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IP-XACT, Standard Structure for Packaging, Integrating, and Reusing IP within Tool Flows

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IEEE Std 1685™-2022
(Revision of IEEE Std 1685-2014)

IEEE Standard for IP-XACT, Standard Structure for Packaging, Integrating, and Reusing IP within Tool Flows

Developed by the

Design Automation Standards Committee
of the
IEEE Computer Society

Approved 21 September 2022

IEEE SA Standards Board

Abstract: Conformance checks for eXtensible Markup Language (XML) data designed to describe electronic systems are formulated by this standard. The meta-data forms that are standardized include components, systems, bus interfaces and connections, abstractions of those buses, and details of the components including address maps, register and field descriptions, and file set descriptions for use in automating design, verification, documentation, and use flows for electronic systems. A set of XML schemas of the form described by the World Wide Web Consortium (W3C®) and a set of semantic consistency rules (SCRs) are included. A generator interface that is portable across tool environments is provided. The specified combination of methodology-independent meta-data and the tool-independent mechanism for accessing that data provides for portability of design data, design methodologies, and environment implementations.

Keywords: abstraction definitions, address space specification, bus definitions, design environment, EDA, electronic design automation, electronic system level, ESL, IEEE 1685™, implementation constraints, IP-XACT, register transfer level, RTL, SCRs, semantic consistency rules, TGI, tight generator interface, tool and data interoperability, use models, XML design meta-data, XML schema

This publication is dedicated to past editor and friend Joe Daniels, who passed away about 8 months after the team started to work on this revision in Accellera. Your work will live on as will your memory.

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Introduction

This introduction is not part of IEEE Std 1685-2022, IEEE Standard for IP-XACT, Standard Structure for Packaging, Integrating, and Reusing IP within Tool Flows.

The purpose of this standard is to provide the electronic design automation (EDA), semiconductor, electronic design intellectual property (IP) provider, and system design communities with a well-defined and unified specification for the meta-data that represents the components and designs within an electronic system. The goals of this specification are to enable delivery of compatible IP descriptions from multiple IP vendors; to improve the importing and exporting of complex IP bundles to, from, and between EDA tools for system on chip (SoC) design environments (DEs); to improve the expression of configurable IP by using IP meta-data; and to improve the provision of EDA vendor-neutral IP creation and configuration scripts (*generators*). The data and data access specification is designed to coexist and enhance the hardware description languages (HDLs) presently used by designers while providing capabilities lacking in those languages.

The SPIRIT Consortium, which originally developed the IP-XACT standard before merging with Accellera, was a consortium of electronic system, IP provider, semiconductor, and EDA companies. IP-XACT enables a productivity boost in design, transfer, validation, documentation, and use of electronic IP and covers components, designs, interfaces, and details thereof. The data specified by IP-XACT is extensible in locations specified in the schema.

IP-XACT enables the use of a unified structure for the meta specification of a design, components, interfaces, documentation, and interconnection of components. This structure can be used as the basis of both manual and automatic methodologies. IP-XACT specifies the tight generator interface (TGI) for access to the data in a vendor-independent manner.

This standardization project provides electronic design engineers with a well-defined standard that meets their requirements in structured design and validation and enables a step function increase in their productivity. This standardization project will also provide the EDA industry with a standard to which they can adhere and that they can support in order to deliver their solutions in this area.

Accellera has prepared a set of bus and abstraction definitions for several common buses. It is expected, over time, that standards groups and manufacturers who define buses will include IP-XACT eXtensible Markup Language (XML) bus and abstraction definitions in their set of deliverables. Until that time, and to cover existing useful buses, a set of bus and abstraction definitions for common buses has been created.

A set of reference bus and abstraction definitions allows many vendors who define IP using these buses to easily interconnect IP together. Accellera posts these definitions for use by its members, with no warranty of suitability, but in the hope that they will be useful. Accellera will, from time to time, update these files and, if a standards body wishes to take over the work of definition, will transfer that work to that body.

These reference bus and abstraction definition templates (with comments and examples) are available from the public area of the Accellera website.[6]

NOTE—Accellera IP-XACT WG Comments on IEEE Std 1685-2014 are acknowledged.

[6]Available at http://www.accellera.org.

IEEE Standard for IP-XACT, Standard Structure for Packaging, Integrating, and Reusing IP within Tool Flows

1. Overview

This clause explains the scope and purpose of this standard; gives an overview of the basic concepts, major semantic components, and conventions used in this standard; and summarizes its contents.

1.1 Scope

This standard describes an eXtensible Markup Language (XML) schema[7] for meta-data documenting *intellectual property* (IP) used in the development, implementation, and verification of electronic systems. This schema provides both a standard method to document IP that is compatible with automated integration techniques and a standard method (generators) for linking tools into a *system development* framework, enabling a more flexible, optimized development environment. Tools compliant with this standard will be able to interpret, configure, integrate, and manipulate IP blocks that comply with the IP meta-data description. The standard is independent of any specific design processes. It does not cover behavioral characteristics of the IP that are not relevant to integration.

1.2 Purpose

This standard enables the creation and exchange of IP in a highly automated design environment.

[7]Information on references can be found in Clause 2.

1.3 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (shall equals is required to).[8, 9]

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (should equals is recommended that).

The word *may* is used to indicate a course of action permissible within the limits of the standard (may equals is permitted to).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (can equals is able to).

1.4 Design environment

The IP-XACT specification is a mechanism to express and exchange information about design IP and its required configuration.[10] While the IP-XACT description formats are the core of this standard, describing the IP-XACT specification in the context of its basic use model, the design environment (DE), more readily depicts the extent and limitations of the semantic intent of the data. The DE coordinates a set of tools and IP, or expressions of that IP (e.g., models), through the creation and maintenance of meta-data descriptions of the system on chip (SoC) so that its system design and implementation flows are efficiently enabled and reuse centric.

The use of the IP-XACT-specified formats and interfaces are shown in **bold** in Figure 1 and described in the following subclauses.

[8]The use of the word *must* is deprecated and cannot be used when stating mandatory requirements; *must* is used only to describe unavoidable situations.

[9]The use of *will* is deprecated and cannot be used when stating mandatory requirements; *will* is only used in statements of fact.

[10]IP-XACT uses the World Wide Web Consortium (W3C®) standard for the XML version 1.0 data (http://www.w3.org/TR/REC-xml/). The valid format of that XML data is described in a *schema* by using the Schema Description Language described therein. W3C is a registered trademark of the World Wide Web Consortium. In addition to XML, many configurability aspects of IP-XACT are inspired from the IEEE 1800 SystemVerilog standard.

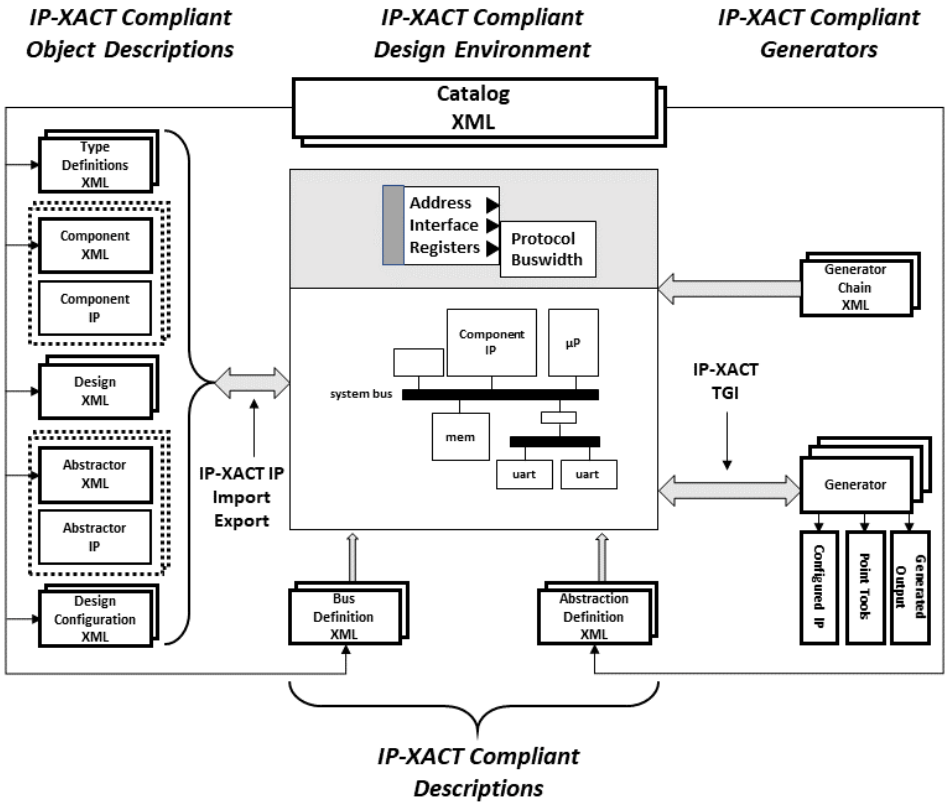

Figure 1—IP-XACT design environment

1.4.1 IP-XACT design environment

A DE enables the designer to work with IP-XACT design IP through a coordinated front-end and IP design database. These tools create and manage the top-level meta-description of system design and may provide two basic types of services: *design capture*, which is the expression of design configuration by the IP provider and design intent by the IP user, and *design build*, which is the creation of a design (or design model) to those intentions.

As part of design capture, a system design tool shall recognize the structure and configuration options of imported IP. In the case of *structure*, this implies both the structure of the design (e.g., how specific pin-outs refer to lines in the hardware description language (HDL) code) as well as the structure of the IP package (e.g., where design descriptions and related generators are provided in the packaged IP data-structure). In the case of *configuration*, this is the set of options for handling the imported IP (e.g., setting the base address and offset, bus width) that may be expressed as configurable parameters in the IP-XACT meta-data.

As part of design build, generators may be provided internally by a system design tool to achieve the required IP integration or configuration, or they may be provided externally (e.g., by an IP provider) and launched by the system design tool as appropriate.

The *system design tool set* defines a DE where the support for conceptual context and management of IP-XACT meta-data resides. However, the IP-XACT specifications make no requirements upon system design

tool architecture or a tool's internal data structures. To be considered IP-XACT enabled, a system design tool shall support the import/export of IP expressed with valid IP-XACT meta-data for both component IP and designs, and it needs to support the tight generator interface (TGI) for interfacing with external generators (to the DE).

1.4.2 IP-XACT object descriptions

The IP-XACT schema is the core of the IP-XACT specification. There are nine top-level schema definitions. Each schema definition can be used to create object descriptions of the corresponding types:

- A *bus definition* description defines the type attributes of a bus.
- An *abstraction definition* description defines the representation attributes of a bus.
- A *typeDefinitions* description defines memory map–related elements, including registers, of a component.
- A *component* description defines an IP or interconnect structure.
- A *design* description defines the configuration of and interconnection between components.
- An *abstractor* description defines an adaptor between interfaces of two different abstractions.
- A *generator chain* description defines the grouping and ordering of generators.
- A *design configuration* description defines additional configuration information for a generator chain or design description.
- A *catalog* description provides a mapping between IP-XACT VLNVs (see 1.4.3) and the physical location of the IP-XACT file defining the IP-XACT object with the given VLNV.

1.4.3 Object interactions

An object description contains a unique identifier in the header. The identifier in IP-XACT terms is called a *VLNV* after the four elements that define its value: vendor, library, name, and version. See C.28 for further details on a VLNV. This VLNV is used to create a reference from one description to another. The links between these objects are illustrated in Figure 2. The arrows (A → B) illustrate a reference of one object to another (e.g., reference of object `B` from object `A`).

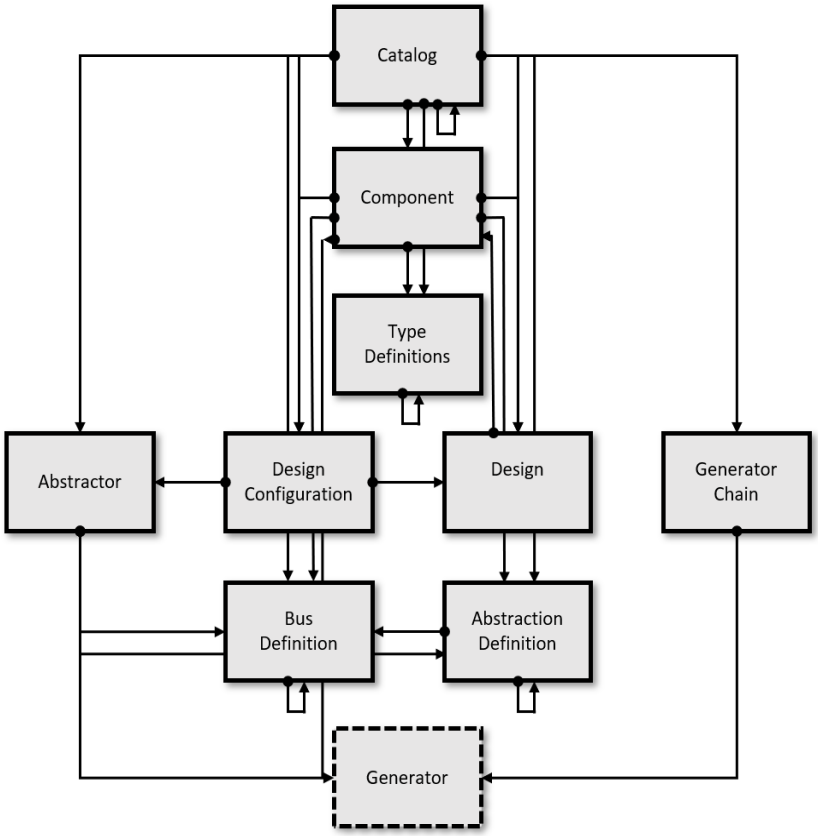

Figure 2—IP-XACT object interactions

1.4.4 IP-XACT generators

Generators are executable objects (e.g., scripts or binary programs) that may be integrated within a DE (referred to as *internal*) or provided separately as an executable (referred to as *external*). Generators may be provided as part of an IP package (e.g., for configurable IP, such as a bus-matrix generator) or as a way of wrapping point tools for interaction with a DE (e.g., an external design netlister, external design checker); see 1.5.2.

An internal generator may perform a wide variety of tasks and may access IP-XACT–compliant meta-data by any method a DE supports. IP-XACT does not describe these protocols.

An *external generator* (often referred to as a *TGI generator*) is an executable program or script invoked from within a DE to query or configure design descriptions and their related component and abstractor descriptions. External generators can use the TGI to *access* their IP-XACT meta-data descriptions (as currently loaded into the DE) and perform the various operations associated with those descriptions. In addition, external generators shall only *operate* upon IP-XACT–compliant meta-data through the defined TGI; see 1.4.6.

Generators can be referenced from a component, abstractor, or generator chain description. Generators can also be grouped and ordered in generator chain descriptions and in chain descriptions contained inside other chain descriptions. This sequencing of generators is *critical* for providing script-based support for SoC flow creation.

1.4.5 IP-XACT design environment interfaces

There are two interfaces expressed in Figure 1: from the DE to the external IP libraries and from the DE to the generators. In the former case, the IP-XACT specifications are *neutral* regarding the design tool interfaces to IP repositories. Being able to read and write IP with IP-XACT meta-data is required; however, the *formal interaction* between an external IP repository and a DE is not specified. In the latter case, the interface between the DE and a generator is the TGI; see 1.4.6.

1.4.6 Tight generator interface

The *tight generator interface* (TGI) is the method a generator uses to access a design or component description in a DE-independent and generator-language-independent manner. Therefore, a generator running on two different DEs produces the same results. The DE and the generator can communicate with each other by sending messages utilizing the Simple Object Access Protocol (SOAP)[11] specified in the Web Services Description Language (WSDL).[12] SOAP or REST[13] provide a simple means for sending XML-format messages using the Hypertext Transfer Protocol (HTTP) or other transport protocols. IP-XACT supports using HTTP or a file protocol.

The messages passed between the generator and the DE allow the generator to get all information about the design interconnections (which contain components and abstractors), provide set information for any configurable elements in a component or abstractor, and make simple modifications of the design description. For additional details on the DE generator invocation and the messages passed between the generator and the DE, see Annex F.

1.4.7 Design intellectual property

IP-XACT is structured around the concept of IP reuse. *Electronic design intellectual property*, or IP, is a term used in the electronic design automation (EDA) community to refer to a reusable collection of design specifications that represent the behavior, properties, and/or description of the design in various media. The name IP is partially derived from the common practice of considering a collection of this type to be the intellectual property of one party. Both hardware and software collections are encompassed by this term.

These collections may include the following:

a) Design objects—This collection can include the following:
   1) Transaction-level modeling (TLM) descriptions: SystemC® and SystemVerilog [14]
   2) Fixed HDL descriptions: Verilog®, VHDL[15]
   3) Configurable HDL descriptions (e.g., bus-fabric generators)
   4) Design models for register transfer level (RTL) and transactional simulation (e.g., compiled core models)
   5) HDL-specified verification IP (VIP) (e.g., basic stimulus generators and checkers)

b) IP views—This collection is a list of different views (levels of description and/or languages) to describe the IP object. In IP-XACT, these views include the following:
   1) Design view: RTL Verilog or VHDL, flat or hierarchical components
   2) Simulation view: model views, targets, simulation directives, etc.
   3) Documentation view: standard, user guide, etc.

[11]Available from the W3C Web site at http://www.w3.org/TR/soap12-part1/.
[12]Available from the W3C Web site at http://www.w3.org/TR/wsdl.
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[14]SystemC is a registered trademark of the Accellera Systems Initiative.
[15]Verilog is an abandoned trademark.

IP-XACT XML meta-data descriptions provide a standardized way of collecting much of the structural information contained in the file sets. IP-XACT also can contain the information that identifies the appropriate files included in a collection to be used for different parts of the design process.

1.5 IP-XACT–enabled implementations

Complying with the rules outlined in this subclause allows providers of tools, IP, or generators to class their products as *IP-XACT enabled*. Conversely, any violation of these rules removes that naming right. This subclause first introduces the set of metrics for measuring the valid use of the specifications. It then specifies when those validity checks are performed by the various classes of products and providers: DEs, point tools, IPs, and generators.

a) Parse validity
   1) Parsing correctness: Ability to read all IP-XACT descriptions.
   2) Parsing completeness: Cannot require information that could be expressed in an IP-XACT format to be specified in a non-IP-XACT format. Processing of all information present in an IP-XACT document is not required.

b) Description validity
   1) Schema correctness: IP is described using XML files that conform to the IP-XACT schema.
   2) Usage completeness: Extensions to the IP-XACT schema shall be used only to express information that cannot otherwise be described in IP-XACT.

c) Semantic validity
   1) Semantic correctness: Adheres to the semantic interpretations of IP-XACT data described in this standard.
   2) Semantic completeness: Obeys all the semantic consistency rules (SCRs) described in Annex B.

These validity rules can be combined with the product class-specific rules to cover the full IP-XACT–enabled space. The following subclauses describe the rules a provider has to check to claim a product is IP-XACT enabled.

An IP-XACT–enabled DE or point tool may read descriptions based on multiple versions of the IP-XACT schema. If the DE or point tool does provide this capability, the effect shall be as if all of the descriptions had been translated to the highest schema version supported by the given tool. This is required for semantic consistency. Schema version translation can be done in a number of different ways, but the most common is to leverage the eXtensible Stylesheet Language Transformations (XSLT)[16] provided with the IP-XACT schema image. In addition, a DE or point tool may preserve information in the initial description for use outside of the scope of the IP-XACT specification.

1.5.1 Design environments

An IP-XACT–enabled DE shall

- Follow the parse validity requirements shown in 1.5.
- Create IP that is IP-XACT enabled.
- Modify any existing IP-XACT descriptions without losing any preexisting information. In particular, it shall preserve any vendor extension data included in the existing IP-XACT description.
- Be able to invoke IP-XACT–enabled generators with **apiType** of **none** (see 6.16.2).

[16] Available from the W3C Web site at http://www.w3.org/TR/xslt.

An IP-XACT–TGI–enabled DE shall be considered as enabled as follows:

— For the base TGI, if it supports all generators utilizing the `TGI_2022_BASE` **apiType** (see 6.16.2).
— For the extended TGI, if it supports all generators utilizing the `TGI_2022_BASE` or `TGI_2022_EXTENDED` **apiType**s (see 6.16.2).

1.5.2 Point tools

A point tool is a tool that has a particular, rather than a general, set of capabilities. In contrast to an IP-XACT–enabled DE (see 1.5.1), an IP-XACT–enabled point tool shall

— Follow the parse validity requirements shown in 1.5.
— Create IP that is IP-XACT enabled.
— Modify any existing IP-XACT descriptions whiletrying not to lose any preexisting information. In particular, it shall preserve any vendor extension data included in the existing IP-XACT description.

1.5.3 IPs

An IP-XACT–enabled IP shall

— Have an IP-XACT description that follows the description and semantic validity requirements shown in 1.5.
— Use IP-XACT–enabled generators for any generators associated with this IP.

XML descriptions compliant with IP-XACT shall provide a namespace reference to the `index.xsd` schema file, not to any of the other files in the release.

1.5.4 Generators

An IP-XACT–enabled generator shall

— Create IP that is IP-XACT enabled.
— Modify any existing IP-XACT descriptions without losing any preexisting information. In particular, it shall preserve any vendor extension data included in the existing IP-XACT description.
— Communicate with the DE that invoked it only through the IP-XACT TGI (see Annex F).

1.6 Conventions used

The conventions used throughout the document are included here.

IP-XACT is case-sensitive.

1.6.1 Visual cues (meta-syntax)

Bold shows required keywords and/or special characters, e.g., **addressSpace**. For the initial definitional use (per element), keywords are shown in **boldface-red text**, e.g, **bitsInLau** (see also 1.7).

Bold italics shows group names or data types, e.g., ***nameGroup*** or ***boolean***. For definitions of types, see Annex D.

`Courier` shows examples, external command names, directories and files, etc., e.g., address `0x0` is on `D[31:0]`.

1.6.2 Notational conventions

The keywords *required, shall, shall not, should, should not, recommended, may,* and *optional* in this standard are to be interpreted as described in 1.3 and IETF RFC-2119 [B5].[17] When a conflict between the two exists, the use in 1.3 takes precedence.

1.6.3 Syntax examples

Any syntax examples shown in this standard are for information only and are intended only to illustrate the use of such syntax (see also Annex I).

1.6.4 Graphics used to document the schema

The W3C Web site[18] specifies the XML schema language used to define the IP-XACT XML schemas. Normative details for compliance to the IP-XACT standard are contained in the schema files. Within this document, pictorial representations of the information in the schema files *illustrate* the structure of the schema and *define* any constraints of the standard. With the exception of visibility issues, the information in the figures and the schema files is intended to be identical (for a fully annotated version of the schema files; see IP-XACT Schema [B8]). Where the figures and schema are in conflict, the XML schema file shall take precedence.[19]

1.6.4.1 Elements and attributes

The *element* is the fundamental building block on which this standard is based. An element may be either a *leaf element*, which is a container for information, or a *branch element*, which may contain further branch elements or leaf elements.

A leaf or branch element may also contain *attributes*. Attributes are containers for information within the containing element.

1.6.4.2 Types

A *type* is a designation of the format for the contents of an element or attribute. There are two different styles of types that can be defined. A type may be assigned to a leaf element or an attribute. This type is called a ***simpleType*** and defines the format of data that may be stored in this container. A type may also be assigned to a branch element. This type is called a ***complexType*** and defines further elements and attributes contained in the branch element.

1.6.4.3 Groups

A group is a collection of elements or attributes, which allow the same collection of items to be referenced consistently in many places. There are two different types of groups that can be defined. A *group* is a combination of leaf or branch elements; an ***attributeGroup***, a simple list of attributes. The names assigned to either group have no representation in the resulting description.

[17]The number in brackets correspond to the numbers of the bibliography in Annex A.

[18]Available from the W3C Web site at https://www.w3.org/TR/REC-xml/.

[19]The graphics for this document have been generated by taking “screen-shots” of the various files as they are displayed in Altova’s XML environment XMLSpy®. XMLSpy is a registered trademark of Altova GmbH. This information is given for the convenience of users of this standard and does not constitute an endorsement by the IEEE of this product. Equivalent products may be used if they can be shown to lead to the same results.

1.6.4.4 Namespace

Each element, attribute, type, or group has a name, which is preceded by a namespace-prefix and separated from the name by a colon (**:**). For the examples in 1.6.4.5, **xyz** is used as the namespace-prefix for all of the items whereas this standard uses **ipxact**. Within the text of this standard, the namespace-prefix is not written when describing an item; it is shown only in examples.

1.6.4.5 Diagrams

The diagrams used throughout this standard graphically detail the organization of elements and attributes.

NOTE—For brevity, the **xml:id** attribute (see C.30) has been removed from all diagrams.[20]

1.6.4.5.1 Elements and sequences

Figure 3 shows the sequence-compositor. At the left is a branch element, **element1**, with some descriptive text below. **element1** is connected to a sequence-compositor. The sequence-compositor defines the order the subelements appear in the branch element. **subElement1** shall appear first inside of **element1**. This is followed by **subElement2**, **subElement3**, **subElement4**, and **subElement5** before closing **element1**.

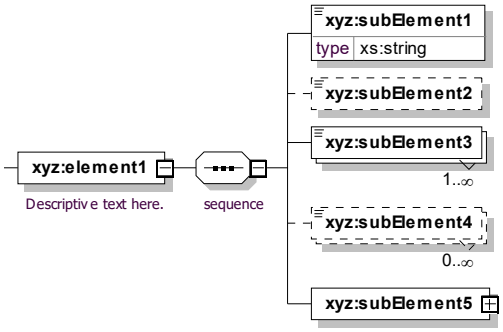

Figure 3—Sequence-compositor

a) **subElement1** is a mandatory element, as indicated by the solid line of the containing box. The type of the data contained in this element is set to ***string***, and it has a default value of `ipxact` if the element is present but left empty.

b) **subElement2** is an optional element, as indicated by the dashed-line of the containing box.

c) **subElement3** is an mandatory element that may appear multiple times, indicated by the double-solid line of the containing box. The number of times the element may appear is indicated by the range of the numbers listed below the element.

d) **subElement4** is an optional element that may appear multiple times, as indicated by the double-dashed line of the containing box. The number of times the element may appear is indicated by the range of the numbers listed below the element.

e) **subElement5** is an mandatory branch element that contains further elements inside, as indicated by the small plus sign (+) in the small box on the right.

[20]Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the standard.

Figure 4 shows variations of a sequence-compositor. **root1** is connected to an optional sequence-compositor, as indicated by the symbol being drawn with a dashed line. **element1** may appear first inside of **root1**; if it does, it shall be followed by **element2**. Each subelement is connected to a sequence-compositor.

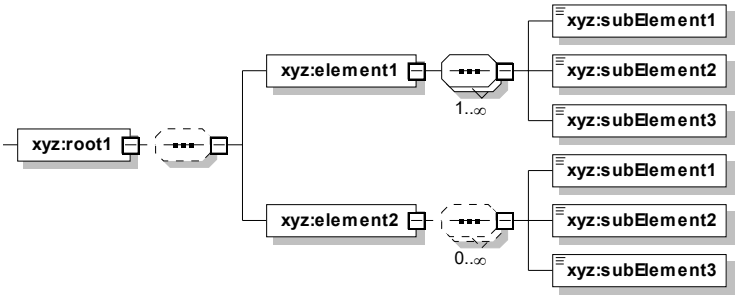

Figure 4—Sequence-compositor variations

— **element1** may contain one or more of the following sequences in the following order: **subElement1** and **subElement2** and **subElement3**. The number of times the sequence-compositor may appear is indicated by the range of the numbers listed below the symbol. If the range is greater than 1, the sequence-compositor symbol is drawn with double lines.

— **element2** is optional and may contain zero or more of the following sequences in the following order: **subElement1** and **subElement2** and **subElement3**. The number of times the sequence-compositor may appear is indicated by the range of the numbers listed below the symbol. If the range starts at 0 and the maximum is greater than 1, the sequence-compositor symbol is drawn with double-dashed lines.

1.6.4.5.2 Elements and choices

Figure 5 shows the variations of the choice-compositor. **root** is connected to a choice-compositor. The choice-compositor specifies that one of the elements on the right side shall be chosen. **root** may contain one of the following: **element1**, **element2**, or **element3**. Each subelement is connected to a choice-compositor.

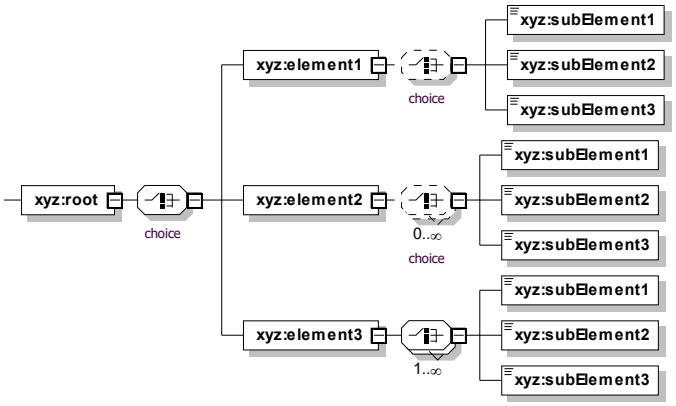

Figure 5—Choice-compositor variations

a) **element1** may contain one of the following: **subElement1**, **subElement2**, or **subElement3**, as indicated by the symbol being drawn with a dashed line.

b) **element2** may contain any (0 or more) of the following: **subElement1**, **subElement2**, or **subElement3** in any order. The number of times the choice-compositor may appear is indicated by

the range of the numbers listed below the symbol. If the range starts at 0, the choice-compositor is drawn with dashed lines.

c) **element3** may contain one or more of the following: **subElement1**, **subElement2**, or **subElement3** in any order. The number of times the choice-compositor may appear is indicated by the range of the numbers listed below the symbol. If the range is greater than 1, the choice-compositor is drawn with double lines.

1.6.4.5.3 Elements, attributes, groups, and attributeGroups

Figure 6 shows the use of attributes, groups, and attributeGroups. **element1** contains two attributes, shown in the tab-shaped box labeled *attributes*. **attribute1** is optional, as indicated by the dashed containing box, and is of type ***integer*** with a default value of 7 if the attribute is not present. **attribute2** is a required attribute, as indicated by the solid containing box, and is of type ***boolean*** with no default. The ordering in which **attribute1** and **attribute2** appear inside **element1** is irrelevant.

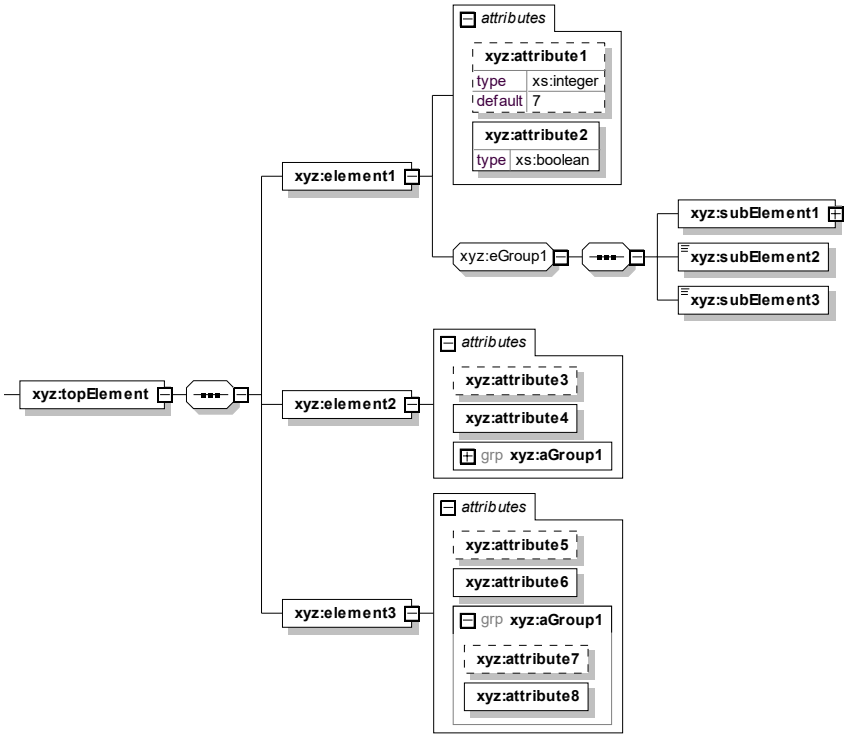

Figure 6—Attributes, groups, and attributeGroups

a) ***eGroup1*** is an element group inside **element1**. This group contains three subelements, and the group symbol can be replaced by a solid line. The name of the group has no representation in the resulting output description. An element group can be optional, as indicated by a dashed outline (not shown), and it can also have a range, as indicated by numbers below the group symbol (not shown).

b) ***aGroup1*** is an ***attributeGroup*** inside **element2** and **element3**. This ***attributeGroup*** contains two attributes, **attribute7** and **attribute8**. Inside **element2**, the ***attributeGroup*** is shown in its collapsed form, as indicated by the small plus sign (+) inside the small box. Inside **element3**, the ***attributeGroup*** is shown in its expanded form, as indicated by the small minus sign (−) inside the small box. **element2** contains four attributes: **attribute3**, **attribute4**, **attribute7**, and **attribute8**. **element3** also contains four attributes: **attribute5**, **attribute6**, **attribute7**, and **attribute8**. The name of the ***attributeGroup*** has no representation in the resulting description.

1.6.4.5.4 Wildcards

Figure 7 shows the use of wildcards. A *wildcard* is depicted by the rounded box with the **any ##any** text. Wildcards indicate that any well-formed attribute or element may be inserted into the containing element.

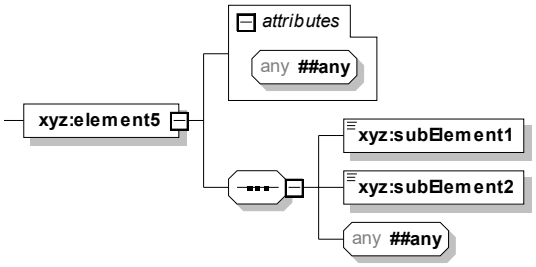

Figure 7—Wildcards

1.7 Use of color in this standard

This standard uses a minimal amount of color to enhance readability. The coloring is not essential and does not affect the accuracy of this standard when viewed in pure black and white. The places where color is used are the following:

- Cross references that are hyperlinked to other portions of this standard are shown in underlined-blue text (hyperlinking works when this standard is viewed interactively as a PDF file).
- In the formal language definitions, syntactic keywords and tokens are shown in **boldface-red text**.

1.8 Contents of this standard

The organization of the remainder of this standard is as follows:

- Clause 2 provides references to other applicable standards that are assumed or required for this standard.
- Clause 3 defines terms, acronyms, and abbreviations used throughout the different specifications contained in this standard.
- Clause 4 defines the interoperability use model.
- Clause 5 defines the bus and abstraction interface definitions.
- Clause 6 defines the component and interconnect models.
- Clause 7 defines the designs and their connections.
- Clause 8 defines the abstractor model between abstraction definitions.
- Clause 9 defines the type definition descriptions.
- Clause 10 defines the generator chain configuration.
- Clause 11 defines design configurations.
- Clause 12 defines the catalog feature.
- Clause 13 defines addressing.
- Clause 14 defines data visibility.
- Annex A Bibliography.
- Annex B Semantic consistency rules.

— Annex C Common elements and concepts.
— Annex D Types.
— Annex E SystemVerilog expressions.
— Annex F Tight generator interface.
— Annex G External bus with an internal/digital interface.
— Annex H Bridges and channels.
— Annex I Examples.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used; therefore, each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

eXtensible Markup Language (XML) schema specification, available from the W3C Web site at http://www.w3.org/TR/xmlschema-0/; http://www.w3.org/TR/xmlschema-1/; http://www.w3.org/TR/xmlschema-2/.

eXtensible Markup Language (XML) version 1.0 specification, available from the W3C Web site at http://www.w3.org/TR/REC-xml/.

eXtensible Stylesheet Language Transformations (XSLT) version 1.0 specification, available from the W3C Web site at http://www.w3.org/TR/xslt.

IEEE Std 1800™, IEEE Standard for SystemVerilog-Unified Hardware Design, Specification, and Verification Language.[21, 22]

REpresentational State Transfer (REST), Web Services Architecture, description of relationship to World Wide Web on the W3C Web site at https://www.w3.org/TR/ws-arch/#relwwwrest

Simple Object Access Protocol (SOAP) version 1.2 specification, available from the W3C Web site at http://www.w3.org/TR/soap12-part1/.

Web Services Description Language (WSDL) version 1.1 specification, available from the W3C Web site at http://www.w3.org/TR/wsdl.

XML schema NameChar definition, available from the W3C Web site at http://www.w3.org/TR/REC-xml/#NT-NameChar.

XML schema NameStartChar definition, available from the W3C Web site at http://www.w3.org/TR/REC-xml/#NT-NameStartChar.

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