item as defined by the OEM and modified accordingly by the board fabricator and the board assembler to reflect the materials and components used in the final electronic assembly.

Component Packages: Physical outlines of mechanical dimensions for electronic and mechanical components, their pins, (lands), and their relation to their logical net description.

Land Patterns: Combinations of lands used on outer layers that are grouped into a pattern so that they coincide with the mounting pins (IO's) of electronic or electromechanical components. The information is through a reference to the

individual land for each pin of a device. Land patterns are for reference only to provide a grouping of lands related to a particular component.

Device Descriptions: Device characterization including the electronic or electromechanical part number, as well as its value, tolerance, and pin ID consisting of a name and function.

Component Descriptions: Consists of the components and their instances on the electronic assembly, including a reference to a specific land pattern, a component package style, and a device if the component is electronic.

Documentation Layers: Information on the details for finishes, tolerances, and other details necessary to complete the full disclosure of the printed board structure and/or assembly.

Net List: A list of physical nets that includes the physical net points, the location, side, as well as additional information required for bare board electrical testing.

Image Layers: Miscellaneous image layers that may be extracted from the originating CAD system that provide supplementary details for either printed circuit board fabrication or printed circuit board assembly processes and testing.

Analysis: Any of the CAD data can have Design for Manufacturing processes run against it. The results of these are referenced in the `Analysis` element.

4.2.2.3 Design Level 3

This information is used to modify an existing or archived design where the original hierarchical information was not maintained or may not be compatible with the design system. The characteristics represent modifying a design using the original CAD data information since the changes impact the electrical characteristics that should be maintained. Design Level 3 requirements are shown as follows:

Bom: Bill of Material information that describes, in sufficient detail, the component descriptions of the printed board, as well as the materials used for board fabrication, assembly, and test.

Avl: An approved vendor list for each item as defined by the OEM and modified accordingly by the board fabricator and the board assembler to reflect the materials and components used in the final electronic assembly.

Component Packages: Physical outlines of mechanical dimensions for electronic and mechanical components, their pins, (lands), and their relation to their logical net description.

Land Patterns: Combinations of lands used on outer layers that are grouped into a pattern so that they coincide with the mounting pins (IO's) of electronic or electromechanical components. The information is through a reference to the individual land for each pin of a device. Land patterns are for reference only to provide a grouping of lands related to a particular component.

Device Descriptions: Device characterization including the electronic or electromechanical part number, as well as its value, tolerance, and pin ID consisting of a name and function.

Component Descriptions: Consists of the components and their instances on the electronic assembly, including a reference to a specific land pattern, a component package style, and a device if the component is electronic.

Masking Layer: Images for solder mask on external layers of a printed circuit board (top and bottom) as well as legend marking to be incorporated on top of solder mask material.

Drilling Routing: Information on hole forming, either through mechanical drilling, laser ablation, or chemical mechanism and the relationship of the conductor routing layer.

Documentation Layers: Information on the details for finishes, tolerances, and other details necessary to complete the full disclosure of the printed board structure and/or assembly.

Net List: A list of physical nets that includes the physical net points, the location, side, as well as additional information required for bare board electrical testing.

Outer Conductive: External copper geometries and features used for electronic probing or component attachment. They may be defined as positive or negative.

Inner Layers: Image description for innerlayers of multilayered PCB's where the description indicates the conductive pattern as well as plated-through holes contained within a layerset. These characteristics are also used to describe embedded passive layers.

Image Layers: Miscellaneous image layers that may be extracted from the originating CAD system that provide supplementary details for either printed circuit board fabrication or printed circuit board assembly processes and testing.

Analysis: Any of the CAD data can have Design for Manufacturing processes run against it. The results of these are referenced in the `Analysis` element.

4.2.3 Fabrication Levels

The Fabrication Level requirements have a variety of element combinations. Each combination is identified by its `mode` and `level` in combination. There are three Fabrication Level descriptions starting with Fabrication Level 1, Fabrication Level 2 and Fabrication Level 3. The following sections show the content of each of the three fabrication levels.

4.2.3.1 Fabrication Level 1

This information represents single, double-sided, or multilayer PCB graphical data. There is no electrical connectivity or performance data included. This level replaces PCB fabrication Gerber data. This level presents the fabrication print notes and material construction information in a machine-readable ASCII file format. The level is for build to documentation instructions. Electrical testing is derived from the conductive images. The characteristics represent single or double sided boards, built to documentation. Fabrication Level 1 requirements are shown as follows:

Bom: Bill of Material information that describes, in sufficient detail, the component descriptions of the printed board, as well as the materials used for board fabrication, assembly, and test.

Masking Layer: Images for solder mask on external layers of a printed circuit board (top and bottom) as well as legend marking to be incorporated on top of solder mask material.

Drilling Routing: Information on hole forming, either through mechanical drilling, laser ablation, or chemical mechanism and the relationship of the conductor routing layer.

Documentation Layers: Information on the details for finishes, tolerances, and other details necessary to complete the full disclosure of the printed board structure and/or assembly.

Outer Conductive: External copper geometries and features used for electronic probing or component attachment. They may be defined as positive or negative.

Inner Layers: Image description for innerlayers of multilayered PCB's where the description indicates the conductive pattern as well as plated-through holes contained within a layerset. These characteristics are also used to describe embedded passive layers.

Analysis: Any of the CAD data can have Design for Manufacturing processes run against it. The results of these are referenced in the `Analysis` element.

4.2.3.2 Fabrication Level 2

This information represents single, double-sided, or multilayer PCB's where electrical connectivity or performance data is included. This replaces the PCB Gerber and IPC-D-356A. This level presents the fabrication print notes and material construction information in a machine-readable ASCII file format. The boards defined may include buried and blind vias with electrical opens and shorts testing and complete stack up definition. Fabrication Level 2 requirements are shown as follows:

Bom: Bill of Material information that describes, in sufficient detail, the component descriptions of the printed board, as well as the materials used for board fabrication, assembly, and test.

Avl: An approved vendor list for each item as defined by the OEM and modified accordingly by the board fabricator and the board assembler to reflect the materials and components used in the final electronic assembly.

Masking Layer: Images for solder mask on external layers of a printed circuit board (top and bottom) as well as legend marking to be incorporated on top of solder mask material.

Drilling Routing: Information on hole forming, either through mechanical drilling, laser ablation, or chemical mechanism and the relationship of the conductor routing layer.

Documentation Layers: Information on the details for finishes, tolerances, and other details necessary to complete the full disclosure of the printed board structure and/or assembly.

Net List: A list of physical nets that includes the physical net points, the location, side, as well as additional information required for bare board electrical testing.

Outer Conductive: External copper geometries and features used for electronic probing or component attachment. They may be defined as positive or negative.

Inner Layers: Image description for innerlayers of multilayered PCB's where the description indicates the conductive pattern as well as plated-through holes contained within a layerset. These characteristics are also used to describe embedded passive layers.

Image Layers: Miscellaneous image layers that may be extracted from the originating CAD system that provide supplementary details for either printed circuit board fabrication or printed circuit board assembly processes and testing.

Analysis: Any of the CAD data can have Design for Manufacturing processes run against it. The results of these are referenced in the `Analysis` element.

4.2.3.3 Fabrication Level 3

This information represents single, double-sided, or multilayer PCB's where electrical connectivity, performance data, and embedded passive information is included. This file level replaces the existing PCB fabrication Gerber and IPC-D-356A data. This level presents the fabrication print notes and material construction information in a machine-readable ASCII file format. These descriptions represent complex printed boards intended to perform a circuit function. Also included is a complete description of core, prepreg and sometimes reinforcement. Fabrication Level 3 requirements are shown as follows:

Bom: Bill of Material information that describes, in sufficient detail, the component descriptions of the printed board, as well as the materials used for board fabrication, assembly, and test.

Avl: An approved vendor list for each item as defined by the OEM and modified accordingly by the board fabricator and the board assembler to reflect the materials and components used in the final electronic assembly.

Component Packages: Physical outlines of mechanical dimensions for electronic and mechanical components and their relation to their logical net description.

Land Patterns: Combinations of lands used on outer layers that are grouped into a pattern so that they coincide with the mounting pins (IO's) of electronic or electromechanical components. The information is through a reference to the individual land for each pin of a device. Land patterns are for reference only to provide a grouping of lands related to a particular component.

Masking Layer: Images for solder mask on external layers of a printed circuit board (top and bottom) as well as legend marking to be incorporated on top of solder mask material.

Drilling Routing: Information on hole forming, either through mechanical drilling, laser ablation, or chemical mechanism and the relationship of the conductor routing layer.

Documentation Layers: Information on the details for finishes, tolerances, and other details necessary to complete the full disclosure of the printed board structure and/or assembly.

Net List: A list of physical nets that includes the physical net points, the location, side, as well as additional information required for bare board electrical testing.

Outer Conductive: External copper geometries and features used for electronic probing or component attachment. They may be defined as positive or negative.

Inner Layers: Image description for innerlayers of multilayered PCB's where the description indicates the conductive pattern as well as plated-through holes contained within a layerset. These characteristics are also used to describe embedded passive (resistive or capacitive) material layers.

Image Layers: Miscellaneous image layers that may be extracted from the originating CAD system that provide supplementary details for either printed circuit board fabrication or printed circuit board assembly processes and testing.

Analysis: Any of the CAD data can have Design for Manufacturing processes run against it. The results of these are referenced in the `Analysis` element.

4.2.4 Assembly Levels

The Assembly Level requirements have a variety of element combinations. Each combination is identified by its `mode` and `level` in combination. There are three Assembly Level descriptions starting with Assembly Level 1, Assembly Level 2 and Assembly Level 3. The following sections show the content of each of the three assembly levels.

4.2.4.1 Assembly Level 1

This information represents pure assembly. There is no Design for Manufacturing (DFM) analysis of the bare board only assembly functions. Parts are provided on a consignment basis; however, an Approved Vendors List (AVL) is still required that includes the part number of parts in the consignment. There is no analysis of the data to improve the design. There are no added value services. The requirements are to build to print. Assembly Level 1 requirements are shown as follows:

Bom: Bill of Material information that describes, in sufficient detail, the component descriptions of the printed board, assembly, and test information.

Avl: An approved vendor list for each item as defined by the OEM and modified accordingly by the board fabricator and the board assembler to reflect the materials and components used in the final electronic assembly.

Component Packages: Physical outlines of mechanical dimensions for electronic and mechanical components, their pins, (lands), and their relation to their logical net description.

Component Descriptions: Consists of the components and their instances on the electronic assembly, including a reference to a component package style, and a Bom item.

Masking Layer: Images for solder mask on external layers of a printed circuit board (top and bottom) as well as legend marking to be incorporated on top of solder mask material.

Drilling Routing: Information on hole forming, either through mechanical drilling, laser ablation, or chemical mechanism and the relationship of the conductor routing layer.

Documentation Layers: Information on the details for finishes, tolerances, and other details necessary to complete the full disclosure of the printed board structure and/or assembly.

Outer Conductive: External copper geometries and features used for electronic probing or component attachment. They may be defined as positive or negative.

Analysis: Any of the CAD data can have Design for Manufacturing processes run against it. The results of these are referenced in the `Analysis` element.

4.2.4.2 Assembly Level 2

The information provided represents assemblies that are to be built to print. Parts are procured by Electronic Manufacturing Services (EMS) companies. There is limited DFM analysis, Automated Optical Inspection (AOI), and Flying probe testing. Assembly Level 2 requirements are shown as follows:

Bom: Bill of Material information that describes, in sufficient detail, the component descriptions of the printed board, as well as the materials used for board fabrication, assembly, and test.

Avl: An approved vendor list for each item as defined by the OEM and modified accordingly by the board fabricator and the board assembler to reflect the materials and components used in the final electronic assembly.

Component Packages: Physical outlines of mechanical dimensions for electronic and mechanical components, their pins, (lands), and their relation to their logical net description.

Land Patterns: Combinations of lands used on outer layers that are grouped into a pattern so that they coincide with the mounting pins (IO's) of electronic or electromechanical components. The information is through a reference to the individual land for each pin of a device. Land patterns are for reference only to provide a grouping of lands related to a particular component.

Component Descriptions: Consists of the components and their instances on the electronic assembly, including a reference to a component package style, and a Bom item.

Masking Layer: Images for solder mask on external layers of a printed circuit board (top and bottom) as well as legend marking to be incorporated on top of solder mask material.

Drilling Routing: Information on hole forming, either through mechanical drilling, laser ablation, or chemical mechanism and the relationship of the conductor routing layer.

Documentation Layers: Information on the details for finishes, tolerances, and other details necessary to complete the full disclosure of the printed board structure and/or assembly.

Net List: A list of physical nets that includes the physical net points, the location, side, as well as additional information required for bare board electrical testing.

Outer Conductive: External copper geometries and features used for electronic probing or component attachment. They may be defined as positive or negative.

Inner Layers: Image description for innerlayers of multilayered PCB's where the description indicates the conductive pattern as well as plated-through holes contained within a layerset. These characteristics are also used to describe embedded passive layers.

Image Layers: Miscellaneous image layers that may be extracted from the originating CAD system that provide supplementary details for either printed circuit board fabrication or printed circuit board assembly processes and testing.

Analysis: Any of the CAD data can have Design for Manufacturing processes run against it. The results of these are referenced in the `Analysis` element.

4.2.4.3 Assembly Level 3

This level of information represents a full service assembly process. This includes full Design for Excellence (DFX) and customer feed back. Procurement of parts is required as well as an analysis of component substitution. Customer contact provides design improvement recommendations. Full testing, including in-circuit, automatic optical inspection (AOI), Automatic X-ray Inspection (AXI), functional testing and some stress or burn-in testing is a part of this level. DFA can include assignment of parts to specific machines. Assembly Level 3 requirements are shown as follows.

Bom: Bill of Material information that describes, in sufficient detail, the component descriptions of the printed board, as well as the materials used for board fabrication, assembly, and test.

Avl: An approved vendor list for each item as defined by the OEM and modified accordingly by the board fabricator and the board assembler to reflect the materials and components used in the final electronic assembly.

Component Packages: Physical outlines of mechanical dimensions for electronic and mechanical components, their pins, (lands), and their relation to their logical net description.

Land Patterns: Combinations of lands used on outer layers that are grouped into a pattern so that they coincide with the mounting pins (IO's) of electronic or electromechanical components. The information is through a reference to the individual land for each pin of a device. Land patterns are for reference only to provide a grouping of lands related to a particular component.

Device Descriptions: Device characterization including the electronic or electromechanical part number, as well as its value, tolerance, and pin ID consisting of a name and function.

Component Descriptions: Consists of the components and their instances on the electronic assembly, including a reference to a component package style, and a Bom item.

Masking Layer: Images for solder mask on external layers of a printed circuit board (top and bottom) as well as legend marking to be incorporated on top of solder mask material.

Drilling Routing: Information on hole forming, either through mechanical drilling, laser ablation, or chemical mechanism and the relationship of the conductor routing layer.

Documentation Layers: Information on the details for finishes, tolerances, and other details necessary to complete the full disclosure of the printed board structure and/or assembly.

Net List: A list of physical nets that includes the physical net points, the location, side, as well as additional information required for bare board electrical testing.

Outer Conductive: External copper geometries and features used for electronic probing or component attachment. They may be defined as positive or negative.

Inner Layers: Image description for innerlayers of multilayered PCB's where the description indicates the conductive pattern as well as plated-through holes contained within a layerset. These characteristics are also used to describe embedded passive layers.

Image Layers: Miscellaneous image layers that may be extracted from the originating CAD system that provide supplementary details for either printed circuit board fabrication or printed circuit board assembly processes and testing.

Analysis: Any of the CAD data can have Design for Manufacturing processes run against it. The results of these are referenced in the `Analysis` element.

4.2.5 Test Levels

The Test Level requirements have a variety of element combinations. Each combination is identified by its `mode` and `level` in combination. There are three Test Level descriptions starting with Test Level 1, Test Level 2 and Test Level 3. The following sections show the content of each of the three test levels.

4.2.5.1 Test Level 1

This information provides testing of the bare board only. It includes opens and shorts, impedance control and dielectric withstanding voltage testing. Test Level 1 requirements are shown as follows:

Masking Layer: Images for solder mask on external layers of a printed circuit board (top and bottom) as well as legend marking to be incorporated on top of solder mask material.

Drilling Routing: Information on hole forming, either through mechanical drilling, laser ablation, or chemical mechanism and the relationship of the conductor routing layer.

Documentation Layers: Information on the details for finishes, tolerances, and other details necessary to complete the full disclosure of the printed board structure and/or assembly.

Net List: A list of physical nets that includes the physical net points, the location, side, as well as additional information required for bare board electrical testing.

Outer Conductive: External copper geometries and features used for electronic probing or component attachment. They may be defined as positive or negative.

Analysis: Any of the CAD data can have Design for Manufacturing processes run against it. The results of these are referenced in the `Analysis` element.

4.2.5.2 Test Level 2

The information provided includes capability for inspection, manual or using automated equipment such as AOI and AXI. It does not include electrical testing. Test Level 2 requirements are shown as follows:

Bom: Bill of Material information that describes, in sufficient detail, the component descriptions of the printed board, as well as the materials used for board fabrication, assembly, and test.

Component Packages: Physical outlines of mechanical dimensions for electronic and mechanical components, their pins, (lands), and their relation to their logical net description.

Land Patterns: Combinations of lands used on outer layers that are grouped into a pattern so that they coincide with the mounting pins (IO's) of electronic or electromechanical components. The information is through a reference to the individual land for each pin of a device. Land patterns are for reference only to provide a grouping of lands related to a particular component.

Component Descriptions: Consists of the components and their instances on the electronic assembly, including a reference to a component package style, and a Bom item.

Masking Layer: Images for solder mask on external layers of a printed circuit board (top and bottom) as well as legend marking to be incorporated on top of solder mask material.

Drilling Routing: Information on hole forming, either through mechanical drilling, laser ablation, or chemical mechanism and the relationship of the conductor routing layer.

Documentation Layers: Information on the details for finishes, tolerances, and other details necessary to complete the full disclosure of the printed board structure and/or assembly.

Outer Conductive: External copper geometries and features used for electronic probing or component attachment. They may be defined as positive or negative.

Image Layers: Miscellaneous image layers that may be extracted from the originating CAD system that provide supplementary details for either printed circuit board fabrication or printed circuit board assembly processes and testing.

Analysis: Any of the CAD data can have Design for Manufacturing processes run against it. The results of these are referenced in the Analysis element.

4.2.5.3 Test Level 3

The information available is for full electrical testing. It includes in-circuit as well as functional testing requirements and boundary scan (self test) analysis. Test Level 3 requirements are shown as follows:

Bom: Bill of Material information that describes, in sufficient detail, the component descriptions of the printed board, as well as the materials used for board fabrication, assembly, and test.

Avl: An approved vendor list for each item as defined by the OEM and modified accordingly by the board fabricator and the board assembler to reflect the materials and components used in the final electronic assembly.

Component Packages: Physical outlines of mechanical dimensions for electronic and mechanical components, their pins, (lands), and their relation to their logical net description.

Land Patterns: Combinations of lands used on outer layers that are grouped into a pattern so that they coincide with the mounting pins (IO's) of electronic or electromechanical components. The information is through a reference to the individual land for each pin of a device. Land patterns are for reference only to provide a grouping of lands related to a particular component.

Device Descriptions: Device characterization including the electronic or electromechanical part number, as well as its value, tolerance, and pin ID consisting of a name and function.

Component Descriptions: Consists of the components and their instances on the electronic assembly, including a reference to a component package style, and a Bom item.

Masking Layer: Images for solder mask on external layers of a printed circuit board (top and bottom) as well as legend marking to be incorporated on top of solder mask material.

Drilling Routing: Information on hole forming, either through mechanical drilling, laser ablation, or chemical mechanism and the relationship of the conductor routing layer.

Documentation Layers: Information on the details for finishes, tolerances, and other details necessary to complete the full disclosure of the printed board structure and/or assembly.

Net List: A list of physical nets that includes the physical net points, the location, side, as well as additional information required for bare board electrical testing.

Outer Conductive: External copper geometries and features used for electronic probing or component attachment. They may be defined as positive or negative.

Inner Layers: Image description for innerlayers of multilayered PCB's where the description indicates the conductive pattern as well as plated-through holes contained within a layerset. These characteristics are also used to describe embedded passive layers.

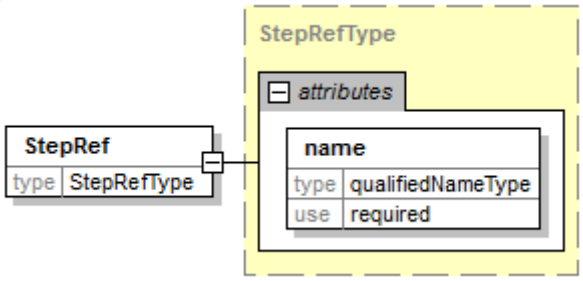
Image Layers: Miscellaneous image layers that may be extracted from the originating CAD system that provide supplementary details for either printed circuit board fabrication or printed circuit board assembly processes and testing.

Analysis: Any of the CAD data can have Design for Manufacturing processes run against it. The results of these are referenced in the `Analysis` element.

4.3 Content: StepRef

The reference to the names of all `Step` elements used in the description of the Printed Circuit Assembly (PCA), the unpopulated board or other related information (e.g., documentation). In manufacturing, this basic `Step` is often step and repeated (nested) inside a larger step (called array, or sub-panel). This array step can be further nested into another step (called a production panel). The `Ecad` element always contains at least one `Step`, but may contain several, some basic ones and others nesting previous steps.

The `StepRef` element, as it appears in the `Content` schema, references the job step's names and thus the various steps that are included in the IPC-2581 file. All the graphical data of a 2581 job are located inside steps that can be nested inside each other (PCB/Sub Panel/Panel, etc.). Steps are referenced in the `Content` schema (`StepRef`) as a `qualifiedName` that relates to the details in the `Ecad` schema.

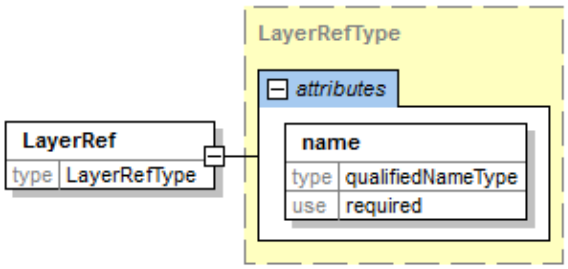


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
StepRef	StepRefType	The reference to all existing `step` elements contained within the file. This feature is a method of checking completeness in file transfer.	1-n
name	qualifiedNameType	The unique name of all Step segment descriptions.	1-1

4.4 Content: LayerRef

Layers, as the name implies, are sheets of two-dimensional data that, when laid on top of each other, create the Printed Circuit Assembly (unpopulated PCB and components or other related information). The `Layer` element appears in the IPC-2581 file as a sub-element of the `CadData` element.

The `LayerRef` element, as it appears in the `Content` schema, references all the file `Layer` unique names included in the IPC-2581 file.

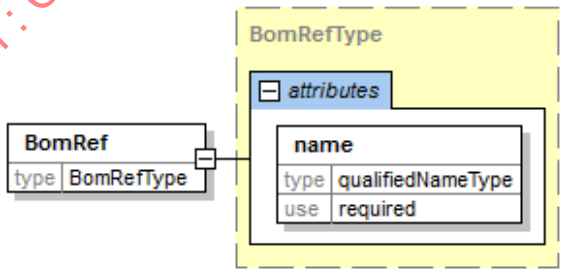


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
LayerRef	LayerRefType	The reference to all existing layer elements contained within the file. This feature is a method of checking completeness in file transfer.	1-n
name	qualifiedNameType	The unique name of all Layer segment descriptions	1-1

4.5 Content: BomRef

The `BOM` section describes the Bill of Materials for the board. A bill of materials is a list of all the different components, materials, mechanical parts, or programmable software used in the electronic product. Components are arranged by the `OEMDesignNumber` or an alternate; materials for board fabrication or component attachment are arranged by their appropriate identifier. Each part number has a list of attributes and is accompanied by a list of the various specific uses or locations on the electronic product, each with its unique name.

Each `BomRef` element, as it appears in the `Content` schema, references one of the potentially many Bom categories and the number of items included in each category in the IPC-2581 file.

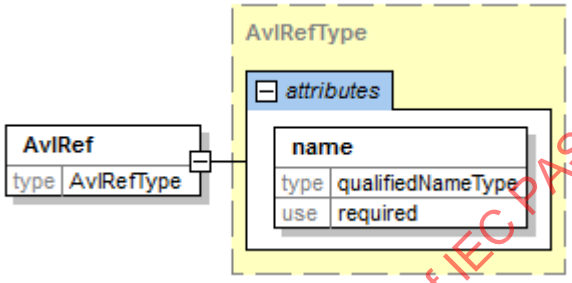


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
BomRef	BomRefType	The reference to all BOM elements that are arranged by the category description contained as an attribute of each BomItem, e.g. ELECTRICAL | PROGRAMMABLE | MECHANICAL | MATERIAL | DOCUMENT. This feature identifies the specific number of BomItems as well as the category to which they pertain, and is a method of checking completeness in file transfer.	0-n
name	qualifiedNameType	The unique name of all Bom segment descriptions.	1-1

4.6 Content: AvlRef

The `Avl` section describes the Approved Vendor Lists for the materials used to fabricate the board and the assembly. The BOM (bill of material) lists include all the different components to be used on the board, arranged by their appropriate part number, and material used to fabricate the board arranged by the part number of the material. There are also BOMs for the material used that are consumed by the fabrication and assembly processes. Each BOM has a corresponding list of approved vendors if the customer wishes to restrict the components and materials used for the electronic assembly to a specific supplier(s). There **shall** be only one `Avl` section in a 2581 file. It **shall** provide the names of each of the approved suppliers and **shall** correlate them with the BOM that contains the material/component descriptions.

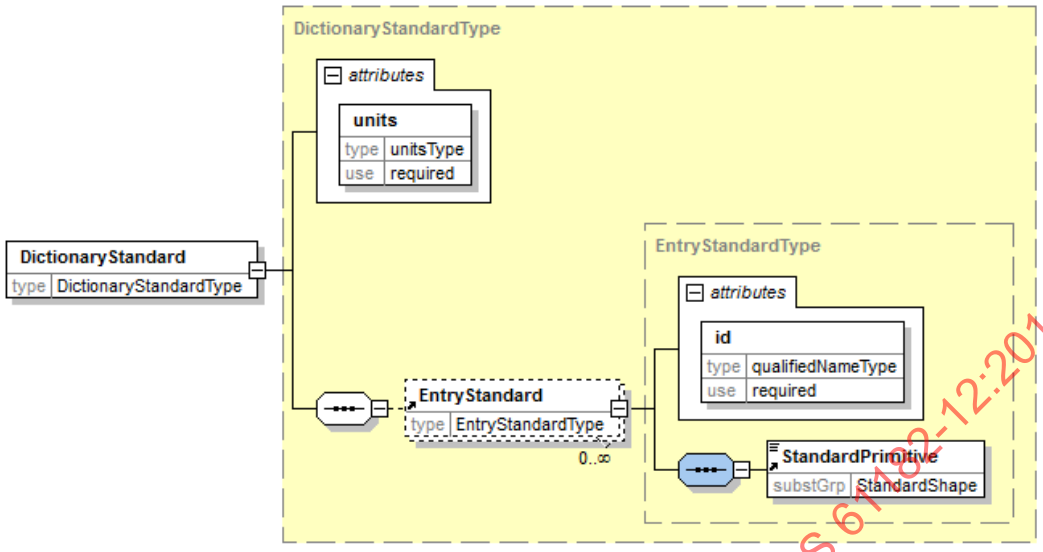
The Avl is used by the customer, the fabricator and the assembler to coordinate the relationship with the bills of materials described in the IPC-2581 file.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
AvlRef	AvlRefType	A reference to the single Approved Vendor List for all the suppliers identified and the total number in the IPC-2581 file. This feature is a method of checking completeness in file transfer.	0-1
name	qualifiedNameType	The unique name of the single Approved Vender List segment descriptions.	1-1

4.7 Content: DictionaryStandard

The `DictionaryStandard` is intended to provide lookup information on predefined Standard Primitives. The `DictionaryStandard` is maintained as part of a substitution group schema. The intent is to have graphic descriptions available that are identified by their characteristics and a specific name (id). They may be reused throughout the file as appropriate. The name (id) of a `StandardPrimitive` must be unique within the `DictionaryStandard`.

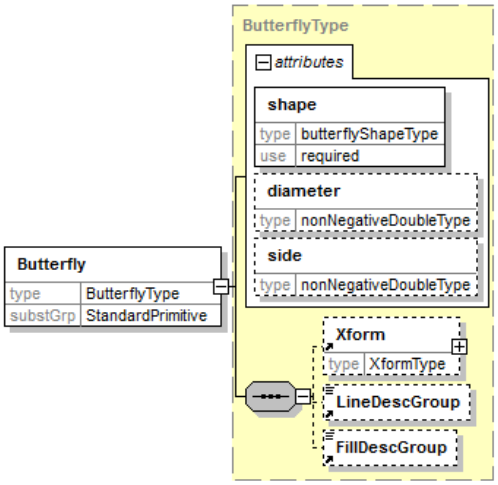


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
DictionaryStandard	DictionaryStandard Type	An element that contains substitution group information using predefined descriptions of standard primitives identified by the 2581 standard and described by the user for reuse in the file.	0-1
units	unitsType	An enumerated string that may be one of the following: MILLIMETER | MICRON | INCH.	1-1
EntryStandard	EntryStandardType	An element that establishes the individual characteristic associated with a StandardPrimitive substitution shape that has been identified by the user of the IPC-2581 file.	0-n
Id	qualifiedNameType	The unique qualified name description assigned as an id for any `StandardPrimitive` for XML schema substitution.	1-1
StandardPrimitive	ABSTRACT	Any standard primitive that is part of the substitution group that permits the substitution of the `StandardShape` element. Candidates for substitution are: Butterfly, Circle, Contour, Diamond, Donut, Ellipse, Hexagon, Moire, Octagon, Oval, RectCham, RectCorner, RectRound, Thermal, and Triangle.	1-n

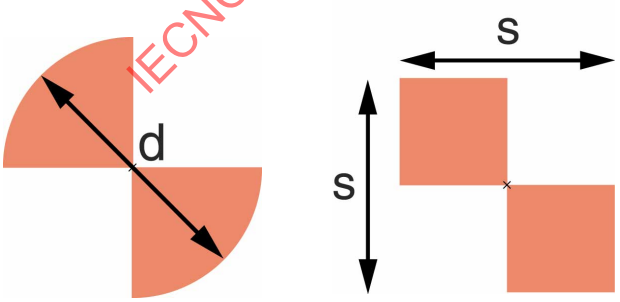
The organization of the `DictionaryStandard` is accomplished in accordance with the substitution group description criteria. The `StandardPrimitive` description may be any of sixteen standard shapes according to the specific characteristics identified in the following paragraphs. The `StandardPrimitiveRef` function is used in the body of the 2581 file when a specific `StandardPrimitive` has been predefined, assigned a name, and the unique "id" is referenced in the file. This feature permits the use of either a predefined `StandardPrimitive`, or defining the details of a `StandardPrimitive` within the file. The description in the file must contain all the features of a particular primitive shape under the rules of the particular shape definition.

4.7.1 StandardPrimitive: Butterfly

A `Butterfly` is a `StandardPrimitive` shape that may have the external periphery be either round or square with two quadrants of the Cartesian coordinate system removed (0 to 90° and 180 to 270°). The round shape is defined by its diameter; the square shape is defined by an equal side dimension. The `Butterfly` is positioned by its point of origin, which is at the center of the `Butterfly`.



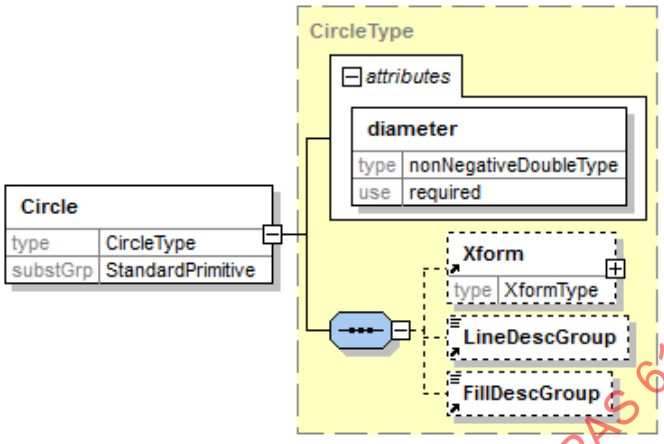
Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Butterfly	ButterflyType	A primitive shape (either ROUND or SQUARE) that has two quadrants of the Cartesian coordinate system removed (0 to 90° and 180 to 270°).	1-1
shape	butterflyShapeType	The inner and outer shapes are one of ROUND or SQUARE: ROUND: The inner and outer shapes are like circleDef. SQUARE: The inner and outer shapes are like RectCenterDef with height and width of each shape being equal.	1-1
diameter	nonNegativeDouble Type	The diameter applies to the circular butterfly and is the outer boundary of the butterfly.	0-1
side	nonNegativeDouble Type	The width along the x-axis and the height along the y-axis of a square.	0-1
Xform	XformType	An element that provides the ability to reset the point of origin of a predefined target that can be scaled, mirror imaged or rotated.	0-1
LineDescGroup	LineDescGroupType	A substitution group that specifies the `LineDesc or LineDescRef`. The LineDesc specifies the `LineWidth, LineEnd and LineProperty` characteristics of any feature that requires that definition. Line descriptions are a part of the `Outline, Polyline` and `Set` element definitions. The `LineDescRef` requires an “id” that must be unique within the 2581 file. `LineDesc` should be used only if `FillDesc` is present and its fill property values are HOLLOW, HATCH, or MESH; otherwise, the `LineDesc` should be omitted.	0-1
FillDescGroup	FillDescGroupType	A substitution group that specifies the `FillDesc` or `FillDescRef`. The `FillDesc` element provides the `FillProperties, LineDesc` and `Color` characteristics of any feature that requires that definition. Fill descriptions are a part of the `StandardPrimitives`, any `UserPrimitive` closed shape and `Set` element definitions. The `FillDescRef` requires an “id” that must be unique within the 2581 file	0-1



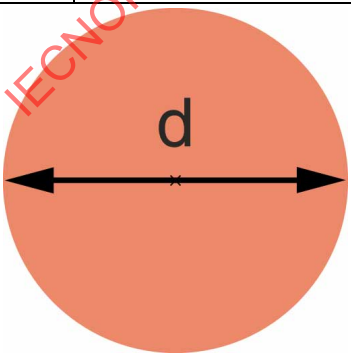

```
<DictionaryStandard units = "MILLIMETER">
    <EntryStandard id = "Butterfly1">
        <Butterfly shape = "ROUND" diameter = "3.2"/>
    </EntryStandard>
    <EntryStandard id = "Butterfly2">
        <Butterfly shape = "SQUARE" side = "1.8"/>
    </EntryStandard>
</DictionaryStandard>
```

4.7.2 StandardPrimitive: Circle

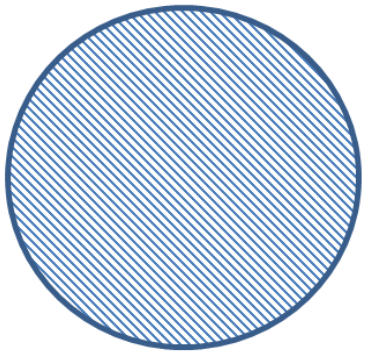
A `Circle` is a `StandardPrimitive` shape that defines a circle by the diameter of the circle. The point of origin is the center of a circle.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Circle	CircleType	An embedded element that defines a circular shape consisting of a diameter. The default for FillDesc is FILL without a LineDesc element.	1-1
diameter	nonNegativeDoubleType	The diameter of the circle.	1-1
Xform	XformType	An element that provides the ability to reset the point of origin of a predefined target that can be scaled, mirror imaged or rotated.	0-1
LineDescGroup	LineDescGroupType	A substitution group that specifies the `LineDesc or LineDescRef`. The LineDesc specifies the `LineWidth`, `LineEnd` and `LineProperty` characteristics of any feature that requires that definition. Line descriptions are a part of the `Outline`, `Polyline` and `Set` element definitions. The `LineDescRef` requires an "id" that must be unique within the 2581 file. LineDesc should be used only if FillDesc is present and its' fill property values are HOLLOW, HATCH, or MESH otherwise the LineDesc should be omitted.	0-1
FillDescGroup	FillDescGroupType	A substitution group that specifies the `FillDesc` or `FillDescRef`. The `FillDesc` element provides the `FillProperties`, `LineDesc` and `Color` characteristics of any feature that requires that definition. Fill descriptions are a part of the `StandardPrimitives`, any `UserPrimitive` closed shape and `Set` element definitions. The `FillDescRef` requires an "id" that must be unique within the 2581 file	0-1



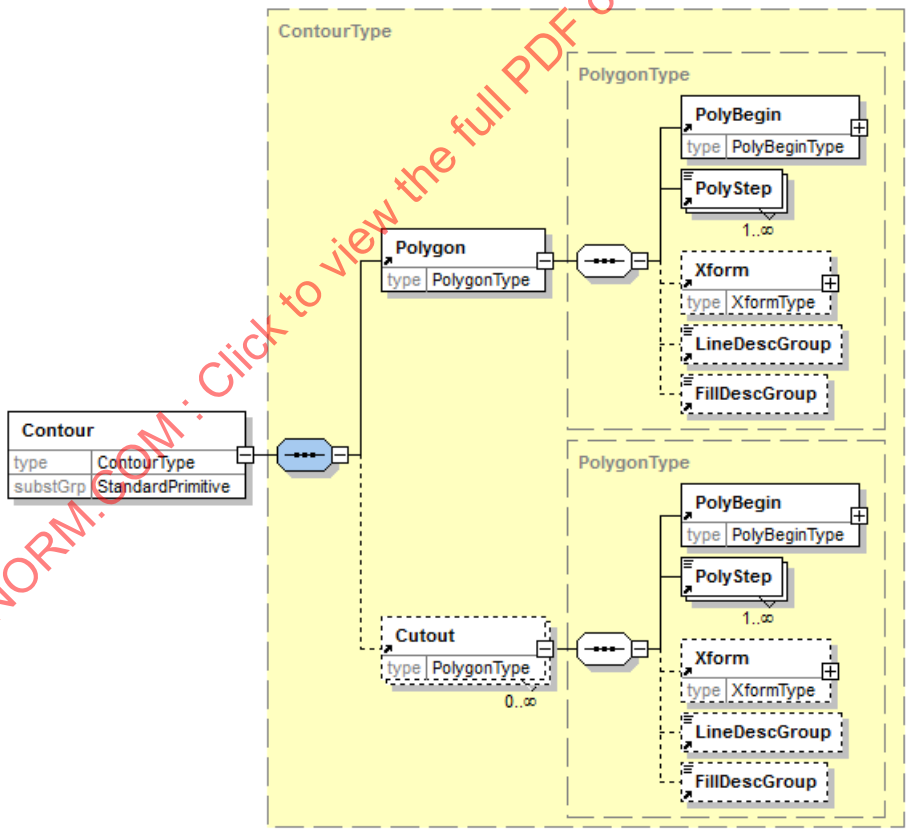

```
<DictionaryStandard units = "MILLIMETER">
    <EntryStandard id = "Circle1">
        <Circle diameter = "3.6"/>
    </EntryStandard>
    <EntryStandard id = "Circle2">
        <Circle diameter = "4.0"/>
    </EntryStandard>
</DictionaryStandard>
```



```
<DictionaryStandard units = "MILLIMETER">
        <EntryStandard id = "Circle5">
            <Circle diameter = "3.6">
                <LineDesc lineEnd="ROUND" lineWidth="0.1"/>
                <FillDesc fillProperty="HATCH" lineWidth="0.02"
                        pitch1="0.08" angle1="135">
                    <Color r="0" g="0" b="200"/>
                </FillDesc>
            </Circle>
        </EntryStandard>
</DictionaryStandard>
```

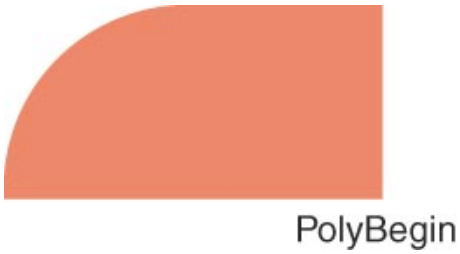
4.7.3 StandardPrimitive: Contour

The `Contour` element is a `StandardPrimitive` shape that defines a sequence of connected edges that form a polygon. An edge can be straight or circular. The `polygon` is a closed shape whose edges do not cross. This same characteristic is also true for `cutout`, which represents the absence of material inside the polygon shape. The coordinates of the `polygon`, `cutout`, and subsequent cutouts are defined relative to the local coordinate system of the original `polygon`. The point of origin may be a centroid of the `polygon` or one of the corners that sets the 0/0 coordinate. This is the point used to place the `polygon` or to rotate the image. The `cutout` uses the same coordinates.

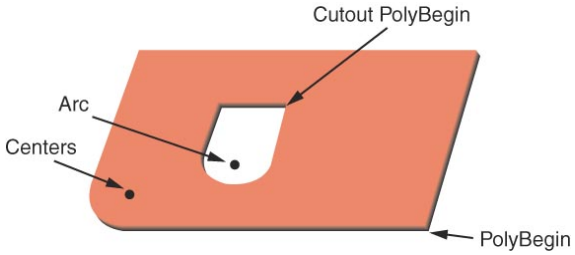


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Contour	ContourType	A sequence of connected edges that form a polygon. An edge can be straight or circular.	1-1
Polygon	PolygonType	A closed shape whose edges do not cross, the coordinates of which are defined relative to the local coordinate system of the polygon. The default for FillDesc is FILL without a LineDesc element.	1-1
PolyBegin	PolyBeginType	The `PolyBegin` element defines the starting point of the polygon.	1-1
X	Double	The X starting point of the first polygon edge.	1-1
Y	Double	The Y starting point of the first polygon edge.	1-1
PolyStep	ABSTRACT	The `PolyStep` element is a substitution group that defines a circular (`PolyStepCurve`) or straight line (`PolyStepSegment`) continuation of the polygon. The `polystep` direction may be clockwise or counterclockwise which must be consistent when any `Arc` description is used as one of the `PolyStep` elements. Straight or curved line segments must not cross. The final X and final Y coordinate must match those of the `PolyBegin` element to signify that the shape is closed.	1-n
Xform	XformType	An element that provides the ability to reset the point of origin of a predefined target that can be scaled, mirror imaged or rotated.	0-1
LineDescGroup	LineDescGroupType	A substitution group that specifies the `LineDesc or LineDescRef`. The LineDesc specifies the `LineWidth, LineEnd and LineProperty` characteristics of any feature that requires that definition. Line descriptions are a part of the `Outline`, `Polyline` and `Set` element definitions. The `LineDescRef` requires an “id” that must be unique within the 2581 file. LineDesc should be used only if FillDesc is present and its’ fill property values are HOLLOW, HATCH, or MESH otherwise the LineDesc should be omitted.	0-1
FillDescGroup	FillDescGroupType	A substitution group that specifies the `FillDesc` or `FillDescRef`. The `FillDesc` element provides the `FillProperties, LineDesc` and `Color` characteristics of any feature that requires that definition. Fill descriptions are a part of the `StandardPrimitives`, any `UserPrimitive` closed shape, and `Set` element definitions. The `FillDescRef` requires an “id” that must be unique within the 2581 file	0-1
Cutout	CutoutType	A polygon closed shape whose edges do not cross, which adopts the coordinates of the original polygon, however represents the absence of material within the original polygon shape.	0-n
PolyBegin	PolyBeginType	The `PolyBegin` element defines the starting point of the polygon.	1-1
x	Double	The X starting point of the first polygon edge.	1-1
y	Double	The Y starting point of the first polygon edge.	1-1
PolyStep	ABSTRACT	The `PolyStep` element is a substitution group that defines a circular (`PolyStepCurve`) or straight line (`PolyStepSegment`) continuation of the polygon. The `polystep` direction may be clockwise or counterclockwise which must be consistent when any `Arc` description is used as one of the `PolyStep` elements. Straight or curved line segments must not cross. The final X and final Y coordinate must match those of the `PolyBegin` element to signify that the shape is closed.	1-n
Xform	XformType	An element that provides the ability to reset the point of origin of a predefined target that can be scaled, mirror imaged or rotated.	0-1
LineDescGroup	LineDescGroupType	A substitution group that specifies the `LineDesc or LineDescRef`. The LineDesc specifies the `LineWidth, LineEnd and LineProperty` characteristics of any feature that requires that definition. Line descriptions are a part of the `Outline`, `Polyline` and `Set` element definitions. The `LineDescRef` requires an “id” that must be unique within the 2581 file. LineDesc should be used only if FillDesc is present and its’ fill property values are HOLLOW, HATCH, or MESH otherwise the LineDesc should be omitted.	0-1

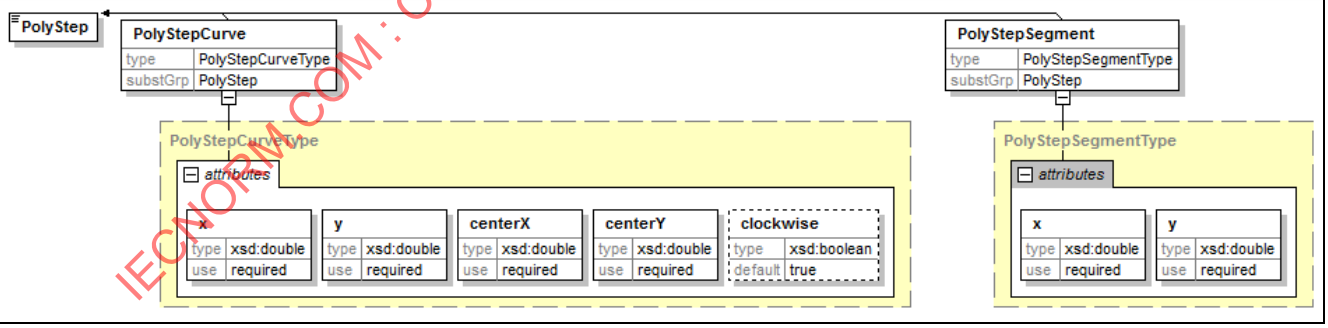
FillDescGroup	FillDescGroupType	A substitution group that specifies the `FillDesc` or `FillDescRef`. The `FillDesc` element provides the `FillProperties`, `LineDesc` and `Color` characteristics of any feature that requires that definition. Fill descriptions are a part of the `StandardPrimitives` , any `UserPrimitive` closed shape and `Set` element definitions. The `FillDescRef` requires an "id" that must be unique within the 2581 file	0-1




```
<DictionaryStandard units = "MILLIMETER">
  <EntryStandard id = "Contour1">
    <Contour>
      <Polygon>
        <PolyBegin x = "0.00" y = "0.00"/>
        <PolyStepSegment x = "0.00" y = "7.00"/>
        <PolyStepSegment x = "-8.00" y = "7.00"/>
        <PolyStepCurve x = "-15.00" y = "0.00" centerX = "-8.00"
            centerY = "0.00"/>
        <PolyStepSegment x = "0.00" y = "0.00"/>
      </Polygon>
    </Contour>
  </EntryStandard>
</DictionaryStandard>
```

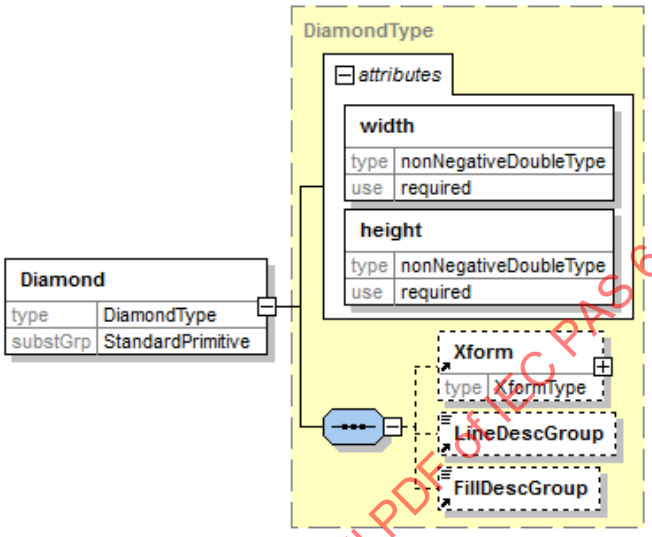



```
  <EntryStandard id = "Contour2">
    <Contour>
      <Polygon>
        <PolyBegin x = "0.00" y = "0.00"/>
        <PolyStepSegment x = "-14.00" y = "0.00"/>
        <PolyStepCurve x = "-3.00" y = "3.00" centerX = "-14.00"
            centerY = "3.00" clockwise = "TRUE"/>
        <PolyStepSegment x = "-17.00" y = "7.00"/>
        <PolyStepSegment x = "0.00" y = "7.00"/>
        <PolyStepSegment x = "0.00" y = "0.00"/>
      </Polygon>
      <Cutout>
        <PolyBegin x = "-10.00" y = "5.00"/>
        <PolyStepSegment x = "-13.00" y = "5.00"/>
        <PolyStepSegment x = "-13.00" y = "3.00"/>
        <PolyStepCurve x = "-10.00" y = "3.00" centerX = "-11.50"
            centerY = "3.00"/>
        <PolyStepSegment x = "-10.00" y = "5.00"/>
      </Cutout>
    </Contour>
  </EntryStandard>
```

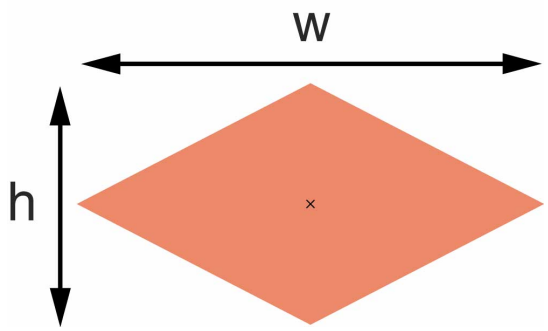


4.7.4 StandardPrimitive: Diamond

A `Diamond` is a 4-sided `StandardPrimitive` shape. The lengths of the sides of a diamond are always equal. A height and a width dimension specify the diamond. The first line defining the outline of the diamond is drawn between the point that is ½ the height dimension along the positive y-axis and the point that is ½ the width dimension along the x-axis. The same process is used to draw the other three lines of the diamond in each of the remaining quadrants. The `Diamond` is positioned with one of its corners facing the North direction.



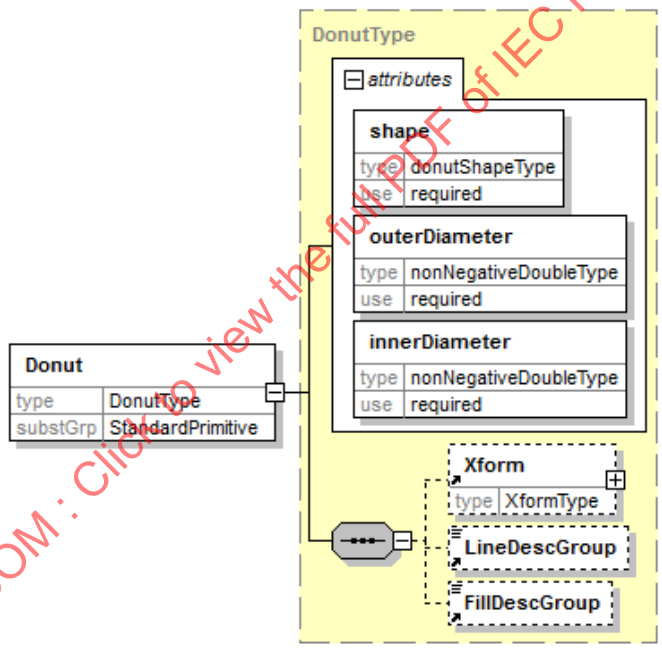
Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Diamond	DiamondType	A primitive shape with four equal sides that are extended from its horizontal center to its vertical center. The lines converge into a point both horizontally and vertically. The overall description of the shape is controlled by the width (distance between vertical point) and the height (distance between horizontal point). The default for FillDesc is FILL without a LineDesc element.	1-1
width	nonNegativeDouble Type	The length of the diamond along, and centered on, the x-axis.	1-1
height	nonNegativeDouble Type	The length of the diamond along, and centered on, the y-axis.	1-1
Xform	XformType	An element that provides the ability to reset the point of origin of a predefined target that can be scaled, mirror imaged or rotated.	0-1
LineDescGroup	LineDescGroupType	A substitution group that specifies the `LineDesc or LineDescRef`. The LineDesc specifies the `LineWidth, LineEnd and LineProperty` characteristics of any feature that requires that definition. Line descriptions are a part of the `Outline, Polyline` and `Set` element definitions. The `LineDescRef` requires an “id” that must be unique within the 2581 file. LineDesc should be used only if FillDesc is present and its’ fill property values are HOLLOW, HATCH, or MESH otherwise the LineDesc should be omitted.	0-1
FillDescGroup	FillDescGroupType	A substitution group that specifies the `FillDesc` or `FillDescRef`. The `FillDesc` element provides the `FillProperties, LineDesc` and `Color` characteristics of any feature that requires that definition. Fill descriptions are a part of the `StandardPrimitives` , any `UserPrimitive` closed shape and `Set` element definitions. The `FillDescRef` requires an “id” that must be unique within the 2581 file	0-1




```
<EntryStandard id = "Diamond1">
    <Diamond width = "10.40" height = "6.20"/>
</EntryStandard>
<EntryStandard id = "Diamond2">
    <Diamond width = "6.00" height = "8.60"/>
</EntryStandard>
```

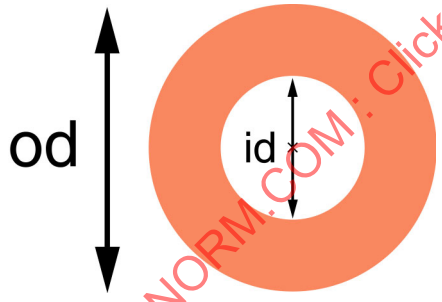
4.7.5 StandardPrimitive: Donut

A `Donut` is a `StandardPrimitive` shape composed of two concentric identical shapes. The shapes are the same but of different sizes with the outer diameter (OD) being larger than the inner diameter (ID). The shapes must be identical and may be square, round, hexagonal, or octagonal. The center of a `Donut` is also the point of origin of the primitive. The hexagonal and octagonal shapes are defined with a point of the shape facing the North direction.

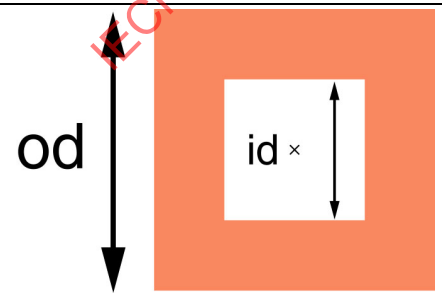


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Donut	DonutType	A round, square, hexagon, or octagon shape consisting of an outer diameter and inner diameter that define physical characteristics of the donut. The default for FillDesc is FILL without a LineDesc element.	1-1
shape	donutShapeType	The inner and outer shapes are one of ROUND, SQUARE , HEXAGON or OCTAGON: ROUND – The inner and outer shapes are like a circle. SQUARE – The inner and outer shapes are like a RectCenter with height and width of each shape being equal. HEXAGON – The inner and outer shapes are like a Hexagon. OCTAGON – The inner and outer shapes are like an Octagon.	1-1

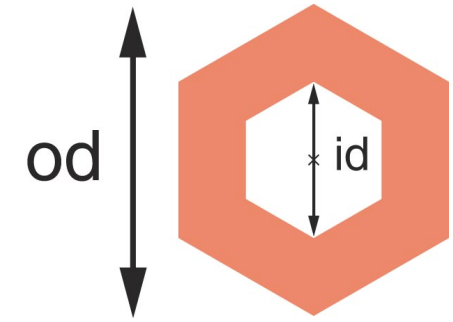
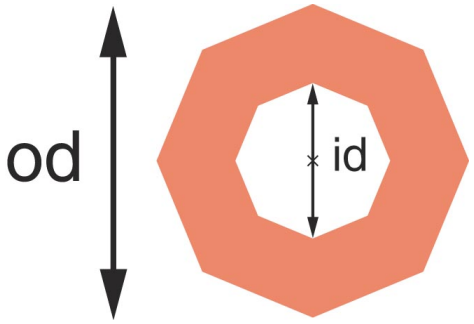
outerDiameter	nonNegativeDouble Type	The outer boundary of the filled region. The meaning based on donutShape: ROUND –The diameter of the circle is the outer boundary of the donut. The center of the circle is at the origin of the donut. SQUARE –The width along the x-axis and the height along the y-axis of a square at the inner boundary of the donut. The center of the square is at the origin. HEXAGON – The point-to-point measurement on the x-axis of the hexagon that forms the outer boundary of the donut. OCTAGON – The point-to-point measurement on the x-axis of the octagon that forms the outer boundary of the donut.	1-1
innerDiameter	nonNegativeDouble Type	The inner boundary of the filled region. The meaning based on donutShape : ROUND – The diameter of the circle is the inner boundary of the donut. The center of the circle is at the origin of the donut. SQUARE – The width along the x-axis and height along the y-axis of a square at the inner boundary of the donut. The center of the square is at the origin. HEXAGON – The point-to-point measurement on the x-axis of the hexagon that forms the inner boundary of the donut. OCTAGON – the point-to-point measurement on the x-axis of the octagon that forms the inner boundary of the donut.	1-1
Xform	XformType	An element that provides the ability to reset the point of origin of a predefined target that can be scaled, mirror imaged or rotated.	0-1
LineDescGroup	LineDescGroupType	A substitution group that specifies the `LineDesc or LineDescRef`. The LineDesc specifies the `LineWidth, LineEnd and LineProperty` characteristics of any feature that requires that definition. Line descriptions are a part of the `Outline, Polyline` and `Set` element definitions. The `LineDescRef` requires an “id” that must be unique within the 2581 file. LineDesc should be used only if FillDesc is present and its' fill property values are HOLLOW, HATCH, or MESH otherwise the LineDesc should be omitted.	0-1
FillDescGroup	FillDescGroupType	A substitution group that specifies the `FillDesc` or `FillDescRef`. The `FillDesc` element provides the `FillProperties, LineDesc` and `Color` characteristics of any feature that requires that definition. Fill descriptions are a part of the `StandardPrimitives`, any `UserPrimitive` closed shape and `Set` element definitions. The `FillDescRef` requires an “id” that must be unique within the 2581 file	0-1




```
<EntryStandard id = "Donut1">
    <Donut shape = "ROUND" outerDiameter = "6.8" innerDiameter = "4.8"/>
</EntryStandard>
<EntryStandard id = "Donut2">
    <Donut shape = "ROUND" outerDiameter = "8.6" innerDiameter = "7.4"/>
</EntryStandard>
```

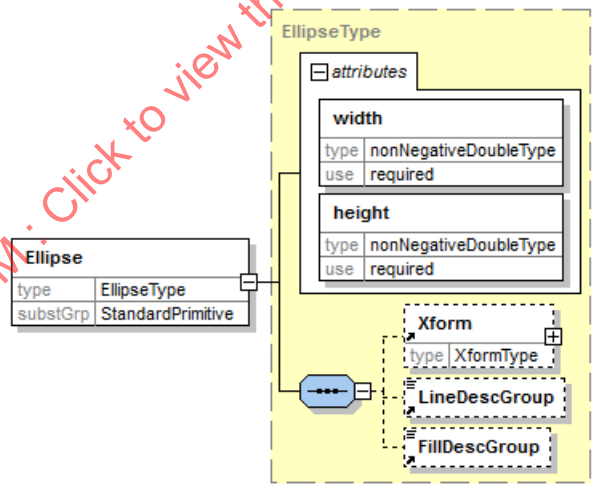



```
<EntryStandard id = "Donut3">
    <Donut shape = "SQUARE" outerDiameter = "6.8" innerDiameter =
"5.0"/>
</EntryStandard>
<EntryStandard id = "Donut4">
    <Donut shape = "SQUARE" outerDiameter = "8.20" innerDiameter =
        "6.20"/>
</EntryStandard>
```

	<EntryStandard id = "Donut5"> <Donut shape = "HEXAGON" outerDiameter = "12.40" innerDiameter = "10.20"/> </EntryStandard> <EntryStandard id = "Donut6"> <Donut shape = "HEXAGON" outerDiameter = "10.00" innerDiameter = "8.00"/> </EntryStandard>
	<EntryStandard id = "Donut7"> <Donut shape = "OCTAGON" outerDiameter = "11.60" innerDiameter = "10.00"/> </EntryStandard> <EntryStandard id = "Donut8"> <Donut shape = "OCTAGON" outerDiameter = "12.00" innerDiameter = "10.00"/> </EntryStandard>

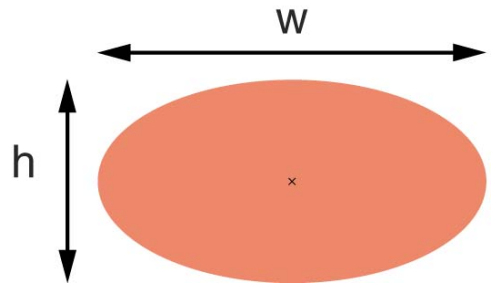
4.7.6 StandardPrimitive: Ellipse

The `Ellipse` is a `StandardPrimitive` shape that is an ellipse with the standard ellipse characteristics. The shape is defined by the width and height dimension. The `Ellipse` is positioned with its point of origin at the center of the `width` and `height` dimensions.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Ellipse	EllipseType	An elliptical shape that follows the standard ellipse characteristics and is defined by a width and height dimension, establishing the overall limits of the feature. The default for FillDesc is FILL without a LineDesc element.	1-1
width	nonNegativeDoubleType	The height of the ellipse on the y-axis.	1-1
height	nonNegativeDoubleType	The width of the ellipse on the x-axis.	1-1

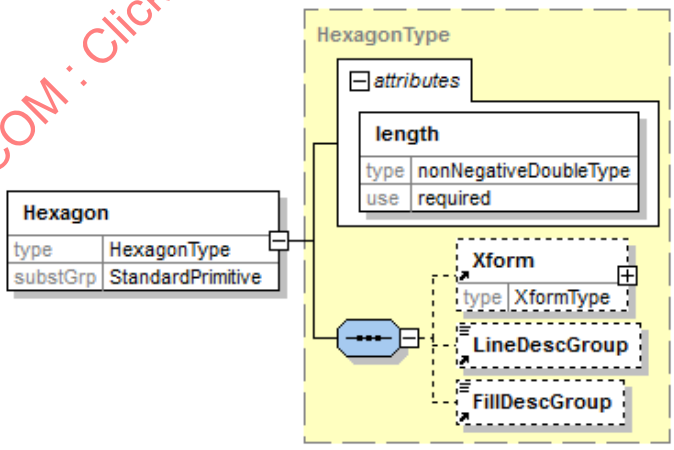
Xform	XformType	An element that provides the ability to reset the point of origin of a predefined target that can be scaled, mirror imaged or rotated.	0-1
LineDescGroup	LineDescGroupType	A substitution group that specifies the `LineDesc or LineDescRef`. The LineDesc specifies the `LineWidth, LineEnd and LineProperty` characteristics of any feature that requires that definition. Line descriptions are a part of the `Outline, Polyline` and `Set` element definitions. The `LineDescRef` requires an "id" that must be unique within the 2581 file. LineDesc should be used only if FillDesc is present and its' fill property values are HOLLOW, HATCH, or MESH otherwise the LineDesc should be omitted.	0-1
FillDescGroup	FillDescGroupType	A substitution group that specifies the `FillDesc` or `FillDescRef`. The `FillDesc` element provides the `FillProperties, LineDesc` and `Color` characteristics of any feature that requires that definition. Fill descriptions are a part of the `StandardPrimitives` , any `UserPrimitive` closed shape and `Set` element definitions. The `FillDescRef` requires an "id" that must be unique within the 2581 file	0-1



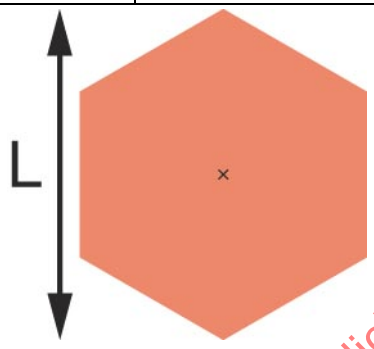

```
<EntryStandard id = "Ellipse1">
    <Ellipse width = "12.60" height = "6.20"/>
</EntryStandard>
<EntryStandard id = "Ellipse2">
    <Ellipse width = "6.20" height = "12.60"/>
</EntryStandard>
<EntryStandard id = "Ellipse3">
    <Ellipse width = "14.80" height = "4.20"/>
</EntryStandard>
<EntryStandard id = "Ellipse4">
    <Ellipse width = "10.60" height = "14.20"/>
</EntryStandard>
```

4.7.7 StandardPrimitive: Hexagon

A `Hexagon` is a six-sided `StandardPrimitive` shape with each of the sides being equal in length and with all angles between adjacent sides also being equal. The orientation of the hexagon is in accordance with one of its points facing the North direction. Only one dimension is required and that is the length across the points. `Rotation` is accomplished using `Xform` at the time the hexagon is instantiated.



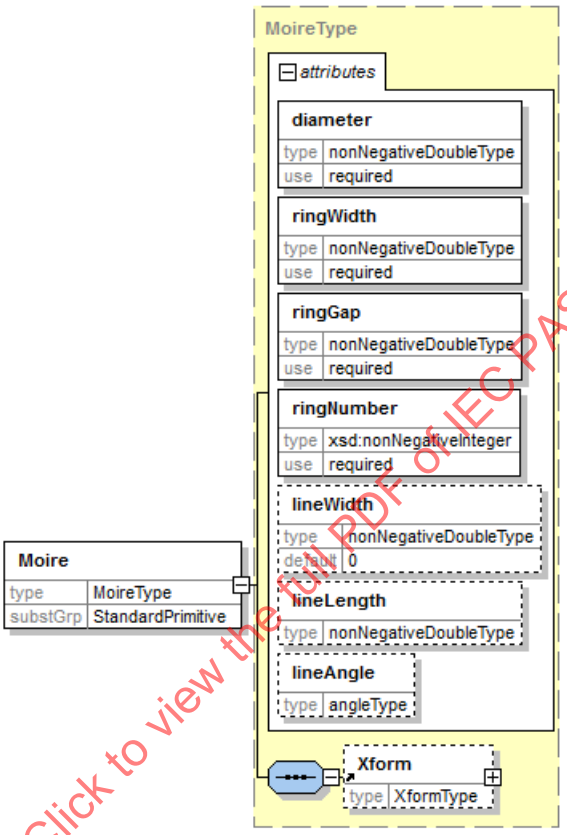
Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Hexagon	HexagonType	A six-sided primitive shape with all sides being equal and which is defined by the length (L) across the points. The position of the octagon is in accordance with one of the points facing North. The default for FillDesc is FILL without a LineDesc element.	0-1
length	nonNegativeDouble Type	The length (L) between any two opposing corner points of the hexagon.	1-1
Xform	XformType	An element that provides the ability to reset the point of origin of a predefined target that can be scaled, mirror imaged or rotated.	0-1
LineDescGroup	LineDescGroupType	A substitution group that specifies the `LineDesc or LineDescRef`. The LineDesc specifies the `LineWidth, LineEnd and LineProperty` characteristics of any feature that requires that definition. Line descriptions are a part of the `Outline, Polyline` and `Set` element definitions. The `LineDescRef` requires an “id” that must be unique within the 2581 file. LineDesc should be used only if FillDesc is present and its’ fill property values are HOLLOW, HATCH, or MESH otherwise the LineDesc should be omitted.	0-1
FillDescGroup	FillDescGroupType	A substitution group that specifies the `FillDesc` or `FillDescRef`. The `FillDesc` element provides the `FillProperties, LineDesc` and `Color` characteristics of any feature that requires that definition. Fill descriptions are a part of the `StandardPrimitives` , any `UserPrimitive` closed shape and `Set` element definitions. The `FillDescRef` requires an “id” that must be unique within the 2581 file	0-1



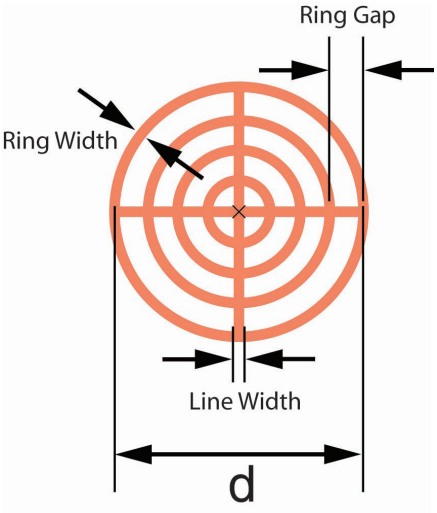

```
<EntryStandard id = "Hexagon1">
    <Hexagon length = "12.8"/>
</EntryStandard>
<EntryStandard id = "Hexagon2">
    <Hexagon length = "11.8"/>
</EntryStandard>
<EntryStandard id = "Hexagon3">
    <Hexagon length = "10.8"/>
</EntryStandard>
<EntryStandard id = "hexagon4">
    <Hexagon length = "9.8"/>
</EntryStandard>
```

4.7.8 StandardPrimitive: Moire

The `Moire` is a primitive shape that consists of a series of circles each with a smaller diameter. The `Moire` is used as an assist in image registration. The `Moire` may be only circles or may also contain a crosshair line to assist in human acknowledgement of moiré alignment. The shape is defined by the number of rings, their center line spacing and the ring line width. The line spacing must be larger than the line width. The crosshair lines can also be described. The `Moire` pattern is positioned using its point of origin which is the center of the ring pattern.

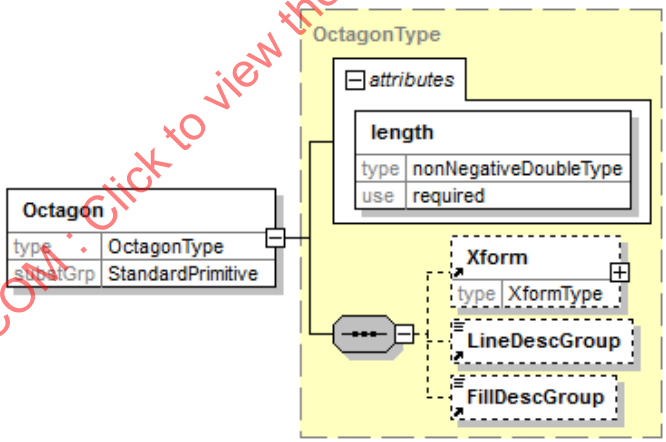


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Moire	MoireType	A series of circles, each consisting of a smaller diameter the shape of which is defined by the number of rings, their center line spacing, and the ring width. The pattern may also contain a crosshair representing its point of origin.	1-1
diameter	nonNegativeDoubleType	The diameter of the center of the outermost circle.	1-1
ringWidth	nonNegativeDoubleType	The width of the line used for each circle.	1-1
ringGap	nonNegativeDoubleType	The gap between circle lines as defined by the dimension between the centerlines of each circle location. The gap between centerlines must be larger than the `ringWidth` so that there is a clearance between individual rings.	1-1
ringNumber	nonNegativeInteger	The number of rings.	1-1
lineWidth	nonNegativeDoubleType	The line width used to develop a cross hair across the moiré. The default is 0.	0-1
lineLength	nonNegativeDoubleType	The length of the line for both the horizontal and vertical cross hair.	0-1
lineAngle	angleType	The angle at which the cross hair may be rotated. Rotation is always counter-clockwise. The default is 0° and can be oriented up to 90°.	0-1

Xform	XformType	An element that provides the ability to reset the point of origin of a predefined target that can be scaled, mirror imaged or rotated.	0-1
		<EntryStandard id = "Moire1"> <Moire diameter = "8.4" ringWidth = "0.3" ringGap = "0.6" ringNumber = "5" lineWidth = "0.3" lineLength = "8.2" lineAngle = "0"/> </EntryStandard> <EntryStandard id = "Moire2"> <Moire diameter = "6.0" ringWidth = "0.2" ringGap = "0.4" ringNumber = "4" lineWidth = "0.2" lineLength = "5.8" lineAngle = "45"/> </EntryStandard>	

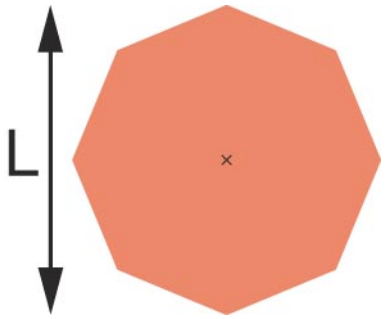
4.7.9 StandardPrimitive: Octagon

An `Octagon` is an eight-sided `StandardPrimitive` shape with each of the sides being equal in length and with all angles between adjacent sides also being equal. The orientation of the `Octagon` is in accordance with one of its points facing the North direction. Only one dimension is required and that is the length across the points. `Rotation` is accomplished using `Xform` at the time the `Octagon` is instanced.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Octagon	OctagonType	An eight-sided primitive shape with all sides being equal and which is defined by the length (L) across the points. The position of the octagon is in accordance with one of its points facing north. The default for FillDesc is FILL without a LineDesc element.	0-1
length	nonNegativeDoubleType	The length (L) between any two opposing corner points of the octagon.	0-1
Xform	XformType	An element that provides the ability to reset the point of origin of a predefined target that can be scaled, mirror imaged or rotated.	0-1

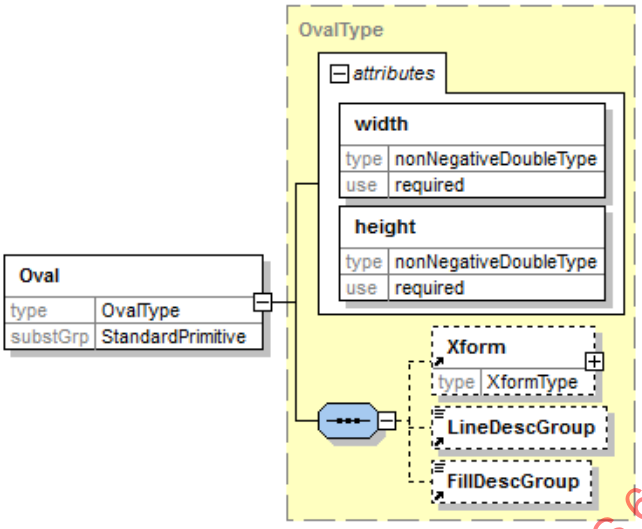
LineDescGroup	LineDescGroupType	A substitution group that specifies the `LineDesc or LineDescRef`. The LineDesc specifies the `LineWidth, LineEnd and LineProperty` characteristics of any feature that requires that definition. Line descriptions are a part of the `Outline, Polyline` and `Set` element definitions. The `LineDescRef` requires an "id" that must be unique within the 2581 file. LineDesc should be used only if FillDesc is present and its' fill property values are HOLLOW, HATCH, or MESH otherwise the LineDesc should be omitted.	0-1
FillDescGroup	FillDescGroupType	A substitution group that specifies the `FillDesc` or `FillDescRef`. The `FillDesc` element provides the `FillProperties, LineDesc` and `Color` characteristics of any feature that requires that definition. Fill descriptions are a part of the `StandardPrimitives`, any `UserPrimitive` closed shape and `Set` element definitions. The `FillDescRef` requires an "id" that must be unique within the 2581 file	0-1



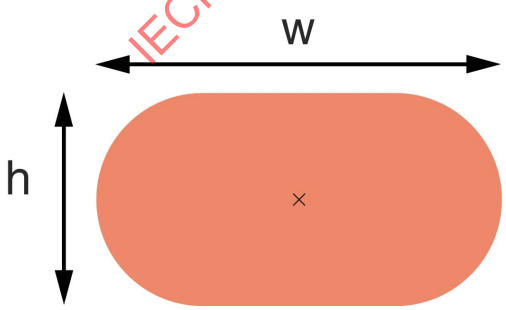

```
<EntryStandard id = "Octagon1">
      <Octagon length = "12.8"/>
</EntryStandard>
<EntryStandard id = "Octagon2">
      <Octagon length = "11.8"/>
</EntryStandard>
<EntryStandard id = "Octagon3">
      <Octagon length = "10.8"/>
</EntryStandard>
<EntryStandard id = "Octagon4">
      <Octagon length = "9.8"/>
</EntryStandard>
```

4.7.10 StandardPrimitive: Oval

An `Oval` is a `StandardPrimitive` shape that defines a rectangle with a complete radius (180 degree arc) at each end. The base rectangle is defined by a width attribute and a height attribute with the center of the rectangle being centered on both the height and width dimensions. The center of the `Oval` rectangle is the point of origin of the shape. The rectangle is defined with edges parallel to the x-axis and y-axis relative to the local coordinate system. Rotation is about the point of origin. The `Oval` is defined with the radius located along the y-axis sides. The radius on the ends of the oval shaped rectangle is always equal to ½ the height.



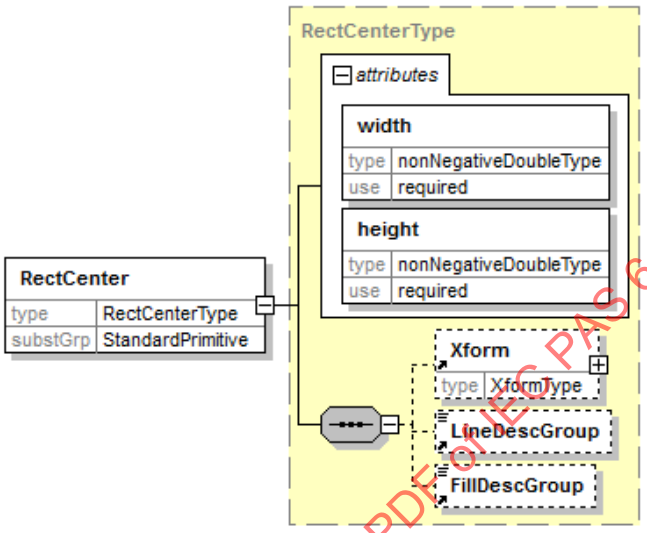
Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Oval	OvalType	A rectangle defined by a width and height attribute with the center of the rectangle being centered on both the height and width dimensions. The default for FillDesc is FILL without a LineDesc element.	1-1
width	nonNegativeDoubleType	The length of the rectangle about the x-axis.	1-1
height	nonNegativeDoubleType	The length of the rectangle about the y-axis. It is an error to define a height greater than the width.	1-1
Xform	XformType	An element that provides the ability to reset the point of origin of a predefined target that can be scaled, mirror imaged or rotated.	0-1
LineDescGroup	LineDescGroupType	A substitution group that specifies the `LineDesc or LineDescRef`. The LineDesc specifies the `LineWidth, LineEnd and LineProperty` characteristics of any feature that requires that definition. Line descriptions are a part of the `Outline, Polyline` and `Set` element definitions. The `LineDescRef` requires an “id” that must be unique within the 2581 file. LineDesc should be used only if FillDesc is present and its’ fill property values are HOLLOW, HATCH, or MESH otherwise the LineDesc should be omitted.	0-1
FillDescGroup	FillDescGroupType	A substitution group that specifies the `FillDesc` or `FillDescRef`. The `FillDesc` element provides the `FillProperties, LineDesc and Color` characteristics of any feature that requires that definition. Fill descriptions are a part of the `StandardPrimitives` , any `UserPrimitive` closed shape and `Set` element definitions. The `FillDescRef` requires an “id” that must be unique within the 2581 file	0-1



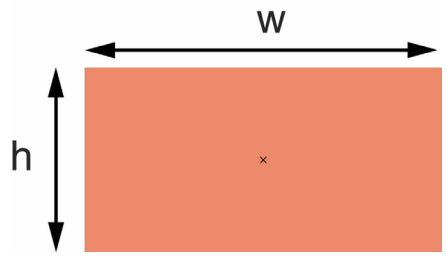
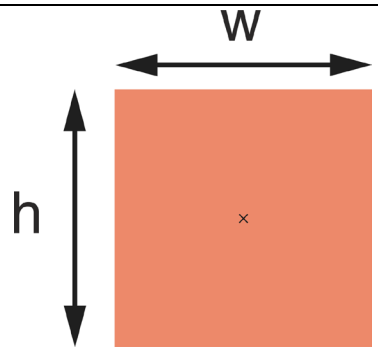

```
<EntryStandard id = "Oval1">
      <Oval width = "10.6" height = "6.4"/>
</EntryStandard>
<EntryStandard id = "Oval2">
      <Oval width = "8.4" height = "8.4"/>
</EntryStandard>
<EntryStandard id = "Oval3">
      <Oval width = "16.4" height = "5.6"/>
</EntryStandard>
<EntryStandard id = "Oval4">
      <Oval width = "14.8" height = "6.8"/>
</EntryStandard>
```

4.7.11 StandardPrimitive: RectCenter

A `RectCenter` is a primitive shape that defines a rectangle by a `width` attribute and a `height` attribute with the center of the rectangle being centered on both the height and width dimensions. The center of the `RectCenter` rectangle is the point of origin of the shape. The rectangle is defined with edges parallel to the x-axis and y-axis relative to the local coordinate system. Rotation is about the point of origin. The `RectCenter` is also used to represent a square shape. The characteristics of the square would be to have the width and height equal.

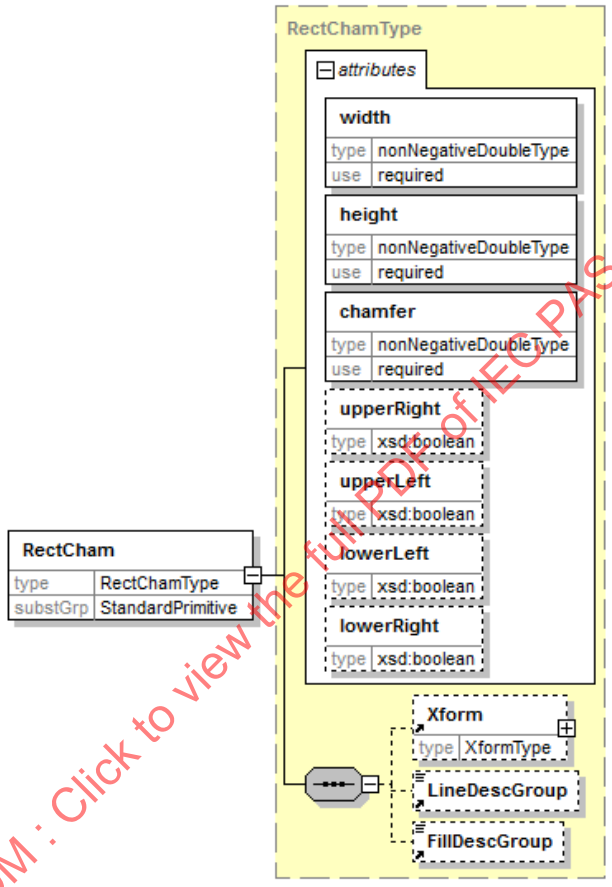


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
RectCenter	RectCenterType	The characteristics of a rectangle defined by a width and height dimension consistent with a horizontal position on the Cartesian coordinate system. The default for FillDesc is FILL without a LineDesc element.	1-1
width	nonNegativeDoubleType	The length of the rectangle about the x-axis.	1-1
height	nonNegativeDoubleType	The length of the rectangle about the y-axis.	1-1
Xform	XformType	An element that provides the ability to reset the point of origin of a predefined target that can be scaled, mirror imaged or rotated.	0-1
LineDescGroup	LineDescGroupType	A substitution group that specifies the `LineDesc or LineDescRef`. The LineDesc specifies the `LineWidth, LineEnd and LineProperty` characteristics of any feature that requires that definition. Line descriptions are a part of the `Outline, Polyline` and `Set` element definitions. The `LineDescRef` requires an “id” that must be unique within the 2581 file. LineDesc should be used only if FillDesc is present and its’ fill property values are HOLLOW, HATCH, or MESH otherwise the LineDesc should be omitted.	0-1
FillDescGroup	FillDescGroupType	A substitution group that specifies the `FillDesc` or `FillDescRef`. The `FillDesc` element provides the `FillProperties, LineDesc` and `Color` characteristics of any feature that requires that definition. Fill descriptions are a part of the `StandardPrimitives`, any `UserPrimitive` closed shape and `Set` element definitions. The `FillDescRef` requires an “id” that must be unique within the 2581 file	0-1

	<EntryStandard id = "RectangleC1"> <RectCenter width = "16.8" height = "6.4"/> </EntryStandard> <EntryStandard id = "RectangleC2"> <RectCenter width = "6.4" height = "12.8"/> </EntryStandard> <EntryStandard id = "RectangleC3"> <RectCenter width = "10.4" height = "6.4"/> </EntryStandard>
	<EntryStandard id = "RectangleSquare1"> <RectCenter width = "8.4" height = "8.4"/> </EntryStandard> <EntryStandard id = "RectangleSquare2"> <RectCenter width = "10.0" height = "10.0"/> </EntryStandard> <EntryStandard id = "RectangleSquare3"> <RectCenter width = "4.8" height = "4.8"/> </EntryStandard>

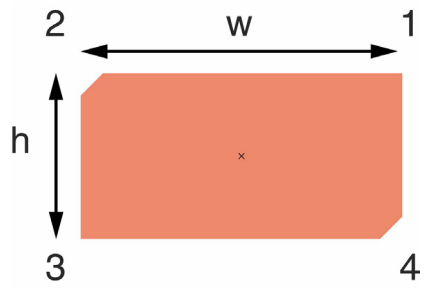
4.7.12 StandardPrimitive: RectCham

A `RectCham` is a `StandardPrimitive` shape that defines a rectangle with chamfered corners. The base rectangle is defined by a `width` attribute and a `height` attribute with the center of the rectangle being centered on both the height and width dimensions. The center of the `RectCham` rectangle is the point of origin of the shape. The rectangle is defined with edges parallel to the x-axis and y-axis relative to the local coordinate system. Rotation is about the point of origin. The `RectCham` is also used to represent a square shape with chamfered corners. The characteristics of the square would be to have the width and height equal.

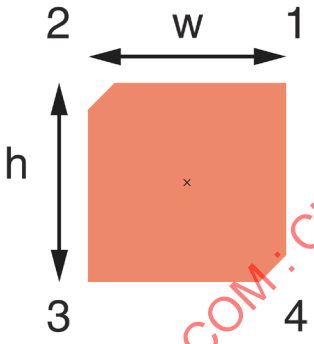


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
RectCham	RectChamType	A rectangle with one or more corners chamfered. The user has the option to define any of the corners as containing the chamfer as well as the chamfered dimensions. A minimum of one (1) chamfered corner must be defined. All chamfers (or opportunities for chamfers) must be identical in size. The default for FillDesc is FILL without a LineDesc element.	1-1
width	nonNegativeDouble Type	The length of the rectangle about the x-axis.	1-1
height	nonNegativeDouble Type	The length of the rectangle about the y-axis.	1-1
chamfer	nonNegativeDouble Type	The length measured from each corner that defines 4 points along the width and 4 points along the height. The corners are clipped between the points at each corner. The resulting chamfers are always cut at 45° relative to the local coordinate system. It is an error to define the value of chamfer to be greater than ½ the height or ½ the width.	1-1

upperRight	Boolean	The upper right corner (1).	0-1
upperLeft	Boolean	The upper left corner (2).	0-1
lowerLeft	Boolean	The lower left corner (3).	0-1
lowerRight	Boolean	The lower right corner (4).	0-1
Xform	XformType	An element that provides the ability to reset the point of origin of a predefined target that can be scaled, mirror imaged or rotated.	0-1
LineDescGroup	LineDescGroupType	A substitution group that specifies the `LineDesc or LineDescRef`. The LineDesc specifies the `LineWidth, LineEnd and LineProperty` characteristics of any feature that requires that definition. Line descriptions are a part of the `Outline, Polyline` and `Set` element definitions. The `LineDescRef` requires an "id" that must be unique within the 2581 file. LineDesc should be used only if FillDesc is present and its' fill property values are HOLLOW, HATCH, or MESH otherwise the LineDesc should be omitted.	0-1
FillDescGroup	FillDescGroupType	A substitution group that specifies the `FillDesc` or `FillDescRef`. The `FillDesc` element provides the `FillProperties, LineDesc` and `Color` characteristics of any feature that requires that definition. Fill descriptions are a part of the `StandardPrimitives` , any `UserPrimitive` closed shape and `Set` element definitions. The `FillDescRef` requires an "id" that must be unique within the 2581 file	0-1



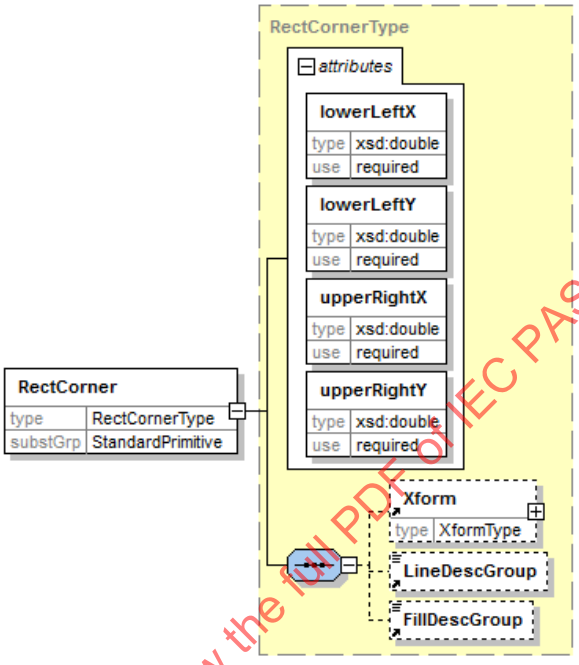

```
<EntryStandard id = "ChamferedRect1">
   <RectCham width = "12.6" height = "8.4" chamfer = "2.0" upperLeft =
        "TRUE" lowerRight = "TRUE" upperRight = "FALSE" lowerLeft =
        "FALSE"/>
</EntryStandard>
<EntryStandard id = "ChamferedRect2">
    <RectCham width = "10.6" height = "6.2" chamfer = "2.0" upperRight
        = "TRUE" upperLeft = "TRUE" lowerLeft = "TRUE" lowerRight =
        "TRUE"/>
</EntryStandard>
```




```
<EntryStandard id = "ChamferedSquare1">
      <RectCham width = "8.4" height = "8.4" chamfer = "2.0" upperRight =
       "TRUE" lowerLeft = "TRUE" lowerRight = "FALSE" upperLeft =
       "FALSE"/>
</EntryStandard>
<EntryStandard id = "ChamferedSquare2">
       <RectCham width = "6.6" height = "6.6" chamfer = "1.8" upperRight
       = "TRUE" upperLeft = "TRUE" lowerLeft = "TRUE" lowerRight =
       "TRUE"/>
</EntryStandard>
```

4.7.13 StandardPrimitive: RectCorner

A `RectCorner` is a `StandardPrimitive` shape that defines a rectangle. The element describes the lower left and upper right corners of the rectangle. The point of origin of a `RectCorner` rectangle is (0, 0). This can be coincident with attribute `lowerLeftX` and `lowerLeftY`, the lower left corner of the rectangle, but there is no requirement for that location to be at (0, 0). The rectangle is defined with edges parallel to the x-axis and y-axis relative to the local coordinate system. Rotation is about the point of origin, not about the lower left or upper right corners.

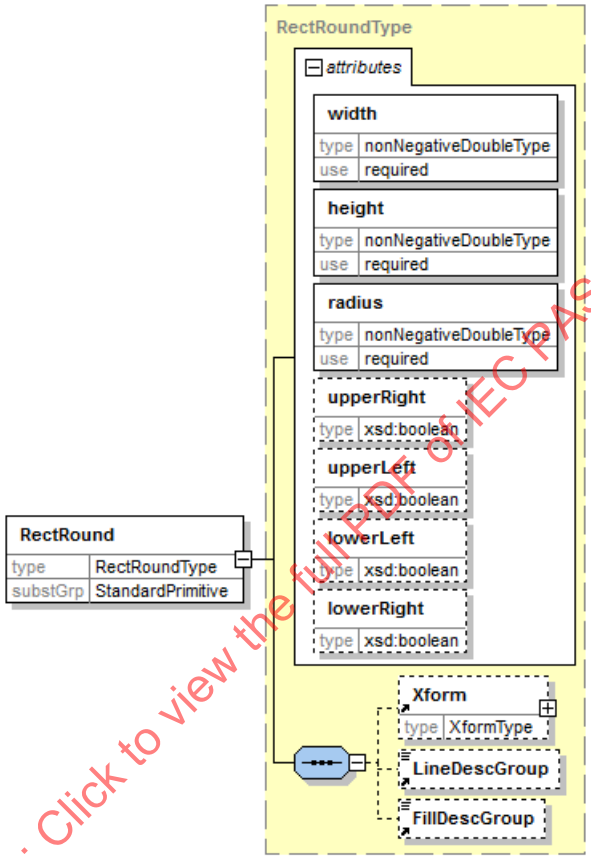


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
RectCorner	RectCornerType	A constraining rectangular area (bounding box) that describes a rectangle consistent with a horizontal position on the Cartesian coordinate system. The default for FillDesc is FILL without a LineDesc element.	1-1
lowerLeftX	double	The lower left hand x dimension of the rectangular area shape.	1-1
lowerLeftY	double	The lower left hand y dimension of the rectangular area shape.	1-1
upperRightX	double	The upper right hand x dimension of the rectangular area shape.	1-1
upperRightY	double	The upper right hand y dimension of the rectangular area shape.	1-1
Xform	XformType	An element that provides the ability to reset the point of origin of a predefined target that can be scaled, mirror imaged or rotated.	0-1
LineDescGroup	LineDescGroupType	A substitution group that specifies the `LineDesc or LineDescRef`. The LineDesc specifies the `LineWidth, LineEnd and LineProperty` characteristics of any feature that requires that definition. Line descriptions are a part of the `Outline`, `Polyline` and `Set` element definitions. The `LineDescRef` requires an “id” that must be unique within the 2581 file. LineDesc should be used only if FillDesc is present and its’ fill property values are HOLLOW, HATCH, or MESH otherwise the LineDesc should be omitted.	0-1
FillDescGroup	FillDescGroupType	A substitution group that specifies the `FillDesc` or `FillDescRef`. The `FillDesc` element provides the `FillProperties, LineDesc` and `Color` characteristics of any feature that requires that definition. Fill descriptions are a part of the `StandardPrimitives` , any `UserPrimitive` closed shape and `Set` element definitions. The `FillDescRef` requires an “id” that must be unique within the 2581 file	0-1

Upper right XY  Lower left XY	<EntryStandard id = "CorneredRectangle1"> <RectCorner lowerLeftX = "0.0" lowerLeftY = "0.0" upperRightX = "12.6" upperRightY = "6.8"/> </EntryStandard> <EntryStandard id = "CorneredRectangle2"> <RectCorner lowerLeftX = "-6.4" lowerLeftY = "-3.2" upperRightX = "6.4" upperRightY = "3.2"/> </EntryStandard>
Upper right XY  Lower left XY	<EntryStandard id = "CorneredSquare1"> <RectCorner lowerLeftX = "0.0" lowerLeftY = "0.0" upperRightX = "8.4" upperRightY = "8.4"/> </EntryStandard> <EntryStandard id = "CorneredSquare2"> <RectCorner lowerLeftX = "-4.6" lowerLeftY = "-4.6" upperRightX = "4.6" upperRightY = "4.6"/> </EntryStandard>

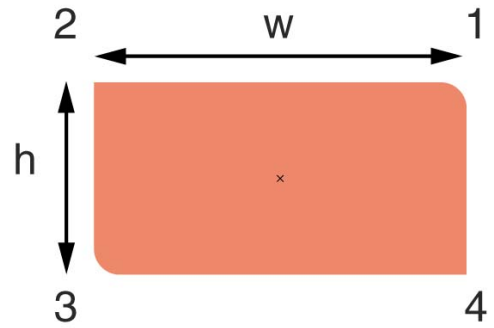
4.7.14 StandardPrimitive: RectRound

A `RectRound` is a `StandardPrimitive` shape that defines a rectangle with radius corners. The base rectangle is defined by a width attribute and a height attribute with the center of the rectangle being centered on both the height and width dimensions. The center of the `RectRound` rectangle is the point of origin of the shape. The rectangle is defined with edges parallel to the x-axis and y-axis relative to the local coordinate system. Rotation is about the point of origin. The `RectRound` is also used to represent a square shape with rounded corners. The characteristics of the square would be to have the width and height equal.

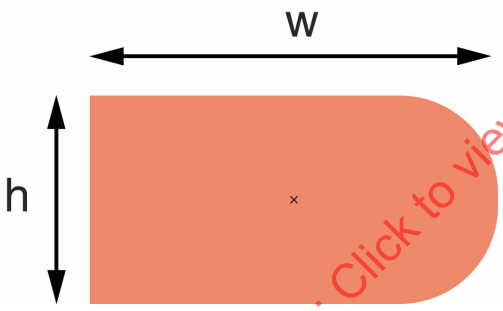


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
RectRound	RectRoundType	A rectangle with one or more corners rounded. The user has the option to define any of the corners as containing the radius as well as the radiused dimensions. A minimum of one (1) rounded corner must be defined.. All corners (or opportunities for corners) must be identical in size. The default for FillDesc is FILL without a LineDesc element.	1-1
width	nonNegativeDoubleType	The length of the rectangle about the x-axis.	1-1
height	nonNegativeDoubleType	The length of the rectangle about the y-axis.	1-1
radius	nonNegativeDoubleType	The radius to be trimmed from the four corners of the rectangle. It is an error to define a radius that is greater than ½ the height value or ½ the width value.	1-1
upperRight	boolean	The upper right corner (1).	0-1
upperLeft	boolean	The upper left corner (2).	0-1
lowerLeft	boolean	The lower left corner (3).	0-1
lowerRight	boolean	The lower right corner (4).	0-1

Xform	XformType	An element that provides the ability to reset the point of origin of a predefined target that can be scaled, mirror imaged or rotated.	0-1
LineDescGroup	LineDescGroupType	A substitution group that specifies the `LineDesc or LineDescRef`. The LineDesc specifies the `LineWidth, LineEnd and LineProperty` characteristics of any feature that requires that definition. Line descriptions are a part of the `Outline, Polyline` and `Set` element definitions. The `LineDescRef` requires an "id" that must be unique within the 2581 file. LineDesc should be used only if FillDesc is present and its' fill property values are HOLLOW, HATCH, or MESH otherwise the LineDesc should be omitted.	0-1
FillDescGroup	FillDescGroupType	A substitution group that specifies the `FillDesc` or `FillDescRef`. The `FillDesc` element provides the `FillProperties, LineDesc` and `Color` characteristics of any feature that requires that definition. Fill descriptions are a part of the `StandardPrimitives` , any `UserPrimitive` closed shape and `Set` element definitions. The `FillDescRef` requires an "id" that must be unique within the 2581 file	0-1




```
<EntryStandard id = "RoundedDshape1">
    <RectRound width = "10.2" height = "6.4" radius = "3.2"
        upperRight = "TRUE" lowerLeft = "TRUE"
        lowerRight = "FALSE" upperLeft = "FALSE"/>
</EntryStandard>
```

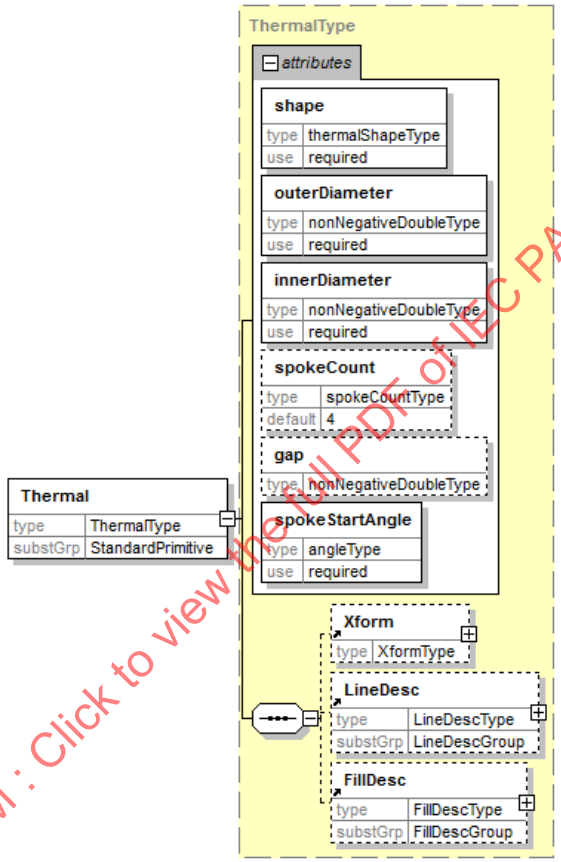



```
<EntryStandard id = "RoundedDshape2">
    <RectRound width = "4.8" height = "4.8" radius = "2.4"
        upperRight = "TRUE" lowerRight = "TRUE" upperLeft
        = "FALSE" lowerLeft = "FALSE"/>
</EntryStandard>
```

4.7.15 StandardPrimitive: Thermal

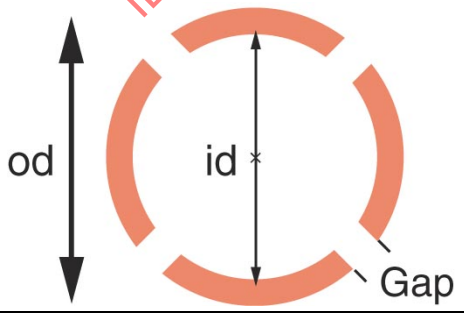
A `Thermal` is a `StandardPrimitive` shape that historically was used to remove material from a plane, conductive filled area or around a plated through hole. The `Thermal` shapes include square, round, hexagonal, or octagonal, and have varying numbers of spokes. The center of a thermal is the point of origin of the primitive.

A spokeless thermal can be used for nonfunctional lands on an innerlayer plane, where the land is not connected to the plane. IPC-2581 defines these using the `Thermal` element with a spoke count of zero. These are similar to a Donut except that they remove material. Many thermal primitive configurations can be generated using different spoke numbers and end types.

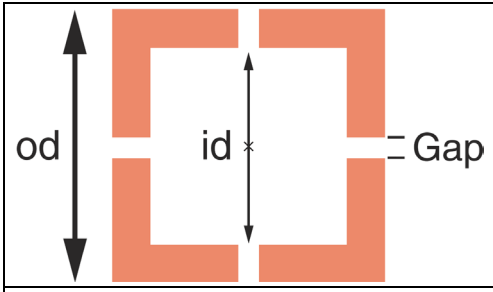
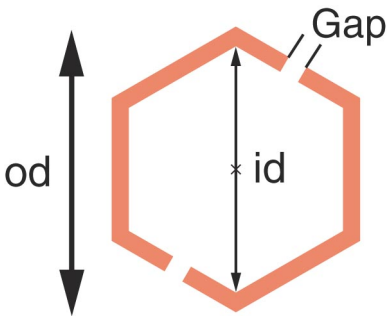
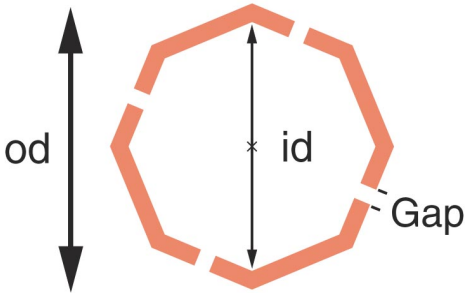
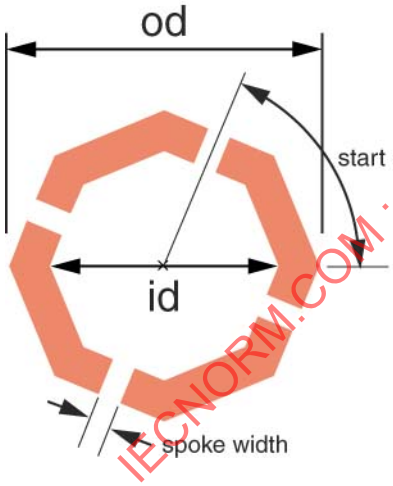


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Thermal	ThermalType	A primitive shape consisting either of ROUND, SQUARE, HEXAGON, or OCTAGON configuration that defines the removal of material from a plane or conductive fill area in accordance to the shape attribute description.	1-1
shape	thermalShapeType	The shape of the thermal. One of ROUND | SQUARE | OCTAGON. ROUND: The inner and outer shapes are like Circle. SQUARE: The inner and outer shapes are like RectCenter with height and width of each shape being equal. HEXAGON: The inner and outer shape are like Hexagon. OCTAGON: The inner and outer shapes are like Octagon.	1-1

outerDiameter	nonNegativeDouble Type	The outer boundary of the filled region. The meaning based on the shape attribute: ROUND: The diameter of the circle is the outer boundary of the thermal. The center of the circle is at the origin of the thermal. SQUARE: The width along the x-axis and the height along the y-axis of a square at the inner boundary of the thermal. The center of the square is at the origin. HEXAGON: The point-to-point measurement (L) on the x-axis of the hexagon that forms the outer boundary of the thermal. OCTAGON: The point-to-point (L) measurement on the x-axis of the octagon that forms the outer boundary of the thermal.	1-1
innerDiameter	nonNegativeDouble Type	The inner boundary of the filled region. The meaning based on the shape attribute: ROUND: The diameter of the circle is the inner boundary of the thermal. The center of the circle is at the origin of the thermal. SQUARE: The width along the x-axis and the height along the y-axis of a square at the inner boundary of the thermal The center of the square is at the origin. HEXAGON: The point-to-point measurement on the x-axis of the hexagon that forms the inner boundary of the thermal. OCTAGON: The point-to-point measurement on the x-axis of the octagon that forms the inner boundary of the thermal.	1-1
spokeCount	spokeCountType	The number of cutouts allowed in the inner and outer shapes. ROUND: must be 0, 2, 3, or 4 (the default is 4) SQUARE: must be 0, 2, or 4 (the default is 4) HEXAGON: must be 0, 2, or 3 (the default is 3) OCTAGON: must be 0, 2, or 4 (the default is 4) If the `spokeCount` is defined as 0 (zero), the other three optional parameters do not apply. The spokeless thermal has a shape like a donut shape.	0-1
gap	nonNegativeDouble Type	The minimum distance between the sides of a spoke cut. The default value is the `innerDiameter` subtracted from the `outerDiameter`.	0-1
spokeStartAngle	angleType	The angle in counterclockwise direction from the x-axis at which the first spoke is cut. The default angle is 45º counterclockwise from the x-axis.	1-1
Xform	XformType	An element that provides the ability to reset the point of origin of a predefined target that can be scaled, mirror imaged or rotated.	0-1
LineDescGroup	LineDescGroupType	A substitution group that specifies the LineDesc or LineDescRef. The LineDesc specifies the LineWidth, LineEnd and LineProperty characteristics of any feature that requires that definition. Line descriptions are a part of the Outline, Polyline and Set element definitions. The LineDescRef requires an “id” that must be unique within the 2581 file. LineDesc should be used only if FillDesc is present and its’ fill property values are HOLLOW, HATCH, or MESH otherwise the LineDesc should be omitted.	0-1
FillDescGroup	FillDescGroupType	A substitution group that specifies the FillDesc or FillDescRef. The FillDesc element provides the FillProperties, LineDesc and Color characteristics of any feature that requires that definition. Fill descriptions are a part of the StandardPrimitives, any UserPrimitive closed shape and Set element definitions. The FillDescRef requires an “id” that must be unique within the 2581 file	0-1

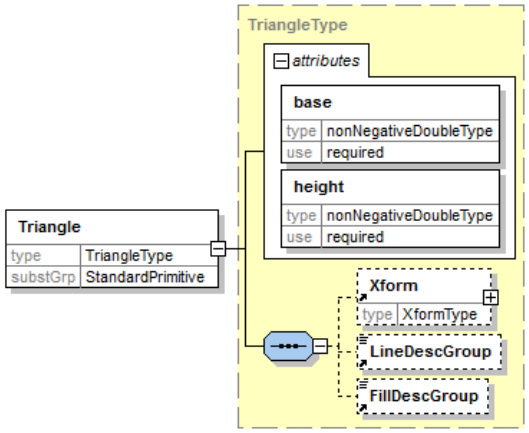



```
<EntryStandard id = "ThermalRound1">
    <Thermal shape = "ROUND" outerDiameter = "10.6" innerDiameter = "6.0."
            spokeCount = "4" gap = "2.0" spokeStartAngle = "45.00"/>
</EntryStandard>
<EntryStandard id = "ThermalRound2">
     <Thermal shape = "ROUND" outerDiameter = "12.0" innerDiameter = "8.0"
            spokeCount = "4" gap = "2.0" spokeStartAngle = "0.00"/>
</EntryStandard>
```

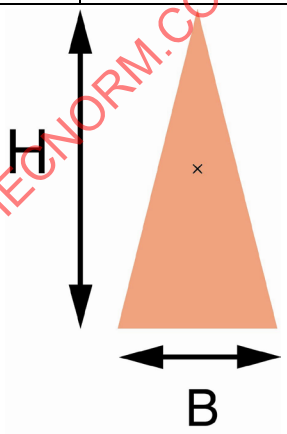
	<EntryStandard id = "ThermalSquare1"> <Thermal shape = "SQUARE" outerDiameter = "10.8" innerDiameter = "6.0" spokeCount = "4" gap = "2.4" spokeStartAngle = "0.00"/> </EntryStandard> <EntryStandard id = "ThermalSquare2"> <Thermal shape = "SQUARE" outerDiameter = "12.8" innerDiameter = "8.0" spokeCount = "4" gap = "2.4" spokeStartAngle = "0.00"/> </EntryStandard>>
	<EntryStandard id = "ThermalHex1"> <Thermal shape = "HEXAGON" outerDiameter = "10.8" innerDiameter = "6.4" spokeCount = "4" gap = "2.0" spokeStartAngle = "45.00"/> </EntryStandard> <EntryStandard id = "ThermalHex2"> <Thermal shape = "HEXAGON" outerDiameter = "12.0" innerDiameter = "8.0" spokeCount = "4" gap = "2.0" spokeStartAngle = "45.00"/> </EntryStandard>
	<EntryStandard id = "ThermalOct1"> <Thermal shape = "OCTAGON" outerDiameter = "10.6" innerDiameter = "6.6" spokeCount = "4" gap = "2.0" spokeStartAngle = "60.00"/> </EntryStandard> <EntryStandard id = "ThermalOct2"> <Thermal shape = "OCTAGON" outerDiameter = "12.0" innerDiameter = "8.0" spokeCount = "4" gap = "2.0" spokeStartAngle = "60.00"/> </EntryStandard>
	<EntryStandard id = "ThermalOct3"> <Thermal shape = "OCTAGON" outerDiameter = "10.6" innerDiameter = "6.0" spokeCount = "4" gap ="2.0" spokeStartAngle = "60.00"/> </EntryStandard> <EntryStandard id = "ThermalOct4"> <Thermal shape = "OCTAGON" outerDiameter = "12.0" innerDiameter = "7.6" spokeCount = "2" gap = "2.2" spokeStartAngle = "60.00"/> </EntryStandard>

4.7.16 StandardPrimitive: Triangle

The `Triangle` is a `StandardPrimitive` shape that is an isosceles triangle that has two equal sides and a base. The shape is defined by the base and height dimension. The triangle is positioned with its point of origin which is at the center of the base and height dimensions.



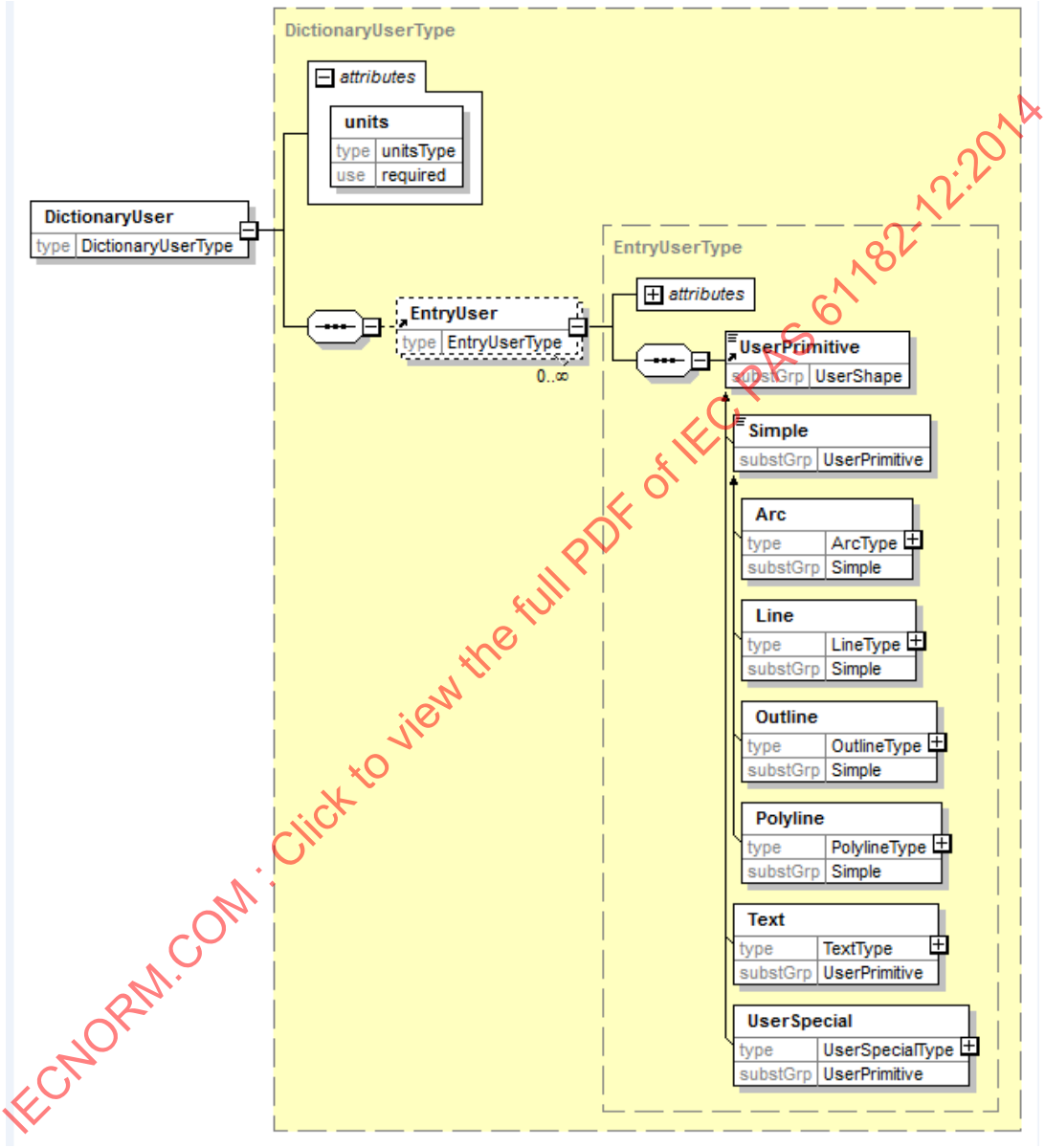
Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Triangle	TriangleType	A primitive shape defined by a base and height dimension. The default for FillDesc is FILL without a LineDesc element.	1-1
base	nonNegativeDoubleType	The distance between the two corner points of the base of the triangle with the point of origin at the center of the base and height dimensions.	1-1
height	nonNegativeDoubleType	The triangle height.	1-1
Xform	XformType	An element that provides the ability to reset the point of origin of a predefined target that can be scaled, mirror imaged or rotated.	0-1
LineDescGroup	LineDescGroupType	A substitution group that specifies the `LineDesc or LineDescRef`. The LineDesc specifies the `LineWidth, LineEnd and LineProperty` characteristics of any feature that requires that definition. Line descriptions are a part of the `Outline, Polyline` and `Set` element definitions. The `LineDescRef` requires an “id” that must be unique within the 2581 file. LineDesc should be used only if FillDesc is present and its’ fill property values are HOLLOW, HATCH, or MESH otherwise the LineDesc should be omitted.	0-1
FillDescGroup	FillDescGroupType	A substitution group that specifies the `FillDesc` or `FillDescRef`. The `FillDesc` element provides the `FillProperties, LineDesc` and `Color` characteristics of any feature that requires that definition. Fill descriptions are a part of the `StandardPrimitives` , any `UserPrimitive` closed shape and `Set` element definitions. The `FillDescRef` requires an “id” that must be unique within the 2581 file	0-1




```
<EntryStandard id = "Triangle1">
      <Triangle base = "4.0" height = "8.0"/>
</EntryStandard>
<EntryStandard id = "Triangle2">
      <Triangle base = "4.0" height = "6.0"/>
</EntryStandard>
<EntryStandard id = "Triangle3">
      <Triangle base = "4.0" height = "12.0"/>
</EntryStandard>
<EntryStandard id = "Triangle4">
      <Triangle base = "8.0" height = "4.0"/>
</EntryStandard>
```

4.8 Content: DictionaryUser

The `DictionaryUser` is intended to provide lookup information on predefined `UserPrimitives`. The `DictionaryUser` is maintained as part of a substitution group schema. The intent is to have graphic descriptions available that are identified by their characteristics and a specific name (id). They may be reused throughout the file as appropriate. The name (id) of a `UserPrimitive` must be unique within the `DictionaryUser`.



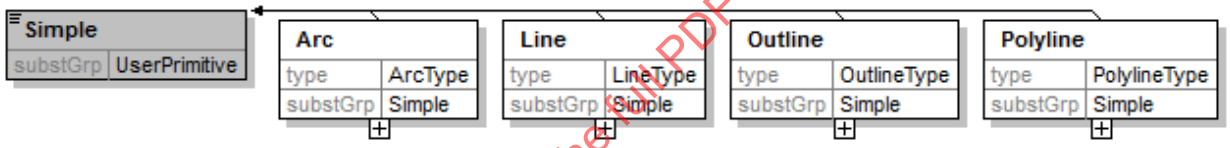
Attribute / Element Name	Attribute / Element Type	Description	Occurrence
DictionaryUser	DictionaryUserType	An element that contains substitution group information using predefined descriptions of user primitives identified by the 2581 standard and described by the user for reuse in the file.	0-1
units	unitsType	An enumerated string that may be one of the following: MILLIMETER | MICRON | INCH.	1-1

EntryUser	EntryUserType	An element that establishes the individual characteristic associated with a `UserPrimitive` substitution shape that has been identified by the user of the IPC-2581 file.	0-n
id	qualifiedNameType	The unique qualified name description assigned as an id for any `StandardPrimitive` for XML schema substitution.	1-1
UserPrimitive	ABSTRACT	Any user primitive that is part of the substitution group that permits the substitution of the user primitives (`arc`, `line`, `Outline`, `Polygon`), a text string, or `UserSpecial` shape.	1-n

The organization of the `DictionaryUser` is accomplished in accordance with the substitution group description criteria. The `UserPrimitive` description may be any of four simple shapes according to the specific characteristics identified in the following paragraphs plus text strings or user combinations of primitives to develop `UserSpecial` graphics for such items as logos, targets, drawing formats etc. The `UserPrimitiveRef` function is used in the body of the IPC-2581 file when a specific `UserPrimitive` has been predefined, assigned a name, and this unique "id" is referenced in the file. This feature permits the use of either a predefined `UserPrimitive` or defining the details of a `UserPrimitive` within the file. The description in the file must contain all the features of a particular primitive shape under the rules of the particular shape definition.

4.8.1 UserPrimitive, Simple

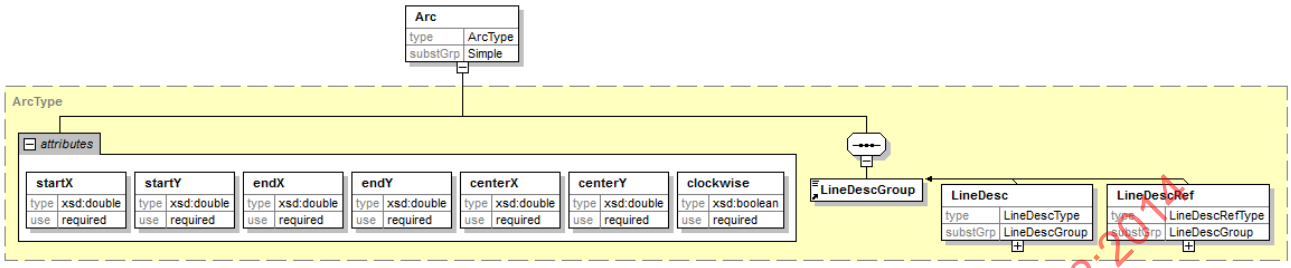
An abstract type identifying a substitution set of pre-defined simple primitive shapes that may be any one of four geometries. Each of the simple primitives must have a unique name within the `DictionaryUser` section. (See 3.4.9)



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Arc	ArcType	The `Arc` element represents an arc. Arcs are curves (defined by three sets of coordinates: `startX`, `startY`, `endX`, `endY`, and `centerX`, `centerY`. The width of the arc is defined as a substitution group for `LineDesc` or applied when the `Arc` is instantiated.	0-n
Line	LineType	The `Line` element is used to describe an individual line segment. The `lineWidth` and `lineEnd` conditions are defined as a substitution group for `LineDesc` or applied when the line segment is instantiated. The `lineEnd` default is ROUND.	0-n
Outline	OutlineType	The `Outline` element is that of a Polygon and represents a closed shape. The point of origin of the shape is identified as the 0:0 coordinate. The element includes the start of the polygon definition (`PolyBegin`) and the appropriate number of PolySteps to complete the closed shape. The `lineWidth` is defined as a substitution group for `LineDesc` or applied when the `Outline` is instantiated.	0-n
Polyline	PolylineType	The `Polyline` element consists of a series of lines that define a particular grouping configuration. These line segments do not result in a closed shape, however they can be predefined and reused as needed. The `lineWidth` and `lineEnd` of the `Polyline` are defined as a substitution group for `LineDesc` or applied at the time the `Polyline` is instantiated.	0-n

4.8.1.1 UserPrimitive, Simple: Arc

Each `Arc` entry (`EntryUser`) in the `DictionaryUser` **shall** have a unique id and consist of the following characteristics:

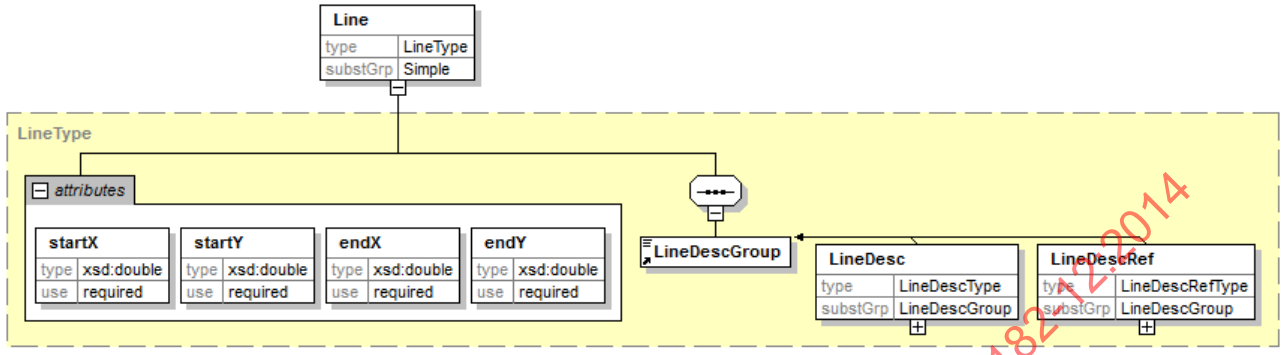


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Arc	ArcType	The `Arc` element represents an arc. Arcs are curves (defined by three sets of coordinates: `startX`, `startY`, `endX`, `endY` and `centerX`, `centerY`. The width of the arc is set by the `LineDesc` substitution group or applied when the `Arc` is instantiated.	0-n
startX	double	Beginning x-coordinate of the `Arc`.	1-1
startY	double	Beginning y-coordinate of the `Arc`.	1-1
endX	double	Ending x-coordinate of the `Arc`.	1-1
endY	double	Ending y-coordinate of the `Arc`.	1-1
centerX	double	The X location for the origin of the radius of the circular `Arc`.	1-1
centerY	double	The Y location for the origin of the radius of the circular `Arc`.	1-1
clockwise	boolean	An enumerated string as either TRUE or FALSE (part of the 3WC standard). TRUE equals that the `Arc` is in a `clockwise` direction; FALSE is the default indicating a counterclockwise direction.	0-1
LineDescGroup	ABSTRACT	A substitution group that specifies the `LineWidth` and `LineEnd` characteristics of the `Arc` by reference to a predefined `LineDesc` or specified when the `Arc` is instantiated.	1-1

```
<EntryUser id = "Arc1">
    <Arc startX = "8.0" startY = "0.0" endX = "-8.0" endY = "0.0" centerX = "0.0" centerY = "0.0" clockwise = "FALSE">
      <LineDescRef id = "MediumLine"/>
    </Arc>
</EntryUser>
<EntryUser id = "Arc2">
    <Arc startX = "0.0" startY = "0.0" endX = "12.0" endY = "0.0" centerX = "6.0" centerY = "0.0" clockwise = "TRUE">
      <LineDescRef id = "HeavyLine"/>
    </Arc>
</EntryUser>
<EntryUser id = "Arc3">
    <Arc startX = "-8.0" startY = "0.0" endX = "0.0" endY = "8.0" centerX = "0.0" centerY = "0.0" clockwise = "TRUE">
      <LineDesc lineEnd = "ROUND" lineWidth = "1.0"/>
    </Arc>
 </EntryUser>
```

4.8.1.2 UserPrimitive, Simple: Line

Each `Line` entry (`EntryUser`) in the `DictionaryUser` **shall** have a unique id and consist of the following characteristics:

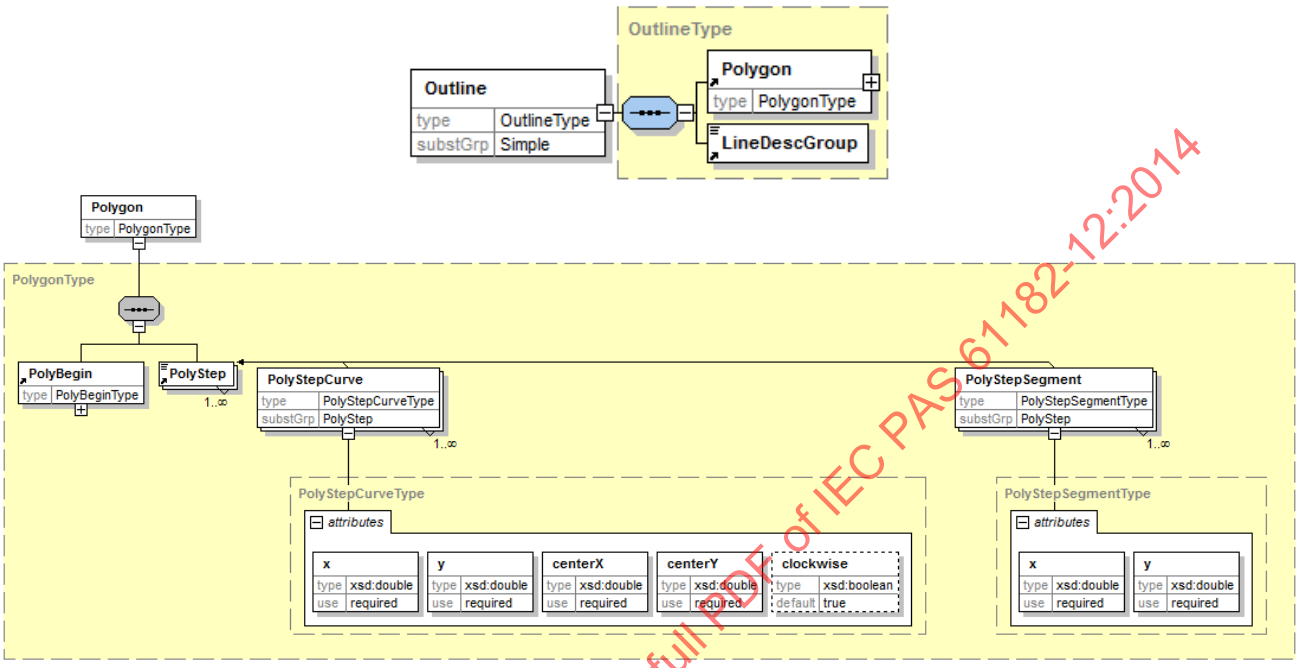


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Line	LineType	The Line element is used to describe an individual line segment. The lineWidth and lineEnd conditions are defined by the LineDescGroup or when the line is instantiated. The lineEnd default is ROUND.	0-n
startX	double	Beginning x-coordinate of the `Line`.	1-1
startY	double	Beginning y-coordinate of the `Line`.	1-1
endX	double	Ending x-coordinate of the `Line`.	1-1
endY	double	Ending y-coordinate of the `Line`.	1-1
LineDescGroup	ABSTRACT	A substitution group that specifies the `LineWidth` and `LineEnd` characteristics of the `Line` by reference to a predefined `LineDesc` or specified when the `Line` is instantiated.	1-1

```
<EntryUser id = "Line1">
    <Line startX = "0.0" startY = "0.0" endX = "12.6" endY = "9.4">
        <LineDesc lineEnd = "ROUND" lineWidth = "1.0"/>
    </Line>
</EntryUser>
<EntryUser id = "Line2">
    <Line startX = "3.6" startY = "4.8" endX = "-4.8" endY = "-3.6">
        <LineDescRef id = "MediumLine"/>
    </Line>
</EntryUser>
<EntryUser id = "Line3">
    <Line startX = "0.0" startY = "0.0" endX = "12.8" endY = "0.0">
        <LineDescRef id = "HeavyLine"/>
    </Line>
</EntryUser>
<EntryUser id = "Line4">
    <Line startX = "12.8" startY = "2.4" endX = "-10.2" endY = "1.2">
        <LineDesc lineEnd = "SQUARE" lineWidth = "0.8"/>
    </Line>
</EntryUser>
```

4.8.1.3 UserPrimitive, Simple: Outline

Each `Outline` entry (`EntryUser`) in the `DictionaryUser` **shall** have a unique id and consist of the following characteristics. The `Outline` element consists of the following characteristics using a `Polygon` shape to represent a closed shaped group of lines.

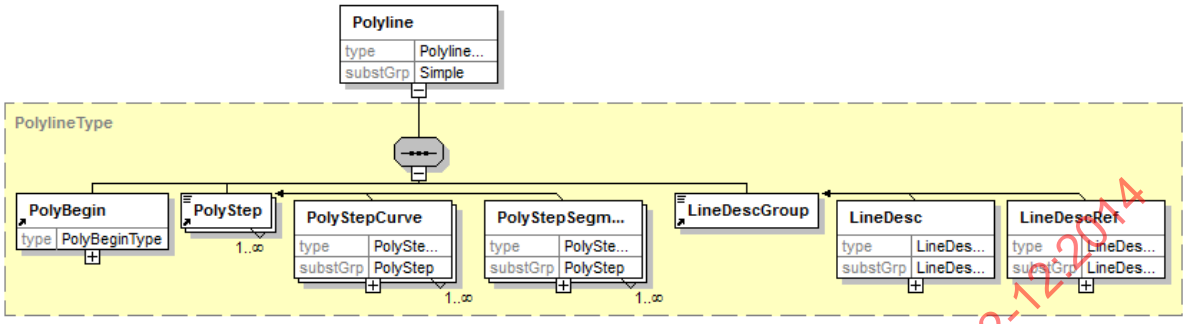


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Outline	OutlineType	An element that has as its sub elements the `Polygon` and `LineDesc` elements in order to define a closed shape that has a line width.	0-n
Polygon	PolygonType	The standard description for the `Polygon` characteristic must be a closed shape. The point of origin of the shape is identified as the 0:0 coordinate. The element includes the start of the polygon definition (`PolyBegin`) and the appropriate number of PolySteps to complete the closed shape. The lineWidth is through the `LineDesc` substitution group or defined at a time when the `Polygon` is instantiated.	0-n
PolyBegin	PolyBeginType	The `PolyBegin` element defines the starting point of the polygon.	1-1
x	double	The X starting point of the first polygon line.	1-1
y	double	The Y starting point of the first polygon line.	1-1
PolyStep	ABSTRACT	The `PolyStep` element is a substitution group that defines a circular (`PolyStepCurve`) or straight line (`PolyStepSegment`) continuation of the polygon. The `polystep` direction may be clockwise or counterclockwise which must be consistent when any `Arc` description is used as one of the `PolyStep` elements. Straight or curved line segments must not cross. The final X and final Y coordinate must match those of the `PolyBegin` element to signify that the shape is closed.	2-n
LineDescGroup	LineDescGroupType	A substitution group that specifies the `LineDesc or LineDescRef`. The LineDesc specifies the `LineWidth, LineEnd and LineProperty` characteristics of any feature that requires that definition. Line descriptions are a part of the `Outline`, `Polyline` and `Set` element definitions. The `LineDescRef` requires an “id” that must be unique within the 2581 file.	1-1

```
<EntryUser id = "Outline1">
    <Outline>
        <Polygon>
            <PolyBegin x = "0.0" y = "6.4"/>
            <PolyStepSegment x = "12.6" y = "6.4"/>
            <PolyStepCurve x = "14.8" y = "4.2" centerX = "12.6" centerY = "4.2" clockwise = "TRUE"/>
            <PolyStepSegment x = "14.8" y = "0.0"/>
            <PolyStepSegment x = "0.0" y = "0.0"/>
            <PolyStepSegment x = "0.0" y = "6.4"/>
        </Polygon>
        <LineDescRef id = "FineLine"/>
    </Outline>
</EntryUser>
<EntryUser id = "Outline2">
    <Outline>
        <Polygon>
            <PolyBegin x = "-10.4" y = "-2.0"/>
            <PolyStepSegment x = "-10.4" y = "0.0"/>
            <PolyStepCurve x = "10.4" y = "0.0" centerX = "0.0" centerY = "0.0" clockwise = "TRUE"/>
            <PolyStepSegment x = "10.4" y = "-2.0"/>
            <PolyStepSegment x = "0.0" y = "-6.0"/>
            <PolyStepSegment x = "-10.4" y = "-2.0"/>
        </Polygon>
        <LineDesc lineEnd = "ROUND" lineWidth = "0.2"/>
    </Outline>
</EntryUser>
```

4.8.1.4 UserPrimitive, Simple: PolyLine

Each `PolyLine` entry (`Entryuser`) in the `DictionaryUser` **shall** have a unique id and consist of the following characteristics. The `PolyLine` characteristics represent an open shaped group of lines.



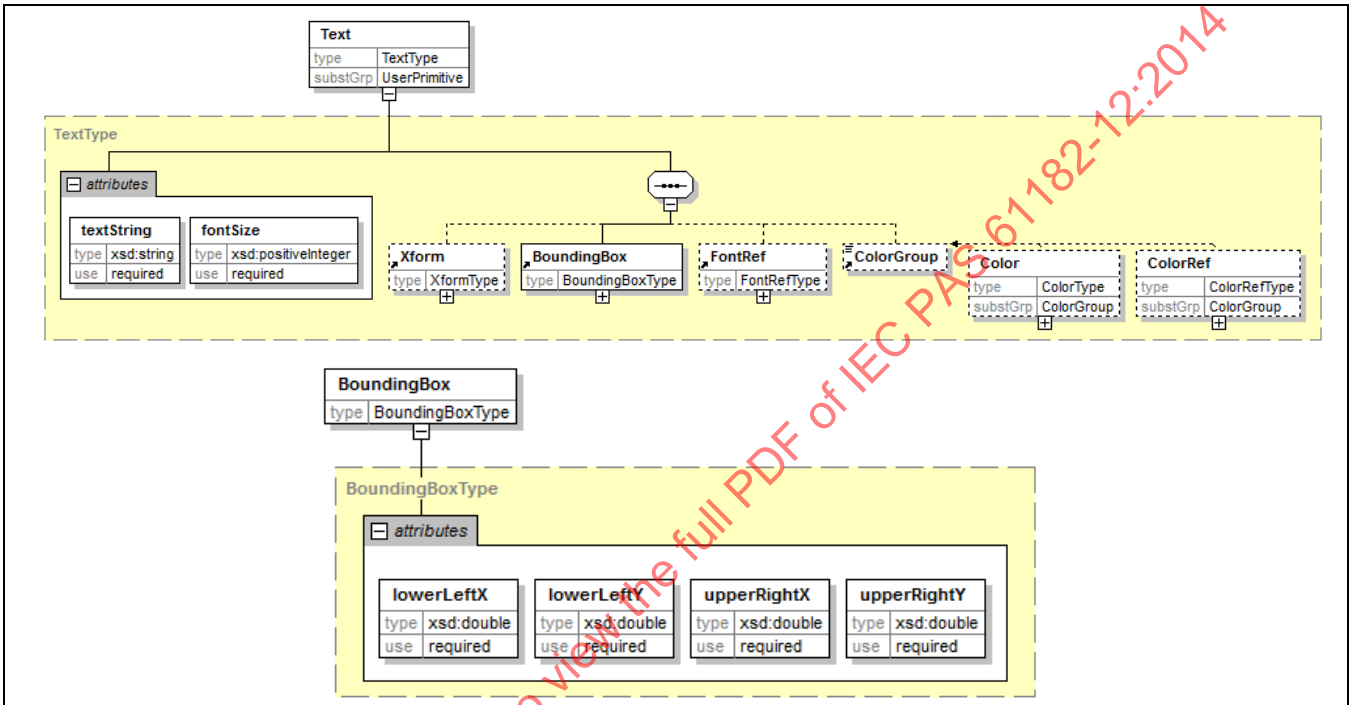
Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Polyline	PolylineType	The `Polyline` element consists of a series of lines that define a particular grouping configuration. These line segments do not result in a closed shape however they can be pre-defined and re-used as needed. The `lineWidth` and `lineEnd` are defined by the substitution group `LineDescGroup` or are defined at the time the `Polyline` is instantiated.	0-n
PolyBegin	PolyBeginType	The `PolyBegin` element defines the starting point of the polyline.	1-1
x	double	The X starting point of the first polyline line segment.	1-1
y	double	The Y starting point of the first polyline line segment.	1-1
PolyStep	ABSTRACT	The `PolyStep` element is a substitution group that defines a circular (`PolyStepCurve`) or straight line (`PolyStepSegment`) continuation of the polyline. The `polystep` direction may be clockwise or counterclockwise which must be consistent when any `Arc` description is used as one of the `PolyStep` elements. Straight or curved line segments must not cross.	1-n
LineDescGroup	ABSTRACT	A substitution group that specifies the `LineWidth` and `LineEnd` characteristics of the `Line` by reference to a predefined `LineDesc` or specified when the `polyline` is instantiated.	1-1

```
<EntryUser id = "Polyline1">
    <Polyline>
        <PolyBegin x = "0.0" y = "0.0"/>
        <PolyStepSegment x = "4.0" y = "0.0"/>
        <PolyStepCurve x = "4.0" y = "6.0" centerX = "4.0" centerY = "3.0" clockwise = "FALSE"/>
        <PolyStepCurve x = "4.0" y = "12.0" centerX = "4.0" centerY = "9.0" clockwise = "TRUE"/>
        <LineDescRef id = "HeavyLine"/>
    </Polyline>
</EntryUser>
<EntryUser id = "Polyline2">
    <Polyline>
        <PolyBegin x = "3.2" y = "2.2"/>
        <PolyStepSegment x = "8.8" y = "10.4"/>
        <PolyStepCurve x = "8.8" y = "16.4" centerX = "8.8" centerY = "13.4" clockwise = "TRUE"/>
        <PolyStepSegment x = "6.0" y = "16.4"/>
        <PolyStepSegment x = "6.0" y = "10.0"/>
        <LineDesc lineEnd = "ROUND" lineWidth = "0.5"/>
    </Polyline>
</EntryUser>
```

4.8.2 UserPrimitive: Text

When text is to be drawn on a product or a drawing the definition includes a bounding rectangle for the text. The `lowerLeftX` and `lowerLeftY` coordinate and the `upperRightX` and `upperRightY` coordinate define the `BoundingBox` rectangle. All portions of the text, including the line width of the strokes of the text, must fit within the `BoundingBox` rectangle. Any portion of a character exceeding the perimeter of the `BoundingBox` rectangle will be clipped at the boundaries of the `BoundingBox` rectangle.

Each `Text` entry (`EntryUser`) in the `DictionaryUser` **shall** have a unique id and consist of the following characteristics:



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Text	TextType	A pre-defined string of text that may be referenced and instantiated within the IPC-2581 file, including specific transformation.	0-n
textString	string	The text phrase (case-sensitive) in accordance with the language element of the `Header` element.	1-1
fontSize	positiveInteger	A dimensional characteristic in terms of an integer that defines the font size.	1-1
Xform	XformType	An element that provides the ability to reset the point of origin of the text box, then scale, mirror image or rotate the text box after the text box origin has been placed at an X and Y location. See 3.3.	0-1
Boundingbox	BoundingBoxType	A constraining rectangular area (bounding box) that encompasses the entire text string including upper and lower case characters.	1-1
lowerLeftX	double	The lower left hand x dimension of the rectangular area encompassing the text.	1-1
lowerLeftY	double	The lower left hand y dimension of the rectangular area encompassing the text.	1-1
UpperRightX	double	The upper right hand x dimension of the rectangular area encompassing the text.	1-1
UpperRightY	double	The upper right hand y dimension of the rectangular area encompassing the text.	1-1

FontRef	FontRefType	An element that is optional to reference a predefined font by its id, if the standard Helvetica font is not being instantiated.	0-1
id	qualifiedNameType	The identification of the `FontDef` stored in the `DictionaryFont`.	1-1
ColorGroup	ABSTRACT	An optional substitution group that permits assigning a particular color through instantiating the three basic colors or by providing a reference to a predefined `Color` in `DictionaryColor`.	0-1

The following diagram and the requirements describe the general case for how text is to be drawn. There are two variations on the use of text. This makes `Text` an element that is incorporated as a layer feature or in a `Package` description. When used in this manner, all the characteristics of `Xform` and the `BoundingBox` apply. The other form of text is as a simple `string` attribute. This is where the word `text` is used to add extra information to a particular element and therefore does not require the special features for `location`, `font`, and `Xform`.

When `text` is used as an element, the attribute `textString` should be defined to be enclosed in the textbox as illustrated in Figure 4. This includes upper and lower case letters, as well as all line widths, line descriptions, and line ends. Anything outside the clipping box will be clipped. The clipping boundary is necessary because fonts vary between computer systems and application implementations.

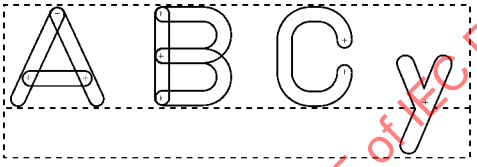


Figure 4 Bounding rectangle to round end character relationships

4.8.2.1 Text restrictions

Text character dimensions are constrained by the bounding rectangle as illustrated in Figure 5. Character height is expressed by the `fontSize` attribute. Incremental units of the `BoundingBox` follow the `Units` element used by the file; this sets the limits (left and right xy coordinates) of the bounding rectangle. Both upper and lower case letters must be inside the `BoundingBox` rectangle. Included in this requirement are the extensions of such descending letters as lower case “g,” “q,” “y,” “j,” and “p.”

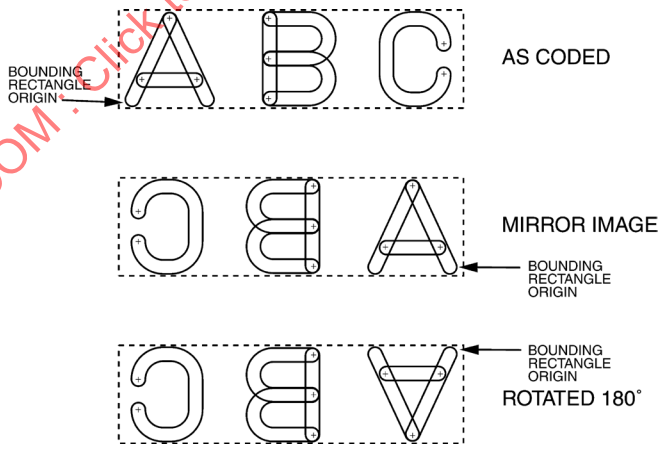


Figure 5 Text transformation examples

4.8.2.2 Text rotation

The bounding rectangle of `Text` is defined relative to the local coordinate system. The `xLocation` and `yLocation` of `Xform` is applied to the bounding rectangle and the text contained within the rectangle to locate the `Text`. The bounding rectangle must be mirrored if required before it is rotated. The text is drawn relative to the bounding rectangle.

The example shown in Figure 6 indicates a `BoundingBox` rectangle that has been rotated 30° about the lower left xy coordinate.

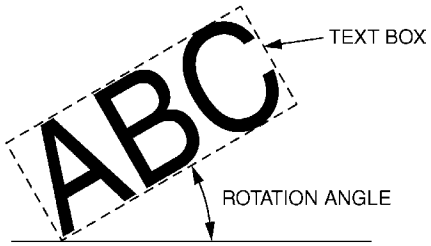
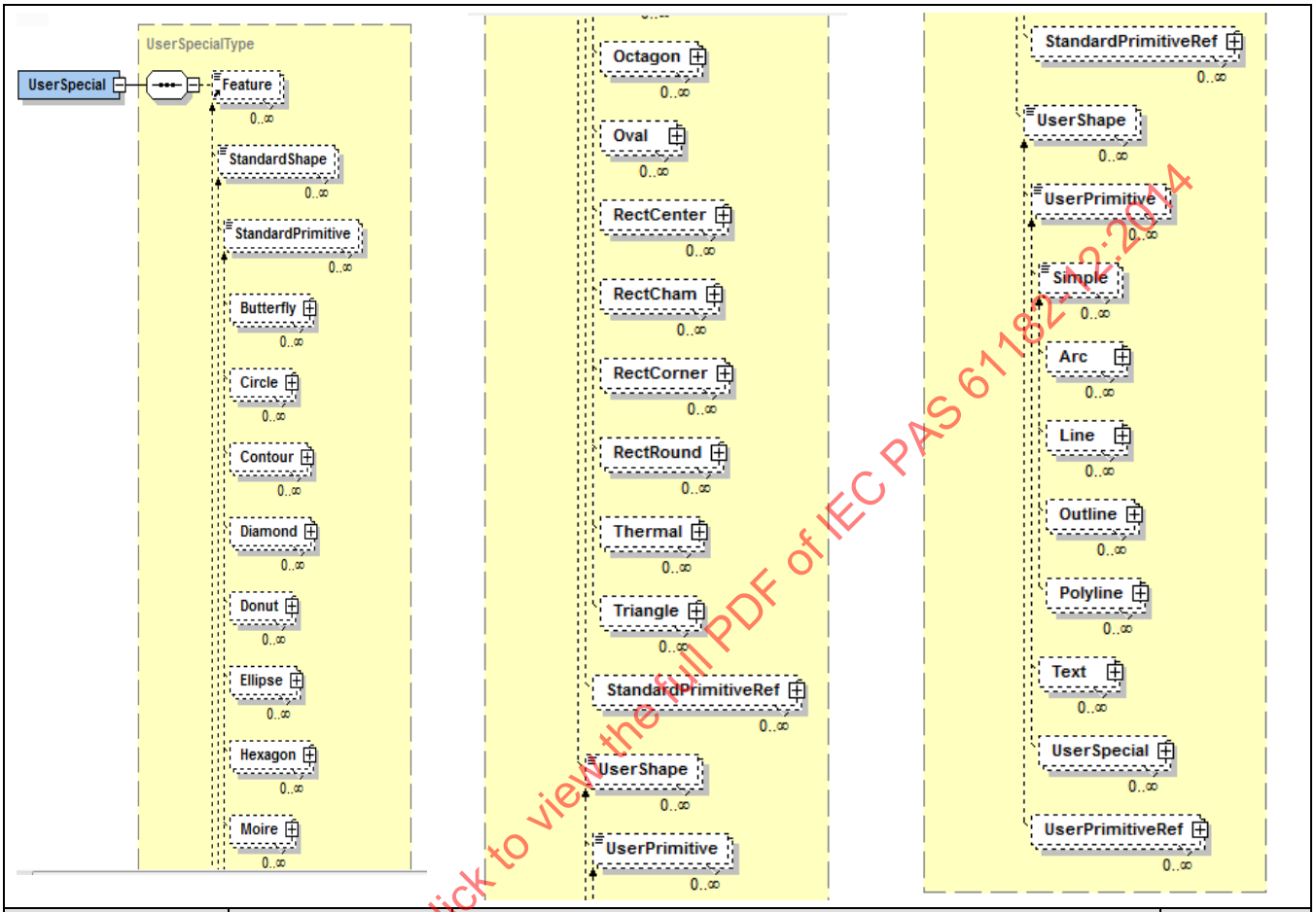


Figure 6 Rotation Angle

4.8.3 UserPrimitive: UserSpecial

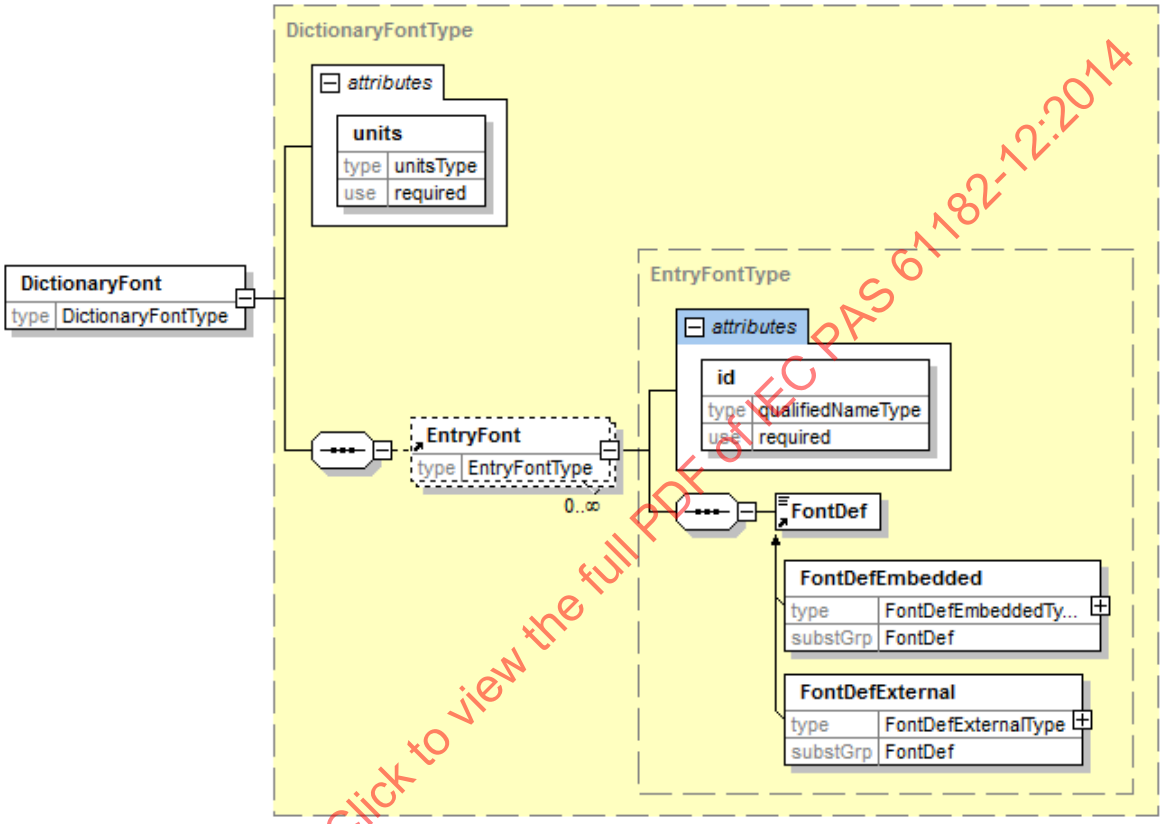
Each `UserSpecial` entry (`EntryUser`) in the `DictionaryUser` **shall** have a unique id and consist of the following characteristics. The `UserSpecial` may be any combination of `StandardShapes` or `UserShapes`, and is used to develop logos, targets, drawing formats or other combination of shapes.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
UserSpecial	UserSpecialType	A combination of primitive shapes that may be organized in any orientation needed to represent the user's needs for defining a special graphic shape.	0-n
Feature	ABSTRACT	A substitution group consisting of any graphic allowed by either the `StandardShape` or `UserShape` substitution groups.	0-n
StandardShape	ABSTRACT	A substitution group that permits the substitution of the `StandardShape` element. The `StandardShape` element may be used to further classify `Feature`. In so doing, `StandardShape` can be substituted by a `StandardPrimitive` or `StandardPrimitiveRef`.	0-n
UserShape	ABSTRACT	A substitution group that permits the substitution or classification of a higher level substitution group. The `UserShape` element may be used to further classify `Feature`. In so doing, `UserShape` can be substituted by a `UserPrimitive` or `UserPrimitiveRef`.	0-n

4.9 Content: DictionaryFont

The `DictionaryFont` is intended to provide lookup information on predefined font descriptions when the standard Helvetica font is not used. The `DictionaryFont` is maintained as part of a substitution group schema. The intent is to have font descriptions available that are identified by their characteristics and a specific name (id). The reference is to individual `Glyph` characters or to a known font through reference to a URN. Font descriptions may be reused throughout the file as appropriate. The name (id) of a `FontDef` must be unique within the `DictionaryFont`.

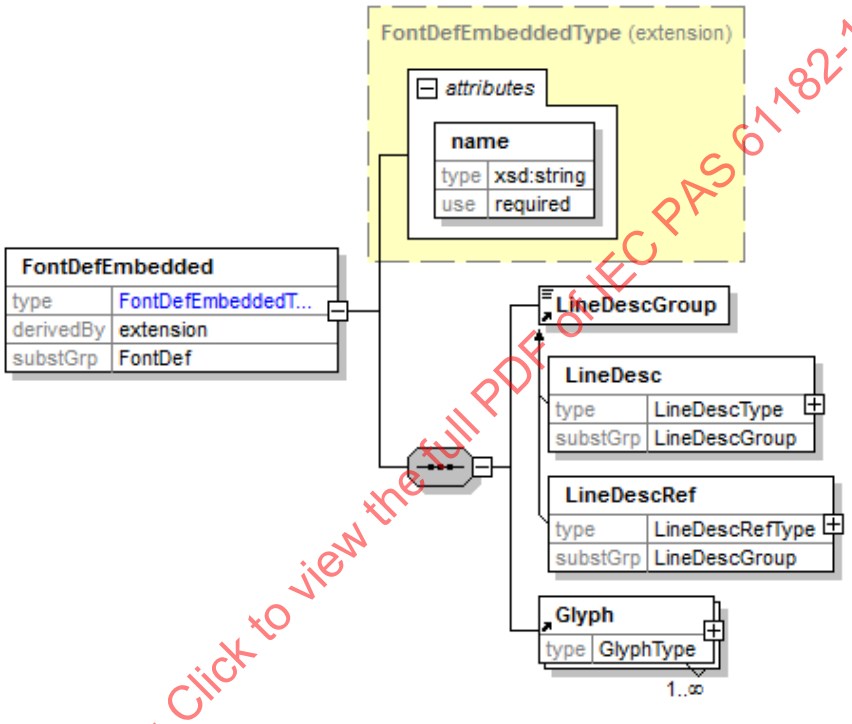


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
DictionaryFont	dictionaryFontType	An element that consists of all the named font descriptions within the IPC-2581 file.	0-n
units	unitsType	An enumerated string that may be one of the following: MILLIMETER | MICRON | INCH.	1-1
EntryFont	EntryFontType	An element that establishes the individual characteristic associated with a font substitution character or characters that have been identified by the user in the IPC-2581 file.	0-n
id	qualifiedNameType	The unique qualified name description assigned as an id for any `EntryFont` for XML schema substitution.	1-1
FontDef	ABSTRACT	A part of the substitution group that permits the substitution of individual `Glyphs (EmbeddedFontDef)` or known font types through reference of a URN `(ExternalFontDef)`.	1-n

The organization of the DictionaryFont is accomplished in accordance with the substitution group description criteria. The FontDef description may be any character represented as a Glyph according to the specific characteristics identified in the following paragraphs. FontDef may also be a know font through reference of a URN. The FontRef function is used in the body of the IPC-2581 file when a specific font has been predefined, assigned a name, and the unique "id" is referenced in the file. This feature permits the substitution of the standard Helvetica font; Font descriptions are only contained in the DictionaryFont and are not instantiated in the body of the IPC-2581 file.

4.9.1 FontDefEmbedded

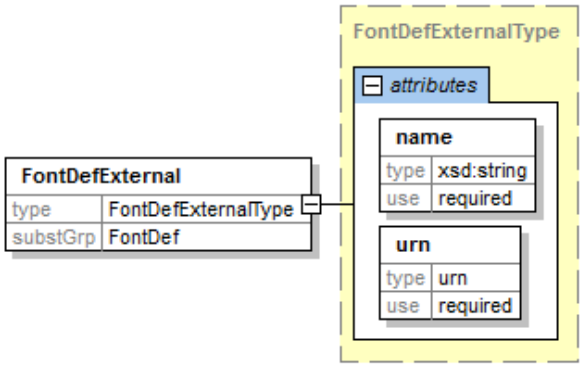
The FontDefEmbedded element is used to capture individual characters and store them in the DictionaryFont.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
FontDefEmbedded	FontDefEmbeddedType	A substitution for FontDef that identifies an individual Glyph character by a specific name and the Glyph characteristics.	0-n
name	string	A unique name related to the charCode of the Glyph character.	0-n
LineDescGroup	ABSTRACT	A substitution group that specifies the LineWidth and LineEnd characteristics of the Font by reference to a predefined LineDesc or specified when the font is instantiated.	1-1
Glyph	GlyphType	The element that contains the description of all the character definitions defined in the user developed font	1-n

4.9.2 FontDefExternal

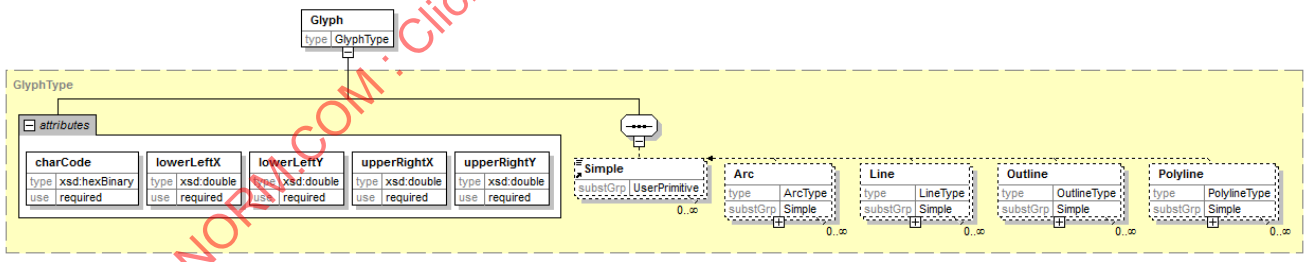
The `FontDefExternal` element is used to capture known font characters and store the reference in the `DictionaryFont`.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
FontDefExternal	FontDefExternalType	A substitution for `FontDef` that identifies a known group of characters through their font style.	0-n
name	string	A unique name related to the character set of a known font.	0-n
urn	urn	A specific `urn` that makes reference to a known font that has the appropriate permission to use the font substitution in a 2581 file.	1-1

4.9.3 FontDef: Glyph

The `Glyph` character set is a group of user defined characters that will be reference by the text command in the file. `Glyph` permits the user to define a special set of characters that need description as a part of the IPC-2581 file. Each character is in a `BoundingBox` that contains all the line strokes needed to completely define each character in the set. The point of origin is the lower left hand corner of the `BoundingBox`. The `lowerLeftX` and `lowerLeftY` point of origin will be used to position, rotate or mirror image all `Glyph` characters.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Glyph	GlyphType	The element that contains the description of all the character definitions defined in the user developed font.	0-n
charCode	hexBinary	A code used by the user to identify a special character.	0-1
lowerLeftX	double	The lower left hand x dimension of the rectangular area encompassing the character.	1-1
lowerLeftY	double	The lower left hand y dimension of the rectangular area encompassing the character.	1-1
upperRightX	double	The upper right hand x dimension of the rectangular area encompassing the character.	1-1

upperRightY	double	The upper right hand y dimension of the rectangular area encompassing the text character.	1-1
Simple	ABSTRACT	A substitution set of simple primitive shapes that may be any one of four geometries: `Arc`, `Line`, `Outline`, or `PolyLine`. The `LineWidth` and `LineEnd` characteristics are established by the Simple substitution	0-n

4.9.4 FontDef: Glyph combination

The developers of individual `Glyph` characters are encouraged to consider the manner in which the characters will be used. Since the `BoundingBox` surrounding the character must entirely encompass the `Glyph`, it is important to leave room in the `BoundingBox` so that the spacing between characters is consistent with the character style.

Using individual `Glyph` characters does not present a problem, however `Glyph` combinations should match the style of `Glyph` chosen by the user. Since it is mostly the `Text` element that instantiates fonts, the `Glyph BoundingBox` must fit into the `Text BoundingBox`. This is a simple strategy when all the `Glyph` characters are of a similar height. In this instance the "Y" dimensional differences between `Glyph` characters bounding boxes and `Text` bounding boxes should be identical in order to keep the `Glyph` characters within the `Text` box. Under those circumstances, only the spacing between characters needs to be considered.

As an example consider the word simple instantiated in capital letters or lower case. When instantiating a `Text` string, the `Glyph` for "SIMPLE" would only require equal bounding boxes in the character height even though the character "I" would have a smaller character width than the character "M". A different strategy for `Glyph` development must be used if the `Text` string were to call for "Simple". Since character height is different, it is recommended that the `Glyph BoundingBox` consider its location position in a `Text BoundingBox` according to the rule that all characters must be inside the `Text` box.

Figure 7 shows and example of `Glyph` bounding boxes related to the `Text BoundingBox`. The characters line up even though they are positioned on the lower y-coordinate. They were designed along a construction line to have this condition occur.

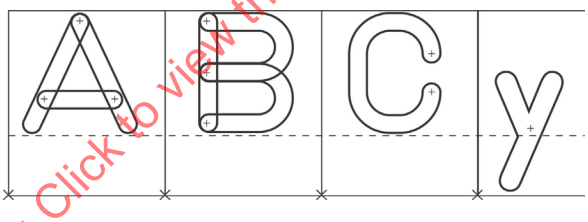
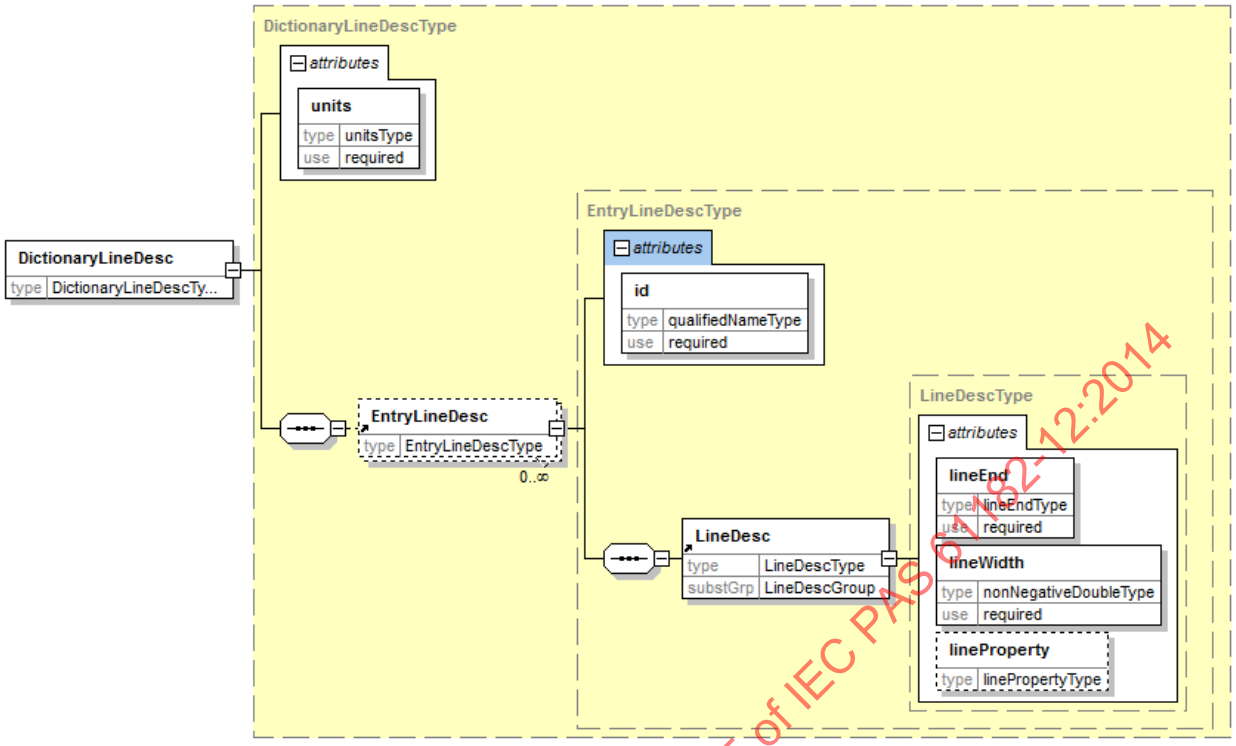


Figure 7 Glyph bounding rectangles to Text bounding box relationships

4.10 Content: DictionaryLineDesc

The `DictionaryLineDesc` is intended to provide lookup information on predefined line descriptions. The `DictionaryLineDesc` is maintained as part of a substitution group schema. The intent is to have line descriptions available that are identified by their characteristics and a specific name (id). They may be reused throughout the file as appropriate. The name (id) of a `LineDesc` must be unique within the `DictionaryLineDesc`.



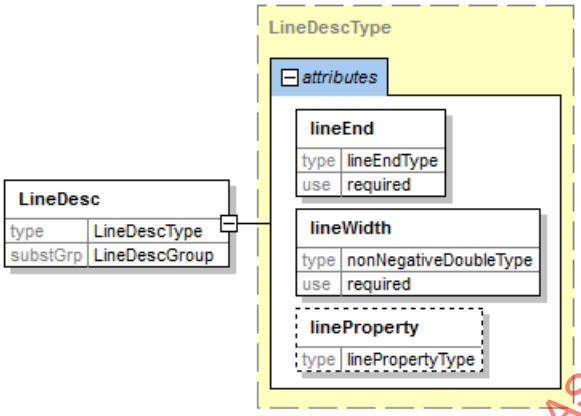
Attribute / Element Name	Attribute / Element Type	Description	Occurrence
DictionaryLineDesc	DictionaryLineDesc Type	An element that contains substitution group information using line description criteria, predefined by the user for reuse in the file.	0-1
units	unitsType	An enumerated string that may be one of the following: MILLIMETER | MICRON | INCH.	1-1
EntryLineDesc	EntryLineDescType	An element that establishes the individual characteristic associated with a line description substitution group that has been identified by the user of the IPC-2581 file.	0-n
id	qualifiedNameType	The unique qualified name description assigned as an id for any `LineDesc` for XML schema substitution.	1-1
LineDesc	LineDescType	An element that defines the `LineEnd, LineWidth,` and `LineProperty` characteristics to become part of the substitution group for defining line descriptions.	1-n

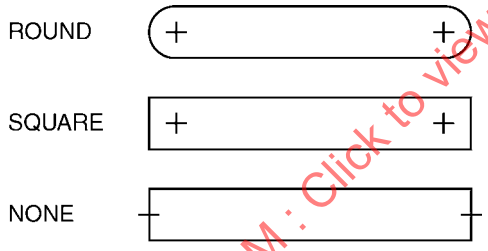
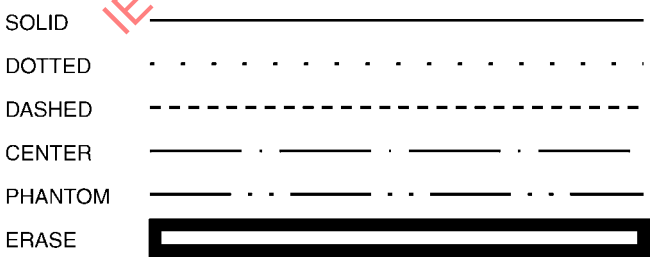
```
<DictionaryLineDesc units = "MILLIMETER">
    <EntryLineDesc id = "FineLine">
        <LineDesc lineEnd = "ROUND" lineWidth = "0.05"/>
    </EntryLineDesc>
    <EntryLineDesc id = "MediumLine">
        <LineDesc lineEnd = "NONE" lineWidth = "0.15"/>
    </EntryLineDesc>
        <EntryLineDesc id = "HeavyLine">
        <LineDesc lineEnd = "SQUARE" lineWidth = "0.30"/>
    </EntryLineDesc>
</DictionaryLineDesc>
```


The organization of the `DictionaryLineDesc` is accomplished in accordance with the substitution group description criteria. The `lineDesc` description defines the `LineEnd` and `LineWidth` according to the specific characteristics identified in the following paragraphs. The `LineDescRef` function is used in the body of the IPC-2581 file when a specific `LineDesc` has been predefined, assigned a name, and the unique “id” is referenced in the file. This feature permits the use of either a predefined `LineDesc`, or defining the details of a `LineDesc` within the file. The description in the file must contain all the features of a line description under the rules of the `LineDesc` definition.

4.10.1 LineDesc

The `LineDesc` element is used throughout the 2581 file to establish the characteristics of `lineEnd` `lineWidth`, and `lineProperty` descriptions. The `LineDesc` definition is according to the following characteristics.

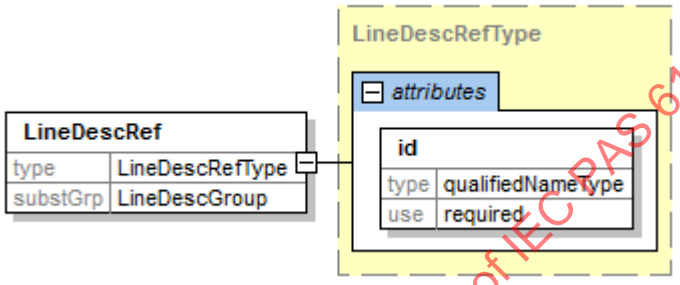


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
LineDesc	LineDescType	An element that defines the characteristics of a line. The `Units` are defined when the `LineDesc` is instantiated; Units is a part of the characteristics when `LineDesc` is contained in the `DictionaryLineDesc`.	1-n
lineEnd	lineEndType	A description of the line ends used in any graphic description. The lineEnd description is an enumerated string that may be ROUND | SQUARE | NONE.	1-1
		This diagram illustrates the `LineDesc/@lineEnd` attribute	
lineWidth	nonNegativeDouble Type	A dimensional characteristic that defines the nominal `lineWidth` of a `Line`, `Polyline`, or `Arc` element. The dimensions are in the same category as all dimensions contained in the IPC-2581 file.	1-1
lineProperty	linePropertyType	The line property is one of SOLID, DOTTED, DASHED, CENTER, PHANTOM or (solid) ERASE. The default is SOLID.	0-1
		This diagram illustrates the `lineProperty` attribute. lineProperty attributes require the following rules to define width, end, and spacing characteristics for the line segments, dashes and dots.	
SOLID Lines	Requires lineWidth with lineEnd default as ROUND		

DOTTED Lines	Dot Diameter 1X lineWidth; Space is 2X lineWidth as the default
DASHED Lines	Dash Length 3X lineWidth; space 3X line Width as the default
CENTER Lines	Length 6X lineWidth; space is 2X lineWidth; Dot =1X lineWidth
PHANTOM Lines	Length 6X lineWidth; Space is 2X lineWidth; Dots =1X lineWidth
ERASE Lines	Requires lineWidth with lineEnd default as NONE

4.10.2 LineDescRef

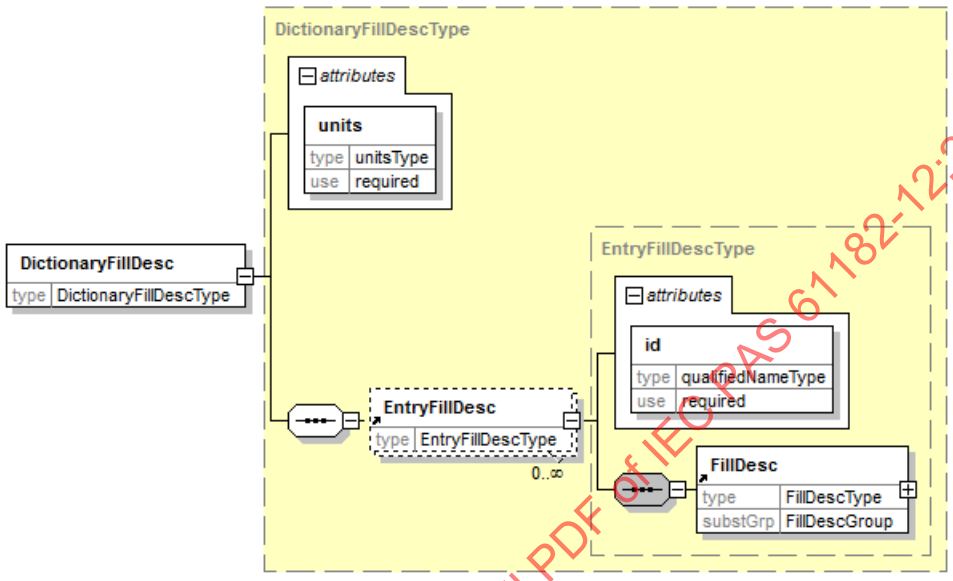
The `LineDescRef` element is used throughout the 2581 file to establish the relationship to a previously defined `LineDesc`. The `Units` of the predefined `LineDesc` must match the `Units` of the `Ecad` section in which it is instantiated. The `LineDescRef` definition is according to the following characteristics.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
LineDescRef	LineDescRefType	An element used to reference a previously defined `LineDesc`, contained in the `DictionaryLineDesc`.	1-n
Id	qualifiedNameType	The identification of the `LineDesc` being referenced from the `DictionaryLineDesc`.	1-1

4.11 Content: DictionaryFillDesc

The `DictionaryFillDesc` is intended to provide lookup information on predefined fill descriptions. The `DictionaryFillDesc` is maintained as part of a substitution group schema. The intent is to have fill descriptions available that are identified by their characteristics and a specific name (id). They may be reused throughout the file as appropriate. The name (id) of a `FillDesc` must be unique within the `DictionaryFillDesc`.

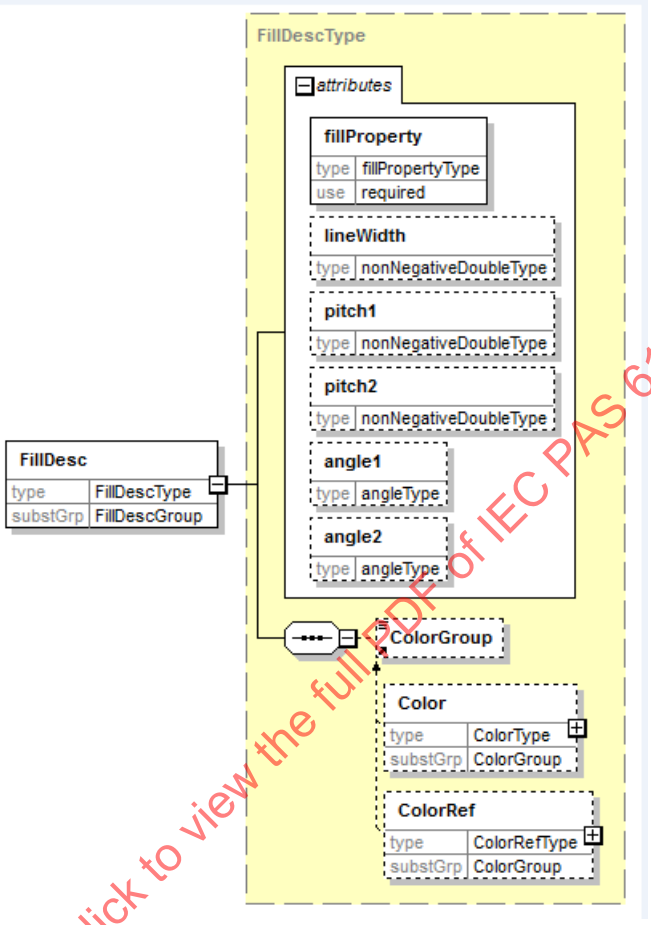


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
DictionaryFillDesc	DictionaryFillDesc Type	An element that contains substitution group information using fill description criteria, predefined by the user for reuse in the file.	0-1
units	unitsType	An enumerated string that may be one of the following: MILLIMETER | MICRON | INCH.	1-1
EntryFillDesc	EntryFillDescType	An element that establishes the individual characteristic associated with a fill description substitution group that has been identified by the user of the IPC-2581 file.	0-n
id	qualifiedNameType	The unique qualified name description assigned as an id for any `FillDesc` for XML schema substitution.	1-1
FillDesc	FillDescType	An element that defines the `FillProperty` and Color characteristics to become part of the substitution group for defining Fill descriptions.	1-n

The organization of the `DictionaryFillDesc` is accomplished in accordance with the substitution group description criteria. The `FillDesc` description defines the `FillProperty` and `Color` according to the specific characteristics identified in the following paragraphs. The `FillDescRef` function is used in the body of the IPC-2581 file when a specific `FillDesc` has been predefined, assigned a name, and the unique “id” is referenced in the file. This feature permits the use of either a predefined `FillDesc`, or defining the details of a `FillDesc` within the file. The description in the file must contain all the features of a Fill description under the rules of the `FillDesc` definition.

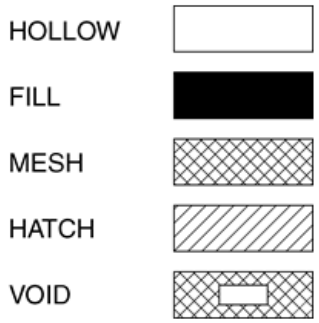
4.11.1 FillDesc

The `FillDesc` element is used throughout the 2581 file to establish the characteristics of `FillProperty`, `lineWidth`, and `Color` descriptions. The `FillDesc` definition is according to the following characteristics.



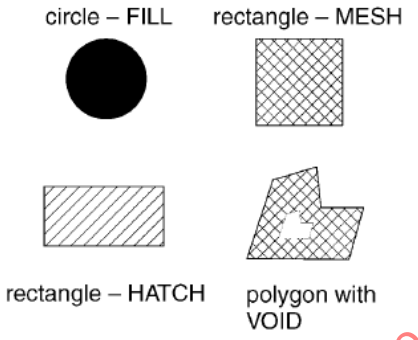
Attribute / Element Name	Attribute / Element Type	Description	Occurrence
FillDesc	FillDescType	An element that defines the characteristics of a fill property. The `Units` are defined when the `LineDesc` is instantiated; Units is a part of the characteristics when `FillDesc` is contained in the `DictionaryFillDesc`.	1-n
fillProperty	fillPropertyType	The texture of the fill is one of HOLLOW, HATCH, MESH, FILL or VOID. The default is HOLLOW. The VOID feature is only applicable if it occurs within a previously defined HATCH, MESH, or FILL feature. All portions of the VOID must be contained within the previously defined feature.	0-1
lineWidth	nonNegativeDouble Type	The width of the lines used in a HATCH or MESH. (This attribute only applies to the fill types HATCH and MESH.)	0-1
pitch1	nonNegativeDouble Type	The distance between the first set of lines in a HATCH or MESH. The default pitch between the hatch lines is 4 times the `lineWidth`. (This attribute only applies to the fill types HATCH and MESH.)	0-1
pitch2	nonNegativeDouble Type	The distance between the second set of lines in a MESH. The default pitch between the hatch lines is 4 times the `lineWidth`. (This attribute only applies to the fill type MESH.)	0-1

angle1	angleType	The angle of a set of lines in a HATCH or a MESH. The angle is measured relative to the x-axis of the local coordinate system. The range of values is limited to between 0 and 180 degrees. The default is 45 degrees. (This attribute only applies to the fill types HATCH and MESH.)	0-1
angle2	angleType	The angle of the second set of lines in a MESH. The angle is measured relative to the x-axis of the local coordinate system. The angle must be between 90 and 180 degrees. The default is 135 degrees. (This attribute only applies to the fill type MESH.)	0-1
ColorGroup	ABSTRACT	An element that is a substitution group which can be used to define a particular `Color` for the surface finish, either in the body of the file or by reference to a predefined `Color` contained in `DictionaryColor`.	0-1



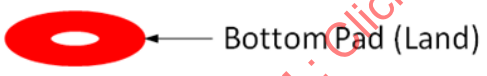
This diagram illustrates the `FillDesc` type Attribute.

The `FillDesc type` is set to SOLID in the examples to provide an outline around the shapes that are painted with MESH, HATCH, or VOID. The VOID rectangle feature is within a previously defined rectangle that has been defined with HATCH lines. As shown all of the VOID characteristics are within the boundaries of the larger HATCH rectangle feature



This diagram illustrates the `FillDesc` type Attribute

The `fillDesc` type is set to SOLID in the examples to provide an outline around the shapes that are painted with MESH, HATCH, or VOID. The VOID within the polygon is completely contained within its boundaries as required.



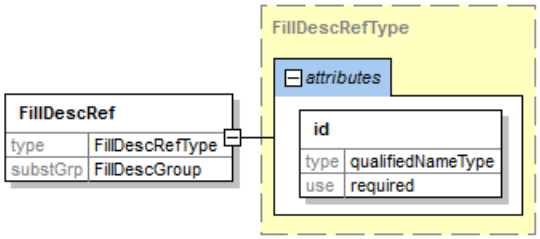
The example may be defined as a UserPrimitive using a Circle fill description with a circular VOID in its center. The User Primitive name may be used in the padstack descriptions.

The fillProperty VOID means the element shape clears an area with respect to contours. Elements (and references to elements) with fillProperty VOID can appear only as elements in a Set element or a UserSpecial element shape. Elements with fillProperty VOID apply only to the elements that appear before the VOID element in the Set element or in the UserSpecial element. Elements with fillProperty VOID only clear filled contours.

A contour is a polygon which is a closed shape whose edges do not cross. The edges of elements with fillProperty VOID do not cross other elements with fillProperty VOID and do not cross the edges of the owning contour element. The order of voids and polygons within Contours and Sets determines their containment order. The outermost polygon comes first. Polygons are before voids that are contained in them. Voids are before polygons that are contained inside them.

4.11.2 FillDescRef

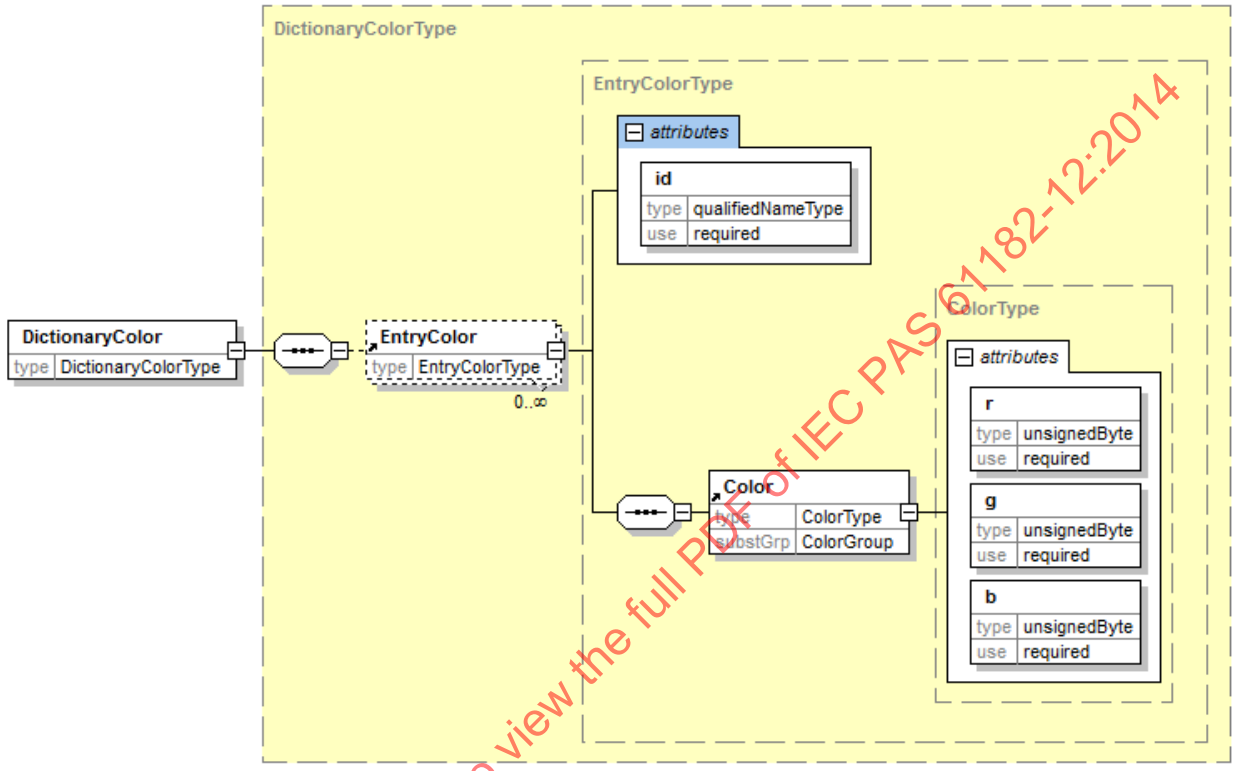
The `FillDescRef` element is used throughout the 2581 file to establish the relationship to a previously defined `FillDesc`. The `Units` of the predefined `FillDesc` must match the `Units` of the `Ecad` section in which it is instantiated. The `FillDescRef` definition is according to the following characteristics.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
FillDescRef	FillDescRefType	An element used to reference a previously defined `FillDesc`, contained in the `DictionaryFillDesc`.	1-n
Id	qualifiedNameType	The identification of the `FillDesc` being referenced from the `DictionaryFillDesc`.	1-1

4.12 Content: DictionaryColor

The `DictionaryColor` is intended to provide lookup information on predefined `Color descriptions`. The `DictionaryColor` is maintained as part of a substitution group schema. The intent is to have color descriptions available that are identified by their three color hues and intensity characteristics and a specific name (id). They may be reused throughout the file as appropriate. The name (id) of a `color` must be unique within the `DictionaryColor`.

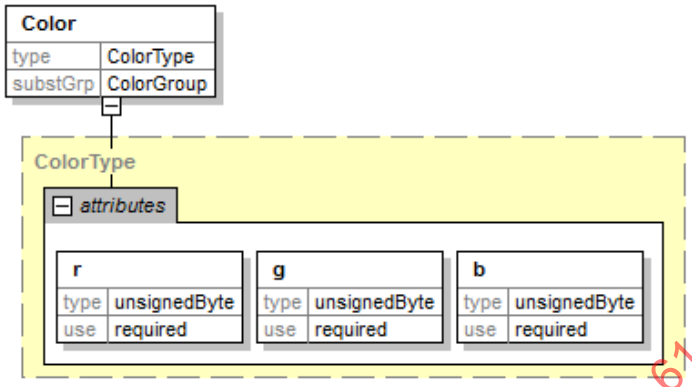


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
DictionaryColor	DictionaryColorType	An element that contains substitution group information using color description criteria, predefined by the user for reuse in the file.	0-1
EntryColor	EntryColorType	An element that establishes the individual characteristic associated with a color substitution that has been identified by the user in the IPC-2581 file.	0-n
id	qualifiedNameType	The qualified description name assigned as an id standard for XML schema color substitution.	1-1
Color	ColorType	A specific color identified through the instantiation of the three color spectrum as a part of the schema within the IPC-2581 file.	1-n

The organization of the `DictionaryColor` is accomplished in accordance with the substitution group description criteria. The `Color` description may be any combination of the three color hues (red, green and blue) at the appropriate intensity according to the specific characteristics identified in the following paragraphs. The `colorRef` function is used in the body of the IPC-2581 file when a specific `Color` has been predefined, assigned a name, and the unique “id” is referenced in the file. This feature permits the use of either a predefined `Color`, or defining the details of a `Color` within the file. The description in the file must contain all the features of a particular `Color` under the rules of the particular `color` definition.

4.12.1 Color

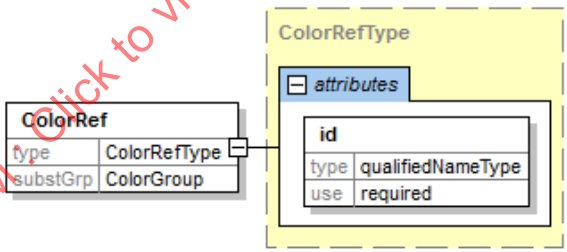
`Color` is defined by three values that represent the red, green and blue components of the composite color. If r, g, and b are all set to 0, the color is black. If all values are 255 then the color is white. The attributes of a `Color` element are defined as follows:



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Color	ColorType	The specific description of the color represented by the three attributes.	1-1
r	unsignedByte	Defines the red color intensity as a value between 0 and 255.	1-1
g	unsignedByte	Defines the green color intensity as a value between 0 and 255.	1-1
b	unsignedByte	Defines the blue color intensity as a value between 0 and 255.	1-1

4.12.2 ColorRef

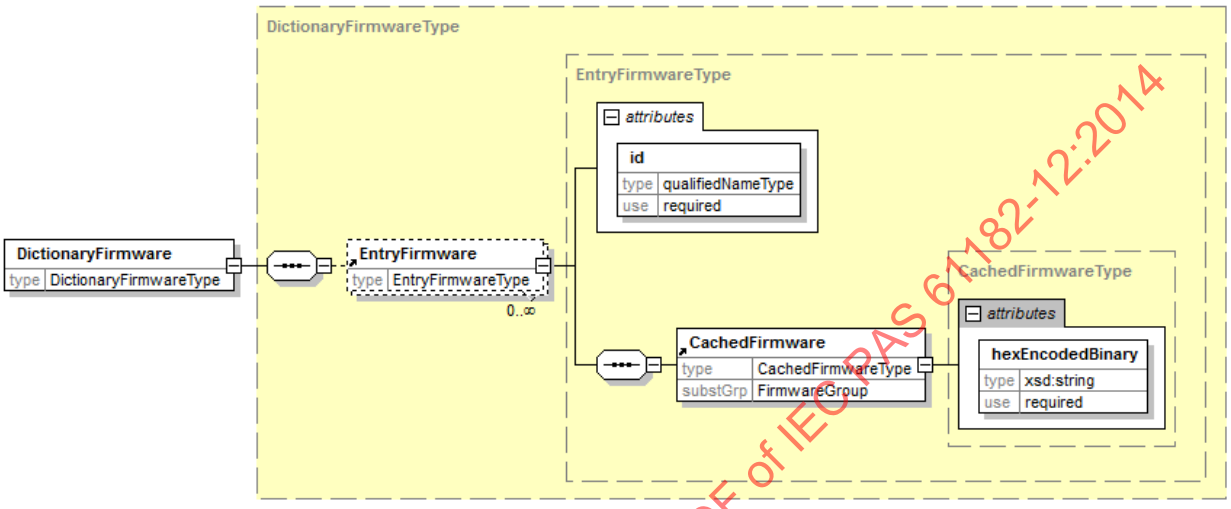
The `ColorRef` element is used throughout the 2581 file to establish the relationship to a previously defined `Color`. The `ColorRef` definition is according to the following characteristics.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
ColorRef	ColorRefType	The specific reference to a predefined color represented by the three attributes and contained in the `DictionaryColor`.	1-1
id	qualifiedNameType	The qualified description name assigned as an `id` standard for XML schema color substitution.	1-1

4.13 Content: DictionaryFirmware

The `DictionaryFirmware` is intended to provide lookup information on predefined `CachedFirmware`. The `DictionaryFirmware` is maintained as part of a substitution group schema. The intent is to have firmware descriptions available that are identified by their characteristics and a specific name (id). They may be reused throughout the file as appropriate. The name (id) of a `CachedFirmware` must be unique within the `DictionaryFirmware`.

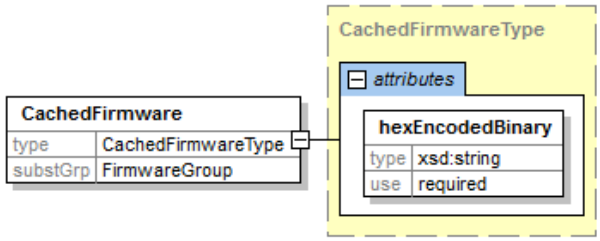


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
DictionaryFirmware	DictionaryFirmwareType	An element that consists of all the named `CachedFirmware` within the IPC-2581 file.	0-n
EntryFirmware	EntryFirmwareType	An element that establishes the individual characteristic associated with a Firmware entry substitution that has been identified by the user in the IPC-2581 file.	0-n
id	qualifiedNameType	The qualified description name assigned as an `id` for XML schema substitution of firmware.	1-1
CachedFirmware	CachedFirmwareType	Any CachedFirmware identified and contained in the `DictionaryFirmware` as a part of the schema within the IPC-2581 file.	1-n

The organization of the `DictionaryFirmware` is accomplished in accordance with the substitution group description criteria. The `CachedFirmware` description may be any `hexEncodedBinary` string according to the specific characteristics identified in the following paragraphs. The `FirmwareRef` function is used in the body of the IPC-2581 file when a specific `CachedFirmware` has been predefined, assigned a name, and the unique "id" is referenced in the file. This feature permits the use of either a predefined `CachedFirmware`, or defining the details of the `Firmware` associated with a particular `Component` identified by reference designator in the `Step` section within the file. The description in the file must contain all the features of a particular `Firmware` under the rules of the particular encoded definition.

4.13.1 CachedFirmware

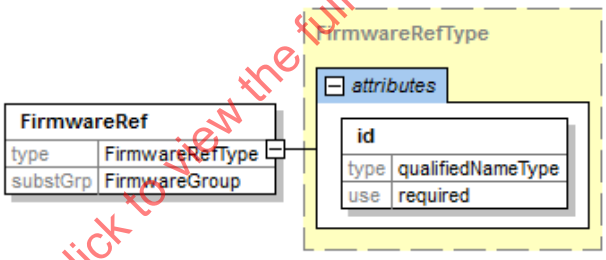
The `CachedFirmware` element is used to describe firmware that will be contained in the `DictionaryFirmware`. The details are in accordance to the following characteristics.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
CachedFirmware	CashedFirmwareType	The firmware description needed by a particular component that becomes part of the predefined firmware in the `DictionaryFirmware`.	1-1
hexEncodedBinary	string	An attribute defining the binary code that **shall** be added to a particular component and which is contained in the `DictionaryFirmware`.	1-1

4.13.2 FirmwareRef

The `FirmwareRef` element is used throughout the 2581 file to establish the relationship to a previously defined `CashedFirmware`. The `FirmwareRef` definition is according to the following characteristics.



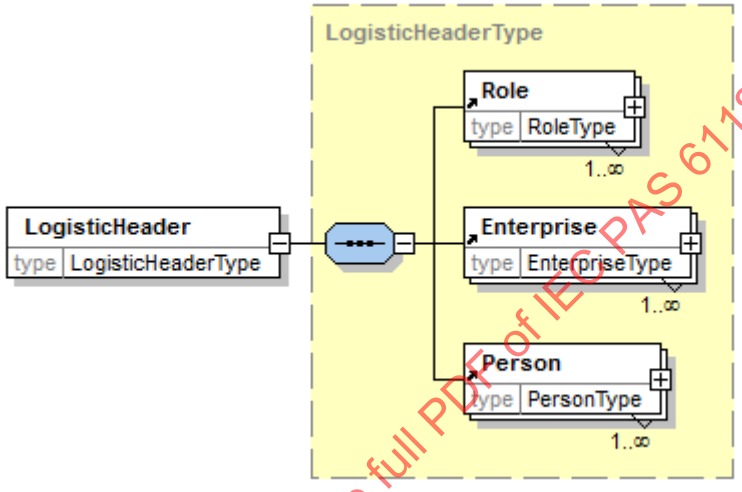
Attribute / Element Name	Attribute / Element Type	Description	Occurrence
FirmwareRef	FirmwareRefType	The specific reference to firmware previously defined and contained in the `DictionaryFirmware`.	1-1
id	qualifiedNameType	The qualified name of `CachedFirmware` contained in the `DictionaryFirmware`.	1-1

5 LOGISTIC HEADER

The `LogisticHeader` element consists of information about the owner of the IPC-2581 file. It can be used for configuration management or contact information. The enterprise is also linked to the Bill of Material and the Approved Vendor List.

5.1 LogisticHeader

The `LogisticHeader` describes information pertaining to ordering and delivery. This includes the role played by the individual providing ordering and delivery information, the title of the person responsible and the address and particulars of the enterprise.

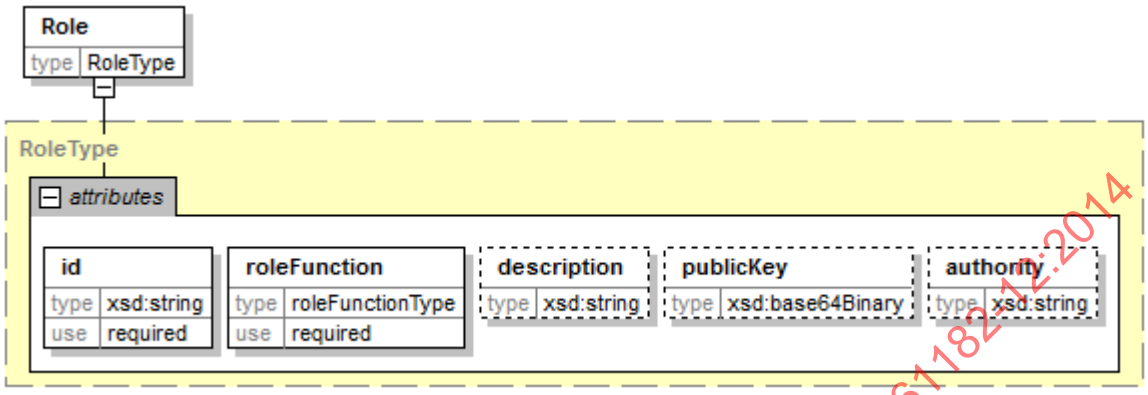


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
LogisticHeader	LogisticHeaderType	The `LogisticHeader` describes information pertaining to ordering and delivery.	1-1
Role	RoleType	Defines the type of activity within the enterprise.	1-n
Enterprise	EnterpriseType	Provides information about the company identified in the BOM or Avl schema.	1-n
Person	PersonType	Identifies the person involved in sending receiving or having anything to do in the trading partner relationship.	1-n

```
<LogisticHeader>
   <Role name = "OWNER" description = "IPC Staff" publicKey = "x6d8rf7xd90mJHR13" authority = "25XX standard development"/>
   <Enterprise id = "IPC" name = "IPC Incorporated - Association Connecting Electronics Industries" code = "57834" codeType = "CAGE"
               address1 = "3000 Lakeside Drive " city = "Bannockburn" stateProvince = "Illinois" country = "US" postalCode = "60015" phone
                = "+1-847-597-2839" fax = "+1-847-597-2839" email = "Dieterbergman@ipc.org" url = "www.ipc.org"/>
   <Person name = "Dieter W. Bergman" enterpriseRef = "IPC" title = "Director Technology Transfer" email = "Bergdi@ipc.org" phone =
               "847-597-2839" fax = "847-615-7105" mailstop = "309S " roleRef = "Owner"/>
</LogisticHeader>
```

5.2 Role

A `Role` element declares a type of activity within an `Enterprise`. The attribute values of the `Role` based on the requirements of the activities performed by the role.



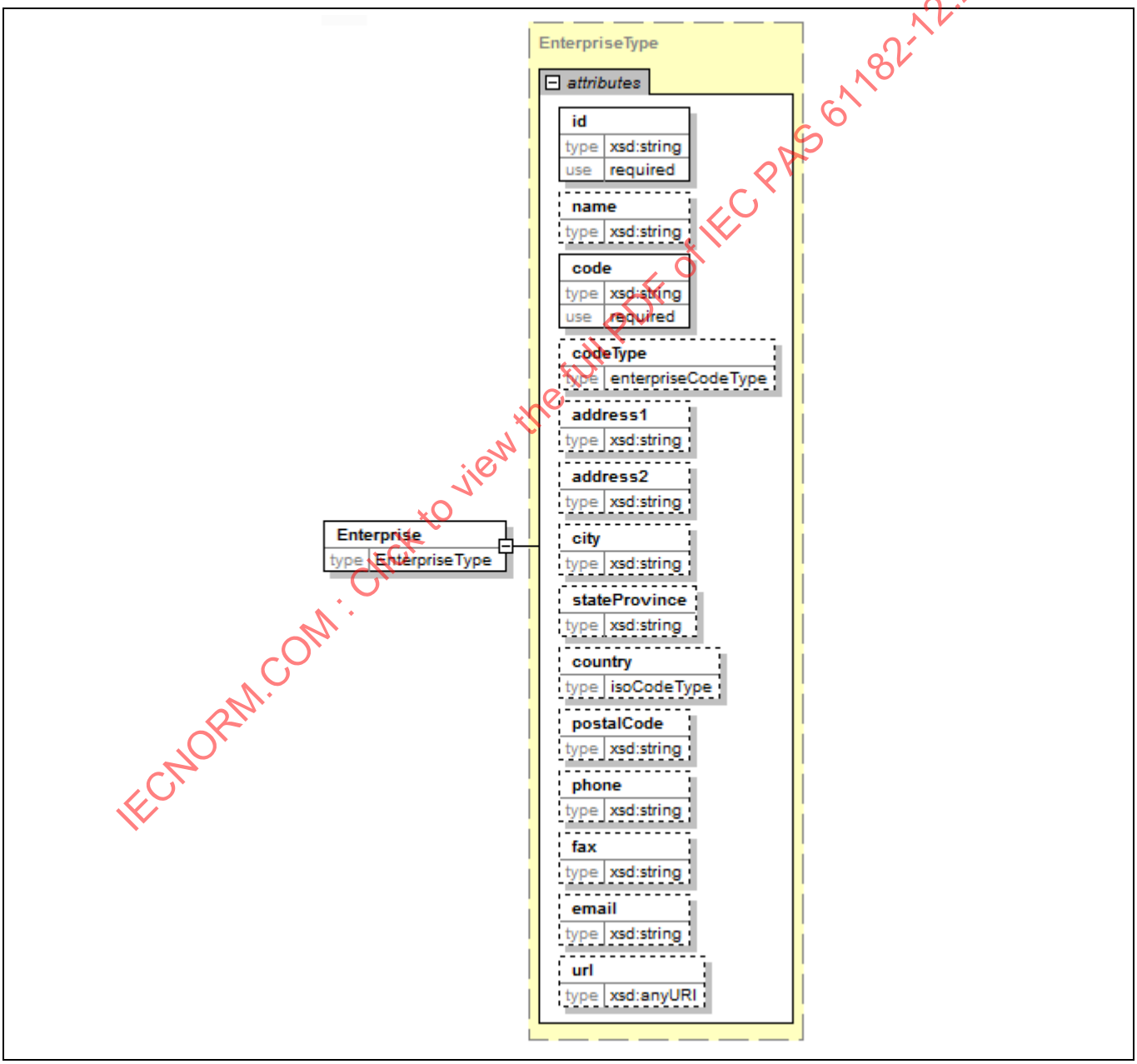
Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Role	RoleType	Defines the type of activity within the enterprise.	1-n
id	shortNameType	A short name that must be consistent throughout the 2581 file that provides the identification of the role. A globally unique name that identifies the specific role responsibility associated with the general role descriptions.	1-1
roleFunction	roleFunctionType	The attribute that defines a globally unique identification of the role within an enterprise The description uniquely identifies a role type used by the enterprise. The name is a `roleType` (a restricted xsd:string) that must be unique within the global (top-level) namespace of the IPC-2581 file. The standard IPC role types are defined as follows: SENDER: Identifies the person sending out the IPC-2581 file. OWNER: Identifies the person who maintains the configuration management of the IPC-2581 file and has the right to increment the file history number of the IPC-2581 file. RECEIVER: Identifies the person receiving the IPC-2581 file. DESIGNER: Identifies the designer of the product described in the IPC-2581 file. ENGINEER: Identifies the engineer who is responsible for the product described in the IPC-2581 file. BUYER: Identifies the person who is responsible for payment. CUSTOMERSERVICE: Identifies the customer service representative who is responsible for the account. DELIVERTO: Identifies the person in the receiving department who takes possession of the shipment in the name of the enterprise. BILLTO: Identifies the person in the billing or purchasing department to whom the billing should be addressed. OTHER: Any other name however completing the description attribute is recommended	1-1
description	string	The `description` attribute further defines a role within an enterprise in order to highlight the specific capabilities of the `roleFunction` in harmony with the `FunctionMode` of the file. (The `description` is optional if the IPC definition is to be used, but useful in order to differentiate between several ENGINEER functions.)	0-1
publicKey	base64Binary	The `publicKey` attribute of a role holds the public encryption key if one exists for the role. The key is base64 encoded. (See IETF *RFC 1421* for the base64 algorithm) If a role `publicKey` is present it can be used instead of a `Person`/`publicKey` to encrypt data. The role's `publicKey` is used to encrypt data so only that someone with access to the role's private key can access the data.	0-1

authority	string	The access level associated with this role as defined by the system referenced by `externalConfigurationControlEntryPoint`	0-1

```
<LogisticHeader>
    <Role id = “CircuitDesign” function = “ENGINEER” description = “In charge of Impedance Control”/>
    <Role id = “LayoutPerson” function = “ENGINEER”/>
    <Role id = “PurchasingNo1” function = “BUYER” description = “To be informed of cost modification”/>
    <Role id = “LayoutEngineer” function = “DESIGNER”/>
</LogisticHeader>
```

5.3 Enterprise

The `Enterprise` element provides information about an enterprise that will be referenced within the IPC-2581 file. The attributes of the `Enterprise` element are defined as follows:

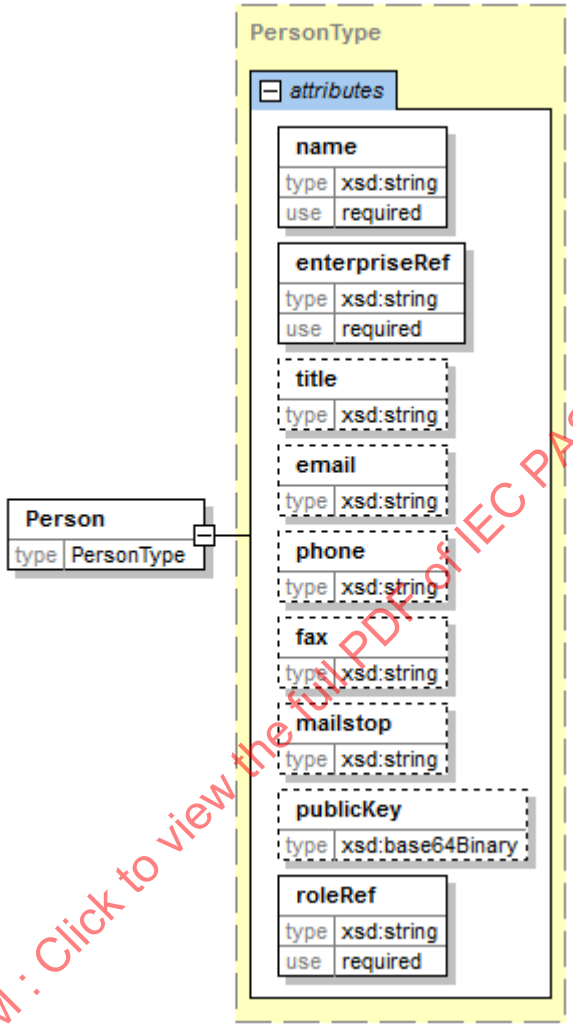


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Enterprise	EnterpriseType	Provides information about the company identified in the `Bom` or `Avl` schema.	1-n
id	shortNameType	The id uniquely identifies an enterprise throughout the IPC-2581 file. The id is a `shortName` data type (a restricted xsd: string) that must be unique within the global (top-level) namespace of the IPC-2581 file. (Suggest “XYZ”, “ACME”…).	1-1
name	string	The full name of the enterprise.	0-1
code	string	Value of a CAGE or DUNS code. If no CAGE or DUNS code is available use “NONE” as the value of the code attribute.	1-1
codeType	enterpriseCodeType	One of DUNS or CAGE. The default is DUNS. If the DUNS codeType is selected, then the `code` attribute of `Enterprise` is the D-U-N-S Number of the enterprise. (See the reference to D&B D-U-N-S Number at http://www.dnb.com/) If the CAGE `codeType` is used then the CAGE code of the `Enterprise` is in the code attribute of Enterprise. (see http://www.dscc.dla.mil/offices/sourcedev/cage.html).	0-1
address1	string	The street address of the `Enterprise`.	0-1
address2	string	Additional address information for the `Enterprise`.	0-1
city	string	The `city`.	0-1
stateProvince	string	The state or province.	0-1
country	isoCodeType	The two-letter ISO country code from the ISO 3166 standard. (See ftp://info.ripe.net/iso3166-countrycodes). The default country is “US.”	0-1
postalCode	string	The postal code.	0-1
phone	string	The general phone number for the `Enterprise`.	0-1
fax	string	The phone number of the `Enterprise` fax machine.	0-1
email	string	The email address for the `Enterprise`.	0-1
url	anyURI	The Internet HTTP Web address of the `Enterprise`.	0-1

<LogisticHeader>
<Role name = “ENGINEER” description = “responsible for data in file”/>
<Enterprise id = “Acme” name = “Acme Tool and Die Company Inc.” code = “1433” codeType = “DUNNS” address1 = “7347 Concorde Ave.” address2 = “suite 42” city = “Camden” stateProvince = “NJ” country = “US” postalCode = “08780” phone = “609-458-5943” fax = “609-458-5900” email = “AcmeCorp@mindspring.com” url = “www.Acmeproducts.com”/>
<Enterprise Id = “Masters” name = “Master Spring Manufacturer” code = “NONE” address1 = “3793 Varembe Ave.” address2 = “Room 412” city = “Geneva” stateProvince = “Switzerland” country = “CH” phone = “+ 49-22-47 64 84” email = “masters@swisscom.ch”/>
</LogisticHeader>

5.4 Person

The `Person` element provides information about a person who will be referenced within the IPC-2581 file. The attributes of a `Person` element are defined as follows:



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Person	PersonType	Identifies the person involved in sending receiving or having anything to do in the trading partner relationship.	1-n
name	string	A string that uniquely identifies the person throughout the IPC-2581 file. The Name must be unique within the global (top-level) namespace of the IPC-2581 file. It may be the full legal name or a known abbreviation.	1-1
enterpriseRef	string	The shortName of the person's company or enterprise. If no enterprise exists, the term "SELF" should be used.	1-1
title	string	The job title of the person.	0-1
email	string	The email address of the person.	0-1
phone	string	The phone number of the person.	0-1
fax	string	The fax machine phone number of the person.	0-1

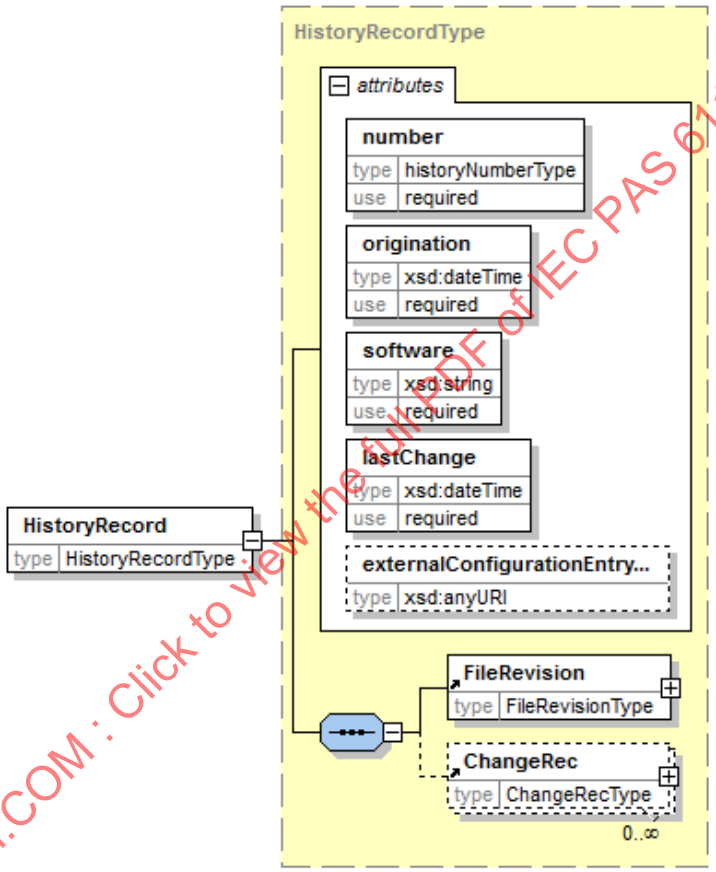
mailstop	string	The mail stop within the Enterprise, however this may be an alternate address from the Enterprise should the mail e directed somewhere else. In that event, the Enterprise shall be named, but contain no address or contact information.	0-1
publicKey	base64Binary	The publicKey attribute of a person holds the public encryption key if one exists for the person. The key is base64 encoded. (see IETF RFC 1421 for the base64 algorithm) The person's publicKey is used to encrypt data so only that person can access the data.	0-1
roleRef	string	A reference to a globally unique name (the Role "id" attribute) that identifies the specific role responsibility associated with the general "roleFunction" descriptions.	1-1
<LogisticHeader> <Person name = "Dilbert" enterpriseRef = "Acme" email = "jdilbert@acme.com" phone = "(301) 555-1212" roleRef = "Purchasing Manager"/> <Person name = "John Jones" enterpriseRef = "Philco Corp" title = "Consultant" email = jones@aol.com phone = "(301) 555-1212" mailstop = "37 Stringer Rd., Overland, OH, 56432" roleRef = "JJ Engineer" /> </LogisticHeader>			

6 HISTORY RECORD

The History Record element consists of changes performed on the file throughout its history. Several attributes are defined as part of the `History` as well as two elements. These are file revision and change records elements.

6.1 HistoryRecord

The `HistoryRecord` element provides a sequential change number for the IPC-2581 file. The number is changed every time the controlled version of the IPC-2581 file is modified. Only the file owner is allowed to change the value of `HistoryRecord/number`. The attributes of a `HistoryRecord` element are defined as follows:



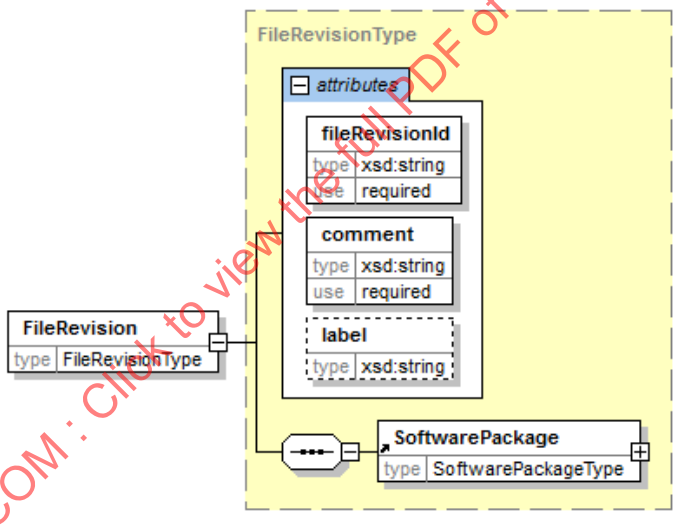
Attribute / Element Name	Attribute / Element Type	Description	Occurrence
HistoryRecord	HistoryRecordType	The `HistoryRecord` element provides a sequential change number for the IPC-2581 file. The number is changed every time the controlled version of the IPC-2581 file is modified. Also identified are the change approval conditions.	1-1
number	historyNumberType	The revision number of the IPC-2581 file. The content of this number is defined and controlled by the file owner.	1-1
origination	dateTime	The timestamp recorded when the IPC-2581 file was first created.	1-1
software	string	The name of the software tool used to create the original file.	1-1
lastChange	dateTime	The timestamp recorded when the History number was last incremented.	1-1

externalConfiguration EntryPoint	anyURI	A URI referencing a configuration control system that “owns” the IPC-2581 file contents.	0-1
FileRevision	FileRevisionType	An element that tracks the changes that have been made to an IPC-2581 file. The revision identifier does not necessarily track the revision of the product but does establish the sequence and software tools used to make the changes.	1-1
ChangeRec	ChangeRecType	An element that is required to manage the configuration of the changes made to the product during its development phases and its final configuration in the field.	0-n

```
<HistoryRecord number = "Example1" origination = "2004-02-11T12:53" software = "ECAD System" lastChange =
                    "2004-02-13T13:24:00">
   <FileRevision fileRevisionId = "Example1" comment = "Primitive layout positioning">
      <SoftwarePackage name = "Manual Interpretation" vendor = "IPC" revision = "none">
         <Certification certificationStatus = "ALPHA" certificationCategory = "DETAILEDDRAWING"/>
      </SoftwarePackage>
   </FileRevision>
</HistoryRecord>
```

6.2 FileRevision

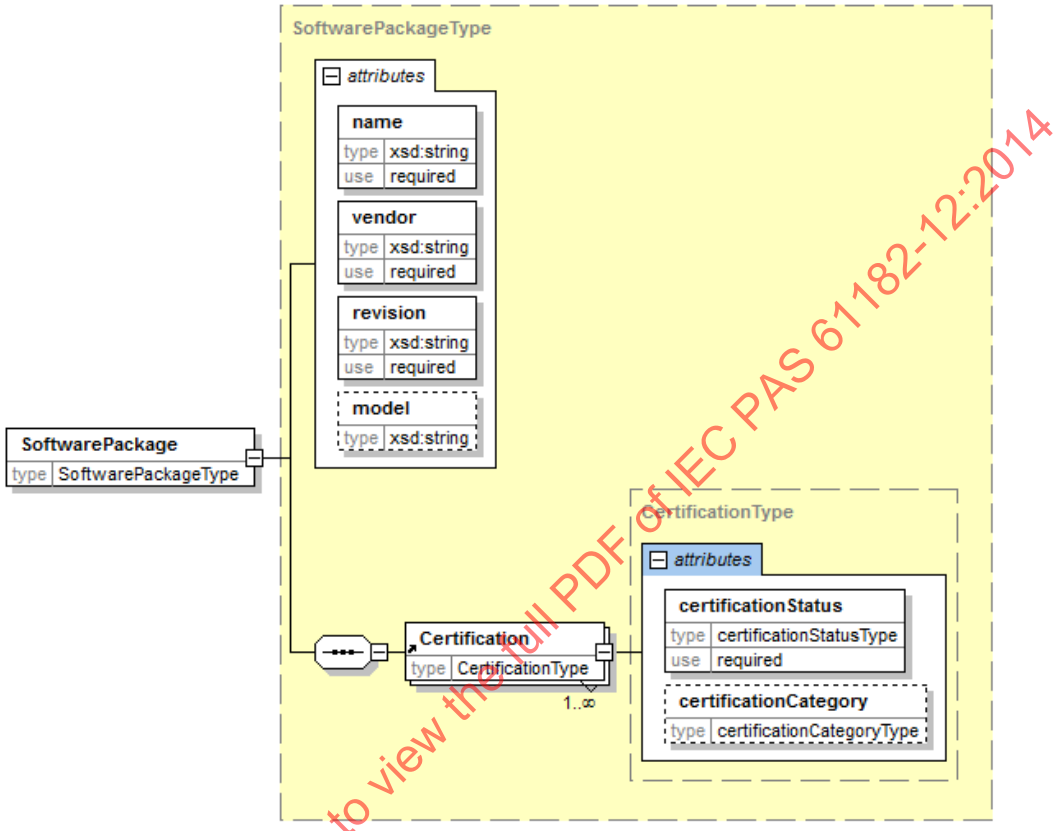
The `FileRevision` element tracks changes to the IPC-2581 file. The revision identifier does not necessarily track the revision of the product. The purpose of the `FileRevision` is to track which software tools were used to make changes to the file and the sequence in which the changes were made.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
FileRevision	FileRevisionType	An element that tracks the changes that have been made to an IPC-2581 file. The revision identifier does not necessarily track the revision of the product but does establish the sequence and software tools used to make the changes.	1-1
fileRevisionId	string	An identifier for the revision. This value may be supplied by a revision control system such as RCS, CVS, or SCCS.	1-1
comment	string	A short description of the revision, such as a changes statement entered by RCS or SCCS.	1-1
label	string	A label that can be applied to a branch head. The label can be used to associate a file revision of special significance.	0-1
SoftwarePackage	SoftwarePackage Type	A nested element, the software package that wrote this revision of the file.	1-1

6.3 SoftwarePackage

The `SoftwarePackage` element is the description of the software package that was used to create the revision to the file. This includes the revision of the software that wrote the file as well as the vendor name and platform model. Also added to the `SoftwarePackage` schema is any certification that has occurred of the software's ability to meet the requirements of the IPC-2581 standard.

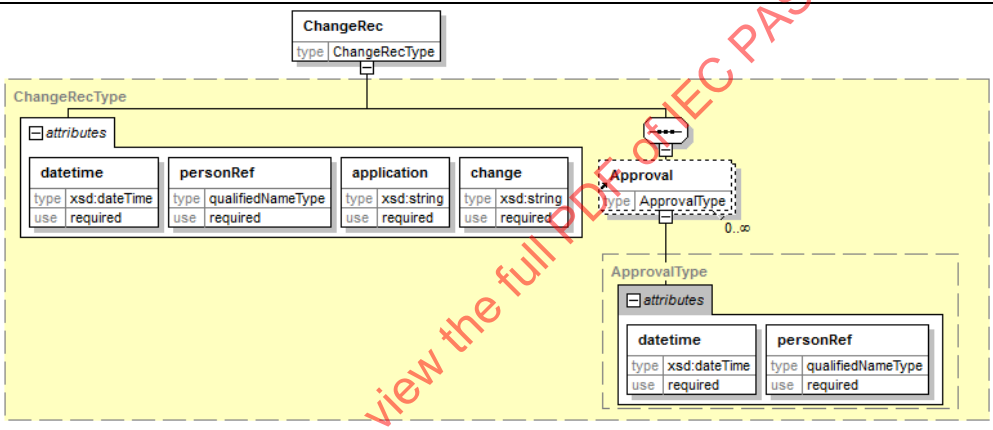


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
SoftwarePackage	SoftwarePackageType	A nested element, the software package that wrote this revision of the file.	1-1
name	string	The name of the software package that wrote the revision to the file.	1-1
vendor	string	The tool providers name both system and software package.	1-1
revision	string	The revision of the software that wrote the file.	1-1
model	string	The model of the software or release number.	0-1
Certification	CertificationType	The different certifications that the tool or software package has acquired.	1-n
certificationStatus	certificationStatusType	An enumerated string that defines the status as one of four types. ALPHA | BETA | CERTIFIED | SELFTEST.	1-1

certificationCategory	certificationCategory Type	The various categories that exist for certification of the type of activities related to building electronic assemblies. An enumerated string consisting of: ASSEMBLYDRAWING | ASSEMBLYFIXTUREGENERATION | ASSEMBLYPANEL | ASSEMBLYPREPTOOLS | ASSEMBLYTESTFIXTUREGENERATION | ASSEMBLYTESTGENERATION | BOARDFABRICATION | BOARDFIXTUREGENERATION | BOARDPANEL | BOARDTESTGENERATION | COMPONENTPLACEMENT | DETAILEDDRAWING | FABRICATIONDRAWING | GENERALASSEMBLY | GLUEDOT | MECHANICALHARDWARE | MULTIBOARDPARTLIST | PHOTOTOOLS | SCHEMATICDRAWINGS | SINGLEBOARDPARTLIST | SOLDERSTENCILPASTE | SPECSOURCECONTROLDRAWING | EMBEDDEDCOMPONENT | OTHER	0-1

6.4 ChangeRec

The `ChangeRec` element is the information needed for configuration management of the changes made to the product that the data file represents. The characteristics are stored by the `datecode` that the change record was executed. The information can also be used to obtain approval of a suggested change.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
ChangeRec	ChangeRecType	An element that is required to manage the configuration of the changes made to the product during its development phases and its final configuration in the field.	0-n
datetime	dateTime	The timestamp recorded when the change was made to the file.	1-n
personRef	qualifiedNameType	The pointer to the 'name' of the person listed in the `LogisticHeader` who initiated the change.	1-1
application	string	The effectivity of the change indicating when it becomes active, such as after so many completed units.	1-1
change	string	A short description of the change.	1-1
Approval	ApprovalType	A nested element that signifies who approved the suggested change submitted by the design, fabrication, assembly or test operation.	0-n
datetime	dateTime	The timestamp recorded when the change made to the file was approved.	0-n 1-1
personRef	qualifiedNameType	The pointer to the 'name' of the person listed in the `LogisticHeader` who approved the change.	1-1
<ChangeRec datetime = "2010-06-12T13:20:00" personRef = "Harry Jones" application = "The change is to be implemented immediately with all produced items reworked" change = "Replace the chip resistors with new part number 34-67-95, sixteen places"/> <Approval datetime = "2010-06-13T10:32:30" personRef = "John Smithy"/>			

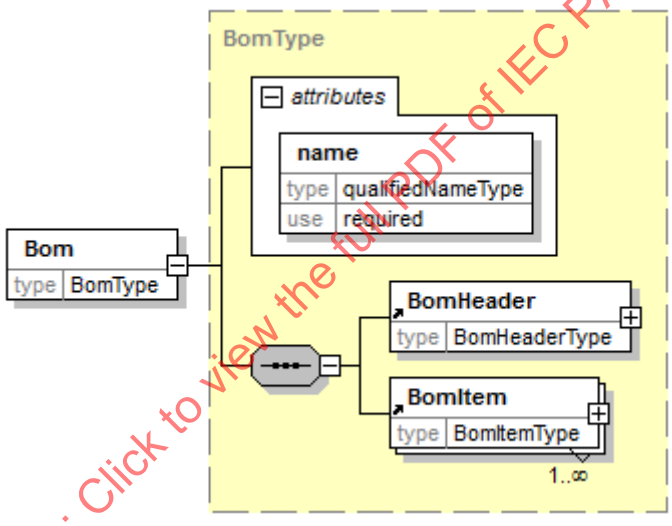
7 BOM (Material List)

This section describes the Bill of Materials for the printed board and printed board assembly. A bill of materials is a list of all the different materials and components to be used in the manufacture of the electronic assembly. The information is arranged by a specific category of material or components and then by the OEM Design Number (ODN). This is the number assigned by the owner of the file. Each ODN has a list of attributes and is accompanied by a list of the various specific uses of the materials or components on the electronic assembly, each with its private name or reference designator.

The `BOM` dataset represents the list of materials or components found on a particular board, keyed by the OEM Design Number (ODN). The original `BOM` is delivered by the owner of the file (OEM, EMS, etc.) in the early stages of the design. The Bom element is composed of the `BomHeader` and the `BomData`.

For example, ODN **348324-001** can be of package **pqfp100**, has an Internal Part Number (IPN) **30020A** and may have four occurrences on the board, labeled **U14**, **U15**, **U75**, **U76**. Each occurrence is called a Reference Designator (RefDes for short).

The IPC-2581 file can contain several `BOM` elements. Each one has a `BomHeader` sub-element with board and date/time information. The main data resides in the sub-element `BomData`.

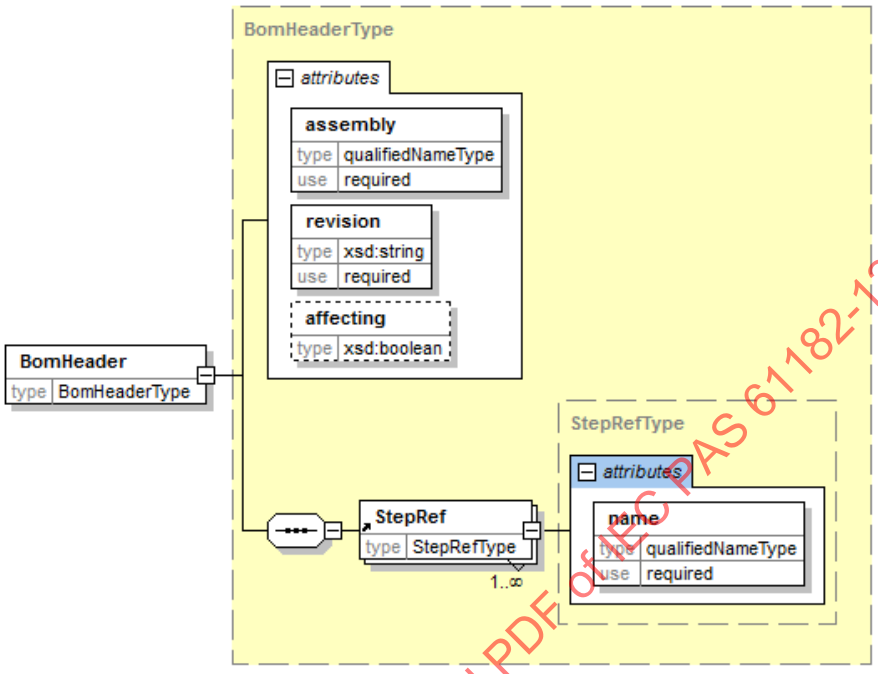


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Bom	BomType	The `Bom` element describes the Bill of Materials for the printed board and printed board assembly. A bill of materials is a list of all the different materials and components to be used in the manufacture of the electronic assembly.	1-1
name	qualifiedNameType	The name string that identifies the specific `Bom` section. This name is referenced in the `AvlDataHeader` element.	1-1
BomHeader	BomHeaderType	A nested element containing identification and logistical information about the `Bom`.	1-1
BomItem	BomItemType	The individual elements that define the details of each of the items in the `Bom`.	1-n

```
<Bom name = "TestBoard1">
<BomHeader assembly = "Karens Design" revision = "Prototype" stepListRef = "KarensBoard"/>
      <BomItem OEMDesignNumberRef = "Fabricated" quantity = "1" pinCount = "4" category = "ELECTRICAL"     description = "Card Edge
Connector">
         <RefDes name = "J1" populate = "FALSE"/>
         <Characteristics category = "ELECTRICAL"/>
      </BomItem>
      <BomItem OEMDesignNumberRef = "Sample1234" quantity = "1" pinCount = "8" category = "ELECTRICAL" internalPartNumber =
                  "Molex 354892" description = "Bifurcated Thru-hole connector"/>
         <RefDes name = "J2"  packageRef =”Connector1” populate = "TRUE"/>          <Characteristics category = "ELECTRICAL"/>
      </BomItem>
      <BomItem OEMDesignNumberRef = "SOIC129867" quantity = "1" pinCount = "8" category = "ELECTRICAL" internalPartNumber =
                  "Phillips IC2436" description = "SOIC 1.27 pitch">   /
         <RefDes name = "U1" packageRef = “SOIC12” populate = "TRUE"/>          <Characteristics category = "ELECTRICAL">
            <Textual definitionSource = "Pretested Logic" textualCharacteristicName = "Per Supplier Data Sheet"/>
         </Characteristics>
      </BomItem>
      <BomItem OEMDesignNumberRef = "CAP 24A1846" quantity = "1" pinCount = "2" category = "ELECTRICAL" internalPartNumber =
        "Phillips Cap1235" description = "3225 Surface Mount Capacitor">
         <RefDes name = "C1" packageRef = “Capacitor1”populate = "TRUE" />          <Characteristics category = "ELECTRICAL">
            <Measured measuredCharacteristicName = "Capacitance" measuredCharacteristicValue = "20"
                  engineeringUnitOfMeasure = "Microfarads" engineeringNegativeTolerance = "3 " engineering
                 PositiveTolerance = "3"/>
```

7.1 BOM Header

Each `Bom` in the IPC-2581 file has a `BomHeader` element. This is a mandatory requirement as a part of the `Bom` element. The following characteristics are necessary to properly describe a `Bom`.

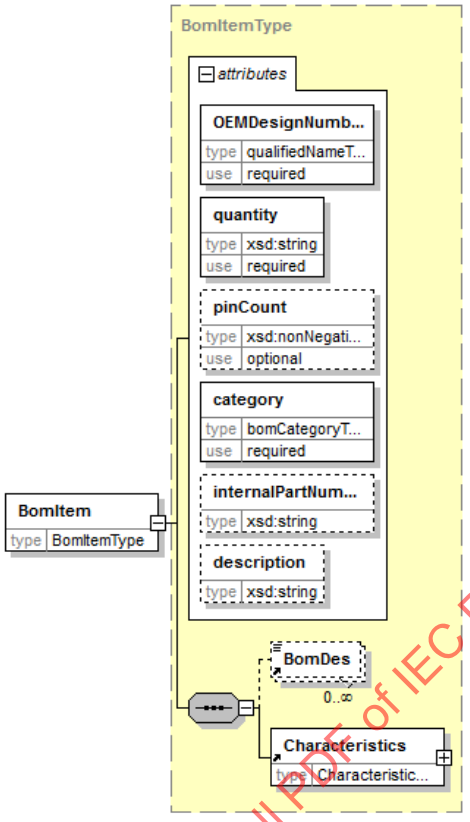


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
BomHeader	BomHeaderType	A nested element containing identification and logistical information about the `Bom`.	1-1
assembly	qualifiedNameType	Electronic assembly name as parsed from the `Bom` file.	1-1
revision	string	Revision as parsed from the `Bom` file.	1-1
affecting	boolean	An enumerated string as either TRUE or FALSE (part of the 3WC standard). True equals that the current BOM was used in the assembly merge process in the job and therefore was the affecting one. This is due to the fact that there can be multiple BOMs in a job, but only one has been used to affect the current top and bottom component placements sections.	0-1
stepRef	qualifiedNameType	Identification of specific steps used to help describe the BomItem within the category of materials	1-n

7.2 BomItem

Each `BomItem` is a part of the `BomItem` list. A `BomItem` consists of a variety of attributes. `BomItem` contains the reference to the OEM Design Number (ODN), the line item of the ODN, a quantity of parts or material required, an optional pin count for component mounting, a required category of the `BomItem` an optional `internalPartNumber` (IPN), and an optional description of the `BomItem` The `BomItem` also contains two additional elements that include the list of the bill of material designators (`BomDes`) associated with the `BomItem`, and the characteristics (`Characteristics`) associated with describing how the bom item is measured, ranged, enumerated, or identified in textual information. `Multiple BomDes` lists may be maintained since there may be several designator file locations.

The attributes are shown in the following table and are a part of the `Bom` section of the IPC-2581 file.

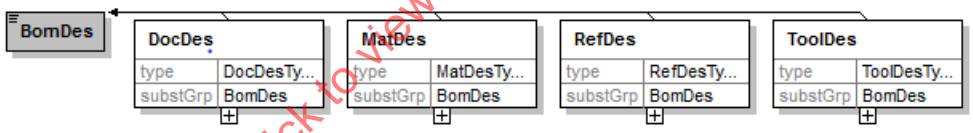


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
BomItem	BomItemType	The individual elements that define the details of each of the items in the Bom.	1-n
OEMDesignNumberRef	qualifiedNameType	A qualified name referencing the OEM part number data.	1-1
quantity	string	The amount of the instances of this item in the board or assembly. This may be a length in the units of the 2581 file, a nonNegativeInteger or an As Required (AR) designation to signify as needed quantity.	1-1
pinCount	nonNegativeInteger	The number of physical pin terminations on the package shown as a lineItem. The number includes power and ground and thermal pads whether connected or not connected to a net.	0-n
category	bomCategoryType	The category of the bomItem as an enumerated string being either ELECTRICAL | PROGRAMMABLE | MECHANICAL | MATERIAL | DOCUMENT	1-1
internalPartNumber	string	Internal or warehouse stock part identifier.	1-1
description	string	The description of the BomItem.	0-1
BomDes	ABSTRACT	A substitution group that permits the designation of Bom Items as they relate to the category identified by the LayerFunction. The substitution includes Reference designators (for components), Material designators (for Material call-outs), Documentation designators (for drawings, graphics or specifications) and Tool Designators (for tools, fixtures or templates) required to be identified in the Bill of Material. .	0-n
Characteristics	CharacteristicsType	A nested element containing descriptive strings that can be linked together and also a reference to a describing line in an external file.	1-1

```
<Bom name = "TestBoard1">
    <BomHeader assembly = "Karens Design" revision = "Prototype" stepListRef = "KarensBoard"/>
     <BomItem OEMDesignNumberRef = "Fabricated" quantity = "1" pinCount = "4" category = "ELECTRICAL"  description = "Card Edge
                Connector">
        <RefDes name = "J1" populate = "FALSE"/>
        <Characteristics category = "ELECTRICAL"/>
     </BomItem>
     <BomItem OEMDesignNumberRef = "Sample1234" quantity = "1" pinCount = "8" category = "ELECTRICAL"     internalPartNumber =
              "Molex 354892" description = "Bifurcated Thru-hole connector">
        <RefDes name = "J2" packageRef = Connector1" populate = "TRUE"/>
        <Characteristics category = "ELECTRICAL"/>
     </BomItem>
     <BomItem OEMDesignNumberRef = "SOIC129867" quantity = "1" pinCount = "8" category = "ELECTRICAL" internalPartNumber =
               "Phillips IC2436" description = "SOIC 1.27 pitch">
        <RefDes name = "U1" packageRef = SOIC12" populate = "TRUE"/>
        <Characteristics category = "ELECTRICAL">
           <Textual definitionSource = "Pretested Logic" textualCharacteristicName = "Per Supplier Data Sheet"/>
        </Characteristics>
     </BomItem>
     <BomItem OEMDesignNumberRef = "CAP 24A1846" quantity = "1" pinCount = "2" category = "ELECTRICAL" internalPartNumber =
                "Phillips Cap1235" description = "3225 Surface Mount Capacitor">
        <RefDes name = "C1" packageRef = “Capacitor1” populate = "TRUE"/>
        <Characteristics category = "ELECTRICAL">
           <Measured measuredCharacteristicName = "Capacitance" measuredCharacteristicValue = "20"
                      engineeringUnitOfMeasure = "Microfarads" engineeringNegativeTolerance = "3"
              engineeringPositiveTolerance = "3"/>
        </Characteristics>
     </BomItem>
```

7.2.1 BomDes

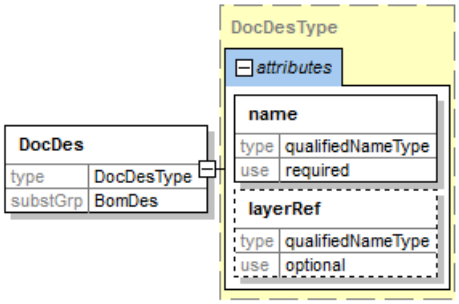
The Bill of Material Designations (BomDes) are intended to identify items that may be contained in the Bom and need a specific designation based on their characteristics. There are four groups of designations which include documents, materials, components, and tools/fixtures.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
BomDes	BomDescType	A substitution group that permits the designation of Bom Items as they relate to the category identified by the LayerFunction.	0-n
DocDes	DocDesType	A Bom item designation used to identify “**Documents**” that are contained in the Bill of Material and may be referenced throughout the 2581 file.	0-n
MatDes	MatDesType	A Bom item designation used to identify “**Materials**” that are contained in the Bill of Material and may be referenced throughout the 2581 file.	0-n
RefDes	RefDesType	A Bom item designation used to identify “**Components**” that are contained in the Bill of Material and may be referenced throughout the 2581 file.	0-n
ToolDes	ToolDesType	A Bom item designation used to identify “**Tools & Fixtures**” that are contained in the Bill of Material and may be referenced throughout the 2581 file.	

7.2.1.1 DocDes

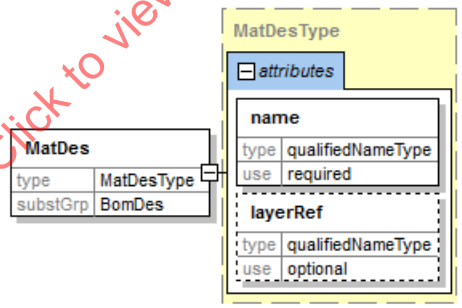
A Bom item designation used to identify "**Documents**" that are contained in the Bill of Material and may be referenced throughout the 2581 file.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
DocDes	BomDesType	A Bom item designation used to identify the properties of specific documents contained in a 2581 file.	0-n
Name	qualifiedNameType	A unique name assigned as a designation for documents consisting of a combination of letter(s) and number(s)	1-1
layerRef	qualifiedNametype	A reference to the identification of the unique name assigned to a specific layer which identifies a layerFunction describing the documents being identified in the CadData.	0-1

7.2.1.2 MatDes

A Bom item designation used to identify "**Materials**" that are contained in the Bill of Material and may be referenced throughout the 2581 file.

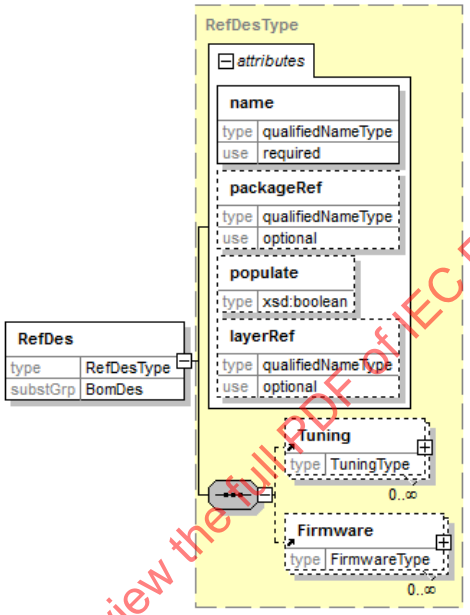


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
MatDes	BomDesType	A Bom item designation used to identify the properties of specific materials contained in a 2581 file.	0-n
name	qualifiedNameType	A unique name assigned as a designation for materials consisting of a combination of letter(s) and number(s)	1-1
layerRef	qualifiedNameType	A reference to the identification of the unique name assigned to a specific layer which identifies a layerFunction describing the materials being identified in the CadData.	0-1

7.2.1.3 RefDes

A Bom item designation used to identify "**Components**" that are contained in the Bill of Material and may be referenced throughout the 2581 file.

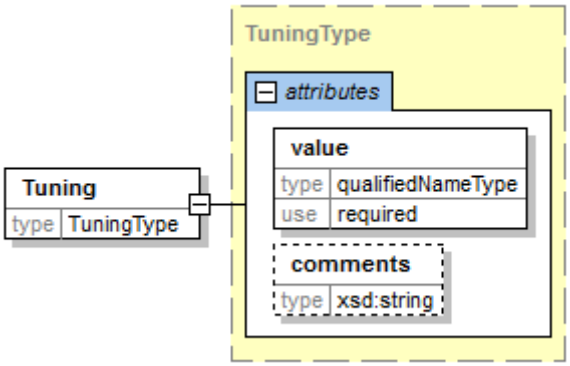
The `RefDes` is an element that represents the specific reference designator associated with a component that becomes a part of the electronic assembly. This is a mandatory requirement for all `BomItems` that have a reference designator associated with their ELECTRICAL descriptions. In this instance the standard set of reference designator letters **shall** be used. i.e., R = Resistor, C = Capacitor, CR = Diode etc. The prefix letter M **shall** be used for all MECHANICAL parts, (e.g., terminals, latches, heatsinks, etc.), and S for all Software PROGRAMMABLE `BomItems`.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
RefDes	RefDesType	A nested element containing the reference designator strings for the individual parts identified in the file for a one to one relationship with the quantity listed for the `BomItem`.	0-1
name	qualifiedNameType	The qualifiedNameType that identifies the reference designator used as the attribute `refDes` of the `Component` element in `Step`.	1-1
packageRef	qualifiedNameType	The name assigned to the package describing the physical outlines, documentation, and land patterns features related to package pin assignment.	0-1
populate	boolean	An enumerated string as either TRUE or FALSE (part of the 3WC standard). True equals that the `RefDes` was populated; False indicates that it was not. TRUE is the default.	0-1
layerRef	qualifiedNameType	A reference to the identification of the unique name assigned to a specific layer which identifies a layerFunction describing the components being identified in the CadData mounted on the top, bottom or internal to the printed board.	0-1
Tuning	TuningType	A number of conditions that determine any adjustment that is needed for a particular `BomItem`.	0-n
Firmware	FirmwareType	A nested element containing descriptive strings that can be linked together to describe the software implementation for an individual `BomItem`.	0-n

7.2.1.3.1 Tuning

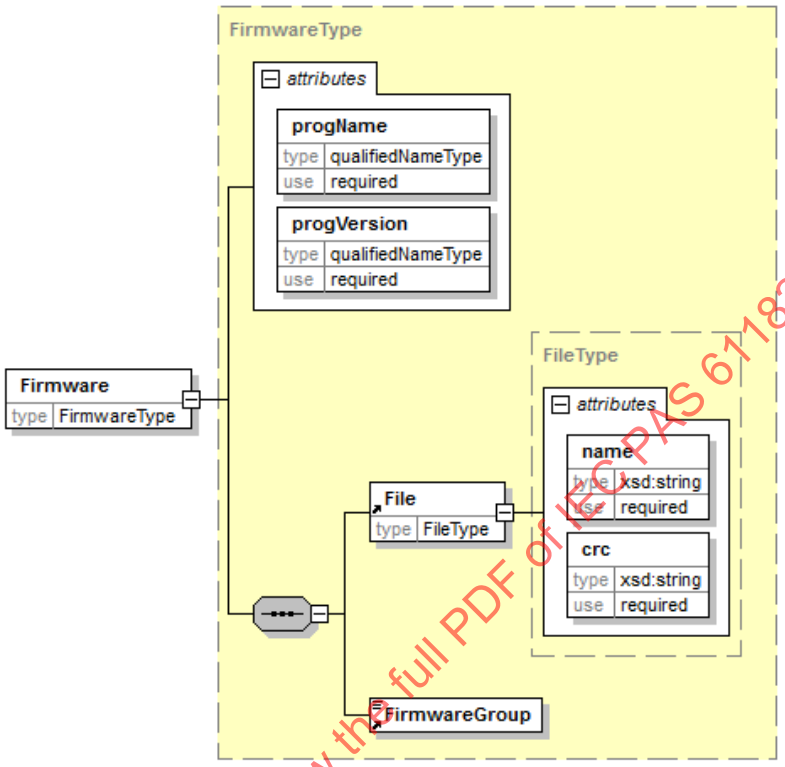
The `Tuning` element represents conditions that determine any adjustment that is needed for a particular `BomItem`.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Tuning	TuningType	A number of conditions that determine any adjustment that is needed for a particular `BomItem`.	0-n
value	qualifiedNameType	The value of the tuning characteristics and its relationship to the other prescribed values.	1-1
comments	string	Any instructions or comments needed to prescribe the proper tuning.	0-n

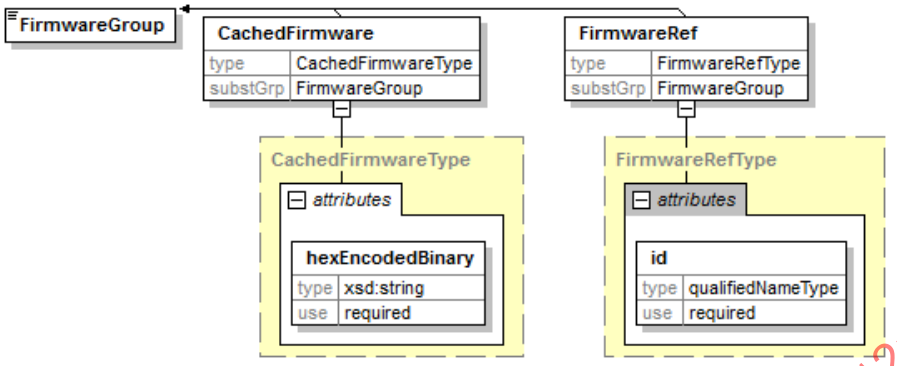
7.2.1.3.2 Firmware

A nested element containing descriptive strings that can be linked together to describe the software implementation for an individual `BomItem` and associates the characteristics of the specific reference designators to which the programmable information is to be included.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Firmware	FirmwareType	A nested element containing descriptive strings that can be linked together to describe the software implementation for an individual `BomItem`.	0-n
progName	qualifiedNameType	Name of the program to be embedded in the BomItem.	0-1
progVersion	qualifiedNameType	Version of program or revision status.	0-1
File	FileType	Computer file containing the program code to be inserted.	1-1
name	string	Name of the file.	1-1
crc	string	Certification status to verify correct program elements.	1-1
FirmwareGroup	ABSTRACT	A substitution group that specifies the `CachedFirmware` which has been stored by the user in the `DictionaryFirmware`.	0-1

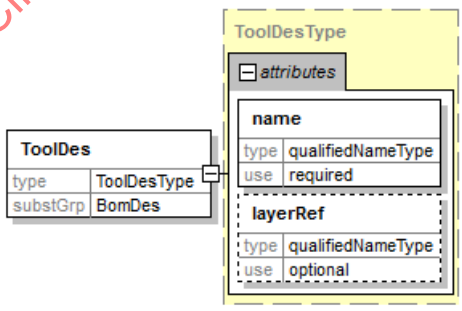
7.2.1.3.3 Firmware Group



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
FirmwareGroup	Abstract	A substitution group that specifies the `CachedFirmware` which has been stored by the user in the `DictionaryFirmware`.	0-1
CachedFirmware	CashedFirmwareType	The firmware description needed by a particular component that becomes part of the predefined firmware in the `DictionaryFirmware`.	1-1
hexEncodedBinary	string	An attribute defining the binary code that **shall** be added to a particular component and which is contained in the `DictionaryFirmware`.	1-1
FirmwareRef	FirmwareRefType	The specific reference to firmware previously defined and contained in the `DictionaryFirmware`.	1-1
id	shortNameType	The id uniquely identifies a firmware that has been stored in the firmware dictionary and is used throughout the IPC-2581 file. The id is a `shortName` data type (a restricted xsd: string) that must be unique within the global (top-level) namespace of the IPC-2581 file.	1-1

7.2.1.4 ToolDes

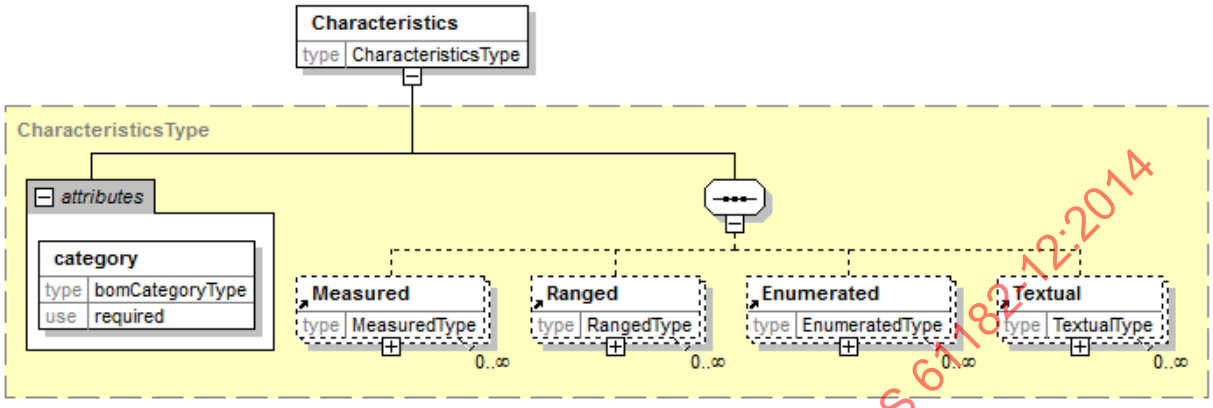
A Bom item designation used to identify "**Tools or Fixtures** " that are contained in the Bill of Material and may be referenced throughout the 2581 file.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
ToolDes	ToolDesType	A Bom item designation used to identify the properties of specific tools or fixtures contained in a 2581 file.	0-n
name	qualifiedNameType	A unique name assigned as a designation for tools or fixtures consisting of a combination of letter(s) and number(s)	1-1
layerRef	qualifiedNameType	A reference to the identification of the unique name assigned to a specific layer which identifies a layerFunction describing the tools or fixtures being identified in the CadData.	0-1

7.2.2 Characteristics

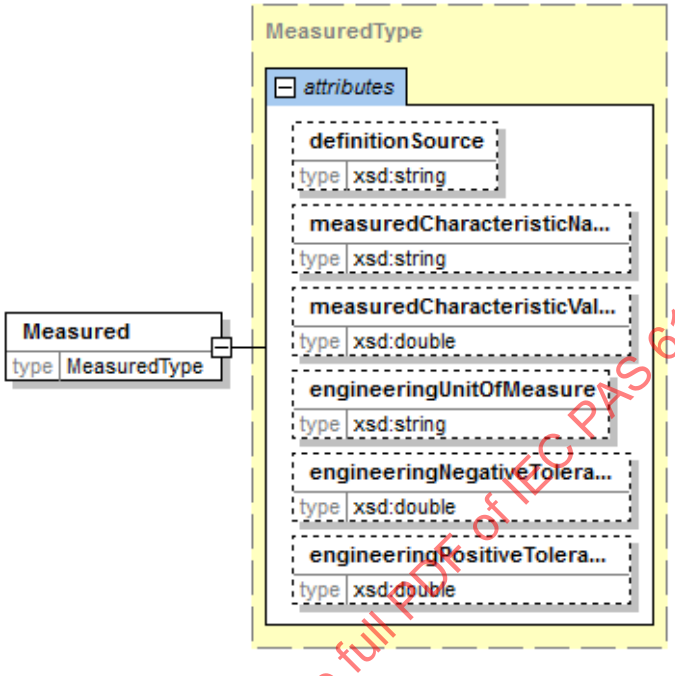
A group of specific characteristics applicable to a particular `BomItem`; they all relate to one of the categories to which the `BomItem` belongs. Each characteristic has its own level of requirements and are defined under the major element `Characteristics`.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Characteristics	CharacteristicsType	A nested element containing descriptive strings that can be linked together and also a reference to a describing line in an external file.	1-1
category	bomCategoryType	Defines the type of material or component category to which the `BomItem` belongs. The bomCatogoryType enumerations may be either ELECTRICAL | PROGRAMMABLE | MECHANICAL | MATERIAL | DOCUMENT	1-1
Measured	MeasuredType	A nested element containing descriptive strings that can be linked together to describe the measurable characteristics for an individual `BomItem`.	0-n
Ranged	RangedType	A nested element containing descriptive strings that can be linked together to describe the tolerances or ranges of variation that can be applied to the characteristics for an individual `BomItem`.	0-n
Enumerated	EnumeratedType	A nested element containing descriptive strings that can be linked together to describe those values that define the numerical characteristics and the source for that information for an individual `BomItem`.	0-n
Textual	TextualType	A nested element containing descriptive strings that can be linked together to describe any textual characteristics and their source for an individual `BomItem`.	0-n

7.2.2.1 Measured

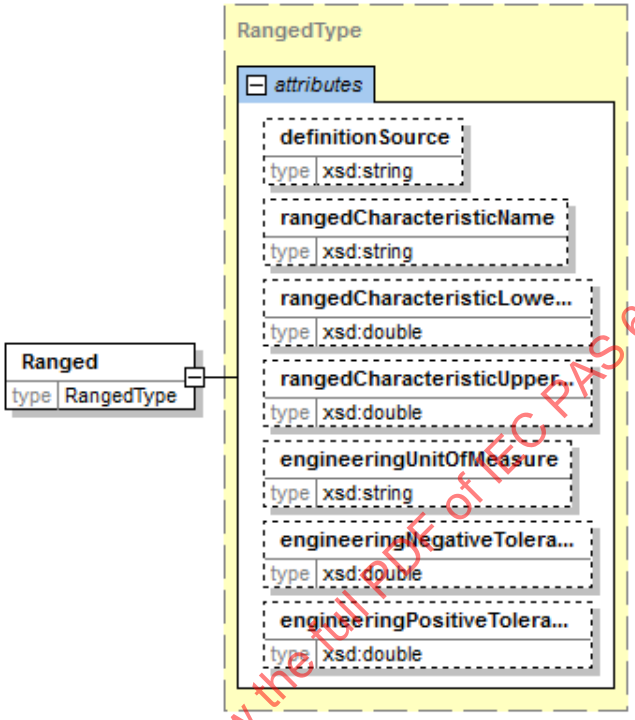
The `Measured` elements are those properties that when linked together describe the measurable characteristics for an individual `BomItem`. These characteristics provide the nominal value and also include the tolerances on the measurement.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Measured	MeasuredType	A nested element containing descriptive strings that can be linked together to describe the measurable characteristics for an individual `BomItem`.	0-n
definitionSource	string	The source of the information about the measurements.	0-1
measuredCharacteristicName	string	A unique name applied to the characteristic (e.g., capacitance)	0-1
measuredCharacteristicValue	double	The value of the measured property at its nominal or target value.	0-1
engineeringUnitOfMeasure	string	The engineering unit of measure.	0-1
engineeringNegativeTolerance	double	The negative tolerance on the value identified.	0-1
engineeringPositiveTolerance	double	The positive tolerance on the value identified.	0-1

7.2.2.2 Ranged

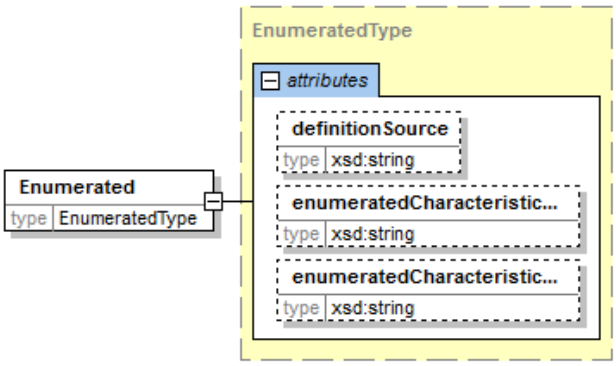
The `Ranged` elements are those properties that when linked together describe the ranges that a `BomItem` must meet. These range characteristics include the upper and lower limit of the range as well as the tolerances on the measurement. These values are compared against those that have been measured to ascertain that the `BomItem` is within specifications.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Ranged	RangedType	A nested element containing descriptive strings that can be linked together to describe the tolerances or ranges of variation that can be applied to the characteristics for an individual `BomItem`.	0-n
definitionSource	string	The source of the information about the measurement ranges.	0-1
rangedCharacteristicName	string	A unique name applied to the characteristic.	0-1
rangedCharacteristicLowerValue	double	The lower value of a ranged characteristic.	0-1
rangedCharacteristicUpperValue	double	The upper value of a ranged characteristic.	0-1
engineeringUnitOfMeasure	string	The engineering unit of measure.	0-1
engineeringNegativeTolerance	double	Any negative tolerance that can may be applied to the range in order to affix the target value of the `BomItem`.	0-1
engineeringPositiveTolerance	double	Any positive tolerance that can may be applied to the range in order to affix the target value of the `BomItem`.	0-1

7.2.2.3 Enumerated

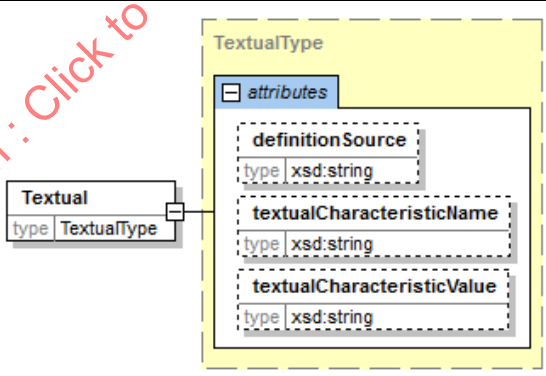
The `Enumerated` elements are those properties that, when linked together, describe the enumerated value of a `BomItem` as well as the source of that information.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Enumerated	EnumeratedType	A nested element containing descriptive strings that can be linked together to describe those values that define the numerical characteristics and the source for that information for an individual `BomItem`.	0-n
definitionSource	string	The source of the information about the enumerated value.	0-1
enumeratedCharacteristicName	string	A unique name applied to the characteristic.	0-1
enumeratedCharacteristicValue	string	The enumerated value identified for the `BomItem`.	0-1

7.2.2.4 Textual

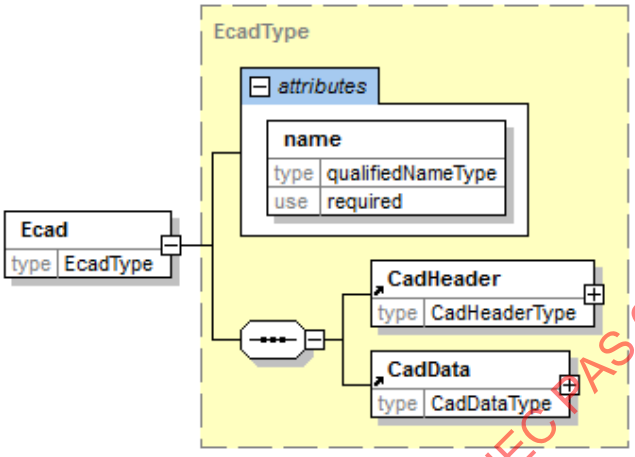
The `Textual` elements are those properties that when linked together describe the textual value of a `BomItem` as well as the source of that information.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Textual	TextualType	A nested element containing descriptive strings that can be linked together to describe any textual characteristics and their source for an individual `BomItem`.	0-n
definitionSource	string	The source of the information about the textual value.	0-1
textualCharacteristicName	string	A unique name applied to the characteristic.	0-1
textualCharacteristicValue	string	The textual value identified for the `BomItem`.	0-1

8 ELECTRONIC COMPUTER AIDED DESIGN (ECAD)

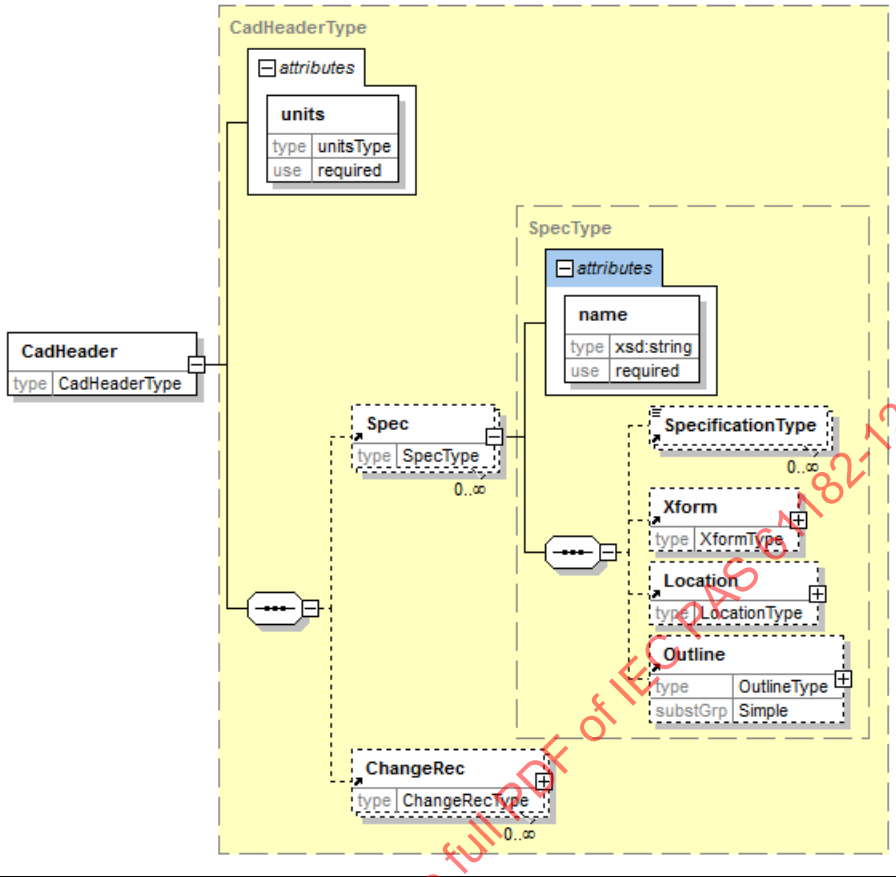
The `Ecad` section describes the Computer Aided Design data of the job, including all the graphical description of the layers, component location, panel design, etc. In most cases, the `Ecad` section is by far the largest body of data inside the 2581 file. To understand how the `Ecad` section is organized, it is important to be familiar with the `Layers` and `Step` elements.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Ecad	EcadType	The `Ecad` section describes the Computer Aided Design data of the job, including all the graphical description of the layers, component location, panel design, etc.	1-1
name	qualifiedNameType	The qualified name related to identify the specific `Ecad` information based on the electronic assembly(s) in the 2581 file.	1-1
CadHeader	CadHeaderType	A nested element containing identification and information about the description of the data in the file.	1-1
CadData	CadDataType	A nested element containing the actual Cad data describing the printed board and printed board assembly characteristics.	1-1

8.1 CadHeader

The `CadHeader` element is mandatory. Inside the `CadHeader` there are general attributes that describe the printed board, characteristics of the assembly, tooling, or documentation as defined by the `CadData`. The `Spec` element helps to define special instructions, tolerances, location where these apply, or any other comments that relate to the `CadData`. Dimensions are defined by the units attribute and may be in imperial (inch) or metric (mm or µm) units. Once defined the unit descriptions apply to all ecad data; however the units may be modified by the incorporation of a specification such that the specification may apply to the information or instructions provided by the Spec. This condition has no impact on the Units established for the 2581 file and only applies to the specification details. Any feature imported from any dictionary file **shall** be configured in the same units as defined by the `Ecad` units attribute.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
CadHeader	CadHeaderType	A nested element containing identification and information about the description of the data in the file.	1-1
units	unitsType	An enumerated string that may be one of the following: MILLIMETER | MICRON | INCH.	1-1
Spec	SpecType	Contains information related to the characteristics of the printed board, the assembly, material or any other layer function and may include the values for conductor width and spacing, compliance requirements, dielectric information, thermal characteristics or other attributes and instructions. The specification is instantiated where it is required through the unique name of the specification which establishes the SpecType and the detailed requirements	0-n
ChangeRec	ChangeRecType	A nested element containing identification and information about the description of the data in the Ecad section of the file.	0-n

8.1.1 Spec

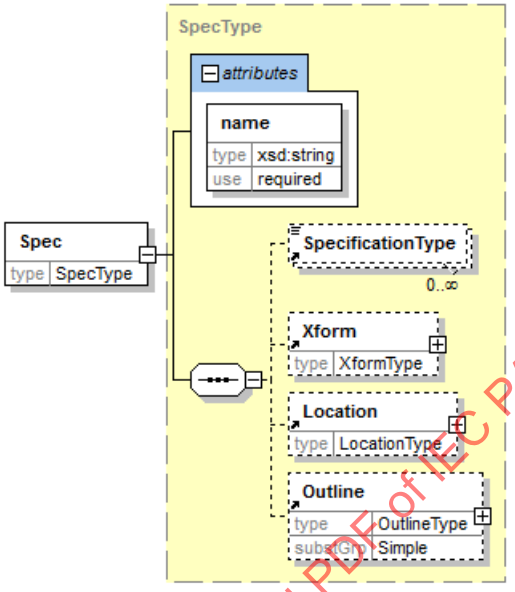
The `Spec` element contains various types of information related to the characteristics of the board or assembly. The concepts may include values for:

- width, spacing, component spacing, component to edge, etc.
- impedance, capacitance and resistance values.
- dimensions between edge/feature/hole to edge/feature/hole, V Cut or backdrill dimensions.

The instance of invoking a specification is provided through the option of including the elements as a part of a characteristic describing the board, assembly or a feature of their manufacturing such as the material or a

physical condition of the final product. The Spec provides that information that clearly identifies the goal conditions of the final product.

Up to two sub-elements may describe the specific `Location` or `Outline` where the spec is to be applied. The xform element permits changing of the original point of origin, scaling of features, rotation or mirror imaging of the spec requirements.

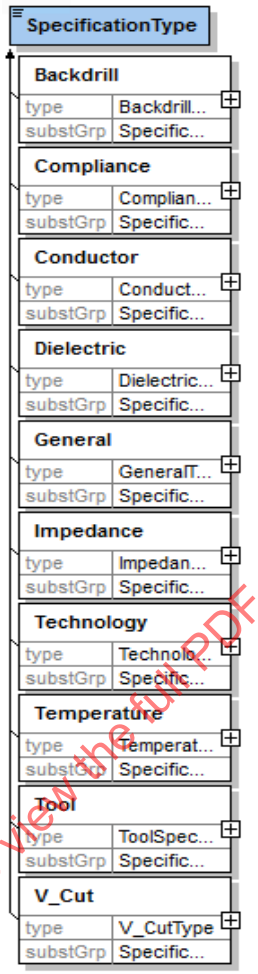


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Spec	SpecType	Contains information that applies to the board or assembly fabrication and relates to the end product capability of the product being produced. Instructions may include various values for conductor width and spacing, component spacing, component to board edge conditions, impedance values, capacitance values, resistance values, compliance to regulations and other requirement dimensions.	0-n
name	qualifiedNameType	The qualified name of the specification. The name must be unique and should indicating to which product in the file the specification pertains.	1-1
SpecificationType	ABSTRACT	A substitution group that permits the substitution of the SpecificationType with the specific elements and their characteristics that identify the purpose of the specification in order to focus the application of the descriptions to where they should apply. Examples of the specificationtypes include: Backdrill, Compliance, Conductor, Dielectric, General, Impedance, Technology, Temperature, Tool, and V_Cut.	0-n
Xform	XformType	An element that provides the ability to reset the point of origin of a predefined area that can be scaled, mirror imaged or rotated. See 3.3	0-1
Location	LocationType	The image defined by `Outline` or a pre-defined image is located to identify where the specification applies. The image may have been reorientated by the Xform.	0-1
x	double	The x coordinate of the location to which the specification applies	1-1
y	double	The y coordinate of the location to which the specification applies	1-1
Outline	OutlineType	A nested element containing a specific area(s) to which the specification(s) apply. The `Outline` is a closed polygon configuration	0-1

Polygon	PolygonType	The standard description for the `Polygon` characteristic must be a closed shape. The point of origin of the shape is identified as the 0:0 coordinate. The element includes the start of the polygon definition (`PolyBegin`) and the appropriate number of `PolyStep`'s to complete the closed shape. The lineWidth is through the LineDesc substitution group or defined at a time when the Polygon is instantiated.	0-n
PolyBegin	PolyBeginType	The PolyBegin element defines the starting point of the polygon.	1-1
x	double	The X starting point of the first polygon line.	1-1
y	double	The Y starting point of the first polygon line.	1-1
PolyStep	ABSTRACT	The `PolyStep` element is a substitution group that defines a circular (`PolyStepCurve`) or straight line (`PolyStepSegment`) continuation of the polygon. The `polystep` direction may be clockwise or counterclockwise which must be consistent when any `Arc` description is used as one of the `PolyStep` elements. Straight or curved line segments must not cross. The final X and final Y coordinate must match those of the PolyBegin element to signify that the shape is closed.	1-n
LineDescGroup	ABSTRACT	A substitution group that specifies the `LineWidth` and `LineEnd` characteristics of the `Line` by reference to a predefined `LineDesc` or specified when the `Outline` is instantiated.	1-1

8.1.1.1 SpecificationType

The SpecificationType is an Abstract substitution feature that permits various specification functions to be defined within the concept of the Spec element.

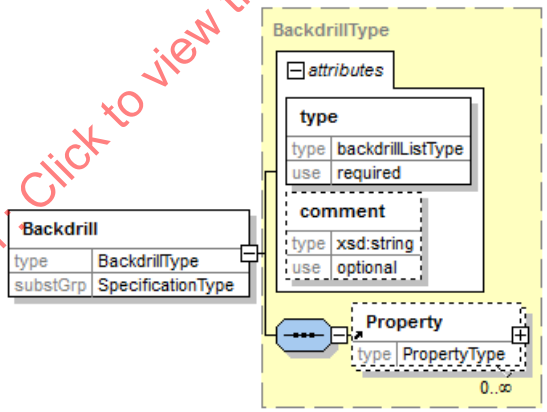


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
SpecificationType	ABSTRACT	A substitution group that permits the substitution of the SpecificationType with any specific elements and their characteristics that identify the purpose of the specification in order to focus the application of the descriptions to where they should apply. Examples of the specificationtypes include Backdrill, Compliance, Conductor, Dielectric, General, Impedance, Technology, Temperature, Tool, and V_Cut.	0-n
Backdrill	BackdrillType	The identification of a SpecificationType related to the backdrill of plated-through holes or vias in order to remove some of the plating without disturbing the interconnection structure.	0-n
Compliance	ComplianceType	The identification of a SpecificationType related to compliance to regulations that are being imposed on the materials or the final product of the board, or the assembly. The requirements may be regional or customer based and may include reclamation or disposal.	0-n
Conductor	ConductorType	The identification of a SpecificationType related to the conductor used to carry signals throughout the printed board assembly describing the characteristics, surface finish or other properties related to the conductor shape or material.	0-n

Dielectric	DielectricType	The identification of a SpecificationType related to the dielectric properties of the material which includes their electrical characteristics as well as their physical makeup such as resin or reinforcement styles and also the processing temperature that they can withstand.	0-n
General	GeneralType	The identification of a SpecificationType related to any general requirements that may be necessary to impose on any feature or product identified through the layer function and which allows instantiation of a spec onto the requirements	0-n
Impedance	ImpedanceType	The identification of a SpecificationType related to the impedance requirements of a stackup construction or an printed board assembly in order to define the characteristics or the relationship to material separation or layering	0-n
Technology	TechnologyType	The identification of a SpecificationType related to the technology being used in the construction of the printed board or the assembly or any process concepts that help identify the process control sensitive areas	0-n
Temperature	TemperatureType	The identification of a SpecificationType related to the thermal capabilities or requirements that are necessary in order to meet the coefficient of expansion of material or parts in an effort to establish reliability conditions	0-n
Tool	ToolType	The identification of a SpecificationType related to the tooling used in the manufacture of a printed board, printed board panel, printed board assembly or a printed board pallet and may be a single cutter or a template used for ensuring process consistency	0-n
V_Cut	V_CutType	The identification of a SpecificationType related to the scoring of printed board panels or pallets in order to allow the removal of individual board or coupon products identifying the cut size or material remaining.	0-n

8.1.1.2 Backdrill

The Backdrill specification feature is intended to define the dimensions and characteristics of backdrilling some of the plated through holes.



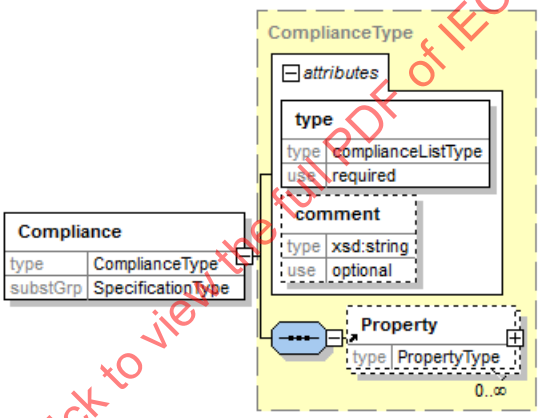
Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Backdrill	BackdrillType	The identification of a SpecificationType related to the backdrill of plated-through holes or vias in order to remove some of the plating without disturbing the interconnection structure.	0-n
type	backdrillListType	A set of enumerated string descriptions that identify the condition of the backdrill requirement. They consist of START_LAYER | MUST_NOT_CUT_LAYER | MAX_STUB_LENGTH | OTHER. If OTHER is noted a comment attribute is required.	1-1
comment	string	A description of the requirements for backdrilling that are different or supplement the backdrillListType enumerations	0-1

Property	PropertyType	A nested element containing numerical attribute descriptions that relate to the backdrill requirements and permit the references to alternate conditions that may apply. Unit descriptions apply only to the specificationType and do not impact the requirements of the overall 2581 file Unit descriptions	0-n

```
<Spec name=”backdrill_1”>
   <Backdrill type=”START_LAYER”>
         <Property layerOrGroupRef=”L12”/>
   </Backdrill>
   <Backdrill type=”MUST_NOT_CUT_LAYER”>
         <Property layerOrGroupRef=”L8”/>
   </Backdrill>
   <Backdrill type=”MAX_STUB_LENGTH”>
         <Property value=”0.5” unit=”MM” plusTol=”0” minusTol=”5” tolPercent=”TRUE”/>
   </Backdrill>
</Spec>
```

8.1.1.3 Compliance

The Compliance specification feature is intended to define the legal requirements imposed under certain conditions and to define the characteristics that need to be adhered to in developing or providing the product defined in the 2581 file.

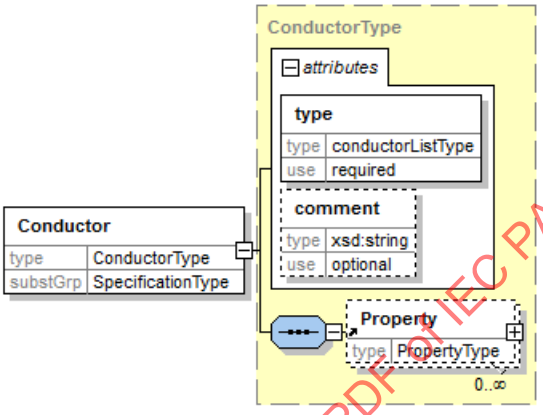


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Compliance	ComplianceType	The identification of a SpecificationType related to the backdrill of plated through holes or vias in order to remove some of the plating without disturbing the interconnection structure.	0-n
type	complianceListType	A set of enumerated string descriptions that identify the condition of the compliance requirement. They consist of ROHS | CONFLICT_MINERALS | WEEE | REACH| HALOGEN_FREE | OTHER. If OTHER is noted a comment attribute is required.	1-1
comment	string	A description of the requirements for meeting compliance regulations that are different or supplement the complianceIListType enumerations	0-1
Property	PropertyType	A nested element containing numerical attribute descriptions that relate to the compliance requirements and permit the references to alternate conditions that may apply. Unit descriptions apply only to the specificationType and do not impact the requirements of the overall 2581 file Unit descriptions	0-n

```
<Spec name=”compliances”>
    <Compliance type=”ROHS”>
    </Compliance>
    <Compliance type=”HALOGEN_FREE”>
    </Compliance>
</Spec>
```

8.1.1.4 Conductor

The Conductor specification feature is intended to define the specific characteristics of conductors, or conductor surfaces that need to be provided in the product defined in the 2581 file.

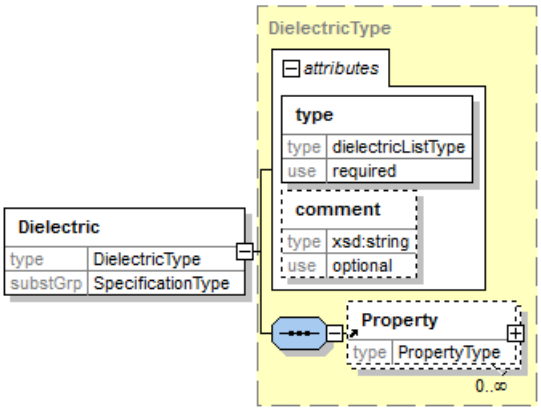


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Conductor	ConductorType	The identification of a SpecificationType related to the conductor characteristics such as dimensions, surface conditions and electrical properties.	0-n
type	conductorListType	A set of enumerated string descriptions that identify the condition of the conductor requirement. They consist of CONDUCTIVITY | SURFACE_ROUGHNESS_UPFACING | SURFACE_ROUGHNESS_DOWNFACING | SURFACE _ROUGHNESS_TREATED | ETCH_FACTOR | FINISHED_HEIGHT | OTHER. If OTHER is noted a comment attribute is required.	1-1
comment	string	A description of the requirements for conductors that are different or supplement the conductorListType enumerations	0-1
Property	PropertyType	A nested element containing numerical attribute descriptions that relate to the conductor requirements and permit the references to alternate conditions that may apply. Unit descriptions apply only to the specificationType and do not impact the requirements of the overall 2581 file Unit descriptions	0-n

```
<Spec name=”copper_foil2”>
    <Conductor type=”CONDUCTIVITY”>
            <Property value=”0.059”  unit=”MHO/CM” refValue=”25” refUnit=”CELCIUS”/>
    </Conductor>
    <Conductor type=”SURFACE_ROUGHNESS_UPFACING”>
            <Property value=”3”  unit=”MICRON” refUnit=”RMS”/>
    </Conductor
</Spec>
```

8.1.1.5 Dielectric

The Dielectric specification feature is intended to define the specific characteristics of dielectric material, or characteristics that need to be provided in the product defined in the 2581 file.

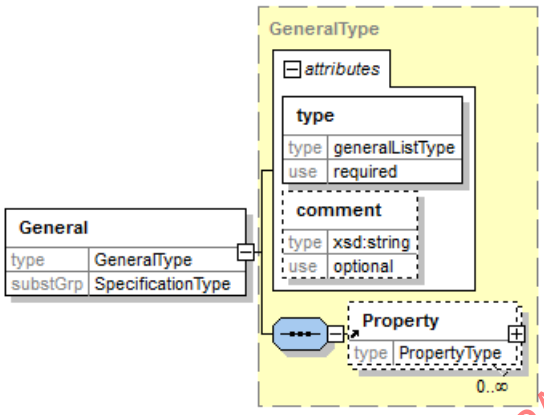


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Dielectric	DielectricType	The identification of a SpecificationType related to the dielectric characteristics such as electrical properties, physical makeup, and process temperature restrictions.	0-n
type	dielectricListType	A set of enumerated string descriptions that identify the condition of the conductor requirement. They consist of DIELECTRIC_CONSTANT | LOSS_TANGENT | GLASS_TYPE | GLASS_STYLE | RESIN_CONTENT | PROCESSABILITY_TEMPERATURE | OTHER. If OTHER is noted a comment attribute is required.	1-1
comment	string	A description of the requirements for dielectric material that are different or supplement the dielectricListType enumerations	0-1
Property	PropertyType	A nested element containing numerical attribute descriptions that relate to the dielectric requirements and permit the references to alternate conditions that may apply. Unit descriptions apply only to the specificationType and do not impact the requirements of the overall 2581 file Unit descriptions	0-n

```
<Spec name="dielec4_15">
   <Dielectric type="DIELECTRIC_CONSTANT">
            <Property value="4.150" refValue="10.0e9" refUnit="Hz"/>
            <Property value="4.148" refValue="15.0e9" refUnit="Hz"/>
   </Dielectric>
   <Dielectric type="LOSS_TANGENT">
            <Property value="0.035" refValue="10.0e9" refUnit="Hz"/>
            <Property value="0.034" refValue="15.0e9" refUnit="Hz"/>
   </Dielectric>
  <Dielectric type="RESIN_CONTENT">
            <PropertyNum value="50"  unit="PERCENT"/>
   </Dielectric>
  <Dielectric type="PROCESSABILITY_TEMP">
            <Property text="A"  refText="270-300" refUnit="CELCIUS"/>
            <Property text="B"  refText="230-270" refUnit="CELCIUS"/>
            <Property text="C"  refText="210-230" refUnit="CELCIUS"/>
            <Property text="D"  refText="150-210" refUnit="CELCIUS"/>
   </Dielectric>
   <Dielectric type="GLASS_STYLE">
            <Property text="1080"/>
   </Dielectric>
</Spec>
```

8.1.1.6 General

The General specification feature is intended to define any general characteristics related to the final product and may be grouped as electrical, thermal, material requirements or identify instructions or standards that influence the product defined in the 2581 file.

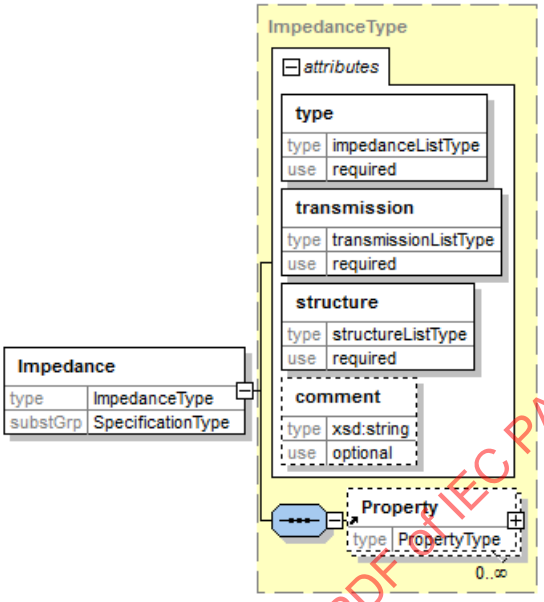


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
General	GeneralType	The identification of a SpecificationType related to any general characteristics such as electrical, thermal or material properties, as well as special instructions or standards that the product must meet.	0-n
type	generalListType	A set of enumerated string descriptions that identify any general requirements. The general groupings consist of ELECTRICAL | THERMAL | MATERIAL | INSTRUCTION | STANDARD | OTHER. If OTHER is noted a comment attribute is required.	1-1
comment	string	A description of any general requirements that are a different category or supplement the generalListType enumerations	0-1
Property	PropertyType	A nested element containing numerical attribute descriptions that relate to the general requirements and permit the references to alternate conditions that may apply. Unit descriptions apply only to the specificationType and do not impact the requirements of the overall 2581 file Unit descriptions	0-n

```
<General type=”STANDARD”>
  <Property text=”Telcordia Standard XYZ” refUnit=”CLASS” refValue=”3” />
   </General>
   <General type=”STANDARD”>
  <Property text=”IPC-4101” refUnit=”SECTION” refText=”8.2.1.13” />
   </General>
</Spec>
<Spec name=”designer_notes”>
   <General type=”INSTRUCTION”>
          <Property text=”Line neckdowns are intentional, build as is.” refUnit=”ITEM” refValue=”1” />
          <Property text=”100 ohm differential pair traces that violate the specified separation are
                intentional, build as is.” refUnit=”ITEM” refValue=”2” />
    </General>
</Spec>
```

8.1.1.7 Impedance

The Impedance specification feature is intended to define any impedance characteristics related to the final product and includes the transmission and structure characteristics that the product defined in the 2581 file must meet.

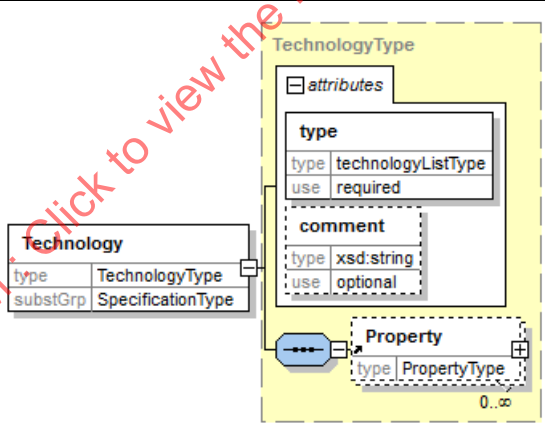


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Impedance	ImpedanceType	The identification of a `SpecificationType` related to the impedance characteristics and structure such as the electrical requirements, relationship to surrounding plane and specific structure properties that the product must meet.	0-n
type	impedanceListType	A set of enumerated string descriptions that identify the impedance requirements. The descriptions consist of IMPEDANCE | LINEWIDTH | SPACING | REF_PLANE_LAYER_ID | OTHER. If OTHER is noted, a comment attribute is required.	1-1
transmission	transmissionListType	A set of enumerated string descriptions that identify the transmission requirements. They consist of SINGLE_ENDED | EDGE_COUPLED | BROADSIDE_COUPLED | OTHER. If OTHER is noted a comment attribute is required.	1-1
structure	structureListType	A set of enumerated string descriptions that identify the impedance structure requirements. They consist of STRIPLINE | PLANE_LESS_STRIPLINE | MICROSTRIP_EMBEDDED | MICROSTRIP_NO_MASK | MICROSTRIP_MASK_COVERED | MICROSTRIP_DUAL_MASK_COVERED | COPLANAR_WAVEGUIDE_STRIPLINE | COPLANAR_WAVEGUIDE_EMBEDDED | COPLANAR_WAVEGUIDE_NO_MASK | COPLANAR_WAVEGUIDE_MASK_COVERED | COPLANAR_WAVEGUIDE_DUAL_MASKED_COVERED | OTHER. If OTHER is noted a comment attribute is required.	1-1
comment	string	A description of any impedance requirements that are different or supplement the `impedanceListType`, `transmissionListType` or `structureListType` enumerations.	0-1
Property	PropertyType	A nested element containing numerical attribute descriptions that relate to the impedance requirements and permit the references to alternate conditions that may apply. Unit descriptions apply only to the `specificationType` and do not impact the requirements of the overall 2581 file Unit descriptions	0-n

```
<Spec name=”controlled_impedance_requirements_TOP”>
    <Impedance type=”IMPEDANCE” transmission=”SINGLE_ENDED” structure=”STRIPLINE”>
  <Property value=”50” unit=”OHMS” plusTol=”10” minusTol=”10”  tolPercent=”TRUE”/>
    </Impedance>
    <Impedance type=”LINEWIDTH” transmission=”SINGLE_ENDED” structure=”STRIPLINE”>
            <Property value=”0.5” unit=”MM”/>
    </Impedance>
    <Impedance type=”IMPEDANCE” transmission=”EDGE_COUPLED” structure=”STRIPLINE”>
  <Property value=”100” unit=”OHMS” plusTol=”10” minusTol=”10”  tolPercent=”TRUE”/>
    </Impedance>
    <Impedance type=”LINEWIDTH transmission=”EDGE_COUPLED” structure=”STRIPLINE”>
            <Property value=”0.3” unit=”MM”/>
    </Impedance>
    <Impedance type=”SPACING” transmission=”EDGE_COUPLED” structure=”STRIPLINE”>
            <Property value=”0.2” unit=”MM”/>
    </Impedance>
  <Impedance type=”REF_PLANE_LAYER_ID” transmission=”SINGLE_ENDED” structure=”STRIPLINE”>
            <Property layerOrGroupRef=”L8”/>
            <Property layerOrGroupRef =”L11”/>
    </Impedance>
  <Impedance type=”REF_PLANE_LAYER_ID” transmission=”EDGE_COUPLED” structure=”STRIPLINE”>
            <Property layerOrGroupRef =”L8”/>
            <Property layerOrGroupRef =”L11”/>
    </Impedance>
</Spec>
```

8.1.1.8 Technology

The Technology specification feature is intended to define the mounting platform technology so that the specifications applied relate to those materials and structures identified by the technology type in order to further influence the product defined in the 2581 file.

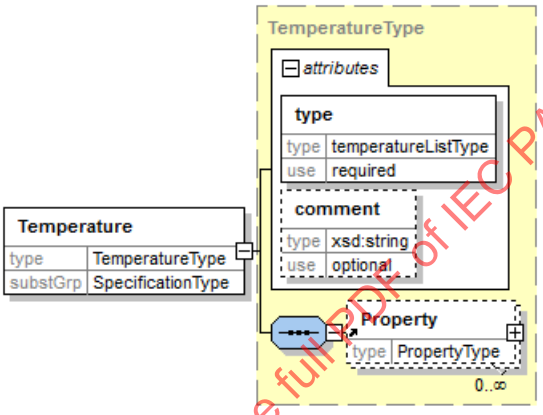


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Technology	TechnologyType	The identification of a SpecificationType related to the category of the product used for mounting components identified by the structure technology of the product identified in the 2581 file.	0-n
type	technologyListType	A set of enumerated string descriptions that identify the mounting platform technology requirements. The description categories consist of RIGID | RIGID_FLEX | FLEX | HDI | EMBEDDED_COMPONENT | OTHER. If OTHER is noted a comment attribute is required.	1-1
comment	string	A description of any technology requirements that are a different category or supplement the technologyListType enumerations	0-1

Property	PropertyType	A nested element containing numerical attribute descriptions that relate to the technology requirements and permit the references to alternate conditions that may apply. Unit descriptions apply only to the `specificationType` and do not impact the requirements of the overall 2581 file Unit descriptions	0-n
<Spec name=”board_technology”> <Technology type=”RIGID”> </Technology> </Spec>			

8.1.1.9 Temperature

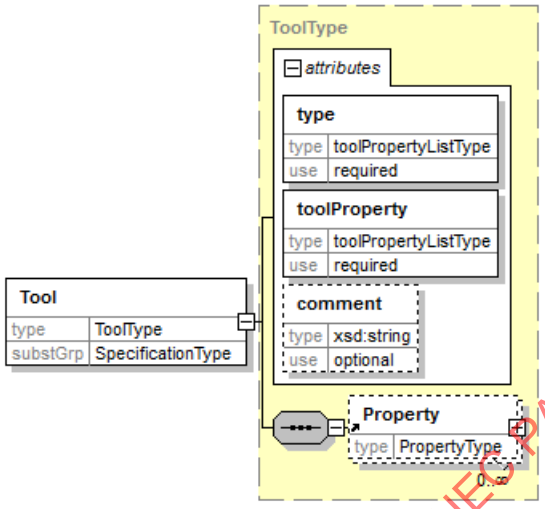
The Temperature specification feature is intended to define the products’ ability to withstand high temperatures in order to maintain its physical characteristics within the requirements identified in the 2581 file.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Temperature	TemperatureType	The identification of a SpecificationType related to the temperature impact on the product identified in the 2581 file and its’ ability to maintain the physical properties needed for reliable performance.	0-n
type	temperatureListType	A set of enumerated string descriptions that identify the temperature extremes at which the material changes state. The description categories are THERMAL_DELAMINATION | EXPANSION_Z_AXIS | EXPANSION_X_Y AXIS | OTHER. If OTHER is noted, a comment attribute is required.	1-1
comment	string	A description of any temperature impact characteristic that is different or supplements the TemperatureListType enumerations	0-1
Property	PropertyType	A nested element containing numerical attribute descriptions that relate to the temperature impact characteristics and permit the references to alternate conditions that may apply. Unit descriptions apply only to the specificationType and do not impact the requirements of the overall 2581 file Unit descriptions	0-n
<Spec name=”minimum_Td”> <Temperature type=”THERMAL_DELAMINATION”> <Property value=”180” unit=”CELCIUS”/> </Temperature> </Spec>			

8.1.1.10 Tool

The Tool specification feature is intended to define the type of tool(s) needed in the fabrication of the board or the assembly and includes those necessary to prepare the products for separation from a panel or pallet as well as providing holes or cutouts needed within the product structure.



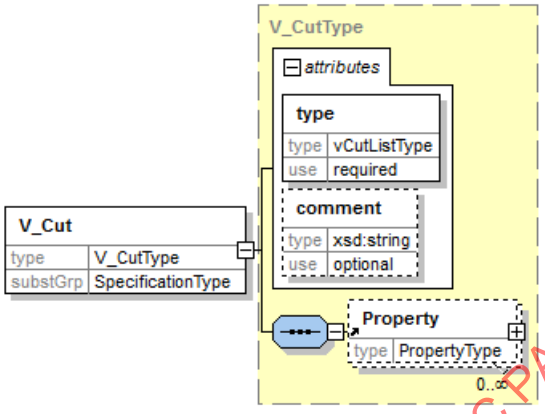
Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Tool	ToolType	The identification of a SpecificationType related to the tools needed to manufacture the product identified in the 2581 file and includes both hard tools and photo (Laser) ablation requirement.	0-n
type	toolListType	A set of enumerated string descriptions that identify the tool types required in the manufacturing of the boards or the assemblies. The tool types include CARBIDE | ROUTER | LASER | FLATNOSE | EXTENSION | V_CUTTER | OTHER. If OTHER is noted a comment attribute is required.	1-1
toolProperty	toolPropertyListType	A set of enumerated string descriptions that identify the tool properties required in the manufacturing of the boards or the assemblies. The tool properties include DRILL_SIZE | FINISHED_SIZE | BIT_ANGLE | OTHER. If OTHER is noted a comment attribute is required.	1-1
comment	string	A description of any tool characteristic that is different or supplements the toolListType or toolPropertyListType enumerations	0-1
Property	PropertyType	A nested element containing numerical attribute descriptions that relate to the tool descriptions and permits the references to alternate conditions that may apply. Unit descriptions apply only to the specificationType and do not impact the requirements of the overall 2581 file Unit descriptions	0-n

```
<Spec name=”drill_1”>
  <Tool  type=”CARBIDE”  toolProperty=”DRILL_SIZE”>
    <Property  text=”B” unit=”GAUGE”/>
  </Tool>
  <Tool  type=”CARBIDE”  toolProperty=”FINISHED_SIZE”>
    <Property value=”0.5” unit=”MM” plusTol =”0.05” minusTol=”0.05”/>
  </Tool>
</Spec>

<Spec name=” v_cutter_tool”>
  <Tool  type=”V_CUTTER”  toolProperty=”BIT_ANGLE”>
    <Property  value=”90” unit=”DEGREES”/>
  </Tool>
</Spec>
```

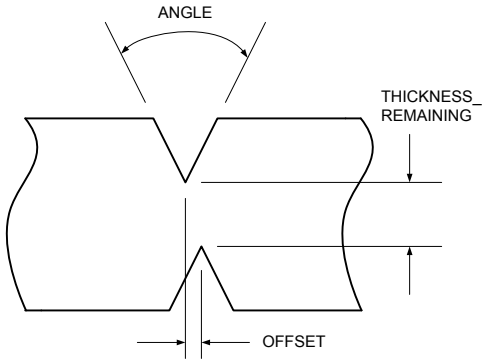
8.1.1.11 V_Cut

The V_Cut specification feature is intended to define the limits and detail descriptions of the scoring requirements when using a diamond wheel cutter intended to remove material from a board or panel in order to reduce the total thickness. This always implies cuts on both the top and bottom of the board. The specification type OFFSET can be used to define the vertical distance and/or tolerance between top and bottom cuts.



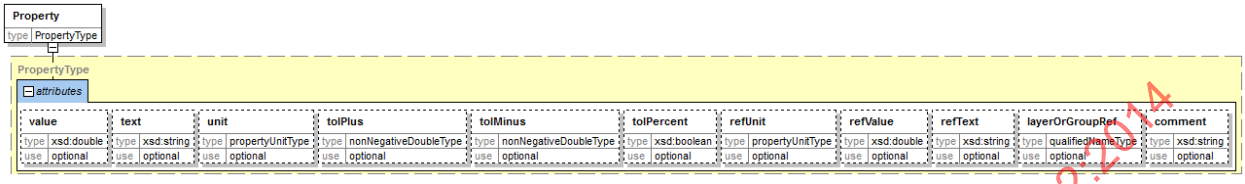
Attribute / Element Name	Attribute / Element Type	Description	Occurrence
V_Cut	V_CutType	The identification of a SpecificationType related to the scoring or groove cutting into a board, panel or pallet where a certain amount of material remains so that the product can be further processed before final separation.	0-n
type	vCutListType	A set of enumerated string descriptions that identify the characteristics of the groove or V cut as related to the thickness of the material. The description categories are ANGLE | THICKNESS_REMAINING | OFFSET | OTHER. If OTHER is noted a comment attribute is required.	1-1
comment	string	A description of any V cut characteristic that is different or supplements the vCutListType enumerations	0-1
Property	PropertyType	A nested element containing numerical attribute descriptions that relate to the temperature impact characteristics and permit the references to alternate conditions that may apply. Unit descriptions apply only to the specificationType and do not impact the requirements of the overall 2581 file Unit descriptions	0-n

```
<Spec name=”vcut_all”>
    <V_Cut type=”ANGLE”>
            <Property value=”90” unit=”DEGREES” plusTol=”5” minusTol=”5”
tolPercent=”TRUE”/>
    </V_Cut>
    <V_Cut type=”THICKNESS_REMAINING”>
            <Property value=”0.5” unit=”MM” plusTol=”0.1” minusTol=”0.1”/>
    </V_Cut>
    <V_Cut type=”OFFSET”>
            <Property value=”0.0” unit=”MM” plusTol=”0.1” minusTol=”0.1”/>
    </V_Cut>
</Spec>
```



8.1.2 Property

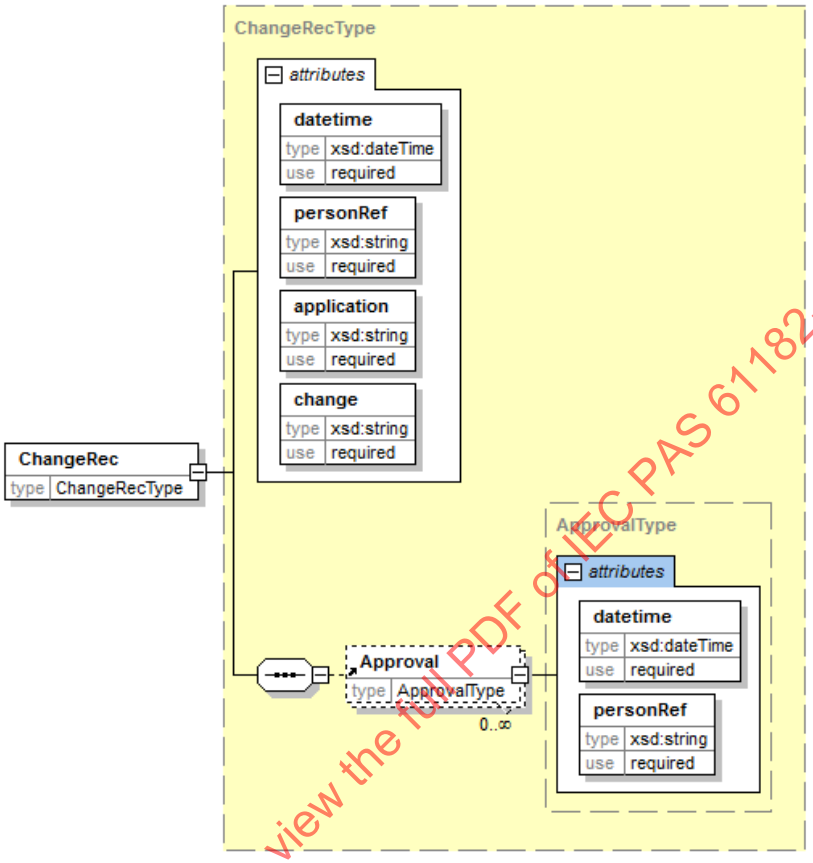
The Property element provides a group of attributes that may be used in order to describe the conditions that are to be associated with a particular specification. The attributes describe values, tolerances instructions and when they apply to a stackup, a reference is provided to which specific stackup layer the requirements apply. When the properties need to take into account other units or values a reference to those is also included. All attributes that are instantiated become a mandatory part of the specification to which they apply.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Property	PropertyType	A set of attributes that becomes a mandatory requirement to a specification and include values, tolerances, units and instructions. Appropriate references may also be provided. Since a specification may include several Property elements any ambiguity must be resolved prior to considering the impact the specification has on the products identified in the 2581 file.	1-1
value	double	A number that identifies the characteristics of the Value to be applied to any specified Unit attribute identified from the propertyUnitType enumerations.	0-1
text	string	Specific conditions or instructions that can be used as a property value when the value in non numeric or can be applied to the combination of Unit, Value and any tolerance attribute conditions.	0-1
unit	propertyUnitType	A set of enumerated string descriptions that identify the Unit properties of the Value attribute requirement. They consist of MM | INCH | MICRON | OHMS | MHO/CM | SIEMENS/M | CELCIUS | FARANHEIT | PERCENT | Hz | DEGREES | RMAX | RZ | RMS | SECTION | CLASS | ITEM | GAUGE | OTHER. If OTHER is noted a comment attribute is required.	0-1
tolPlus	nonNegativeDouble	The plus tolerance that may be applied to the nominal number defined in the Value attribute setting the upper control limit.	0-1
tolMinus	nonNegativeDouble	The minus tolerance that may be applied to the nominal number defined in the Value attribute setting the lower control limit.	0-1
tolPercent	boolean	An enumerated string as either TRUE or FALSE (part of the 3WC standard). TRUE equals that the attribute(s) “tolPlus” and/or “tolMinus” are a percentage. FALSE indicates that they represent a nonNegativeDouble. The Default is FALSE	0-1
refUnit	propertyUnitType	A second Unit set of enumerated string descriptions that are to be used as reference Unit properties of the basic attribute requirement. They consist of MM | INCH | MICRON | OHMS | MHO/CM | SIEMENS/M | CELCIUS | FARANHEIT | PERCENT | Hz | DEGREES | RMAX | RZ | RMS | SECTION | CLASS | ITEM | GAUGE | OTHER. If OTHER is noted, a comment attribute is required.	0-1
refValue	double	A second Value number that is to be used as reference Value in considering the properties of the basic attribute requirement.	0-1
refText	string	A second set of instructions that need to be applied when considering the references established for the Value number, unit, tolerances or instructions applied to the properties of the basic attribute requirement.	0-1
layerOrGroupRef	qualifiedNameType	A reference to the identification of the unique name assigned to a specific layerOrGroup to which the properties of the specification are to be applied.	0-1
comment	string	A description of any unit or refUnit characteristic that is different or supplements the propertyUnitType enumerations	0-1

8.1.3 ChangeRec

The `ChangeRec` element contains the `ChangeRec` elements specifying deviations requested by the manufacturer and approved by the customer (OEM, EMS, other).



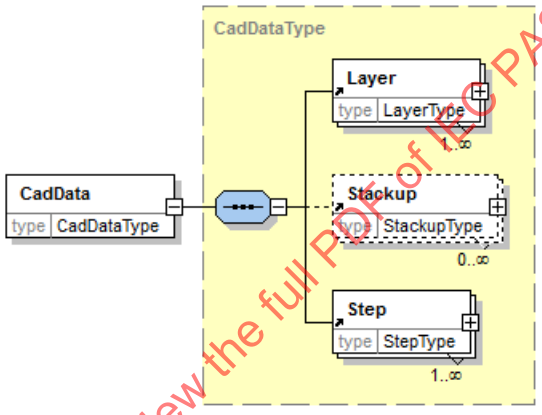
Attribute / Element Name	Attribute / Element Type	Description	Occurrence
ChangeRec	ChangeRecType	A nested element containing identification and information about the description of the data in the Ecad section of the file.	0-n
datetime	dateTime	The standard date and time indication of the change request.	1-1
personRef	string	The name of the person to whom the request was made.	1-1
application	string	The effectivity of the change and exactly where the change was to be made.	1-1
change	string	A detailed description of the change, including a reference to a URL if graphic descriptions are involved.	1-1
Approval	ApprovalType	A nested element that signifies who approved the suggested change submitted by the design, fabrication, assembly or test operation.	0-n
datetime	dateTime	The standard date and time indication of the change approval.	1-1
personRef	string	The name of the person who approved the change request.	1-1

8.2 CadData

The `CadData` element is the three-dimensional structure of the design that is retrieved from the Cad system as a group of layers. The information is contained in the `Layer` elements. The layers are listed in the correct order inside `CadData` and are grouped by `name`, and `layerFunction`.

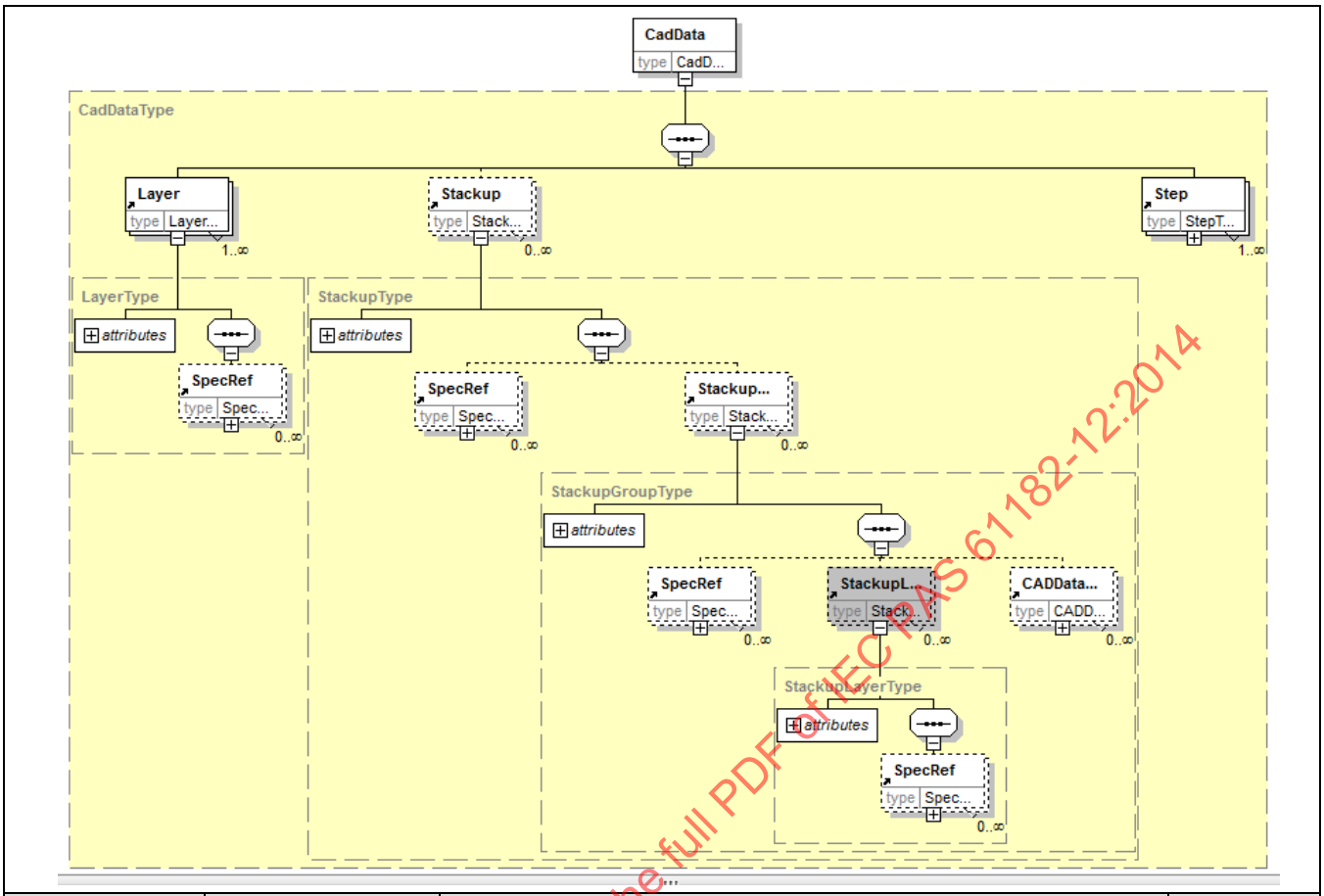
Layers are also identified by, `side`, `polarity`, `span`, and `SpecRef` that can be applied to help define each layer. CAD data layers are required in 2581 to successfully hold ECAD layout information. These layers are not necessarily physical layers, but the myriad of layers that can be represented in the `Ecad` data but not actually fabricated into the bare board.

Layers, as the name implies, are sheets of two-dimensional data which, when laid on top of each other, create the Printed Circuit Assembly (unpopulated PCB and components or other related information). Some layers are physical layers that are laminated together to form the board. Other layers represent masks, films or phototools used to expose the board in a process that applies materials selectively on the outer layers of the boards. Some layers contain only drawings and annotations, which are not put physically on the board but can be used to further define it. These layers are organized in the IPC-2581 file by their specific type.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
CadData	CadDataType	A nested element containing the actual Cad data describing the printed board and printed board assembly characteristics.	1-1
Layer	LayerType	A nested element containing the different layer information represented in the CAD data base which describes the electronic assembly to be manufactured.	1-n
Stackup	StackupType	A nested element containing the construction information for the printed board. If the file contains more than one Stackup the unique name assignment is required for each board configuration	0-n
Step	StepType	The `Step` element consists of multiple sub-elements each intended to help describe the different steps needed in the board fabrication, or assembling the electronic product.	1-n

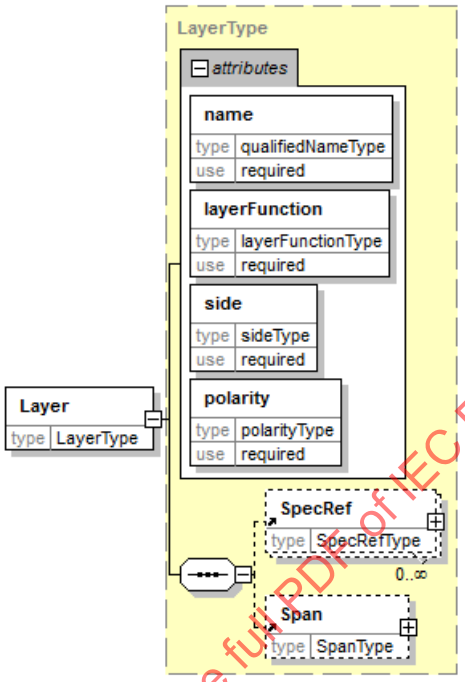
Everything about the design starts in CadData. The relationships are expanded through the hierarchy of the layer and stackup elements.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
CadData	CadDataType	A nested element containing the actual Cad data describing the printed board and printed board assembly characteristics.	1-1
Layer	LayerType	A nested element containing the different layer information represented in the CAD data base which describes the electronic assembly to be manufactured.	1-n
Stackup	StackupType	A nested element containing the construction information for the printed board. If the file contains more than one Stackup the unique name assignment is required for each board configuration	0-n
Step	StepType	The `Step` element consists of multiple sub-elements each intended to help describe the different steps needed in the board fabrication, or assembling the electronic product.	1-n

8.2.1 Layer

The `Layer` element describes the characteristics of specific layers. The layers may be for the board or the assembly and may be individual characterization or those of the board fabrication panel and the arrangement of boards in the assembly pallet. There are also documentation, tooling and miscellaneous layers. The `layerFunction` helps to identify the purpose of the layer.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Layer	LayerType	A nested element containing the different layer information represented in the CAD data base which describes the electronic assembly to be manufactured.	1-n
name	qualifiedNameType	The identification of the Cad data element identifying a particular layer. If the layerFunction STACKUP_COMPOSITE is indicated the unique name assigned shall match the name assigned to the related `Stackup` element	1-1
layerFunction	layerFunctionType	The type of layer and its main use as established by the following: COATINGCOND | COATINGNONCOND | DIELBASE | DIELCORE | DIELPREG | DIELADHV | SOLDERBUMP | RESISTIVE | CAPACITIVE| COMPONENT_EMBEDDED | SOLDERPASTE | CONDFOIL | CONDFILM STACKUP_COMPOSITE | LEGEND | SOLDERMASK | CONDUCTOR | PLANE | SIGNAL| MIXED | PASTEMASK | DRILL| ROUTE | SCORE | CONDUCTIVE_ADHESIVE GLUE | SOLDERBUMP | HOLEFILL | PROBE | REWORK | FIXTURE| | ASSEMBLY | SILKSCREENCOURTYARD| GRAPHIC | DOCUMENT | LANDPATTERN | COMPONENT_TOP | COMPONENT_BOTTOM | BOARD_OUTLINE | OTHER	1-1
side	sideType	A fixed field parameter that defines the side of the layer. The fixed attribute is one of the following TOP | BOTTOM | BOTH | INTERNAL | ALL | NONE	1-1
polarity	polarityType	Applies for layers of type signal, power/ground or mixed. In such layers, positive means that the layer features represent copper. NEGATIVE means that the layer features represent laminate. For example, on a negative power/ground layer, features represent clearances. All other layers should be defined as positive. POSITIVE is the default.	1-1

SpecRef	SpecRefType	The identification of a particular specification(s) from the SpecificationType that is able to provide additional details or instructions that apply to the board or assembly descriptions of the Layer. The linkage is provided through the specific “specificationId” (spec Name)	0-n
Span	SpanType	A nested element where the field may be added to layers of type drill and route that are either buried or blind. In such a case, it represents the start and end board layers between which drilling/routing is done. If the drill is going through the board a span subsection will NOT be included.	0-1

There is a close relationship between the `Layer` and `Step` elements of the 2581 format. The correlation exists between the `Step` elements and attributes and the `layerFunction` attribute of the particular layer.

In general, the `Step` elements and their respective attributes have a significant purpose. Since there may be many steps in a 2581 file, users usually identify the step `name` attribute as a method to group steps that relate to a particular purpose. The following are the recommended organizational structures:

BOARD for all the ‘important’ steps representing the graphics of the board itself.

BOARDPANEL for all the ‘important’ steps representing the graphics of the board panel itself.

ASSEMBLY for all the ‘important’ steps representing the graphics of the assembly itself.

ASSEMBLYPALLET for all the ‘important’ steps representing the graphics of the assembly pallet itself.

DOCUMENTATION for all the ‘important’ steps representing the documentation of the board or the assembly.

TOOLING for all the ‘important’ steps representing the tooling used on the board or the assembly.

COUPON for test coupons that are embedded in the design of the board or assembly.

MISCELLANEOUS, for all the remaining steps that do not have a home in any of the other context identification.

The purpose of a group of step elements should relate to the layer descriptions which are identified by their attributes that include the mandatory requirements of name, layerFunction, side, and polarity. Due to the layerRef attributes of several Step elements, the recommendations shown in Table 5 apply to good file management. Table 5 shows all possible combinations of the layerFunction attributes and their potential characteristics. The appropriate designation to make the link to the Bill of Material has been added to the table where appropriate and consists of Material Designations (MatDes), Document Designations (DocDes), Component Designations (RefDes), and Tooling Designations (ToolDes). Table 5-1 indicates the recommendations of layer attributes to the Step elements that are intended to describe the board or board panel. Table 5-2 shows the recommendations related to assembly and assembly pallet. Table 5-3 shows the recommendations related to the coupon step elements. Step documentation, tooling, and miscellaneous element recommendations are shown in Table 5-4.

Table 5 Step Elements to Layer Attribute Recommendations

Step elements that describe:	Layer Attributes				
	name	layerFunction		side letters for reference only	Polarity numbers for reference only
All Possible Combinations	A unique name in a 2581 file	MATERIAL	MatDes	COATINGCOND	A_TOP B_BOTTOM C_BOTH D_INTERNAL E_ALL F_OTHER	1-POSITIVE 2 NEGATIVE
			MatDes	COATINGNONCOND		
			MatDes	DIELBASE		
			MatDes	DIELCORE		
			MatDes	DIELPREG		
			MatDes	DIELADHV		
			MatDes	SOLDERBUMP		
			MatDes	RESISTIVE		
			MatDes	CAPACITIVE		
			RefDes	COMPONENT_EMBEDDED		
			MatDes	SOLDERPASTE		
			MatDes	CONDFOIL		
			MatDes	CONDFILM		
		BOARD	RefDes	STACKUP_COMPOSITE	A_TOP B_BOTTOM C_BOTH D_INTERNAL E_ALL F_ OTHER	1- POSITIVE 2-NEGATIVE
			MatDes	LEGEND		
			MatDes	SOLDERMASK		
			MatDes	CONDUCTOR		
			MatDes	PLANE		
			MatDes	SIGNAL		
			MatDes	MIXED		
			ToolDes	PASTEMASK		
			RefDes	COMPONENT_EMBEDDED		
			ToolDes	DRILL		
			ToolDes	ROUTE		
			MatDes	CONDUCTIVE_ADHESIVE.		
			ToolDes	SCORE		
		PROCESS	MatDes	GLUE	A_TOP B_BOTTOM C_BOTH D_INTERNAL E_ALL F_ OTHER	1- POSITIVE 2-NEGATIVE
			MatDes	SOLDERBUMP		
			MatDes	HOLEFILL		
			ToolDes	PROBE		
			ToolDes	REWORK		
			ToolDes	FIXTURE		
			MatDes	COATINGCOND		
			MatDes	COATINGNONCOND		
			RefDes	ASSEMBLY		
			ToolDes	SILKSCREEN		
		DOCUMENTATION			A_TOP B_BOTTOM C_BOTH D_INTERNAL E_ALL F_ OTHER	1- POSITIVE 2-NEGATIVE
			DocDes	COURTYARD		
			DocDes	GRAPHIC		
			DocDes	DOCUMENT		
			DocDes	LANDPATTERN		
			DocDes	COMPONENT_TOP		
			DocDes	COMPONENT_BOTTOM		
			DocDes	BOARD_OUTLINE		
			(TBD)	OTHER		

Table 5-1 Step Elements to Layer Attribute Recommendations for Board or Board Panel

Step elements that describe:	Layer Attributes				
	name	layerFunction		side letters for reference only	Polarity numbers for reference only
BOARD AND BOARD PANEL	A unique name in a 2581 file	MATERIAL	COATINGCOND	A|B|C|D|E	1
			COATINGNONCOND	A|B|C|D|E	1|2
			DIELBASE	A|B|C|D	1|2
			DIELCORE	A|B|C|D	1|2
			DIELPREG	D	1|2
			DIELADHV	A|B|C|D	1
			SOLDERBUMP	A|B|C|D	1|2
			RESISTIVE	D	1|2
			CAPACITIVE	D	1|2
			COMPONENT_EMBEDDED	D	1
			SOLDERPASTE	A|B	1
			CONDFOIL	A|B|C|D|E	1|2
			CONDFILM	A|B|C|D|E	1|2
		BOARD	STACKUP_COMPOSITE	A|B|C|D	1|2
			LEGEND.	A|B|C|D	1|2
			SOLDERMASK	A|B|C|	1|2
			CONDUCTOR	A|B|C|D	1|2
			PLANE	A|B|C|D	1|2
			SIGNAL	A|B|C|D	1|2
			MIXED	A|B|C|D	1|2
			PASTEMASK	A|B|C	1|2
			COMPONENT_EMBEDDED	D	1
			DRILL	A|B|C|D|E	1
			ROUTE	A|B|C|D|E	1|2
			CONDUCTIVE_ADHESIVE	A|B|C|D	1
			SCORE	A|B|C|D|E	1|2
		PROCESS	GLUE	A|B	1
			SOLDERBUMP	A|B	1
			HOLEFILL	A|B|C	1
			PROBE	A|B|C	1
			REWORK	F	1
			FIXTURE	F	1
			COATINGCOND	A|B|C|D|E	1
			COATINGNONCOND	A|B|C|D|E	1|2
			ASSEMBLY	F	1
			SILKSCREEN	F	1|2
		DOCUMENTATION	COURTYARD	F	1
			GRAPHIC	A|B|C|D|E	1|2
			DOCUMENT	A|B|C|D|E	1
			LANDPATTERN	A|B|C|D|E	1
			COMPONENT_TOP	A	1
			COMPONENT_BOTTOM	B	1
			BOARD_OUTLINE	A|B|C|D|E	1
			OTHER	A|B|C|D|E	1

Table 5-2 Step Elements to Layer Attribute Recommendations for Assembly and AssemblyPallet

Step elements that describe:	Layer Attributes				
	name	layerFunction		Side letters for reference only	Polarity numbers for reference only
ASSEMBLY AND ASSEMBLY PALLET	A unique name in a 2581 file	MATERIAL	COATINGCONDMAT	A|B|C|E	1
			COATINGNONCONDMAT	A|B|C|E	1
			DIELADHV	A|B|C	1
			SOLDERBUMP	A|B	1
			RESISTIVE	A|B|C	1
			CAPACITIVE	A|B|C	1
			SOLDERPASTE	A|B|C	1
		BOARD	STACKUP_COMPOSITE	A|B|C|E	1|2
			PASTEMASK	A|B|C	1|2
			EMBEDDED COMPONENT	A|B|C	1|2
			CONDUCTIVE_ADHESIVE	A|B|C	1
			CONDUCTOR	A|B|C	1|2
			PLANE	A|B|C|D	1|2
			SIGNAL	A|B|C|D	1|2
			MIXED	A|B|C|D	1|2
		PROCESS	GLUE	A|B	1|2
			SOLDERBUMP	A|B	1|2
			PROBE	A|B|C	1|2
			REWORK	F	1
			FIXTURE	F	1
			COATINGNONCOND	A|B|C|D|E	1|2
			ASSEMBLY	A|B|C|D|E	1|2
		DOCUMENTATION	COURTYARD	A|B|C	1
			GRAPHIC	A|B|C|D|E	1|2
			DOCUMENT	A|B|C|D|E	1
			COMPONENT_TOP	A	1
			COMPONENT_BOTTOM	B	1
			BOARD_OUTLINE	C	1
			OTHER	A|B|C|D|E	1

Table 5-3 Step Element to Layer Attribute Recommendations for Coupon

Step elements that describe:	Layer Attributes				
	name	layerFunction		Side letters for reference only	Polarity numbers for reference only
COUPON	A unique name in a 2581 file	MATERIAL	COATINGCOND	A|B|C|D|E	1
			COATINGNONCOND	A|B|C|D|E	1|2
			DIELBASE	A|B|C|D	1|2
			DIELCORE	A|B|C|D	1|2
			DIELPREG	D	1|2
			DIELADHV	A|B|C|D	1
			RESISTIVE	D	1|2
			CAPACITIVE	D	1|2
			CONDFOIL	A|B|C|D|E	1|2
			CONDFILM	A|B|C|D|E	1|2
			COMPONENT_EMBEDDED	D	1|2
		BOARD	STACKUP_COMPOSITE	A|B|C|D|E	1|2
			LEGEND	A|B|C|D	1|2
			SOLDERMASK	A|B|C|	1|2
			CONDUCTOR	A|B|C|D	1|2
			PLANE	A|B|C|D	1|2
			SIGNAL	A|B|C|D	1|2
			MIXED	A|B|C|D	1|2
			COMPONENT_EMBEDDED	D	1
			DRILL	A|B|C|D|E	1
			ROUTE	A|B|C|D|E	1|2
			SCORE	A|B|C|D|E	1|2
		PROCESS	GLUE	A|B	1
			SOLDERBUMP	A|B	1
			HOLEFILL	A|B|C	1
			PROBE	A|B|C	1
			REWORK	F	1
			FIXTURE	F	1
			COATINGCOND	A|B|C|D|E	1
			COATINGNONCOND	A|B|C|D|E	1|2
			ASSEMBLY	F	1
		DOCUMENTATION	COURTYARD	F	1
			GRAPHIC	A|B|C|D|E	1|2
			DOCUMENT	A|B|C|D|E	1
			LANDPATTERN	A|B|C|D|E	1
			COMPONENT_TOP	A	1
			COMPONENT_BOTTOM	B	1
			BOARD_OUTLINE	E	1
			OTHER	A|B|C|D|E	1

Table 5-4 Step Purpose to Layer Restrictions for Documentation, Tooling and Miscellaneous

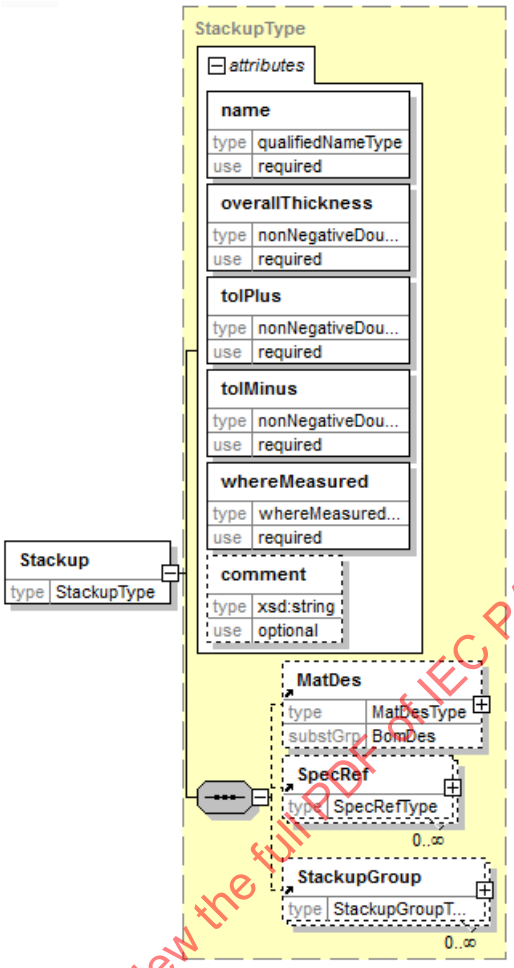
Step elements that describe:	Layer Attributes				
	name	layerFunction		Side letters for reference only	Polarity numbers for reference only
DOCUMENTATION	A unique name in a 2581 file	DOCUMENTATION	COURTYARD	A|B|C	1
			GRAPHIC	A|B|C|D|E	1|2
			DOCUMENT	A|B|C|D|E	1
			COMPONENT_TOP	A	1
			COMPONENT_BOTTOM	B	1
			BOARD_OUTLINE	E	1
			OTHER	A|B|C|D|E	1
TOOLING	A unique name in a 2581 file	PROCESS	GLUE	A|B|C	1|2
			SOLDERBUMP	A|B	1|2
			PROBE	A|B	1
			REWORK	A|B|C	1
			FIXTURE	F	1|2
			COATINGNONCOND	A|B	1
			ROUTE	A|B|C|D|E	1|2
			SCORE	A|B|C|D|E	1|2
MISCELLANEOUS	A unique name in a 2581 file	DOCUMENTATION	OTHER	A|B|C|D|E|F	1

When combining steps that describe BOARD and COUPON information on the same PANEL, the layer construction **shall** be identical between those elements being instantiated on the same panel. They also refer to the layering so that it is consistent such that the top layer is identical for all steps referenced in the panel construction.

The viewer should always display the graphical features but store the layer polarity as an attribute.

8.2.2 Stackup

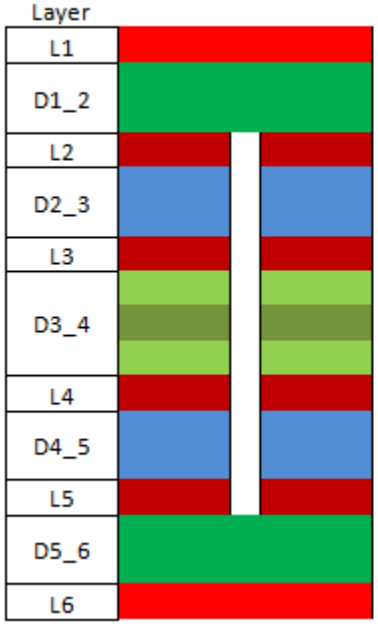
The `Stackup` element represents the construction for the printed board. The `Stackup` element consists of several sub-elements that help to define various sections of the construction permitting the description of core material or prepreg definition. These are accomplished in the `StackupGroup` element. The attributes of the `Stackup` element represent the finished board and apply to the entire board characteristics. The reference in the Bill of Material is to the finished board and as such uses theMatDes identification as the BomDesType.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Stackup	StackupType	A nested element containing the construction information for the printed board.	0-1
name	qualifiedNameType	A unique name assigned by the user to the printed board. The name must be unique and match the name used for the layerFunction STACKUP_COMPOSITE assigned by the `CadData` element	1-1
overallThickness	nonNegativeDouble Type	Describes the overall nominal thickness of the finished printed board including all plating and coatings.	1-1
tolPlus	nonNegativeDouble Type	The plus tolerance that may be applied to the nominal thickness to set the printed board upper control limit.	1-1
tolMinus	nonNegativeDouble Type	The minus tolerance that may be applied to the nominal thickness to set the printed board lower control limit.	1-1
whereMeasured	whereMeasuredType	An enumerated string that may be one of the following: LAMINATE | METAL | MASK | OTHER that defines the location on the printed board, panel, or assembly where the overall thickness is to be measured.	1-1
comment	Xsd:string	An optional attribute used to provide any special instructions about the layering, specification requirements or stackup of an HDI, multilayer, single-sided, or double-sided printed board.	0-1
MatDes	MatDesType	A unique reference designator that is part of the BomDes substitution using the letters in Appendix C followed by a number in order to represent a particular material or layer pair that could be called for in a Bill of Material for the printed board construction	0-1

SpecRef	SpecRefType	The identification of a particular specification(s) from the SpecificationType that is able to provide additional details or instructions that apply to the board or assembly descriptions of the Stackup. The linkage is provided through the specific "specificationId" (spec Name)	0-n
StackupGroup	StackupGroupType	A nested element containing in formation of the printed board construction. StackupGroup elements should be defined within the Stackup before they are referenced in the 2581 file.	0-n

CAD View



BOM View

sequence	MatDes name
1	CF1
2	DP1
3	DC1
4	DP2
5	DP3
6	DP2
7	DC1
8	DP1
9	CF1

Initial Draft From Designer

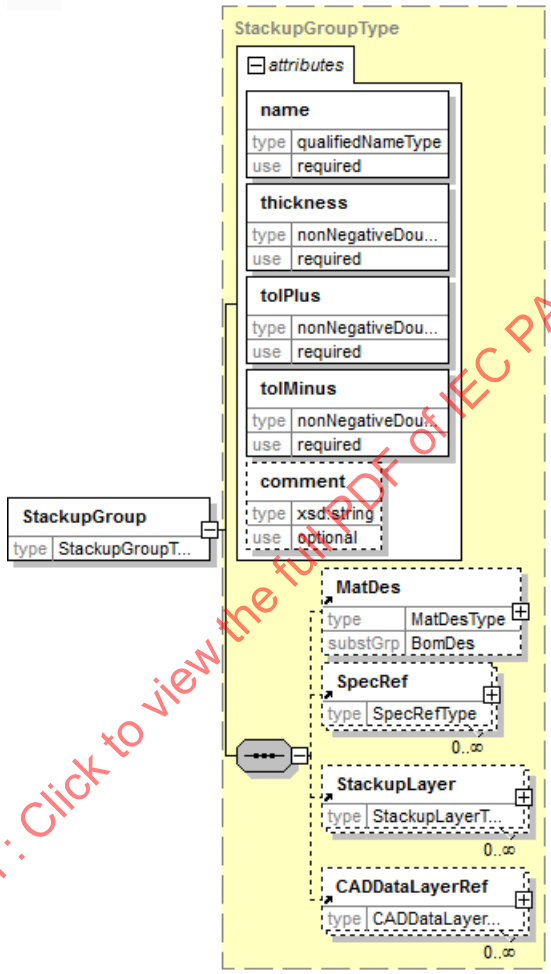
```
<Stackup overallThickness="1.1778" tolPlus="0.0" tolMinus="0.0" whereMeasured="OTHER">
  <StackupGroup name="AllStackupLayers" thickness="1.1778" tolPlus="0.0" tolMinus="0.0">
      <StackupLayer layerOrGroupRef=”L1” sequence="1" thickness="0.0559">
          </StackupLayer>
      <StackupLayer layerOrGroupRef=”D1_2”sequence="2" thickness="0.1321">
          </StackupLayer>
      <StackupLayer layerOrGroupRef=”L2” sequence="3" thickness="0.0559">
          </StackupLayer>
      <StackupLayer layerOrGroupRef=”D2_3”sequence="4" thickness="0.1625">
          </StackupLayer>
      <StackupLayer layerOrGroupRef=”L3” sequence="5" thickness="0.0559">
          </StackupLayer>
      <StackupLayer layerOrGroupRef=”D3_4”sequence="6" thickness="0.2532">
          </StackupLayer>
      <StackupLayer layerOrGroupRef=”L4” sequence="7" thickness="0.0559">
          </StackupLayer>
      <StackupLayer layerOrGroupRef=”D4_5”sequence="8" thickness="0.1625">
          </StackupLayer>
      <StackupLayer layerOrGroupRef=”L5” sequence="9" thickness="0.0559">
          </StackupLayer>
    <StackupLayer layerOrGroupRef=”D5_6” sequence=”10” thickness="0.1321">
          </StackupLayer>
      <StackupLayer layerOrGroupRef=”L6” sequence=”11” thickness="0.0559">
          </StackupLayer>
  </StackupGroup>
</Stackup>
```

Stackup back from FAB Vendor

```
<Stackup overallThickness="1.1778" tolPlus="0.0" tolMinus="0.0" whereMeasured="OTHER">
  <StackupGroup name="AllStackupLayers" thickness="1.1778" tolPlus="0.0" tolMinus="0.0">
      <StackupLayer layerOrGroupRef=”L1” sequence="1" thickness="0.0559">
                                    <MatDes name=”CF1”/>
          </StackupLayer>
      <StackupLayer layerOrGroupRef=”D1_2”sequence="2" thickness="0.1321">
                                    <MatDes name=”DP1”/>
          </StackupLayer>
    <StackupLayer layerOrGroupRef=”FabMe1st” thickness="0.7018">
      </StackupLayer>
    <StackupLayer layerOrGroupRef=”D5_6” sequence=”8” thickness="0.1321">
                                    <MatDes name=”DP1”/>
          </StackupLayer>
      <StackupLayer layerOrGroupRef=”L6” sequence=”9” thickness="0.0559">
                                    <MatDes name=”CF1”/>
          </StackupLayer>
  </StackupGroup>
  <StackupGroup name="FabMe1st" thickness="0.7018" tolPlus="0.0" tolMinus="0.0">
    <StackupLayer layerOrGroupRef=”laminate1” sequence=”3” thickness="0.2243">
                                    <MatDes name=”DC1”/>
          </StackupLayer>
    <StackupLayer layerOrGroupRef=”inner_prepreg” thickness="0.2532">
          </StackupLayer>
    <StackupLayer layerOrGroupRef=”laminate2” sequence=”7” thickness="0.2243">
                                    <MatDes name=”DC1”/>
          </StackupLayer>
  </StackupGroup>
  <StackupGroup name=”laminate1” thickness="0.2243" tolPlus="0.0" tolMinus="0.0">
    <StackupLayer layerOrGroupRef=”L2” thickness="0.0559">
      </StackupLayer>
        <StackupLayer layerOrGroupRef=”D2_3” thickness="0.1625">
      </StackupLayer>
        <StackupLayer layerOrGroupRef =”L3” thickness="0.0559">
      </StackupLayer>
  </StackupGroup>
<StackupGroup name="laminate2" thickness="0.2243" tolPlus="0.0" tolMinus="0.0">
    <StackupLayer layerOrGroupRef=”L4” thickness="0.0559">
      </StackupLayer>
        <StackupLayer layerOrGroupRef=”D4_5” thickness="0.1625">
      </StackupLayer>
        <StackupLayer layerOrGroupRef=”L5” thickness="0.0559">
      </StackupLayer>
    </StackupGroup>
    <StackupGroup name=”inner_prepreg” thickness="0.2532" tolPlus="0.0" tolMinus="0.0" >
    <CADDataLayerRef layerRef=”D3_4”/>
    <StackupLayer sequence=”4” thickness="0.1015">
                                    <MatDes name=”DP2”/>
          </StackupLayer>
    <StackupLayer sequence=”5” thickness="0.0502”>
                                    <MatDes name=”DP3”/>
          </StackupLayer>
    <StackupLayer sequence=”6” thickness="0.1015">
                                    <MatDes name=”DP2”/>
          </StackupLayer>
  </StackupGroup>
</Stackup>
```

8.2.2.1 StackupGroup

The `StackupGroup` represents all the layers of the printed board and defines the order of their occurrence in the board construction. Individual layers may be identified as layer pairs. In this manner the user has the ability to define the characterization of the multilayer construction as well as preparing layer prelamination sequences. The order, however, must be in accordance with the description of the final board. If StackupGroup represents the finished board the attributes apply to the entire finished board; if StackupGroup identifies layer pairs the attributes apply to the specific layer pair only and that product is called for in the stackup by its qualified name in the order of occurrence in the total stackup.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
StackupGroup	StackupGroupType	A nested element containing in formation of the printed board construction.	0-n
name	qualifiedNameType	A unique name assigned to an individual or group of layers that make up the printed board. The name must be unique so that when a group becomes nested in the over all board it is referenced in the proper order of occurrence in the stackup.	1-1
thickness	nonNegativeDouble Type	The nominal thickness of the stackup group. If the stackup group represents the total board rather than a subset the thickness must match the information provided in the stackup element attributes.	1-1
tolPlus	nonNegativeDouble Type	The plus tolerance that may be applied to the nominal thickness to set the stackupGroup upper control limit.	1-1

tolMinus	nonNegativeDouble Type	The minus tolerance that may be applied to the nominal thickness to set the stackupGroup lower control limit.	1-1
comment	string	An optional attribute used to provide any special instructions about the layering, layer pairs or stackupGroup	0-1
MatDes	MatDesType	A unique reference designator that is part of the BomDes substitution using the letters in Appendix C followed by a number in order to represent a particular material or layer pair that could be called for in a Bill of Material for the printed board construction	0-1
SpecRef	SpecRefType	The identification of a particular specification(s) from the SpecificationType that is able to provide additional details or instructions that apply to the board or assembly descriptions of the StackupGroup. The linkage is provided through the specific "specificationId" (spec Name)	0-n
StackupLayer	StackupLayerType	A nested element containing in all the layer formation as to how the printed board is constructed. If layer pairs are produced separately possibly containing buried vias they are defined as a separate group and then positioned in the appropriate order of their occurrence in the stackup. A relationship to the particular BOMItem should be established through use of the appropriate RefDes description provided in bomItem such as DB2 for a dielectric base material type. See Appendix C.	0-n
CADDataLayerRef	LayerType	A single or set of layer names that have been assigned by the CAD system and represent a link or comparison to the names assigned to the layers shown in the stackupGroup	0-n

Example of Property References for a Stackup Spec

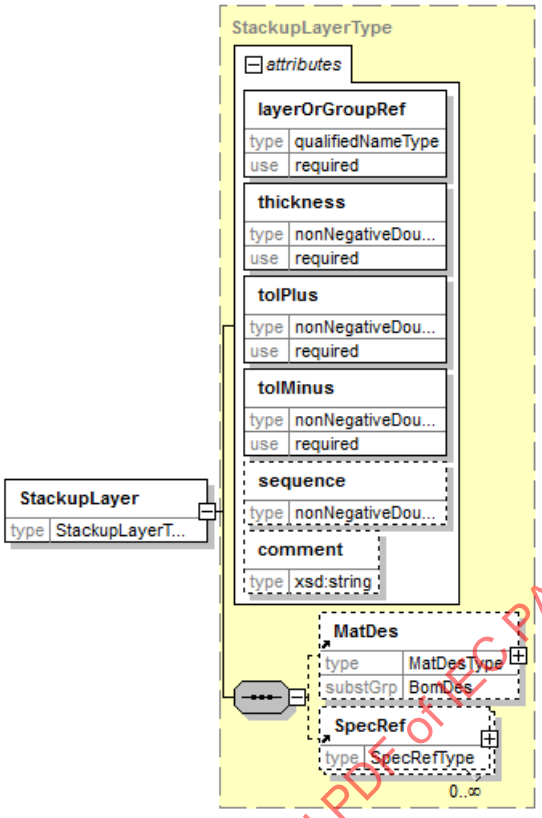
The example below shows:

a. A given Spec definition can contain multiple Specification Types
b. When a Specification Type for a StackupLayer Spec contains multiple values at different refValues, which could be required for simulation purposes (see DIELECTRIC_CONSTANT example in section 8.1.1.5) then a refValue can be a assigned within a Spec referenced at the Stackup level, to indicate a reference value for board fabrication

```
<Spec name = "property_references">
  <Dielectric type="DIELECTRIC_CONSTANT">
    <Property refValue="10.0e9" refUnit="Hz"/>
  </Dielectric>
  <Dielectric type="LOSS_TANGENT">
    <Property refValue="10.0e9" refUnit="Hz"/>
  </Dielectric>
  <Conductor type="CONDUCTIVITY">
    <Property refValue="25" refUnit="CELCIUS"/>
  </Conductor>
  <Impedance type="IMPEDANCE">
    <Property refValue="25" refUnit="CELCIUS"/>
  </Impedance>
</Spec>
```


8.2.2.1.1 StackupLayer

The `Stackuplayer` represents all the layers of the printed board. Individual layers may be identified as material layers and are used to help define the layer pairs designated in StackupGroup.



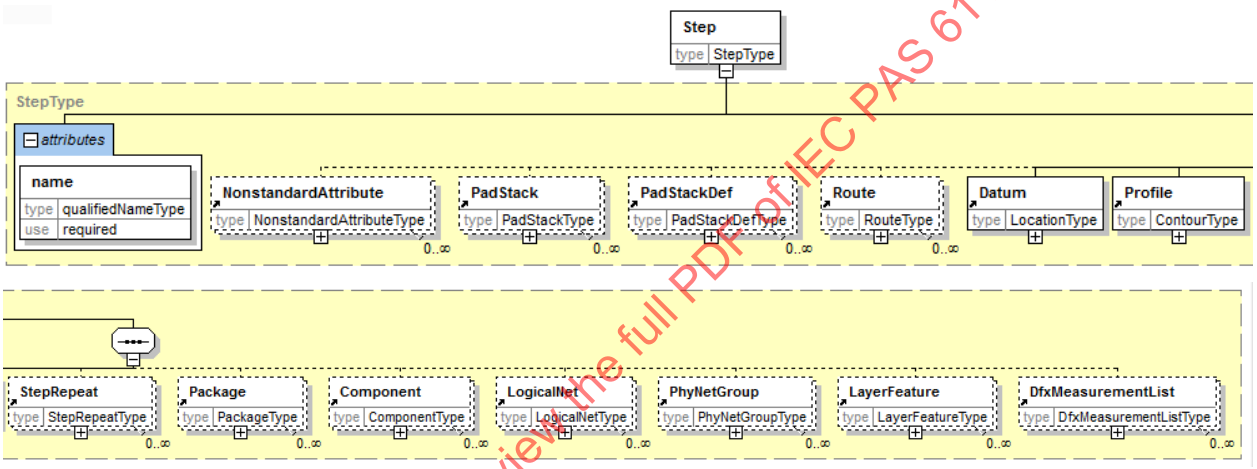
LayerOrGroupRef	qualifiedNameType	A reference to an individual layer or a group that has been previously identified. A single sheet of copper foil may be a named layer and would thus apply to the group, as would a layer pair of copper clad laminate purchased from a laminator.	1-1
thickness	nonNegativeDouble Type	The thickness of the particular material being defined. The thickness matches nominal thickness of a predefined StackupGroup.	1-1
tolPlus	nonNegativeDouble Type	The plus tolerance that may be applied to the nominal thickness to set the layer upper control limit. If this is a stackupGroup the tolerances shall match those indicated in the group description	1-1
tolMinus	nonNegativeDouble Type	The minus tolerance that may be applied to the nominal thickness to set the layer lower control limit. If this is a stackupGroup the tolerances shall match those indicated in the group description	1-1
sequence	nonNegativeDouble Type	The specific order in which the layer materials or layer pairs are positioned in the stackup stating with the top of the board as sequence 1 followed by the entire board construction of imaged or un imaged layers/layer pairs.	0-1
comment	string	An optional attribute used to provide any special instructions about the layering or stackup of a multilayer single-sided, or double-sided printed board.	0-1
MatDes	MatDesType	A unique reference designator that is part of the BomDes substitution using the letters in Appendix C followed by a number in order to represent a particular material or layer pair that could be called for in a Bill of Material for the printed board construction	0-1
SpecRef	SpecRefType	The identification of a particular specification(s) from the SpecificationType that is able to provide additional details or instructions that apply to the board or assembly descriptions of the Stackup Layer. The linkage is provided through the specific “specificationId” (spec Name)	0-n

8.2.3 Step

The `Step` element represents a collection of layers, each with a profile that defines its outer shape. The basic step is the Printed Circuit Assembly (PCA), the unpopulated board or other related information (e.g., documentation). In manufacturing, this basic step is often step and repeated (nested) inside a larger step (called array, or sub-panel). This array step can be further nested into another step; called a production panel. The `Ecad` element always contains at least one `Step`, but may contain several, some basic ones and others nesting previous steps.

The CAD `Step` tag can be repeated multiple times inside a job to represent several job Steps and their optional panelization. Each Step contains all the relevant information including `Datum`, `Profile`, `StepRepeat`, `LayerAttribute`, `Package`, `Component`, `VplComponent`, `LogicalNet` and `LayerFeature`.

All steps inside an `Ecad` element share the exact same layer structure, since they are 'cut' from the same basic panel. Each `layer`, in the list of layers, exists in every step, although in each `step` it may contain different graphical information or be empty.

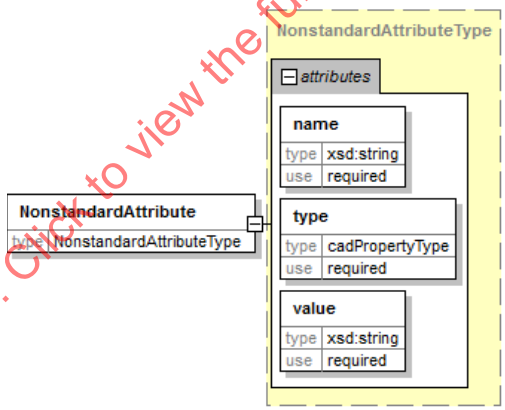


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Step	StepType	The `Step` element consists of multiple sub-elements each intended to help describe the different steps needed in the board fabrication, or assembling the electronic product.	1-n
name	qualifiedNameType	The name assigned by the user for the individual Steps used to make up the layers identified in a particular `StepList`.	1-1
NonstandardAttribute	NonstandardAttributeType	A nested element that can be used to provide extra details regarding a particular "Step" description in terms of BOOLEAN, DOUBLE, INTEGER, or STRING data. The properties of the NonstandardAttribute become unique due to its' Name.	0-n
PadStack	PadStackType	A nested element containing a list of all the `PadStack` configurations taken from the CAD file as a descriptions of the original design of the board or panel and their application to the electronic product. The data is redundant when layered fabrication is defined in the file, and serves the purpose of archiving CAD data used for reference.	0-n
PadStackDef	PadStackDefType	An element that describes the construction of various padstack types used in the design of the printed board, and provides a correlation to the usage of the padstack to those holes or pads that help to form the padstack.	0-n
Route	RouteType	The individual route segment list captured from the CAD system. The data is redundant when layered fabrication is defined in the file, and serves the purpose of archiving CAD data used for reference.	0-n

Datum	LocationType	The `Datum` element defines the location of the point of origin for the individual `Step` file. The name of the `StepList` helps to associate the datum between boards and panels or arrays.	1-1
Profile	ContourType	The profile of all the elements in the `Step` established as a `Contour`.	1-1
StepRepeat	StepRepeatType	A nested element list containing the Step and Repeat 8s that impact the information of the electronic product.	0-n
Package	PackageType	Generic component package descriptions for use by the `Step` file schemas.	0-n
Component	ComponentType	A nested element list of component descriptions and their application to the electronic product. Each component references a package style from the `Package` section.	0-n
LogicalNet	LogicalNetType	A nested element list of logical net descriptions and their application to the electronic product.	0-n
PhyNetGroup	PhyNetGroupType	A nested element list of physical net descriptions and their application to the electronic product.	0-n
LayerFeature	LayerFeatureType	A nested element list of all the features associated with a specific layer and their application to the electronic product.	0-n
DfxMeasurementList	DfxMeasurement ListType	A nested element list of the recommended modifications of the design features, indicating the measurements made of the physical conditions that might be considered as manufacturing improvements.	0-n

8.2.3.1 NonstandardAttribute

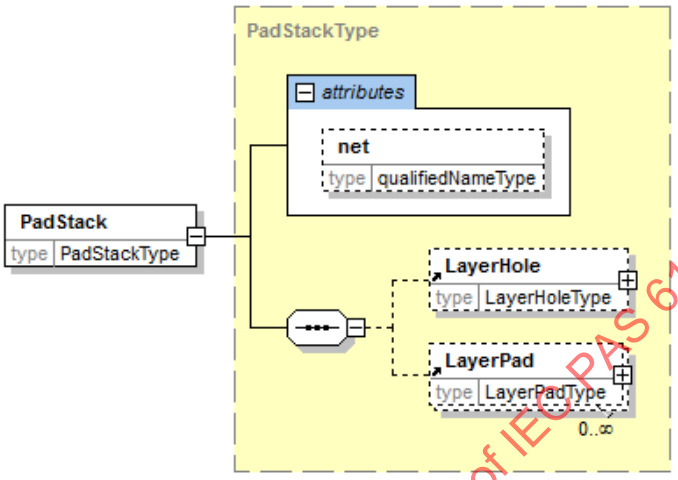
The NonstandardAttribute element consists of various conditions that may be used in association with the `Step` element. The NonstandardAttribute element has several attributes which include a name, type and value thus making each NonstandardAttribute unique. The type attribute is a cadPropertyType and identifies the “value” attribute as being BOOLEAN, DOUBLE, INTEGER or STRING data.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Nonstandard Attribute	Nonstandard AttributeType	A nested element that can be used to provide extra details regarding a particular “Step” description in terms of BOOLEAN, DOUBLE, INTEGER, or STRING data. The properties of the NonstandardAttribute become unique due to its Name.	0-n
name	qualifiedNameType	A unique name assigned by the user to the NonstandardAttribute. The name must be unique and should match the purpose of the actions to be taken.	1-1
type	cadPropertyType	A set of enumerated string descriptions that identify the condition of the value requirement. They consist of BOOLEAN | DOUBLE | INTEGER or STRING data.	1-1
value	string	The detail requirements as they pertain to the particular Step description and interpreted - according to the type enumeration that is part of the particular NonstandardAttribute.	1-1

8.2.3.2 PadStack

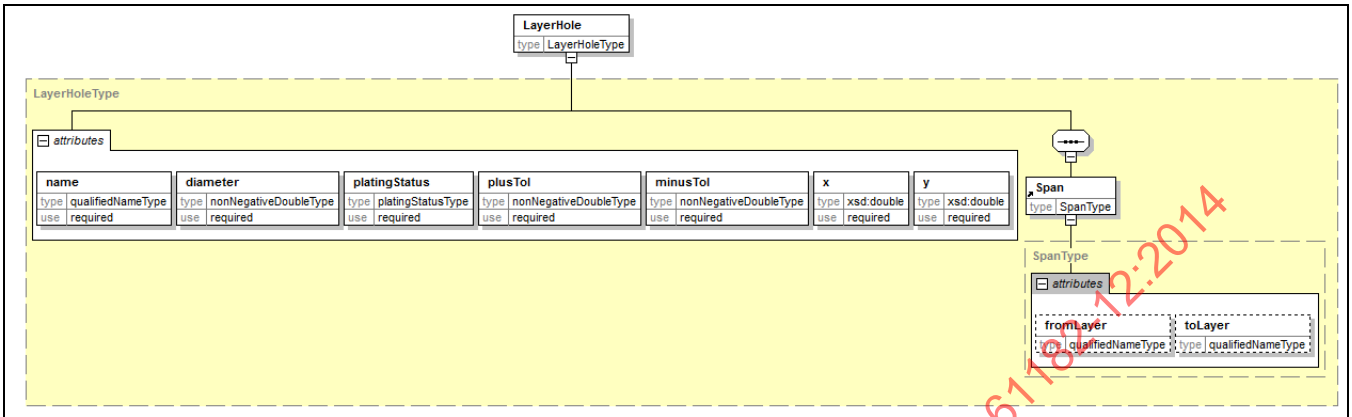
The `PadStack` element consists of multiple padstacks taken from the CAD system and is intended to preserve the data from the layout system. The information noted pertain to the `CadProperty` of which the padstack is a part. The relationship is identified by the `CadProperty` unique name and is the original design file from the CAD system. The data becomes redundant when the individual layered features are defined and is then for reference only.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
PadStack	PadStackType	A nested element containing a list of all the `PadStack` configurations taken from the CAD file as a descriptions of the original design of the board or panel and their application to the electronic product. The data is redundant when layered fabrication is defined in the file, and therefore is for reference only.	0-n
net	qualifiedNameType	The name attached to the electrical description of the conductive hole pattern.	0-1
LayerHole	layerHoleType	The hole description of the padstack including all its attributes.	0-1
LayerPad	layerPadType	A nested element defining the pad(s) that the hole traverses indicating location and layer reference for different pad sizes.	0-n

8.2.3.2.1 LayerHole

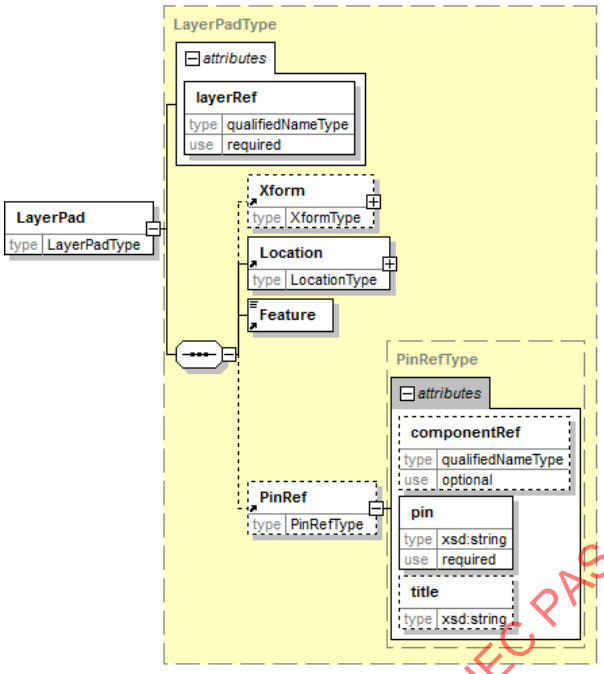
The `LayerHole` element associated with a padstack identifies the distance through which the hole transcends as a span between individual layers.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
LayerHole	LayerHoleType	The hole description of the padstack including all its attributes.	0-1
name	qualifiedNameType	A unique identification of a particular hole.	1-1
diameter	nonNegativeDouble Type	The nominal diameter of the hole in the as-finished state.	1-1
platingStatus	platingStatusType	The type of hole defined as an enumerated string indicating PLATED | NONPLATED | VIA.	1-1
plusTol	nonNegativeDouble Type	The plus tolerance that defines the variation permitted from the nominal hole-diameter.	1-1
minusTol	nonNegativeDouble Type	The minus tolerance that defines the variation permitted from the nominal hole-diameter.	1-1
x	double	The x-location of the hole.	1-1
y	double	The y-location of the hole.	1-1
Span	SpanType	A nested element where the field may be added to layers of type drill and route that are either buried or blind. In such a case, it represents the start and end board layers between which drilling/routing is done. If the drill layer is going through the board, it is required not to be included in a span subsection.	1-1

8.2.3.2.2 LayerPad

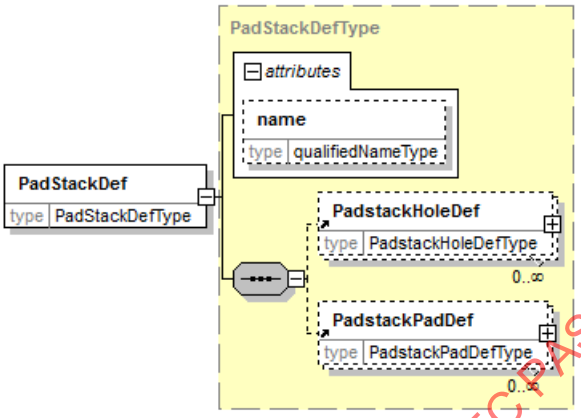
The `LayerPad` element is a group of specific graphic features that become part of the padstack with a description of the pin to which the padstack applies and the layer on which the individual pad is located.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
LayerPad	LayerPadType	A nested element defining the pad(s) that the hole traverses indicating location and layer reference for different pad sizes	0-n
layerRef	qualifiedNameType	A reference to the appropriate layer to which the attribute applies.	1-1
Xform	XformType	An element that provides the ability to reset the point of origin of a predefined pad that can be scaled, mirror imaged or rotated. See 3.3	0-1
Location	LocationType	The location of the image defined by the `StandardShape, UserShape` or a pre-defined `StandardShape or User Shape` of the pad. The image may have been reorientated by the Xform.	1-1
x	double	The x coordinate of the location of the pad.	1-1
y	double	The y coordinate of the location of the pad.	1-1
Feature	ABSTRACT	An embedded element that defines a substitution group of any `StandardShape` or `UserShape` that may be instantiated as a part of the `pad` description. A predefined `StandardShape or UserShape` may also be instantiated by its unique “id” when the feature is contained in the `DictionaryStandard or User`. When a reference is made to the dictionary predefined primitive the `Units` must match.	
PinRef	PinRefType	An individual `Pin` related to the place where a component attaches to the net. This description facilitates location of lands on the surface of the board or places where through-hole components are mounted.	1-n
componentRef	qualifiedNameType	The qualifiedNameType that identifies the reference designator used as the attribute `refDes` of the `Component` element in `Step` It is the reference to the component that is connected by the particular Pin and becomes a part of the electrical description of the net. The `componentRef` attribute is not required when used for a `PinRef` element under `Pad` elements which are under `LandPattern` elements. Otherwise, the `componentRef` attribute is required for `PinRef` elements under `Pad`, `LayerPad` and `LogicalNet` elements.	0-1
pin	string	An identification of the component pin that becomes a part of the electrical description.	1-1
title	string	An alternate method of relating the pin information providing characteristics of the component lead or termination description.	0-1

8.2.3.3 PadStackDef

The `PadStackDef` element consists of multiple padstacks types or descriptions taken from the CAD system and is intended to preserve the data from the layout system. The information noted pertain to the `CadProperty` of which the padstack is a part. The relationship is identified by the `CadProperty` unique name and is the original design file from the CAD system. The data becomes although redundant when the individual layered features are defined provides a reference for the padstack usage.

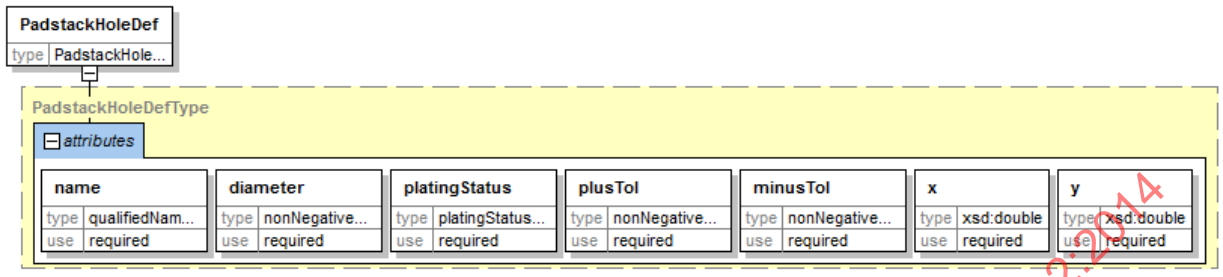


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
PadStackDef	PadStackDefType	An element that provides the characteristics of individual padstacks in the design, as established by the CAD system, and provides the link to the layer distribution of the padstacks individual characteristics.	0-n
name	qualifiedNameType	A unique name assigned to the construction of a particular padstack type.	0-n
PadstackHoleDef	PadstackHoleDefType	The hole description of a padstack including all its attributes as defined by the CAD system.	0-n
PadstackPadDef	PadstackPadDefType	The Pad description of a padstack including all its attributes as defined by the CAD system.	0-n

```
<Step name = "C027D17P">
   <PadStackDef name = " C027D17P ">
      <PadstackHoleDef name=”PSHD_1” Diameter= “.027” platingStatus=”PLATED” plusTol=”0.002” minusTol=”0.002” X=”0.0” Y=”0.0”/>
      <PadstackPadDef  layerRef=”TOP”  PadUse=”REGULAR” >
         <Location X = “0.0” Y=”0.0”/>
         <StandardPrimitive id = “CIRCLE_10”/>
       </PadstackPadDef>
       <PadstackPadDef  layerRef=”IL-1”  PadUse=”REGULAR” >
         <Location X = “0.0” Y=”0.0”/>
         <StandardPrimitive id = “CIRCLE_10”/>
       </PadstackPadDef>
      <PadstackPadDef  layerRef=”IL-1”  PadUse=”ANTIPAD” >
         <Location X = “0.0” Y=”0.0”/>
         <StandardPrimitive id = “PAD15”/>
       </PadstackPadDef>
      <PadstackPadDef  layerRef=”IL-1”  PadUse=”THERMAL” >
         <Location X = “0.0” Y=”0.0”/>
         <StandardPrimitive id = “FIGURE_THERMAL_25_+”/>
       </PadstackPadDef>
      <PadstackPadDef  layerRef=”IL-2”  PadUse=”REGULAR” >
         <Location X = “0.0” Y=”0.0”/>
         <StandardPrimitive id = “CIRCLE_10”/>
       </PadstackPadDef>
       <PadstackPadDef  layerRef=”IL-2”  PadUse=”ANTIPAD” >
         <Location X = “0.0” Y=”0.0”/>
         <StandardPrimitive id = “PAD15”/>
       </PadstackPadDef>
      <PadstackPadDef  layerRef=”IL-2”  PadUse=”THERMAL” >
         <Location X = “0.0” Y=”0.0”/>
         <StandardPrimitive id = “FIGURE_THERMAL_25_+”/>
       </PadstackPadDef>
      <PadstackPadDef  layerRef=”BOTTOM”  PadUse=”REGULAR” >
         <Location X = “0.0” Y=”0.0”/>
         <StandardPrimitive id = “CIRCLE_10”/>
       </PadstackPadDef>
   </PadStackDef>
</Step>
```

8.2.3.3.1 PadstackHoleDef

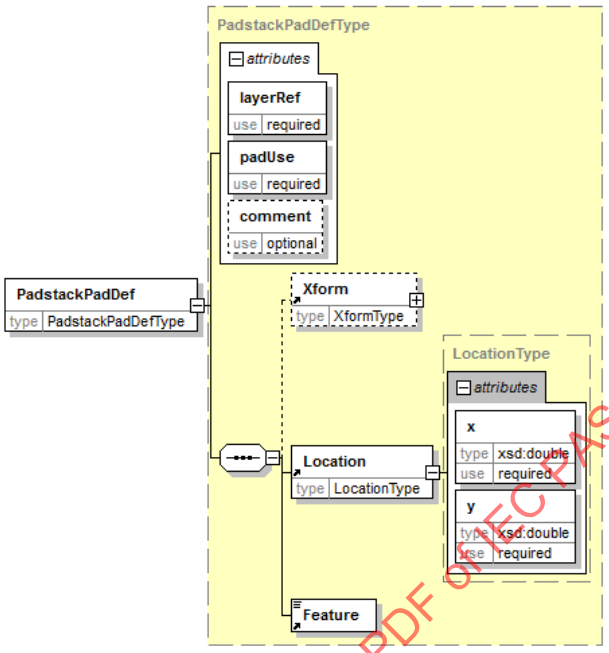
The `PadstackHoleDef` element associated with a padstack identifies the diameter, tolerance and plating status of a particular padstack location.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
PadstackHoleDef	PadstackHoleDefType	The hole description of the padstack including all its attributes.	0-1
name	qualifiedNameType	A unique identification of a particular padstack hole description.	1-1
diameter	nonNegativeDouble Type	The nominal diameter of the hole in the as-finished state.	1-1
platingStatus	platingStatusType	The type of hole defined as an enumerated string indicating PLATED | NONPLATED | VIA.	1-1
plusTol	nonNegativeDouble Type	The plus tolerance that defines the variation permitted from the nominal hole-diameter.	1-1
minusTol	nonNegativeDouble Type	The minus tolerance that defines the variation permitted from the nominal hole-diameter.	1-1
x	double	The x-location of the hole.	1-1
y	double	The y-location of the hole.	1-1

8.2.3.3.2 PadstackPadDef

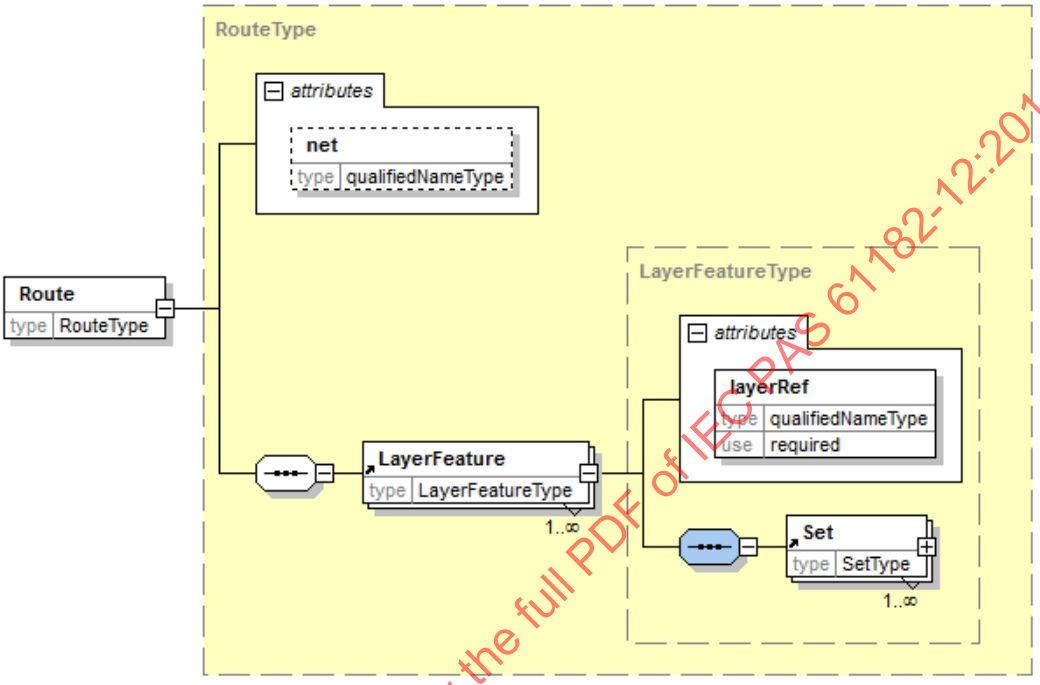
The `PadstackPadPDef` element is a specific graphic feature that becomes part of the padstack with a description of shape (Feature) and a location in order to establish the linkage to pads on individual layers.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
PadstackPadDef	PadstackPadDefType	An element that provides the definition of various pads that are used to make up a padstack within the CAD system and provides the ability to locate where these are used in the design of the board.	0-n
layerRef	qualifiedNameType	The reference to a specific layer element by it's "name" attribute. The layer referenced is where the pad image is located.	1-1
padUse	padUseType	An enumerated value of the pad type used on the particular layer, such as a power or signal or mask layer. The enumerations are REGULAR | ANTIPAD | THERMAL | OTHER. If OTHER is used a comment is required to explain the purpose of the pad.	1-1
comment	string	An explanation as to the condition of the Pad if OTHER is defined as the padUse. A comment may also be used if the pad is not connected to circuitry and has been removed by the manufacturer to improve clearance conditons.	0-1
Xform	XformType	An element that provides the ability to reset the point of origin of a predefined target that can be scaled, mirror imaged or rotated. (See 3.3)	0-1
Location	LocationType	The location of the image defined by the standard shape, user shape or a pre-defined standard shape of the pad. The image may have been reorientated by the Xform.	1-1
x	double	The x coordinate of the location of the pad relative to the origin of the padstack.	1-1
y	double	The y coordinate of the location of the pad relative to the origin of the padstack.	1-1
Feature	ABSTRACT	An embedded element that defines a substitution group of any `StandardShape` or `UserShape` that may be instantiated as a part of the `Pad` Description. A predefined `StandardShape or UserShape` may also be instantiated by its unique "id" when the feature is contained in the `DictionaryStandard or User`. When a reference is made to the dictionary predefined primitive the `Units` must match.	1-1

8.2.3.4 Route

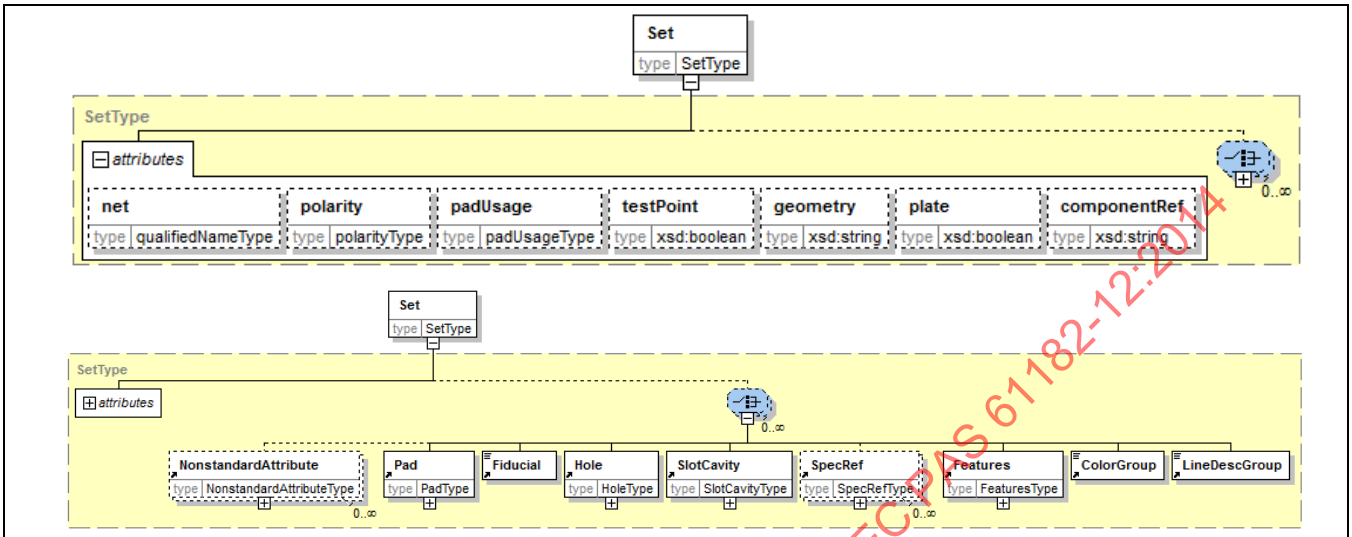
The `Route` element consists of multiple routes taken from the CAD system and is intended to preserve the data from the layout system. Each `Route` is referenced to a particular `Net` and a layer on which the route or net occurs as taken from the CAD system. The data becomes redundant when the individual layered features are defined and is then for reference only. The `Route` element uses the same characteristics of the `Step` description as defined in the `LayerFeature` schema (see 8.3.13).



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Route	RouteType	The individual route segment list captured from the CAD system. The data is redundant when layered fabrication is defined in the file, and therefore is for reference only.	0-n
net	qualifiedNameType	Each route is linked to a particular net which is defined in the Cad system and matches the padstacks that are associated with the net.	0-1
LayerFeature	LayerFeatureType	The standard IPC-2581 `Step` characteristics for layer features related to the route taken from the Cad system.	1-n
layerRef	qualifiedNameType	The reference to the unique layer name to which the `LayerFeature`(s) pertain.	1-1
Set	SetType	The multiple Set elements and attributes defined in 8.3.13 `LayerFeature` used to define specific features associated with a conductive layer.	1-n

8.2.3.4.1 Set

A specific set of graphical descriptions for a particular set of graphical shapes. These shapes are applied defining the conductive pattern of the printed board.

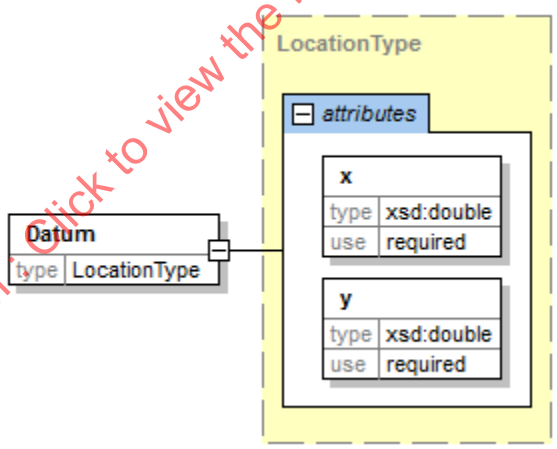


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Set	SetType	The multiple Set elements and attributes defined in 8.3.1 used to define specific features associated with a conductive layer.	1-n
net	qualifiedNameType	The electrical relationship of any feature, through the name of the `PhyNet`, when the `Set` feature has conductivity checked in the `PhyNetPoint` descriptions. This attribute is left blank if the `Set` descriptions are for other than printed board fabrication or assembly conductivity.	0-1
polarity	polarityType	`Polarity` indicates whether the information described in the `Set` is POSITIVE | NEGATIVE. A NEGATIVE connotation can be used to describe the removal of a dark field to the specific dimensions described for another attribute. Thus, a surface that contains islands may have the islands described in a negative format.	0-1
padUsage	padUsageType	An indication as to the usage of any pad that becomes a part of the `LayerFeature Set`. The descriptions are enumerated strings and must be one of the following: TERMINATION | VIA | PLANE | TOOLING_HOLE | MASK | NONE.	0-1
testPoint	boolean	An enumerated string as either TRUE or FALSE (part of the 3WC standard). TRUE indicates that the feature is a candidate for a test point used for either in-circuit or functional testing. FALSE indicates that it is not.	0-1
geometry	string	An identification to describe the overall geometry of the features contained in the `Set` and their particular application to the electronic product.	0-1
plate	boolean	An enumerated string as either TRUE or FALSE (part of the 3WC standard). TRUE indicates that the feature is plated in a secondary operation . FALSE indicates that it is not.	0-1
componentRef	string	A reference to the component instance associated with the reference designation that links the information together so that graphic representation in the Set can be accurately described in Assembly or Silk screen documentation.	0-1
NonstandardAttribute	NonstandardAttribute Type	A nested element that can be used to provide extra details regarding a particular “Set” description in terms of BOOLEAN, DOUBLE, INTEGER, or STRING data. The properties of the NonstandardAttribute become unique due to its’ Name.	0-n

Pad	PadType	A series of pads that are associated with the `LayerFeature Set`.	0-n
Fiducial	ABSTRACT	A substitution that consists of four elements that may be used to replace the fiducial element. When the `Fiducial` element is substituted it **shall** be by a `Global`, `Local`, `BadBoardMark`, or `GoodPanelMark`.	0-n
Hole	HoleType	A series of holes associated with the `LayerFeature Set`.	0-n
SlotCavity	SlotCavityType	A series of slots or cavities associated with the `LayerFeature Set`.	0-n
SpecRef	SpecRefType	The identification of a particular specification(s) from the SpecificationType that is able to provide additional details or instructions that apply to the Hole, SlotCavity or Features of the Set descriptions.. The linkage is provided through the specific “specificationId” (spec Name)	0-n
Features	FeaturesType	An embedded element that defines a substitution group of any predefined `StandardShape` or `UserShape` that may be instantiated as a part of the `LayerFeature Set`.	0-n
ColorGroup	ABSTRACT	A substitution group that permits assigning a particular color through instantiating the three basic colors or by providing a reference to a predefined `Color` in `DictionaryColor`.	0-n
LineDescGroup	ABSTRACT	A substitution group that specifies the `LineWidth` and `LineEnd` characteristics of a `Feature` that requires that description. If a predefined feature is instantiated the presents of a `LineDescGroup` will override the previously defined `LineDesc`.	0-n

8.2.3.5 Datum

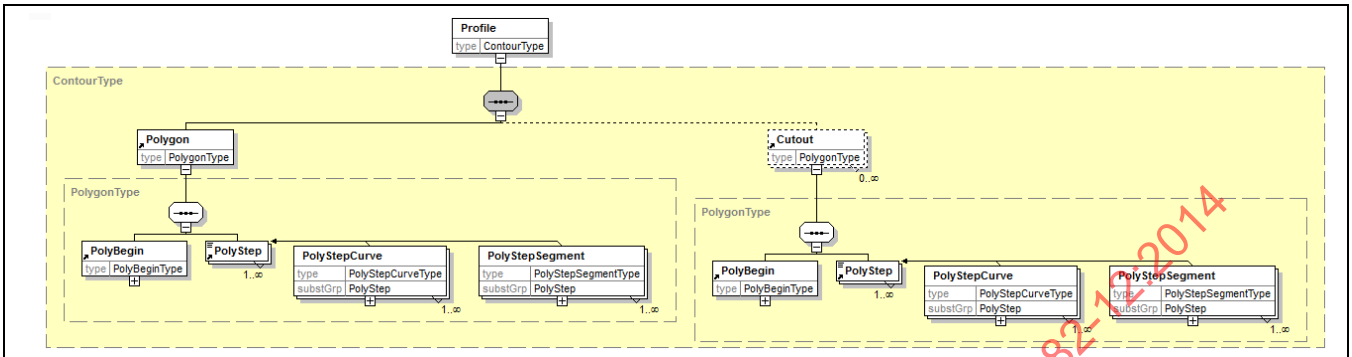
The `Datum` element of the `Step` schema (`StepType/Datum`) defines the location of the point of origin for the individual `Step` file. The unique name of the `Step` helps to associate the datum between boards and panels or pallets.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Datum	LocationType	A nested element containing the datum origin for the overall Step.	1-1
x	double	The x location of the datum.	1-1
y	double	The y location of the datum.	1-1

8.2.3.6 Profile

The `Profile` element of the `Step` schema (`StepTypeProfile`) defines the exact periphery of the board or assembly and therefore all the characteristics of the `Step` element.



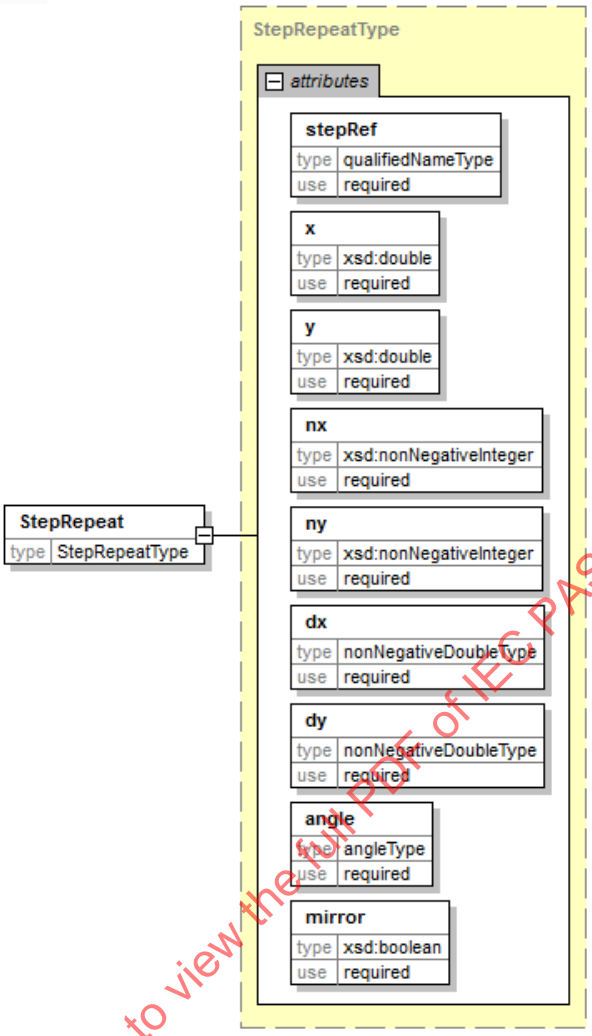
Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Profile	ContourType	The profile is a `contourType` and thus describes the periphery that encompasses all the elements in the `Step`.	1-1
PolyBegin	PolyBeginType	The `PolyBegin` element defines the starting point of the polygon.	1-1
x	double	The X starting point of the first polygon edge.	1-1
y	double	The Y starting point of the first polygon edge.	1-1
PolyStep	ABSTRACT	The `PolyStep` element is a substitution group that defines a circular (`PolyStepCurve`) or straight line (`PolyStepSegment`) continuation of the polygon. The `polystep` direction may be clockwise or counterclockwise which must be consistent when any `Arc` description is used as one of the `PolyStep` elements. Straight or curved line segments must not cross. The final X and final Y coordinate must match those of the PolyBegin element to signify that the shape is closed.	1.n
Cutout	CutoutType	A polygon closed shape whose edges do not cross, which adopts the coordinates of the original polygon, however represents the absence of material within the original polygon shape.	0-n
PolyBegin	PolyBeginType	The `PolyBegin` element defines the starting point of the polygon.	1-1
x	double	The X starting point of the first polygon edge.	1-1
y	double	The Y starting point of the first polygon edge.	1-1
PolyStep	ABSTRACT	The `PolyStep` element is a substitution group that defines a circular (`PolyStepCurve`) or straight line (`PolyStepSegment`) continuation of the polygon. The `polystep` direction may be clockwise or counterclockwise which must be consistent when any `Arc` description is used as one of the `PolyStep` elements. Straight or curved line segments must not cross. The final X and final Y coordinate must match those of the PolyBegin element to signify that the shape is closed.	1-n

```
<Step name = "KarensSingleBoard">
    <Datum x = "10.00" y = "10.00"/>
      <Profile>
        <Polygon>
          <PolyBegin x = "0.00" y = "10.00"/>
          <PolyStepSegment x = "0.00" y = "90.00"/>
          <PolyStepCurve x = "10.00" y = "100.00" centerX = "10.00" centerY = "90.00" clockwise = "TRUE"/>
          <PolyStepSegment x = "200.00" y = "100.00"/>
          <PolyStepSegment x = "200.00" y = "50.00"/>
          <PolyStepSegment x = "150.00" y = "50.00"/>
          <PolyStepSegment x = "150.00" y = "0.00"/>
          <PolyStepSegment x = "10.00" y = "0.00"/>
          <PolyStepCurve x = "0.00" y = "10.00" centerX = "10.00" centerY = "10.00" clockwise = "TRUE"/>
        </Polygon>
      </Profile>
  </Step>
```

8.2.3.7 StepRepeat

The `StepRepeat` elements provides information for steps representing panels or assembly pallets. Coupons may also use this feature to step the coupon description on the borders of the panel. The layer descriptions of any `Board` and `Coupon` combined in a `Panel` description must be of the same construction. The attribute stepRef is restricted in the XML schema to the unique name of the `Step` element referenced.

If the features of a `StepRepeat` function become unique due to different characteristics such as one `Step` is at 90 degrees while the next `Step` is at 180 degrees two separate `stepRepeat` elements are required.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
StepRepeat	StepRepeatType	A nested element list containing the Step and Repeat functions that impact the information of the electronic product.	0-n
stepRef	qualifiedNameType	A reference to the step that should be replicated on the panel.	1-1
x	double	The X point of origin where the first step should be placed in relationship to the datum. This may be coincident or may be offset from the datum of the particular step.	1-1
y	double	The Y point of origin where the first step should be placed in relationship to the datum. This may be coincident or may be offset from the datum of the particular step.	1-1
nx	nonNegativeInteger	The number of times that the referenced step should be repeated in the X direction.	1-1
ny	nonNegativeInteger	The number of times that the referenced step should be repeated in the Y direction.	1-1
dx	nonNegativeDouble Type	The dimensional distance in the positive X direction as a step from the first position point of origin (not necessarily from the datum).	1-1
dy	nonNegativeDouble Type	The dimensional distance in the positive Y direction as a step from the first position point of origin (not necessarily from the datum).	1-1
angle	angleType	A unique angle to allow rotation of the `StepRepeat` image description where “0°” is as defined with the angle descriptions being counterclockwise (i.e., 45° 90°) from the horizontal zero angle.	1-1

mirror	boolean	An enumerated string as either TRUE or FALSE (part of the 3WC standard). TRUE equals that the image is mirrored; FALSE indicates that it is not.	1-1

```
<Step name = "KarensAssemblyPanel">
    <Datum x = "0.00" y = "0.00"/>
        <Profile>
            <Polygon>
                <PolyBegin x = "0.00" y = "0.00"/>
                <PolyStepSegment x = "0.00" y = "427.00"/>
                <PolyStepSegment x = "260.00" y = "427.00"/>
                <PolyStepSegment x = "260.00" y = "0.00"/>
                <PolyStepSegment x = "0.00" y = "0.00"/>
            </Polygon>
        </Profile>
        <StepRepeat stepRef = "KarensSingleBoard" x = "110.00" y = "20.00" nx = "1" ny = "1" dx = "120.00" dy = "207.00" angle =
                    "90.00" mirror = "FALSE"/>
        <LayerFeature layerRef = "1-Top Signal">
            <Set polarity = "POSITIVE">
            <GlobalFiducial>
                <Location x = "250.00" y = "10.00"/>
                <Circle diameter = "1.00"/>
            </GlobalFiducial>
            <GlobalFiducial>
                <Location x = "250.00" y = "417.00"/>
                <Circle diameter = "1.00"/>
            </GlobalFiducial>
            <GlobalFiducial>
                <Location x = "10.00" y = "10.00"/>
                <Circle diameter = "1.00"/>
            </GlobalFiducial>
            <BadBoardMark>
                <Location x = "190.00" y = "5.00"/>
                <Circle diameter = "1.50"/>
            </BadBoardMark>
            <BadBoardMark>
                <Location x = "70.00" y = "5.00"/>
                <Circle diameter = "1.00"/>
            </BadBoardMark>
            <BadBoardMark>
                <Location x = "190.00" y = "213.00"/>
                <Circle diameter = "1.00"/>
            </BadBoardMark>
            <BadBoardMark>
                <Location x = "70.00" y = "213.00"/>
                <Circle diameter = "1.00"/>
            </BadBoardMark>
            <GoodPanelMark>
                <Location x = "250.00" y = "213.00"/>
                <Donut shape = "ROUND" outerDiameter = "1.50" innerDiameter = "0.80"/>
            </GoodPanelMark>
        </Set>
    </LayerFeature>
</Step>
```


The following are examples of the step and repeat functions

The following are 6 Panelization use cases that the IPC-2580 series must consider in its output. The number in the dark green area refers to a Design (in the last example, there are 4 unique Designs placed within a Panel).

8.2.3.7.1 Single

A single Design is placed in a Panel.

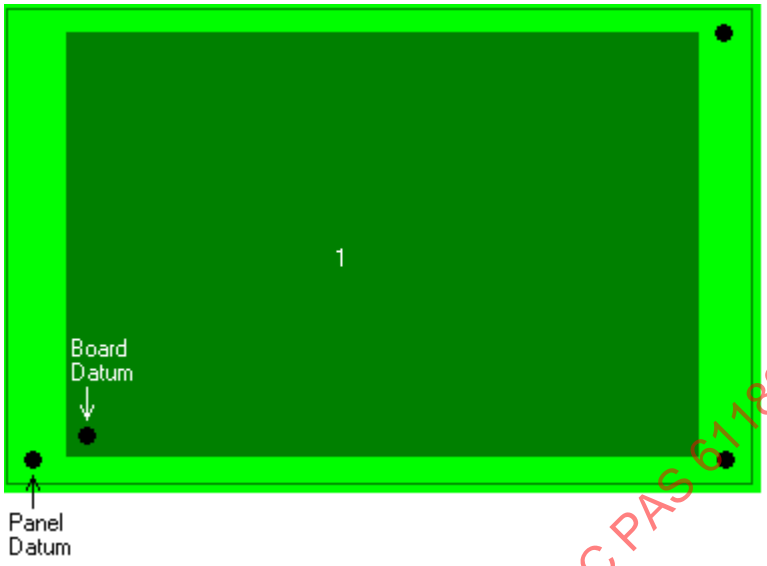


Figure 8 Single Design within a Panel

Requires one StepRepeat element that positions the design on the panel at the appropriate X-Y location.

8.2.3.7.2 Single Array

Step and repeat produces a matrix of steps. The size of the matrix is nx+1 in the x direction, and ny+1 in the y direction.

One Design is placed in the same orientation throughout the panel, based on a single row X column matrix.

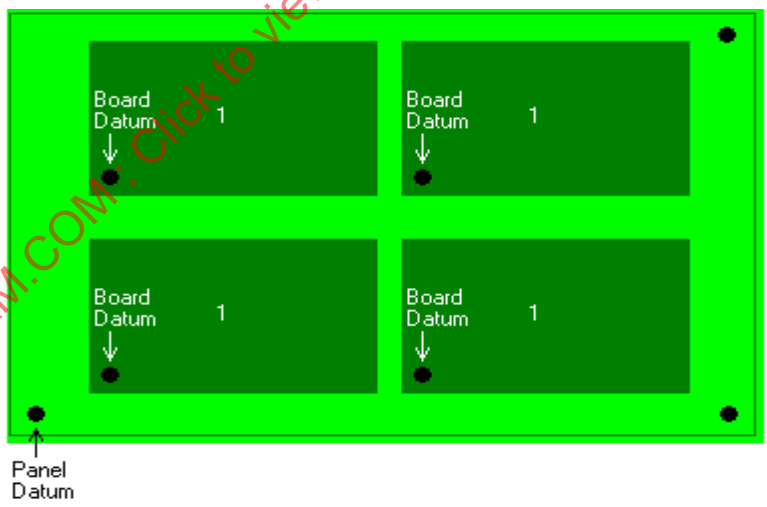


Figure 9 Design Arrayed based on one R x C matrix within a Panel

Requires one StepRepeat element that positions the design on the panel at the appropriate X-Y location. The design is stepped once in the X direction and once in the Y direction. (The upper right hand corner design is automatically created as part of the X-Y step and repeat matrix.)

8.2.3.7.3 Double Array

A single design, but arrayed in two distinct row X column matrices. This panelization method is to use the maximum area of the PCB fabricator's raw panel stock.

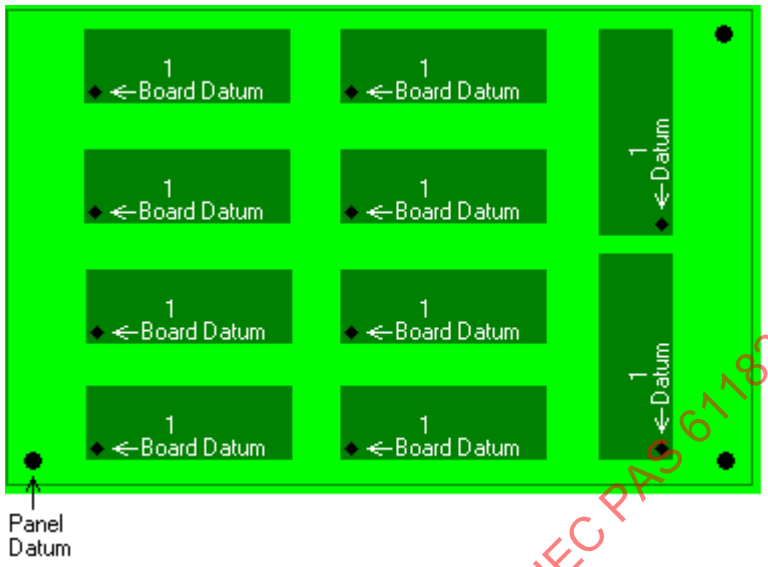


Figure 10 Design Arrayed based on two R x C matrices within a Panel

Requires two StepRepeat elements, one positions the design on the panel at the appropriate X-Y location. The design is then stepped once in the X direction and three times in the Y direction. The second Step Repeat element orients the design on a 90° angle. This new orientation is then positioned on the panel at the appropriate X-Y location, and stepped zero in the X direction and once in the Y direction.

8.2.3.7.4 Tiled

This example is to place a pair of single designs 180° out of phase with each other.

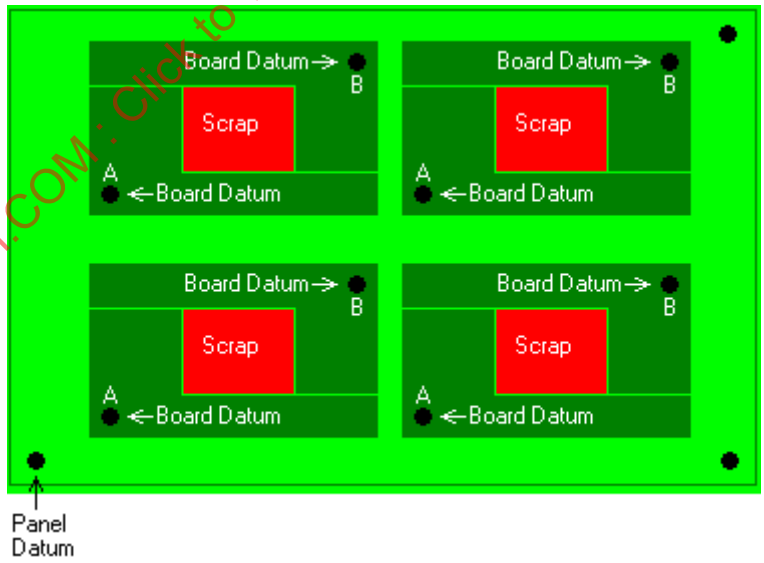


Figure 11 Design tiled as pairs within a Panel

Requires two StepRepeat elements, where one positions the design on the panel at the appropriate X-Y location. This design is then stepped once in the X direction and once in the Y direction. The second Step Repeat element rotates the design 180°, and then positions the new orientation on the panel at the appropriate X-Y location. This reoriented design is then stepped once in the X direction and once in the Y direction. An appropriate X-Y location may be in the lower left portion of the panel with a positive X-Y step or in the upper right corner of the panel with a negative X-Y step.

8.2.3.7.5 Flipped

“Flip” board pairing. This methodology is recent. The most important concern is that the board must be a symmetrical stackup, which means that the layer stackup must be verified to allow this type of panelization.

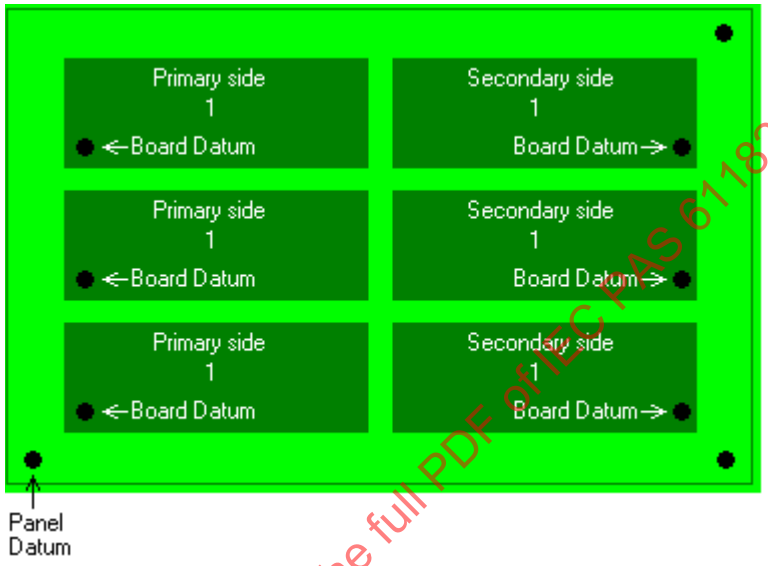


Figure 12 Design flipped as a pair within a Panel

Requires two StepRepeat elements, one positions the design on the panel at the appropriate X-Y location. The second Step Repeat element identifies the design as a mirrorImage, which is then positioned on the panel at the appropriate X-Y location. There is no StepRepeat description necessary as the designs are both uniquely positioned.

8.2.3.7.6 Multiple Designs

The most important consideration with placing multiple designs (each number represents a unique design) within one panel is that all designs need to have been created within the same layer stackup. The advantage is that an entire product can be assembled/tested all at once. The disadvantage is that if one board of the panel has a problem (either with part availability or performance), this can lead to several additional scheduling/building/etc. problems as well.

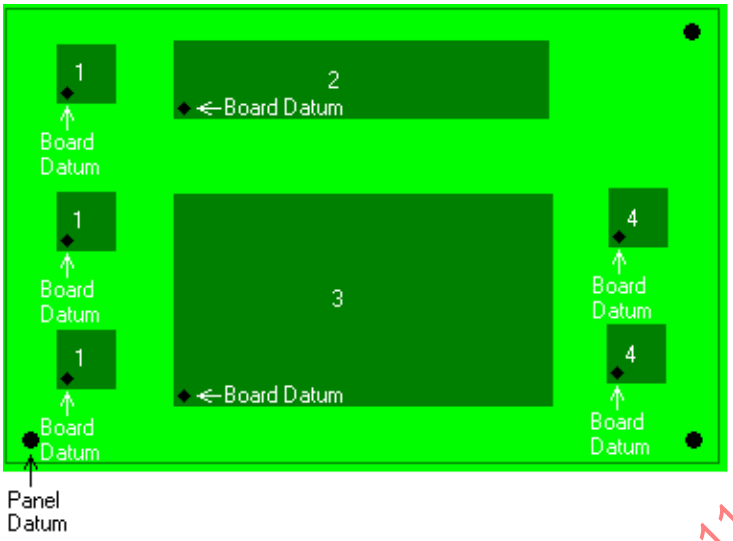


Figure 13 Multiple Designs placed within a Panel

The panel requires four StepRepeat elements. Design 1 is positioned on the panel at the appropriate X-Y location, and is then stepped zero times in the X direction and twice in the Y direction. Design 2 references a different Step and is positioned on the panel at the appropriate X-Y location. Design 3 references a different Step and is positioned on the panel at the appropriate X-Y location. Neither design 2 or 3 requires any stepRepeat information. The fourth Step Repeat element identifies design 4 is also a different Step which is positioned on the panel at the appropriate X-Y location, and stepped zero times in the X direction and once in the Y direction.

See Appendix B for an example of an XML instance file.

8.2.3.7.7 Tooling Step and Repeat

The Step and repeat function can also be used to duplicate features that are to become part of the board, panel, or pallet. Figure 14 shows a series of slots that need to be included in a set of layers of the stackup. They may be replicated on each sheet that must be matched within the stackup.

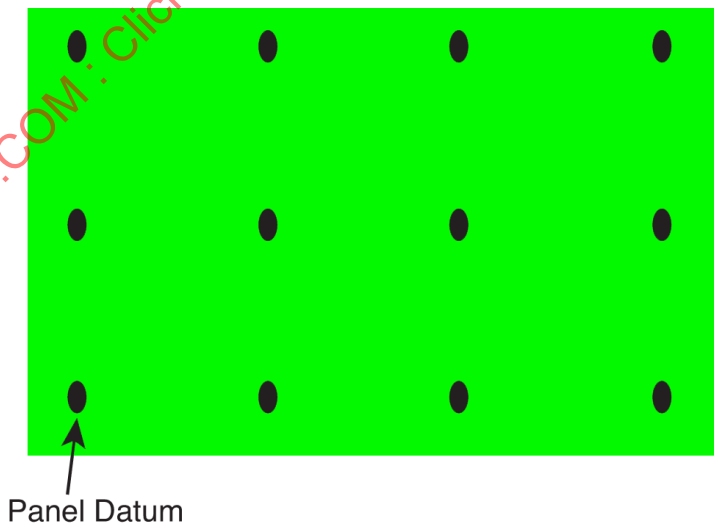
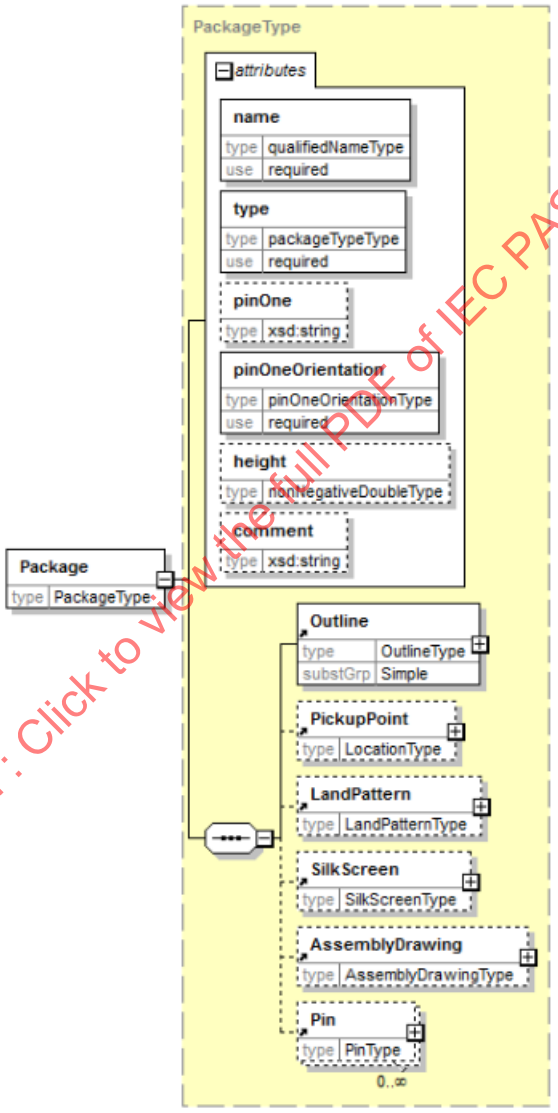


Figure 14 Multiple Slots provided for tooling within a Panel

Requires one StepRepeat element that positions the slot on the panel at the X-Y location that becomes the point of origin or Panel Datum. The Slot is stepped three times in the X direction and twice in the Y direction. The function may be accomplished as a step and repeat even if the features has a third dimension such as a depth of a cutout. The feature needs to be fully described as a single entity before it is repeated.

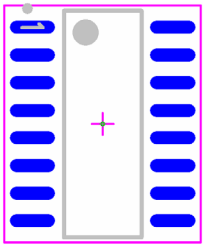
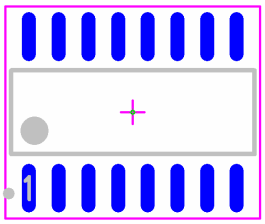
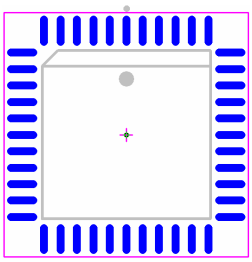
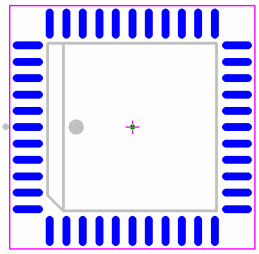
8.2.3.8 Package

The `Package` element descriptions define the package shape (`Outline`), library descriptions including land patterns, silk screen information, assembly drawing details, and pin identification. The `Package` element defines all the physical description of all the packages used by the `Component` element inside the `Step`. The names assigned to the package should be consistent with the naming convention established in IPC-7351 for parts and land pattern descriptions. (See Appendix A)



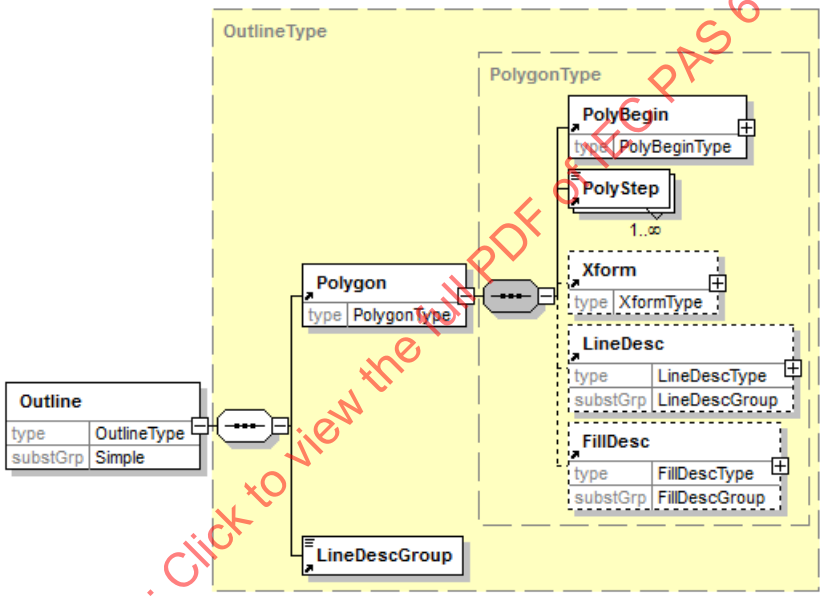
Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Package	PackageType	Generic component package descriptions for use by the `Step` file schemas.	0-n
name	qualifiedNameType	A unique name assigned to the physical and graphical description of a part in accordance with the IPC-7351 Naming Convention for Packages and Land Patterns.	1-1

type	PackageTypeType	A specific body construction indicated as an enumerated string using one of the following naming conventions: AXIAL_LEADED | BARE_DIE | CERAMIC_BGA | CERAMIC_DIP | CERAMIC_FLATPACK | CERAMIC_QUAD_FLATPACK | CERAMIC_SIP | CHIP | CHIP_SCALE | CHOKE_SWITCH_SM | COIL | CONNECTOR_SM | CONNECTOR_TH | EMBEDDED | FLIPCHIP | HERMETIC_HYBRID | LEADLESS_CERAMIC_CHIP_CARRIER | MCM | MELF | FINEPITCH_BGA | MOLDED | NETWORK | PGA | PLASTIC_BGA | PLASTIC_CHIP_CARRIER | PLASTIC_DIP | PLASTIC_SIP | POWER_TRANSISTOR | RADIAL_LEADED | RECTANGULAR_QUAD_FLATPACK | RELAY_SM | RELAY_TH | SOD123 | SOIC | SOJ | SOPIC | SOT143 | SOT23 | SOT52 | SOT89 | SQUARE_QUAD_FLATPACK | SSOIC | SWITCH_TH | TANTALUM | TO_TYPE | TRANSFORMER | TRIMPOT_SM | TRIMPOT_TH | OTHER	1-1
pinOne	string	A reference to the landpattern PinRef pin number which is considered the first pin in the sequence of all pin numbers in the package. Examples are ‘1’, ‘A1’, ‘ANODE’, ‘2’ (when there is no pin ‘1’).”	0-1
pinOneOrientation	pinOneOrientationtype	An enumerated string that defines the location of pinOne relative to the centroid of the package, within the library definition of the package that is captured in the design. The enumerations are LOWER_LEFT | UPPER_LEFT | LEFT | UPPER_CENTER | LEFT_CENTER | OTHER. If OTHER is used a comment is required to describe the condition. The intent is to describe the default orientation of the package (e.g. ‘landscape’ or ‘portrait’ for an IC), which could establish a relationship to a library definition standard such as IEC or IPC, or provide a zero degree rotation reference for assembly.”	1-1
height	double	A description of the component height in terms of the mounting surface to the highest protrusion of the `Package`. The units are in the `Units` set by the `Cadheader`.	0-1
Comment	string	A description of the orientation of the Package as provided in the original CAD data	0-1
Outline	OutlineType	A nested element that defines the physical outline of the part as seen from the top, related to the graphical image that appears on the assembly. Includes body and pin profiles if applicable. The outline is an enclosed polygon type.	1-1
PickupPoint	LocationType	The optimum location for an automatic assembly machine to pickup the package. This may or may not be the centroid of the package outline”	0-1
x	double	The x coordinate of the location of the PickupPoint.	1-1
y	double	The y coordinate of the location of the PickupPoint.	1-1
LandPattern	LandPatternType	A nested element that defines the surface land pattern consisting of Lands in a particular pattern that matches the footprint of the component outline. The point of origin of the `LandPattern` and `Outline` are identical.	0-1
SilkScreen	SilkScreenType	A nested element that defines the symbolization and legend required to be placed on the board for the particular package. Includes location of the reference designator or other `Text`. The point of origin of the image is the same as the origin of the `LandPattern` and `Outline`.	0-1
AssemblyDrawing	AssemblyDrawing Type	A nested element that defines the graphics required for the assembly drawing. The images relate to the component body outline and any text needed. The point of origin for the assembly drawing is the same as the images of the `Outline`, LandPattern, and `SilkScreen` schema.	0-1
Pin	PinType	A nested element that defines the pin relationship of all the pins that are a part of the package style related to the land pattern description.	0-n

UPPER_LEFT	LOWER_LEFT	UPPER_CENTER	LEFT_CENTER
			

8.2.3.8.1 Outline

A nested element that defines the physical outlines of the part related to the graphical image that appears on the assembly. The `Outline` includes the body of the part, the `Pin` element and the `Pin` element includes the `Pin` profiles. These are combined to describe the component.

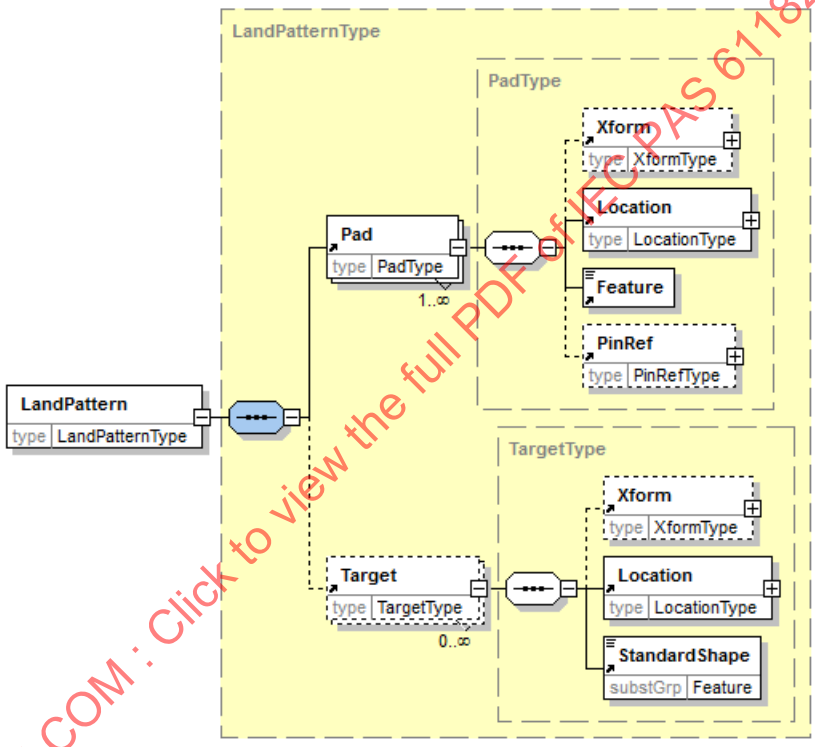


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Outline	OutlineType	A nested element that defines the physical outlines of the part viewed from the top, related to the graphical image that appears on the assembly. Includes the body only. `Pin` profiles are defined by the Pin element. The `Outline` is an enclosed polygon type.	1-1
Polygon	PolygonType	A closed shape whose edges do not cross, the coordinates of which are defined relative to the local coordinate system of the polygon.	1-1
PolyBegin	PolyBeginType	The `PolyBegin` element defines the starting point of the polygon.	1-1
x	double	The X starting point of the first polygon edge.	1-1
y	double	The Y starting point of the first polygon edge.	1-1
PolyStep	ABSTRACT	The `PolyStep` element is a substitution group that defines a circular (`PolyStepCurve`) or straight line (`PolyStepSegment`) continuation of the polygon. The `polystep` direction may be clockwise or counterclockwise which must be consistent when any `Arc` description is used as one of the `PolyStep` elements. Straight or curved line segments must not cross. The final X and final Y coordinate must match those of the `PolyBegin` element to signify that the shape is closed.	1-n

Xform	XformType	An element that provides the ability to reset the point of origin of a predefined target that can be scaled, mirror imaged or rotated.	0-1
LineDescGroup	LineDescGroup Type	A substitution group that specifies the `LineDesc or LineDescRef`. The LineDesc specifies the `LineWidth, LineEnd and LineProperty` characteristics of any feature that requires that definition. Line descriptions are a part of the `Outline`, `Polyline` and `Set` element definitions. The `LineDescRef` requires an "id" that must be unique within the 2581 file.	1-1

8.2.3.8.2 LandPattern

The `LandPattern` element consists of those characteristics that define the pattern to which surface mount components are attached. The embedded elements include both the `Pad` description and the potential for providing a target, usually indicating `pinOne`. Land pattern descriptions should be used wherever a relationship to component pins needs to be established. This information is redundant when layers for component attachment are defined.

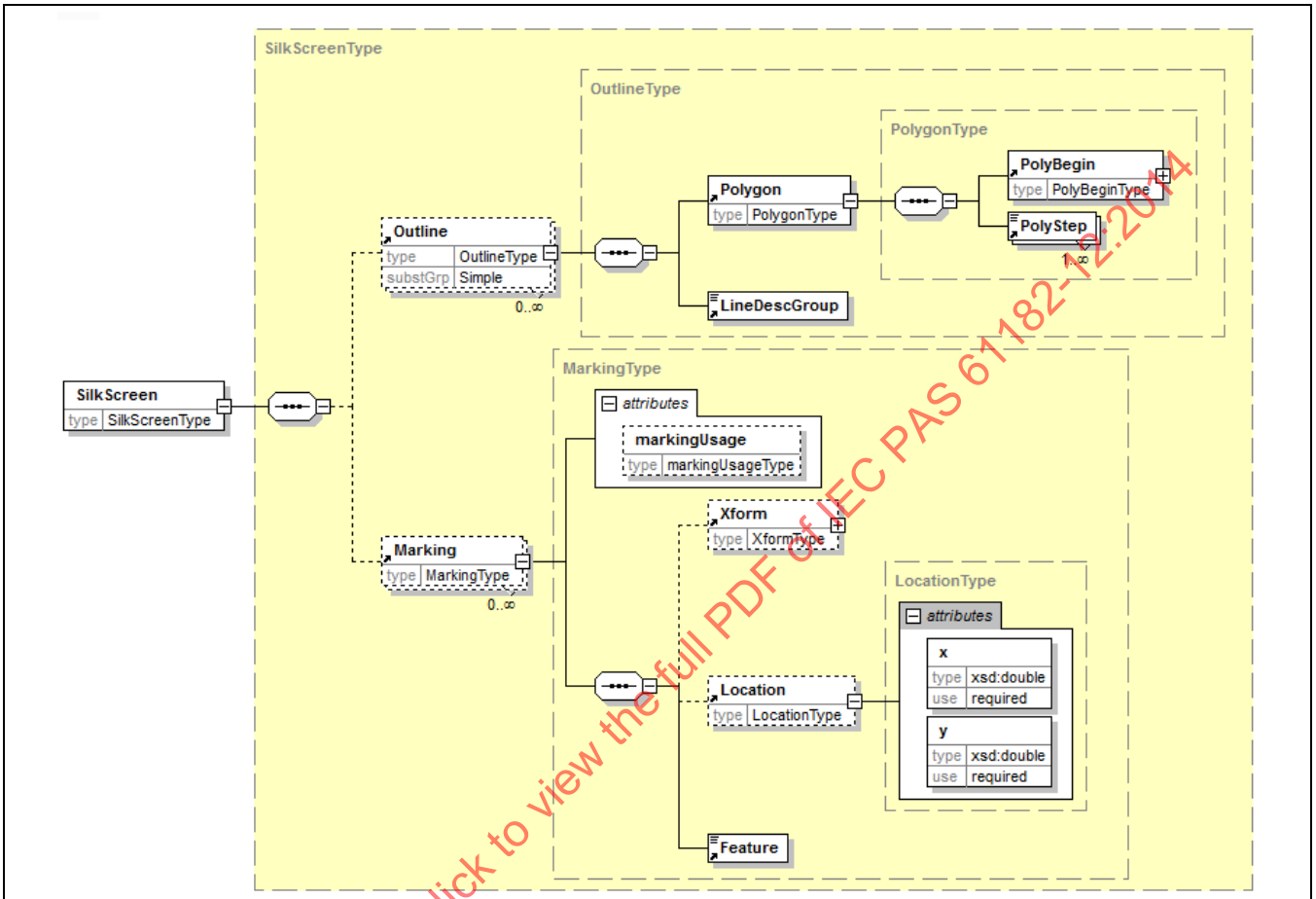


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
LandPattern	LandPatternType	A nested element that defines the surface land pattern consisting of Pads in a particular pattern that matches the footprint of the component.	0-1
Pad	PadType	A nested element defining the pad to be located as part of the land pattern.	1-n
Xform	XformType	An element that provides the ability to reset the point of origin of a predefined pad that can be scaled, mirror imaged or rotated. See 3.3	0-1
Location	LocationType	The location of the image defined by the standard shape or Usershape or a pre-defined standard shape, or Usershape of the pad. The image may have been reorientated by the Xform.	1-1
x	double	The x coordinate of the location of the pad.	1-1
y	double	The y coordinate of the location of the pad.	1-1

Feature	ABSTRACT	An embedded element that defines a substitution group of any `StandardShape` or `UserShape` that may be instantiated as a part of the `Pad` Description. A predefined `StandardShape or UserShape` may also be instantiated by its unique "id" when the feature is contained in the `DictionaryStandard or User`. When a reference is made to the dictionary predefined primitive the `Units` must match.	1-1
PinRef	PinRefType	An individual `Pin` related to the place where a component attaches to the net. This description facilitates location of lands on the surface of the board or places where through-hole components are mounted.	1-n
Target	TargetType	A nested element defining the target to be located as part of the land pattern.	0-n
Xform	XformType	An element that provides the ability to reset the point of origin of a predefined target that can be scaled, mirror imaged or rotated. See 3.3	0-1
Location	LocationType	The location of the image defined by the standard shape or a pre-defined standard shape of the target. The image may have been reorientated by the Xform.	1-1
x	double	The x coordinate of the location of the target.	1-1
y	double	The y coordinate of the location of the target.	1-1
StandardShape	ABSTRACT	A substitution group that permits the substitution of any of the `StandardPrimitive` shapes in accordance with their individual descriptions. A predefined `StandardPrimitive` may also be instantiated by its unique "id" when the feature is contained in the `DictionaryStandard`. When a reference is made to the dictionary predefined primitive the `Units` must match.	1-1

8.2.3.8.3 SilkScreen

The `SilkScreen` element defines the symbolization and legend required to be placed on the board for the particular package. The `SilkScreen` descriptions include location of the reference designator or other `Text`. The point of origin of the image is the same as the origin of the `LandPattern` and `Outline`.

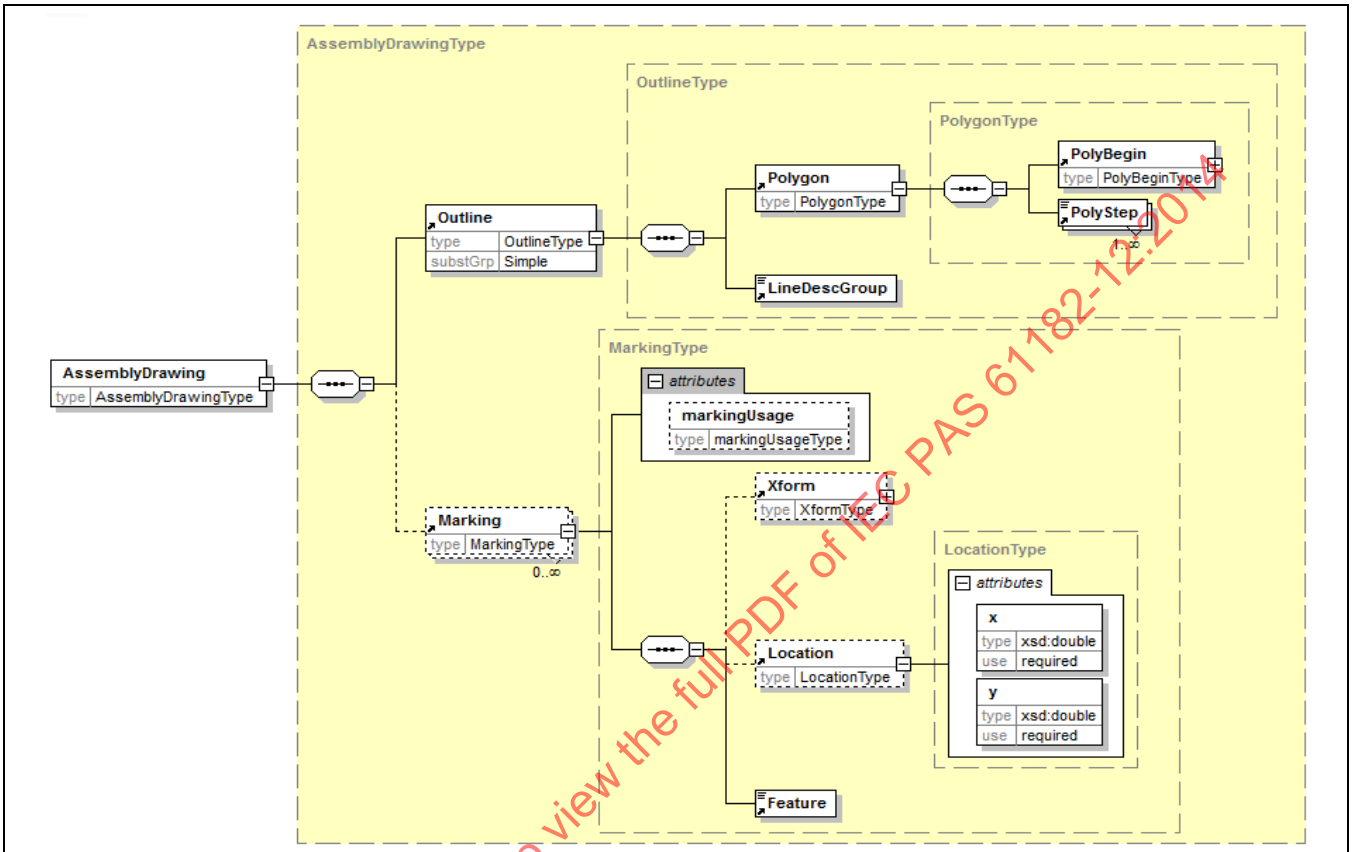


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
SilkScreen	SilkScreenType	A nested element that defines the symbolization and legend required to be placed on the board for the particular package. Includes location of the reference designator or other `Text`. The point of origin of the image is the same as the origin of the `LandPattern` and `Outline`.	0-1
Outline	OutlineType	A nested element that defines the outlines of the part related to the graphical image that appears on the board. The outline is an enclosed polygon type.	0-n
Polygon	PolygonType	A closed shape whose edges do not cross, the coordinates of which are defined relative to the local coordinate system of the polygon.	1-1
PolyBegin	PolyBeginType	The `PolyBegin` element defines the starting point of the polygon.	1-1
PolyStep	ABSTRACT	The `PolyStep` element is a substitution group that defines a circular (`PolyStepCurve`) or straight line (`PolyStepSegment`) continuation of the polygon. The `polystep` direction may be clockwise or counterclockwise which must be consistent when any `Arc` description is used as one of the `PolyStep` elements. Straight or curved line segments must not cross. The final X and final Y coordinate must match those of the `PolyBegin` element to signify that the shape is closed.	1-n

LineDescGroup	ABSTRACT	A substitution group that specifies the `LineWidth` and `LineEnd` characteristics of the `Outline`. The `LineDesc` may also have been predefined in the `DictionaryLineDesc` and instantiated from the dictionary.	1-1
Marking	markingType	A nested element that defines the characteristics of the feature being instantiated as a part of the SilkScreen	0-n
markingUsage	markingUsageType	An indication as to the usage of any marking that becomes a part of the SilkScreen. The descriptions are enumerated strings and must be one of the following: REFDES | PARTNAME | TARGET | POLARITY_MARKING | ATTRIBUTE_GRAPHICS | PIN_ONE | NONE>	1-1
Xform	XformType	An element that provides the ability to reset the point of origin of the marking, then scale, mirror image or rotate the marking feature after it has been placed at an X and Y location.	0-1
Location	LocationType	The location of the image defined by the feature or a pre-defined feature. The image may have been reorientated by the Xform.	1-1
x	double	The x coordinate of the location of the feature.	1-1
y	double	The y coordinate of the location of the feature.	1-1
Feature	ABSTRACT	A substitution group that permits the substitution of any of the `StandardShape`, `StandardPrimitive`, or `UserPrimitive` shape in accordance with their individual descriptions. A predefined `StandardPrimitive`, or `UserPrimitive` may also be instantiated by its unique “id” when the feature is contained in the DictionaryStandard or DictionaryUser. When a reference is made to either of the dictionaries the predefined primitive Units must match with the Units of the file.	0-n

8.2.3.8.4 AssemblyDrawing

The `AssemblyDrawing` element reuses the same embedded elements and attributes as defined for the `Silkscreen` characteristics. The construction schemas are repeated to aid the reader in interpretation of the library structure.

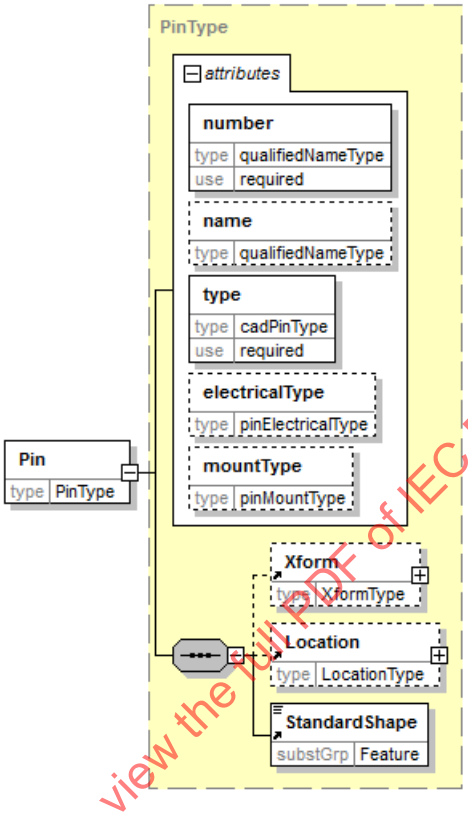


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
AssemblyDrawing	AssemblyDrawing Type	A nested element that defines the graphics required for the assembly drawing. The images relate to the component body outline and any text needed. The point of origin for the assembly drawing is the same as the images of the outline, land pattern, and silk screen schema.	0-1
Outline	OutlineType	A nested element that defines the outlines of the part related to the graphical image that appears on the board. The `Outline` is an enclosed polygon type.	0-1
Polygon	PolygonType	A closed shape whose edges do not cross, the coordinates of which are defined relative to the local coordinate system of the polygon	1-1
PolyBegin	PolyBeginType	The `PolyBegin` element defines the starting point of the polygon.	1-1
PolyStep	ABSTRACT	The `PolyStep` element is a substitution group that defines a circular (`PolyStepCurve`) or straight line (`PolyStepSegment`) continuation of the polygon. The `polystep` direction may be clockwise or counterclockwise which must be consistent when any `Arc` description is used as one of the `PolyStep` elements. Straight or curved line segments must not cross. The final X and final Y coordinate must match those of the `PolyBegin` element to signify that the shape is closed.	1-n
LineDescGroup	ABSTRACT	A substitution group that specifies the `LineWidth` and `LineEnd` characteristics of the `Outline`. The `LineDesc` may also have been predefined in the `DictionaryLineDesc` and instantiated from the dictionary.	1-1

Marking	markingType	A nested element that defines the characteristics of the feature being instantiated as a part of the AssemblyDrawing	0-n
markingUsage	markingUsageType	An indication as to the usage of any marking that becomes a part of the AssemblyDrawing. The descriptions are enumerated strings and must be one of the following: REFDES | PARTNAME | TARGET | POLARITY_MARKING | ATTRIBUTE_GRAPHICS | PIN_ONE | NONE.	1-1
Xform	XformType	An element that provides the ability to reset the point of origin of the marking, then scale, mirror image or rotate the marking feature after it has been placed at an X and Y location.	0-1
Location	LocationType	The location of the image defined by the feature or a pre-defined feature. The image may have been reorientated by the Xform.	1-1
x	double	The x coordinate of the location of the target.	1-1
y	double	The y coordinate of the location of the target.	1-1
Feature	ABSTRACT	A substitution group that permits the substitution of any of the `StandardShape, StandardPrimitive, or UserPrimitive` shape in accordance with their individual descriptions. A predefined `StandardPrimitive, or UserPrimitive` may also be instantiated by its unique “id” when the feature is contained in the DictionaryStandard or DictionaryUser. When a reference is made to either of the dictionaries the predefined primitive Units must match with the Units of the file.	0-n

8.2.3.8.5 Pin

The `Pin` element represents a set of `Pin` characteristics that are attached to each component package. Each `Pin` has a `number`, `name`, type, `electricalType` and `mountType`. Each `Pin` also contains its relative location and outline.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Pin	PinType	A nested element that defines the pin relationship of all the pins that are a part of the package style related to the land pattern description.	0-n
number	qualifiedNameType	An alphanumeric indicator identified as the pin number which is unique within the package description and is established by the netlist	1-1
name	qualifiedNameType	A name assigned by the user to describe the Pin at a particular location. The same name may be applied to multiple pins at the users discretion	0-1
type	cadPinType	An enumerated string that defines the type of Pin as being one of the following: THRU | BLIND | SURFACE.	1-1
electricalType	pinElectricalType	The electrical type enumerated string that defines the Pin as one of three possible conditions. These are: ELECTRICAL | MECHANICAL | UNDEFINED.	0-1
mountType	pinMountType	An enumerated string that defines the mounting characteristics of the Pins and may be any one of the following: SURFACE_MOUNT_PIN | SURFACE_MOUNT_PAD | THROUGH_HOLE_PIN | THROUGH_HOLE_HOLE | PRESSFIT | NONBOARD | HOLE | UNDEFINED	0-1
Xform	XformType	An element that provides the ability to reset the point of origin of the graphic outline pin shape, then scale, mirror image or rotate the shape it has been placed at an X and Y location. See 3.3	0-1