

PD IEC/PAS 61182-12:2014



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

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A list of organizations represented on this committee can be obtained on request to its secretary.

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

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

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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

Following publication of this PAS, the technical committee or subcommittee concerned may transform it into an International Standard.

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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*

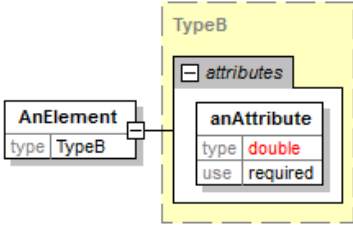
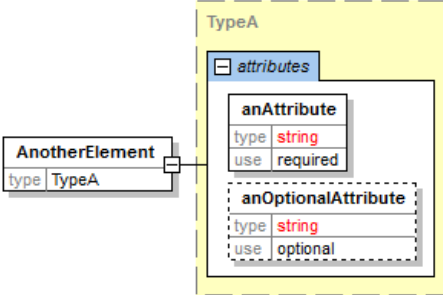
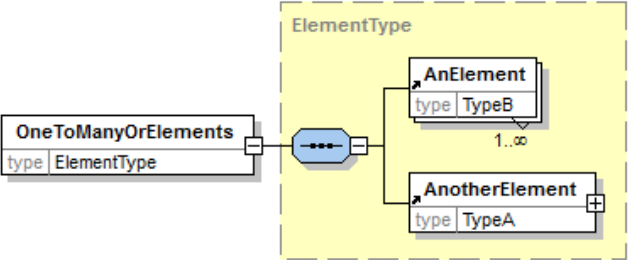
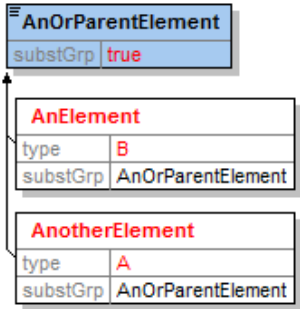
2.1 Documentation conventions

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.

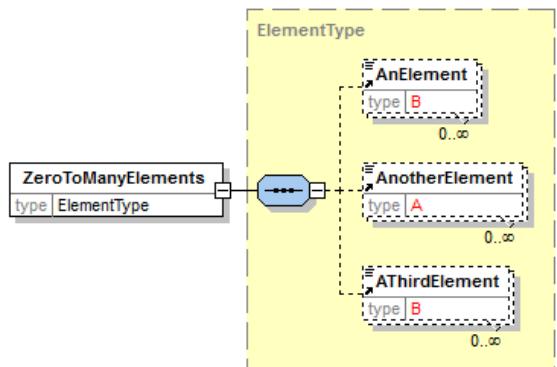
In addition to the text based schema notation, this document provides graphical representation of the structure of the file format. The XML diagrams are designed to effectively illustrate the structure and cardinality of elements and attributes that make up any IPC-258X file. The notation in the graphics 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.

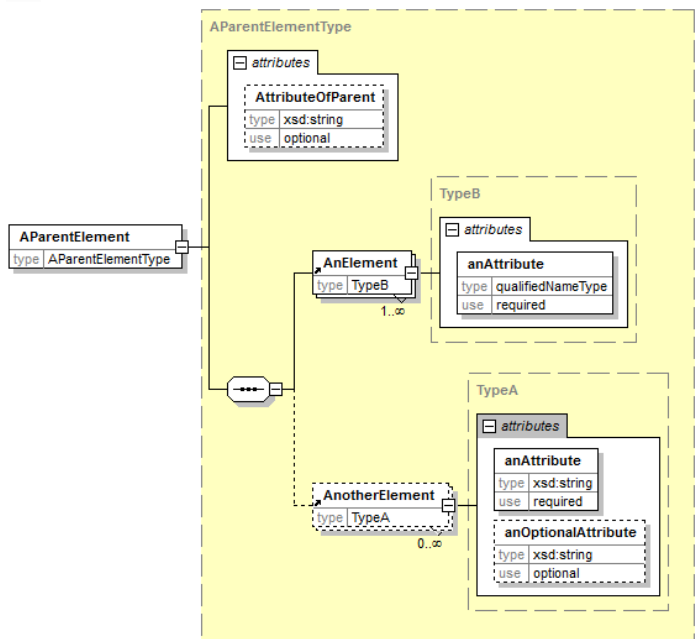
Table 1 Graphical Notation Overview

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.	 The diagram shows a box for 'AnElement' with 'type TypeB'. It is connected to a larger box for 'TypeB' which contains an 'attributes' section. Inside 'attributes' is 'anAttribute' with 'type double' and 'use required'.
Example: <AnElement anAttribute="14.44e-3"/> Note that all attribute values must be enclosed in quotes, regardless of type.	
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.	 The diagram shows a box for 'AnotherElement' with 'type TypeA'. It is connected to a larger box for 'TypeA' which contains an 'attributes' section. Inside 'attributes' are 'anAttribute' (type string, use required) and 'anOptionalAttribute' (type string, use optional).
Examples: <AnotherElement anAttribute="red" anOptionalAttribute="a string" /> <AnotherElement anAttribute="blue" />	
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.	 The diagram shows a box for 'OneToManyOrElements' with 'type ElementType'. It is connected to a blue oval containing a list of elements. The list includes 'AnElement' (type TypeB) with a multiplicity of '1..∞' and 'AnotherElement' (type TypeA) with a multiplicity of '1'.
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.	 The diagram shows a box for 'AnOrParentElement' with 'substGrp true'. It has two child elements: 'AnElement' (type B, substGrp AnOrParentElement) and 'AnotherElement' (type A, substGrp AnOrParentElement).

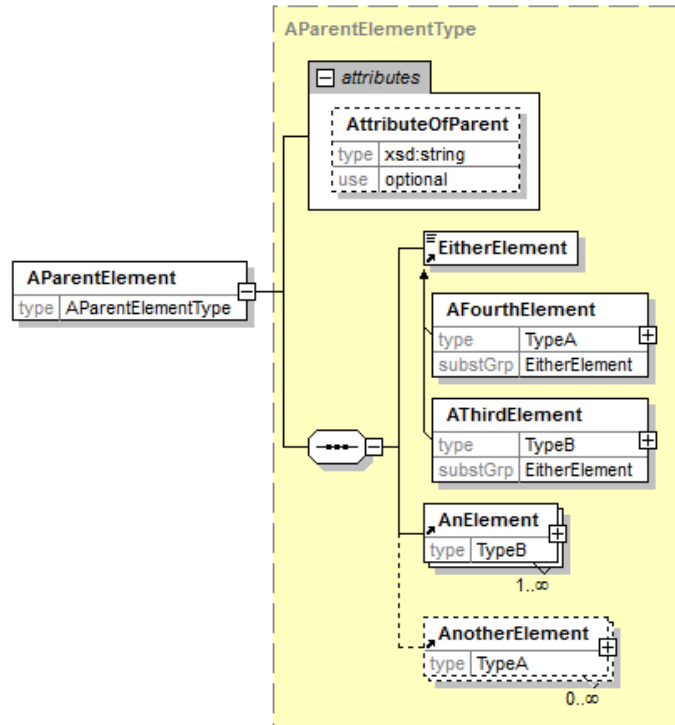
The optional indication for the three element children shows that none may be present or many versions of all three are possible.



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).

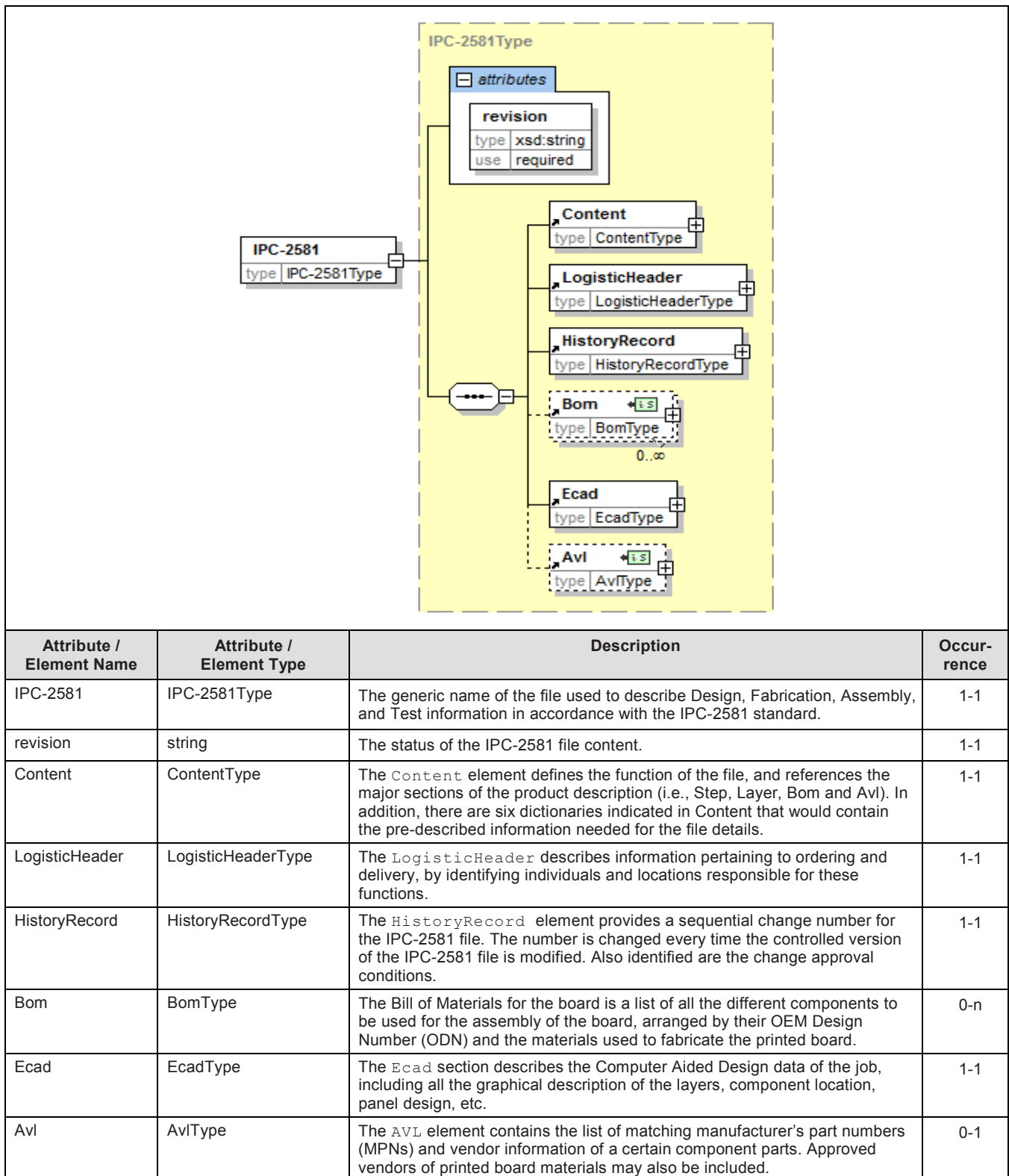


Figure 1 IPC-258X Children Element

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 led 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 $3.4 \times 10^{-38} \leq \text{value} \leq 3.4 \times 10^{+38}$. 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 $0 \leq \text{value} \leq 2147483647$ (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 $1 \leq \text{value} \leq 2147483647$ (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 <code>qualifiedName</code> data type is a data type defined for the 258X series. The type is a restricted <code>xsd:string</code> data type where the pattern of the string must match the regular expression “[a-zA-Z][a-zA-Z0-9_\\#]*.+. ”. The definition of the <code>qualifiedName</code> data type is: <pre><xsd:simpleType name = "qualifiedName"> <xsd:restriction base = "xsd:string"> <xsd:pattern value = "[a-zA-Z][a-zA-Z0-9_\\#]*.+.+"/> </xsd:restriction> </xsd:simpleType></pre> An example of a string that matches the pattern is: “prefix:name”. The “prefix” is a <code>Namespace</code> name. The “name” is the name of an object within the <code>Namespace</code>.
nonNegativeDouble	The <code>nonNegativeDouble</code> data type is defined for the 258X series. The type restricts an <code>xsd:double</code> to positive numbers, inclusive of 0. The non-negative range of values for IEEE doubles is defined as $0.0 \leq \text{value} \leq 3.4 \times 10^{38}$.
shortName	The <code>shortName</code> data type is a data type defined for the 258X series. The type is a restricted <code>xsd:string</code> data type where the pattern of the string must match the regular expression “[a-zA-Z][a-zA-Z0-9_]* ”. The <code>xsd</code> definition of the <code>shortName</code> data type is: <pre><xsd:simpleType name = "shortName"> <xsd:restriction base = "xsd:string"> <xsd:pattern value = "[a-zA-Z][a-zA-Z0-9_]*"/> </xsd:restriction> </xsd:simpleType></pre> 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.

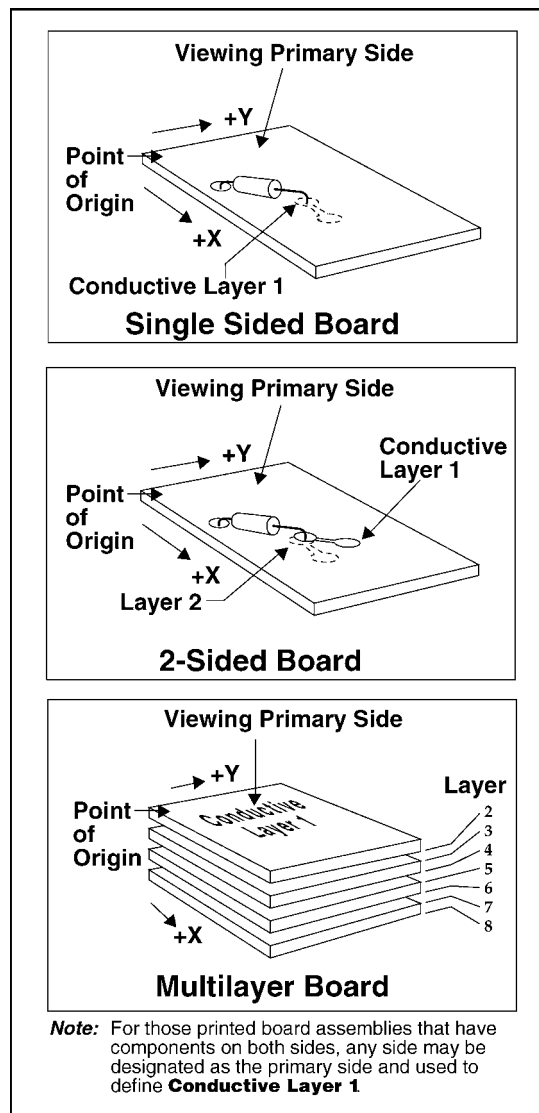


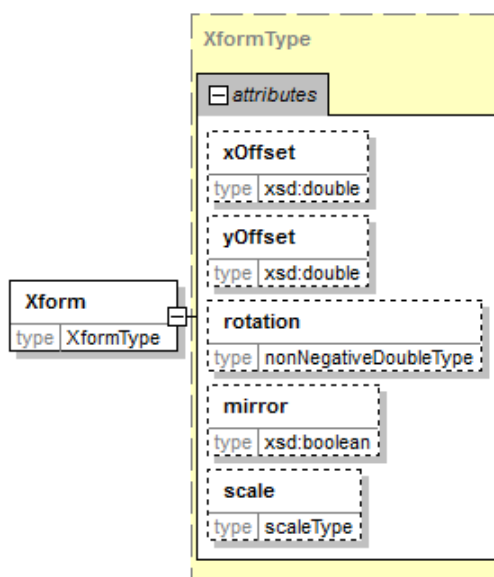
Figure 2 Printed Board Viewing

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 be 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 <code>CadHeader</code> 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 <code>CadHeader</code> 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 <code>minExclusiveValue=0.0</code> 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`.

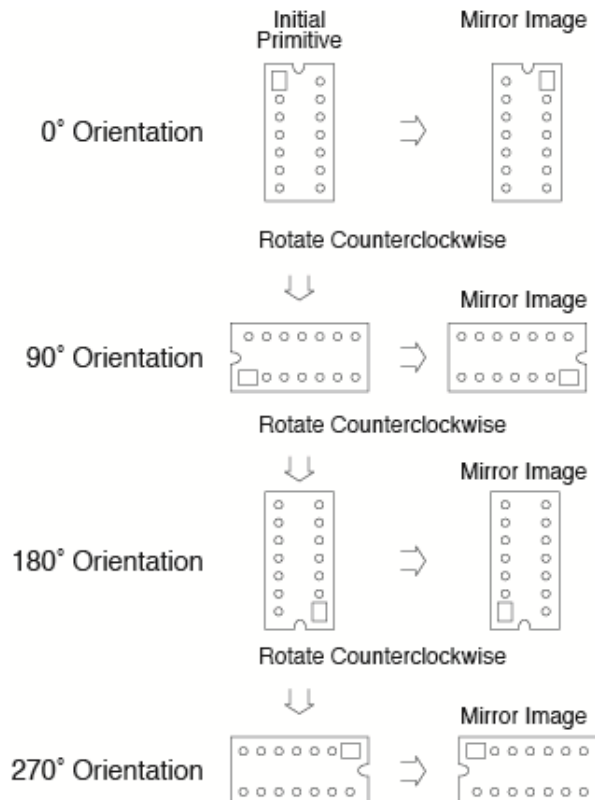


Figure 3 Rotation and Mirror Diagram

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.

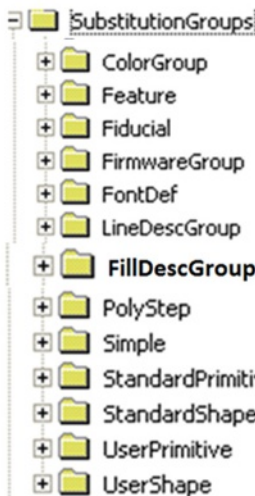
Often a schema needs to specify that one of several different XML Elements can be used with equal validity. For example, in every case where a `Triangle` can be used, it is also permissible to use a `Diamond`, `Hexagon`, `Octagon`, `Oval`, or one of several others: even though these shapes are quite 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.

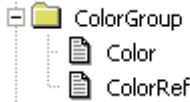
IPC-2581 features several dictionaries that permit specifying some type of information (such as a `StandardPrimitive` or a `LineDesc`) one time, and to reuse that definition as often as necessary. Some substitution groups in IPC-2581 are present to enable specifying either a dictionary entry or the same 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 <code>Color</code> element when it is a child of the parent <code>Set</code> , or <code>Text</code> Elements.	3
Feature	ABSTRACT	A substitution group that permits the substitution of the <code>Feature</code> element when it is a child of the parent <code>Set</code> element.	1
Fiducial	ABSTRACT	A substitution group that permits the substitution of the <code>Fiducial</code> element when it is a child of the parent <code>Set</code> element.	1
FirmwareGroup	ABSTRACT	A substitution group that permits the substitution of the <code>FirmwareGroup</code> element when it is a child of the parent <code>Firmware</code> element.	1
FontDef	ABSTRACT	A substitution group that permits the substitution of the <code>FontDef</code> element when it is a child of the parent <code>EntryFont</code> element.	1
LineDescGroup	ABSTRACT	A substitution group that permits the substitution of the <code>LineDescGroup</code> element when it is a child of the parent of most <code>StandardPrimitives</code> , <code>Outline</code> , <code>Polyline</code> , or <code>Set</code> elements.	16
FillDescGroup	ABSTRACT	A substitution group that permits the substitution of the <code>FillDescGroup</code> element when it is a child of the parent of most <code>StandardPrimitives</code> , <code>Outline</code> , <code>Polyline</code> , or <code>Set</code> elements.	16
PolyStep	ABSTRACT	A substitution group that permits the substitution of the <code>PolyStep</code> element when it is a child of the parent <code>Polyline</code> or <code>Polygon</code> elements.	2
Simple	ABSTRACT	A substitution group that permits the substitution of the <code>Simple</code> element when it is a child of the parent <code>DfxMeasurement</code> , <code>Glyph</code> , or <code>Slot</code> elements.	3
StandardPrimitive	ABSTRACT	A substitution group that permits the substitution of the <code>StandardPrimitive</code> element when it is a child of the parent <code>EntryStandard</code> element.	1
StandardShape	ABSTRACT	A substitution group that permits the substitution of the <code>StandardShape</code> element when it is a child of the parent <code>LayerPad</code> or <code>Pad</code> elements.	2
UserPrimitive	ABSTRACT	A substitution group that permits the substitution of the <code>UserPrimitive</code> element when it is a child of the parent <code>EntryUser</code> element.	1
UserShape	ABSTRACT	A substitution group that permits the substitution or classification of a higher level substitution group. The <code>UserShape</code> element may be used to further classify <code>Feature</code> . In so doing, <code>UserShape</code> can be substituted by a <code>UserPrimitive</code> or <code>UserPrimitiveRef</code> .	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 <code>DictionaryColor</code> .	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 <code>StandardShape</code> element when it is a child of the parent <code>LayerPad</code> or <code>Pad</code> 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 <code>UserShape</code> element may be used to further classify <code>Feature</code> . In so doing <code>UserShape</code> can be substituted by a <code>UserPrimitive</code> or <code>UserPrimitiveRef</code> .	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 aid 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 <code>hexEncodeBinary</code> format.	0-n
FirmwareRef	FirmwareType	An element that references <code>CachedFirmware</code> stored in the <code>DictionaryFirmware</code> through the callout of the firmware "id"	0-n

3.4.5 FontDef

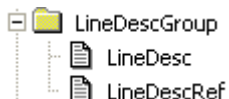
The `FontDef` substitution group consists of the description of a font that is different than the standard Helvetica and which is contained in the `DictionaryFont`. Fonts in the dictionary have an “id” which is called out when a `FontRef` is instantiated. `FontRef` is used by the element `Text`, which 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 <code>Glyph</code> element and are contained in the <code>DictionaryFont</code> . 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 <code>DictionaryFont</code> . 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 <code>LineEnd</code> , <code>LineWidth</code> and <code>LineProperty</code> characteristics	0-n
LineDescRef	LineDescRefType	A reference to a <code>LineDesc</code> that is contained in the <code>DictionaryLineDesc</code> and identified by its unique “id”. The units for the dictionary are defined and must be consistent with the units of the <code>CadHeader</code> when referenced from the <code>Ecad</code> section.	0-n

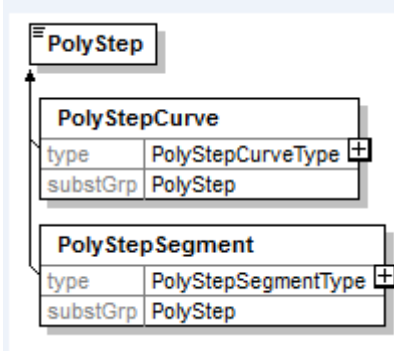
3.4.7 FillDescGroup

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 <code>FillProperties</code> , <code>LineDesc</code> and <code>Color</code> characteristics	0-n
FillDescRef	FillDescRefType	A reference to a <code>FillDesc</code> that is contained in the <code>DictionaryFillDesc</code> and identified by its unique "id". The units for the dictionary are defined and must be consistent with the units of the <code>CadHeader</code> when referenced from the <code>Ecad</code> section.	0-n

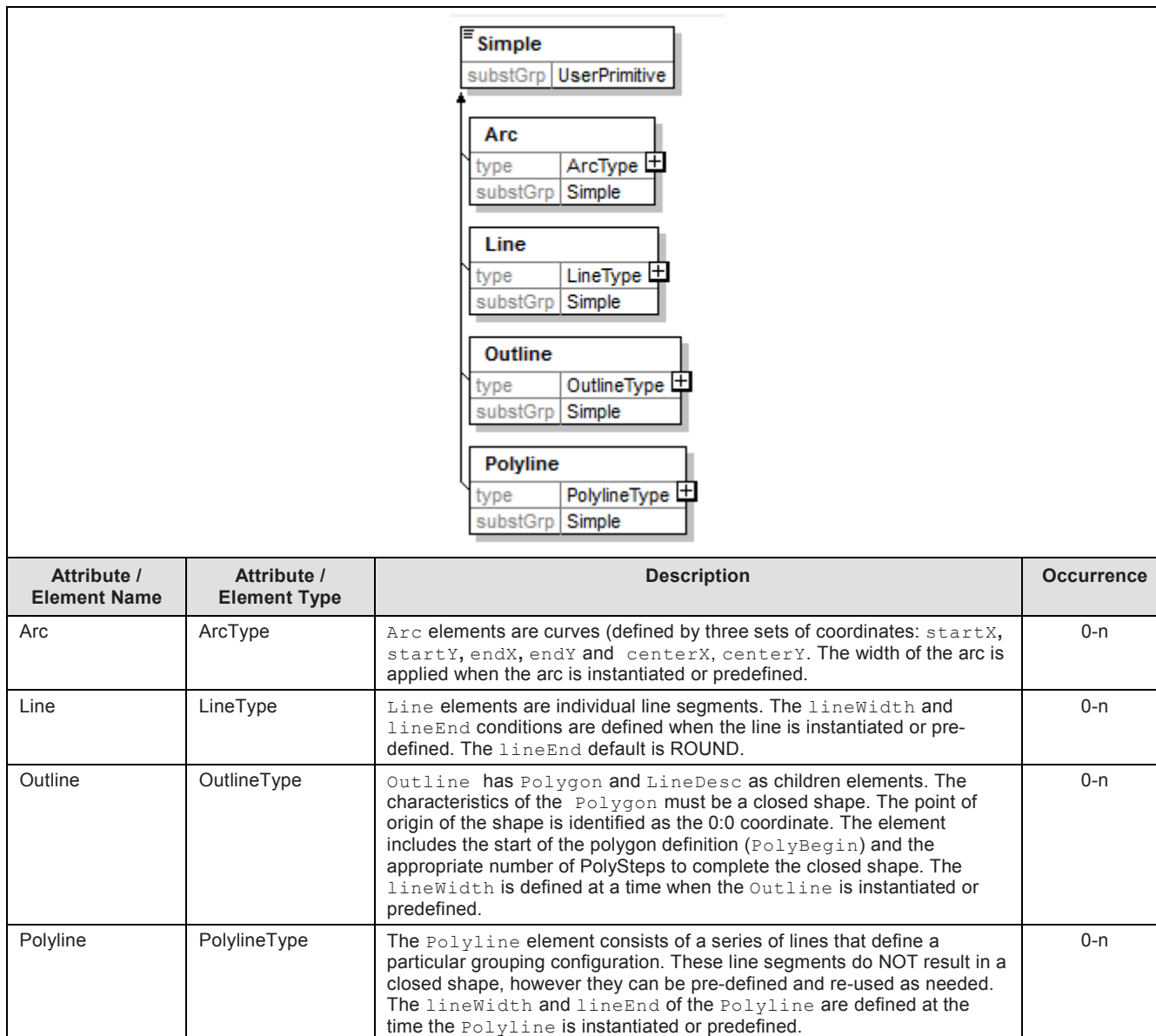
3.4.8 PolyStep

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 <code>Polyline</code> or <code>Polygon</code> 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. <code>CounterClockwise</code> is the default direction	0-n
PolyStepSegment	PolyStepSegmentType	The continuation of the linear description of a <code>Polyline</code> or <code>Polygon</code> if the next portion to be defined is a line segment. The end point of the line is defined.	0-n

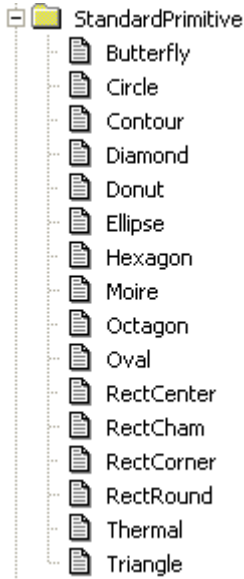
3.4.9 Simple

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.



3.4.10 StandardPrimitive

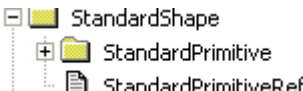
There are sixteen `StandardPrimitive` defined in the `IPC-2581` structure. Any of the primitive shapes may be a candidate for substitution when `StandardPrimitive` is called for in the schema. The names of the various shapes indicate their type; each has its attributes that identify the physical requirements. 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

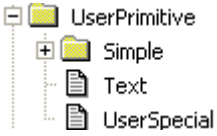
3.4.11 StandardShape

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	StandardPrimitive RefType	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

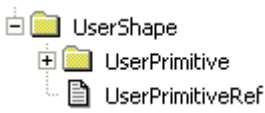
3.4.12 UserPrimitive

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

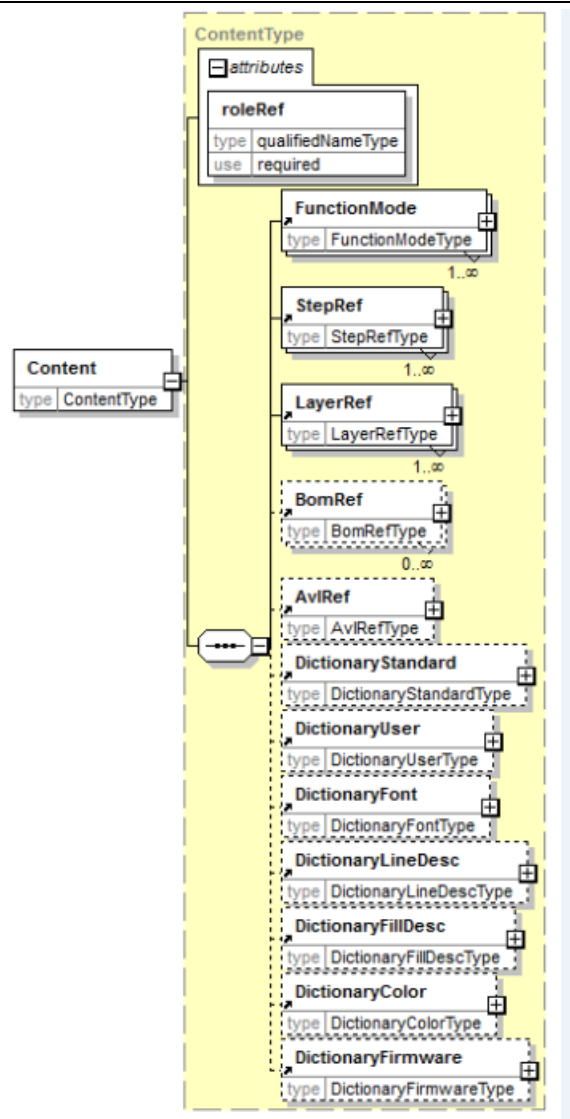
3.4.13 UserShape

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 `Dictionary`s: `DictionaryStandard`, `DictionaryUser`, `DictionaryFont`, `DictionaryLineDesc`, `DictionaryColor`, and `DictionaryFirmware`.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Content	ContentType	The <code>Content</code> 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 <code>Content</code> 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 <code>Avl</code> name established in the file. This file contains the approved vendor list for all items contained in the <code>BomData</code> .	0-1
DictionaryStandard	DictionaryStandardType	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	DictionaryLineDescType	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	DictionaryFirmwareType	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 <code>StepRef</code> , <code>LayerRef</code> , <code>BomRef</code> , and <code>AvlRef</code> 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.

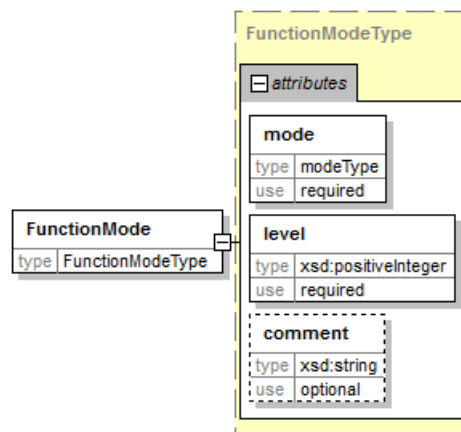
4.1.5 TEST mode

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.

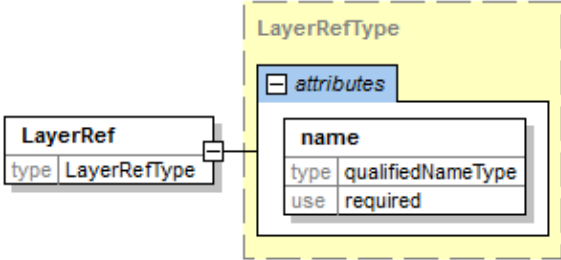
The `StepRef` element, as it appears in the `Content` schema, references the job step's names and thus the various steps that are included in the IPC-2581 file. All the graphical data of a 2581 job are located inside steps that can be nested inside each other (PCB/Sub Panel/Panel, etc.). Steps are referenced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

<pre> classDiagram class StepRef { type StepRefType } class StepRefType { attributes { name qualifiedNameType use required } } StepRef --> StepRefType : type StepRefType --> qualifiedNameType : name </pre>			
Attribute / Element Name	Attribute / Element Type	Description	Occurrence
StepRef	StepRefType	The reference to all existing <code>step</code> 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 <code>Step</code> 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.

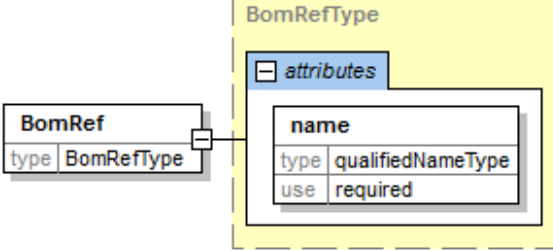


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
LayerRef	LayerRefType	The reference to all existing layer elements contained within the file. This feature is a method of checking completeness in file transfer.	1-n
name	qualifiedNameType	The unique name of all Layer segment descriptions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

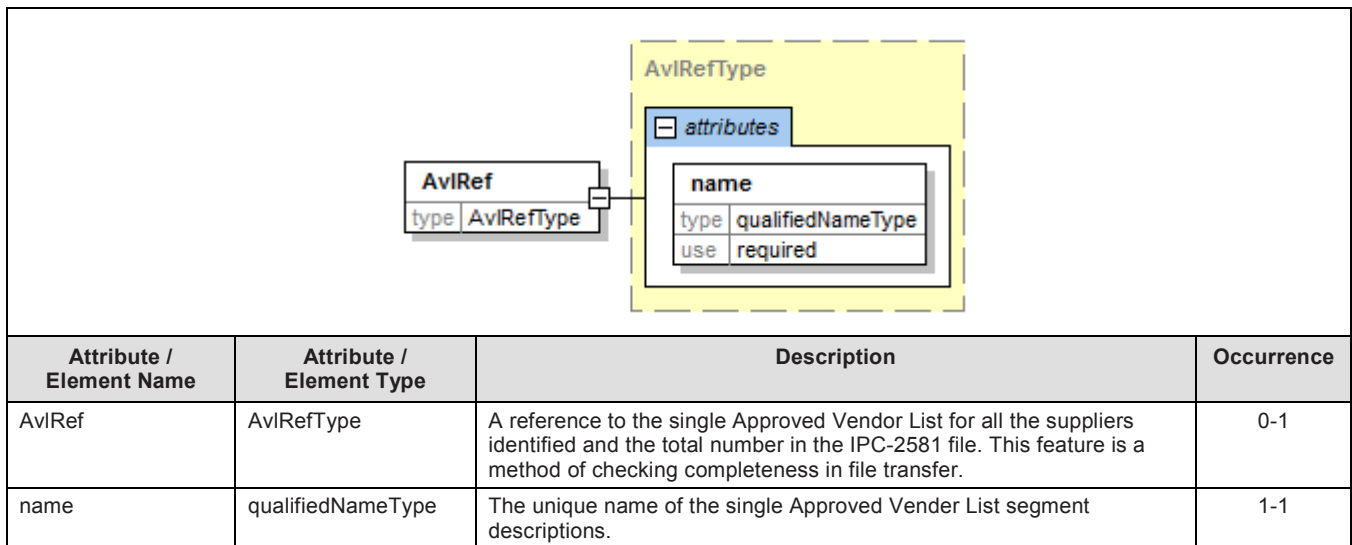


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
BomRef	BomRefType	The reference to all BOM elements that are arranged by the category description contained as an attribute of each BomItem, e.g. ELECTRICAL PROGRAMMABLE MECHANICAL MATERIAL DOCUMENT. This feature identifies the 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

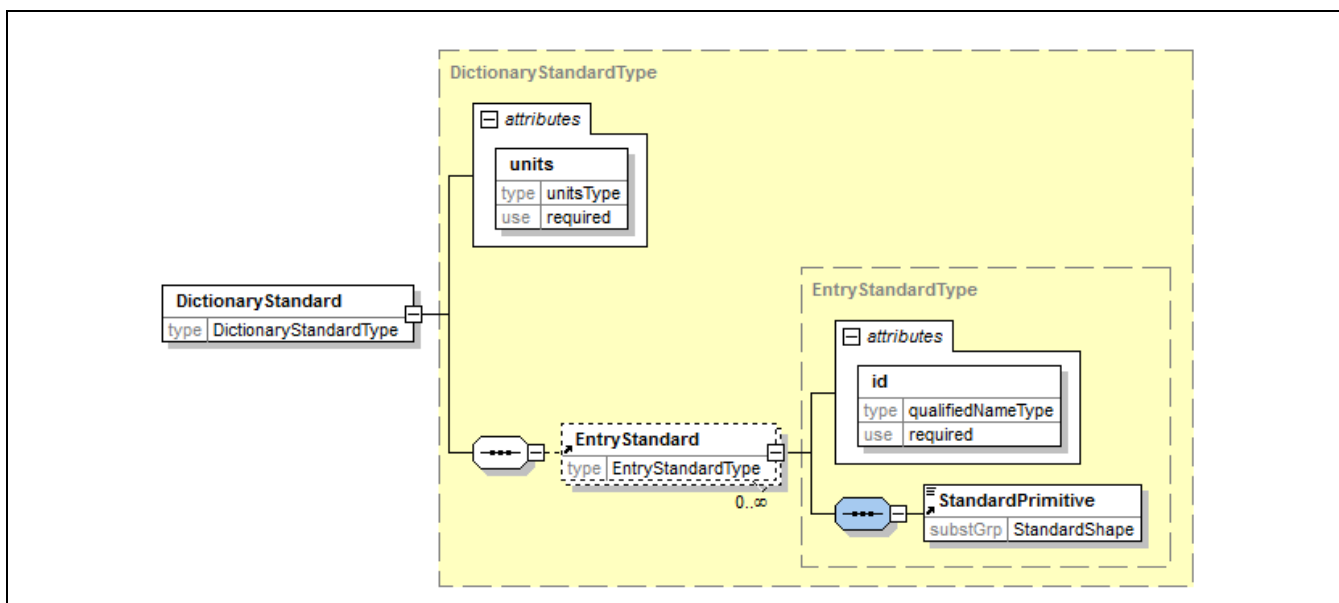
The `Avl` section describes the Approved Vendor Lists for the materials used to fabricate the board and the assembly. The BOM (bill of material) lists include all the different components to be used on the board, arranged by their appropriate part number, and material used to fabricate the board arranged 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.



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.