JEDEC PUBLICATION

PartModel Thermal Guidelines for Electronic-Device Packages – XML Requirements

JEP30-T100C

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JEDEC SOLID STATE TECHNOLOGY ASSOCIATION

NOTICE

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PartModel Thermal Guidelines for Electronic-Device Packages – XML Requirements

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(From JEDEC Board Ballots JCB-17-48, JCB-24-29, JCB-24-53 and JCB-25-59, formulated under the cognizance of the JC-11 Committee on Mechanical Standardization.)

1 Scope

The JEP30 document establishes the requirements for exchanging part data between part manufacturers and their customers for electrical and electronic products. The JEP30 documents are part of a series to describe XML data exchange structure and hierarchy. The JEP30 document series will detail data exchange between companies for design at the next level, analysis, and interconnection. The parent JEP30 document specifically focuses on the parental structure, under which several sub-sections are listed, such as electrical, physical, thermal, supply chain, assembly process classification, design kit, generated ECAD models, product substrate and assemblies, and environment including material declaration. This document specifically focuses on the Thermal sub-section of the PartModel.

All releases of the *Thermal* sub-schema must be under the umbrella of the PartModel Schema to ensure that the PartModel schema is referencing the correct version of the thermal sub-schema. In addition, this will enable the *Thermal* sub-schema to connect to the Manufacturer Part Number and the Manufacturer of the Part.

1.1 Purpose

This standard is intended to benefit part manufacturers and their customers by providing consistency and efficiency to the transfer of part data from part manufacturer to customers. This standard specifically covers data applicable to the thermal modelling of the device.

2 Applicable Documents

The following documents form a part of this standard to the extent specified herein. The revision of the document in effect at the time of solicitation shall take precedence.

2.1 JEDEC (www.jedec.org)

JEP30, *PartModel Guidelines for Electronic-Device Packages – XML Requirements*

JEP30-10, *PartModel Schema*

JEP30-T101, *PartModel Thermal Schema*

JEP30-D10, *PartModel Schema Types Dictionary* (Required to support the PartModel Schema and each of its sectional sub-schemas.)

JESD15, *Thermal Modelling Overview*

JESD15-1, *Compact Thermal Model Overview*

JESD51, *Methodology for the Thermal Measurement of Component Packages (Single Semiconductor Device),* Dec. 1995

JESD51-1, *Integrated Circuits Thermal Measurement Method – Electrical Test Method (Single Semiconductor Device)*

2.1 JEDEC (www.jedec.org) **(cont'd)**

JESD51-2, *Integrated Circuit Thermal Test Method Environmental Conditions – Natural Convection (Still Air)*

JESD51-6, *Integrated Circuit Thermal Test Method Environmental Conditions – Forced Convection (Moving Air)*

JESD51-12, *Guidelines for Reporting and Using Electronic Package Thermal Information*

JESD51-13, *Glossary of Thermal Measurement Terms and Definitions*

JESD51-53, *Terms, Definitions and Units Glossary for LED Thermal Testing*

JESD99C, *Terms, Definitions, and Letter Symbols for Microelectronic Devices*

2.2 IPC (www.ipc.org)

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

3 Requirements

The following terms and definitions are applicable to this XML Schema.

3.1 Terms and Definitions

All definitions and terms associated with the Thermal Data are defined in the JESD51 series of documents, as listed in the applicable documents section. The Thermal details of the part are defined in the *ThermalSection* of the XML Schema.

All common Terms and Definitions that are used by more than one sectional sub-schema, such as any of the Electrical, Package, Environmental, Assembly Process Classification, are defined in the “PartModel Schema Types Library”.

All other definitions and terms necessary to define the schema, are defined by this document.

PartModel: A PartModel is a data representation described in an XML file that conforms to the rules and structure of the PartModel XML Schema.

NOTE 1 Companies who use the PartModel XML Files and claim compliance to JEDEC, must ensure that their PartModel XML file conforms to the specific released version of the PartModel XML Schema released by JEDEC.

NOTE 2 Section 4 will define the outline of the structure of the Thermal XML Schema. Specific components of the XML Schema and their hierarchy are specifically controlled by the JC-15 Standards Committee who retain the expertise for these structures.

NOTE 3 The *ThermalSection* of the schema forms part of the PartModel XML Schema and is not intended to act as a standalone schema. In addition, there is a “PartModel Schema Types Library” XML Schema, which is a common set of xml structures shared across the PartModel XML Schema and all of its sub-section schemas.

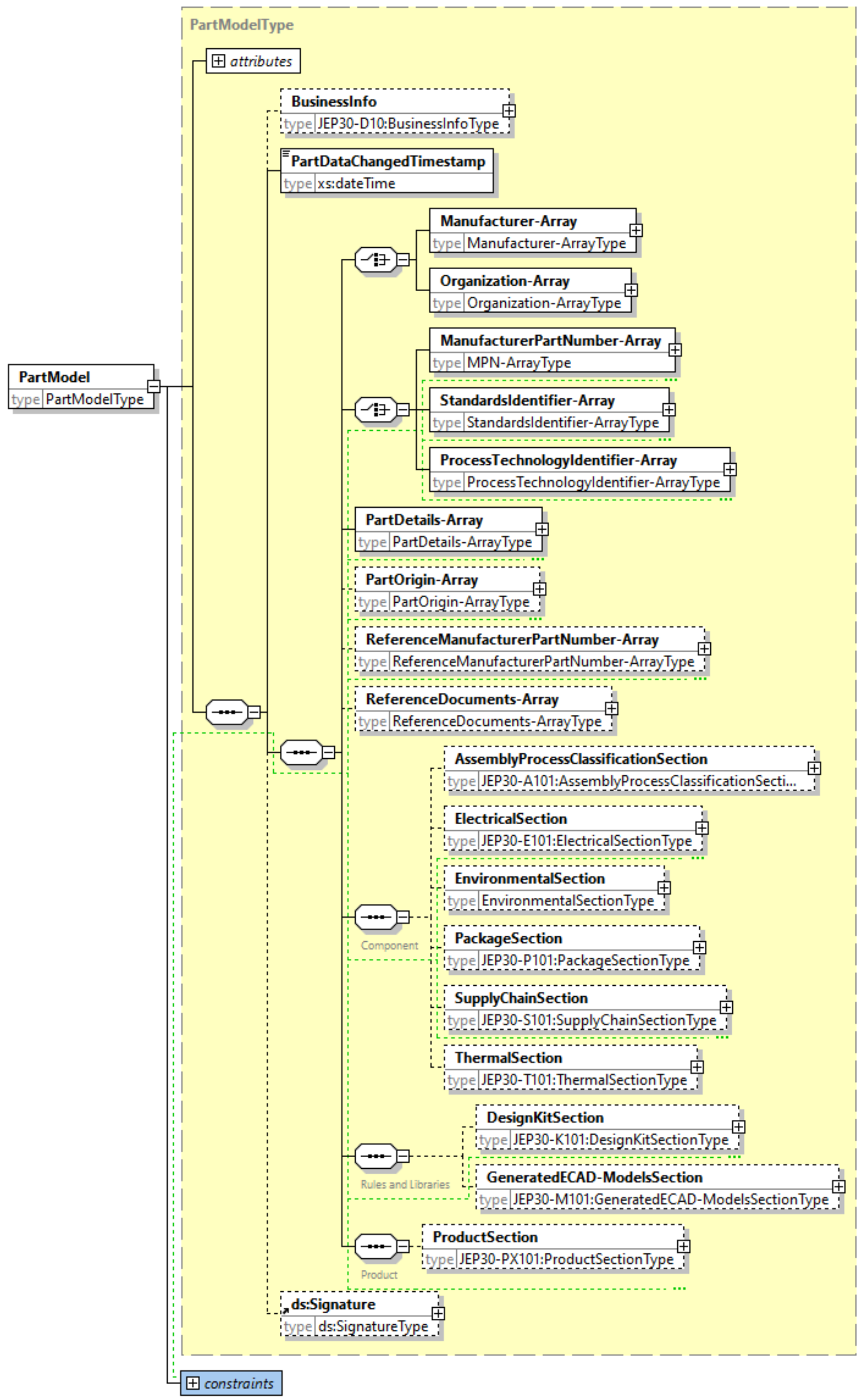
3.2 XML Schema Key Terms and Definitions

Reference the JEP30 publication for details of the "XML Schema Key Terms and Definitions".

4 PartModel Schema Definition

The following section describes the XML Schema structure.

4.1 PartModel - Thermal Section

diagram	
type	**PartModelType -> ThermalSection**

4.1 PartModel - Thermal Section (cont'd)

The *PartModelType* belongs to the "PartModel XML Schema". The *ThermalSection* belongs to the "PartModel Thermal XML Schema". The primary purpose of the PartModel Schema is to provide the structure for identifying unique parts (Manufacturer and MPN), and the structure to include the sub schemas which define the part details, as outline in the JEP30 - PartModel Guidelines for Electronic-Device Packages – XML Requirements.

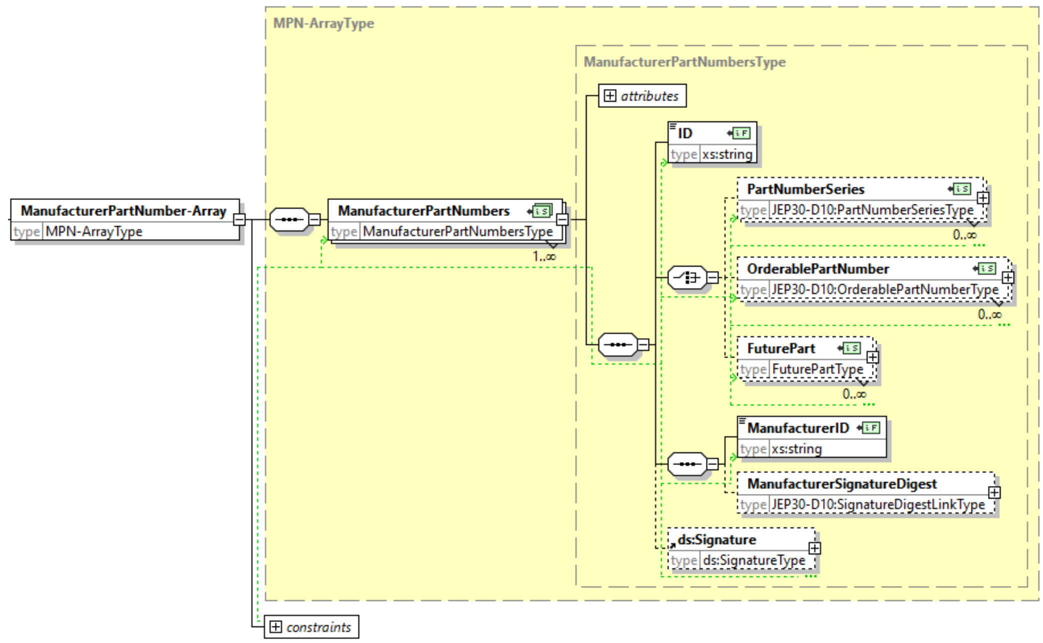
This document covers the *ThermalSection*, which is referenced from its parent's structure, the *PartModel*. The contents under the *ThermalSection* is tied to the Manufacturer's name and Manufacturer's part number.

The *ComplianceToPartModelSchemaVersion* indicates the version of the Schema to which the XML file is to be validated against. All new releases to this document or XML Schema is governed by the rules outlined in JEP30, and must be released in sync with the PartModel.

> *"Each time that a Sub-schema gets updated, then the PartModel version also gets updated in order to release that Sub-schema under the umbrella of the PartModel. This is because the PartModel must now reference the new version of Sub-schema, since all subschemas have their own version number. The parent schema includes them by referring to a precise version, so a version bump in the subschema requires a version bump in the parent only at the time of release of the Parent."*

The *PartModelContentRevision* indicates the revision of the data for the Part that is submitted in the XML file. This enables the Component Manufacturer to provide a new XML file for a Part each time they wish to upgrade a new set of data for a part, in any of the sub-sections such as this *ThermalSection*.

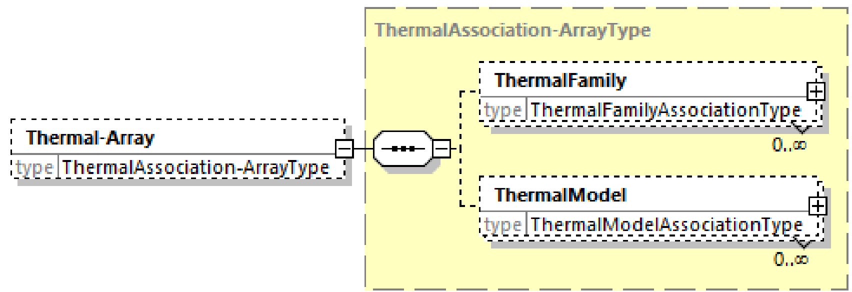
4.2 Manufacturer Part Number - Array

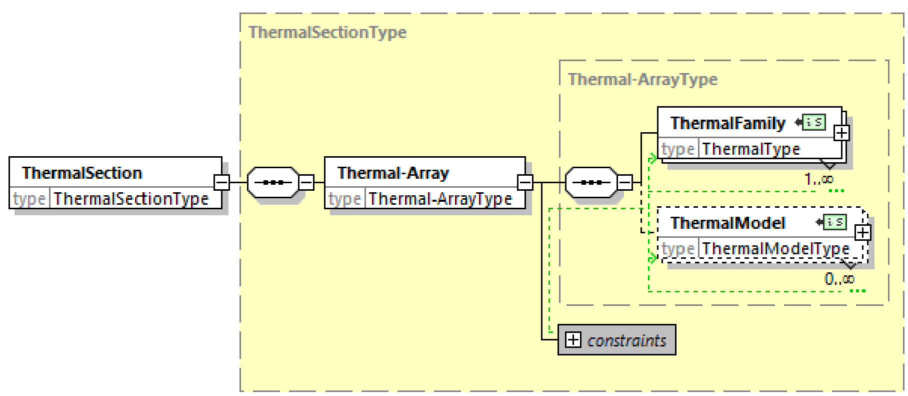
path	**PartModel/ManufacturerPartNumber-Array.**
diagram	
type	**MPN–ArrayType, ManufacturerPartNumbersType, JEP30-D10:PartNumberSeriesType, JEP30-D10:OrderablePartNumberType, FuturePartType, JEP30-D10:SignatureDigestLinkType, ds:SignatureType.**

The *ManufacturerPartNumber-Array/ManufacturerPartNumber* provides the definition of the part number, so that it can be connected to the technical specification details in the *ThermalSection* via the *PartDetails-Array* section.

4.3 Linking the Manufacturing Part Number to a specific Thermal Data set

The linking of the Parts to its technical data is done via the *PartDetails-Array* section as outline in the JEP30 - PartModel Guidelines for Electronic-Device Packages – XML Requirements. This consists of two sections called *PartsSelection-Array* and *Association-Array* which defines the relationship between identifying the specific set of parts and how they are associated with the supply chain content. Reference the JEP30 parent document for more details on this association.

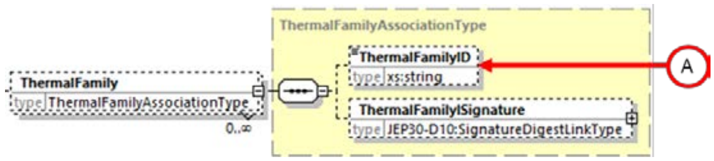
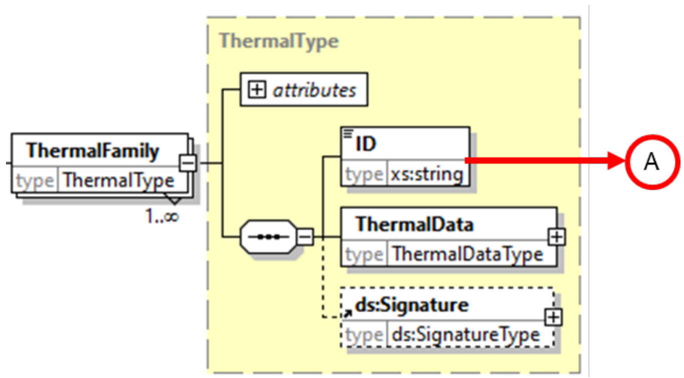
<table>
<tr><td>path</td><td>PartModel/PartDetails-Array/PartDetails/Association-Array/Association/Thermal-Array</td></tr>
<tr><td>diagram at the Association level</td><td>


</td></tr>
<tr><td>type</td><td>ThermalFamilyAssociation-ArrayType, ThermalFamilyAssociationType, ThermalModelAssociationType.</td></tr>
<tr><td>diagram at the Thermal Section level</td><td>


</td></tr>
<tr><td>type</td><td>ThermalSectionType, Thermal-ArrayType, ThermalType, ThermalModelType.</td></tr>
</table>

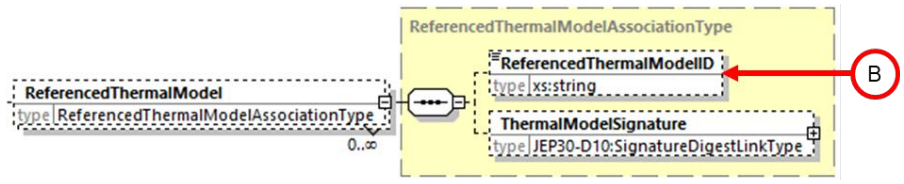
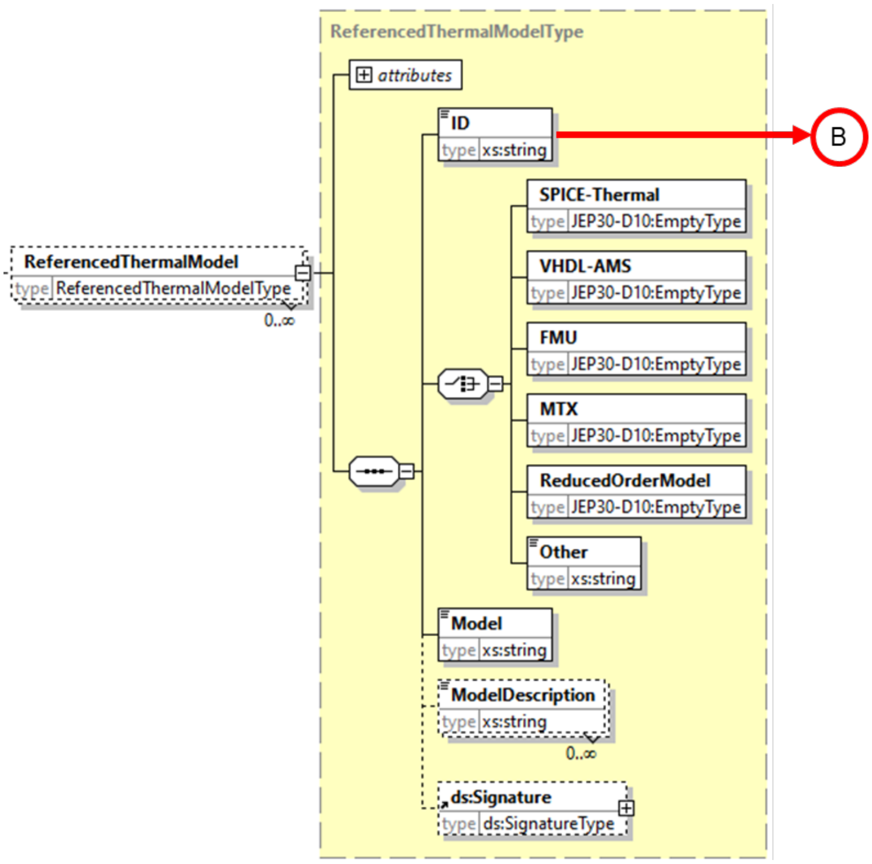
The thermal content is now sub-grouped into 2 major sections as shown in the diagram. This enables each section to be digitally signed independently of each other. The linkage between the 2 sections is shown below.

4.3.1 Linking the Manufacturing Part Number to Thermal Family Content

path	**PartModel/PartDetails-Array/PartDetails/Association-Array/Association/Thermal-Array/ThermalFamily**
diagram at the Electrical Parameters Association level	
type	**ThermalFamilyAssociationType, JEP30-D10:SignatureDigestLinkType.**
path	**PartModel/ThermalSection/Thermal-Array/ThermalFamily**
diagram at the Electrical Parameters-Array level	
type	**ThermalType, ThermalDataType, ds:SignatureType.**

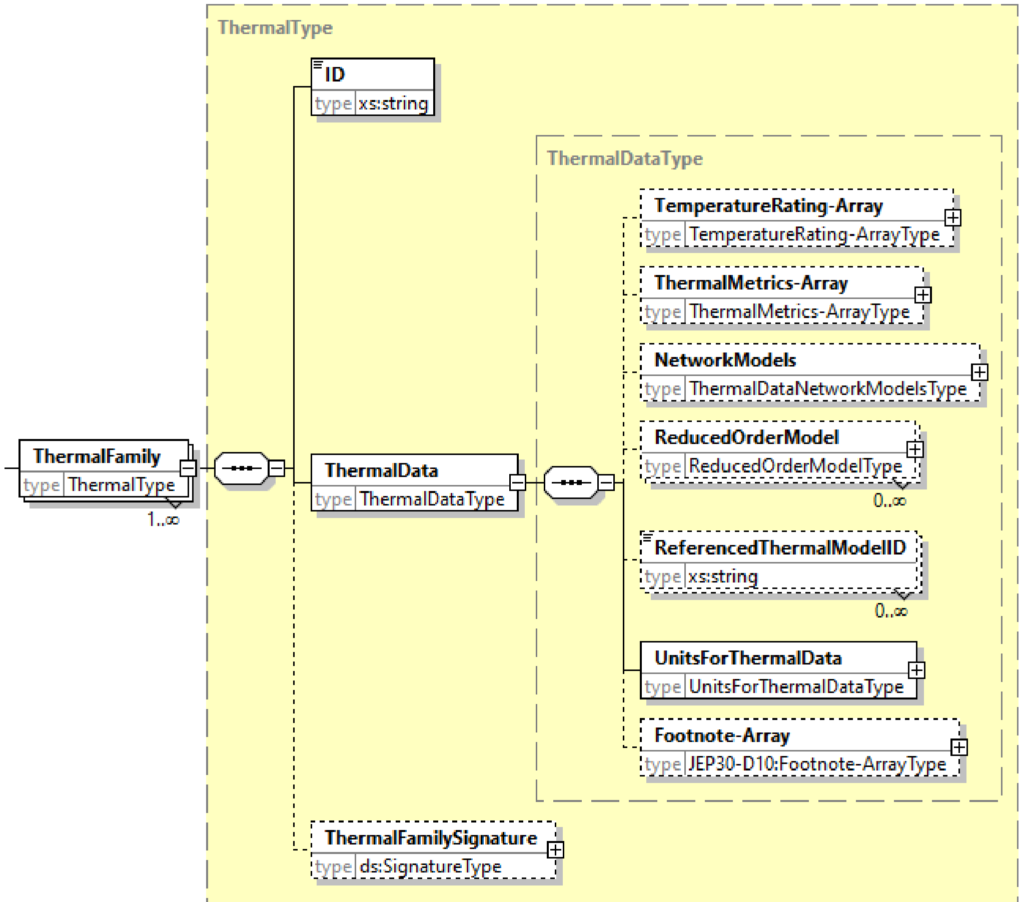
The *ThermalFamilyID* references the *ThermalFamily/ID* under the *ThermalSection/Thermal-Array*. This is enforced by the key named as *ThermalFamilyKey* that is assigned to the *ThermalFamily/ID* element, which is referenced by the *ThermalFamilyID* which has a Keyref that refers to the *JEP30-T101:ThermalFamilyKey*.

4.3.2 Linking the Manufacturing Part Number to Thermal Model Content

path	**PartModel/PartDetails-Array/PartDetails/Association-Array/Association/ThermalFamily-Array/ThermalModel**
diagram at the Electrical Parameters Association level	
type	**ThermalModelAssociationType, JEP30-D10:SignatureDigestLinkType.**
path	**PartModel/ThermalSection/Thermal-Array/ThermalModel**
diagram at the Electrical Parameters-Array level	
type	**ThermalModelType, JEP30-D10:EmptyType, ds:SignatureType.**

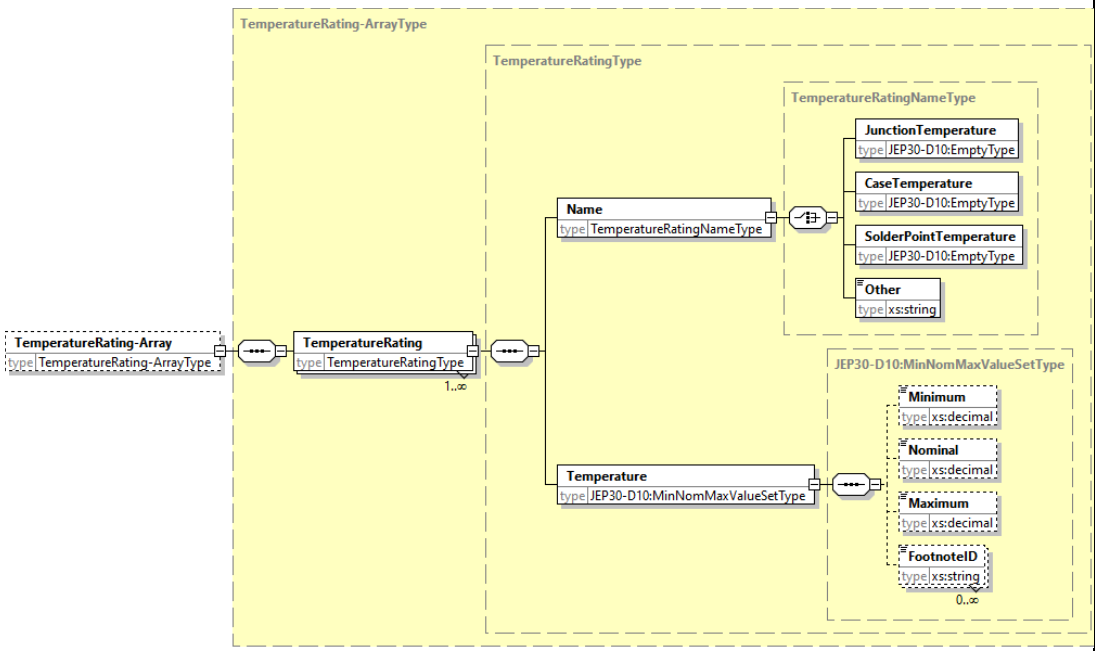
The *ThermalModelID* references the *ThermalModel/ID* under the *ThermalSection/Thermal-Array*. This is enforced by the key named as *ThermalModelKey* that is assigned to the *ThermalModel/ID* element, which is referenced by the *ThermalModelID* which has a Keyref that refers to the *JEP30-T101:ThermalModelKey*.

4.4 Thermal Family

path	**PartModel/ThermalSection/Thermal-Array/ThermalFamily/ThermalData.**
diagram	
type	**ThermalType, ThermalDataType, TemperatureRating-ArrayType, ThermalMetricsArrayType, ThermalDataNetworkModelsType, ReducedOrderModelType, UnitsforThermalDataType, JEP30-D10:Footnote-ArrayType**

ThermalData allows for the definition of temperature ratings (via the *TemperatureRating-Array*), thermal metrics (via the *ThermalMetrics-Array* and intended for part comparison purposes) and thermal models (via the *NetworkModels* and intended for simulation purposes). The *UnitsForThermalData* apply to all of the previous respective branches where applicable.

4.4.1 Temperature Rating - Array

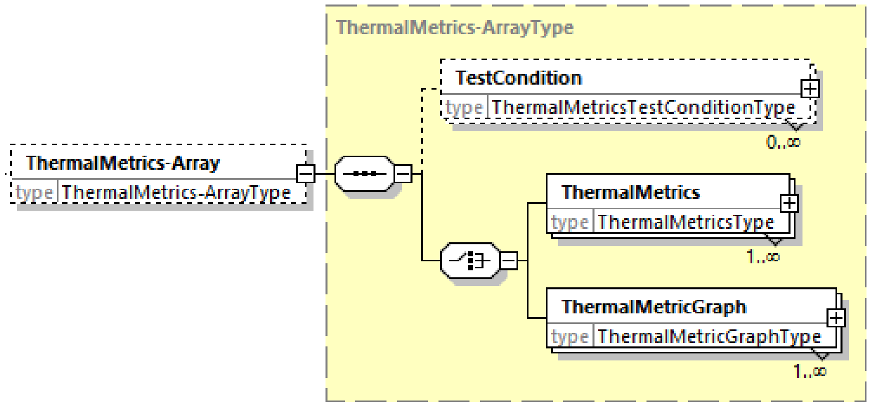
<table>
<tr><td>path</td><td>PartModel/ThermalSection/Thermal-Array/ThermalFamily/ThermalData/TemperatureRating-Array.</td></tr>
<tr><td>diagram</td><td>
</td></tr>
<tr><td>type</td><td>TemperatureRating-ArrayType, TemperatureRatingType, TemperatureRatingNameType, JEP30-D10:EmptyType, JEP30-D10:MinNomMaxValueSetType.</td></tr>
</table>

Minimum, nominal, or maximum temperature rating values can be defined for:

1. *JunctionTemperature*,
2. *CaseTemperature*,
3. *SolderPointTemperature*.

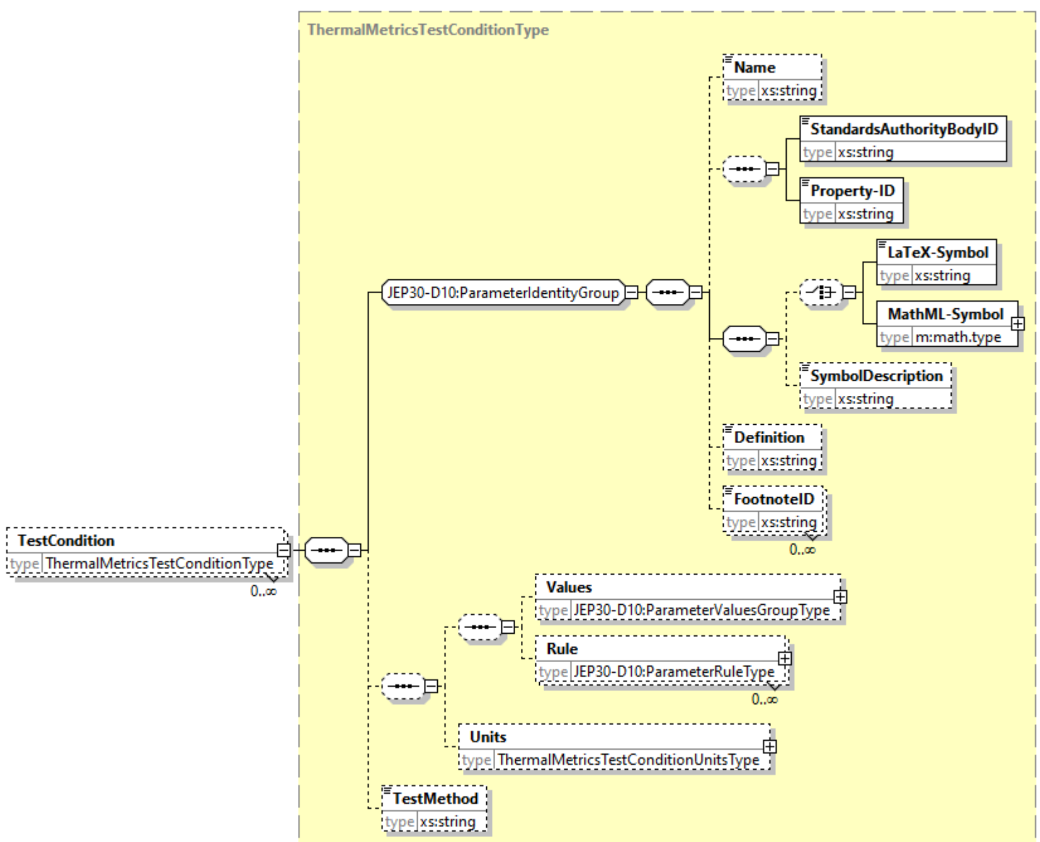
Or any other user defined string(s) indicating the location at which the temperature is rated at.

4.4.2 Thermal Metrics - Array

<table>
<tr><td>path</td><td>PartModel/ThermalSection/Thermal-Array/ThermalFamily/ThermalData/ThermalMetrics-Array.</td></tr>
<tr><td>diagram</td><td>


</td></tr>
<tr><td>type</td><td>ThermalMetrics-ArrayType, ThermalMetricsTestConditionType, ThermalMetricsType, ThermalMetricGraphType</td></tr>
</table>

4.4.2.1 Test Condition

<table>
<tr><td>path</td><td>PartModel/ThermalSection/Thermal-Array/ThermalFamily/ThermalData/ThermalMetrics-Array/TestCondition.</td></tr>
<tr><td>diagram 1 of 5</td><td>


</td></tr>
</table>

4.4.2.1 Test Condition (cont'd)

diagram 2 of 3

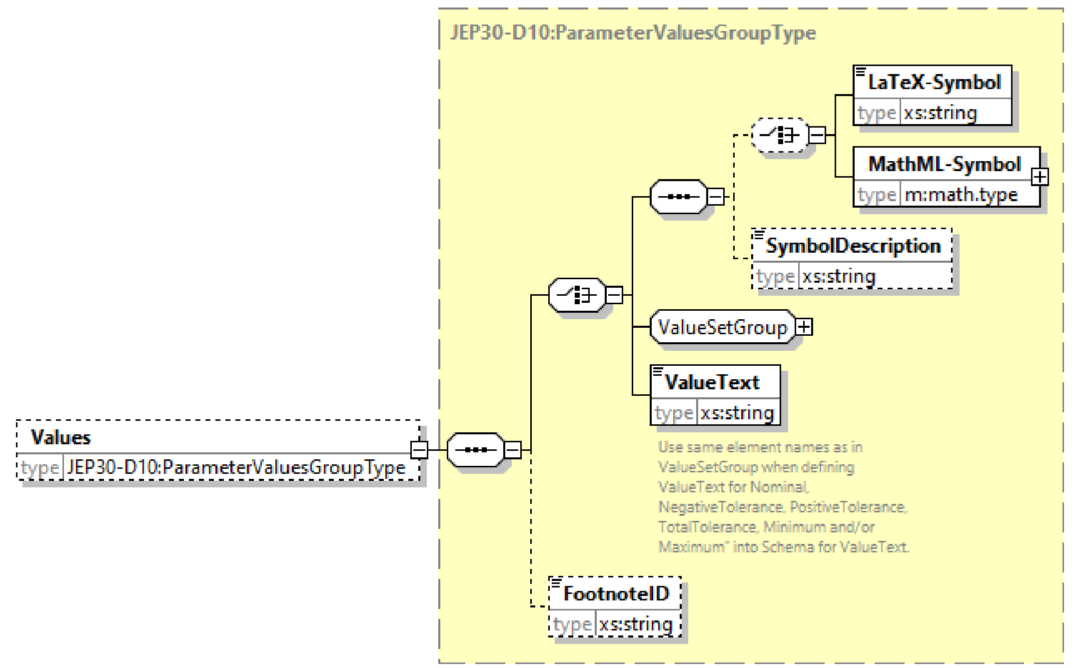
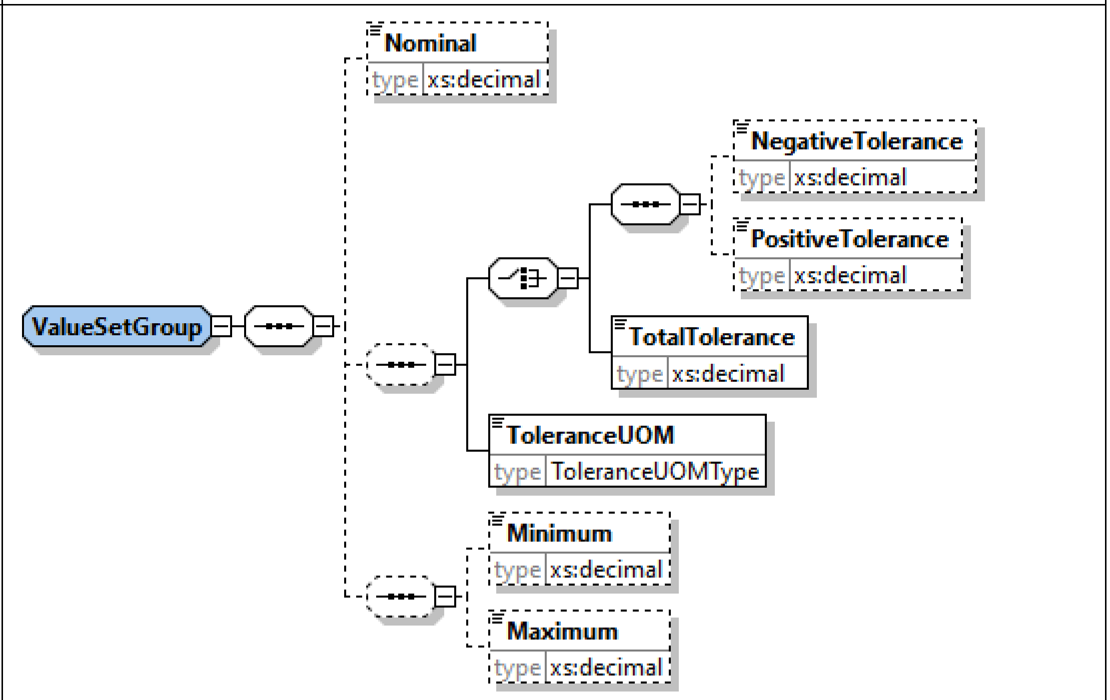
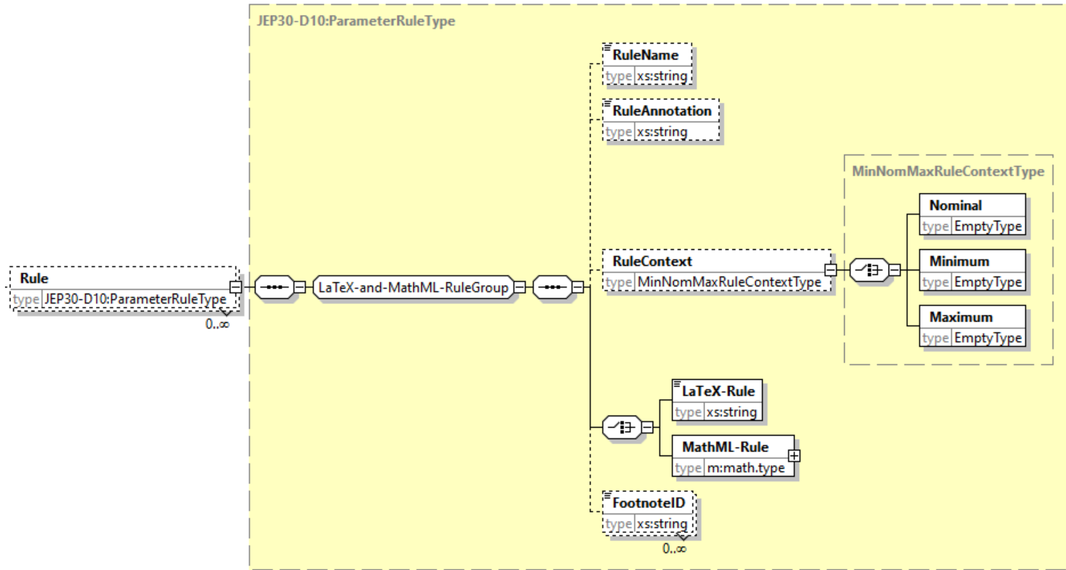
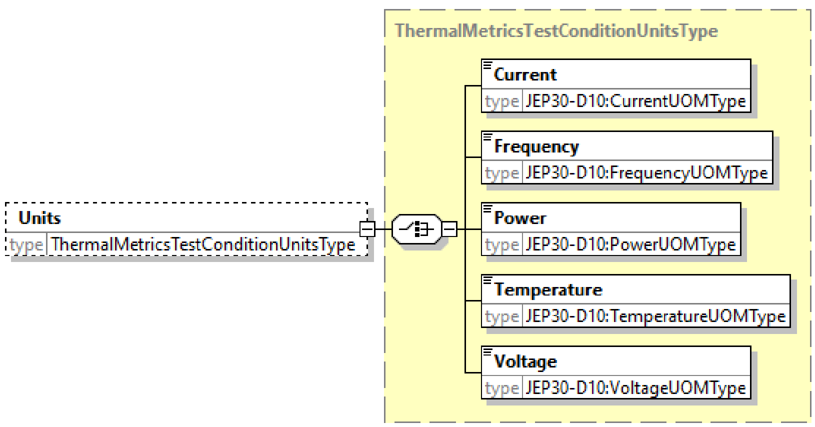


diagram 3 of 5



4.4.2.1 Test Condition (cont'd)

diagram 4 of 5	
diagram 5 of 5	
type	**ThermalMetricsTestConditionType, m:math.type, JEP30-D10:ParameterValuesGroupType, JEP30-D10:ParameterRuleType, ThermalMetricsTestConditionUnitsType, JEP30-D10:Current UOM Type, JEP30-D10:Frequency UOM Type, JEP30-D10:Power UOM Type, JEP30-D10:Temperature UOM Type, JEP30-D10:Voltage UOM Type.**
group	**JEP30-D10:ParameterIdentityGroup, ValueSetGroup.**

4.4.2.1 Test Condition (cont'd)

An example *TestCondition* (T_a = 25 °C) is shown below in its XML representation. The use of the _{} parentheses indicate that subscript formatting is applied to the string within those parentheses.

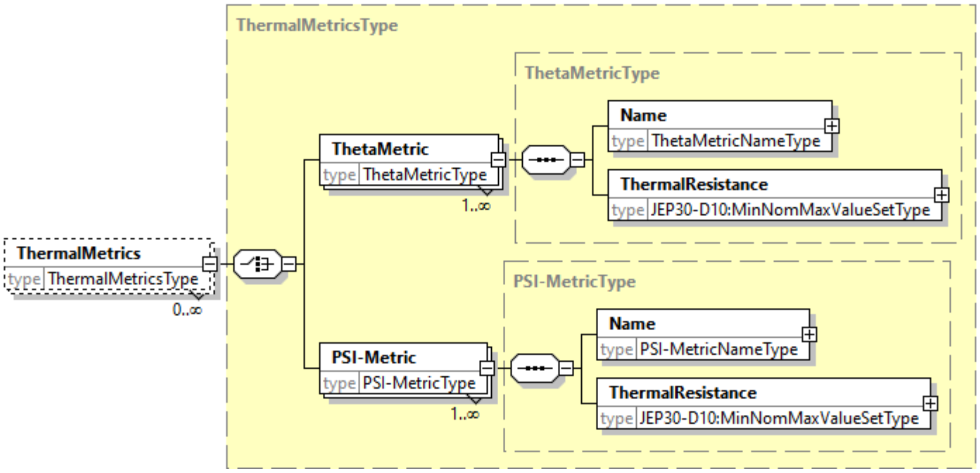
```xml
<TestCondition>
    <LaTeX-Symbol>T_{a}</LaTeX-Symbol>
    <SymbolDescription>Ambient Temperature</SymbolDescription>
    <Values>
        <Nominal>25</Nominal>
    </Values>
    <Units>
        <Temperature>°C</Temperature>
    </Units>
</TestCondition>
```

The enumerated list of values for each of the UOM's specified above are identified in Table 1 – Test Condition Units UOM Enumerated Lists

Table 1 – Test Condition Units UOM Enumerated Lists

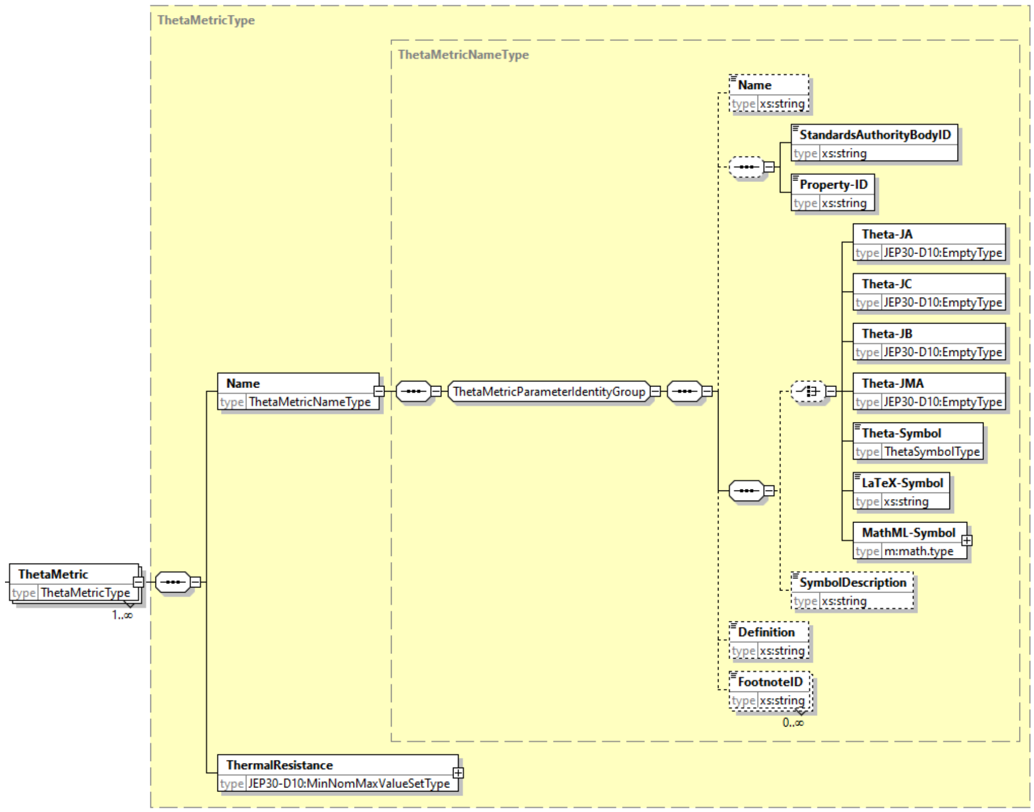
Current	Frequency	Power	Temperature	Voltage
pA	mHz	pW	K	µV
nA	Hz	nW	°C	mV
µA	KHz	µW	°F	V
mA	MHz	mW		kV
A	GHz	W		
kA	THz	kW		
		MW		

4.4.2.2 Thermal Metrics

path	**PartModel/ThermalSection/Thermal-Array/ThermalFamily/ThermalData/ThermalMetrics-Array/ThermalMetrics.**
diagram	
type	**ThermalMetricsType, ThetaMetricType, ThetaMetricNameType, JEP30-D10:MinNomMaxValueSetType, PSI-MetricType, PSI-MetricNameType.**

Two types of thermal metrics are supported; Theta (Θ) metrics and Psi (Ψ) metrics, as defined in JESD51-2, JESD51-6 and JESD51-12.

4.4.2.2.1 Theta Metric

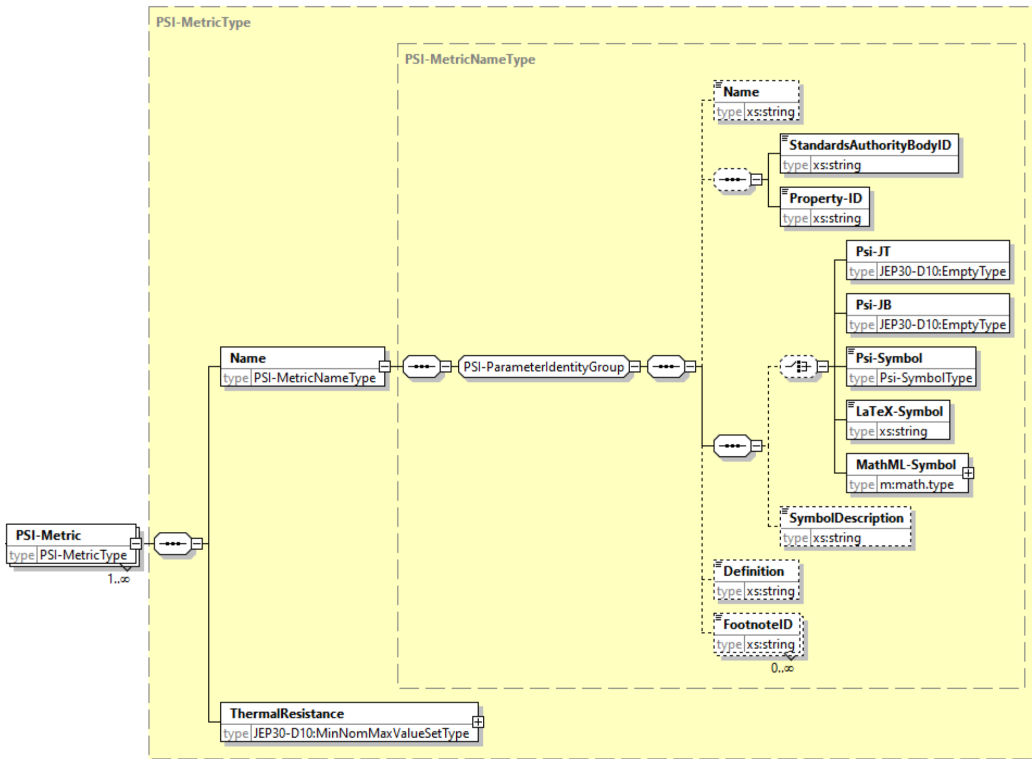
<table>
<tr><td>path</td><td>PartModel/ThermalSection/Thermal-Array/ThermalFamily/ThermalData/ThermalMetrics-Array/ThermalMetrics/ThetaMetric.</td></tr>
<tr><td>diagram</td><td>
</td></tr>
<tr><td>type</td><td>ThetaMetricType, ThetaMetricNameType, JEP30-D10:EmptyType, JEP30-D10:MinNomMaxValueSetType.</td></tr>
<tr><td>group</td><td>ThetaMetricParameterIdentityGroup</td></tr>
</table>

Minimum, nominal or maximum values of thermal resistance can be defined for each *ThetaMetric*:-

1. *Theta-JA*,
2. *Theta-JC*,
3. *Theta-JB*,
4. *Theta-JMA*.

Or any other user defined string(s) indicating the name of the Theta metric. The Theta-Symbol has the enumerated values of θ_{JA}, θ_{JC}, θ_{JB} or θ_{JMA}, which are the short name representations of their ascii definitions above.

4.4.2.2.2 PSI - Metric

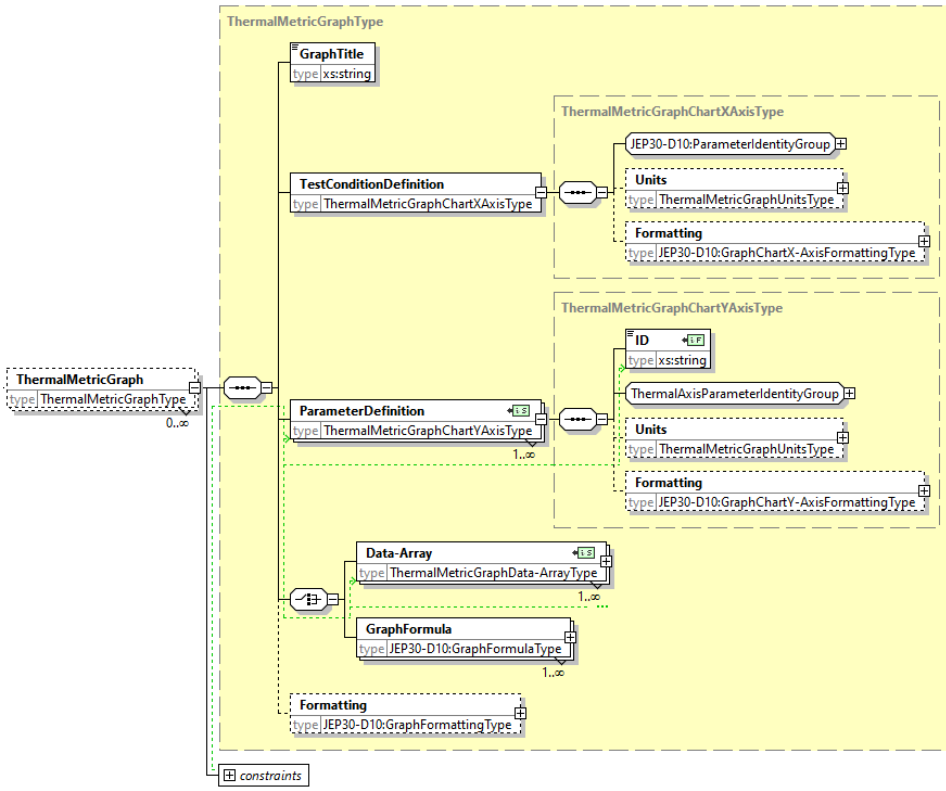
path	**PartModel/ThermalSection/Thermal-Array/ThermalFamily/ThermalData/ThermalMetrics-Array/ThermalMetrics/PSI-Metric.**
diagram	
type	**PSI-MetricType, PSI-MetricNameType, JEP30-D10:EmptyType, JEP30-D10:MinNomMaxValueSetType.**
group	**Psi-ParameterIdentityGroup**

Minimum, nominal or maximum values of thermal resistance can be defined for each *PSI-Metric*:-

1. *Psi-JT*,
2. *Psi-JB*.

Or any other user defined string(s) indicating the name of the Psi metric. The Psi-Symbol has the enumerated values of Ψ_{JB} or Ψ_{JT} which are the short name representations of their ascii definitions above.

4.4.2.3 Thermal Metric Graph

<table>
<tr><td>path</td><td>PartModel/ThermalSection/Thermal-Array/ThermalFamily/ThermalData/ThermalMetrics-Array/ThermalMetricGraph.</td></tr>
<tr><td>diagram</td><td>
</td></tr>
<tr><td>type</td><td>ThermalMetricGraphType, ThermalMetricGraphChartXAxisType, ThermalMetricGraphChartYAxisType, ThermalMetricGraphData-ArrayType, JEP30-D10:GraphFormulaType, JEP30-D10:GraphFormattingType, ThermalMetricGraphUnitsType, JEP30-D10:GraphChartXAxisFormattingType, JEP30-D10:GraphChartYAxisFormattingType</td></tr>
<tr><td>group</td><td>JEP30-D10:ParameterIdentityGroup, ThermalAxisParameterIdentityGroup</td></tr>
</table>

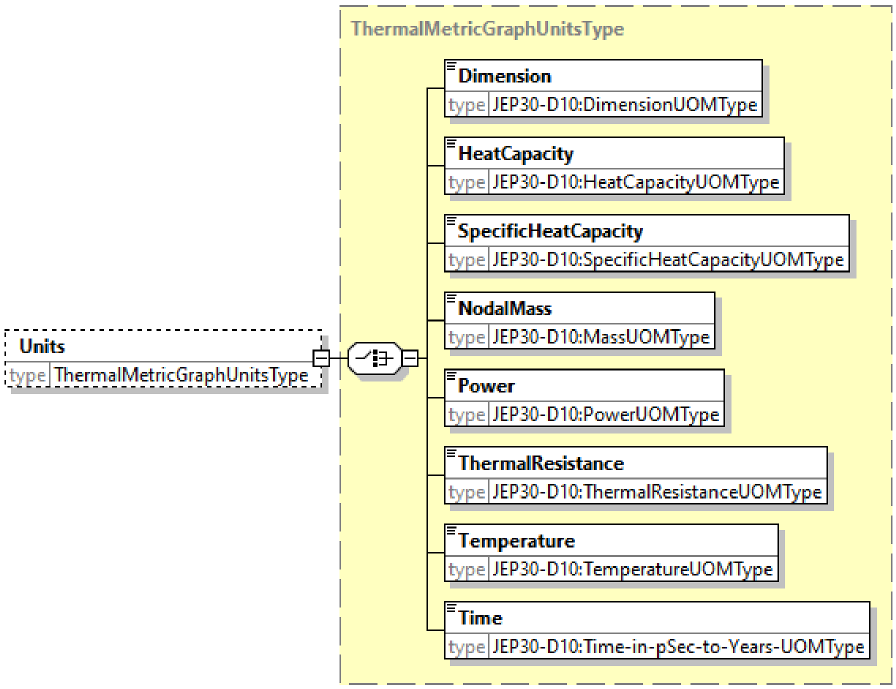
A *ThermalMetricGraph* has 2 axis that are defined by the *TestConditionDefinition* (The X-axis definition), and the *ParameterDefinition* (The Y-axis definition). Each axis is labelled by the *AxisTitle*. When possible, the *Symbol* which represents the *AxisTitle* should be added to the PartModel file and should represent a standards-based symbol as defined in the appropriate Terms and Definitions standards. If appropriate, a more detailed *Description* can be used to describe the definition of the *AxisTitle*. Each axis will also have a pre-defined set of *Units* but can be optionally excluded for those axis' which are unitless.

Note that the *ParameterDefinition* is unbounded whereas the *TestConditionDefinition* is bounded to a single instance. This is to cater for those graphs in which there are 2 or more y-axis, each with their own definition.

The graph can either be captured under the *Data-Array* or represented via a *GraphFormula* (A string representing the equation of the *ParameterDefinition* relationship to the Test *TestConditionDefinition*).

4.4.2.3.1 Thermal Metrics Graph Units

<table>
<tr><td>path</td><td>PartModel/ThermalSection/Thermal-Array/ThermalFamily/ThermalData/ThermalMetrics-Array/ThermalMetricGraph/TestConditionDefinition/Units.

PartModel/ThermalSection/Thermal-Array/ThermalFamily/ThermalData/ThermalMetrics-Array/ThermalMetricGraph/ParameterDefinition/Units.</td></tr>
<tr><td>diagram</td><td>
</td></tr>
<tr><td>type</td><td>JEP30-D10:DimensionUOMType, JEP30-D10:HeatCapacityUOMType,
JEP30-D10:SpecificHeatCapacityUOMType, JEP30-D10:MassUOMType, JEP30-D10:PowerUOMType,
JEP30-D10:ThermalResistanceUOMType, JEP30-D10:TemperatureUOMType,
JEP30-D10:Time-in-pSec-to-Years-UOMType</td></tr>
</table>

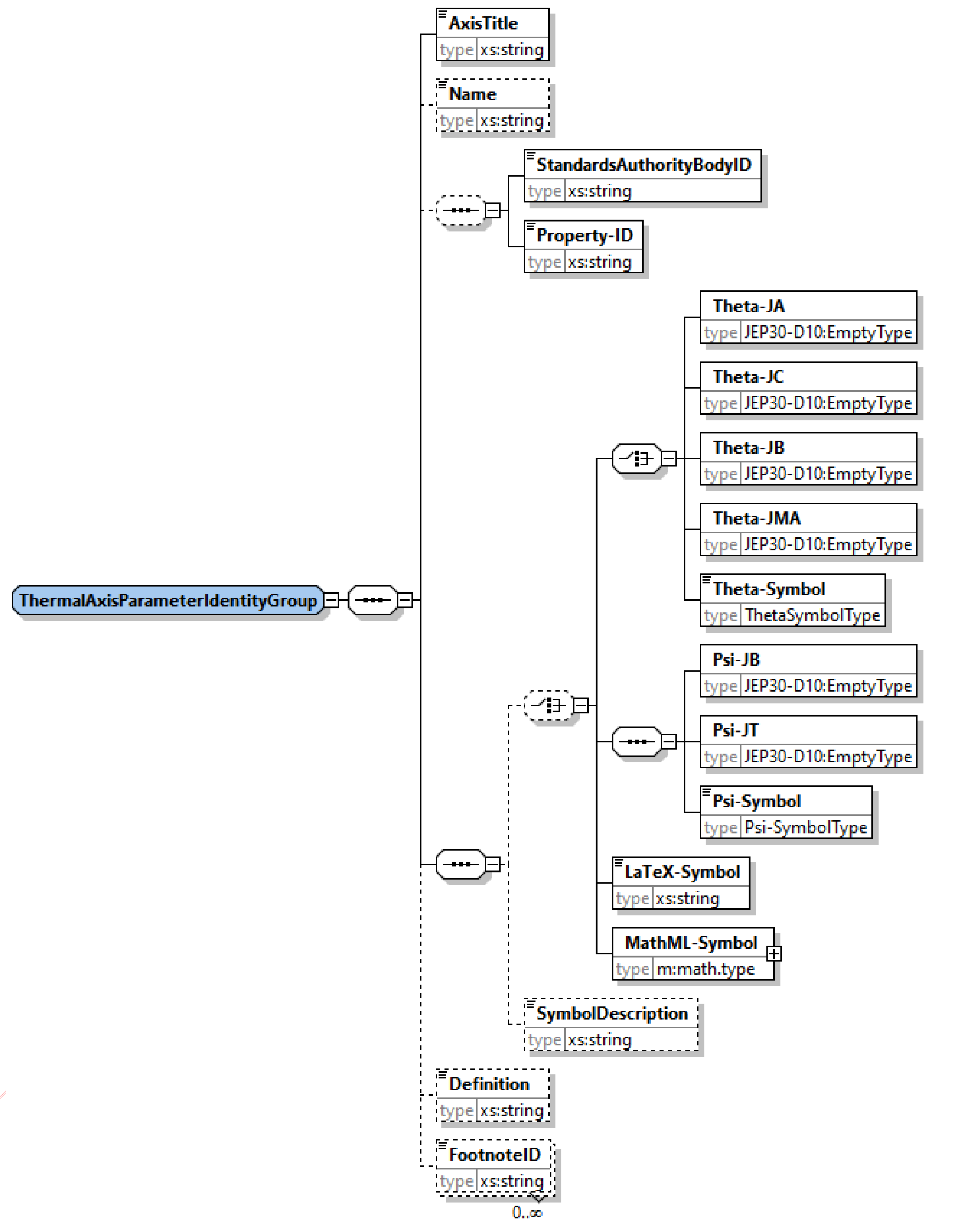
The enumerated list of values for each of the UOM's specified above are identified in Table 1 - UOM Enumerated Lists.

4.4.2.3.1 Thermal Metric Graph Units (cont'd)

Table 2 – Thermal Metrics Graph Units UOM Enumerated Lists

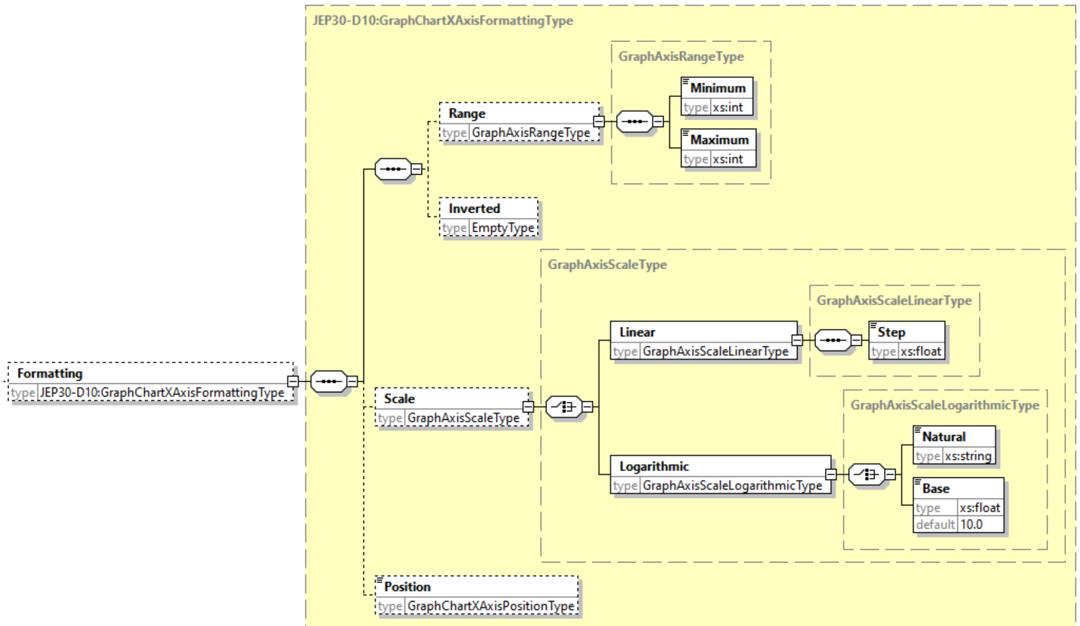
Dimension UOM	Heat Capacity	Specific Heat Capacity	Nodal Mass UOM	Power	Thermal Resistance UOM	Temperature UOM	Time
nm	mJ/K	J/(g·K)	ug	pW	K/mW	See Table 1	ps
µm	J/K	J/(kg·K)	mg	nW	K/W		ns
mm	mJ/°C	J/(g·°C)	g	µW	K/kW		µs
m	J/°C	J/(kg·°C)	kg	mW	°C/mW		ms
in		calIT/(g·K)	oz	W	°C/W		s
mil		kcalIT/(g·K)	lb	kW	°C/kW		min
µin		calIT/(g·°C)		MW			h
		kcalIT/(g·°C)					d
		calth/(g·K)					wk
		kcalth/(g·K)					mo
		calth/(g·°C)					Y
		kcalth/(g·°C)					
		BtuIT/(lb·°F)					
		Btuth/(lb·°F)					

4.4.2.3.2 Thermal Axis Parameter Identity Group

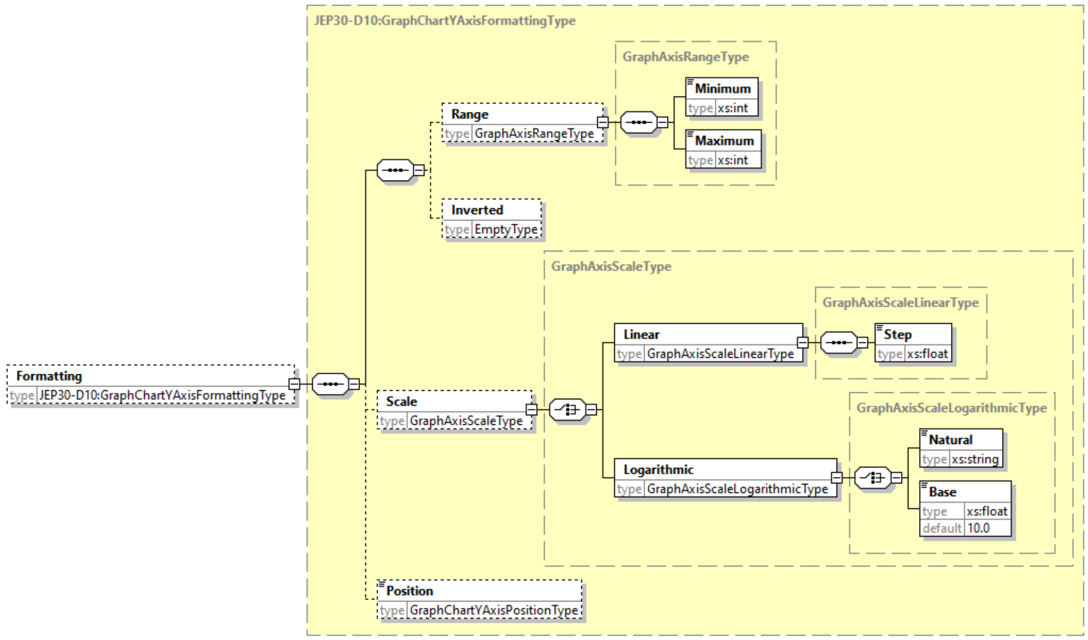
path	PartModel/ThermalSection/Thermal-Array/ThermalFamily/ThermalData/ThermalMetrics-Array/ThermalMetricGraph/ParameterDefinition
diagram	
type	JEP30-D10:DimensionUOMType, JEP30-D10:HeatCapacityUOMType, JEP30-D10:SpecificHeatCapacityUOMType, JEP30-D10:MassUOMType, JEP30-D10:PowerUOMType, JEP30-D10:ThermalResistanceUOMType, JEP30-D10:TemperatureUOMType, JEP30-D10:Time-in-pSec-to-Years-UOMType

4.4.2.3.3 Formatting

The Formatting is an optional set of data that enables the user to re-create the graph for visualization purposes. Formatting applies to the following

<table>
<tr><td>path</td><td>PartModel/ThermalSection/Thermal-Array/ThermalFamily/ThermalData/ThermalMetrics-Array/ThermalMetricGraph/TestConditionDefinition/Formatting.</td></tr>
<tr><td>diagram</td><td>
</td></tr>
<tr><td>type</td><td>JEP30-D10:GraphChartXAxisFormattingType, GraphAxisRangeType, EmptyType, GraphAxisScaleType, GraphAxisScaleLinearType, GraphAxisScaleLogarithmicType, GraphChartXAxisPositionType.</td></tr>
</table>

4.4.2.3.3 Formatting (cont'd)

path	**PartModel/ThermalSection/Thermal-Array/ThermalFamily/ThermalData/ThermalMetrics-Array/ThermalMetricGraph/ParameterDefinition/Formatting.**
diagram	
type	**JEP30-D10:GraphChartYAxisFormattingType, GraphAxisRangeType, EmptyType, GraphAxisScaleType, GraphAxisScaleLinearType, GraphAxisScaleLogarithmicType, GraphChartYAxisPositionType.**

The axis range which is usually defined from minimum to maximum can be inverted to show a graph going from maximum to minimum. The scale can be defined in either a linear step amount, a natural logarithm, or a logarithm of the specified base. The *Base* log is set to a default of *Base 10* but can be defined to any base number.

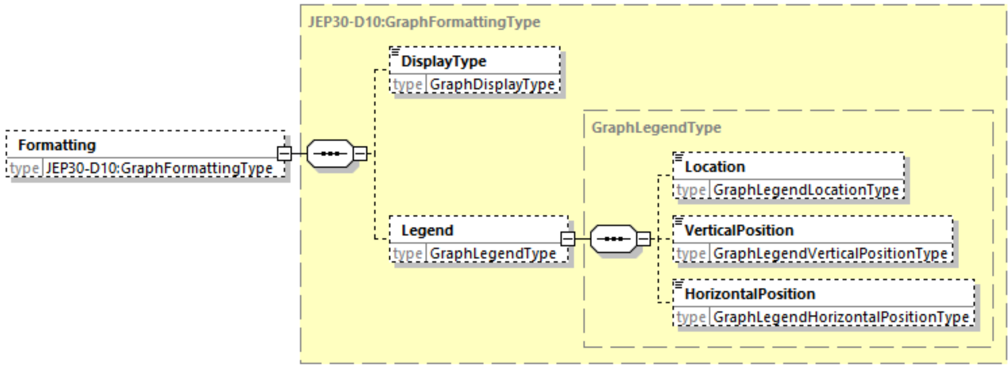
The *Position* enumerated list for the *GraphChartXAxisPositionType* is

- Top
- Bottom

And for the *GraphChartYAxisPositionType*, the enumerated values are

- Left
- Right

4.4.2.3.3 Formatting (cont'd)

path	**PartModel/ThermalSection/Thermal-Array/ThermalFamily/ThermalData/ThermalMetrics-Array/ThermalMetricGraph/Formatting.**
diagram	
type	**JEP30-D10:GraphFormattingType, GraphDisplayType, GraphLegendType, GraphLegendLocationType, GraphLegendVerticalPositionType, GraphLegendHorizontalPositionType.**

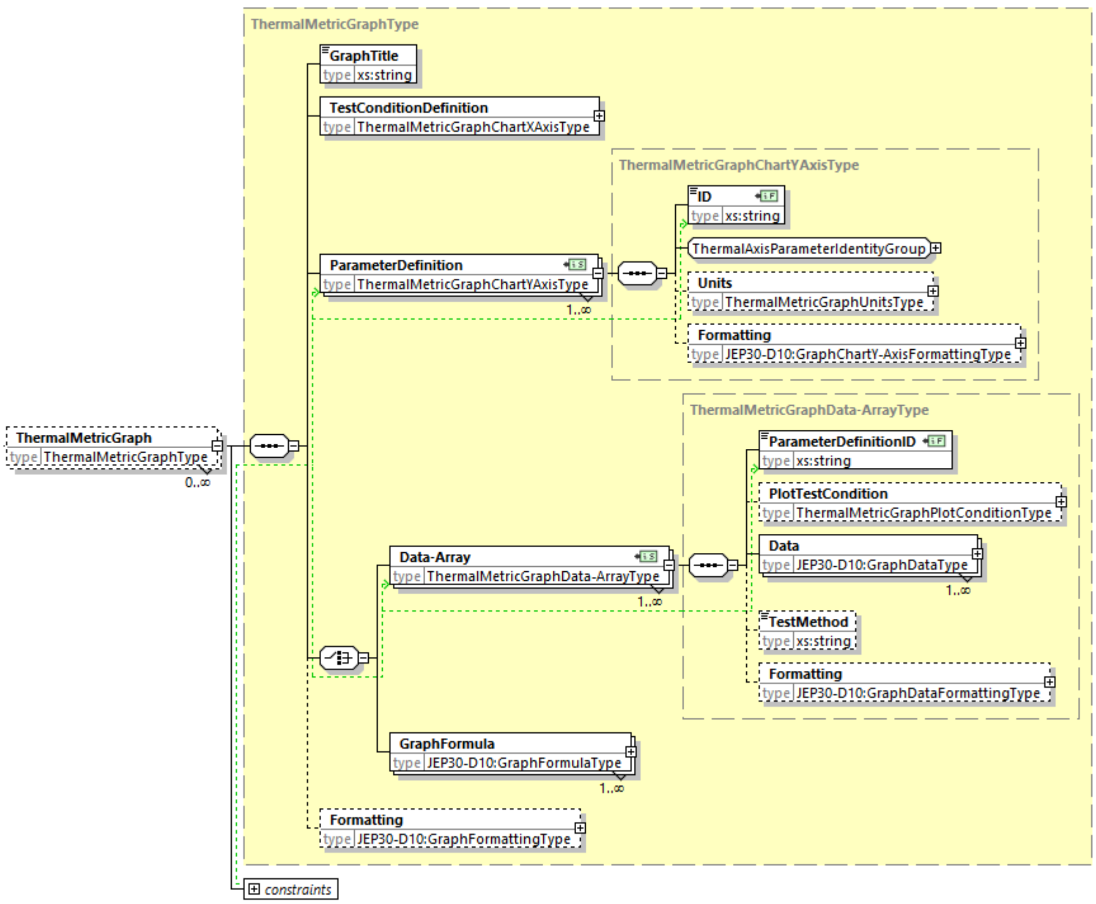
The body of the graph can be formatted under the *GraphFormattingType*. The *DisplayType* enumerated list is

- Line
- Bar

The graph Legend can also be positioned around the graph in any of the following locations:

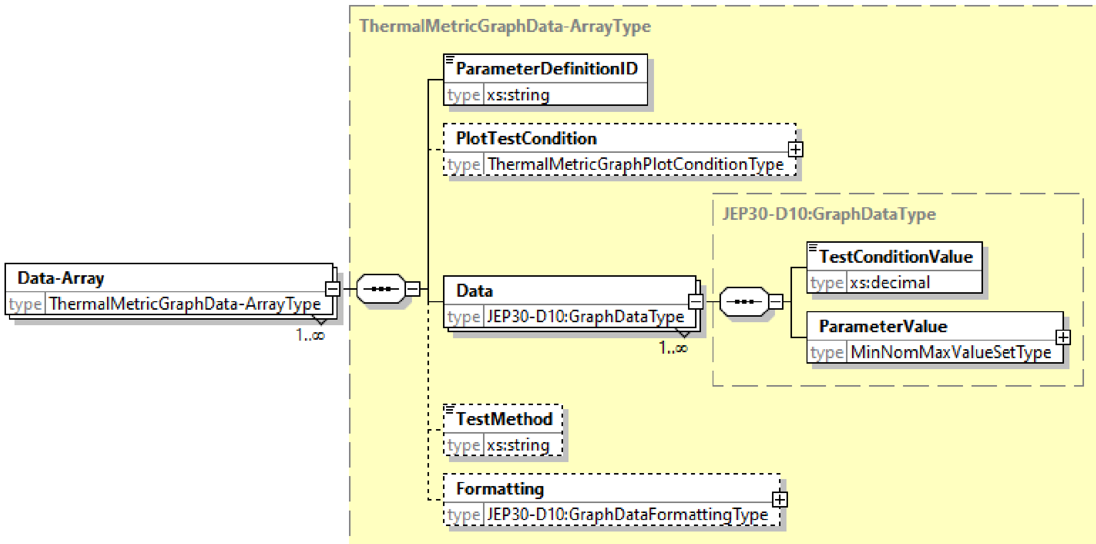
- Location
  - Inside Graph,
  - Outside Graph,
- Vertical Position
  - Top,
  - Center,
  - Bottom,
- Horizontal Position
  - Left,
  - Center,
  - Right.

4.4.2.3.4 Linking the Data-Array to the Appropriate Parameter Definition

path	**PartModel/ThermalSection/Thermal-Array/ThermalFamily/ThermalData/ThermalMetrics-Array/ThermalMetricGraph.**
diagram	
type	**ThermalMetricsGraphType, ThermalMetricGraphChartXAxisType, ThermalMetricGraphChartYAxisType, ThermalMetricGraphUnitsType, JEP30-D10:GraphChartYAxisFormattingType, ThermalMetricGraphData-ArrayType, ThermalMetricGraphPlotConditionType, JEP30-D10:GraphDataType, JEP30-D10:GraphDataFormattingType, JEP30-D10:GraphFormattingType.**
group	**ThermalAxisParameterIdentityGroup**

When populating the *Data-Array* for a given graph, the set of data is referenced to the specific *ParameterDefinition* via the *ParameterDefinitionID. The process is replicated for each ParameterDefinition* if there are 2 or more vertical *ParameterDefinition* axis defined. Each set of data captured under the *Data-Array* is now tied to the appropriate *ParameterDefinition* axis.

4.4.2.3.5 Data - Array

path	**PartModel/ThermalSection/Thermal-Array/ThermalFamily/ThermalData/ThermalMetrics-Array/ThermalMetricGraph/Data-Array.**
diagram	
type	**ThermalMetricGraphData-ArrayType, ThermalMetricGraphPlotConditionType, JEP30-D10:GraphDataType, MinNomMaxValueSetType, JEP30-D10:GraphDataFormattingType**

Each data set consisting of the *TestConditionValue* and the *ParameterValue,* represents one point of a piecewise linear graph. A Z_{th} thermal impedance response example of the *ThermalMetricGraph* is shown and represented in the xml data below.

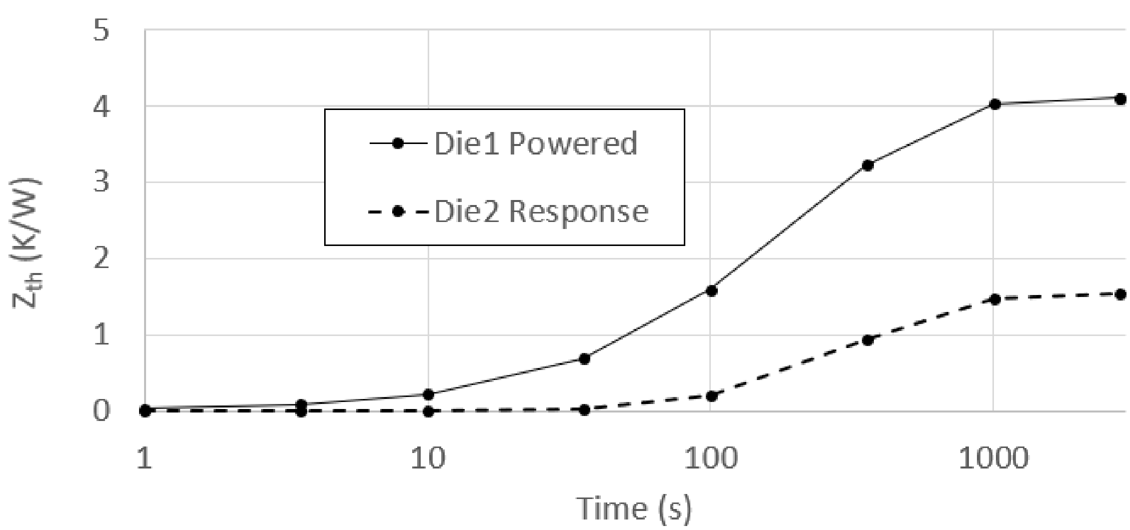
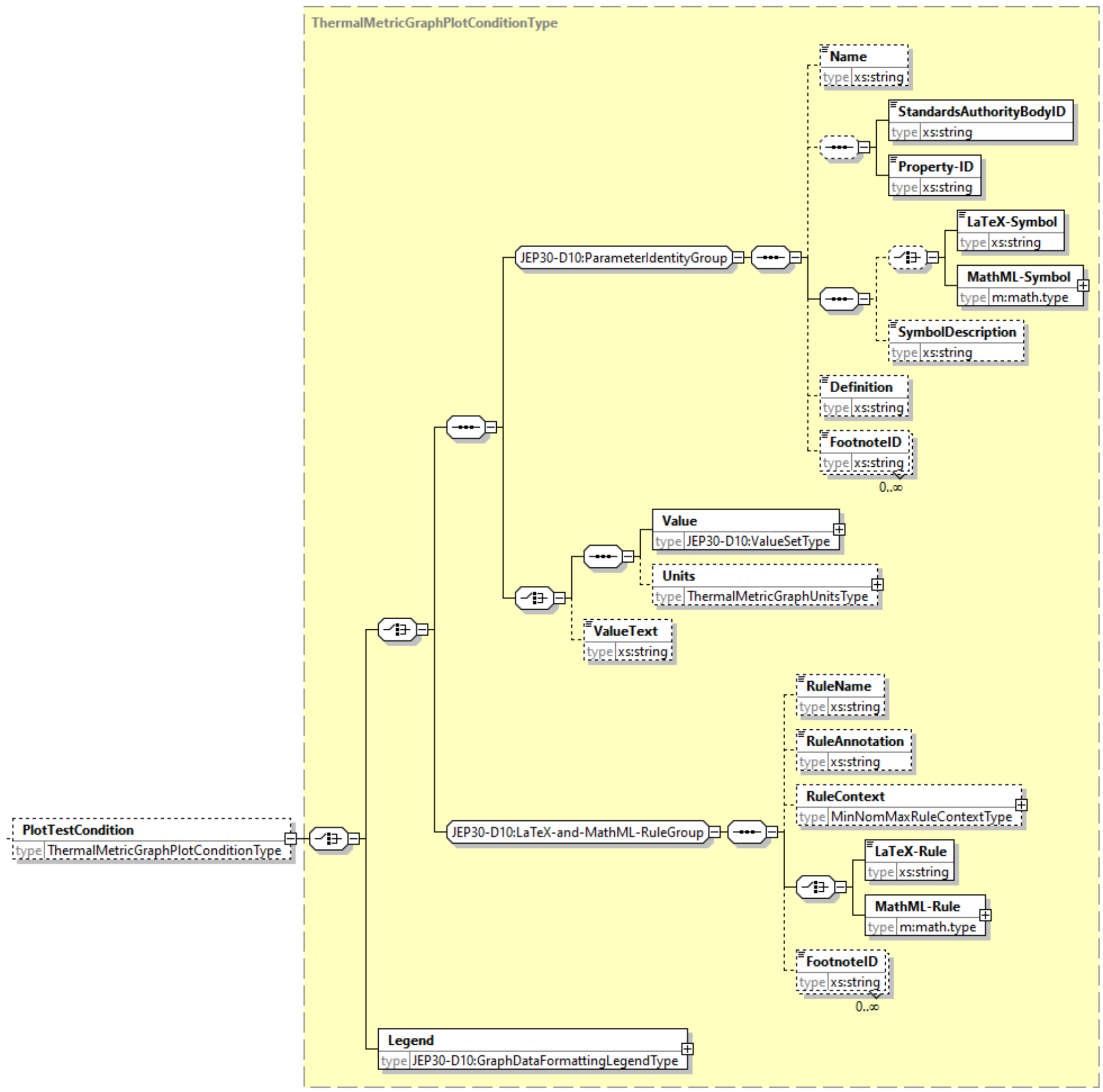


Figure 1 – Zth Thermal Impedance Curves

The *TestCondition* represents different plots on the same graph, as shown in Figure 1 - Zth Thermal Impedance Curves . The Z_{th} curves representing ‘Die1 Powered’ and ‘Die2 Response’ are captured with their own *TestCondition* as shown in the below XML file (first 2 points only shown for brevity).

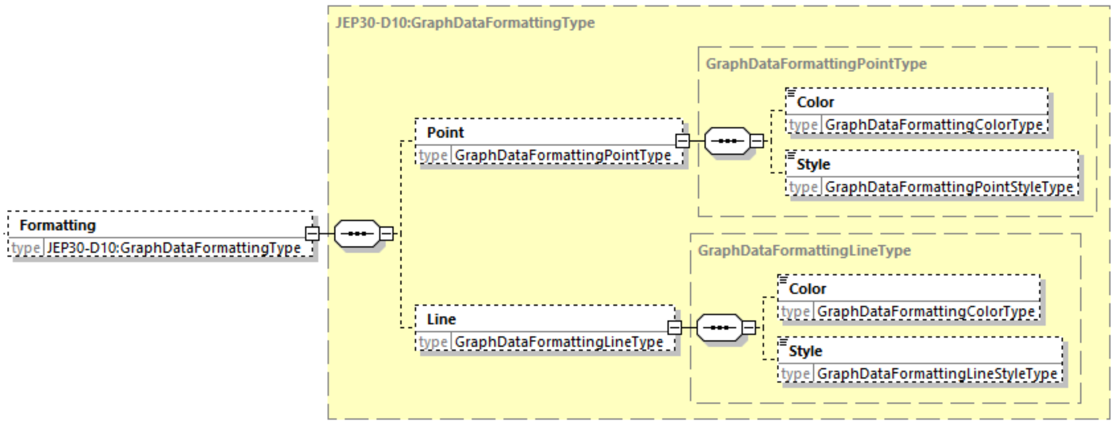
4.4.2.3.5 Data-Array (cont'd)

<table>
<tr><td>path</td><td>PartModel/ThermalSection/Thermal-Array/ThermalFamily/ThermalData/ThermalMetrics-Array/ThermalMetricGraph/Data-Array/PlotTestCondition</td></tr>
<tr><td>diagram</td><td>
</td></tr>
<tr><td>type</td><td>ThermalMetricGraphPlotConditionType, JEP30-D10:ValueSetType, ThermalMetricGraphUnitsType, MinNomMaxRuleContextType, JEP30-D10:GraphDataFormattingLegendType.</td></tr>
<tr><td>group</td><td>JEP30-D10:ParameterIdentityGroup, JEP30-D10:LaTeX-and-MathML-RuleGroup</td></tr>
</table>

Depending upon the type of test condition, its value may be a string or label that describes the *TestCondition*, in which case the value is populated under the *Legend* branch.

When possible, the *ParameterIdentityGroup* which represents the *TestCondition* should be added to the PartModel file and should represent a standards-based symbol definition as defined in the appropriate Terms and Definitions standards. If appropriate, a more detailed *SymbolDescription* can be defined to describe the definition of the *TestCondition*. The *ParameterIdentityGroup* can have a pre-defined set of *Units* but can be optionally excluded for those *TestCondition* which are unitless.

4.4.2.3.5 Data-Array (cont'd)

path	**PartModel/ThermalSection/Thermal-Array/ThermalFamily/ThermalData/ThermalMetrics-Array/ThermalMetricGraph/Data-Array/Formatting.**
diagram	
type	**JEP30-D10:GraphDataFormattingType, GraphDataFormattingPointType. GraphDataFormattingLineType, GraphDataFormattingColorType, GraphDataFormattingPointStyleType, GraphDataFormattingLineStyleType.**

The data points can also be formatted. Individual data points can have the following styles

- Point Styles are
  - Circle,
  - Square,
  - Triangle,
  - None.
- Line Style are
  - Solid,
  - Dash,
  - Dot,
  - Dash-dot,
  - Dash-dash-dot,
  - None.
- Colors are
  - Red,
  - Green,
  - Blue,
  - Orange,
  - Brown,
  - Pink,
  - Purple,
  - Yellow,
  - Black.

The xml fragment shown below represents the data plotted in Figure 1 – Zth Thermal Impedance Curves.

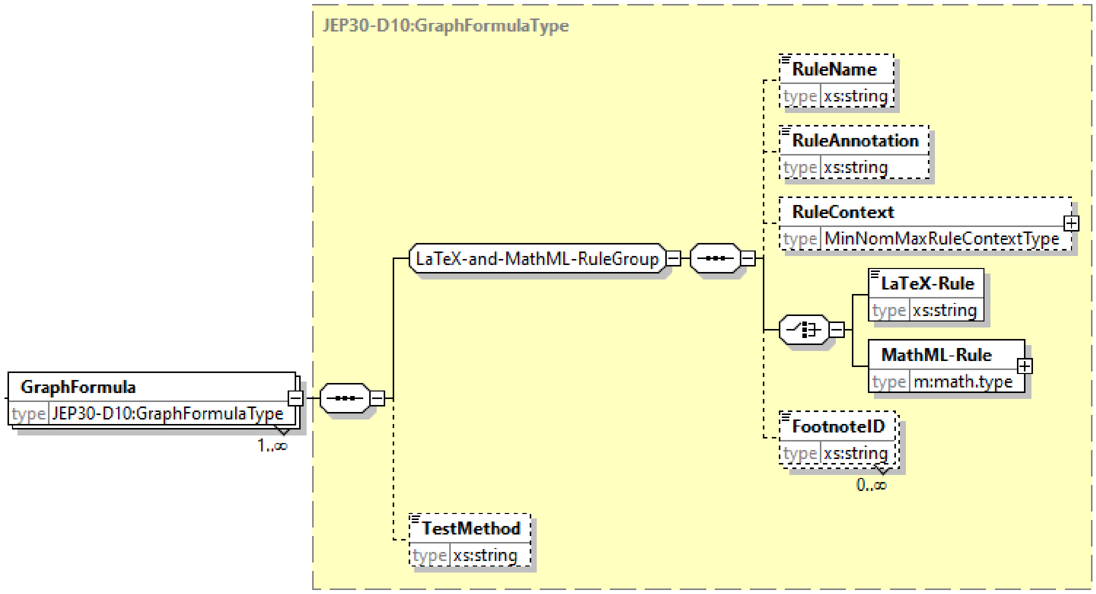
4.4.2.3.5 Data-Array (cont'd)


```
< ThermalMetricGraph>
    <GraphTitle>Zth Thermal Impedance Curves</GraphTitle>
    <TestConditionDefinition>
        <AxisTitle>Time (s)</AxisTitle>
        <LaTeX-Symbol>t</LaTeX-Symbol>
        <Description>Time since power step</Description>
        <Units>
            <Time>s</Time>
        </Units>
        <Formatting>
            <Range>
                <Minimum>1</Minimum>
                <Maximum>10000</Maximum>
            </Range>
            <Scale>
                <Logarithmic>
                    <Base>10</Base>
                </Logarithmic>
            </Scale>
            <Position>Bottom</Position>
        </Formatting>
    </TestConditionDefinition>
    <ParameterDefinition>
        <ID>Y1</ID>
        <AxisTitle>Z_{th} (K/W)</AxisTitle>
        <LaTeX-Symbol>Z_{th}</LaTeX-Symbol>
        <Description>Thermal Impedance Response</Description>
        <Units>
            <ThermalResistanceUOM>K/W</ThermalResistanceUOM>
        </Units>
        <Formatting>
            <Range>
                <Minimum>0</Minimum>
                <Maximum>5</Maximum>
            </Range>
            <Scale>
                <Linear>
                    <Step>1</Step>
                </Linear>
            </Scale>
            <Position>Left</Position>
        </Formatting>
    </ParameterDefinition>
    <Data-Array>
        <ParameterDefinitionID>Y1</ParameterDefinitionID>
        <TestCondition>
            <Legend>
                <Title>Die1 Powered</Title>
            </Legend>
        </TestCondition>
        <Data>
            <TestConditionValue>1</TestConditionValue>
```

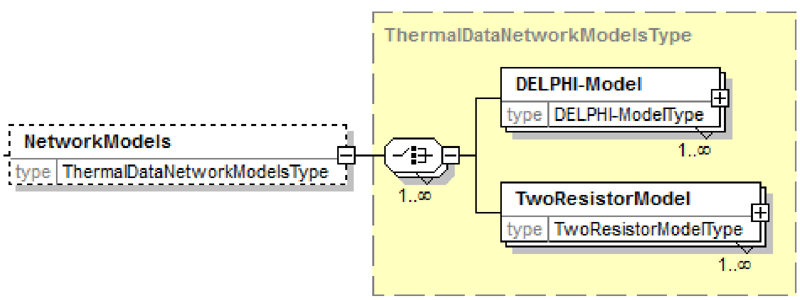
4.4.2.3.5 Data-Array (cont'd)

```
                    <ParameterValue>
                        <Nominal>0.026</Nominal>
                    </ParameterValue>
                </Data>
                <Data>
                    <TestConditionValue>3.55</TestConditionValue>
                    <ParameterValue>
                        <Nominal>0.085</Nominal>
                    </ParameterValue>
                </Data>
                    …
                    …
            </Data-Array>
            <Data-Array>
                <ID>Y1</ID>
                <TestCondition>
                    <Legend>
                        <Title>Die2 Response</Title>
                    </Legend>
                </TestCondition>
                <Data>
                    <TestConditionValue>1</TestConditionValue>
                    <ParameterValue>
                        <Nominal>9.7e-7</Nominal>
                    </ParameterValue>
                </Data>
                <Data>
                    <TestConditionValue>3.55</TestConditionValue>
                    <ParameterValue>
                        <Nominal>4.4e-5</Nominal>
                    </ParameterValue>
                </Data>
                    …
                    …
                <Formatting>
                    <Point>
                        <Color>Blue</Color>
                        <Style>Circle</Style>
                    </Point>
                    <Line>
                        <Color>Black</Color>
                        <Style>Solid</Style>
                    </Line>
                </Formatting>
            </Data-Array>
            <Formatting>
                <DisplayType>Line</DisplayType>
                <Legend>
                    <Location>Inside Graph</Location>
                    <VerticalPosition>Center</VerticalPosition>
                    <HorizontalPosition>Center</HorizontalPosition>
                </Legend>
            </Formatting>
        </ThermalMetricGraph>
```

4.4.2.3.6 Graph Formula

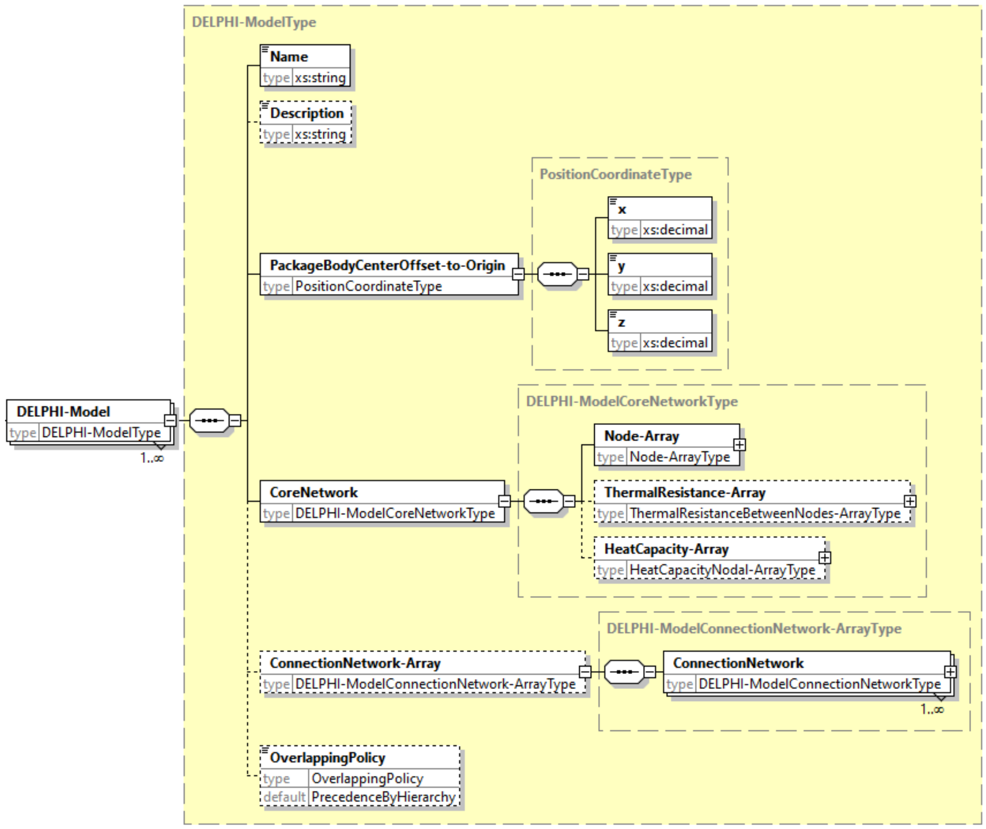
path	**PartModel/ThermalSection/Thermal-Array/ThermalFamily/ThermalData/ThermalMetrics-Array/ThermalMetricGraph/GraphFormula**
diagram	
type	**JEP30-D10:GraphFormulaType, MinNomMaxRuleContextType, m:math.type**
group	**LaTeX-and-MathML-RuleGroup**

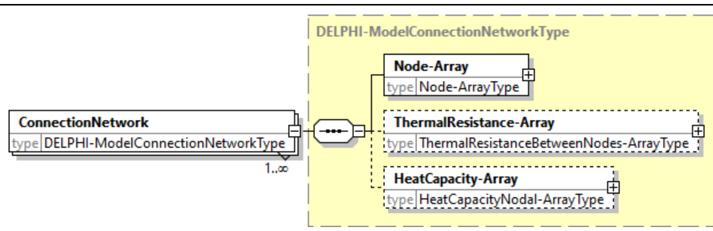
4.4.3 Network Models

path	**PartModel/ThermalSection/Thermal-Array/ThermalFamily/ThermalData/NetworkModels.**
diagram	
type	**ThermalDataNetworkModelsType, DELPHI-ModelType, TwoResistorModelType**

Two types of thermal *NetworkModels* are supported; *DELPHI-Model*, as defined in JESD15-4 and *2-ResistorModel*, as defined in JESD15-3. Both models involve the definition of a nodal thermal network. Any number of 2-resistor or DELPHI Network Models may be defined.

4.4.3.1 DELPHI - Model

<table>
<tr><td>path</td><td>PartModel/ThermalSection/Thermal-Array/ThermalFamily/ThermalData/NetworkModels/DELPHI-Model.</td></tr>
<tr><td>diagram 1 of 2</td><td>


</td></tr>
<tr><td>diagram 2 of 2</td><td>


</td></tr>
<tr><td>type</td><td>DELPHI-ModelType, PositionCoordinateType, DELPHI-ModelCoreNetworkType, DELPHI-ModelConnectionNetwork-ArrayType, DELPHI-ModelConnectionNetworkType, Node-ArrayType, ThermalResistanceBetweenNodes-ArrayType, HeatCapacityNodal-ArrayType, OverlappingPolicy.</td></tr>
</table>

A *DELPHI-Model* is defined by a *Name*, an optional *Description*, its *PackageBodyCenterOffset-to-Origin*, a single *CoreNetwork* and optional *ConnectionNetworks* representing level 2 interconnects or sockets (unless those were considered part of the package when the DELPHI-Model was extracted).

In order to connect the Thermal Model to the Package Model, a reference for the position of the Node Array to the Origin is specified, via the *PackageBodyCenterOffset-to-Origin*. Since the Node Array Position is in respect to the Origin, specifying the offset here from the Package Body Center to the Origin will enable the alignment of the Thermal Model to the Physical Model that is defined under the *PackageSection*.

4.4.3.1 DELPHI Model (cont'd)

The *CoreNetwork* and *ConnectionNetwork* are defined in the same way and is similar for a Two Resistor Model Network apart from the ability to define nodal thermal capacitances.

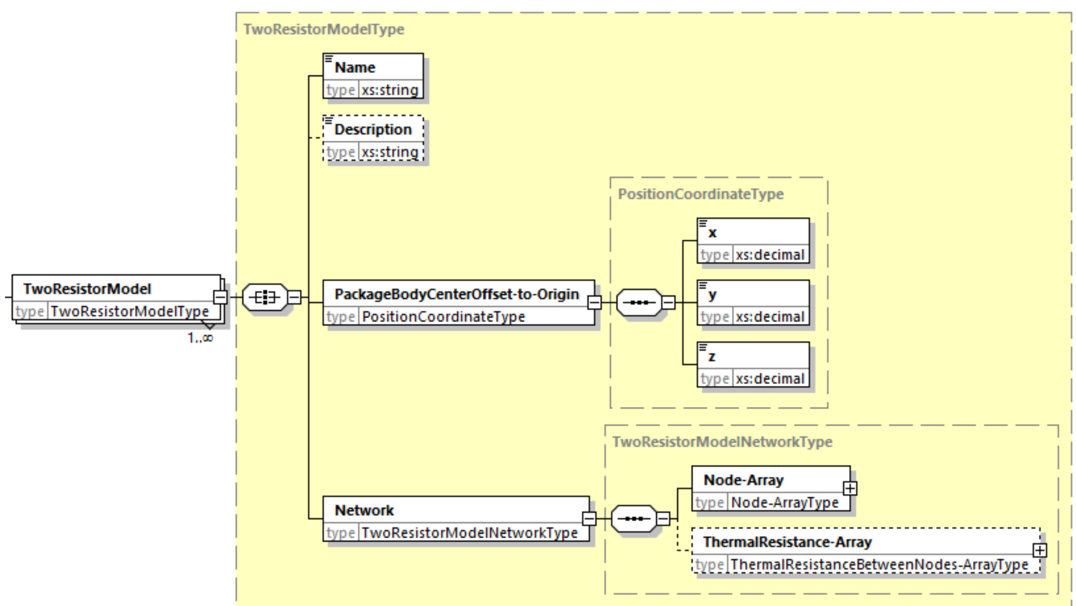
If two *RectangularNodeFaces* (see section 4.14 below) are defined as spatially overlapping, as is commonly the case for 'top inner' and 'top outer' nodal areas, then an *OverlappingPolicy* may be set to one of the following:

1. Precedence By Hierarchy
2. Precedence By Size

PrecedenceByHierarchy indicates that the Rectangular Node Face defined first in the sequence of the xml file will be interpreted as being overwritten by the overlapping *RectangularNodeFace* defined after. *PrecedenceByHierarchy* is the default setting.

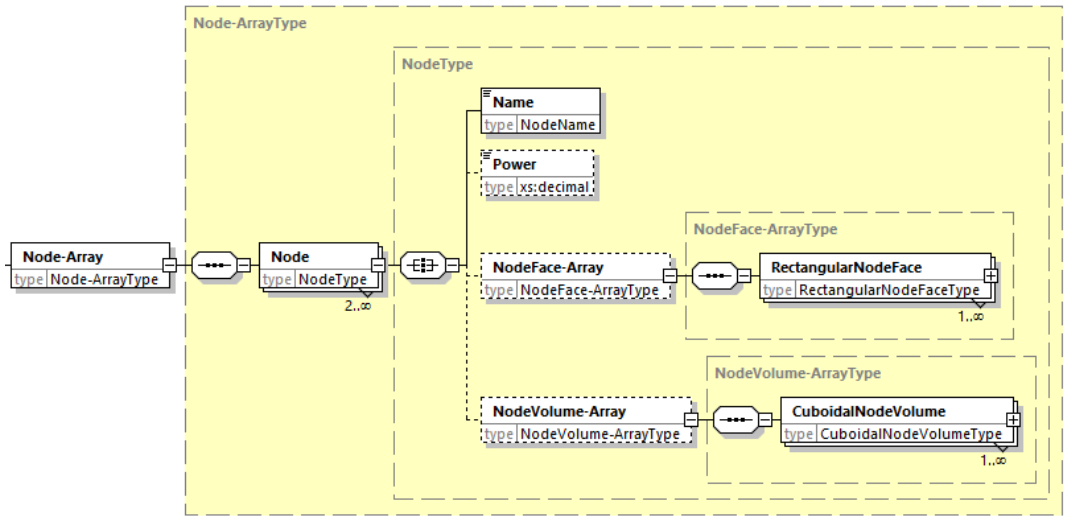
PrecedenceBySize indicates that, regardless of the order in which the *RectangularNodeFaces* are defined in the xml, the smaller one (by area) will be interpreted as overwriting the larger one (by area).

4.4.3.2 Two Resistor Model

path	**PartModel/ThermalSection/Thermal-Array/ThermalFamily/ThermalData/NetworkModels/TwoResistorModel.**
diagram	
type	**TwoResistorModelType, PositionCoordinateType, TwoResistorModelNetworkType, Node-ArrayType, ThermalResistanceBetweenNodes-ArrayType.**

A *TwoResistorModel* is defined by a *Name*, an optional *Description,* its *PackageBodyCenterOffset-to-Origin*, and a *Network*. The Network is defined by a *Node-Array* and a *Thermal Resistance-Array*.

4.4.3.3 Node-Array

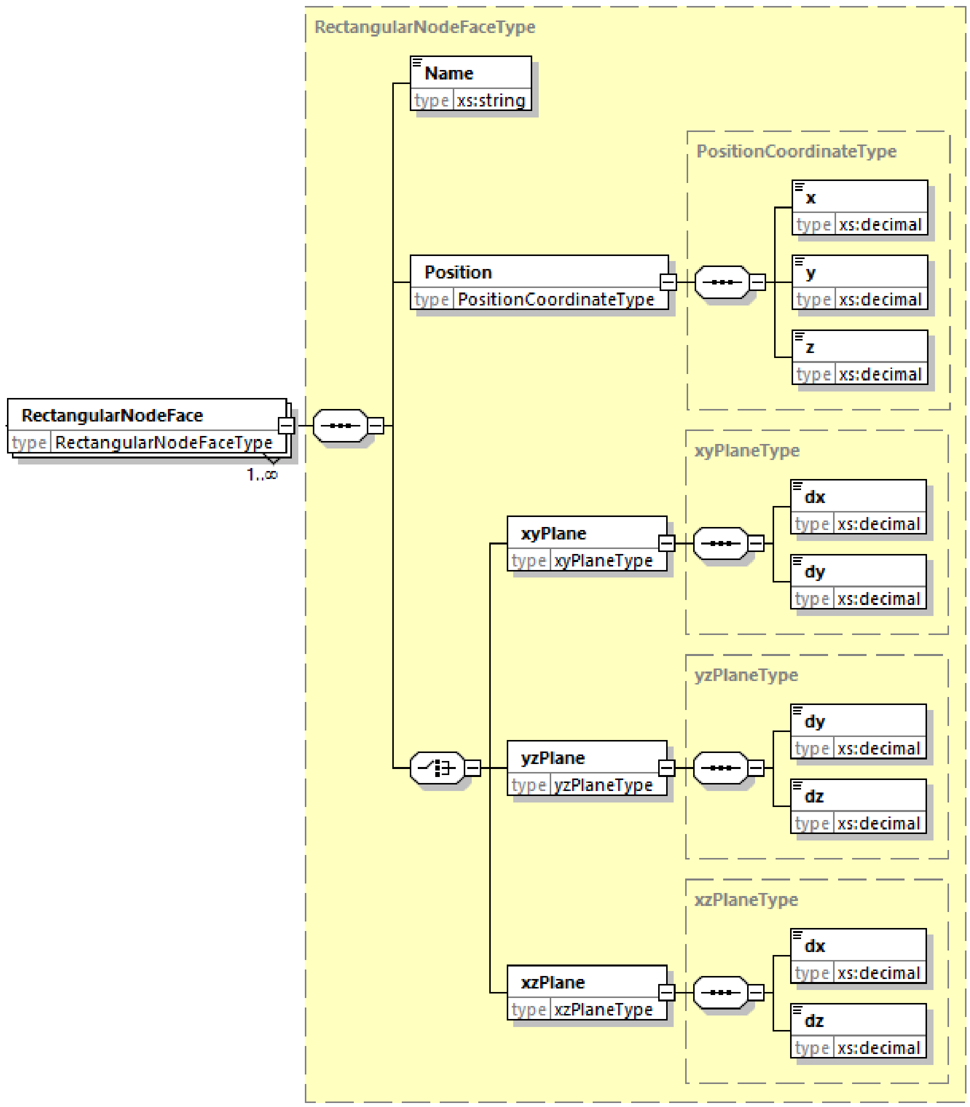
path	1. PartModel/ThermalSection/Thermal-Array/ThermalFamily/ThermalData/NetworkModels/DELPHI-Model/CoreNetwork/Node-Array, 2. PartModel/ThermalSection/Thermal-Array/ThermalFamily/ThermalData/NetworkModels/DELPHI-Model/ConnectionNetwork-Array/ConnectionNetwork/Node-Array 3. PartModel/ThermalSection/Thermal-Array/ThermalFamily/ThermalData/NetworkModels/TwoResistorModel/Network/Node-Array.
diagram	
type	Nodal–ArrayType, NodeType, NodeFace–ArrayType, NodeVolume–ArrayType, RectangularNodeFaceType, CuboidalNodeVolumeType

The *Node-Array* should consist of at least 2 named *Node* elements. One or more *Nodes* may have a *Power* value defined.

Such a nodal thermal model could be used for thermal or electro-thermal circuit simulation. However, if the model is to be used as part of a 3D simulation it is required to have a 3D physical definition. This is achieved by defining the following shapes, which includes their respective *Name*, *Position* and *Size as shown below*:

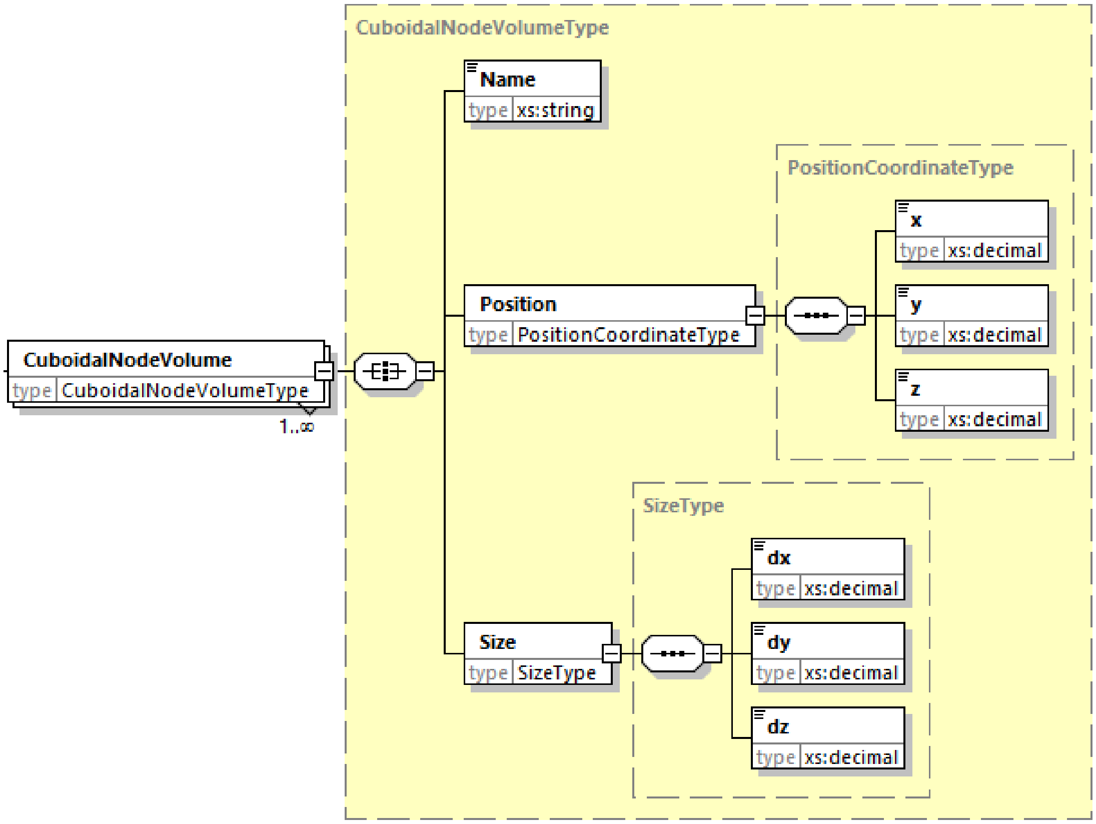
1. Rectangular Node Face
2. Cuboidal Node Volume

4.4.3.3.1 Rectangular Node Face

path	**1. PartModel/ThermalSection/Thermal-Array/ThermalFamily/ThermalData/NetworkModels/DELPHI-Model/CoreNetwork/Node-Array/Node/NodeFace-Array/RectangularNodeFace,** **2. PartModel/ThermalSection/Thermal-Array/ThermalFamily/ThermalData/NetworkModels/DELPHI-Model/ConnectionNetwork-Array/ConnectionNetwork/Node-Array/Node/NodeFace-Array/RectangularNodeFace,** **3. PartModel/ThermalSection/Thermal-Array/ThermalFamily/ThermalData/NetworkModels/TwoResistorModel/Network/Node-Array/Node/NodeFace-Array/RectangularNodeFace.**
diagram	
type	**RectangularNodeFaceType, PositionCoordinateType, xyPlaneType, yzPlaneType, xzPlaneType**

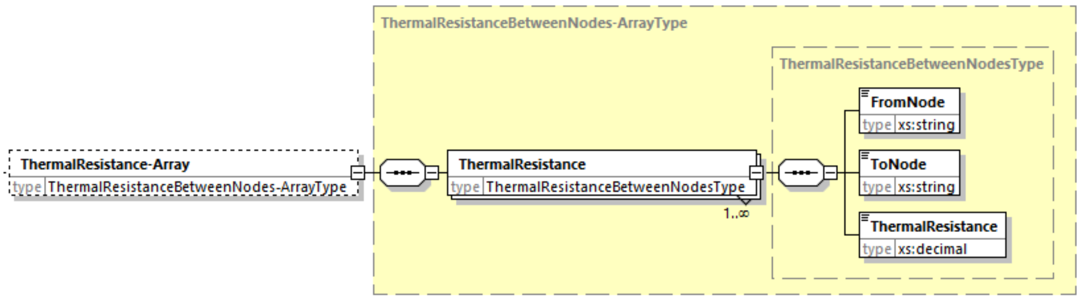
The *RectangularNodeFace* is a 2D rectangular shape defined by a *Name*, an *x*, *y*, and *z Position*, a *xyPlane* or *yzPlane* or *xzPlane* orientation and the dimension of the rectangle in that plane, *dx*, *dy*, *dz*. When defined as a child of a node, it nominates that node to be peripheral in that it will act as a fixed temperature thermal connection to the surrounding 3D simulation space. One or more Rectangular Node Face shapes can be defined as children of a node.

4.4.3.3.2 Cuboidal Node Volume

path	1. PartModel/ThermalSection/Thermal-Array/ThermalFamily/ThermalData/NetworkModels/DELPHI-Model/CoreNetwork/Node-Array/Node/NodeVolume-Array/CuboidalNodeVolume, 2. PartModel/ThermalSection/Thermal-Array/ThermalFamily/ThermalData/NetworkModels/DELPHI-Model/ConnectionNetwork-Array/ConnectionNetwork/Node-Array/Node/NodeVolume-Array/CuboidalNodeVolume.
diagram	
type	CuboidalNodeVolumeType, PositionCoordinateType, SizeType.

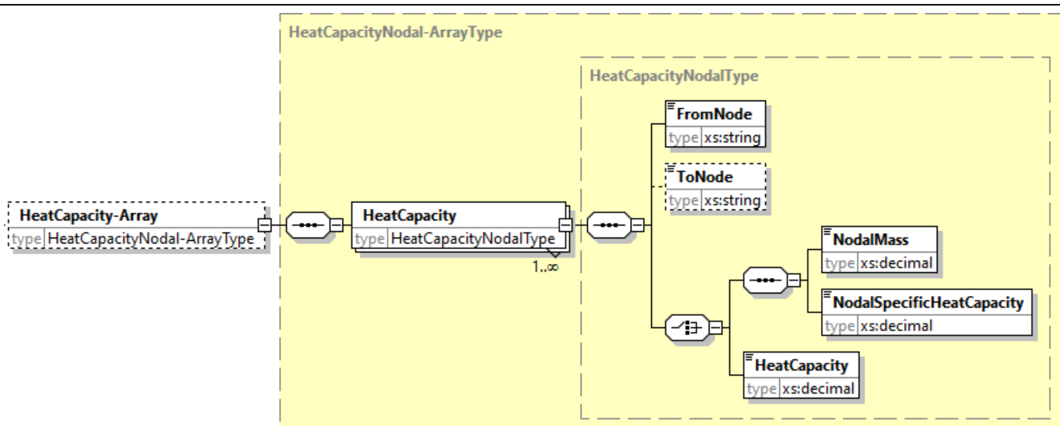
The *CuboidalNodeVolume* is a 3D cuboidal shape defined by a *Name*, an *x*, *y*, *z Position* and *dx, dy, dz Size*. It is intended to block out the physical space occupied by the Part within the 3D simulation context. One or more Cuboidal Node Volume shapes can be defined as children of a Node.

4.4.3.4 Thermal Resistance - Array

path	1. **PartModel/ThermalSection/Thermal-Array/ThermalFamily/ThermalData/NetworkModels/DELPHI-Model/CoreNetwork/ThermalResistance-Array,** 2. **PartModel/ThermalSection/Thermal-Array/ThermalFamily/ThermalData/NetworkModels/DELPHI-Model/ConnectionNetwork-Array/ConnectionNetwork/ThermalResistance-Array,** 3. **PartModel/ThermalSection/Thermal-Array/ThermalFamily/ThermalData/NetworkModels/TwoResistorModel/Network/ThermalResistance-Array**
diagram	
type	**ThermalResistanceBetweenNodes–ArrayType, ThermalResistanceBetweenNodesType**

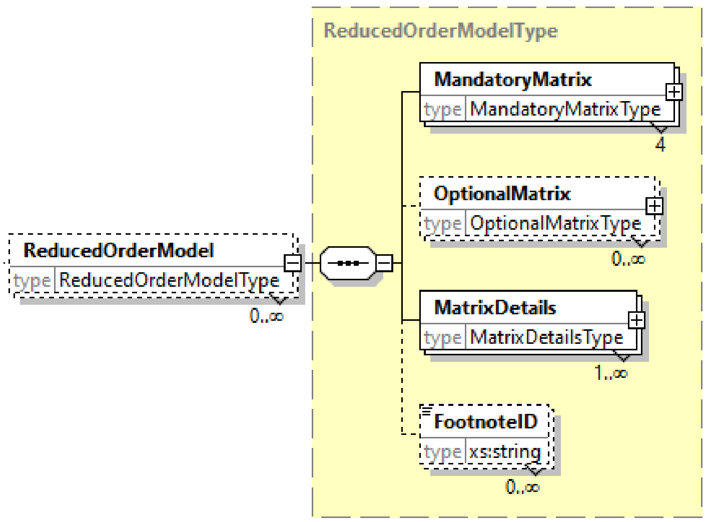
The *ThermalResistance-Array* lists the thermal links of the Network by specifying the *FromNode* name, the *ToNode* name and the *ThermalResistance* value linking them.

4.4.3.5 Heat Capacity - Array

path	1. **PartModel/ThermalSection/Thermal-Array/ThermalFamily/ThermalData/NetworkModels/DELPHI-Model/CoreNetwork/HeatCapacity-Array,** 2. **PartModel/ThermalSection/Thermal-Array/ThermalFamily/ThermalData/NetworkModels/DELPHI-Model/ConnectionNetwork-Array/ConnectionNetwork/ HeatCapacity-Array**
diagram	
type	**HeatCapacityNodal-ArrayType, HeatCapacityNodalType**

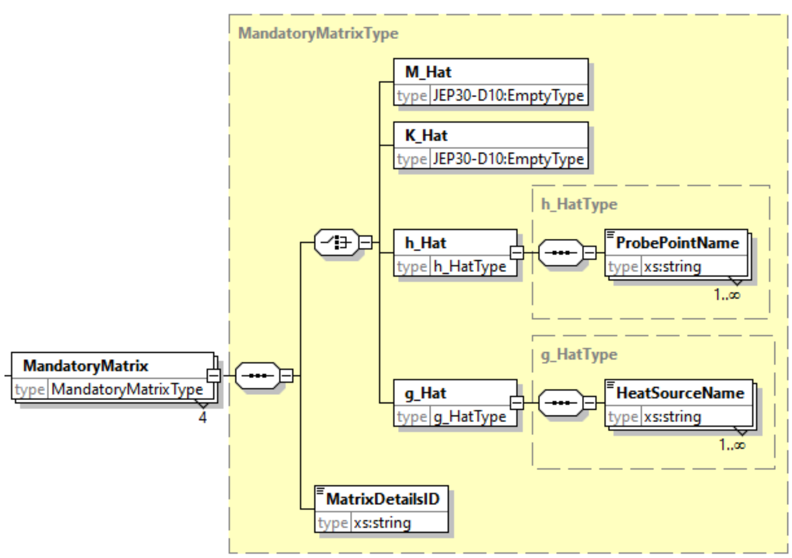
HeatCapacity is defined by a *HeatCapacity-Array* by specifying the *FromNode* name, an optional *ToNode* name and a *HeatCapacity* value. If no *ToNode* name is defined, then the heat capacity will be assumed to be connected to the thermal ground, e.g., as in a Cauer type network.

4.4.4 Reduced Order Model

path	**PartModel/ThermalSection/Thermal-Array/ReducedOrderModel**
diagram	
type	**ReducedOrderModelsType, MandatoryMatrixType, OptionalMatrixType, MatrixDetailsType**

Reduced Order Models (ROMs), distinct from lumped equivalent thermal circuit approaches, are comprised of a collection of matrices, extracted from mesh discretized full order models. Systematic techniques to extract ROMs include Krylov subspace projection, Proper Orthogonal Decomposition, and Balanced Truncation.

4.4.4.1 Mandatory Matrix

path	**PartModel/ThermalSection/Thermal-Array/ROM-Matrices/MandatoryMatrix**
diagram	
type	**MandatoryMatrixType, JEP30-D10:EmptyType, h_HatType, g_HatType'**

Definition of a ROM requires 4 mandatory matrices. Three of them *M_Hat*, *K_Hat* and *g_Hat* comprise the ROM governing equation:

4.4.4.1 Mandatory Matrix (cont'd)

$$\hat{M}\frac{d\hat{T}(t)}{dt} + \hat{K}\hat{T}(t) = \hat{g}S(t)$$

Where:

- M_hat is the ROM space thermal Mass matrix
- K_Hat is the ROM space thermal Conductance matrix
- g_Hat is the source input matrix in ROM space

S(t) is the physical space time-dependent heat source vector that is prescribed when the ROM is solved.

The ROM governing equation is to be solved using an ODE solver. In doing so T_hat(t) will be the predicted time-dependent ROM space temperature rises above a single ambient temperature.

The 4th mandatory matrix h_Hat is then used to reconstruct physical space temperatures from the predicted ROM space temperatures at one or more spatial probe point locations:

$$T_{\text{probes}} = \hat{T}(t)^T \times \hat{h}$$

By considering the following size parameters:

- N – size (degrees of freedom) of the ROM
- Ns – number of heat sources
- Np – number of probe points

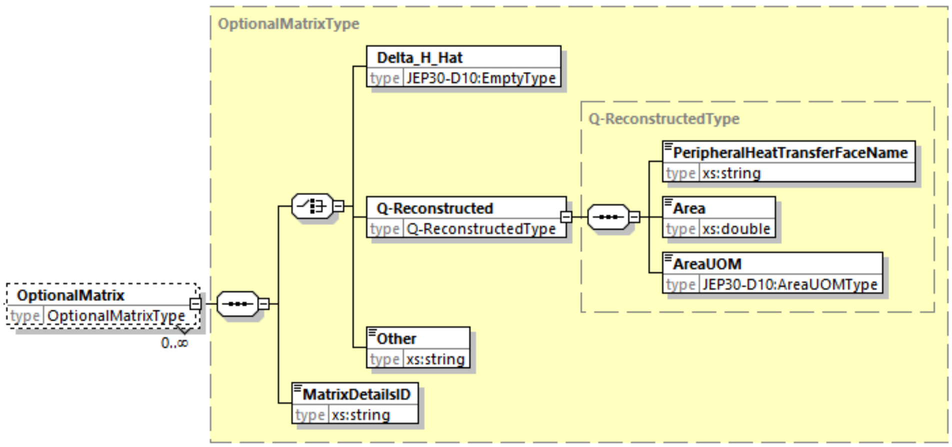
The bounding sizes of the 4 mandatory matrices are (*Rows* x *Columns*):

- *M_Hat* – N x N
- *K_Hat* – N x N
- *g_Hat* – N x Ns
- *h_Hat* – N x Np

Note that:

1. To aid in results post-processing and interpretation, Np Probe point name strings are to be defined. The order of which reflects the order of the *h_Hat* matrix
2. To aid in the definition of the time-dependent heat sources, Ns *HeatSourceName* strings are to be defined. The order of which reflects the order of the *g_Hat* matrix.
3. ROMs defined using just these mandatory matrices represent the entire full order model from which they were extracted. This includes any peripheral heat transfer coefficients (HTCs) that are themselves incorporated ('baked into') the *K_hat* matrix and thus are not editable. Also, only a single ambient temperature is considered so that, due to the linearity of the thermal model, T_probes (when reconstructed) will be temperature rises above this ambient temperature.

4.4.4.2 Optional Matrix

<table>
<tr><td>path</td><td>PartModel/ThermalSection/Thermal-Array/ROM-Matrices/OptionalMatrix</td></tr>
<tr><td>diagram</td><td>
</td></tr>
<tr><td>type</td><td>OptionalMatrixType, JEP30-D10:EmptyType, Q-ReconstructedType, JEP30-D10:AreaUOMType</td></tr>
</table>

To allow for both the consideration of different HTCs and associated ambient temperatures over peripheral faces of the thermal model, as well as the effect those HTCs have on the internal thermal resistances in the model, *OptionalMatrix* information can be defined in addition to the mandatory information.

Consider the following parameters:

- NB – number of peripheral heat transfer faces (k) over which differing HTCs and ambient temperatures can be applied
- h_k – HTC on peripheral face k
- $T_{amb,k}$ – Ambient temperature on peripheral face k

Note that h_k and $T_{amb,k}$ are not themselves considered part of the ROM definition, but are prescribed as boundary conditions when the ROM is solved.

The K_Hat matrix is adapted to account for the differing peripheral face HTCs:

$$\hat{K} = \hat{K}_{\text{bci}} + \sum_{k=1}^{NB} h_k \cdot \Delta\hat{H}_k$$

Where there exists one Delta_H_Hat matrix for each k peripheral face. Each Delta_H_Hat matrix is of bounding size N x N.

To account for the differing HTC and ambient temperatures on each peripheral heat transfer face, the ROM governing equation is modified:

$$\hat{M}\frac{d\hat{T}(t)}{dt} + \hat{K}\hat{T}(t) = \hat{g}\,S(t) + \text{htcTambSource}$$

4.4.4.2 Optional Matrix (cont'd)

Where htcTambSource is defined as:

$$\text{htcTambSource} = \sum_{k=1}^{NB} h_k \, T_{\text{amb},k} \, q^T_{\text{reconstruct},k}$$

This additional source term involves the prescribed h_k and $T_{amb,k}$ as well as additional Q-Reconstructed matrices. There exists one Q-Reconstructed matrix for each k peripheral face, each of bounding size N x N.

After solving for T_hat, the physical space temperatures are reconstructed as before using the (mandatory) h_Hat matrix.

Unlike the ROM based on just the mandatory matrices, which predicts temperature rise over a single assumed ambient, the extended formulation (using in addition these optional matrices) explicitly incorporate face-specific ambient temperatures into the governing equations. As a result, the reconstructed probe temperatures are **absolute** temperatures that already account for the prescribed variation in ambient temperature boundary conditions.

For each Q-Reconstructed matrix (i.e. for each peripheral heat transfer face) a face name string is to be defined to aid in appropriate boundary condition setting. In addition, an area is to be set that then enables additional post-processing in terms of the heat flux through each face:

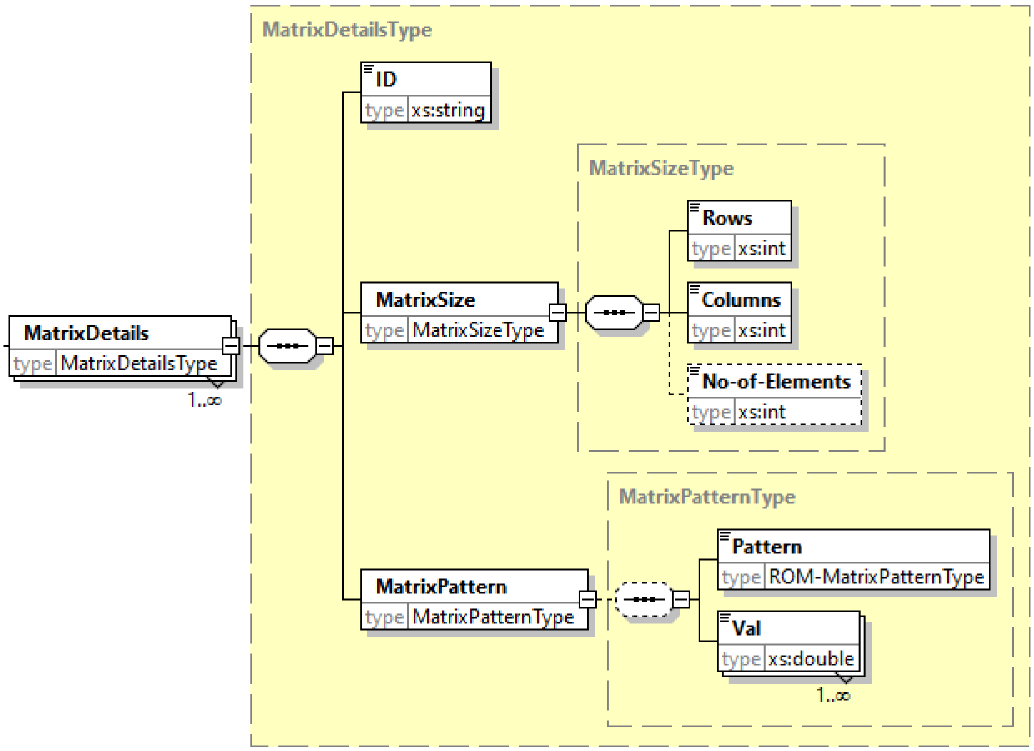
$$\text{HeatFlux}_k = h_k \left(\hat{T}^T q_{\text{reconstruct},k} - T_{\text{amb},k} \, \text{Area}_k \right)$$

and so subsequently the absolute physical temperature of each face:

$$T_k^* = \frac{\text{HeatFlux}_k}{h_k \, \text{Area}_k} + T_{\text{amb},k}$$

The *AreaUOM* enumerated values are nm², µm², mm², cm², and m².

4.4.4.3 Matrix Details

<table>
<tr><td>path</td><td>PartModel/ThermalSection/Thermal-Array/ROM-Matrices/MatrixDetails</td></tr>
<tr><td>diagram</td><td>
</td></tr>
<tr><td>type</td><td>MatrixDetailsType, MatrixSizeType, MatrixPattern-ArrayType</td></tr>
</table>

Thermal ROM Matrices can only be populated in two possible ways, namely

1. Full Matrix, or
2. Diagonal Matrix.

If the thermal matrix is a full matrix, then the values can be recorded in a column-by-column sequence as denoted by the pattern code ZZ-V in Table 3 – Thermal Matrix Patterns below. Alternatively, the matrix values can be recorded row-by-row as denoted by the pattern code ZZ-H.

If the thermal matrix is a diagonal matrix, then the values are recorded in the sequence from Top Left to Bottom Right. The number of values recorded can also be used to define the size of the matrix since the number of rows equals the number of columns in this matrix.

The enumerated values of the ROM Matrix Pattern type are

1. ZZ-V-TL (represents Zig-Zag Vertical with a starting position of Top Left),
2. ZZ-H-TL (represents Zig-Zag Horizontal with a starting position of Top Left),
3. D-TL-BR (represents diagonal with a starting position of Top Left and a finish at Bottom Right),

4.4.4.3 Matrix Details (cont'd)

TABLE 3 – THERMAL MATRIX PATTERNS

Pattern	Terminal Numbering Pattern	Sequential Code	Start Position	Towards Point 2	Towards Point 3	Towards Point 4	Towards Point 5	Last Point
1		ZZ-V	TL	BL	TL+1	BL+1	TL+2	BR
2		ZZ-H	TL	TR	T-1L	T-1R	T-2L	BR
3		D	TL	T-1L+1	T-2L+2	T-3L+3	T-4L+4	BR

4.4.4.4 Reduced Order Model Sample

```
<ReducedOrderModel>
   <MandatoryMatrix>
      <h_Hat>
         <ProbePointName>U0 [APOLLONIA3_BC_A0_P9991, APOL</ProbePointName>
         <ProbePointName>U10 [PRASA_21_L_BC_A0_P9991, PRA</ProbePointName>
         <ProbePointName>U12 [PRASA_3_L_BC_A0_P9991, PRAS</ProbePointName>
         <ProbePointName>U20 [PRASA_3_R_BC_A0_P9991, PRAS</ProbePointName>
         <ProbePointName>U22 [PRASA_3_R_BC_A0_P9991, PRAS</ProbePointName>
         <ProbePointName>U50 [SSHBM_BC_A0_P9991, SSHBM_BC</ProbePointName>
         <ProbePointName>U51 [SSHBM_BC_A0_P9991, SSHBM_BC</ProbePointName>
         <ProbePointName>U0[APOLLONIA3_BC_A0_P9991,APOL</ProbePointName>
         <ProbePointName>U10[PRASA_21_L_BC_A0_P9991,PRA</ProbePointName>
         <ProbePointName>U12[PRASA_3_L_BC_A0_P9991,PRAS</ProbePointName>
         <ProbePointName>U20[PRASA_3_R_BC_A0_P9991,PRAS</ProbePointName>
         <ProbePointName>U22[PRASA_3_R_BC_A0_P9991,PRAS</ProbePointName>
         <ProbePointName>U50[SSHBM_BC_A0_P9991,SSHBM_BC</ProbePointName>
         <ProbePointName>U51[SSHBM_BC_A0_P9991,SSHBM_BC</ProbePointName>
      </h_Hat>
      <MatrixDetailsID>Matrix Details ID 1</MatrixDetailsID>
   </MandatoryMatrix>
   <MandatoryMatrix>
      <K_Hat/>
      <MatrixDetailsID>Matrix Details ID 2</MatrixDetailsID>
   </MandatoryMatrix>
   <MandatoryMatrix>
      <M_Hat/>
      <MatrixDetailsID>Matrix Details ID 3</MatrixDetailsID>
   </MandatoryMatrix>
   <MandatoryMatrix>
      <g_Hat>
         <HeatSourceName>U0 [APOLLONIA3_BC_A0_P9991, APOL</HeatSourceName>
         <HeatSourceName>U10 [PRASA_21_L_BC_A0_P9991, PRA</HeatSourceName>
         <HeatSourceName>U12 [PRASA_3_L_BC_A0_P9991, PRAS</HeatSourceName>
         <HeatSourceName>U20 [PRASA_3_R_BC_A0_P9991, PRAS</HeatSourceName>
         <HeatSourceName>U22 [PRASA_3_R_BC_A0_P9991, PRAS</HeatSourceName>
```

4.4.4.4 Reduced Order Model Sample (cont'd)

```
        <HeatSourceName>U50 [SSHBM_BC_A0_P9991, SSHBM_BC</HeatSourceName>
        <HeatSourceName>U51 [SSHBM_BC_A0_P9991, SSHBM_BC</HeatSourceName>
    </g_Hat>
    <MatrixDetailsID>Matrix Details ID 4</MatrixDetailsID>
</MandatoryMatrix>
<OptionalMatrix>
    <Delta_H_Hat/>
    <MatrixDetailsID>Matrix Details ID 5</MatrixDetailsID>
</OptionalMatrix>
<OptionalMatrix>
    <Delta_H_Hat/>
    <MatrixDetailsID>Matrix Details ID 6</MatrixDetailsID>
</OptionalMatrix>
<OptionalMatrix>
    <Delta_H_Hat/>
    <MatrixDetailsID>Matrix Details ID 7</MatrixDetailsID>
</OptionalMatrix>
<OptionalMatrix>
    <Q-Reconstructed>
        <PeripheralHeatTransferFaceName>Sides</PeripheralHeatTransferFaceName>
        <Area>2.108887050883e-03</Area>
        <AreaUOM>m²</AreaUOM>
    </Q-Reconstructed>
    <MatrixDetailsID>Matrix Details ID 8</MatrixDetailsID>
</OptionalMatrix>
<OptionalMatrix>
    <Q-Reconstructed>
        <PeripheralHeatTransferFaceName>Bottom</PeripheralHeatTransferFaceName>
        <Area>1.157469640782e-03</Area>
        <AreaUOM>m²</AreaUOM>
    </Q-Reconstructed>
    <MatrixDetailsID>Matrix Details ID 9</MatrixDetailsID>
</OptionalMatrix>
<OptionalMatrix>
    <Q-Reconstructed>
        <PeripheralHeatTransferFaceName>Top</PeripheralHeatTransferFaceName>
        <Area>3.024999967217e-03</Area>
        <AreaUOM>m²</AreaUOM>
    </Q-Reconstructed>
    <MatrixDetailsID>Matrix Details ID 10</MatrixDetailsID>
</OptionalMatrix>
<MatrixDetails>
    <ID>Matrix Details ID 1</ID>
    <MatrixSize>
        <Rows>53</Rows>
        <Columns>14</Columns>
        <No-of-Elements>742</No-of-Elements>
    </MatrixSize>
    <MatrixPattern>
        <Pattern>ZZ-H-TL</Pattern>
        <Val>-6.904682475170e-02</Val>
        <Val>3.812622415901e-01</Val>
        <Val>-2.840978633256e-01</Val>
```

4.4.4.4 Reduced Order Model Sample (cont'd)

```
            :
            Total # of Val entries is 742
            :
        <Val>-1.020640481137e-01</Val>
    </MatrixPattern>
</MatrixDetails>
<MatrixDetails>
    <ID>Matrix Details ID 2</ID>
    <MatrixSize>
        <Rows>53</Rows>
        <Columns>53</Columns>
        <No-of-Elements>53</No-of-Elements>
    </MatrixSize>
    <MatrixPattern>
        <Pattern>D-TL-BR</Pattern>
        <Val>2.686884742480e+06</Val>
        <Val>2.669832241867e+06</Val>
            :
            Total # of Val entries is 53
            :
        <Val>7.611107573533e-15</Val>
    </MatrixPattern>
</MatrixDetails>
<MatrixDetails>
    <ID>Matrix Details ID 3</ID>
    <MatrixSize>
        <Rows>53</Rows>
        <Columns>53</Columns>
        <No-of-Elements>53</No-of-Elements>
    </MatrixSize>
    <MatrixPattern>
        <Pattern>D-TL-BR</Pattern>
        <Val>1.000000000000e+00</Val>
        <Val>1.000000000000e+00</Val>
        <Val>1.000000000000e+00</Val>
            :
            Total # of Val entries is 53
            :
        <Val>1.000000000000e+00</Val>
    </MatrixPattern>
</MatrixDetails>
<MatrixDetails>
    <ID>Matrix Details ID 4</ID>
    <MatrixSize>
        <Rows>53</Rows>
        <Columns>7</Columns>
        <No-of-Elements>371</No-of-Elements>
    </MatrixSize>
    <MatrixPattern>
        <Pattern>ZZ-H-TL</Pattern>
        <Val>-5.675568005805e-02</Val>
        <Val>3.667727047983e-01</Val>
        <Val>-2.746510410807e-01</Val>
```

4.4.4.4 Reduced Order Model Sample (cont'd)

```
            :
            Total # of Val entries is 371
            :
        <Val>-1.02064048149e-01</Val>
    </MatrixPattern>
</MatrixDetails>
<MatrixDetails>
    <ID>Matrix Details ID 5</ID>
    <MatrixSize>
        <Rows>53</Rows>
        <Columns>53</Columns>
        <No-of-Elements>2809</No-of-Elements>
    </MatrixSize>
    <MatrixPattern>
        <Pattern>ZZ-H-TL</Pattern>
        <Val>3.130696467268e-06</Val>
        <Val>3.525847563808e-06</Val>
        <Val>1.032695353553e-06</Val>
            :
            Total # of Val entries is 2809
            :
        <Val>2.196842408733e-05</Val>
    </MatrixPattern>
</MatrixDetails>
<MatrixDetails>
    <ID>Matrix Details ID 6</ID>
    <MatrixSize>
        <Rows>53</Rows>
        <Columns>53</Columns>
        <No-of-Elements>2809</No-of-Elements>
    </MatrixSize>
    <MatrixPattern>
        <Pattern>ZZ-H-TL</Pattern>
        <Val>4.585053948969e-08</Val>
        <Val>1.178648490467e-08</Val>
        <Val>5.032244034376e-09</Val>
            :
            Total # of Val entries is 2809
            :
        <Val>1.20574422701e-05</Val>
    </MatrixPattern>
</MatrixDetails>
<MatrixDetails>
    <ID>Matrix Details ID 7</ID>
    <MatrixSize>
        <Rows>53</Rows>
        <Columns>53</Columns>
        <No-of-Elements>2809</No-of-Elements>
    </MatrixSize>
    <MatrixPattern>
        <Pattern>ZZ-H-TL</Pattern>
        <Val>1.302705616633e-08</Val>
        <Val>3.832833592987e-09</Val>
```

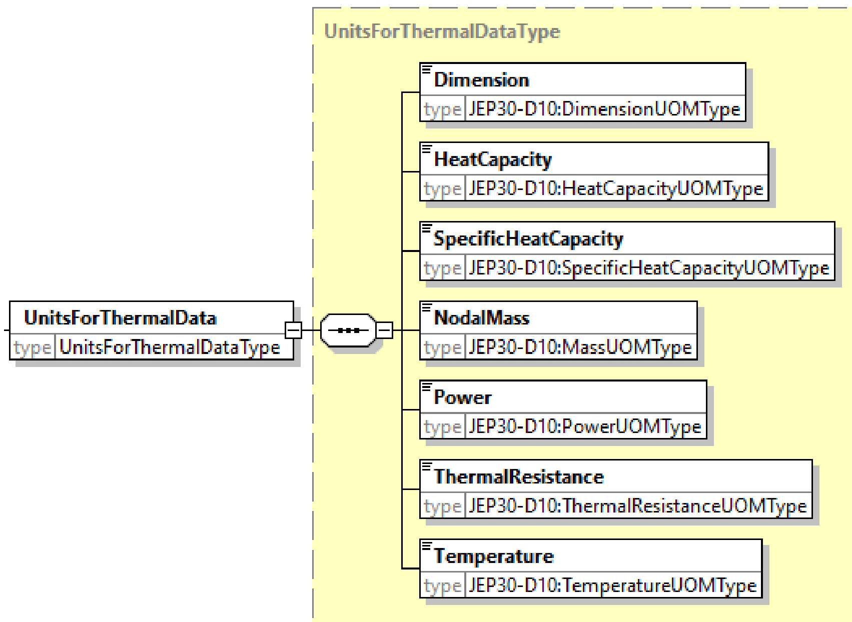
4.4.4.4 Reduced Order Model Sample (cont'd)


```
      <Val>4.615528983501e-09</Val>
      <Val>-5.975611506556e-09</Val>
         :
         Total # of Val entries is 2809
         :
      <Val>3.151163641308e-05</Val>
   </MatrixPattern>
</MatrixDetails>
<MatrixDetails>
   <ID>Matrix Details ID 8</ID>
   <MatrixSize>
      <Rows>1</Rows>
      <Columns>53</Columns>
      <No-of-Elements>53</No-of-Elements>
   </MatrixSize>
   <MatrixPattern>
      <Pattern>ZZ-H-TL</Pattern>
      <Val>-5.36528628733e-05</Val>
      <Val>-6.35656957828e-05</Val>
      <Val>-1.705347446301e-05</Val>
         :
         Total # of Val entries is 53
         :
      <Val>-2.152415505568e-04</Val>
   </MatrixPattern>
</MatrixDetails>
<MatrixDetails>
   <ID>Matrix Details ID 9</ID>
   <MatrixSize>
      <Rows>1</Rows>
      <Columns>53</Columns>
      <No-of-Elements>53</No-of-Elements>
   </MatrixSize>
   <MatrixPattern>
      <Pattern>ZZ-H-TL</Pattern>
      <Val>9.248392037812e-07</Val>
      <Val>1.775917630744e-06</Val>
      <Val>5.112609363163e-07</Val>
         :
         Total # of Val entries is 53
         :
      <Val>-1.181360375716e-04</Val>
   </MatrixPattern>
</MatrixDetails>
<MatrixDetails>
   <ID>Matrix Details ID 10</ID>
   <MatrixSize>
      <Rows>1</Rows>
      <Columns>53</Columns>
      <No-of-Elements>53</No-of-Elements>
   </MatrixSize>
   <MatrixPattern>
      <Pattern>ZZ-H-TL</Pattern>
```

4.4.4.4 Reduced Order Model Sample (cont'd)

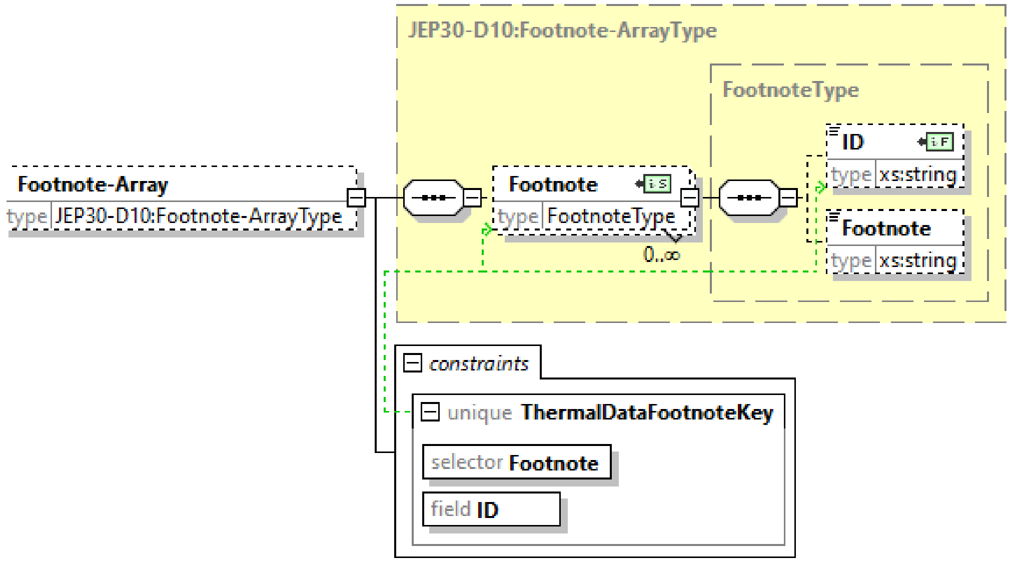
```
            <Val>-3.260413002971e-06</Val>
            <Val>-5.66493323599e-06</Val>
            <Val>-2.445477084306e-06</Val>
               :
               Total # of Val entries is 53
               :
            <Val>-3.087437434452e-04</Val>
         </MatrixPattern>
      </MatrixDetails>
</ReducedOrderModel>
```

4.4.5 Units for Thermal Data

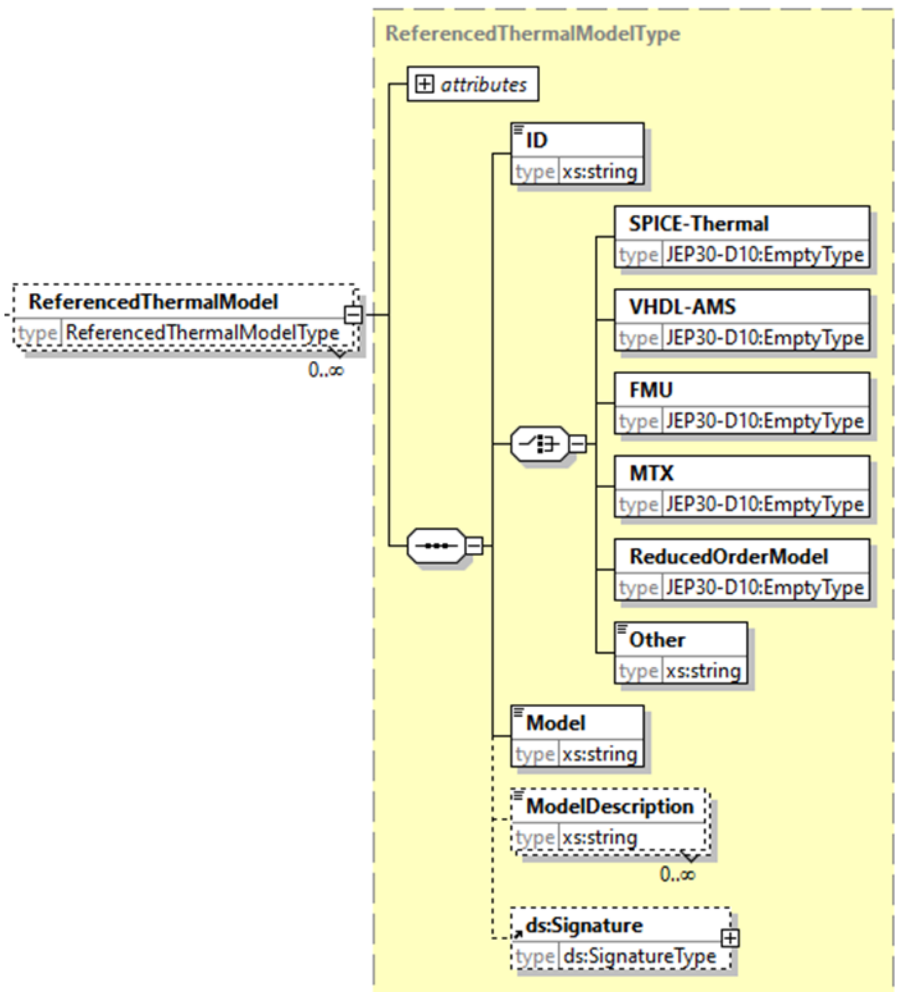
path	PartModel/ThermalSection/Thermal-Array/ThermalFamily/ThermalData/UnitsForThermalData.
diagram	
type	UnitsForThermalDataType, JEP30-D10:DimensionUOMType, JEP30-D10:HeatCapacityUOMType, JEP30-D10:SpecificHeatCapacityUOMType, JEP30-D10:MassUOMType, JEP30-D10:PowerUOMType, JEP30-D10:ThermalResistanceUOMType, JEP30-D10:TemperatureUOMType,

The units of measure values are shown in Table 2 – Thermal Metrics Graph Units UOM Enumerated Lists.

4.4.6 Footnote - Array

path	PartModel/ThermalSection/Thermal-Array/ThermalFamily/ThermalData/Footnote-Array.
diagram	
type	JEP30-D10:Footnote-ArrayType, FootnoteType.

4.5 Referenced Thermal Model

path	PartModel/ThermalSection/Thermal-Array/ReferencedThermalModel
diagram	
type	ReferencedThermalModelType, JEP30-D10:EmptyType, ds:SignatureType.

One or more references to external thermal simulation model files can be defined by the *ReferencedThermalModel* section. The *Model* element can refer to either a file name of a file that is provided together with the corresponding JEP30 xml archive or a URL definition. *ReferencedThermalModel* enables a standardized thermal simulation file format to be defined so that the importing tool can correctly interpret that file format. An *Other* file format is accommodated to account for non-standard formats where it is advised that the optional *ModelDescription* element is used to describe the format and its intended usage.

Annex A (informative) Differences between JEP30-T100 and its predecessors

This table briefly describes most of the changes made to entries that appear in this standard, JEP30-T100, compared to its predecessor; Punctuation changes may or may not be included.

Initial Issue: 1	Date: February 2018	Item Number: 11.2-938

Change Record History

Issue: A	Date: March 2023	Item Number: 11.2-938S
Description of changes		
Section 4.5 Thermal Data: Added new section for *External Model-Array*.		
Sections 4.5.1, 4.5.2.2.1, 4.5.2.2.2, :Added “Empty Type” for several elements through schema that did not have types.		
Section 4.5.2 Thermal Metrics: Re-labelled the section title to Thermal Metrics-Array. Added in a new section for “Thermal Metric Graph”. Also added in “Test Conditions” that can be applied to either the “Thermal Metrics” or the “Thermal Metrics Graph”.		
Section 4.5.2.1 Test Condition: Added new “Test Condition” section		
Section 4.5.2.3 Thermal Metric Graph: Added new section to represent thermal parametric data in graph form.		
Section 4.5.3.3: Update descriptive text on the Rectangular Node Face and the Cuboidal Node Volume		
Section 4.5.3.3.1 RectangularNodeFace: Added in “Name” element in under “RectangularNodeFace”		
Section 4.5.3.3.2 CuboidalNodeVolume: Added in “Name” element in under “CuboidalNodeVolume”		
Section 4.5.4 External Model-Array: Added new section to capture external models		

Issue: B	Date: August 2024	Item Number: 11.2-1059
Description of changes		
Section 4.1, and section 4.2: Update sections to align with modifications performed at the JEP30 parent structure		

Issue: B.01	Date: February 2025	Item Number: 11.2-1073
Description of Change		
Sections 1, 4.1, and 4.2: Update sections to align with modifications performed at the JEP30 parent structure.		

Annex A (cont'd)

Issue: C	Date: September 2025	Item Number: 11.2-1083
Description of Change		
Section 4.1 PartModel - Thermal Section: Updated images to match changes in the JEP30 parent schema		
Section 4.2 Manufacturer Part Number-Array: Updated images to match changes in the JEP30 parent schema		
Section 4.3.1 & 4.3.2 Linking the Manufacturing Part Number to Thermal Family Content and Thermal Models. Updated images.		
Section 4.4 Thermal Family: Added Reduced Oreder Models and Footnote-Array to Thermal Data. Also changed Thermal Model ID to Reference Thermal Model ID.		
Section 4.4.1 Temperature Rating – Array: Expanded temperature structure		
Section 4.4.2.1 Test Condition: Added Parameter Identity Group, Parameter Values Group type, Parameter Rule type and Test Method. Updated units values to comply with IEC definition and shared with electrical schema.		
Section 4.4.2.2 Thermal Metrics, and sub-sections: Moved footnote under the "Min Nom Max Value Set Type" as shared with other schemas.		
Section 4.4.2.2.1 Theta Metric: Added Thera Metric Parameter Identity Group under Name.		
Section 4.4.2.2.2 Psi Metric: Added Psi Parameter Identity Group under Name.		
Section 4.4.2.3 Thermal Metric Graph: Added Parameter Identity Group under Test Condition Definition. Added Thermal Axis Parameter Identity Group under Parameter Definition. Updated Graph Formula to a LaTeX or MathML rule structure. Added sub-sections for each of these structures. Updated Value to Parameters Values Group.		
Section 4.4.2.3.1 Thermal Metrics Graph Units: Update Thermal Metrics Graph Units to comply with IEC definitions. Updated GraphFormula from string to LaTeX or MathML formula.		
Section 4.4.2.3.5 Data – Array: Added optional Test Method to Data - Array. Updated Plot Test Condition with the Parameter Identity Group plus added a choice for Value Text and a LaTeX-and-MathML-RuleGroup to the Value Set Group.		
Section 4.4.3.1 DELPHI – Model: Changed Thermal Capacitance to Heat Capacity		
Section 4.4.3.5 Heat Capacity Array: Changed Thermal Capacitance to Heat Capacity		
Added new section 4.4.4 Reduced Order Models.		
Section 4.4.5 Units for Thermal Data: Moved all Units to dictionary since they are shared with other schemas. Added Table to reflect the units.		
Section 4.4.6 Added Footnote Array.		
Section 4.6 Referenced Thermal Model: Changed Thermal Model to Referenced thermal Model and added ReducedOrderModel as a new thermal model type.		
Changed signature element names to ds:Signature in all sections		

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Standard Improvement Form **JEDEC Standard No._ _JEP30-T100C_**

The purpose of this form is to provide the Technical Committees of JEDEC with input from the industry regarding usage of the subject standard. Individuals or companies are invited to submit comments to JEDEC. All comments will be collected and dispersed to the appropriate committee(s).

If you can provide input, please complete this form and return to:

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---

1. I recommend changes to the following:

☐ Requirement, clause number ____________

☐ Test method number ____________ Clause number ____________

The referenced clause number has proven to be:

☐ Unclear ☐ Too Rigid ☐ In Error

☐ Other ____________

---

2. Recommendations for correction:

---

3. Other suggestions for document improvement:

Submitted by

Name: ____________ Phone: ____________

Company: ____________ E-mail: ____________

Address: ____________

City/State/Zip: ____________ Date ____________

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