VDMA 40010-1

ICS 25.040.30; 35.240.50

Comments by 2025-08-01
Intended to replace
VDMA 40010-1:2019-07

OPC UA for Robotics –
Part 1: Vertical Integration

OPC UA für Robotik –
Teil 1: Vertikale Integration

VDMA 40010-1:2025-06 is identical with OPC 40010-1 (Release Candidate 1.01)

Application Warning Notice

This draft with date of issue 2025-04-25 is being submitted to the public for review and comment.

Because the final VDMA Specification may differ from this version, the application of this draft is subject to special agreement.

Comments are requested

– preferably as a file by e-mail to suprateek.banerjee@vdma.org

– or in paper form to VDMA e.V. ,
Lyoner Straße 18, 60528 Frankfurt.

Document comprises 127 pages

VDMA

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ISSUE REPORTING

If an error or problem is found in this specification, the UaNodeSet, or any associated supplementary files, it should be reported as an issue.

The reporting process can be found here: https://opcfoundation.org/resources/issue-tracking/

The Link to the issue tracking project for this document is here:

https://mantis.opcfoundation.org/set_project.php?project_id=<nnn>&make_default=no

<nnn> is the project_id in Mantis which is created for any document when requested by the working group. Example: https://mantis.opcfoundation.org/set_project.php?project_id=142&make_default=no is the Link for OPC 40001-* (Machinery).

If you have no Mantis Project or do not know the project_id, please send a request to TechnicalDirector@opcfoundation.org.

Foreword

Compared with the previous versions, the following changes have been made:

Version	Changes
OPC 40010-1 1.00	Initial release
OPC 40010-1 1.01	Mantis Issue ID: 5204 Problem: Fig 10 Robotics Top Level Overview Component Type Incorrect Inheritance Resolution: Figure adapted Mantis Issue ID: 5203 Problem: Figures B15-B20 -> “IsConnectedTo” Reference with wrong arrows Resolution: Figures adapted Mantis Issue ID: 5331 Problem: Figure B20 describes 2 x MotionDevice 2 Resolution: Figure adapted Mantis Issue ID: 5729 Problem: Typo in Table A.1 Resolution: Typo corrected Mantis Issue ID: 6079 Problem: References PowerTrains/Axis are wrong in Figure B.20 and B.19 Resolution: Figures adapted Mantis Issue ID: 6629 Problem: Object has invalid Parent Reference Resolution: IsConnectedTo reference deleted in MotorType and GearType, description of use of reference described in PowerTrainType NodeSet Version V1.00.01 Usage: VDMA Machinery Building Blocks for Identification Resolution: Added Profile for use of Robotics and Machinery Identification Usage examples added in Annex. Added Remote Operation Capabilities via AddIns and State Machines for System and Task Control Operation.

This specification was created by a joint working group of the OPC Foundation and VDMA.

OPC Foundation

OPC is the interoperability standard for the secure and reliable exchange of data and information in the industrial automation space and in other industries. It is platform independent and ensures the seamless flow of information among devices from multiple vendors. The OPC Foundation is responsible for the development and maintenance of this standard.

OPC UA is a platform independent service-oriented architecture that integrates all the functionality of the individual OPC Classic specifications into one extensible Framework. This multi-layered approach accomplishes the original design specification goals of:

- Platform independence: allows manufacturers independent exchange of information.
- Scalable: from an embedded microcontroller to a cloud-based infrastructure

– Secure: encryption, authentication, authorization, and auditing
– Expandable: ability to add new features including transports without affecting existing applications
– Comprehensive information modelling capabilities: for defining any model from simple to complex.

VDMA Robotics Initiative

The VDMA is the biggest mechanical engineering industry association in Europe and represents over 3,200 mainly small and medium size member companies in the engineering industry, making it one of the largest and most important industrial associations in Europe. As part of the VDMA Robotics + Automation association, VDMA Robotics unites more than 75 members: companies offering robots, components of a robot, control units and motion device system integrations. The objective of this industry-driven platform is to support the robotics industry through a wide spectrum of activities and services such as standardization, statistics, marketing, public relations, trade fair policy, networking events and representation of interests.

Under the auspices of VDMA, a companion specification for robotics is developed by leading robot manufacturers and users within the "VDMA OPC Robotics Initiative". This Working Group has the status of an international joint working group with worldwide lead to develop a companion specification for robotics and is supported by the OPC Foundation. The aim is to create an information model with object types, which enables the modelling of robotic systems according to OPC UA as an interface for higher-level control and evaluation systems (plant control, MES, cloud). Not included are "application-related" interfaces, that can also be modelled via OPC UA. These interfaces are defined in further working groups for OPC UA Companion Specifications (e.g. EUROMAP 79, Integrated Assembly Solutions (e.g. gripper), Machine Vision).

The VDMA Robotics Initiative is a working group within VDMA Robotics and was formed for the creation of this companion specification. The following members were actively involved in creating this document:

– ABB Automation GmbH
– Beckhoff Automation GmbH & Co. KG
– ENGEL AUSTRIA GmbH
– EPSON Deutschland GmbH
– fortiss – Forschungsinstitut des Freistaats Bayern
– Fraunhofer IGCV
– KEBA AG
– KraussMaffei Automation GmbH
– KUKA Deutschland GmbH
– Mitsubishi Electric Europe B.V.
– SIEMENS AG
– Unified Automation GmbH
– YASKAWA Europe GmbH

The following members provided further input for the working group:

– AUDI AG
– B+R automatizace, spol. s r.o.
– Daimler AG
– Microsoft Corporation
– Volkswagen AG

1 Scope

This document specifies an OPC UA Information Model for the representation of a complete motion device system as an interface for higher-level control and evaluation systems. A motion device system consists out of one or more motion devices, which can be any existing or future robot type (e.g. industrial robots, mobile robots), kinematics or manipulator as well as their control units and other peripheral components.

Additionally, this document shows in Annex C the use of the OPC 40001-1 - UA CS for Machinery Part 1 - Basic Building Blocks together with the Information Model described in this part.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

– ISO 8373:2012 Robots and robotic devices — Vocabulary

– ISO 10218-1:2011 Robots and robotic devices — Safety requirements for industrial robots — Part 1: Robots

– OPC 10000-3, *OPC Unified Architecture - Part 3: Address Space Model*

  http://www.opcfoundation.org/UA/Part3/

– OPC 10000-4, *OPC Unified Architecture - Part 4: Services*

  http://www.opcfoundation.org/UA/Part4/

– OPC 10000-5, *OPC Unified Architecture - Part 5: Information Model*

  http://www.opcfoundation.org/UA/Part5/

– OPC 10000-100, *OPC Unified Architecture - Part 100: Devices*

  http://www.opcfoundation.org/UA/Part100/

– OPC 40001-1: *OPC UA for Machinery - Basic Building Blocks*

  http://opcfoundation.org/UA/Machinery/

3 Terms, definitions, and conventions

For the purposes of this document, the following terms and definitions apply.

3.1 Overview

It is assumed that the reader of this document understands the basic concepts of OPC UA information modelling and the referenced documents. This specification will use these concepts to describe the Robotics Information Model.

Note that OPC UA terms and terms defined in this specification are written in *italics* in the specification.

3.2 Terms

Table 1 – Terms and definitions

Term	Definition of Term
Asset management	The management of the maintenance of physical assets of an organization throughout each asset's lifecycle.
Automatic mode	Operational mode in which the robot control system operates in accordance with the task programme (ISO 10218).
Axis	The mechanical joint (ISO 8373). Joint is used as a synonym for axis.
Condition monitoring	Acquisition and processing of information and data that indicate the state of a machine over time (ISO 13372:2012).
Controller	Controlling unit of one or more motion devices. A controller can be e.g. a specific control cabinet or a PLC.
Industrial robot	Automatically controlled, reprogrammable multipurpose manipulator, programmable in three or more axes, which can be either fixed in place or mobile for use in industrial automation applications (ISO 10218).
Industrial Robot System	system comprising industrial robot, end effectors and any machinery, equipment, devices, external auxiliary axes or sensors supporting the robot performing its task (ISO 8373)
Joint	See Axis definition.
Manipulator	Machine in which the mechanism usually consists of a series of segments, jointed or sliding relative to one another, for the purpose of grasping and/or moving objects (pieces or tools) usually in several degrees of freedom (ISO 8373)
Manual mode	Control state that allows for the direct control by an operator (ISO 10218).
Motion device	A motion device has as least one axis and is a multifunctional manipulator designed to move material, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks. Examples are an industrial robot, positioner, or mobile platform.
Motion device system	The entire system in which one or more motion devices and one or more controllers are integrated, e.g. a robot system.
Operating mode	State of the robot control system (ISO 8373), i.e. Controller
Operational mode	ISO 10218-1:2011 Ch.5.7 Operational Modes
Operator	Person designated to start, monitor, and stop the intended operation of a robot or robot system (ISO 8373).
Teach pendant	Hand-held unit linked to the control system with which a robot can be programmed or moved (ISO 8373).
Power train	The composition of switch gears, fuses, transformers, converters, drives, motors, encoders and gears to convert power to motion of one or more axis.

Predictive maintenance	Maintenance performed as governed by condition monitoring programmes (ISO 13372:2012)
Preventive maintenance	Maintenance performed according to a fixed schedule, or according to a prescribed criterion, that detects or prevents degradation of a functional structure, system or component, in order to sustain or extend its useful life.
Protective stop	Type of interruption of operation that allows a cessation of motion for safeguarding purposes, and which retains the programme logic to facilitate a restart (ISO 10218).
Safe state	A defined state of the robot which is free of hazards
Safety function	A safety rated function which will signal the controller to bring motion devices to a safe state, e.g. emergency stop, protective stop
Safety states	Set of safety functions and states which are related to a motion device system.
Software	Runtime software or firmware of the controller. In ISO 8373, this is called control program, and is defined like this: Inherent set of control instructions which defines the capabilities, actions and responses of a robot or robot system NOTE This type of program is usually generated before installation and can only be modified thereafter by the manufacturer.
Task control	Execution engine that loads and runs task programs. Synomyms for a task control are a sequence control or a flow control.
Task program	Program running on the task control. From ISO 8373: Set of instructions for motion and auxiliary functions that define the specific intended task of the robot or robot system NOTE 1 This type of program is usually generated after the installation of the robot and can be modified by a trained person under defined conditions. NOTE 2 An application is a general area of work; a task is specific within the application.
Task module	A module is a self-contained unit of code that can be reused across different parts of a program or in different programs.
Tool center point	Point defined for a given application with regards to the mechanical interface coordinate system (ISO 8373)
User level	Current assigned user role.
User roles	User roles consist of specific permissions to access features within a software. Users can be assigned to roles.
Virtual axis	Virtual axis has no power trains directly assigned.

Annex B contains examples of the described terms.

3.3 Abbreviations

Table 2 – Abbreviations and definitions

Abbreviation	**Definition of Abbreviation**
CPU	Central Processing Unit
DOF	Degrees of freedom
ERP	Enterprise Resource Planning
HMI	Human Machine Interface
HTTP	Hypertext Transfer Protocol
MES	Manufacturing Execution System
OPC	Open Platform Communications
OPC UA	OPC Unified Architecture
OPC 10000-100	OPC Unified Architecture for Devices (DI) OPC Unified Architecture - Part 100 – Devices
PLC	Programmable logic controller
PMS	Preventive Maintenance System
TCP	Tool center point
TCP/IP	Transmission Control Protocol/Internet Protocol
TCS	Tool Coordinate System
UPS	Uninterruptible Power Supply
URL	Uniform resource locator
URI	A uniform resource identifier (URI) is a string of characters used to identify names or resources on the Internet. The URI describes the mechanism used to access resources, the computers on which resources are housed and the names of the resources on each computer.
VDMA	The Mechanical Engineering Industry Association (VDMA) represents more than 3,200 member companies in the SME-dominated mechanical and systems engineering industry in Germany and Europe.

3.4 Conventions used in this document

3.4.1 Conventions for Node descriptions

Node definitions are specified using tables (see Table 4).

Attributes are defined by providing the *Attribute* name and a value, or a description of the value.

References are defined by providing the *ReferenceType* name, the *BrowseName* of the *TargetNode* and its *NodeClass*.

– If the *TargetNode* is a component of the *Node* being defined in the table, the *Attributes* of the composed *Node* are defined in the same row of the table.

The *DataType* is only specified for *Variables*; “[<number>]” indicates a single-dimensional array, for multi-dimensional arrays the expression is repeated for each dimension (e.g. [2][3] for a two-dimensional array). For all arrays, the *ArrayDimensions* is set as identified by <number> values. If no <number> is set, the corresponding dimension is set to 0, indicating an unknown size. If no number is provided at all the *ArrayDimensions* can be omitted. If no brackets are provided, it identifies a scalar *DataType* and the *ValueRank* is set to the corresponding value (see OPC 10000-3). In addition, *ArrayDimensions* is set to null or is omitted. If it can be Any or ScalarOrOneDimension, the value is put into “{<value>}”, so either “{Any}” or “{ScalarOrOneDimension}” and the *ValueRank* is set to the corresponding value (see OPC 10000-3) and the *ArrayDimensions* is set to null or is omitted. Examples are given Table 3.

Table 3 – Examples of Data Types

Notation	Data-Type	Value-Rank	ArrayDimensions	Description
Int32	Int32	-1	omitted or null	A scalar Int32.
Int32[]	Int32	1	omitted or {0}	Single-dimensional array of Int32 with an unknown size.
Int32[][]	Int32	2	omitted or {0,0}	Two-dimensional array of Int32 with unknown sizes for both dimensions.
Int32[3][]	Int32	2	{3,0}	Two-dimensional array of Int32 with a size of 3 for the first dimension and an unknown size for the second dimension.
Int32[5][3]	Int32	2	{5,3}	Two-dimensional array of Int32 with a size of 5 for the first dimension and a size of 3 for the second dimension.
Int32{Any}	Int32	-2	omitted or null	An Int32 where it is unknown if it is scalar or array with any number of dimensions.
Int32{ScalarOrOneDimension}	Int32	-3	omitted or null	An Int32 where it is either a single-dimensional array or a scalar.

– The TypeDefinition is specified for *Objects* and *Variables*.

– The TypeDefinition column specifies a symbolic name for a *NodeId*, i.e. the specified *Node* points with a *HasTypeDefinition Reference* to the corresponding *Node*.

– The *ModellingRule* of the referenced component is provided by specifying the symbolic name of the rule in the *ModellingRule* column. In the *AddressSpace*, the *Node* shall use a *HasModellingRule Reference* to point to the corresponding *ModellingRule Object*.

If the *NodeId* of a *DataType* is provided, the symbolic name of the *Node* representing the *DataType* shall be used.

Nodes of all other *NodeClasses* cannot be defined in the same table; therefore, only the used *ReferenceType*, their *NodeClass* and their *BrowseName* are specified. A reference to another part of this document points to their definition.

Table 4 illustrates the table. If no components are provided, the DataType, TypeDefinition and ModellingRule columns may be omitted and only a Comment column is introduced to point to the *Node* definition.

Table 4 – Type Definition Table

Attribute	Value				
Attribute name	Attribute value. If it is an optional Attribute that is not set "--"will be used.				
References	**NodeClass**	**BrowseName**	**DataType**	**TypeDefinition**	**ModellingRule**
ReferenceType name	*NodeClass* of the Target*Node*.	*BrowseName* of the target *Node*. If the *Reference* is to be instantiated by the server, then the value of the target Node's BrowseName is "--".	*DataType* of the referenced *Node*, only applicable for *Variables*.	*TypeDefinition* of the referenced *Node*, only applicable for *Variables* and *Objects*.	Referenced *ModellingRule* of the referenced *Object*.
NOTE Notes referencing footnotes of the table content.					

Components of Nodes can be complex that is containing components by themselves. The TypeDefinition, NodeClass, DataType and ModellingRule can be derived from the type definitions, and the symbolic name can be created as defined in chapter 3.4.3.1. Therefore, those containing components are not explicitly specified; they are implicitly specified by the type definitions.

3.4.2 NodeIds and BrowseNames

3.4.2.1 NodeIds

The *NodeIds* of all *Nodes* described in this standard are only symbolic names. **Fehler! Verweisquelle konnte n icht gefunden werden.** defines the actual *NodeIds*.

The symbolic name of each *Node* defined in this specification is its *BrowseName*, or, when it is part of another *Node*, the *BrowseName* of the other *Node*, a ".", and the *BrowseName* of itself. In this case "part of" means that the whole has a *HasProperty* or *HasComponent Reference* to its part. Since all *Nodes* not being part of another *Node* have a unique name in this specification, the symbolic name is unique.

The namespace for all *NodeIds* defined in this specification is defined in **Fehler! Verweisquelle konnte nicht gefunden werden.**. The namespace for this NamespaceIndex is *Server*-specific and depends on the position of the namespace URI in the server namespace table.

Note that this specification not only defines concrete *Nodes*, but also requires that some *Nodes* shall be generated, for example one for each *Session* running on the *Server*. The *NodeIds* of those *Nodes* are *Server*-specific, including the namespace. But the NamespaceIndex of those *Nodes* cannot be the NamespaceIndex used for the *Nodes* defined in this specification, because they are not defined by this specification but generated by the *Server*.

3.4.2.2 BrowseNames

The text part of the BrowseNames for all Nodes defined in this specification is specified in the tables defining the Nodes. The NamespaceIndex for all BrowseNames defined in this specification is defined in Annex A.

If the BrowseName is not defined by this specification, a namespace index prefix like '0:EngineeringUnits' or '2:DeviceRevision' is added to the BrowseName. This is typically necessary if a property of another specification is overwritten or used in the OPC UA types defined in this specification. Table 148 provides a list of namespaces and their indexes as used in this specification.

3.4.3 Common Attributes

3.4.3.1 General

The *Attributes* of *Nodes*, their *DataTypes* and descriptions are defined in OPC 10000-3. Attributes not marked as optional are mandatory and shall be provided by a *Server*. The following tables define if the *Attribute* value is defined by this specification or if it is server specific.

For all *Nodes* specified in this specification, the *Attributes* named in Figure 5 shall be set as specified in the table.

Table 5 – Common Node Attributes

Attribute	**Value**
DisplayName	The *DisplayName* is a *LocalizedText*. Each server shall provide the *DisplayName* identical to the *BrowseName* of the *Node* for the LocaleId "en". Whether the server provides translated names for other LocaleIds is server specific.
Description	Optionally a server-specific description is provided.
NodeClass	Shall reflect the *NodeClass* of the *Node.*
NodeId	The *NodeId* is described by *BrowseNames* as defined in 3.4.2.1.
WriteMask	Optionally the *WriteMask Attribute* can be provided. If the *WriteMask Attribute* is provided, it shall set all non-server-specific *Attributes* to not writable. For example, the *Description Attribute* may be set to writable since a *Server* may provide a server-specific description for the *Node*. The *NodeId* shall not be writable, because it is defined for each *Node* in this specification.
UserWriteMask	Optionally the *UserWriteMask Attribute* can be provided. The same rules as for the *WriteMask Attribute* apply.
RolePermissions	Optionally server-specific role permissions can be provided.
UserRolePermissions	Optionally the role permissions of the current Session can be provided. The value is server-specific and depend on the *RolePermissions Attribute* (if provided) and the current *Session*.
AccessRestrictions	Optionally server-specific access restrictions can be provided.

3.4.3.2 Objects

For all *Objects* specified in this specification, the *Attributes* named in Table 6 shall be set as specified in the table. The definitions for the *Attributes* can be found in OPC 10000-3.

Table 6 – Common Object Attributes

Attribute	Value
EventNotifier	Whether the *Node* can be used to subscribe to *Events* or not is server specific.

3.4.3.3 Variables

For all *Variables* specified in this specification, the *Attributes* named in Table 7 shall be set as specified in the table. The definitions for the *Attributes* can be found in OPC 10000-3.

Table 7 – Common Variable Attributes

Attribute	Value
MinimumSamplingInterval	Optionally, a server-specific minimum sampling interval is provided.
AccessLevel	The access level for *Variables* used for type definitions is server-specific, for all other *Variables* defined in this specification, the access level shall allow reading; other settings are server-specific.
UserAccessLevel	The value for the *UserAccessLevel Attribute* is server specific. It is assumed that all *Variables* can be accessed by at least one user.
Value	For *Variables* used as *InstanceDeclarations,* the value is server-specific; otherwise, it shall represent the value described in the text.
ArrayDimensions	If the *ValueRank* does not identify an array of a specific dimension (i.e. *ValueRank* <= 0) the *ArrayDimensions* can either be set to null or the *Attribute* is missing. This behaviour is server specific. If the *ValueRank* specifies an array of a specific dimension (i.e. *ValueRank* > 0) then the *ArrayDimensions Attribute* shall be specified in the table defining the *Variable*.
Historizing	The value for the *Historizing Attribute* is server specific.
AccessLevelEx	If the *AccessLevelEx Attribute* is provided, it shall have the bits 8, 9, and 10 set to 0, meaning that read and write operations on an individual *Variable* are atomic, and arrays can be partly written.

3.4.3.4 VariableTypes

For all *VariableTypes* specified in this specification, the *Attributes* named in Table 8 be set as specified in the table. The definitions for the *Attributes* can be found in OPC 10000-3.

Table 8 – Common VariableType Attributes

Attributes	Value
Value	Optionally a server-specific default value can be provided.
ArrayDimensions	If the *ValueRank* does not identify an array of a specific dimension (i.e. *ValueRank* <= 0) the *ArrayDimensions* can either be set to null or the *Attribute* is missing. This behaviour is server specific. If the *ValueRank* specifies an array of a specific dimension (i.e. *ValueRank* > 0) then the *ArrayDimensions Attribute* shall be specified in the table defining the *VariableType*.

3.4.3.5 Methods

For all *Methods* specified in this specification, the *Attributes* named in Table 9 shall be set as specified in the table. The definitions for the *Attributes* can be found in OPC 10000-3.

Table 9 – Common Method Attributes

Attributes	Value
Executable	All *Methods* defined in this specification shall be executable (*Executable Attribute* set to "True") unless it is defined differently in the *Method* definition.
UserExecutable	The value of the *UserExecutable Attribute* is server specific. It is assumed that all *Methods* can be executed by at least one user.

3.4.3.6 Expanding conventions

For the following illustrations, the legend is as follows:

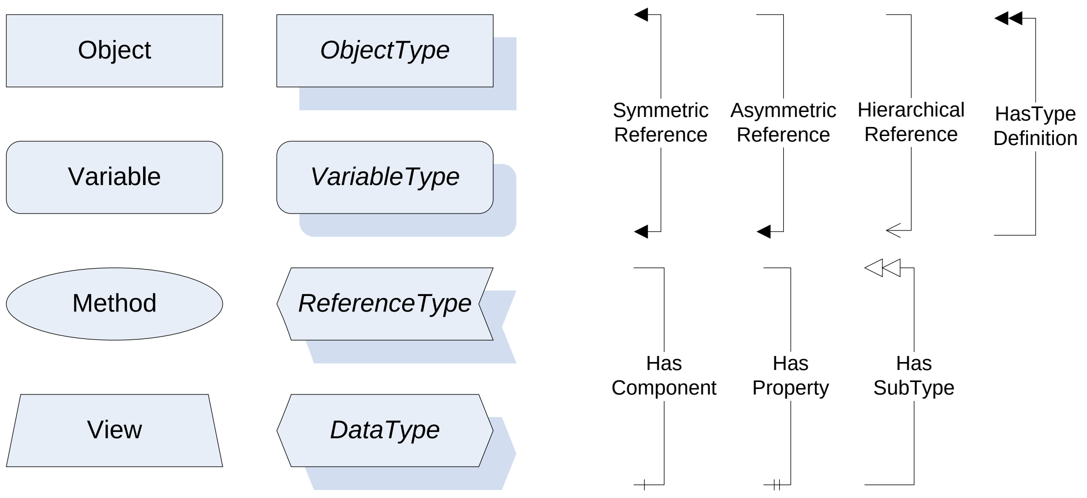


Figure 1 – OPC UA standard definitions

Additional definitions:

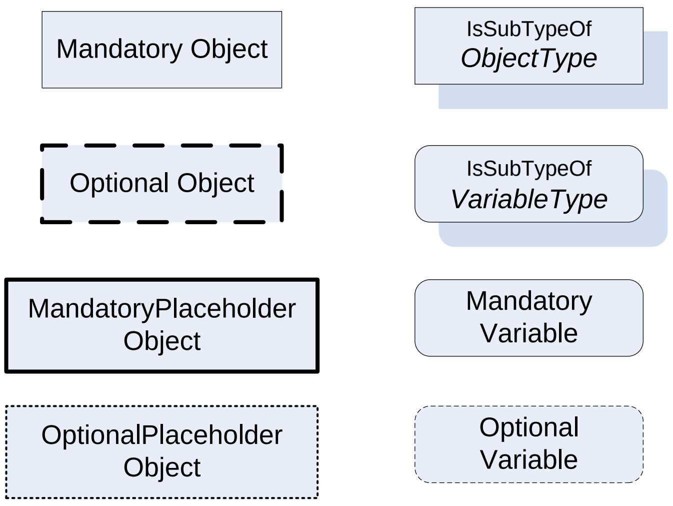


Figure 2 – OPC UA and additional definitions

Table 10 describes the additional definitions.

Table 10 – Description of additional definitions

Node element	Graphical representation	Definition of node element
Mandatory Object	Rectangular Frame	A mandatory object with its type definition
Optional Object	Rectangular bold dashed Frame	An optional object with its type definition
Mandatory Placeholder Object	Rectangular bold Frame	A mandatory placeholder for objects with its type definition
Optional Placeholder Object	Rectangular dotted Frame	An optional placeholder for objects with its type definition
ObjectType	Rectangular Frame with shadow	An object type with its type definition
VariableType	Rounded rectangular Frame with shadow	A variable type with its type definition
Mandatory Variable	Rectangular Frame with rounded corners	A mandatory variable with its type definition
Optional Variable	Dotted rectangular Frame with rounded corners	An optional variable with its type definition

3.4.3.7 Handling of not supported properties

In case of not supported *Properties* the following default shall be provided:

– *Properties* with *DataType* String: **empty string**

– *Properties* with *DataType* LocalizedText: **empty text field**

– *RevisionCounter Property*: **- 1**

4 General information to OPC Robotics and OPC UA

4.1 Introduction to OPC Robotics

The OPC Robotics specification describes an information model, which aims to cover all current and future robotic systems such as:

– Industrial robots

– Mobile robots

– Several control units

– Peripheral devices, which do not have their own OPC UA server.

Part 1 provides information for asset management and condition monitoring. In future parts, the information model will be extended to cover more use cases.

The following functionalities are covered:

– Provision of asset configuration and runtime data of a running motion device system and its components e.g. manipulators, axes, motors, controllers, and software

Following functions are not included and might be covered in future parts:

– A messaging mechanism covered by events and alarms to provide conditions.

– A state machine to inform about the status of task controls and to interact via methods.

– The possibility for the operator to store customer specific information inside the motion device system e.g. location, cost centre, ERP data, ...

4.2 Introduction to OPC Unified Architecture

4.2.1 What is OPC UA?

OPC UA is an open and royalty free set of standards designed as a universal communication protocol. While there are numerous communication solutions available, OPC UA has key advantages:

– A state of art security model (see OPC 10000-2).

– A fault tolerant communication protocol.

– An information modelling Framework that allows application developers to represent their data in a way that makes sense to them.

OPC UA has a broad scope which delivers for economies of scale for application developers. This means that a larger number of high-quality applications at a reasonable cost are available.

The OPC UA model is scalable from small devices to ERP systems. OPC UA *Servers* process information locally and then provide that data in a consistent format to any application requesting data - ERP, MES, PMS, Maintenance Systems, HMI, Smartphone, or a standard Browser, for example. For a more complete overview see OPC 10000-1.

4.2.2 Basics of OPC UA

As an open standard, OPC UA is based on standard internet technologies, like TCP/IP, HTTP, Web Sockets.

As an extensible standard, OPC UA provides a set of *Services* (see OPC 10000-4) and a basic information model Framework. This Framework provides an easy manner for creating and exposing vendor defined information in a standard way. More importantly all OPC UA *Clients* are expected to be able to discover and use vendor-defined information. This means OPC UA users can benefit from the economies of scale that come with generic visualization and historical applications. This specification is an example of an OPC UA *Information Model* designed to meet the needs of developers and users.

OPC UA *Clients* can be any consumer of data from another device on the network to browser based thin clients and ERP systems. The full scope of OPC UA applications is shown in Figure 3.

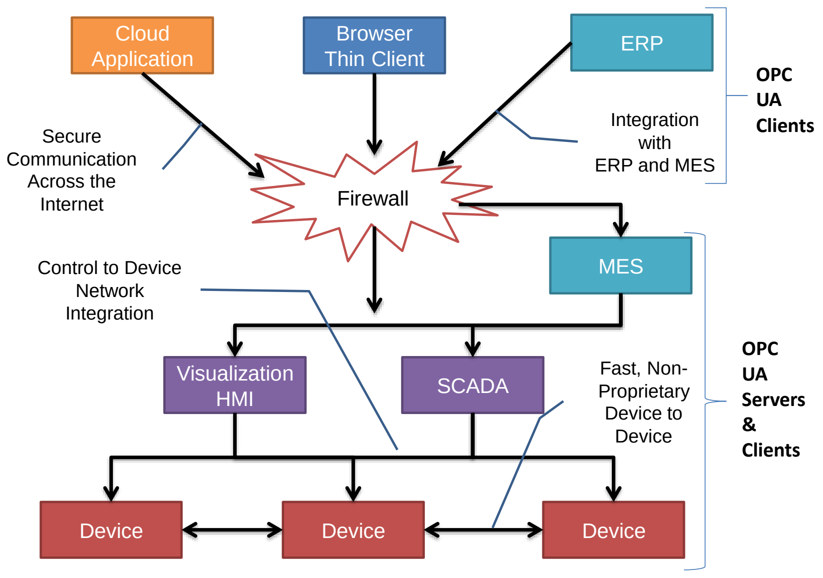

Cloud Application
Browser Thin Client
ERP
OPC UA Clients
Secure Communication Across the Internet
Integration with ERP and MES
Firewall
MES
Control to Device Network Integration
Visualization HMI
SCADA
Fast, Non-Proprietary Device to Device
OPC UA Servers & Clients
Device
Device
Device

Figure 3 – The Scope of OPC UA within an Enterprise

OPC UA provides a robust and reliable communication infrastructure having mechanisms for handling lost messages, failover, heartbeat, etc. With its binary encoded data, it offers a high-performing data exchange solution. Security is built into OPC UA as security requirements become increasingly important especially since environments are connected to the office network or the internet and attackers are starting to focus on automation systems.

4.2.3 Information modelling in OPC UA

4.2.3.1 Concepts

OPC UA provides a Framework that can be used to represent complex information as *Objects* in an *AddressSpace* which can be accessed with standard services. These *Objects* consist of *Nodes* connected by *References*. Different classes of *Nodes* convey different semantics. For example, a *Variable Node* represents a value that can be read or written. The *Variable Node* has an associated *DataType* that can define the actual value, such as a string, float, structure etc. It can also describe the *Variable* value as a variant. A *Method Node* represents a function that can be called. Every *Node* has a number of *Attributes* including a unique identifier called *NodeId* and non-localized name called *BrowseName*. An *Object* representing a 'Reservation' is shown in Figure 4.

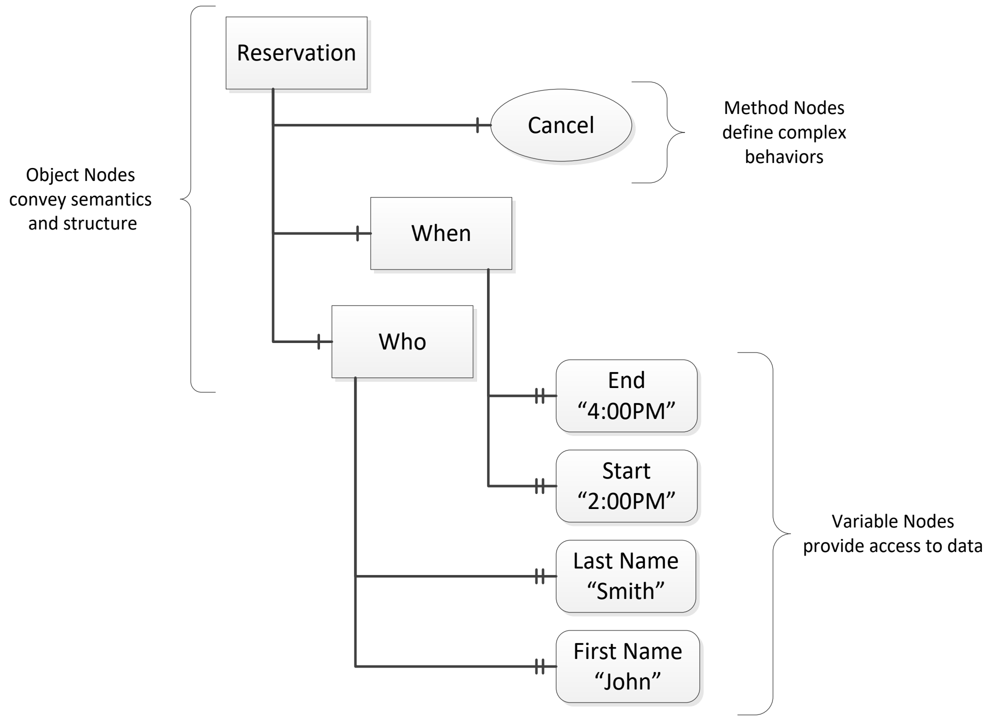

Reservation
Cancel
Method Nodes define complex behaviors
Object Nodes convey semantics and structure
When
Who
End "4:00PM"
Start "2:00PM"
Last Name "Smith"
First Name "John"
Variable Nodes provide access to data

Figure 4 – A Basic Object in an OPC UA Address Space

Object and *Variable Nodes* represent instances and they always reference a *TypeDefinition* (*ObjectType* or *VariableType*) *Node* which describes their semantics and structure. Figure 5 illustrates the relationship between an instance and its *TypeDefinition*.

The type *Nodes* are templates that define all the children that can be present in an instance of the type. In the example in Figure 5 the PersonType *ObjectType* defines two children: First Name and Last Name. All instances of PersonType are expected to have the same children with the same *BrowseNames*. Within a type the *BrowseNames* uniquely identifies the children. This means *Client* applications can be designed to search for children based on the *BrowseNames* from the type instead of *NodeIds*. This eliminates the need for manual reconfiguration of systems if a *Client* uses types that multiple *Servers* implement.

OPC UA also supports the concept of sub-typing. This allows a modeller to take an existing type and extend it. There are rules regarding sub-typing defined in OPC 10000-3, but in general they allow the extension of a given type or the restriction of a *DataType*. For example, the modeller may decide that the existing *ObjectType* in some cases needs an additional *Variable*. The modeller can create a subtype of the *ObjectType* and add the *Variable*. A *Client* that is expecting the parent type can treat the new type as if it were of the parent type. Regarding *DataTypes*, subtypes can only restrict. If a *Variable* is defined to have a numeric value, a sub type could restrict it to a float.

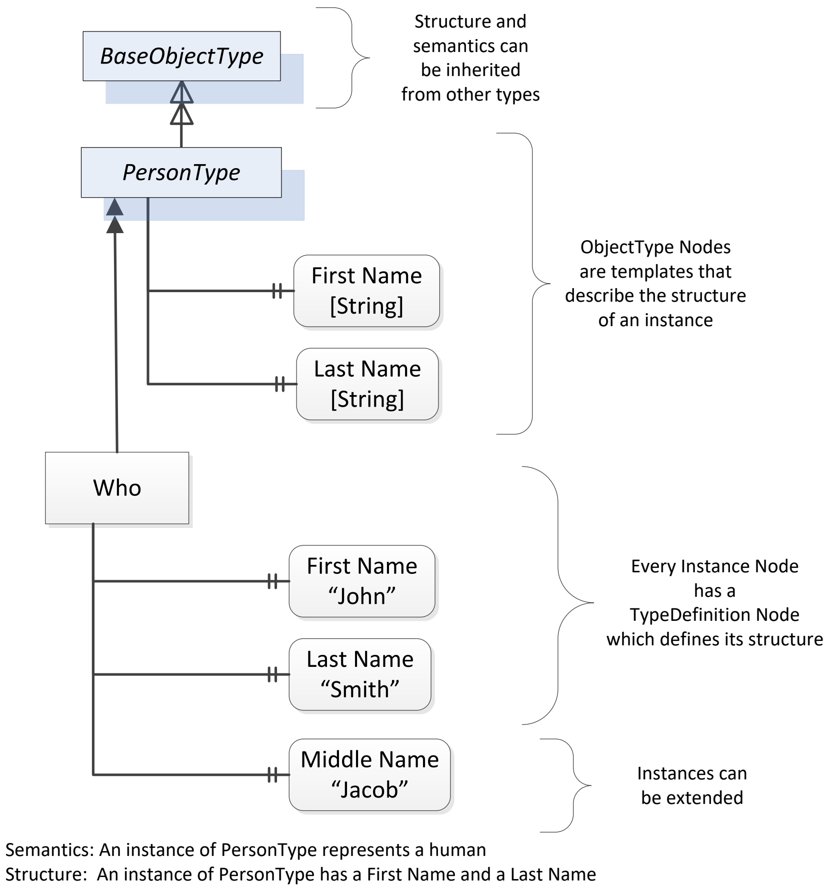

BaseObjectType
Structure and semantics can be inherited from other types
PersonType
First Name [String]
Last Name [String]
ObjectType Nodes are templates that describe the structure of an instance
Who
First Name “John”
Last Name “Smith”
Every Instance Node has a TypeDefinition Node which defines its structure
Middle Name “Jacob”
Instances can be extended
Semantics: An instance of PersonType represents a human
Structure: An instance of PersonType has a First Name and a Last Name

Figure 5 – The Relationship between Type Definitions and Instances

References allow *Nodes* to be connected in ways that describe their relationships. All *References* have a *ReferenceType* that specifies the semantics of the relationship. *References* can be hierarchical or non-hierarchical. Hierarchical references are used to create the structure of *Objects* and *Variables*. Non-hierarchical are used to create arbitrary associations. Applications can define their own *ReferenceType* by creating subtypes of an existing *ReferenceType*. Subtypes inherit the semantics of the parent but may add additional restrictions. Figure 6 depicts several *References,* connecting different *Objects*.

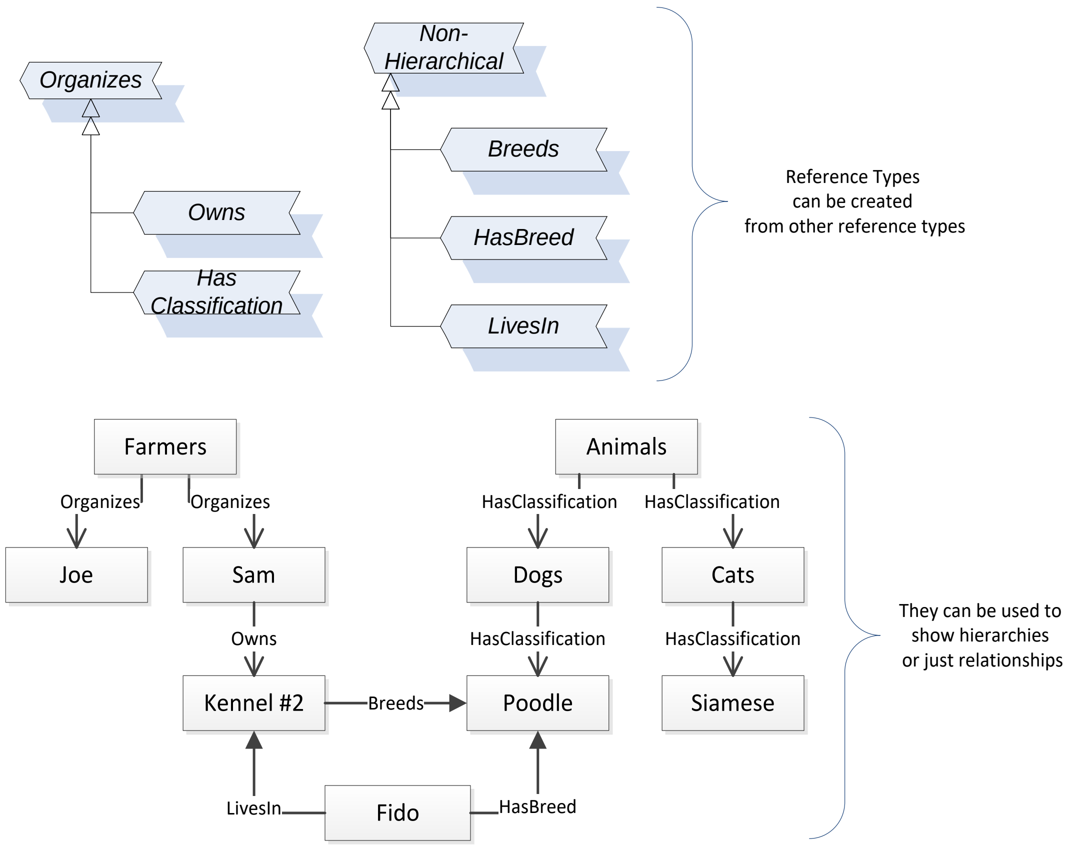


Figure 6 – Examples of References between Objects

The figures above use a notation that was developed for the OPC UA specification. The notation is summarized in Figure 7. UML representations can also be used; however, the OPC UA notation is less ambiguous because there is a direct mapping from the elements in the figures to *Nodes* in the *AddressSpace* of an OPC UA *Server*.

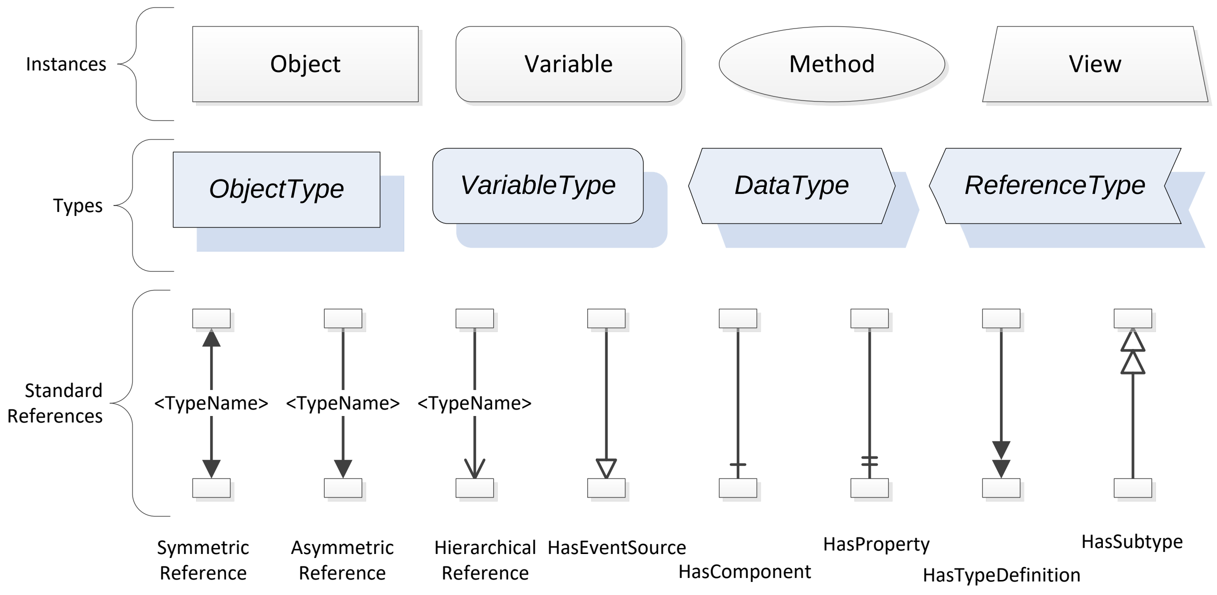


Figure 7 – The OPC UA Information Model Notation

A complete description of the different types of Nodes and References can be found in OPC 10000-3 and the base structure is described in OPC 10000-5.

OPC UA specification defines a very wide range of functionality in its basic information model. It is not expected that all *Clients* or *Servers* support all functionality in the OPC UA specifications. OPC UA includes the concept of *Profiles*, which segment the functionality into testable certifiable units. This allows the definition of functional subsets (that are expected to be implemented) within a companion specification. The *Profiles* do not restrict functionality but generate requirements for a minimum set of functionality (see OPC 10000-7).

4.2.3.2 Namespaces

OPC UA allows information from many different sources to be combined into a single coherent *AddressSpace*. Namespaces are used to make this possible by eliminating naming and id conflicts between information from different sources. Namespaces in OPC UA have a globally unique string called a NamespaceUri and a locally unique integer called a NamespaceIndex. The NamespaceIndex is only unique within the context of a *Session* between an OPC UA *Client* and an OPC UA *Server*. The *Services* defined for OPC UA use the NamespaceIndex to specify the Namespace for qualified values.

There are two types of values in OPC UA that are qualified with Namespaces: NodeIds and QualifiedNames. NodeIds are globally unique identifiers for *Nodes*. This means the same *Node* with the same NodeId can appear in many *Servers*. This, in turn, means Clients can have built in knowledge of some *Nodes*. OPC UA *Information Models* define globally unique *NodeIds* for the *TypeDefinitions* defined by the *Information Model*.

QualifiedNames are non-localized names qualified with a Namespace. They are used for the *BrowseNames* of *Nodes* and allow the same names to be used by different information models without conflict. *TypeDefinitions* are not allowed to have children with duplicate *BrowseNames*; however, instances do not have that restriction.

4.2.3.3 Companion Specifications

An OPC UA companion specification for an industry specific vertical market describes an *Information Model* by defining *ObjectTypes*, *VariableTypes*, *DataTypes* and *ReferenceTypes* that represent the concepts used in the vertical market, and potentially also well-defined Objects as entry points into the AddressSpace.

5 Use Cases

Part 1 of this companion specification describes an interface that provides access to asset management and condition monitoring data of motion device systems. Based on the provided data the following use cases are supported:

1) Supervision: With the provided data by the companion specification the robot system can be supervised and monitored. Functional analysis of individual robot systems within the factory ground is possible. During production phase the companion specification provides data about the operational and safety states as well as process data.
2) Condition monitoring: Condition monitoring is the process of determining the condition of machinery while in operation, to identify a significant change which is indicative of a developing fault. This is a major component of Predictive Maintenance where the maintenance is scheduled to shorten the downtime. The typical parameters needed for condition monitoring like motor temperature, load, on time are provided by the companion specification for robotics.
3) Asset management: The companion specification for robotics provides detailed information of the main electrical and mechanical parts like part number, brand name, serial number etc. With these data an effective maintenance is possible because the technician knows in advance which parts need to be changed and can be prepared.
4) Remote operation: The companion specification provides state machines at the controller and the task control level to provide remote operation capability via OPC UA. This includes, upload, download, loading, unloading, starting, stopping of robot programs, handling conditions etc.

Figure 8 shows the communication structure with OPC UA.

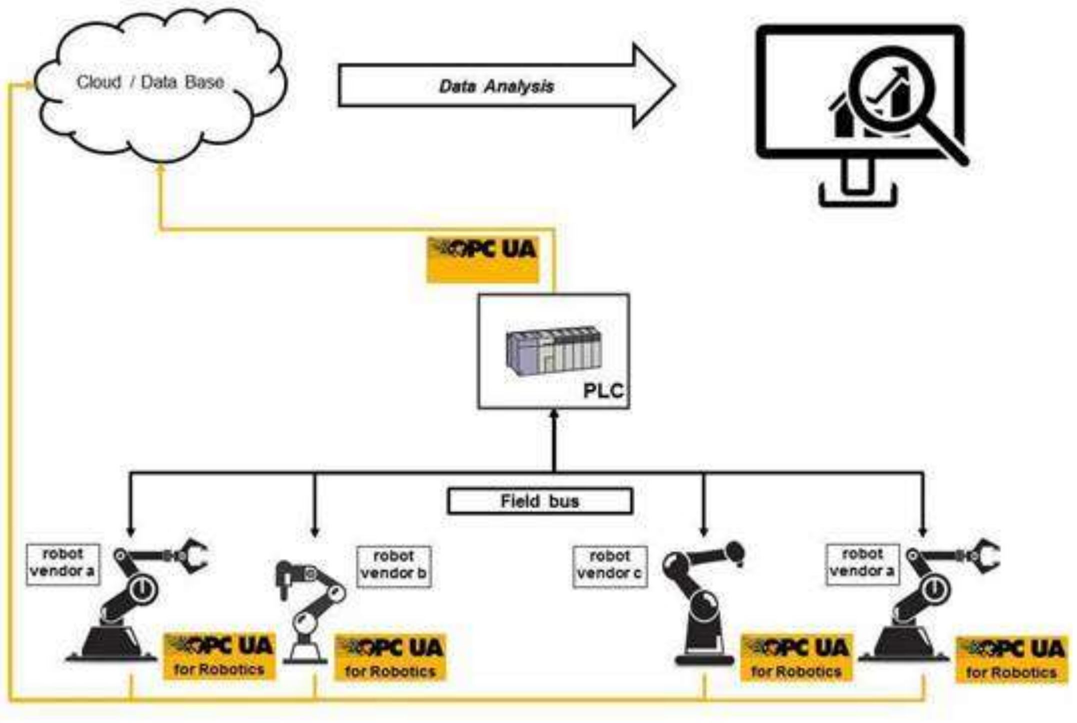


Figure 8 – Communication structure with OPC UA

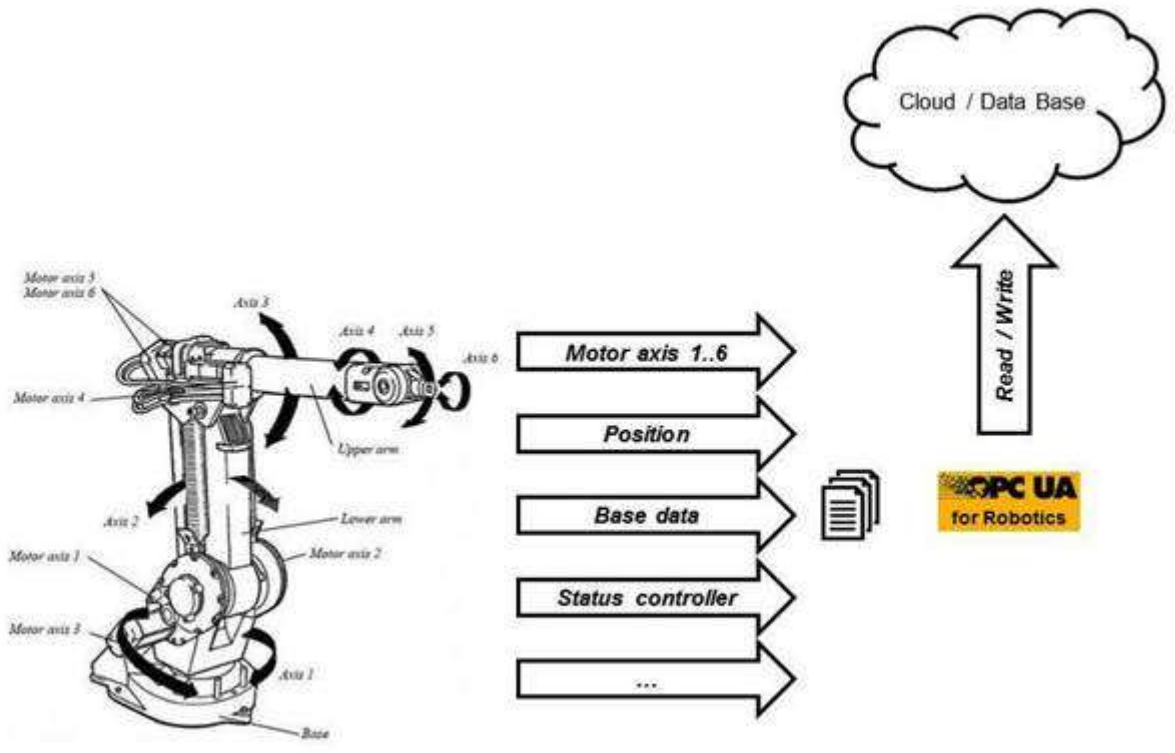


Figure 9 – OPC Robotics describes the semantic self-description.

6 OPC Robotics Information Model overview

The *MotionDeviceSystemType* as a subtype of the *ComponentType* (OPC UA for Devices) is used as the root object representing the motion device system with all its subcomponents, see Figure 10.

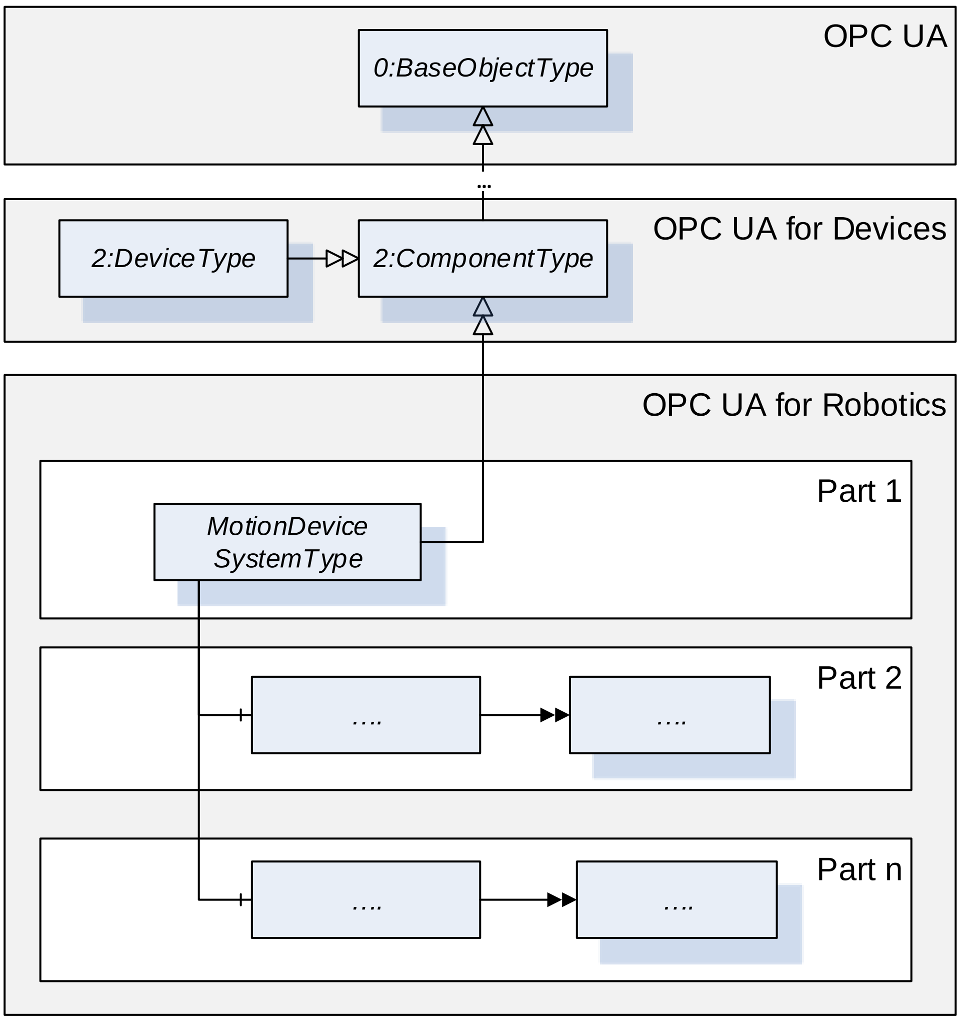


Figure 10 – OPC Robotics top level view.

Figure 11 shows the main objects and the relations between them in an abstract view.

In Part 1 in general all variables and properties are read only unless stated otherwise in the description. A vendor can decide to provide variables or properties as writeable by client side as well.

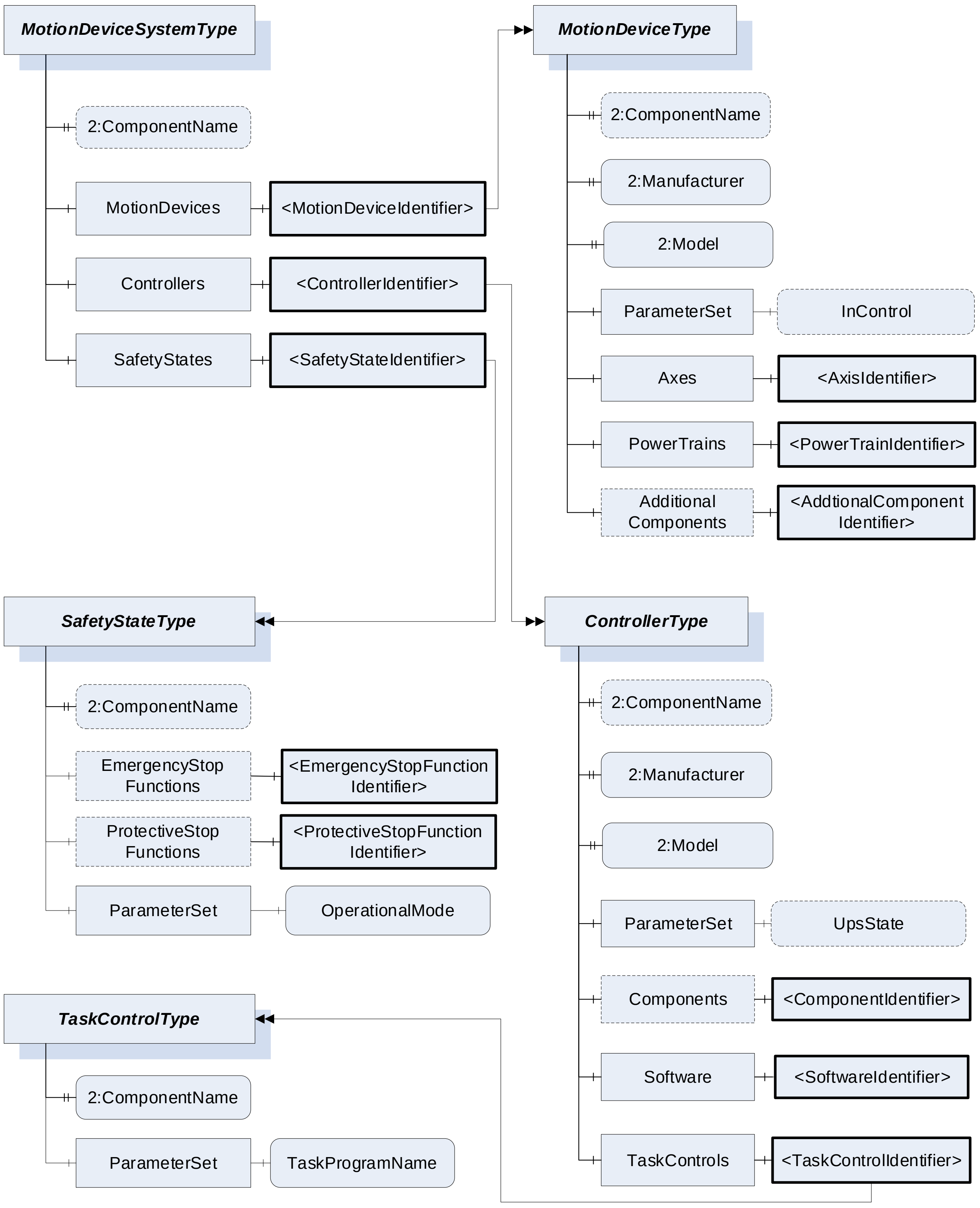


Figure 11 – OPC Robotics overview.

7 OPC UA ObjectTypes

7.1 MotionDeviceSystemType ObjectType Definition

7.1.1 Overview

The *MotionDeviceSystemType* provides a representation of a motion device system as an entry point to the OPC UA device set. At least one instance of a MotionDeviceSystemType must be instantiated in the *DeviceSet*. This instance organises the information model of a complete robotics system using instances of the described ObjectTypes. The *MotionDeviceSystemType is* formally defined in Table 11.

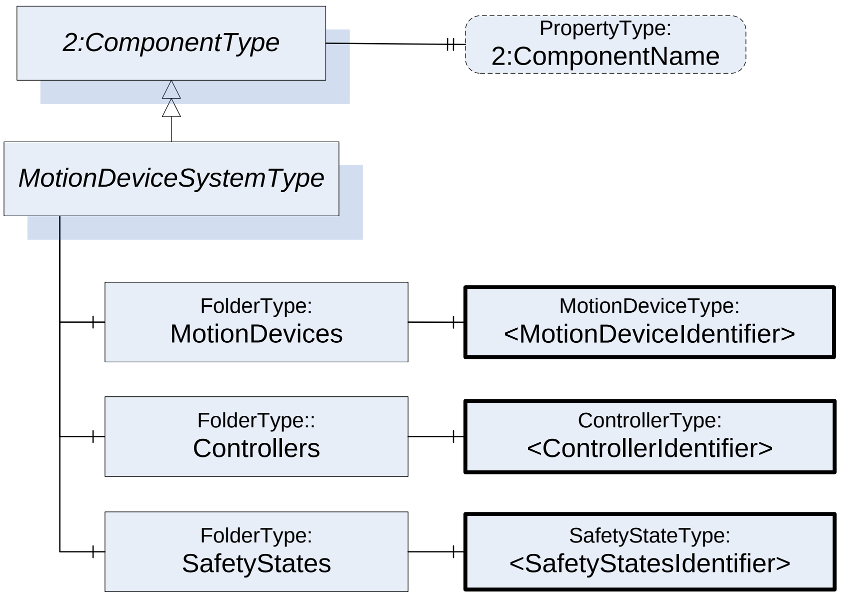


Figure 12 – Overview MotionDeviceSystemType

7.1.2 MotionDeviceSystemType definition

Table 11 – MotionDeviceSystemType Definition

Attribute	**Value**				
BrowseName	MotionDeviceSystemType				
IsAbstract	False				
References	**Node Class**	**BrowseName**	**DataType**	**TypeDefinition**	**Other**
Subtype of the ComponentType defined in OPC Unified Architecture for Devices (DI), inheriting the InstanceDeclarations of that Node					
0:HasComponent	Object	MotionDevices		0:FolderType	M
0:HasComponent	Object	Controllers		0:FolderType	M
0:HasComponent	Object	SafetyStates		0:FolderType	M
0:HasProperty	Variable	2:ComponentName	0:LocalizedText	0:PropertyType	O
Conformance Units					
Rob MotionDeviceSystem Base					

The components of the *MotionDeviceSystemType* have additional subcomponents which are defined in Table 12.

Table 12 – MotionDeviceSystemType Additional Subcomponents

Source Path	Reference	NodeClass	BrowseName	DataType	TypeDefinition	Others
MotionDevices	0:HasComponent	Object	<MotionDeviceIdentifier>		MotionDeviceType	MP
Controllers	0:HasComponent	Object	<ControllerIdentifier>		ControllerType	MP
SafetyStates	0:HasComponent	Object	<SafetyStateIdentifier>		SafetyStateType	MP

A motion device system may consist of multiple motion devices, controllers, and safety systems. References are used to describe the relations between those subsystems. Examples are described in Annex B.

The *ComponentName* property provides a user writeable name provided by the vendor, integrator, or user of the device. The *ComponentName* may be a default name given by the vendor. This property is defined by *ComponentType* defined in OPC 10000-100.

MotionDevices is a container for one or more instances of the *MotionDeviceType*.

Controllers is a container for one or more instances of the *ControllerType*.

SafetyStates is a container for one or more instances of the *SafetyStatesType*.

7.2 MotionDeviceType ObjectType Definition

7.2.1 Overview

The *MotionDeviceType* describes one independent motion device, e.g. a manipulator, a turn table, or a linear axis. Examples are described in Annex B.

A MotionDevice shall have at least one axis and one power train. The *MotionDeviceType is* formally defined in 7.2.2

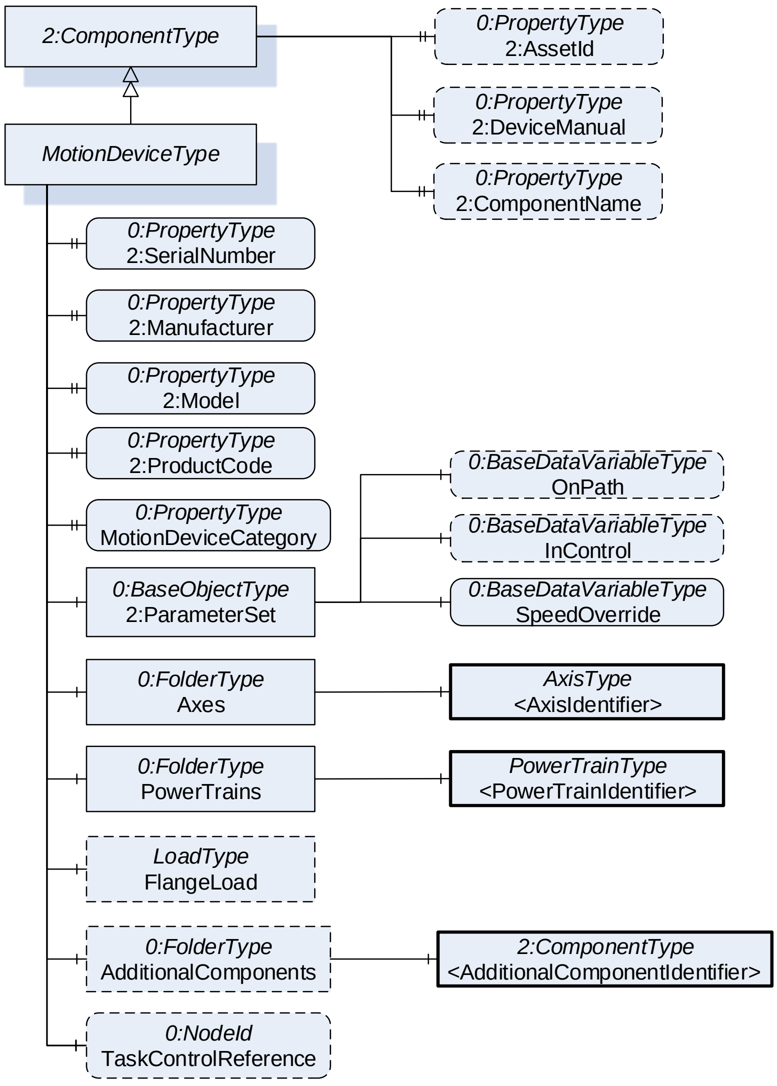

2:ComponentType
0:PropertyType 2:AssetId
0:PropertyType 2:DeviceManual
0:PropertyType 2:ComponentName
MotionDeviceType
0:PropertyType 2:SerialNumber
0:PropertyType 2:Manufacturer
0:PropertyType 2:Model
0:PropertyType 2:ProductCode
0:PropertyType MotionDeviceCategory
0:BaseObjectType 2:ParameterSet
0:BaseDataVariableType OnPath
0:BaseDataVariableType InControl
0:BaseDataVariableType SpeedOverride
0:FolderType Axes
AxisType <AxisIdentifier>
0:FolderType PowerTrains
PowerTrainType <PowerTrainIdentifier>
LoadType FlangeLoad
0:FolderType AdditionalComponents
2:ComponentType <AdditionalComponentIdentifier>
0:NodeId TaskControlReference

Figure 13 – Overview MotionDeviceType

7.2.2 MotionDeviceType definition

Table 13 – MotionDeviceType Definition

Attribute	Value				
BrowseName	MotionDeviceType				
IsAbstract	False				
References	**Node Class**	**BrowseName**	**DataType**	**TypeDefinition**	**Other**
Subtype of the ComponentType defined in OPC Unified Architecture for Devices (DI), inheriting the InstanceDeclarations of that Node					
0:HasProperty	Variable	2:SerialNumber	0:String	0:PropertyType	M
0:HasProperty	Variable	2:Manufacturer	0:LocalizedText	0:PropertyType	M
0:HasProperty	Variable	2:Model	0:LocalizedText	0:PropertyType	M
0:HasProperty	Variable	2:ProductCode	0:String	0:PropertyType	M
0:HasProperty	Variable	MotionDeviceCategory	MotionDeviceCategoryEnumeration	0:PropertyType	M
0:HasComponent	Variable	TaskControlReference	0:NodeId	0:BaseDataVariableType	O
0:HasComponent	Object	2:ParameterSet		0:BaseObjectType	M
0:HasComponent	Object	Axes		0:FolderType	M
0:HasComponent	Object	PowerTrains		0:FolderType	M
0:HasComponent	Object	FlangeLoad		LoadType	O
0:HasComponent	Object	AdditionalComponents		0:FolderType	O
0:HasProperty	Variable	2:AssetId	0:String	0:PropertyType	O
0:HasProperty	Variable	2:DeviceManual	0:String	0:PropertyType	O
0:HasProperty	Variable	2:ComponentName	0:LocalizedText	0:PropertyType	O
Conformance Units					
Rob MotionDeviceSystem Base					
Rob MotionDevice AM Extended					
Rob MotionDevice CM Extended					
Rob MotionDevice Flangeload					
Rob TC Relationship					

The components of the MotionDeviceType have additional subcomponents which are defined in Table 15.

Table 14 – MotionDeviceType Additional Subcomponents

Source Path	Reference	NodeClass	BrowseName	DataType	TypeDefinition	Other
2:ParameterSet	0:HasComponent	Variable	OnPath	0:Boolean	0:BaseDataVariableType	O
2:ParameterSet	0:HasComponent	Variable	InControl	0:Boolean	0:BaseDataVariableType	O
2:ParameterSet	0:HasComponent	Variable	SpeedOverride	0:Double	0:BaseDataVariableType	M
Axes	0:HasComponent	Object	<AxisIdentifier>		AxisType	MP
PowerTrains	0:HasComponent	Object	<PowerTrainIdentifier>		PowerTrainType	MP
AdditionalComponents	0:HasComponent	Object	<AdditionalComponentIdentifier>		0:BaseObjectType	MP

The *SerialNumber* property is a unique production number assigned by the manufacturer of the device. This is often stamped on the outside of the device and may be used for traceability and warranty purposes. This property is derived from *ComponentType* defined in OPC 10000-100.

The *Manufacturer* property provides the name of the company that manufactured the device. This property is derived from *ComponentType* defined in OPC 10000-100.

The *Model* property provides the name of the product. This property is derived from *ComponentType* defined in OPC 10000-100.

The *ProductCode* property provides a unique combination of numbers and letters used to identify the product. It may be the order information displayed on type shields or in ERP systems. This property is derived from *ComponentType* defined in OPC 10000-100.

The *AssetId* property is a user writable alphanumeric character sequence uniquely identifying a component. The vendor, integrator or user of the device provides the ID. It contains typically an identifier in a branch, use case or user specific naming scheme. This could be for example a reference to an electric scheme. For electric schemes typically EN 81346-2 is used. A use case could be to build up a location-oriented view in a spare part management client software. It enables to identify parts with the same article number which is not possible if this entry is not used. This property is defined by *ComponentType* defined in OPC 10000-100.

The *DeviceManual* property allows specifying an address of the user manual for the device. It may be a pathname in the file system or a URL (Web address). This property is defined by *ComponentType* defined in OPC 10000-100.

The *ComponentName* property provides a user writeable name provided by the vendor, integrator, or user of the device. The *ComponentName* may be a default name given by the vendor. This property is defined by *ComponentType* defined in OPC 10000-100.

FlangeLoad provides data for the load at the flange or mounting point of the motion device.

The variable *MotionDeviceCategory* provides the kind of motion device defined by MotionDeviceCategory*Enumeration* based on ISO 8373 (10.1).

The *Variable TaskControlReference* provides a *NodeId pointing to the instance of TaskControlOperationType* defined in 7.15, which controls this motion device in combination with the loaded program.

Description of ParameterSet of MotionDeviceType:

– Variable *OnPath*: The variable *OnPath* is true if the motion device is on or near enough the planned program path such that program execution can continue. If the MotionDevice deviates too much from this path in case of errors or an emergency stop, this value becomes false. If *OnPath* is false, the motion device needs repositioning to continue program execution.

– Variable *InControl*: The variable *InControl* provides the information if the actuators (in most cases a motor) of the motion device are powered up and in control: "true". The motion device might be in a standstill.

– Variable *SpeedOverride*: The *SpeedOverride* provides the current speed setting in percent of programmed speed (0 - 100%).

Axes is a container for one or more instances of the *AxisType* (7.3).

PowerTrains is a container for one or more instances of the *PowerTrainType*.

AdditionalComponents is a container for one or more instances of any other ObjectType (any subtype of *0:BaseObjectType)*. The listed components are installed at the motion device, e.g. an IO-board.

NOTE: Components like motors or gears of a motion device are placed inside the power train object and not inside this *AdditionalComponents* container. The intention of this folder is to integrate devices which are defined in companion specifications that use OPC 10000-100 *ComponentType*. From this specification, only instances of AuxiliaryComponentType and DriveType can be used in this container.

7.3 AxisType ObjectType Definition

7.3.1 Overview

The *AxisType* describes an axis of a motion device. It is formally defined in Table 15.

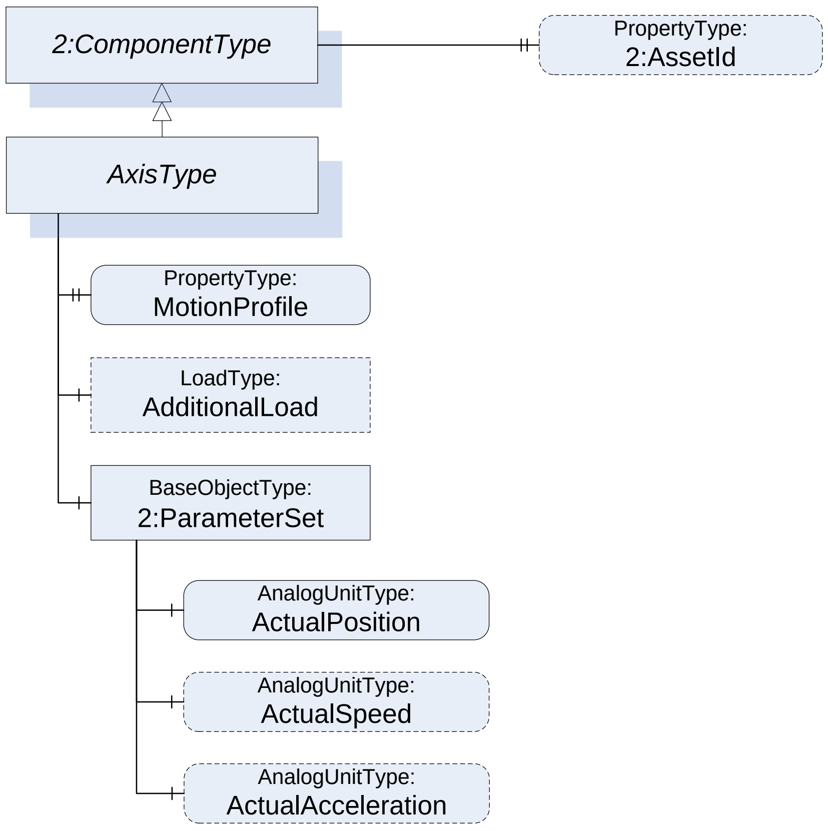

2:ComponentType
PropertyType: 2:AssetId
AxisType
PropertyType: MotionProfile
LoadType: AdditionalLoad
BaseObjectType: 2:ParameterSet
AnalogUnitType: ActualPosition
AnalogUnitType: ActualSpeed
AnalogUnitType: ActualAcceleration

Figure 14 – Overview AxisType

7.3.2 AxisType definition

Table 15 – AxisType Definition

Attribute	**Value**				
BrowseName	AxisType				
IsAbstract	False				
References	**Node Class**	**BrowseName**	**DataType**	**TypeDefinition**	**Other**
Subtype of the ComponentType defined in OPC Unified Architecture for Devices (DI), inheriting the InstanceDeclarations of that Node					
0:HasProperty	Variable	MotionProfile	AxisMotionProfileEnumeration	0:PropertyType	M
0:HasComponent	Object	AdditionalLoad		LoadType	O
0:HasComponent	Object	2:ParameterSet		0:BaseObjectType	M
Requires	Object	<PowerTrainIdentifier>		PowerTrainType	OP
0:HasProperty	Variable	2:AssetId	0:String	0:PropertyType	O
Conformance Units					
Rob MotionDeviceSystem Base					
Rob Axis AM Extended					
Rob Axis CM Extended					
Rob Axis AdditionalLoad					

The components of the AxisType have additional subcomponents which are defined in Table 18.

Table 16 – AxisType Additional Subcomponents

Source Path	Reference	NodeClass	BrowseName	DataType	TypeDefinition	Others
2:ParameterSet	0:HasComponent	Variable	ActualPosition	0:Double	0:AnalogUnitType	M
2:ParameterSet	0:HasComponent	Variable	ActualSpeed	0:Double	0:AnalogUnitType	O
2:ParameterSet	0:HasComponent	Variable	ActualAcceleration	0:Double	0:AnalogUnitType	O

The *AssetId* property is a user writable alphanumeric character sequence uniquely identifying a component. The vendor, integrator or user of the device provides the ID. It contains typically an identifier in a branch, use case or user specific naming scheme. This could be for example a reference to an electric scheme. For electric schemes typically EN 81346-2 is used. The AssetID of the AxisType provides a manufacturer-specific axis identifier within the control system. This property is defined by *ComponentType* defined in OPC 10000-100.

The *MotionProfile* property provides the kind of axis motion as defined by the *AxisMotionProfileEnumeration* (10.2)

AdditionalLoad provides data for the load that is mounted on this axis, e.g., a transformer for welding.

The Requires reference provides the relationship of axes to power trains. For complex kinematics this does not need to be a one-to-one relationship, because more than one power train might influence the motion of one axis. This reference connects all power trains to an axis that must be actively driven when only this axis should move and all other axes should stand still.

Virtual axes that are not actively driven by a power train do not have this reference. The InverseName is IsRequiredBy.

Description of ParameterSet of AxisType:

– Variable *ActualPosition*: The *ActualPosition* variable provides the current position of the axis and may have limits. If the axis has physical limits, the *EURange* property of the *AnalogUnitType* shall be provided.

– Variable *ActualSpeed*: The *ActualSpeed* variable provides the axis speed. Applicable speed limits of the axis shall be provided by the *EURange* property of the *AnalogUnitType.*

– Variable *ActualAcceleration*: The *ActualAcceleration* variable provides the axis acceleration. Applicable acceleration limits of the axis shall be provided by the *EURange* property of the *AnalogUnitType*.

7.4 PowerTrainType ObjectType Definition

7.4.1 Overview

A power train typically consists of one motor and gear to provide the required torque. Often there is a one-to-one relation between axes and power trains, but it is also possible to have axis coupling and thus one power train can move multiple axes and one axis can be moved by multiple power trains. One power train can have multiple drives, motors, and gears when these components move logically the same axes, for example in a master/slave setup. Examples are described in Annex B. The *PowerTrainType* represents instances of power trains of a motion device and is formally defined in

Table 17.

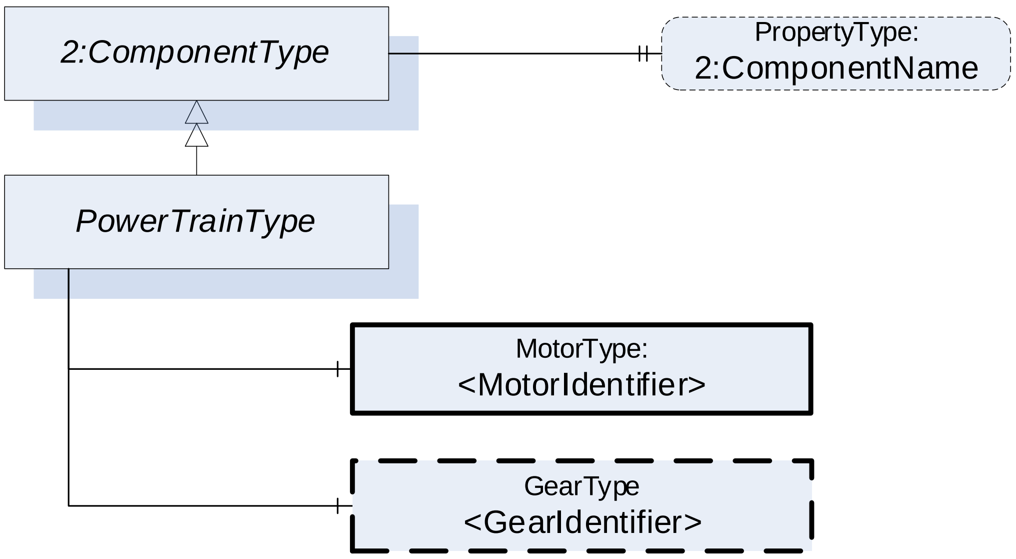


Figure 15 – Overview PowerTrainType

7.4.2 PowerTrainType definition

Table 17 – PowerTrainType Definition

Attribute	**Value**				
BrowseName	PowerTrainType				
IsAbstract	False				
References	**Node Class**	**BrowseName**	**DataType**	**TypeDefinition**	**Other**
Subtype of the ComponentType defined in OPC Unified Architecture for Devices (DI), inheriting the InstanceDeclarations of that Node					
0:HasComponent	Object	<MotorIdentifier>		MotorType	MP
0:HasComponent	Object	<GearIdentifier>		GearType	OP
Moves	Object	<AxisIdentifier>		AxisType	OP
HasSlave	Object	<PowerTrainIdentifier>		PowerTrainType	OP
0:HasProperty	Variable	2:ComponentName	0:LocalizedText	0:PropertyType	O
Conformance Units					
Rob MotionDeviceSystem Base					
Rob PowerTrain AM Extended					

The *ComponentName* property provides a user writeable name provided by the vendor, integrator, or user of the device. The *ComponentName* may be a default name given by the vendor.

The *ComponentName* of the PowerTrainType provides a manufacturer-specific power train identifier within the control system.

This property is defined by *ComponentType* defined in OPC 10000-100.

<*MotorIdentifier*> indicates that a power train contains one or more motors represented by *MotorType* instances.

The *IsConnectedTo ReferenceType* defined in 8.6 is intended to provide the relationship between a motor and a gear of a power train.

<*GearIdentifier*> indicates that a power train may contain one or more gears represented by *GearType* instances.

The *IsConnectedTo ReferenceType* defined in 8.6 is intended to provide the relationship between a motor and a gear of a power train.

Moves is a reference to provide the relationship of power trains to axes. For complex kinematics this does not need to be a one-to-one relationship, because a power train might influence the motion of more than one axis. This reference connects all axis to a power train that that move when *only this power train* moves and all other powertrains stand still. The *InverseName* is *IsMovedBy*.

HasSlave is a reference to provide the master-slave relationship of power trains which provide torque for a common axis. The *InverseName* is *IsSlaveOf*.

7.5 MotorType ObjectType Definition

7.5.1 Overview

The *MotorType* describes a motor in a power train. It is formally defined in Table 18.

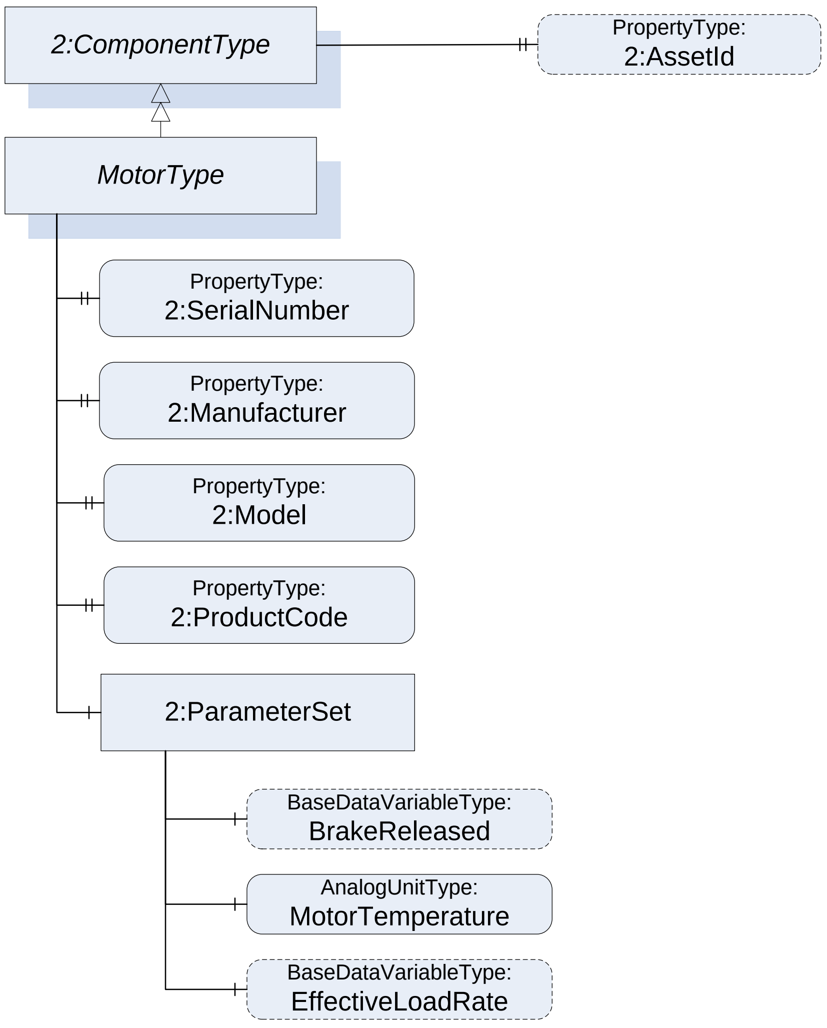

2:ComponentType
PropertyType: 2:AssetId
MotorType
PropertyType: 2:SerialNumber
PropertyType: 2:Manufacturer
PropertyType: 2:Model
PropertyType: 2:ProductCode
2:ParameterSet
BaseDataVariableType: BrakeReleased
AnalogUnitType: MotorTemperature
BaseDataVariableType: EffectiveLoadRate

Figure 16 – Overview MotorType

7.5.2 MotorType definition

Table 18 – MotorType Definition

Attribute	**Value**				
BrowseName	MotorType				
IsAbstract	False				
References	**Node Class**	**BrowseName**	**DataType**	**TypeDefinition**	**Other**
Subtype of the ComponentType defined in OPC Unified Architecture for Devices (DI), inheriting the InstanceDeclarations of that Node					
0:HasProperty	Variable	2:SerialNumber	0:String	0:PropertyType	M
0:HasProperty	Variable	2:Manufacturer	0:LocalizedText	0:PropertyType	M
0:HasProperty	Variable	2:Model	0:LocalizedText	0:PropertyType	M
0:HasProperty	Variable	2:ProductCode	0:String	0:PropertyType	M
0:HasComponent	Object	2:ParameterSet		0:BaseObjectType	M
IsDrivenBy	Object	<DriveIdentifier>		0:BaseObjectType	OP
0:HasProperty	Variable	2:AssetId	0:String	0:PropertyType	O
Conformance Units					
Rob MotionDeviceSystem Base					
Rob Motor AM Extended					
Rob Motor CM Extended					

The components of the *MotorType* have additional subcomponents which are defined in Table 19.

Table 19 – MotorType Additional Subcomponents

Source Path	Reference	NodeClass	BrowseName	DataType	TypeDefinition	Others
2:ParameterSet	0:HasComponent	Variable	BrakeReleased	0:Boolean	0:BaseDataVariableType	O
2:ParameterSet	0:HasComponent	Variable	MotorTemperature	0:Double	AnalogUnitType	M
2:ParameterSet	0:HasComponent	Variable	EffectiveLoadRate	0:UInt16	0:BaseDataVariableType	O

The *SerialNumber* property is a unique production number assigned by the manufacturer of the device. This is often stamped on the outside of the device and may be used for traceability and warranty purposes. This property is derived from *ComponentType* defined in OPC 10000-100.

The *Manufacturer* property provides the name of the company that manufactured the device. This property is derived from *ComponentType* defined in OPC 10000-100.

The *Model* property provides the name of the product. This property is derived from *ComponentType* defined in OPC 10000-100.

The *ProductCode* property provides a unique combination of numbers and letters used to identify the product. It may be the order information displayed on type shields or in ERP systems. This property is derived from *ComponentType* defined in OPC 10000-100.

The *AssetId* property is a user writable alphanumeric character sequence uniquely identifying a component. The vendor, integrator or user of the device provides the ID. It contains typically an identifier in a branch, use case or user specific naming scheme.

This could be for example a reference to an electric scheme. For electric schemes typically EN 81346-2 is used.

A use case could be to build up a location-oriented view in a spare part management client software. It enables to identify parts with the same article number which is not possible if this entry is not used.

This property is defined by *ComponentType* defined in OPC 10000-100.

IsDrivenBy is a reference to provide a relationship from a motor to a drive, which can be a multi-slot-drive or single slot drive*. The TypeDefinition* of the reference destination as *BaseObjectType* provides the possibility to point to a slot of a multi-slot-drive or a motor-integrated-drive. If this reference points to a physical drive (and not a drive slot) it should point to an *DriveType*.

Annex B.10 shows different possibilities of usage.

Description of ParameterSet of MotorType:

– Variable *BrakeReleased*: The *BrakeReleased* is an optional variable used only for motors with brakes. If *BrakeReleased* is TRUE the motor is free to run. FALSE means that the motor shaft is locked by the brake.

– Variable *MotorTemperature*: The *MotorTemperature* provides the temperature of the motor. If there is no temperature sensor the value is set to “null”.

– Variable *EffectiveLoadRate*: *EffectiveLoadRate* is expressed as a percentage of maximum continuous load. The Joule integral is typically used to calculate the current load, i.e.:

$$I^2 t = \int_{t_0}^{t_1} i^2 \, dt$$

Duration should be defined and documented by the vendor.

7.6 GearType Definition

7.6.1 Overview

The *GearType* describes a gear in a power train, e.g. a gear box or a spindle. It is formally defined in Table 20.

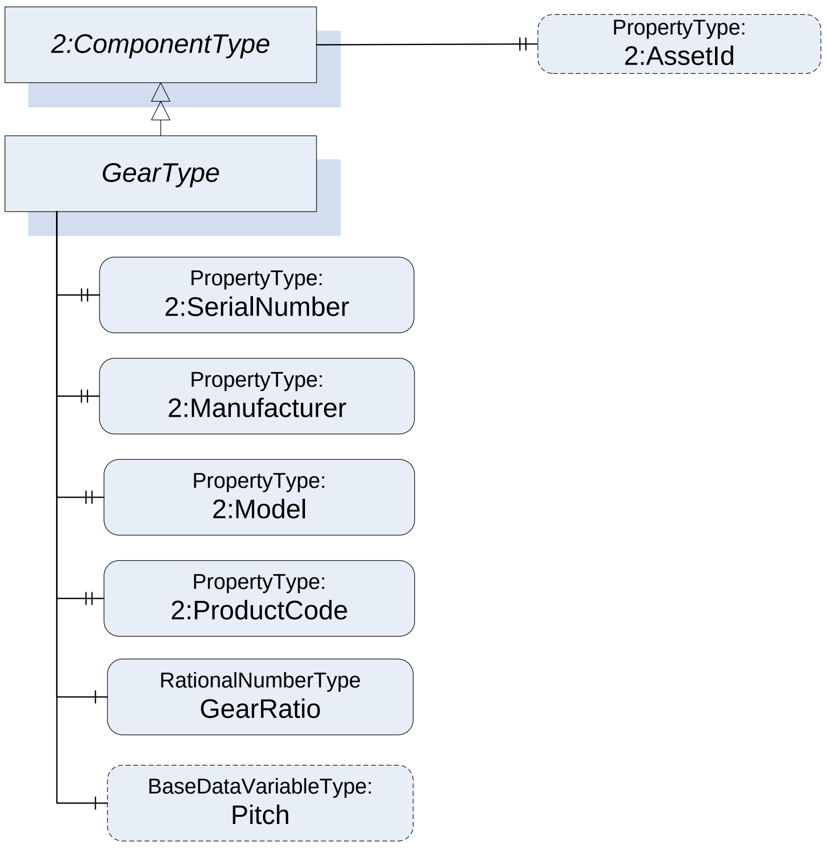


Figure 17 – Overview GearType

7.6.2 GearType definition

Table 20 – GearType Definition

Attribute	**Value**				
BrowseName	GearType				
IsAbstract	False				
References	**Node Class**	**BrowseName**	**DataType**	**TypeDefinition**	**Other**
Subtype of the ComponentType defined in OPC Unified Architecture for Devices (DI), inheriting the InstanceDeclarations of that Node					
0:HasProperty	Variable	2:SerialNumber	0:String	0:PropertyType	M
0:HasProperty	Variable	2:Manufacturer	0:LocalizedText	0:PropertyType	M
0:HasProperty	Variable	2:Model	0:LocalizedText	0:PropertyType	M
0:HasProperty	Variable	2:ProductCode	0:String	0:PropertyType	M
0:HasComponent	Variable	GearRatio	0:RationalNumber	0:RationalNumberType	M
0:HasComponent	Variable	Pitch	0:Double	0:BaseDataVariableType	O
0:HasProperty	Variable	2:AssetId	0:String	0:PropertyType	O
Conformance Units					
Rob Gear CM Extended					
Rob Gear AM Extended					

In case of a one-to-one relation between powertrains and axes, gear ratio and pitch may reflect the relation between motor and axis velocities. This is not possible when axis coupling is involved because different ratios for all motor-axis combinations may be needed. Additionally, there could be a nonlinear coupling between the load side of the gear box and the axis. Thus, GearRatio and Pitch only reflect the properties of the physical gear box and it may not be possible to use these values to transform between axis and motor movements.

The *SerialNumber* property is a unique production number assigned by the manufacturer of the device. This is often stamped on the outside of the device and may be used for traceability and warranty purposes. This property is derived from *ComponentType* defined in OPC 10000-100.

The *Manufacturer* property provides the name of the company that manufactured the device. This property is derived from *ComponentType* defined in OPC 10000-100.

The *Model* property provides the name of the product. This property is derived from *ComponentType* defined in OPC 10000-100.

The *ProductCode* property provides a unique combination of numbers and letters used to identify the product. It may be the order information displayed on type shields or in ERP systems. This property is derived from *ComponentType* defined in OPC 10000-100.

The *AssetId* property is a user writable alphanumeric character sequence uniquely identifying a component. The vendor, integrator or user of the device provides the ID. It contains typically an identifier in a branch, use case or user specific naming scheme. This could be for example a reference to an electric scheme. For electric schemes typically EN 81346-2 is used. A use case could be to build up a location-oriented view in a spare part management client software. It enables to identify parts with the same article number which is not possible if this entry is not used. This property is defined by *ComponentType* defined in OPC 10000-100.

GearRatio is the transmission ratio of the gear expressed as a fraction as input velocity (motor side) by output velocity (load side).

Pitch describes the distance covered in millimetres (mm) for linear motion per one revolution of the output side of the driving unit. *Pitch* is used in combination with *GearRatio* to describe the overall transmission from input to output of the gear.

Calculation formula:

$$Linear\ distance = \frac{Revolutions\ of\ input}{GearRatio} \times Pitch$$

7.7 SafetyStateType ObjectType Definition

7.7.1 Overview

SafetyStateType describes the safety states of the motion devices and controllers. One motion device system is associated with one or more instances of the *SafetyStateType*.

The *SafetyStateType* was modelled directly in the *MotionDeviceSystemType* for the following reasons:

- The manufacturers of systems have different concepts where safety is functional located, e.g. the hardware and software implementation.
- The safety state typically applies to the entire robotic system. If multiple safety state instances are implemented in robotic systems, these can be represented by individual instances of the *SafetyStateType* and associated with the controller by reference.

The safety state is for informational purpose only and not intended for use with functional safety applications as defined in ISO 61508.

The *SafetyStateType* is formally defined in Table 21.

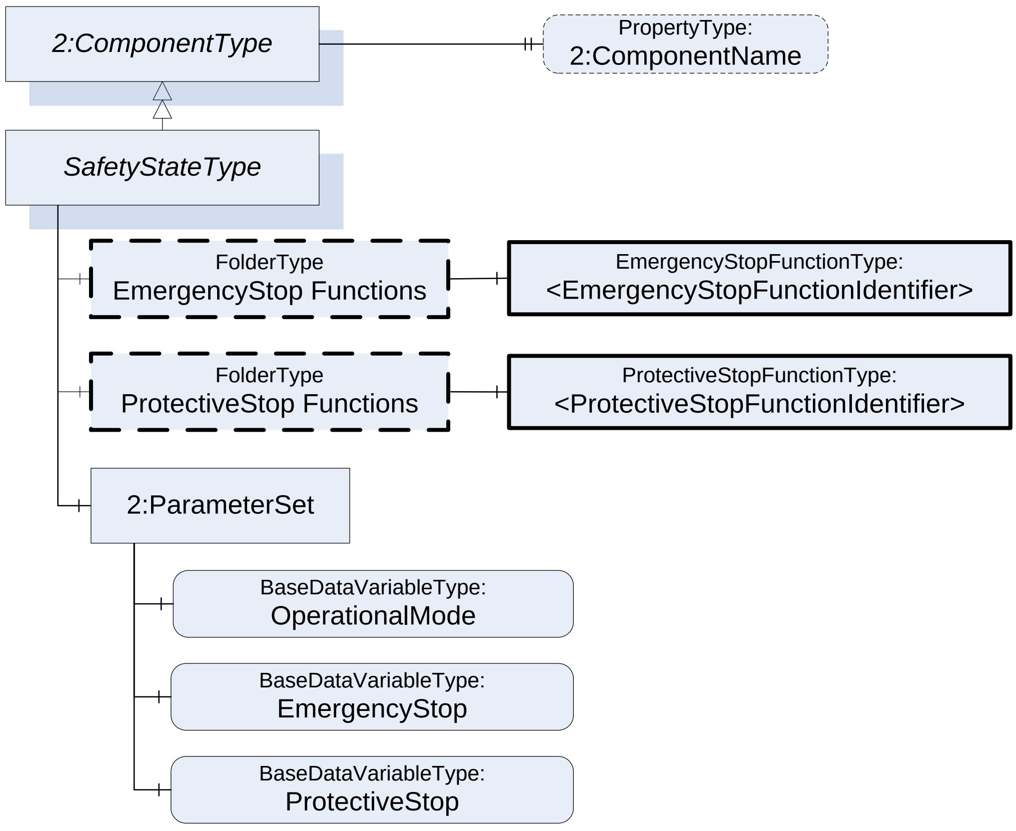


Figure 18 – Overview SafetyStateType

7.7.2 SafetyStateType definition

Table 21 – SafetyStateType Definition

Attribute	**Value**				
BrowseName	SafetyStateType				
IsAbstract	False				
References	**Node Class**	**BrowseName**	**DataType**	**TypeDefinition**	**Other**
Subtype of the ComponentType defined in OPC Unified Architecture for Devices (DI), inheriting the InstanceDeclarations of that Node					
0:HasComponent	Object	EmergencyStopFunctions		0:FolderType	O
0:HasComponent	Object	ProtectiveStopFunctions		0:FolderType	O
0:HasComponent	Object	2:ParameterSet		0:BaseObjectType	M
0:HasProperty	Variable	2:ComponentName	0:LocalizedText	0:PropertyType	O
Conformance Units					
Rob MotionDeviceSystem Base					
Rob Emergency Stop Function					
Rob Protective Stop Function					

The components of the SafetyStateType have additional subcomponents which are defined in Table 22.

Table 22 – SafetyStateType Additional Subcomponents

Source Path	**Reference**	**NodeClass**	**BrowseName**	**DataType**	**TypeDefinition**	**Others**
EmergencyStopFunctions	0:HasComponent	Object	<EmergencyStopFunctionIdentifier>		EmergencyStopFunctionType	MP
ProtectiveStopFunctions	0:HasComponent	Object	<ProtectiveStopFunctionIdentifier>		ProtectiveStopFunctionType	MP
2:ParameterSet	0:HasComponent	Variable	OperationalMode	OperationalModeEnumeration	0:BaseDataVariableType	M
2:ParameterSet	0:HasComponent	Variable	EmergencyStop	0:Boolean	0:BaseDataVariableType	M
2:ParameterSet	0:HasComponent	Variable	ProtectiveStop	0:Boolean	0:BaseDataVariableType	M

The *ComponentName* property provides a user writeable name provided by the vendor, integrator, or user of the device. The *ComponentName* may be a default name given by the vendor. This property is defined by *ComponentType* defined in OPC 10000-100.

EmergencyStopFunctions is a container for one or more instances of the *EmergencyStopFunctionType*. The number and names of emergency stop functions is vendor specific. When provided, this object contains a list of all emergency stop functions with names and current state. See description of *EmergencyStopFunctionType* for examples of emergency stop functions.

ProtectiveStopFunctions is a container for one or more instances of the *ProtectiveStopFunctionType*. The number and names of protective stop functions is vendor specific. When provided, this object contains a list of all protective stop functions with names and current state. See description of *ProtectiveStopFunctionType* for examples of protective stop functions.

Description of *ParameterSet* of *SafetyStateType*:

– The *OperationalMode* variable provides information about the current operational mode. Allowed values are described in *OperationalModeEnumeration* (0).

– The *EmergencyStop* variable is TRUE if one or more of the emergency stop functions in the robot system are active, FALSE otherwise. If the *EmergencyStopFunctions* object is provided, then the value of this variable is TRUE if one or more of the listed emergency stop functions are active.

– The *ProtectiveStop* variable is TRUE if one or more of the enabled protective stop functions in the system are active, FALSE otherwise. If the *ProtectiveStopFunctions* object is provided, then the value of this variable is TRUE if one or more of the listed protective stop functions are enabled and active.

7.8 EmergencyStopFunctionType ObjectType Definition

7.8.1 Overview

According to ISO 10218-1:2011 Ch.5.5.2 Emergency stop, the robot shall have one or more emergency stop functions. This shall be done with the help of the *EmergencyStopFunctionType* is defined in Table 23.

7.8.2 EmergencyStopFunctionType definition

Table 23 – EmergencyStopFunctionType Definition

Attribute	**Value**				
BrowseName	EmergencyStopFunctionType				
References	**Node Class**	**BrowseName**	**DataType**	**TypeDefinition**	**Modelling Rule**
Subtype of the BaseObjectType defined in OPC Unified Architecture					
0:HasProperty	Variable	Name	0:String	0:PropertyType	M
0:HasComponent	Variable	Active	0:Boolean	0:BaseDataVariableType	M
Conformance Units					
Rob Emergency Stop Function					

The *Name* of the EmergencyStopFunctionType provides a manufacturer-specific emergency stop function identifier within the safety system. The only named emergency stop function in the ISO 10218-1:2011 standard is the "Pendant emergency stop function". Other than that, the standard does not give any indication on naming of emergency stop functions.

The Active variable is TRUE if this emergency stop function is active, e.g. that the emergency stop button is pressed, FALSE otherwise.

7.9 ProtectiveStopFunctionType ObjectType Definition

7.9.1 Overview

According to ISO 10218-1:2011 Ch.5.5.3 the robot shall have one or more protective stop functions designed for the connection of external protective devices. This type is formally defined in Table 24

7.9.2 ProtectiveStopFunctionType definition

Table 24 – ProtectiveStopFunctionType Definition

Attribute	**Value**				
BrowseName	ProtectiveStopFunctionType				
References	**NodeClass**	**BrowseName**	**DataType**	**TypeDefinition**	**Others**
Subtype of the BaseObjectType defined in OPC Unified Architecture					
0:HasProperty	Variable	Name	0:String	0:PropertyType	M
0:HasComponent	Variable	Enabled	0:Boolean	0:BaseDataVariableType	M
0:HasComponent	Variable	Active	0:Boolean	0:BaseDataVariableType	M
Conformance Units					
Rob Protective Stop Function					

The *Name* of the ProtectiveStopFunctionType provides a manufacturer-specific protective stop function identifier within the safety system.

The *Enabled* variable is TRUE if this protective stop function is currently supervising the system, FALSE otherwise. A protective stop function may or may not be always enabled, e.g. the protective stop function of the safety doors is typically enabled in automatic operational mode and disabled in manual mode. On the other hand, for example, the protective stop function of the teach pendant enabling device is enabled in manual modes and disabled in automatic modes.

The *Active* variable is TRUE if this protective stop function is active, i.e. that a stop is initiated, FALSE otherwise. If *Enabled* is FALSE then *Active* shall be FALSE.

Examples

The table below shows an example with a door interlock function. In this example, the door is only monitored during automatic modes. During manual modes, the operators may open the door without causing a protective stop.

Table 25 – Door Interlock Protective Stop Example

	Automatic Mode		**Manual Mode**	
Door interlock	**Enabled**	**Active**	**Enabled**	**Active**
Door closed	TRUE	FALSE	FALSE	FALSE
Door open	TRUE	TRUE	FALSE	FALSE

The next example shows how the three-position enabling device normally found on teach pendants is processed. In this case it does not matter if the enabling device is pressed or not during automatic modes, while in manual modes, a protective stop is active if the enabling device is released or fully pressed.

Table 26 – Teach Pendant Enabling Device Protective Stop Example

	Automatic Mode		Manual Mode	
Teach Pendant Enabling Device	**Enabled**	**Active**	**Enabled**	**Active**
Released	FALSE	FALSE	TRUE	TRUE
Middle position	FALSE	FALSE	TRUE	FALSE
Fully pressed (panic)	FALSE	FALSE	TRUE	TRUE

7.10 OperationStateMachineType Definition

The *OperationStateMachineType* provides an abstract state machine for operation. The state machine can be used for entities whose states can be represented by Idle, Ready or Executing and which can be started and stopped.

At the system and task control levels, concrete state machine types are derived from the *OperationStateMachineType*. The states of these state machines can be further enhanced with substate machines.

The overview of the state machine with all transitions is shown in Figure 19.

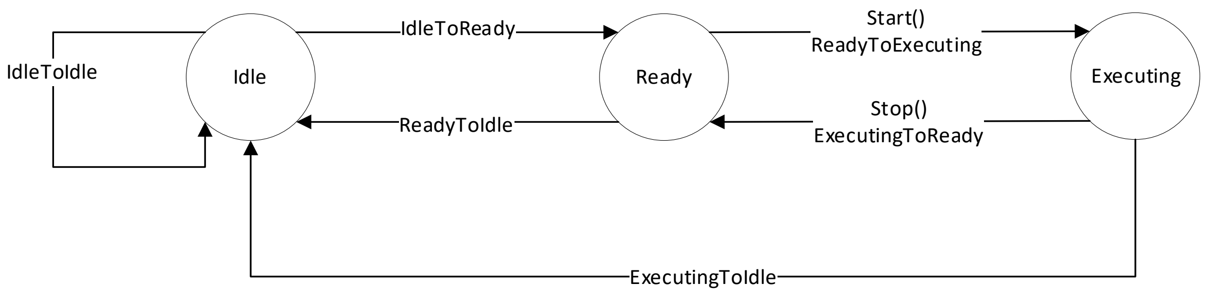


Figure 19 – OperationStateMachine.

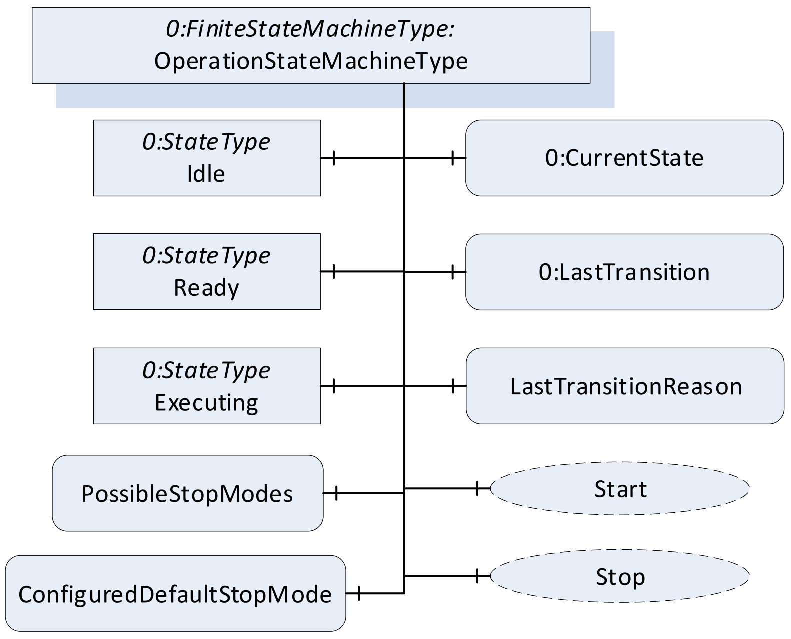


Figure 20 – The OperationStateMachineType

Figure 20 shows the OPC UA representation of the *OperationStateMachineType*, the transitions between the states have not been shown for the sake of simplicity. The *OperationStateMachineType* is formally defined in Table 77.

Table 27 – OperationStateMachineType Definition

Attribute	Value				
BrowseName	OperationStateMachineType				
IsAbstract	True				
References	**Node Class**	**BrowseName**	**DataType**	**TypeDefinition**	**Other**
Subtype of the FiniteStateMachineType defined in OPC 10000-5.					
0:HasComponent	Variable	LastTransitionReason	0:Int16	0:MultiStateValueDiscreteType	M
0:HasComponent	Variable	PossibleStopModes	0:EnumValueType[]	0:BaseDataVariableType	O
0:HasComponent	Variable	ConfiguredDefaultStopMode	0:Int16	0:BaseDataVariableType	O
0:HasComponent	Object	Idle		0:StateType	
0:HasComponent	Object	Ready		0:StateType	
0:HasComponent	Object	Executing		0:StateType	
0:HasComponent	Object	ReadyToIdle		0:TransitionType	
0:HasComponent	Object	IdleToReady		0:TransitionType	
0:HasComponent	Object	ExecutingToReady		0:TransitionType	
0:HasComponent	Object	ReadyToExecuting		0:TransitionType	
0:HasComponent	Object	ExecutingToIdle		0:TransitionType	
0:HasComponent	Object	IdleToIdle		0:TransitionType	
0:HasComponent	Method	Start			O
0:HasComponent	Method	Stop			O
Inherited from FiniteStateMachineType					
0:HasComponent	Variable	LastTransition	0:LocalizedText	0:FiniteTransitionVariableType	M
0:GeneratesEvent	ObjectType	TransitionEventType			O

The states of the *OperationStateMachineType* are described in Table 28.

The component Variables of the *OperationStateMachineType* have additional *Attributes* defined in Table 30.

Table 28 – OperationStateMachineType State Descriptions

StateName	Description
Idle	Entity is not in a condition to start execution.
Ready	Entity is in a condition to start execution.
Executing	Entity is in a condition of execution.

The *Variable LastTransitionReason* provides the reason for the *LastTransition.* The *EnumValue* and *ValueAsText* of this *0:MultiStateValueDiscreteType* are described in Table 29*.* This specification does not define an explicit error state. The *LastTransitionReason* indicates if a state change was caused due to an error.

Table 29 – Values for LastTransitionReason

EnumValue	ValueAsText	Description
0	Unknown	Caused by an unknown reason
1	External	Caused by external operation
2	Direct	Caused by direct operation
3	System	Caused by system specific behaviour
4	Error	Caused by an error
5	Application	Caused explicitly by end user program logic

The component *Variables* of the *OperationStateMachineType* have additional *Attributes* defined in Table 30.

Table 30 – OperationStateMachineType Attribute values for child nodes

BrowsePath	**Value Attribute**	**Description Attribute**
LastTransitionReason 0:EnumValues	[{"Value":0,"DisplayName":"Unknown","Description":"Caused by an unknown reason"}, {"Value":1,"DisplayName":"External","Description":"Caused by external operation"}, {"Value":2,"DisplayName":"Direct","Description":"Caused by direct operation"}, {"Value":3,"DisplayName":"System","Description":"Caused by system specific behavior"}, {"Value":4,"DisplayName":"Error", "Description": "Caused by an error"}, {"Value":5,"DisplayName":"Application","Description":"Caused explicitly by end user program logic"}]	

LastTransitionReason EnumValues 1 and 2 describe where an operation was initiated, which reasoned the last transition. External means that the operation was initiated by a control station, which is not part of the robot system, e.g a cell PLC. Direct means that the operation was initiated by a control station, which is part of the robot system, e.g. the teach pendant.

The *Variable PossibleStopModes* is an array of *EnumValueType*, which contains a list of supported stop modes (see Table 31.

Table 31 – PossibleStopMode Array Values

Nr.	**Stop Mode**	**Description**
1	OnPath	Stop program execution in a controlled manner along the programmed path.
2	EndOfCycle	Stop program execution when the current production cycle has been finished.
3	ProcessStop	Application dependent stop instruction that stops program execution at a "favourable" point for the application, e.g. at the end of a paint stroke or sealing bead.
4	QuickStop	This stop is performed by ramping down motion as fast as possible using optimum motor performance. The robot may not stay on the path.
5	EndOfInstruction	This stop can be used to stop the program execution when the current instruction is completed.
>=1000		Reserved for other OPC UA Companion Specifications
>=2000		Used for vendor specific stop modes

Table 32 – OperationStateMachineType Attribute values for child nodes

BrowsePath	**Value Attribute**	**Description Attribute**
PossibleStopModes	[{"Value": 1, "DisplayName": "OnPath", "Description": "Stop program execution in a controlled manner along the programmed path"}, {"Value": 2, "DisplayName": "EndOfCycle", "Description": "Stop program execution when the current production cycle has been finished"}, {"Value": 3, "DisplayName": "ProcessStop", "Description": "Application dependent stop instruction that stops program execution at a favourable point for the application, e.g. at the end of a paint stroke or sealing bead"}, {"Value": 4, "DisplayName": "QuickStop", "Description": "This stop is performed by ramping down motion as fast as possible using optimum motor performance. The robot may not stay on the path"}, {"Value": 5, "DisplayName": "EndOfInstruction", "Description": "This stop can be used to stop the program execution when the current instruction is completed"}]	

The Variable *ConfiguredDefaultStopMode* is an integer, which contains the value of the configured stop mode for this system. This shall be one of the values in the *PossibleStopModes* array.

The *Variable LastTransition,* inherited from the *FiniteStateMachineType*, is defined as mandatory in the *OperationStateMachineType*.

The transitions of the *OperationStateMachineType* are described in Table 33.

Table 33 – OperationStateMachineType Transition Descriptions

TransitionName	**Description**
IdleToReady	Changes from Idle to Ready.
IdleToIdle	Changes from Idle to Idle.
ReadyToIdle	Changes from Ready to Idle.
ReadyToExecuting	Changes from Ready to Executing.
ExecutingToReady	Changes from Executing to Ready.
ExecutingToIdle	Changes from Executing to Idle.

The components of the *OperationStateMachineType* have additional references which are defined in Table 81.

Table 34 – OperationStateMachineType Additional References

SourceBrowsePath	Reference Type	Is Forward	TargetBrowsePath
IdleToIdle	0:FromState	True	Idle
	0:ToState	True	Idle
	0:HasEffect	True	TransitionEventType
IdleToReady	0:FromState	True	Idle
	0:ToState	True	Ready
	0:HasEffect	True	TransitionEventType
ReadyToIdle	0:FromState	True	Ready
	0:ToState	True	Idle
	0:HasEffect	True	TransitionEventType
ReadyToExecuting	0:FromState	True	Ready
	0:ToState	True	Executing
	0:HasCause	True	Start
	0:HasEffect	True	TransitionEventType
ExecutingToReady	0:FromState	True	Executing
	0:ToState	True	Ready
	0:HasCause	True	Stop
	0:HasEffect	True	TransitionEventType
ExecutingToIdle	0:FromState	True	Executing
	0:ToState	True	Idle
	0:HasEffect	True	TransitionEventType

The component *Variables* of the *OperationStateMachine* have additional *Attributes* defined in the table below.

Table 35 – OperationStateMachineType Attribute values for child Nodes

BrowsePath		Value Attribute
Idle	0:StateNumber	1
Ready	0:StateNumber	2
Executing	0:StateNumber	3
IdleToIdle	0:TransitionNumber	1
IdleToReady	0:TransitionNumber	2
ReadyToIdle	0:TransitionNumber	3
ReadyToExecuting	0:TransitionNumber	4
ExecutingToReady	0:TransitionNumber	5
ExecutingToIdle	0:TransitionNumber	6

7.10.1 Start Method

The signature of this *Method* is specified below.

Signature

```
Start (
[out]      0:Int32          Status
);
```

The *Start Method* is called by a *Client* to start execution of the entity which is represented by the state machine.

Table 36 – Start Method Arguments

Argument	Description
Status	0 – OK Values > 0 are reserved for errors defined by this and future standards. Values < 0 shall be used for application-specific errors.

The possible *Method* result codes are formally defined in Table 37.

Table 37 – Method Result Codes (defined in Call Service)

Result Code	Description
Good	The operation succeeded
Bad_InternalError	The operation failed because of an internal error
Bad_ResourceUnavailable	The Method cannot be executed because a required resource is locked.
Bad_UserAccessDenied	The caller is not allowed to execute this *Method.*

The *Start Method* representation in the *AddressSpace* is formally defined in table below.

Table 38 – Start Method AddressSpace definition.

Attribute	Value				
BrowseName	Start				
References	**NodeClass**	**BrowseName**	**DataType**	**TypeDefinition**	**ModellingRule**
0:HasProperty	Variable	0:OutputArguments	0:Argument[]	0:PropertyType	0:Mandatory

7.10.2 Stop Method

The signature of this *Method* is specified below.

Signature

```
Stop (
[in]       0:Int64          StopMode
[out]      0:Int32          Status
);
```

The *Stop Method* is called by a *Client* to stop execution of the entity which is represented by the state machine.

Table 39 –Stop Method Arguments

Argument	Description
StopMode	provides a way to differentiate between different stop modes. This parameter should correspond to one of the values in the PossibleStopModes array.
Status	0 – OK Values > 0 are reserved for errors defined by this and future standards. Values < 0 shall be used for application-specific errors.

The possible *Method* result codes are formally defined in Table 40.

Table 40 - Method Result Codes (defined in Call Service)

Result Code	Description
Good	The operation succeeded
Bad_InternalError	The operation failed because of an internal error
Bad_ResourceUnavailable	The Method is locked by another Client/Clientgroup
Bad_UserAccessDenied	The caller is not allowed to call this *Method.*

The *Stop Method* representation in the *AddressSpace* is formally defined in the table below.

Table 41 – Stop Method AddressSpace definition.

Attribute	**Value**				
BrowseName	Stop				
References	**NodeClass**	**BrowseName**	**DataType**	**TypeDefinition**	**Others**
0:HasProperty	Variable	0:InputArguments	0:Argument[]	0:PropertyType	M
0:HasProperty	Variable	0:OutputArguments	0:Argument[]	0:PropertyType	M

7.11 SystemOperationType ObjectType

7.11.1 Overview

The *SystemOperationType* is an *AddIn Type* to extend instances of *ControllerType* described in 7.18. The *SystemOperationType* provides a state machine to monitor and/or command the controller behaviour at the system level and is formally defined in Table 42.

Robot systems may have conditions that must be acknowledged before some operational commands can be executed.

The system has two possibilities to enable the *Client* to acknowledge conditions.

- By exposing at least one instance of *AcknowledgeableConditionType* inside the *Server's AddressSpace* located within the *Conditions* folder as defined in the *ConformanceUnit RobAckCondInstance*.
- By handling such conditions using the OPC UA Eventing mechanisms as defined in the *ConformanceUnit RobAckCondEventing.*

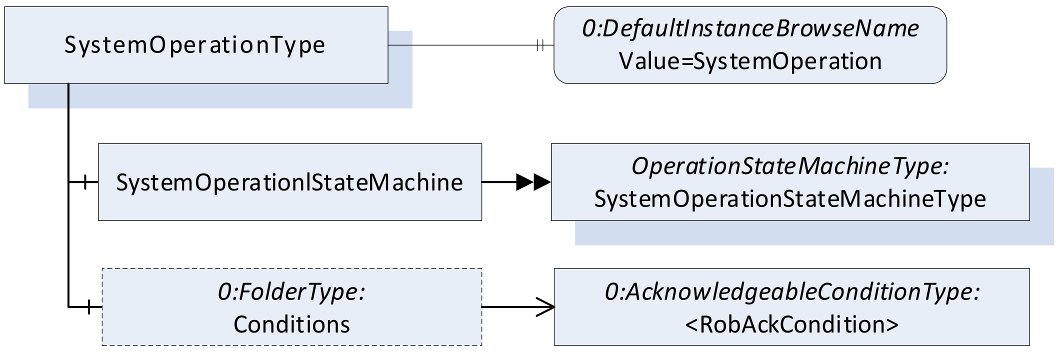

SystemOperationType
0:DefaultInstanceBrowseName
Value=SystemOperation
SystemOperationlStateMachine
OperationStateMachineType:
SystemOperationStateMachineType
0:FolderType:
Conditions
0:AcknowledgeableConditionType:
<RobAckCondition>

Figure 21 – SystemOperationType Overview

7.11.2 SystemOperationType definition

The *SystemOperationType* is formally defined in Table 42.

Table 42 – SystemOperationType Definition

Attribute	Value				
BrowseName	SystemOperationType				
IsAbstract	False				
References	**Node Class**	**BrowseName**	**DataType**	**TypeDefinition**	**Other**
Subtype of the *BaseObjectType* defined in OPC 10000-5.					
0:HasComponent	Object	SystemOperationStateMachine		SystemOperationStateMachineType	M
0:HasComponent	Object	Conditions		0:FolderType	O
0:HasProperty	Variable	0:DefaultInstanceBrowseName	0:QualifiedName	0:PropertyType	
ConformanceUnits					
Rob System Monitor					
Rob System Operation					
Rob RobAckCondInstance					

The Object SystemOperationStateMachine provides a state machine to monitor or command the controller at the system level. The *SystemOperationStateMachineType* is inherited from the *OperationStateMachineType.*

The folder *Conditions* (part of the *ConformanceUnit RobAckCondInstance*) provides instances of *AcknowledgeableConditionType* for the acknowledgement of single conditions or instances of *MultiAcknowledgeableConditionType* (see 8.1) for the acknowledgement of multiple conditions.

The *Property 0:DefaultInstanceBrowseName* of the *SystemOperationType* has an additional *Attribute* defined in

Table 44.

Table 43 – SystemOperationType additional subcomponents

BrowsePath	References	NodeClass	BrowseName	DataType	TypeDefinition	Others
Conditions	Organizes	Object	<AcknowledgeableCondition>		AcknowledgeableConditionType	MP

Table 44 – SystemOperationType Attribute values for child Nodes

BrowsePath	Value Attribute	Description Attribute
0:DefaultInstanceBrowseName	SystemOperation	

7.12 SystemOperationStateMachineType

The *SystemOperationStateMachineType* represents the behaviour of a controller at the system level and can be used for monitoring and for external or direct operation. In robot systems, a distinction is typically made between external and direct operation, depending on the *OperationalMode* (see 7.7.2).

If the system takes a significant amount of time to transition from the *Idle State* to the *Ready State*, the *Idle State* can be extended by the sub state machine *IdleSubstateMachine*. Alternatively, a vendor/application specific substate machine may also be used.

For certain stop modes, the transition from the *Executing State* to the *Ready State* can take a significant amount of time. In such cases, the *Executing State* can be extended by the sub state machine *ExecutingSubstateMachine*. Alternatively, an application or vendor specific substate machine may also be used.

The substate machines enable the client to get more information during the transition.

The *SystemMonitor* Server *Facet* supports monitoring of the activities performed by the operator or system internally. (e.g. monitor condition changes and base causes) The *SystemOperation* Server *Facet* extends on the *SystemMonitor* Server *Facet* and adds support to operate the system.

The overview of the *SystemOperationStateMachine* with the *IdleSubstateMachine* as substate machine of *Idle State* and the *ExecutingSubstateMachine* as substate machine of *Executing State* with all transitions is shown in Figure 8.

The transitions in this state machine can occur due to internal processes of the system or they may be triggered by a method call. In case the transition is triggered by a method call, the transition might not occur immediately (e.g. it will be delayed until internal conditions are met).

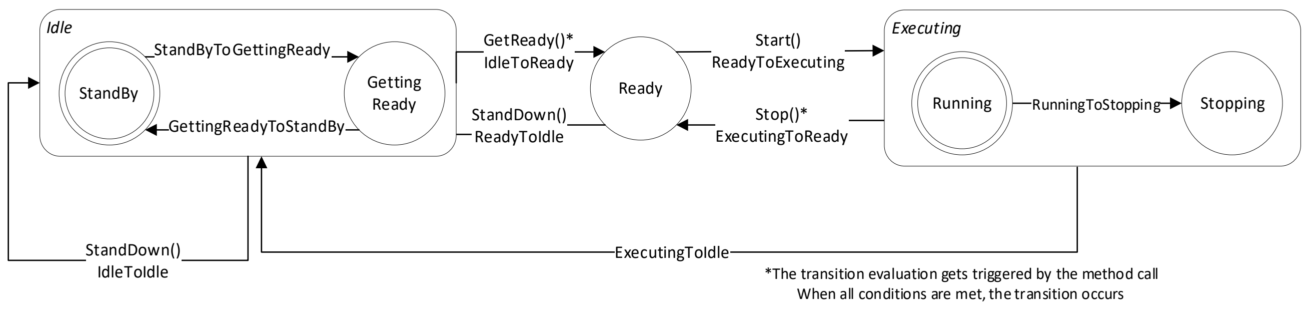


Figure 22– SystemOperationStateMachine.

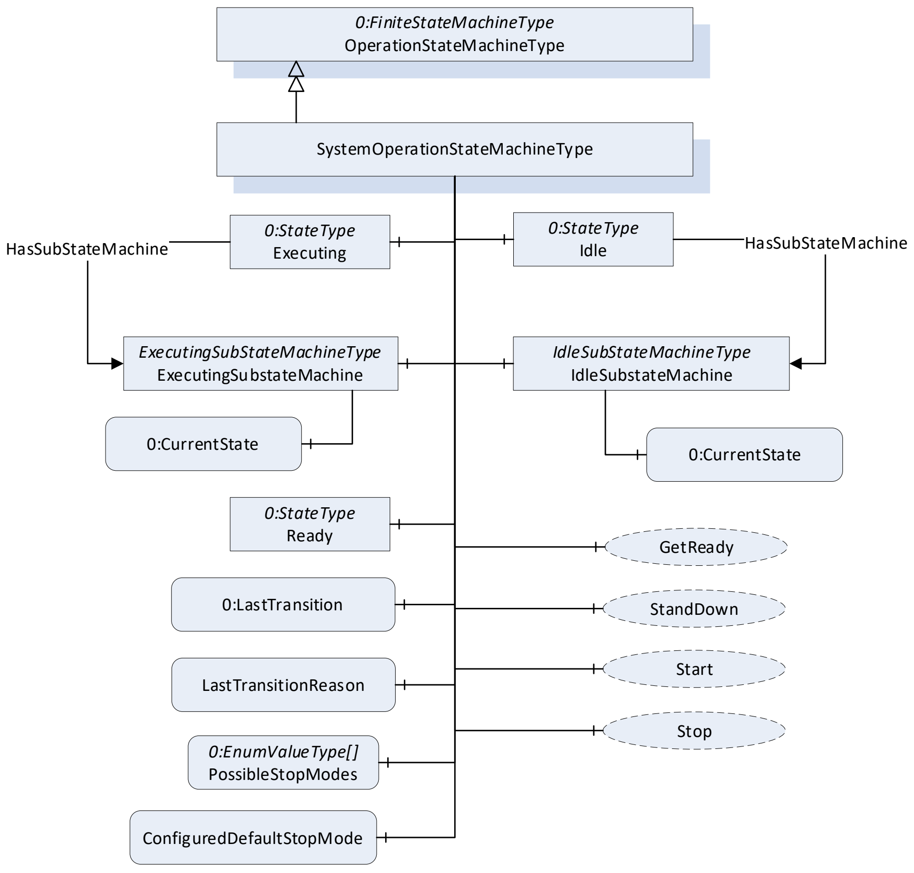


Figure 23 – SystemOperationStateMachineType.

The *SystemOperationStateMachineType* is formally defined in Table 45.

Table 45 – SystemOperationStateMachineType Definition

Attribute	Value				
BrowseName	SystemOperationStateMachineType				
IsAbstract	False				
References	**Node Class**	**BrowseName**	**DataType**	**TypeDefinition**	**Other**
Subtype of the OperationStateMachineType					
0:HasComponent	Object	IdleSubstateMachine		IdleSubstateMachineType	O
0:HasComponent	Object	ExecutingSubstateMachine		ExecutingSubstateMachine Type	O
Inherited from OperationStateMachineType					
0:HasComponent	Variable	LastTransitionReason	0:Int16	0:MultiStateValueDiscrete Type	M
0:HasComponent	Variable	PossibleStopModes	0:EnumValueType[]	0:BaseDataVariableType	O
0:HasComponent	Variable	ConfiguredDefaultStopMo de	0:Int16	0:BaseDataVariableType	O
0:HasComponent	Object	Idle		0:StateType	
0:HasComponent	Object	Ready		0:StateType	
0:HasComponent	Object	Executing		0:StateType	
0:HasComponent	Object	ReadyToIdle		0:TransitionType	
0:HasComponent	Object	IdleToReady		0:TransitionType	
0:HasComponent	Object	ExecutingToReady		0:TransitionType	
0:HasComponent	Object	ReadyToExecuting		0:TransitionType	
0:HasComponent	Object	ExecutingToIdle		0:TransitionType	
0:HasComponent	Object	IdleToIdle		0:TransitionType	
0:HasComponent	Method	Start			O
0:HasComponent	Method	Stop			O
0:HasComponent	Method	StandDown			O
0:HasComponent	Method	GetReady			O
0:HasComponent	Variable	LastTransition	0:LocalizedText	0:FiniteTransitionVariableT ype	M
0:GeneratesEvent	ObjectType	TransitionEventType			O
ConformanceUnits					
Rob System Monitor					
Rob System Operation					
Rob System Events					
Rob System IdleSubstate					
Rob System ExecutingSubstate					

The *Idle State* of *SystemOperationStatemachineType* has additional subcomponents which are defined in Table 46

Table 46 – SystemOperationStateMachineType Additional Subcomponents

Browsepath	References	Node Class	BrowseName	DataTy pe	TypeDefinition	Other
Idle	0:HasSubStateMachine	Object	IdleSubstateMachine		IdleSubstateMachineType	O
Executing	0:HasSubStateMachine	Object	ExecutingSubstateMachine		ExecutingSubstateMachineT ype	O

To acknowledge the state changes in a system the *Conditions* within the *Conditions* folder of *SystemOperationType* must be taken under consideration. A client might need to acknowledge them so that the robot system can be activated. (e.g. operational mode change requires acknowledgement to start the system)

Table 47 – SystemOperationStateMachineType State Descriptions

StateName	Description
Idle	The system is available, but cannot be started because preparation is needed
Ready	The system is ready to start execution.
Executing	The system is executing. Typically, at least one task control is executing, however it is a system specific behaviour.

Table 48 – SystemOperationStateMachine Transition Descriptions

TransitionName	Description
IdleToIdle	Occurs in response to StandDown(), internal events, or when preparations to get the system ready are unsuccessful.
IdleToReady	Occurs in response to GetReady() or internal events, when preparations to get the system ready are successful.
ReadyToIdle	Occurs in response to StandDown() or internal events.
ReadyToExecuting	Occurs in response to Start() or internal events.
ExecutingToReady	Occurs in response to Stop() or internal events when the system has come to a stop
ExecutingToIdle	Occurs in response to internal events (typically in case of an error)

The components of the *SystemOperationStateMachineType* have additional references which are defined in the table below.

Table 49 – SystemOperationStateMachineType Additional References

SourceBrowsePath	Reference Type	Is Forward	TargetBrowsePath
IdleToIdle	0:FromState	True	Idle
	0:ToState	True	Idle
	0:HasCause	True	StandDown
	0:HasEffect	True	TransitionEventType
IdleToReady	0:FromState	True	Idle
	0:ToState	True	Ready
	0:HasCause	True	GetReady
	0:HasEffect	True	TransitionEventType
ReadyToIdle	0:FromState	True	Ready
	0:ToState	True	Idle
	0:HasCause	True	StandDown
	0:HasEffect	True	TransitionEventType
ReadyToExecuting	0:FromState	True	Ready
	0:ToState	True	Executing
	0:HasCause	True	Start
	0:HasEffect	True	TransitionEventType
ExecutingToIdle	0:FromState	True	Executing
	0:ToState	True	Idle
	0:HasEffect	True	TransitionEventType
ExecutingToReady	0:FromState	True	Executing
	0:ToState	True	Ready
	0:HasCause	True	Stop
	0:HasEffect	True	TransitionEventType

The component *Variables* of the *SystemOperationStateMachineType* have additional *Attributes* defined in the table below.

Table 50 – SystemOperationStateMachineType Attribute values for child Nodes

BrowsePath	Value Attribute
Idle 0:StateNumber	1
Ready 0:StateNumber	2
Executing 0:StateNumber	3
IdleToIdle 0:TransitionNumber	1
IdleToReady 0:TransitionNumber	2
ReadyToIdle 0:TransitionNumber	3
ReadyToExecuting 0:TransitionNumber	4
ExecutingToReady 0:TransitionNumber	5
ExecutingToIdle 0:TransitionNumber	6

7.12.1 Start Method

The signature of this *Method* is specified below.

Signature

```
Start (
[out]      0:Int32          Status
);
```

The Start Method is called by a Client to start execution of the system that is represented by the state machine. If the method is successfully called, the method should return with a *Good* or *Uncertain* result code.

The *Start Method* allows an authorized *Client* to command the system to the *Executing State.*

Table 51 – Start Method Arguments

Argument	Description
Status	0 – OK – Everything is OK 1 – E_SystemState – The system is not in correct state for this operation 2 – E_UnexpectedError – Unexpected Error during the method call 3 – E_ActiveAlarm – An Active Alarm prevents the system start 4 – E_AcknowledgeRequired – Condition needs to be acknowledged <0 – shall be used for vendor-specific errors. >0 – are reserved for errors defined by this and future standards

The possible *Method* result codes are formally defined in Table 52

Table 52 - Method Result Codes (defined in Call Service)

Result Code	Description
Good	The system level operation succeeded
Uncertain	The value is uncertain. A concrete reason is defined in the Status Output-Argument.
Bad_InternalError	The method could not be called due to an internal error
Bad_ResourceUnavailable	The Method is locked by another Client/Clientgroup
Bad_UserAccessDenied	The caller is not allowed to call this *Method.*

The *Start Method* representation in the *AddressSpace* is formally defined in Table 53.

Table 53 – Start Method AddressSpace definition.

Attribute	Value				
BrowseName	Start				
References	**NodeClass**	**BrowseName**	**DataType**	**TypeDefinition**	**Others**
0:HasProperty	Variable	0:OutputArguments	0:Argument[]	0:PropertyType	M
ConformanceUnits					
Rob System Operation					

7.12.2 Stop Method

The signature of this *Method* is specified below.

Signature

```
Stop (
[in]      0:Int64         StopMode
[out]     0:Int32         Status
);
```

The *Stop Method* allows an authorized *Client* to command the system to stop executing and leave the *Executing* state.

In conjunction with the usage of this method, the transient states can be expressed with substate machines within the *Executing* state (e.g. the *ExecutingSubstateMachine* in 7.14)

The input argument *StopMode* must be either 0 or one of those listed in the *PossibleStopModes Variable* (see Table 31). If not, then a Bad_InvalidArgument Result Code is returned.

Table 54 – Stop Method Arguments

Argument	Description
StopMode	must either be 0 or one of those listed in the PossibleStopModes Variable (see Table 31. Table 31)
Status	0 – OK – Everything is OK 1 – E_SystemState – The system is not in correct state for this operation 2 – E_UnexpectedError – Unexpected Error during the method call <0 – shall be used for vendor-specific errors. >0 – are reserved for errors defined by this and future standards

The possible *Method* result codes are formally defined in Table 55

Table 55 - Method Result Codes (defined in Call Service)

Result Code	Description
Good	The system level operation succeeded
Bad_InternalError	The system level operation failed because of an internal error
Bad_ResourceUnavailable	The Method is locked by another Client/Clientgroup
Bad_UserAccessDenied	The caller is not allowed to call this *Method.*
Bad_InvalidArgument	The input argument is invalid

The *Stop Method* representation in the AddressSpace is formally defined in Table 56

Table 56 – Stop Method AddressSpace definition.

Attribute	Value				
BrowseName	Stop				
References	**NodeClass**	**BrowseName**	**DataType**	**TypeDefinition**	**Others**
0:HasProperty	Variable	0:InputArguments	0:Argument[]	0:PropertyType	M
0:HasProperty	Variable	0:OutputArguments	0:Argument[]	0:PropertyType	M
ConformanceUnits					
Rob System Operation					

7.12.3 GetReady Method

The signature of this *Method* is specified below.

Signature

```
GetReady (
[out]     0:Int32          Status
);
```

The *GetReady Method* allows an authorized *Client* to request the system to transition from the *Idle* state to the *Ready* state. Internally the system prepares to get started in the next step (e.g. switching on the intermediate circuit). If the internal preparations for this transition are successful, the system will transition from *Idle* to *Ready*. If the internal preparations are unsuccessful then the *IdleToIdle* transition occurs.

In conjunction with the usage of this method, the transient states can be expressed with substate machines within the *Idle* state (e.g. the *IdleSubstateMachine* in 7.13)

Table 57 – GetReady Method Arguments

Argument	Description
Status	0 – OK – Everything is OK 1 – E_SystemState – The system is not in correct state for this operation 2 – E_UnexpectedError – Unexpected Error during the method call 3 – E_ActiveAlarm – An Active Alarm prevents the system start 4 – E_AcknowledgeRequired – Condition needs to be acknowledged <0 – shall be used for vendor-specific errors. >0 – are reserved for errors defined by this and future standards

The possible *Method* result codes are formally defined in Table 58

Table 58 - Method Result Codes (defined in Call Service)

Result Code	Description
Good	The system level operation succeeded
Bad_InternalError	The system level operation failed because of an internal error
Bad_ResourceUnavailable	The Method is locked by another Client/Clientgroup
Bad_UserAccessDenied	The caller is not allowed to call this *Method.*

The *Start Method* representation in the *AddressSpace* is formally defined in Table 59.

Table 59 – GetReady Method AddressSpace definition

Attribute	Value				
BrowseName	GetReady				
References	**NodeClass**	**BrowseName**	**DataType**	**TypeDefinition**	**Others**
0:HasProperty	Variable	0:OutputArguments	0:Argument[]	0:PropertyType	M
ConformanceUnits					
Rob System Operation					

7.12.4 StandDown Method

The signature of this *Method* is specified below.

Signature

```
StandDown (
[out]      0:Int32          Status
);
```

The *StandDown* method allows an authorized Client to request the system to:

- transition from the *Ready* state to the *Idle* state or
- cancel an ongoing preparation of the system and causes the IdleToIdle transition.

Table 60 – StandDown Method Arguments

Argument	Description
Status	0 – OK – Everything is OK 1 – E_SystemState – The system is not in correct state for this operation 2 – E_UnexpectedError – Unexpected Error during the method call <0 – shall be used for vendor-specific errors. >0 – are reserved for errors defined by this and future standards

In conjunction with the usage of this method, the transient states can be expressed with substate machines within the Idle state (e.g. the IdleSubstateMachine in 7.13)

The possible *Method* result codes are formally defined in Table 61.

Table 61 - Method Result Codes (defined in Call Service)

Result Code	Description
Good	The system level operation succeeded
Bad_InternalError	The system level operation failed because of an internal error
Bad_ResourceUnavailable	The Method is locked by another Client/Clientgroup
Bad_UserAccessDenied	The caller is not allowed to call this *Method.*

The *StandDown Method* representation in the *AddressSpace* is formally defined in Table 62.

Table 62 – StandDown Method AddressSpace definition

Attribute	**Value**				
BrowseName	StandDown				
References	**NodeClass**	**BrowseName**	**DataType**	**TypeDefinition**	**ModellingRule**
0:HasProperty	Variable	0:OutputArguments	0:Argument[]	0:PropertyType	M
ConformanceUnits					
Rob System Operation					

7.13 IdleSubstateMachineType

The *IdleSubstateMachineType*, a substate machine of the *Idle State* of the *SystemOperationStateMachine,* represents a mechanism to prepare a system in a way that it will reach *Ready State* of the *SystemOperationStateMachine after preparation.*

The overview of the *IdleSubstateMachine* with all transitions is shown in Figure 24.

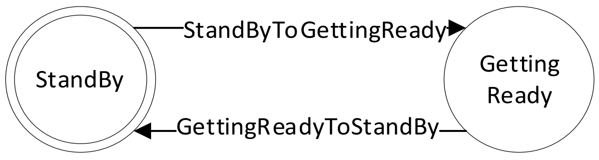


Figure 24 – IdleSubstateMachine

7.13.1 Overview

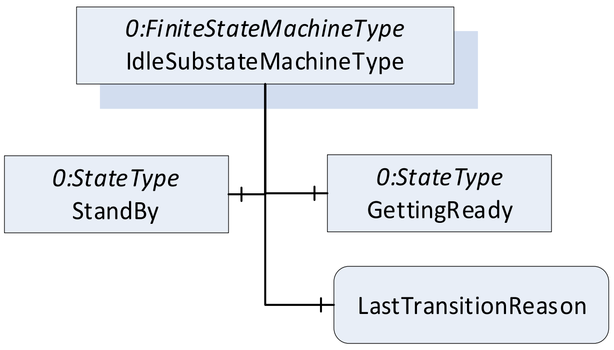


Figure 25 – IdleSubstateMachineType Overview

The *IdleSubstateMachineType* is formally defined in Table 63.

Table 63 – IdleSubstateMachineType Definition

Attribute	**Value**				
BrowseName	IdleSubstateMachineType				
IsAbstract	False				
References	**Node Class**	**BrowseName**	**DataType**	**TypeDefinition**	**Other**
Subtype of the FiniteStateMachineType defined in OPC 10000-5					
0:HasComponent	Variable	LastTransitionReason	0:Int16	0:MultiStateValueDiscreteType	M
0:HasComponent	Object	StandBy		0:InitialStateType	
0:HasComponent	Object	GettingReady		0:StateType	
0:HasComponent	Object	StandByToGettingReady		0:TransitionType	
0:HasComponent	Object	GettingReadyToStandBy		0:TransitionType	
0:HasComponent	Variable	LastTransition	0:LocalizedText	0:FiniteTransitionVariableType	M
0:GeneratesEvent	ObjectType	TransitionEventType			O
ConformanceUnits					
Rob System IdleSubstate					
Rob System Events					

The Variable LastTransitionReason provides the reason for the LastTransition. The EnumValue and ValueAsText of this 0:MultiStateValueDiscreteType are described in the table below.

Table 64 – IdleSubstateMachineType Attribute values for child nodes

BrowsePath	Value Attribute	Description Attribute
LastTransitionReason 0:EnumValues	[{"Value":0,"DisplayName":"Unknown","Description":"Caused by an unknown reason"}, {"Value":1,"DisplayName":"External","Description":"Caused by external operation"}, {"Value":2,"DisplayName":"Direct","Description":"Caused by direct operation"}, {"Value":3,"DisplayName":"System","Description":"Caused by system specific behavior"}, {"Value":4,"DisplayName":"Error", "Description": "Caused by an error"}, {"Value":5,"DisplayName":"Application","Description":"Caused explicitly by end user program logic"}]	

The states of the *IdleSubstateMachineType* are described in Table 65.

Table 65 – IdleSubstateMachineType State Descriptions

StateName	Description
StandBy	The system is available, but cannot be started because a preparation is needed
GettingReady	The system was commanded to get ready (internally or via *GoToReady*()) and the needed preparation to get ready is done in this state by the system. In the *GettingReady* state the system prepares what is to be done (e.g. switching on intermediate circuit) to be ready to start execution in a next step. Typically, all task controls which participate in system functionality are in in *Ready* (or *Executing*) state before calling the GoToReady() method on system level. When the preparation is done successfully the IdleSubstateMachine will be left and the *Ready* state *of the SystemOperationStateMaschine* will be entered. The ongoing preparation can be interrupted by calling the GoToStandBy Method.

The transitions are described in Table 66.

Table 66 – IdleSubstateMachineType Transition Descriptions

TransitionName	Description
StandByToGettingReady	Changes from *StandBy* to *GettingReady* because the preparation was initiated.
GettingReadyToStandBy	Changes from *GettingReady* to *StandBy* because the preparation was aborted.

The components of the *IdleSubstateMachineType* have additional references which are defined in Table 67.

Table 67 – IdleSubstateMachineType Additional References

SourceBrowsePath	Reference Type	Is Forward	TargetBrowsePath
StandByToGettingReady	0:FromState	True	StandBy
	0:ToState	True	GettingReady
	0:HasEffect	True	TransitionEventType
GettingReadyToStandBy	0:FromState	True	GettingReady
	0:ToState	True	StandBy
	0:HasEffect	True	TransitionEventType

The component *Variables* of the *IdleSubstateMachineType* have additional *Attributes* defined in Table 68.

Table 68 – IdleSubstateMachineType Attribute values for child Nodes

BrowsePath	Value Attribute
StandBy 0:StateNumber	1
GettingReady 0:StateNumber	2
StandByToGettingReady 0:TransitionNumber	1
GettingReadyToStandBy 0:TransitionNumber	2

7.14 ExecutingSubstateMachineType

The *ExecutingSubstateMachineType*, a substate machine of *Executing State* of the *SystemOperationStateMachine*, represents a mechanism for describing the stopping behaviour of the system. This can be used to display the stopping behaviour in more detail depending on the StopMode commanded.

The overview of the *ExecutingSubstateMachine* with all transitions is shown in Figure 8.

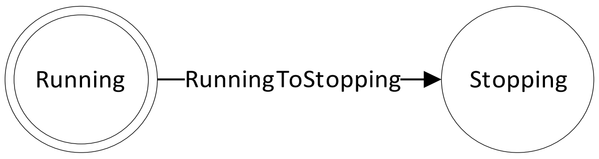


Figure 26 – ExecutingSubstateMachine

7.14.1 Overview

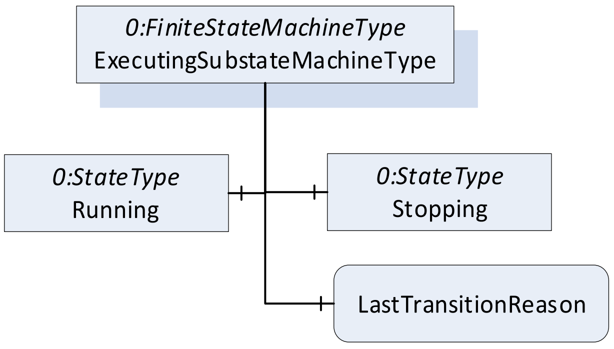


Figure 27 – ExecutingSubstateMachineType Overview

The *ExecutingSubstateMachineType* is formally defined in the table below.

Table 69 – ExecutingSubstateMachine Type Definition

Attribute	Value				
BrowseName	ExecutingSubstateMachineType				
IsAbstract	False				
References	**Node Class**	**BrowseName**	**DataType**	**TypeDefinition**	**Other**
Subtype of the FiniteStateMachineType defined in OPC 10000-5					
0:HasComponent	Variable	LastTransitionReason	0:Int16	0:MultiStateValueDiscreteType	M
0:HasComponent	Object	Running		0:InitialStateType	
0:HasComponent	Object	Stopping		0:StateType	
0:HasComponent	Object	RunningToStopping		0:TransitionType	
Inherited from FiniteStateMachineType					
0:HasComponent	Variable	LastTransition	0:LocalizedText	0:FiniteTransitionVariableType	M
0:GeneratesEvent	ObjectType	TransitionEventType			O
ConformanceUnits					
Rob System ExecutingSubstate					
Rob System Events					

The Variable *LastTransitionReason* provides the reason for the *LastTransition*. The *EnumValues* of this 0:MultiStateValueDiscreteType are described in Table 70.

Table 70 – ExecutingSubstateMachineType Attribute values for child nodes

BrowsePath	Value Attribute	Description Attribute
LastTransitionReason 0:EnumValues	[{"Value":0,"DisplayName":"Unknown","Description":"Caused by an unknown reason"}, {"Value":1,"DisplayName":"External","Description":"Caused by external operation"}, {"Value":2,"DisplayName":"Direct","Description":"Caused by direct operation"}, {"Value":3,"DisplayName":"System","Description":"Caused by system specific behavior"}, {"Value":4,"DisplayName":"Error", "Description": "Caused by an error"}, {"Value":5,"DisplayName":"Application","Description":"Caused explicitly by end user program logic"}]	

The states of the *ExecutingSubstateMachineType* are described in Table 71.

Table 71 – ExecutingSubstateMachineType State Descriptions

StateName	Description
Running	The system is available, but cannot started because a preparation is needed
Stopping	The system was commanded to stop (internally or via Stop() and the needs some time for necessary background processes before entering the Ready state.

The transitions are described in Table 72.

Table 72 – ExecutingSubstateMachineType Transition Descriptions

TransitionName	Description
RunningToStopping	Changes from *Running* to *Stopping* because a system stop was initiated.

The components of the *ExecutingSubstateMachineType* have additional references which are defined in the table below.

Table 73 – ExecutingSubstateMachineType Additional References

SourceBrowsePath	Reference Type	Is Forward	TargetBrowsePath
RunningToStopping	0:FromState	True	Running
	0:ToState	True	Stopping
	0:HasEffect	True	TransitionEventType

The component *Variables* of the *IdleSubstateMachineType* have additional *Attributes* defined in the table below.

Table 74 – ExecutingSubstateMachineType Attribute values for child Nodes

BrowsePath		Value Attribute
Running	0:StateNumber	1
Stopping	0:StateNumber	2
RunningToStopping	0:TransitionNumber	1

7.15 TaskControlOperationType ObjectType

The *TaskControlOperationType* is an *AddIn* to extend instances of *TaskControlType described in* 7.21*.* It provides the possibility to handle programs with designated task controls. The task controls may be started manually or in a system context by use of *SystemOperation*.

The *TaskControlOperationType* provides a state machine to monitor or control a task control and information about which motion devices are controlled by this task control and is formally defined in Table 75.

7.15.1 Overview

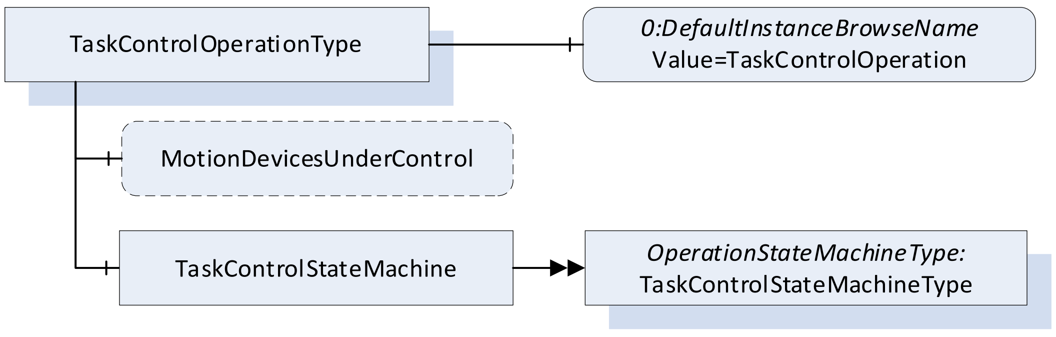

TaskControlOperationType
0:DefaultInstanceBrowseName
Value=TaskControlOperation
MotionDevicesUnderControl
TaskControlStateMachine
OperationStateMachineType:
TaskControlStateMachineType

Figure 28 – TaskControlOperationType Overview

Table 75 – TaskControlOperationType Definition

Attribute	Value				
BrowseName	TaskControlOperationType				
IsAbstract	False				
References	**Node Class**	**BrowseName**	**DataType**	**TypeDefinition**	**Other**
Subtype of the *BaseObjectType* defined in OPC 10000-5.					
0:HasProperty	Variable	MotionDevicesUnderControl	0:NodeId[]	0:PropertyType	O, RO
0:HasComponent	Object	TaskControlStateMachine		TaskControlStateMachineType	M
0:HasProperty	Variable	0:DefaultInstanceBrowseName	0:QualifiedName	0:PropertyType	
ConformanceUnits					
Rob Task Control Monitor					
Rob Task Control Operation					
Rob TC MD Relationship					

The optional *Variable MotionDevicesUnderControl* provides an array of *NodeIds pointing to instances of MotionDeviceType* described in 7.2, which are under control of this task control, in combination with the loaded program.

The Object TaskControlStateMachine provides a state machine to monitor or to control the task controls which instantiated the TaskControlOperationType.

The Property *0:DefaultInstanceBrowseName* of the *TaskControlOperationType* has an additional *Attribute* defined in Table 76.

Table 76 – TaskControlOperationType Attribute values for child Nodes

BrowsePath	Value Attribute	Description Attribute
0:DefaultInstanceBrowseName	TaskControlOperation	

7.16 TaskControlStateMachineType

The *TaskControlStateMachineType* represents the behaviour of a task control and can be used for monitoring or for remote control.

To provide information about the condition of a program loaded inside a task control and the possibility to reset the loaded program the *Ready State* can be extended by the *ReadySubstateMachineType*.

The *Task Control Monitor ConformanceUnit* supports monitoring of the activities done by the operator or system internally. The *Task Control Operation ConformanceUnit supports* additional operations by *Methods*.

The overview of the state machine with all transitions is shown in

Figure 29

When the state machine changes from *Executing State* to *Ready State* caused by internal behaviour of the task control (e.g. because program is ended) it is expected that the task control can be started immediately again e.g. by the *Start()* method. So, the application may set the loaded program to its entry point (like the *ResetToProgramStart Method*) while transition *ExecutingToReady* or when the *Start()* Method is called, that no additional reset of the program is needed.

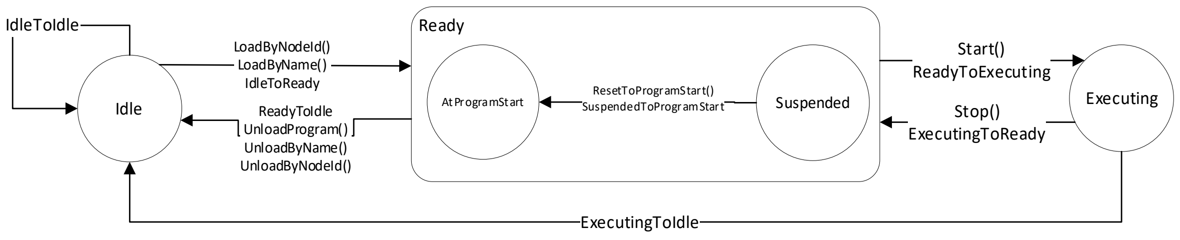


Figure 29 – TaskControl State Machine with ReadySubstateMachine in Ready State

7.16.1 Overview

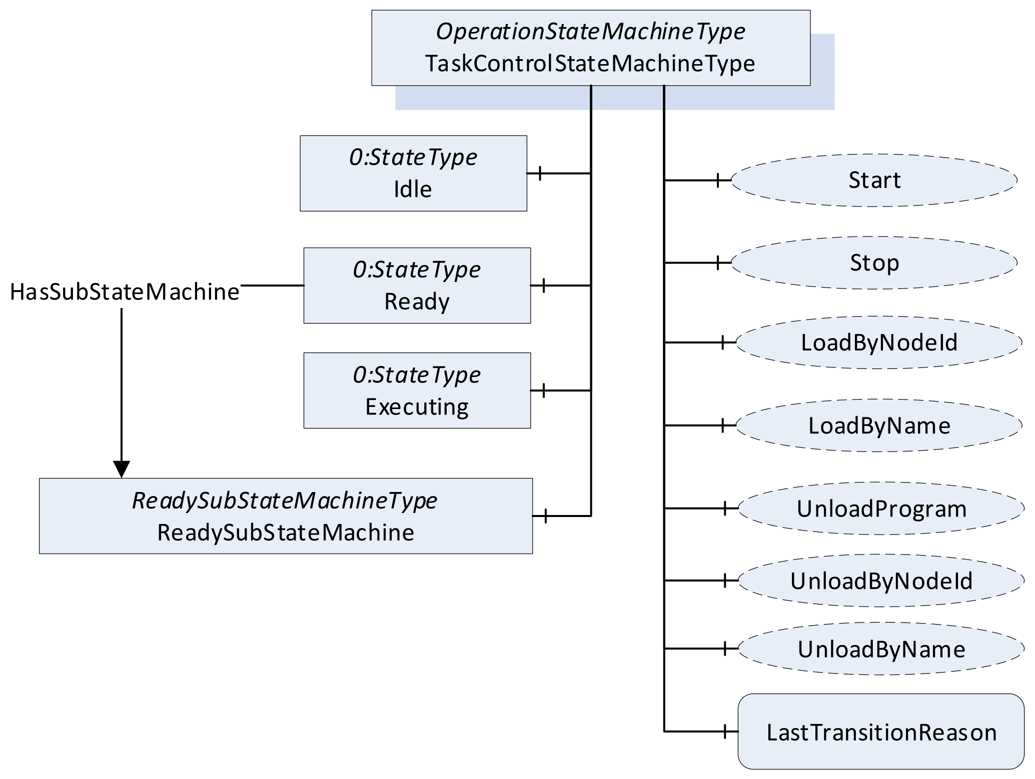


Figure 30 – TaskControlStateMachineType with the ReadySubstateMachine

The *TaskControlStateMachineType* is formally defined in Table 77.

Table 77 – TaskControlStateMachineType Definition

Attribute	Value				
BrowseName	TaskControlStateMachineType				
IsAbstract	False				
References	**Node Class**	**BrowseName**	**DataType**	**TypeDefinition**	**Other**
Subtype of the OperationStateMachineType					
0:HasComponent	Object	ReadySubstateMachine		ReadySubstateMachineType	O
0:HasComponent	Method	LoadByNodeId			O
0:HasComponent	Method	LoadByName			O
0:HasComponent	Method	UnloadProgram			O
0:HasComponent	Method	UnloadByNodeId			O
0:HasComponent	Method	UnloadByName			O
Inherited from OperationStateMachineType					
0:HasComponent	Variable	LastTransitionReason	0:Int16	0:MultiStateValueDiscreteType	M
0:HasComponent	Variable	PossibleStopModes	0:EnumValueType[]	0:BaseDataVariableType	O
0:HasComponent	Variable	ConfiguredDefaultStopMode	0:Int16	0:BaseDataVariableType	O
0:HasComponent	Object	Idle		0:StateType	
0:HasComponent	Object	Ready		0:StateType	
0:HasComponent	Object	Executing		0:StateType	
0:HasComponent	Object	IdleToIdle		0:TransitionType	
0:HasComponent	Object	ReadyToIdle		0:TransitionType	
0:HasComponent	Object	IdleToReady		0:TransitionType	
0:HasComponent	Object	ExecutingToReady		0:TransitionType	
0:HasComponent	Object	ReadyToExecuting		0:TransitionType	
0:HasComponent	Object	ExecutingToIdle		0:TransitionType	
0:HasComponent	Method	Start			O
0:HasComponent	Method	Stop			O
0:HasComponent	Variable	LastTransition	0:LocalizedText	0:FiniteTransitionVariableType	M
0:GeneratesEvent	ObjectType	TransitionEventType			O
ConformanceUnits					
Rob Task Control Monitor					
Rob Task Control Operation					
Rob Task Control ReadySubstate					
Rob System Events					

The Ready State of TaskControlStateMachineType has additional subcomponents which are defined in Table 78.defined in

Table 78 – TaskControlStateMachineType Additional Subcomponents

Source Path	Reference	NodeClass	BrowseName	DataType	TypeDefinition	Others
Ready	0:HasSubStateMachine	Object	ReadySubstateMachine		ReadySubstateMachineType	O

The states of the *TaskControlStateMachineType* are described in Table 79.

Table 79 – TaskControlStateMachineType State Descriptions

StateName	Description
Idle	The task control is not loaded with a program.
Ready	The task control is loaded with a program and is not executing the program.
Executing	The task control is loaded with a program and is executing the program. If the task control automatically starts the program at the beginning, after reaching the end, it shall stay in *Executing* state (continuously executing).

The transitions are described in the table below.

Table 80 – TaskControlStateMachineType Transition Descriptions

TransitionName	Description
IdleToIdle	Occurs if the program could not be loaded correctly
IdleToReady	Occurs in response to LoadProgram() or internal events, when loading a program to the task control
ReadyToIdle	Occurs in response to UnloadProgram() or internal events, when unloading a program from the task control.
ReadyToExecuting	Occurs in response to Start() or internal events, when starting a loaded program in the task control.
ExecutingToReady	Occurs in response to Stop() or internal events, when stopping a loaded program in the task control.
ExecutingToIdle	Occurs in response to internal events, when stopping a loaded program in the task control and unloading the task control.

The componentts of the *TaskControlStateMachineType* have additional references which are defined in Table 81.

Table 81 – TaskControlStateMachineType Additional References

SourceBrowsePath	Reference Type	Is Forward	TargetBrowsePath
IdleToIdle	0:FromState	True	Idle
	0:ToState	True	Idle
	0:HasEffect	True	TransitionEventType
IdleToReady	0:FromState	True	Idle
	0:ToState	True	Ready
	0:HasCause	True	LoadByNodeId
	0:HasCause	True	LoadByName
	0:HasEffect	True	TransitionEventType
ReadyToIdle	0:FromState	True	Ready
	0:ToState	True	Idle
	0:HasCause	True	UnloadProgram
	0:HasCause	True	UnloadByNodeId
	0:HasCause	True	UnloadByName
	0:HasEffect	True	TransitionEventType
ReadyToExecuting	0:FromState	True	Ready
	0:ToState	True	Executing
	0:HasCause	True	Start
	0:HasEffect	True	TransitionEventType
ExecutingToReady	0:FromState	True	Executing
	0:ToState	True	Ready
	0:HasCause	True	Stop
	0:HasEffect	True	TransitionEventType
ExecutingToIdle	0:FromState	True	Executing
	0:ToState	True	Idle
	0:HasEffect	True	TransitionEventType

The component *Variables* of the *TaskControlStateMachineType* have additional *Attributes* defined in Table 82.

Table 82 – TaskControlStateMachineType Attribute values for child Nodes

BrowsePath		Value Attribute
Idle	0:StateNumber	1
Ready	0:StateNumber	2
Executing	0:StateNumber	3
IdleToIdle	0:TransitionNumber	1
IdleToReady	0:TransitionNumber	2
ReadyToIdle	0:TransitionNumber	3
ReadyToExecuting	0:TransitionNumber	4
ExecutingToReady	0:TransitionNumber	5
ExecutingToIdle	0:TransitionNumber	6

7.16.2 LoadByNodeId Method

The signature of this *Method* is specified below.

Signature

```
LoadByNodeId (
   [in]    0:ExpandedNodeId  Id
   [out]   0:Int32           Status
);
```

Table 83 specifies the *Arguments*.

Table 83 – LoadByNodeId Method Arguments

Argument	Description
Id	ExpandedNodeId pointing to an instance of *FileType* representing a task control program or module
Status	0 – OK – Everything is OK 1 – E_SystemState – The system is not in correct state for this operation 2 – E_UnexpectedError – Unexpected Error during the method call 3 – E_ActiveAlarm – An Active Alarm prevents the system start 4 – E_AcknowledgeRequired – Condition needs to be acknowledged <0 – shall be used for vendor-specific errors. >0 – are reserved for errors defined by this and future standards

The *LoadByNodeId Method* is called by a *Client* to load a program or a module into a task control.

For the storage of programs, the *Server* may support the *Programs* folder defined within the *ControllerType.* (see 7.18). This method can be used to load the program or module into the Task Control if the program or module itself is available in the address space (e.g. within the *Programs* folder). The *Id* input argument shall be used to identify the program in the address space. This method can be a synchronous or an asynchronous method. In case it is a synchronous method, the return output arguments may contain more information about the Success or Failure of the method call. If the system is in the Idle state when the method is called, and something goes wrong internally then instead of the *IdleToReady* transition, the *IdleToIdle* transition shall be observed by the client. If the system is already in the Ready state and the *LoadByNodeId* is called and fails, it is system dependent, whether the system goes back to the Idle state or remains in the Ready state. Calling *LoadByNodeId* in the Executing state will fail in normal circumstances.

The possible *Method* result codes are formally defined in Table 84. Some of these *StatusCodes* correspond to the *ProgramId* input argument.

Clients may inspect the *Status* output argument to determine if the program was successfully loaded or if it failed.

Table 84 - Method Result Codes (defined in Call Service)

Result Code	Description
Good	The task control operation succeeded
Bad_InternalError	The task control operation failed because of an internal error
Bad_ResourceUnavailable	The Method is locked by another Client/Clientgroup
Bad_UserAccessDenied	The caller is not allowed to call this *Method.*
Bad_NodeIdUnknown	The *NodeId* refers to a non-existent *TCProgram*.
Bad_NodeIdInvalid	The syntax of the *NodeId* is not valid.

The *LoadByNodeId Method* representation in the *AddressSpace* is formally defined in Table 85.

Table 85 – LoadByNodeId Method AddressSpace definition

Attribute	Value				
BrowseName	LoadByNodeId				
References	**NodeClass**	**BrowseName**	**DataType**	**TypeDefinition**	**ModellingRule**
0:HasProperty	Variable	0:InputArguments	0:Argument[]	0:PropertyType	M
0:HasProperty	Variable	0:OutputArguments	0:Argument[]	0:PropertyType	M
ConformanceUnits					
Rob Task Control Operation					

7.16.3 LoadByName Method

The signature of this *Method* is specified below.

Signature

```
LoadByName (
   [in]    0:String         Name
   [out]   0:Int32          Status
);
```

The table below specifies the *Arguments*.

Table 86 – LoadByName Method Arguments

Argument	Description
Name	Name to identify a task control program or module
Status	0 – OK – Everything is OK 1 – E_SystemState – The system is not in correct state for this operation 2 – E_UnexpectedError – Unexpected Error during the method call 3 – E_ActiveAlarm – An Active Alarm prevents the system start 4 – E_AcknowledgeRequired – Condition needs to be acknowledged <0 – shall be used for vendor-specific errors. >0 – are reserved for errors defined by this and future standards

The *LoadByName Method* is called by a *Client* to load a program or module to a task control. The controller uses the *Name* input argument to identify the program or module to load into the task control. The behaviour of this method is identical to the *LoadByNodeId* (see 7.16.2).

The possible *Method* result codes are formally defined in the table below. Some of these *StatusCodes* correspond to the *Name* input argument.

Clients may inspect the *Status* output argument to determine if the program was successfully loaded or if it failed.

Table 87 - Method Result Codes (defined in Call Service)

Result Code	Description
Good	The task control operation succeeded
Bad_InternalError	The task control operation failed because of an internal error
Bad_ResourceUnavailable	The Method is locked by another Client/Clientgroup
Bad_UserAccessDenied	The caller is not allowed to call this *Method.*

The *LoadByName Method* representation in the *AddressSpace* is formally defined in the table below.

Table 88 – LoadByName Method AddressSpace definition

Attribute	Value				
BrowseName	LoadByName				
References	**NodeClass**	**BrowseName**	**DataType**	**TypeDefinition**	**ModellingRule**
0:HasProperty	Variable	0:InputArguments	0:Argument[]	0:PropertyType	0:Mandatory
0:HasProperty	Variable	0:OutputArguments	0:Argument[]	0:PropertyType	0:Mandatory
ConformanceUnits					
Rob Task Control Operation					

7.16.1 UnloadProgram Method

The signature of this *Method* is specified below.

Signature

```
UnloadProgram (
   [out]   0:Int32               Status
);
```

The table below specifies the *Arguments*.

Table 89 – UnloadProgram Method Arguments

Argument	Description
Status	0 – OK – Everything is OK 1 – E_SystemState – The system is not in correct state for this operation 2 – E_UnexpectedError – Unexpected Error during the method call 3 – E_ActiveAlarm – An Active Alarm prevents the system start 4 – E_AcknowledgeRequired – Condition needs to be acknowledged <0 – shall be used for vendor-specific errors. >0 – are reserved for errors defined by this and future standards

The *UnloadProgram Method* is called by a *Client* to unload the program from a task control.

The possible *Method* result codes are formally defined in the table below.

Table 90 - Method Result Codes (defined in Call Service)

Result Code	Description
Good	The task control operation succeeded
Bad_InternalError	The task control operation failed because of an internal error
Bad_ResourceUnavailable	The Method is locked by another Client/Clientgroup
Bad_UserAccessDenied	The caller is not allowed to call this *Method.*

The *UnloadProgram Method* representation in the *AddressSpace* is formally defined in the table below.

Table 91 – UnloadProgram Method AddressSpace definition

Attribute	Value				
BrowseName	UnloadProgram				
References	**NodeClass**	**BrowseName**	**DataType**	**TypeDefinition**	**ModellingRule**
0:HasProperty	Variable	0:OutputArguments	0:Argument[]	0:PropertyType	0:Mandatory
ConformanceUnits					
Rob Task Control Operation					

7.16.2 UnloadByNodeId Method

The signature of this *Method* is specified below.

Signature

```
UnloadByNodeId (
    [in]    0:ExpandedNodeId    Id
   [out]   0:Int32              Status
);
```

Table 92 specifies the *Arguments*.

Table 92 – UnloadByNodeId Method Arguments

Argument	Description
Id	Expanded NodeId of the module to be unloaded
Status	0 – OK – Everything is OK 1 – E_SystemState – The system is not in correct state for this operation 2 – E_UnexpectedError – Unexpected Error during the method call 3 – E_ActiveAlarm – An Active Alarm prevents the system start 4 – E_AcknowledgeRequired – Condition needs to be acknowledged <0 – shall be used for vendor-specific errors. >0 – are reserved for errors defined by this and future standards

The *UnloadByNodeId Method* is called by a *Client* to unload a task module from a task control. This only works if the task modules are expressed in the address space (7.22).

The possible *Method* result codes are formally defined in the table below.

Table 93 - Method Result Codes (defined in Call Service)

Result Code	Description
Good	The task control operation succeeded
Bad_InternalError	The task control operation failed because of an internal error
Bad_ResourceUnavailable	The Method is locked by another Client/Clientgroup
Bad_UserAccessDenied	The caller is not allowed to call this *Method.*

The *UnloadByNodeId Method* representation in the *AddressSpace* is formally defined in Table 94. This method might not always result in a state change from *Ready* to *Idle*.

Table 94 – UnloadByNodeId Method AddressSpace definition

Attribute	**Value**				
BrowseName	UnloadByNodeId				
References	**NodeClass**	**BrowseName**	**DataType**	**TypeDefinition**	**ModellingRule**
0:HasProperty	Variable	0:InputArguments	0:Argument[]	0:PropertyType	0:Mandatory
0:HasProperty	Variable	0:OutputArguments	0:Argument[]	0:PropertyType	0:Mandatory
ConformanceUnits					
Rob Task Control Operation					

7.16.3 UnloadByName Method

The signature of this *Method* is specified below.

Signature

```
UnloadByName (
    [in]    0:String    Name
    [out]   0:Int32      Status
);
```

Table 95 specifies the *Arguments*.

Table 95 – UnloadByName Method Arguments

Argument	Description
Name	Name of the module to be unloaded
Status	0 – OK – Everything is OK 1 – E_SystemState – The system is not in correct state for this operation 2 – E_UnexpectedError – Unexpected Error during the method call 3 – E_ActiveAlarm – An Active Alarm prevents the system start 4 – E_AcknowledgeRequired – Condition needs to be acknowledged <0 – shall be used for vendor-specific errors. >0 – are reserved for errors defined by this and future standards

The *UnloadByName Method* is called by a *Client* to unload a module from a task control. This can be used to unload the task modules if they are not expressed in the address space and internal logic is used to find the module to be unloaded based on the *Name* input argument.

This method might not always result in a state change from *Ready* to *Idle*.

The possible *Method* result codes are formally defined in the table below.

Table 96 - Method Result Codes (defined in Call Service)

Result Code	Description
Good	The task control operation succeeded
Bad_InternalError	The task control operation failed because of an internal error
Bad_ResourceUnavailable	The Method is locked by another Client/Clientgroup
Bad_UserAccessDenied	The caller is not allowed to call this *Method.*

The *UnloadByName Method* representation in the *AddressSpace* is formally defined in the table below.

Table 97 – UnloadByName Method AddressSpace definition

Attribute	**Value**				
BrowseName	UnloadByName				
References	**NodeClass**	**BrowseName**	**DataType**	**TypeDefinition**	**ModellingRule**
0:HasProperty	Variable	0:InputArguments	0:Argument[]	0:PropertyType	0:Mandatory
0:HasProperty	Variable	0:OutputArguments	0:Argument[]	0:PropertyType	0:Mandatory
ConformanceUnits					
Rob Task Control Operation					

7.16.4 Start Method

The signature of this *Method* is specified below.

Signature

```
Start (
   [out]   0:Int32          Status
);
```

Table 98 specifies the *Arguments*.

Table 98 – Start Method Arguments

Argument	Description
Status	0 – OK – Everything is OK 1 – E_SystemState – The system is not in correct state for this operation 2 – E_UnexpectedError – Unexpected Error during the method call 3 – E_ActiveAlarm – An Active Alarm prevents the system start 4 – E_AcknowledgeRequired – Condition needs to be acknowledged <0 – shall be used for vendor-specific errors. >0 – are reserved for errors defined by this and future standards

The *Start* method can only be successfully called when the task control is in the *Ready* state. Depending on the program pointer, the system shall attempt to start executing from the beginning of the program or continue executing from where it was suspended (See substate machine description of this state in 7.17).

The possible *Method* result codes are formally defined in Table 99.

Table 99 - Method Result Codes (defined in Call Service)

Result Code	Description
Good	The task control operation succeeded
Bad_InternalError	The task control operation failed because of an internal error
Bad_ResourceUnavailable	The Method is locked by another Client/Clientgroup
Bad_UserAccessDenied	The caller is not allowed to call this *Method.*

The *Start Method* representation in the *AddressSpace* is formally defined in Table 100.

Table 100 – Start Method AddressSpace definition.

Attribute	**Value**				
BrowseName	Start				
References	**NodeClass**	**BrowseName**	**DataType**	**TypeDefinition**	**Others**
0:HasProperty	Variable	0:OutputArguments	0:Argument[]	0:PropertyType	M
ConformanceUnits					
Rob Task Control Operation					

7.16.5 Stop Method

The signature of this *Method* is specified below.

Signature

```
Stop (
[in]      0:Int64         StopMode
[out]     0:Int32         Status
);
```

Table 101 specifies the *Arguments*.

Table 101 – StopMethod Arguments

Argument	Description
StopMode	must either be 0 or one of those listed in the PossibleStopModes Variable (see Table 31. Table 31)
Status	0 – OK – Everything is OK 1 – E_SystemState – The system is not in correct state for this operation 2 – E_UnexpectedError – Unexpected Error during the method call 3 – E_ActiveAlarm – An Active Alarm prevents the system start 4 – E_AcknowledgeRequired – Condition needs to be acknowledged <0 – shall be used for vendor-specific errors. >0 – are reserved for errors defined by this and future standards

The *Stop Method* allows an authorized Client to command the task control to stop executing and leave the *Executing* state and go to the *Ready* state. If the *ReadySubstateMachine* (see 7.17) is present, the task control shall be in the *Suspended* state of the substate machine.

The input argument *StopMode* must be either 0 or one of those listed in the *PossibleStopModes* Variable (see Section). If not, then a *Bad_InvalidArgument* Result Code is returned.

The possible *Method* result codes are formally defined in the table below.

Table 102 – Method Result Codes (defined in Call Service)

Result Code	Description
Good	The task control operation succeeded
Bad_InternalError	The task control operation failed because of an internal error
Bad_ResourceUnavailable	The Method is locked by another Client/Clientgroup
Bad_UserAccessDenied	The caller is not allowed to call this *Method.*

The *Stop Method* representation in the *AddressSpace* is formally defined in Table 103.

Table 103 – Stop Method AddressSpace definition.

Attribute	**Value**				
BrowseName	Stop				
References	**NodeClass**	**BrowseName**	**DataType**	**TypeDefinition**	**ModellingRule**
0:HasProperty	Variable	0:InputArguments	0:Argument[]	0:PropertyType	0:Mandatory
0:HasProperty	Variable	0:OutputArguments	0:Argument[]	0:PropertyType	0:Mandatory
ConformanceUnits					
Rob Task Control Operation					

7.17 ReadySubstateMachineType

The *ReadySubstateMachineType* represents the condition of a program loaded into a task control (*TaskControlStateMachine* is in *Ready State*). The state machine has two states to distinguish whether the program pointer is at an initial program position (AtProgramStart) or anywhere else in the program (Suspended). It provides the information whether the program pointer is at the start or in the middle of the program. The method *ResetToProgramStart* can be used to set the program pointer to the start of the program. The state after entering this state machine depends on the program pointer position.

The *TaskControlReadyMonitor ConformanceUnit* defines monitoring of the *ReadySubstateMachine*. The *TaskControlReadyReinitalize ConformanceUnit* defines additionally the reinitialization of the program by a method.

The overview of the state machine with all transitions is shown in Figure 31.

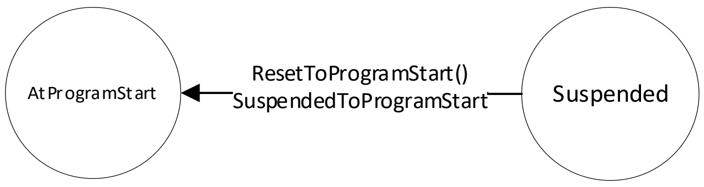


Figure 31 – ReadySubstateMachine

7.17.1 Overview

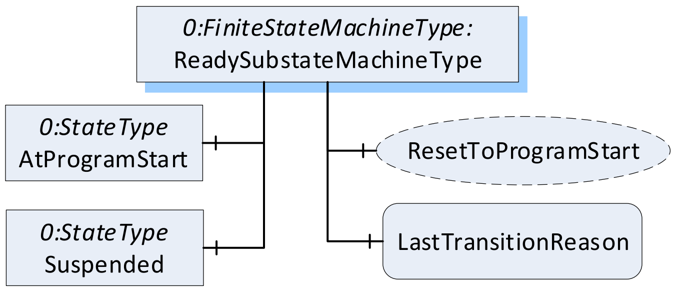


Figure 32 – ReadySubstateMachineType Overview

The *ReadySubstateMachineType* is formally defined in Table 104.

Table 104 – ReadySubstateMachineType Definition

Attribute	Value				
BrowseName	ReadySubstateMachineType				
IsAbstract	False				
References	**Node Class**	**BrowseName**	**DataType**	**TypeDefinition**	**Other**
Subtype of the FiniteStateMachineType defined in OPC 1000-5					
0:HasComponent	Variable	LastTransitionReason	0:Int16	0:MultiStateValueDiscreteType	M
0:HasComponent	Object	AtProgramStart		0:StateType	
0:HasComponent	Object	Suspended		0:StateType	
0:HasComponent	Object	ProgramStartToSuspended		0:TransitionType	
0:HasComponent	Object	SuspendedToProgramStart		0:TransitionType	
0:HasComponent	Method	ResetToProgramStart			O
Inherited from FiniteStateMachineType					
0:HasComponent	Variable	LastTransition	0:LocalizedText	0:FiniteTransitionVariableType	M
0:GeneratesEvent	ObjectType	TransitionEventType			O
ConformanceUnits					
Rob Task Control ReadySubstate					
Rob Task Control Ready Reset					

The *Variable LastTransitionReason* provides the reason for the *LastTransition.* The *EnumValue* and ValueAsText of this 0:MultiStateValueDiscreteType are described in Table 105.

Table 105 – ReadySubstateMachineType Attribute values for child nodes

BrowsePath	Value Attribute	Description Attribute
LastTransitionReason 0:EnumValues	[{"Value":0,"DisplayName":"Unknown","Description":"Caused by an unknown reason"}, {"Value":1,"DisplayName":"External","Description":"Caused by external operation"}, {"Value":2,"DisplayName":"Direct","Description":"Caused by direct operation"}, {"Value":3,"DisplayName":"System","Description":"Caused by system specific behavior"}, {"Value":4,"DisplayName":"Error", "Description": "Caused by an error"}, {"Value":5,"DisplayName":"Application","Description":"Caused explicitly by end user program logic"}]	

The states of the *ReadySubstateMachineType* are described in Table 106.

Table 106 – ReadySubstateMachineType State Descriptions

StateName	**Description**
AtProgramStart	The program pointer of the program loaded in the task control is at the starting point.
Suspended	The program pointer of the program loaded in the task control is anywhere in the program, but not at starting point.

The components of the *ReadySubstateMachineType* have additional references which are defined in Table 107.

Table 107 – ReadySubstateMachineType Additional References

SourceBrowsePath	Reference Type	Is Forward	TargetBrowsePath
ProgramStartToSuspended	0:FromState	True	AtProgramStart
	0:ToState	True	Suspended
	0:HasEffect	True	TransitionEventType
SuspendedToProgramStart	0:FromState	True	Suspended
	0:ToState	True	AtProgramStart
	0:HasEffect	True	TransitionEventType
	0:HasCause	True	ResetToProgramStart

The transitions are described in Table 108 – ReadySubstateMachineType Transition Descriptions.

Table 108 – ReadySubstateMachineType Transition Descriptions

TransitionName	**Description**
ProgramStartToSuspended	Changes from AtProgramStart to Suspended,
SuspendedToProgramStart	Changes from Suspended to AtProgramStart because program was restarted. (Direct, External, System)

The component *Variables* of the *ReadySubstateMachineType* have additional *Attributes* defined in Table 109.

Table 109 – ReadySubstateMachineType Attribute values for child Nodes

BrowsePath	**Value Attribute**
AtProgramStart 0:StateNumber	1
Suspended 0:StateNumber	2
ProgramStartToSuspended 0:TransitionNumber	1
SuspendedToProgramStart 0:TransitionNumber	2

7.17.2 ResetToProgramStart Method

The signature of this *Method* is specified below. .

Signature

```
ResetToProgramStart  (
   [out]   0:Int32          Status
);
```

Tabelle 110 specifies the *Arguments*.

Table 110 – ResetToProgramStart Method Arguments

Argument	Description
Status	0 – OK – Everything is OK 1 – E_SystemState – The system is not in correct state for this operation 2 – E_UnexpectedError – Unexpected Error during the method call 3 – E_ActiveAlarm – An Active Alarm prevents the system start 4 – E_AcknowledgeRequired – Condition needs to be acknowledged <0 – shall be used for vendor-specific errors. >0 – are reserved for errors defined by this and future standards

The *ResetToProgramStart Method* is called by a *Client* to set the program pointer to the starting point of the program.

The possible *Method* result codes are formally defined in the table below.

Table 111 - Method Result Codes (defined in Call Service)

Result Code	Description
Good	The operation succeeded
Bad_InternalError	The operation failed because of an internal error
Bad_ResourceUnavailable	The Method is locked by another Client/Clientgroup
Bad_UserAccessDenied	The caller is not allowed to call this *Method.*

The *ResetToProgramStart Method* representation in the *AddressSpace* is formally defined in Table 112.

Table 112 – ResetToProgramStart Method AddressSpace definition

Attribute	**Value**				
BrowseName	ResetToProgramStart				
References	**NodeClass**	**BrowseName**	**DataType**	**TypeDefinition**	**ModellingRule**
0:HasProperty	Variable	0:OutputArguments	0:Argument[]	0:PropertyType	M
ConformanceUnits					
Task Control Ready Reset					

7.18 ControllerType ObjectType Definition

7.18.1 Overview

The *ControllerType* describes the control unit of motion devices. One motion device system can have one or more instances of the *ControllerType*. The *ControllerType* is formally defined in Table 113.

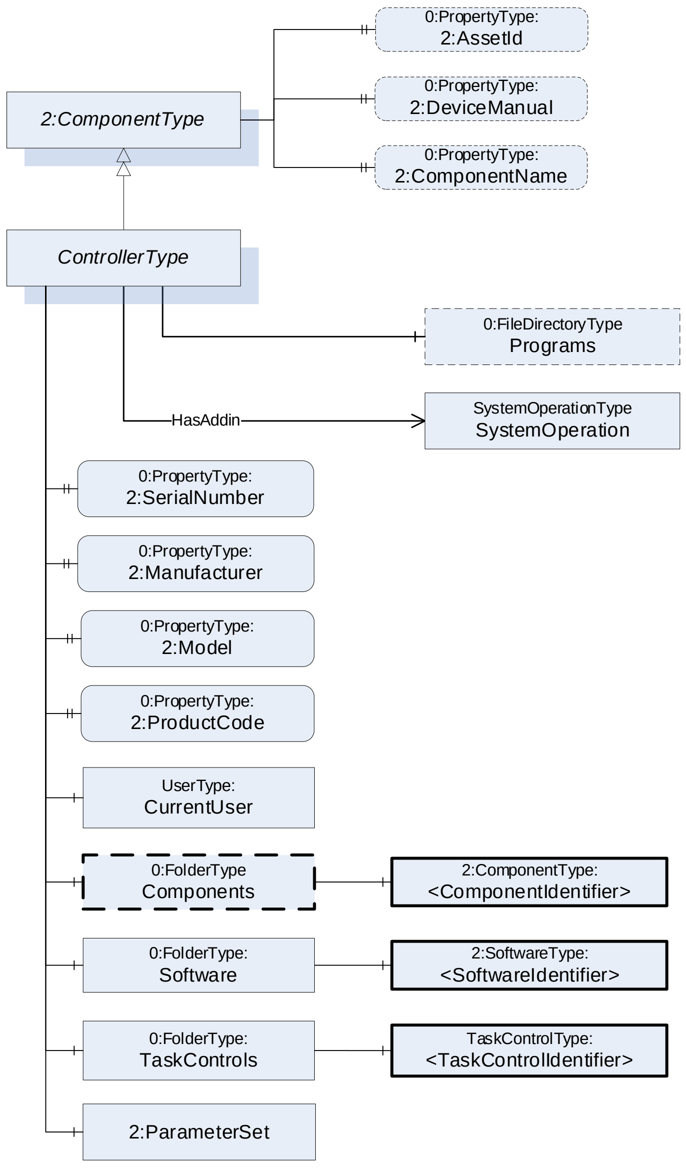


Figure 33 – Overview ControllerType

7.18.2 ControllerType definition

Table 113 – ControllerType Definition

Attribute	Value				
BrowseName	ControllerType				
IsAbstract	False				
References	**Node Class**	**BrowseName**	**DataType**	**TypeDefinition**	**Modelling Rule**
Subtype of the ComponentType defined in OPC Unified Architecture for Devices (DI)					
0:HasProperty	Variable	2:SerialNumber	0:String	0:PropertyType	M
0:HasProperty	Variable	2:Manufacturer	0:LocalizedText	0:PropertyType	M
0:HasProperty	Variable	2:Model	0:LocalizedText	0:PropertyType	M
0:HasProperty	Variable	2:ProductCode	0:String	0:PropertyType	M
0:HasComponent	Object	CurrentUser		UserType	M
0:HasComponent	Object	Components		0:FolderType	O
0:HasComponent	Object	Software		0:FolderType	M
0:HasComponent	Object	TaskControls		0:FolderType	M
0:HasComponent	Object	2:ParameterSet		0:BaseObjectType	O
HasSafetyStates	Object	<SafetyStatesIdentifier>		SafetyStateType	OP
0:HasComponent	Object	Programs		0:FileDirectoryType	O
0:HasAddIn	Object	SystemOperation		SystemOperationType	O
Controls	Object	<MotionDeviceIdentifier>		MotionDeviceType	OP
0:HasProperty	Variable	2:AssetId	0:String	0:PropertyType	O
0:HasProperty	Variable	2:DeviceManual	0:String	0:PropertyType	O
0:HasProperty	Variable	2:ComponentName	0:LocalizedText	0:PropertyType	O
Conformance Units					
Rob System Monitor					
Rob System Operation					
Rob Program File Directory					
Rob System Events					
Rob Controller AM Extended					
Rob Controller AM Extended					
Rob MotionDeviceSystem Base					

The components of the ControllerType have additional subcomponents which are defined in Table 114.

Table 114 – ControllerType Additional Subcomponents

Source Path	Reference	NodeClass	BrowseName	DataType	TypeDefinition	Others
Components	0:HasComponent	Object	<ComponentIdentifier>		2:ComponentType	MP
Software	0:HasComponent	Object	<SoftwareIdentifier>		2:SoftwareType	MP
TaskControls	0:HasComponent	Object	<TaskControlIdentifier>		TaskControlType	MP
2:ParameterSet	0:HasComponent	Variable	TotalPowerOnTime	DurationString	0:BaseDataVariableType	O
2:ParameterSet	0:HasComponent	Variable	StartUpTime	DateTime	0:BaseDataVariableType	O
2:ParameterSet	0:HasComponent	Variable	UpsState	0:String	0:BaseDataVariableType	O
2:ParameterSet	0:HasComponent	Variable	TotalEnergyConsumption	0:Double	0:AnalogUnitType	O
2:ParameterSet	0:HasComponent	Variable	CabinetFanSpeed	0:Double	0:AnalogUnitType	O
2:ParameterSet	0:HasComponent	Variable	CPUFanSpeed	0:Double	0:AnalogUnitType	O
2:ParameterSet	0:HasComponent	Variable	InputVoltage	0:Double	0:AnalogUnitType	O
2:ParameterSet	0:HasComponent	Variable	Temperature	0:Double	0:AnalogUnitType	O

The *SerialNumber* property is a unique production number assigned by the manufacturer of the device. This is often stamped on the outside of the device and may be used for traceability and warranty purposes. This property is derived from *ComponentType* defined in OPC 10000-100.

The *Manufacturer* property provides the name of the company that manufactured the device. This property is derived from *ComponentType* defined in OPC 10000-100.

The *Model* property provides the name of the product. This property is derived from *ComponentType* defined in OPC 10000-100.

The *ProductCode* property provides a unique combination of numbers and letters used to identify the product. It may be the order information displayed on type shields or in ERP systems. This property is derived from *ComponentType* defined in OPC 10000-100.

The *AssetId* property is a user writable alphanumeric character sequence uniquely identifying a component. The vendor, integrator or user of the device provides the ID. It contains typically an identifier in a branch, use case or user specific naming scheme. This could be for example a reference to an electric scheme. For electric schemes typically EN 81346-2 is used. A use case could be to build up a location-oriented view in a spare part management client software. It enables to identify parts with the same article number which is not possible if this entry is not used. This property is defined by *ComponentType* defined in OPC 10000-100.

The *DeviceManual* property allows specifying an address of the user manual for the controller. It may be a pathname in the file system or a URL (Web address). This property is defined by *ComponentType* defined in OPC 10000-100.

The *ComponentName* property provides a user writeable name provided by the vendor, integrator, or user of the device. The *ComponentName* may be a default name given by the vendor. This property is defined by *ComponentType* defined in OPC 10000-100.

The *CurrentUser* object provides information about the active vendor specific user level of the controller.

Components is a container for one or more instances of subtypes of *ComponentType* defined in OPC 10000-100. The listed components are installed in the motion device system, e.g. a processing-unit, a power-supply, an IO-board, or a drive, and have an electrical interface to the controller.

NOTE: This specification recommends using the 3*:Components* folder defined in OPC 40001-1 instead of the one defined in this specification above.

Table 115 – TypeDefinition of Components of ControllerType

Attribute	**Value**				
BrowseName	Components				
References	**Node Class**	**BrowseName**	**DataType**	**TypeDefinition**	**Modelling Rule**
0:HasComponent	Object	<ComponentIdentifier>		2:ComponentType	MandatoryPlaceholder

The *AuxiliaryComponentType* and *DriveType* are the only subtypes of *ComponentType* for use in this container which are described in this specification. The intention is to integrate inside this container devices which are defined in other companion specifications using DI.

Software is a container for one or more instances of *SoftwareType* defined in OPC 10000-100. Each controller has at least one software installed.

TaskControls is a container for one or more instances of *TaskControlType*.

Description of *ParameterSet* of *ControllerType*:

– Variable :The *TotalPowerOnTime* variable provides the total accumulated time the controller was powered on.

– Variable *StartUpTime*: The *StartUpTime* variable provides the date and time of the last start-up of the controller.

– Variable *UpsState*: The *UpsState* variable provides the vendor specific status of an integrated uninterruptible power supply or accumulator system.

– Variable *TotalEnergyConsumption*: The *TotalEnergyConsumption* variable provides total accumulated energy consumed by the motion devices related with this controller instance.

– Variable *CabinetFanSpeed*: The *CabinetFanSpeed* variable provides the speed of the cabinet fan.

– Variable *CPUFanSpeed*: The *CPUFanSpeed* variable provides the speed of the CPU fan.

– Variable *InputVoltage*: The *InputVoltage* variable provides the input voltage of the controller which can be a configured value. To distinguish between an AC or DC supply the optional property *Definition* of the base type *DataItemType* shall be used.

– Variable *Temperature*: The *Temperature* variable provides the controller temperature given by a temperature sensor inside of the controller.

To transfer programs for task controls from or to the controller a file directory named *Programs* can be extended to instances of the *ControllerType*, which is the entry point for organizing programs. Within this file directory programs can be organized in underlaying file directories. This file directory is a virtual folder, so it does not need to be mapped to a folder naming and structure of the file system on the controller.

The *HasSafetyStates* reference provides the relationship of safety states to a controller. The *InverseName* is *SafetyStatesOf.*

The *Controls* reference provides the relationship of a motion device and controller. The InverseName is *IsControlledBy*.

7.19 AuxiliaryComponentType ObjectType Definition

7.19.1 Overview

The *AuxiliaryComponentType* describes components mounted in a controller cabinet or a motion device e.g. an IO-board or a power supply.

It is formally defined in Table 116.

This type should not be used for instances of components which represent a motor, a gear, or a drive For these components this specification describes specific types.

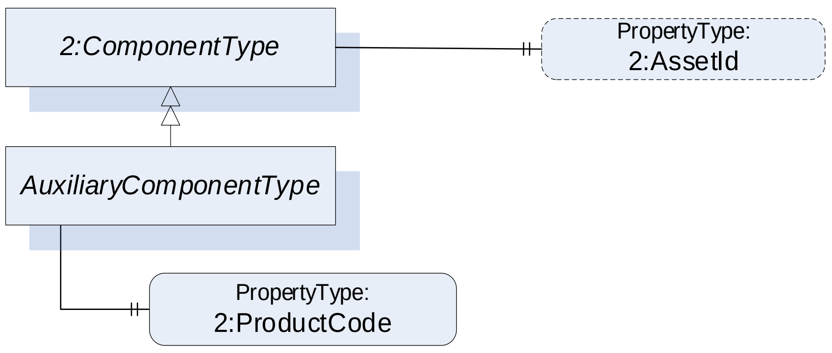


Figure 34 – Overview AuxiliaryComponentType

7.19.2 AuxiliaryComponentType definition

Table 116 – AuxiliaryComponentType Definition

Attribute	**Value**				
BrowseName	AuxiliaryComponentType				
IsAbstract	False				
References	**Node Class**	**BrowseName**	**DataType**	**TypeDefinition**	**Others**
Subtype of the ComponentType defined in OPC Unified Architecture for Devices (DI)					
0:HasProperty	Variable	2:ProductCode	0:String	0:PropertyType	M
0:HasProperty	Variable	2:AssetId	0:String	0:PropertyType	O

The *ProductCode* property provides a unique combination of numbers and letters used to identify the product. It may be the order information displayed on type shields or in ERP systems. This property is derived from *ComponentType* defined in OPC 10000-100.

The *AssetId* property is a user writable alphanumeric character sequence uniquely identifying a component. The vendor, integrator or user of the device provides the ID. It contains typically an identifier in a branch, use case or user specific naming scheme. This could be for example a reference to an electric scheme. For electric schemes typically EN 81346-2 is used. A use case could be to build up a location-oriented view in a spare part management client software. It enables to identify parts with the same article number which is not possible if this entry is not used. This property is defined by *ComponentType* defined in OPC 10000-100.

7.20 DriveType ObjectType Definition

7.20.1 Overview

The *DriveType* describes drives (multi-slot or single-slot axis amplifier) mounted in a controller cabinet or a motion device. When used inside a motion device it should be part of a power train. It is formally defined in Table 117.

B.10.1 shows different possibilities of usage.

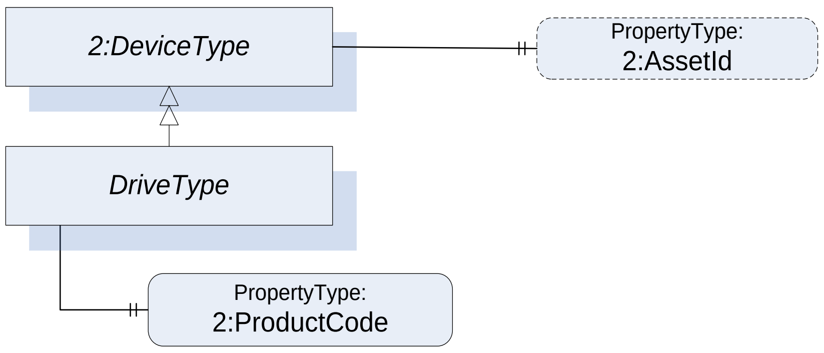


Figure 35 – Overview DriveType

7.20.2 DriveType definition

Table 117 – DriveType Definition

Attribute	**Value**				
BrowseName	DriveType				
IsAbstract	False				
References	**Node Class**	**BrowseName**	**DataType**	**TypeDefinition**	**Modelling Rule**
Subtype of the ComponentType defined in OPC Unified Architecture for Devices (DI)					
0:HasProperty	Variable	2:ProductCode	0:String	0:PropertyType	M
The following instance declarations are not defined by this type, but by the supertype ComponentType are repeated here for better readability					
0:HasProperty	Variable	2:AssetId	0:String	0:PropertyType	O

The *ProductCode* property provides a unique combination of numbers and letters used to identify the product. It may be the order information displayed on type shields or in ERP systems. This property is derived from *ComponentType* defined in OPC 10000-100.

The *AssetId* property is a user writable alphanumeric character sequence uniquely identifying a component. The vendor, integrator or user of the device provides the ID. It contains typically an identifier in a branch, use case or user specific naming scheme. This could be for example a reference to an electric scheme. For electric schemes typically EN 81346-2 is used. A use case could be to build up a location-oriented view in a spare part management client software. It enables to identify parts with the same article number which is not possible if this entry is not used. This property is defined by *ComponentType* defined in OPC 10000-100.

7.21 TaskControlType ObjectType Definition

7.21.1 Overview

TaskControlType represents instances of task controls of a controller and is formally defined in Table 118.

The task control describes an execution engine that loads and runs task programs. One task runs one task program at the time. The system should instantiate the maximum allowed number of task controls.

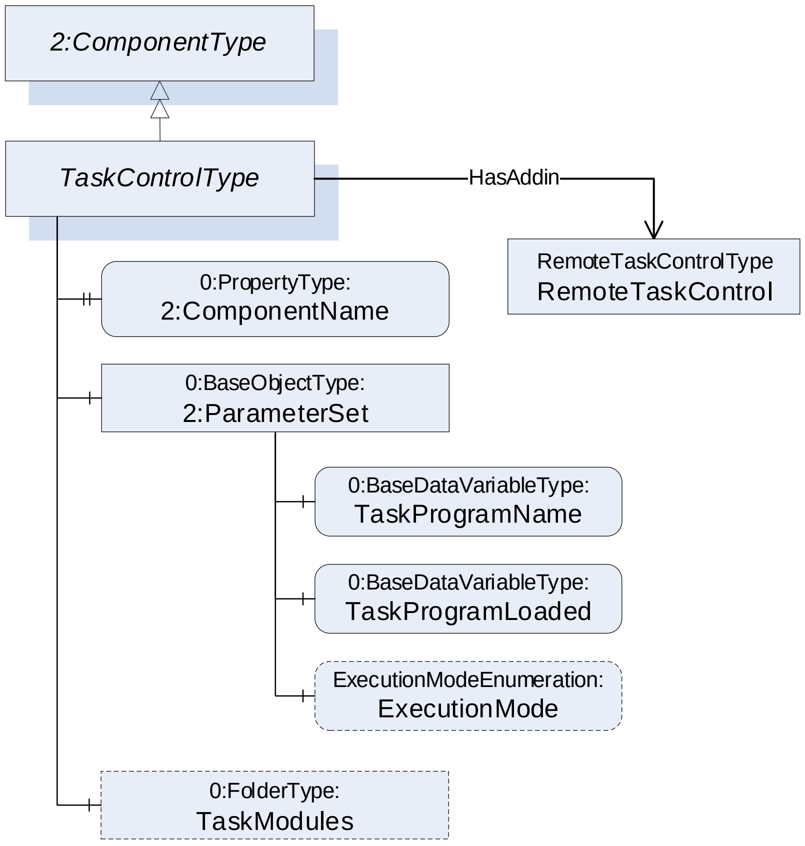


Figure 36 – Overview TaskControlType

7.21.2 TaskControlType definition

Table 118 – TaskControlType Definition

Attribute	Value				
BrowseName	TaskControlType				
IsAbstract	False				
References	**Node Class**	**BrowseName**	**DataType**	**TypeDefinition**	**Modelling Rule**
Subtype of the ComponentType defined in OPC Unified Architecture for Devices (DI)					
0:HasProperty	Variable	2:ComponentName	0:LocalizedText	0:PropertyType	M
0:HasComponent	Object	2:ParameterSet		0:BaseObjectType	M
Controls	Object	<MotionDeviceIdentifier>		MotionDeviceType	OP
0:HasAddIn	Object	TaskControlOperation		TaskControlOperationType	O
0:HasComponent	Object	TaskModules		0:FolderType	O
Conformance Units					
Rob Task Control CM Extended					
Rob Task Control Monitor					
Rob Task Control Operation					
Rob Task Control Modules					
Rob MotionDeviceSystem Base					

The components of the TaskControlType have additional subcomponents which are defined in Table 119.

Table 119 – TaskControlType Additional Subcomponents

Source Path	Reference	NodeClass	BrowseName	DataType	TypeDefinition	Others
2:ParameterSet	0:HasComponent	Variable	TaskProgramName	0:String	0:BaseDataVariableType	M
2:ParameterSet	0:HasComponent	Variable	TaskProgramLoaded	0:Boolean	0:BaseDataVariableType	M
2:ParameterSet	0:HasComponent	Variable	ExecutionMode	ExecutionModeEnumeration	0:BaseDataVariableType	O
TaskModules	0:Organizes	Object	<TaskModule>		TaskModuleType	OP

The *ComponentName* property provides a user writeable name provided by the vendor, integrator, or user of the device. The *ComponentName* of the *TaskControlType* provides a customer given identifier for the task control or a default name given by the vendor. This property is derived from *ComponentType* defined in OPC 10000-100*.*

Object *TaskModules* is a folder of *TaskModuleType* (see 7.22) instances that provides more information about the loaded task modules.

Description of *ParameterSet* of *TaskControlType*:

– Variable *TaskProgramName*: The *TaskProgramName* variable provides a customer given identifier for the task program.

– Variable *TaskProgramLoaded*: The *TaskProgramLoaded* variable is TRUE if a task program is loaded in the task control, FALSE otherwise.

– Variable *ExecutionMode*: The *ExecutionMode* variable tells how the task control executes the task program (see 10.3).

Controls is a reference to provide the relationship between a task control and a motion device. The *InverseName* is *IsControlledBy.*

7.22 TaskModuleType ObjectType Definition

7.22.1 Overview

TaskModuleType provides information about modules loaded on to the TaskControl. It is formally defined in Table 118.

7.22.2 TaskModuleType definition

Table 120 – TaskModuleType Definition

Attribute	**Value**				
BrowseName	TaskModuleType				
IsAbstract	False				
References	**Node Class**	**BrowseName**	**DataType**	**TypeDefinition**	**Modelling Rule**
Subtype of the BaseObjectType defined in OPC Unified Architecture					
0:HasProperty	Variable	Name	0:String	0:PropertyType	M
0:HasProperty	Variable	Version	0:String	0:PropertyType	O
0:HasProperty	Variable	IsReferenced	0:Boolean	0:PropertyType	O
Conformance Units					
Rob Task Control Modules					

The components of the TaskControlType have additional subcomponents which are defined in Table 119.

Variable *Name* provides a name for the task module.

Variable *Version* provides a version information for the task module.

Variable *IsReferenced* provides a boolean flag to indicate if the module is referenced in other modules and/or the program. This information can be useful to determine if the unloading of a module is possible.

7.23 LoadType ObjectType Definition

7.23.1 Overview

The *LoadType* is for describing loads mounted on the motion device typically by an integrator or a customer and is formally defined in Table 121. Instances of this *ObjectType* definition are used to describe the load mounted on one of several mounting points. A common mounting point is the flange of a motion device. Typically, a motion device has additional mounting points on some of the axis. The provided values can either be determined by the robot controller or can be set up by an operator.

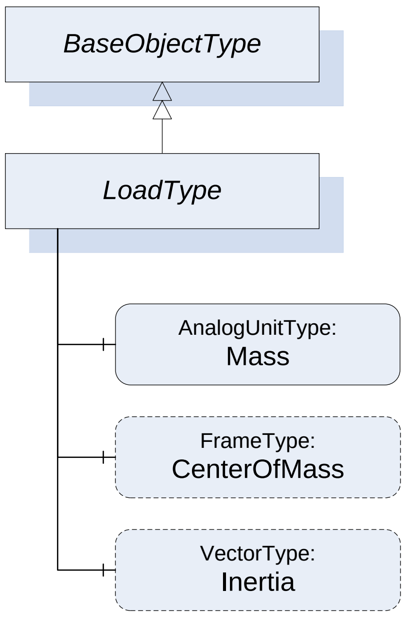


Figure 37 – Overview LoadType

7.23.2 LoadType definition

Table 121 – LoadType Definition

Attribute	**Value**				
BrowseName	LoadType				
IsAbstract	False				
References	**Node Class**	**BrowseName**	**DataType**	**TypeDefinition**	**Modelling Rule**
Subtype of the 0:BaseObjectType defined in OPC Unified Architecture					
0:HasComponent	Variable	Mass	0:Double	AnalogUnitType	M
0:HasComponent	Variable	CenterOfMass	3DFrame	3DFrameType	O
0:HasComponent	Variable	Inertia	3DVector	3DVectorType	O

The variable *Mass* provides the weight of the load mounted on one mounting point. The *EngineeringUnits* of the *Mass* shall be provided.

The variable *CenterOfMass* provides the position and orientation of the center of the mass related to the mounting point using a *3DFrameType*. X, Y, Z define the position of the center of gravity relative to the mounting point coordinate system. A, B, C define the orientation of the principal axes of inertia relative to the mounting point coordinate system. Orientation A, B, C can be "0" for systems which do not need these values.

If the instance of the *LoadType* describes the flange load of a motion device the mounting point coordinate system is the flange coordinate system. If the instance of the *LoadType* describes an additional load of an axis the mounting point coordinate system is vendor specific and it is up to the vendor to model this coordinate system.

The variable *Inertia* uses the *3DVectorType* to describe the three values of the principal moments of inertia with respect to the mounting point coordinate system. If inertia values are provided for rotary axis the *CenterOfMass* shall be provided as well.

Table 122 describes the possible degrees of modelling from a minimal one e.g. only the weight of the mass to a complete one comprising weight, center of mass, principal axes, and inertia.

Table 122 – LoadType possible degrees of modelling

	Mass	CenterOfMass		Inertia
		X, Y, Z	A, B, C	
Mass only	Used	-	-	-
Mass with center of gravity	Used	Used	0, 0, 0	-
Mass with inertia	Used	Used	Used	Used

7.24 UserType ObjectType Definition

7.24.1 Overview

The *UserType ObjectType* describes information of the registered user groups within the control system.

It is formally defined in Table 123.

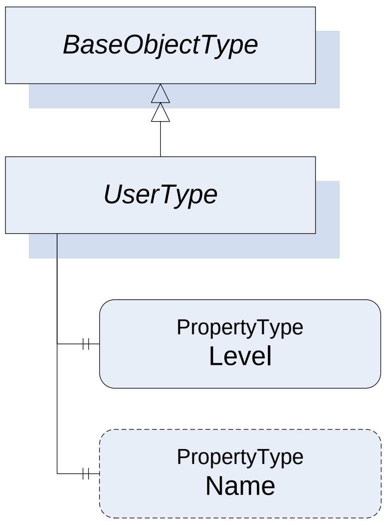


Figure 38 – Overview UserType

7.24.2 UserType definition

Table 123 – UserType Definition

Attribute	**Value**				
BrowseName	UserType				
IsAbstract	False				
References	**Node Class**	**BrowseName**	**DataType**	**TypeDefinition**	**Modelling Rule**
Subtype of the BaseObjectType defined in OPC Unified Architecture					
0:HasProperty	Variable	Level	0:String	0:PropertyType	M
0:HasProperty	Variable	Name	0:String	0:PropertyType	O
Conformance Units					
Rob MotionDeviceSystem Base					

The *Level* property provides information about the access rights and determines what can be viewed, updated, or deleted by a user. Depending on the user level different functionalities are available. The robot vendors might use different descriptions and access levels for the users and might require authentication.

The *Name* property provides the name for the current user within the control system.

8 OPC UA ReferenceTypes

8.1 General

This section defines the ReferenceTypes that are inherent to the present companion specification. Figure 39 describes informally the hierarchy of these Reference Types. OPC UA Reference Types are defined in OPC 10000-3.

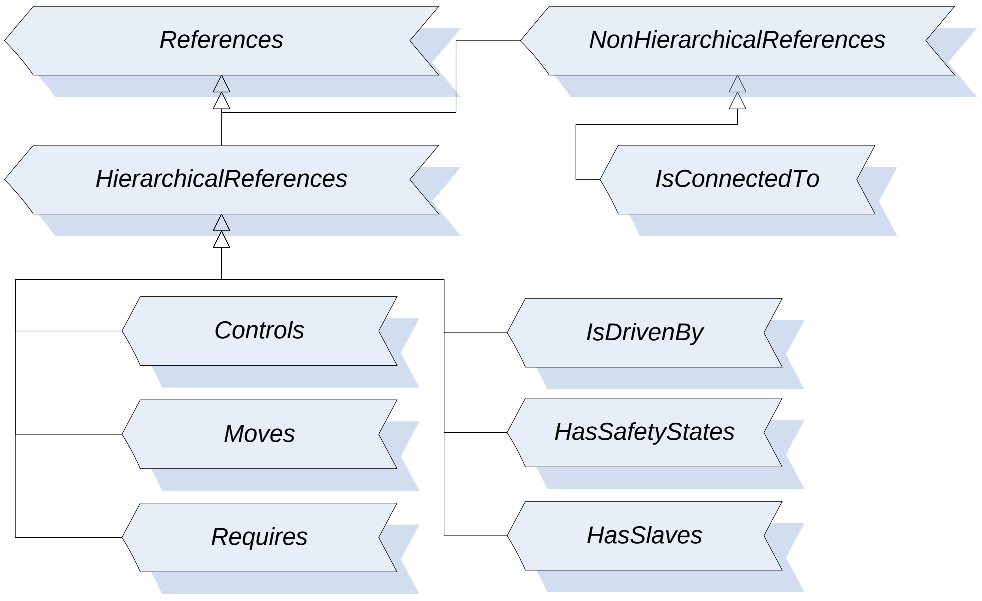


Figure 39 – Reference Type Hierarchy

8.2 Controls (IsControlledBy) Reference Type

The OPC UA *ReferenceType Controls* is used to describe dependencies between objects which have a controlling character. The *BrowseName Controls* and the *InverseName IsControlledBy* describe semantically the hierarchical dependency e.g. a controlling device *Controls* a controlled machine module.

Example for usage in this companion specification: If one controller Controls several motion devices, each motion device IsControlledBy the same controller.

The *SourceNode* of this type shall be an *ObjectType* or *Object* and the *TargetNode* shall be an *Object*.

Table 124 – Controls Reference Definition

Attributes	**Value**				
BrowseName	Controls				
InverseName	IsControlledBy				
Symmetric	False				
IsAbstract	False				
Subtype of the HierarchicalReferences defined in OPC Unified Architecture Part 5					
References	**NodeClass**	**BrowseName**	**DataType**	**TypeDefinition**	**ModellingRule**

8.3 Moves (IsMovedBy) Reference Type

The OPC UA *ReferenceType Moves* is used to describe the coupling between a power train and the axes from the power train point of view. A power train has a *Moves* reference to all axis that are moving when only this powertrain moves.

For examples see B.9.

The *SourceNode* of this type shall be an *ObjectType* or *Object* and the *TargetNode* shall be an *Object*.

Table 125 – Moves Reference Definition

Attributes	**Value**				
BrowseName	Moves				
InverseName	IsMovedBy				
Symmetric	False				
IsAbstract	False				
Subtype of the HierarchicalReferences defined in OPC Unified Architecture Part 5					
References	**NodeClass**	**BrowseName**	**DataType**	**TypeDefinition**	**ModellingRule**

8.4 Requires (IsRequiredBy) Reference Type

The OPC UA *ReferenceType Requires* is used to describe the coupling between a power train and axes from the axis point of view. An axis has a *Requires* reference to all powertrains that need to move such that only this single axis moves.

For examples see Annex B.9.

The *SourceNode* of this type shall be an *ObjectType* or *Object* and the *TargetNode* shall be an *Object*.

Table 126 – Requires Reference Definition

Attributes	**Value**				
BrowseName	Requires				
InverseName	IsRequiredBy				
Symmetric	False				
IsAbstract	False				
Subtype of the HierarchicalReferences defined in OPC Unified Architecture Part 5					
References	**NodeClass**	**BrowseName**	**DataType**	**TypeDefinition**	**ModellingRule**

8.5 IsDrivenBy (Drives) Reference Type

The OPC UA *ReferenceType IsDrivenBy* is used to describe dependencies between objects which have a driving or powering character. The BrowseName *IsDrivenBy* and the InverseName *Drives* describe semantically the hierarchical dependency.

Example for usage in this companion specification: an electrical motor IsDrivenBy and servo amplifier (drive) and an internal drive of a motion device or a drive as a component of a controller Drives a motor.

The *SourceNode* of this type shall be an *ObjectType* or *Object* and the *TargetNode* shall be an *Object*.

Table 127 – Drives Reference Definition

Attributes	**Value**				
BrowseName	IsDrivenBy				
InverseName	Drives				
Symmetric	False				
IsAbstract	False				
Subtype of the HierarchicalReferences defined in OPC Unified Architecture Part 5					
References	**NodeClass**	**BrowseName**	**DataType**	**TypeDefinition**	**ModellingRule**

8.6 IsConnectedTo Reference Type

The OPC UA *ReferenceType* IsConnectedTo is used to describe dependencies between objects which are mounted or mechanically linked or connected to each other. The IsConnectedTo reference is symmetric and has no InverseName.

Example for usage in this companion specification: a motor IsConnectedTo to a gear and vice versa.

Typically, the reference is used to describe the relationships of motors and gears within the same powertrain.

The *SourceNode* of this type shall be an *ObjectType* or *Object* and the *TargetNode* shall be an *Object*.

Table 128 – IsConnectedTo Reference Definition

Attributes	**Value**				
BrowseName	IsConnectedTo				
InverseName					
Symmetric	True				
IsAbstract	False				
Subtype of the NonHierarchicalReferences defined in OPC Unified Architecture Part 5					
References	**NodeClass**	**BrowseName**	**DataType**	**TypeDefinition**	**ModellingRule**

8.7 HasSafetyStates (SafetyStatesOf) Reference Type

The OPC UA *ReferenceType* HasSafetyStates is used to describe dependencies between objects to show which (controller) object is responsible for the execution of the safety-functionality. The BrowseName HasSafetyStates and the InverseName SafetyStatesOf describe semantically the hierarchical dependency.

Example for usage in this companion specification: a controller HasSafetyStates and the reference shows to an instance of SafetyStatesType. It is possible that there are two controller in one motion device system.

The *SourceNode* of this type shall be an *ObjectType* or *Object* and the *TargetNode* shall be an *Object*.

Table 129 – HasSafetyStates Reference Definition

Attributes	**Value**				
BrowseName	HasSafetyStates				
InverseName	SafetyStatesOf				
Symmetric	False				
IsAbstract	False				
Subtype of the HierarchicalReferences defined in OPC Unified Architecture Part 5					
References	**NodeClass**	**BrowseName**	**DataType**	**TypeDefinition**	**ModellingRule**

8.8 HasSlave (IsSlaveOf) Reference Type

The OPC UA *ReferenceType HasSlave* is a reference to provide the master-slave relationship of power trains which provide torque for a common axis. The *InverseName* is *IsSlaveOf*.

The *SourceNode* of this type shall be an *ObjectType* or *Object* and the *TargetNode* shall be an *Object*.

Table 130 – HasSlave Reference Definition

Attributes	**Value**				
BrowseName	HasSlave				
InverseName	IsSlaveOf				
Symmetric	False				
IsAbstract	False				
Subtype of the HierarchicalReferences defined in OPC Unified Architecture Part 5					
References	**NodeClass**	**BrowseName**	**DataType**	**TypeDefinition**	**ModellingRule**

9 OPC UA EventTypes

9.1 MultiAcknowledgeableConditionType

Before commanding robot actions, a control source may need to acknowledge certain conditions first. The information model provides two possibilities for a Client to acknowledge conditions of the system, either with Instances of specific Events in the Address space or with the standard OPC UA Eventing mechanism. The MultiAcknowledgeable*ConditionType* may be used to simply the handling of multiple conditions, which need to be acknowledged by a *Client* to use the *SystemOperationStateMachine* or *IdleSubstateMachine*. Its representation in the *AddressSpace* is formally defined in Table 131.

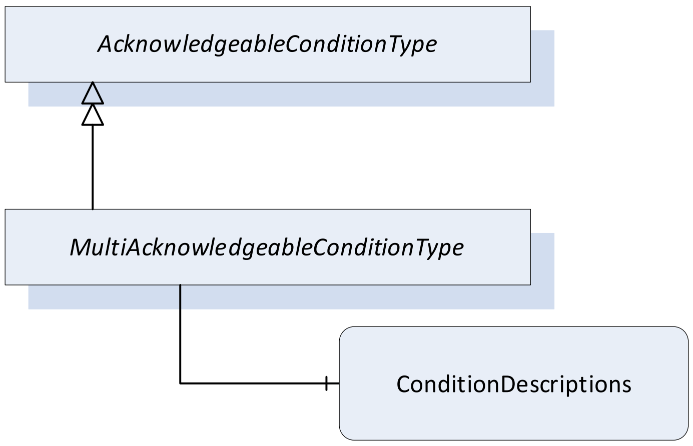

AcknowledgeableConditionType
MultiAcknowledgeableConditionType
ConditionDescriptions

Figure 40 – MultiAcknowledgeableConditionType

Table 131 – MultiAcknowledgeableConditionType Definition

Attribute	**Value**				
BrowseName	MultiAcknowledgeableConditionType				
IsAbstract	False				
References	**NodeClass**	**BrowseName**	**DataType**	**TypeDefinition**	**Other**
Subtype of the Acknowledgeable*ConditionType* defined in OPC 10000-9, it inherits the InstanceDeclarations of that Node.					
0:HasProperty	Variable	ConditionDescriptions	0:LocalizedText[]	0:PropertyType	M
Conformance Units					
Rob RobAckCondInstance					

The MultiAcknowledgeableConditionType inherits all Properties of the AcknowledgeableConditionType.

The *Variable ConditionDescriptions* provides in an Array of descriptions of all conditions, which need acknowledgement.

When a *Client* calls the *Acknowledge Method,* the system tries to acknowledge all conditions described in the *ConditionDescriptions* array at once. If a condition cannot be acknowledged (e.g. cable is broken) and the condition is still active, the instance of the *MultiAcknowledgeableConditionType* stays in *AckedState* False and the ConditionDescriptions are updated with all pending conditions.

There is a race condition here with respect to keeping the *ConditionDescriptions* array up to date, however it is assumed that the logic behind starting the system will never be solely dependent on this variable, but there will be internal checks to make sure that the system can safely start.

Confirmation of the *MultiAcknowledgeableConditionType* instances (using the optional *Confirm* method, inherited from the *AcknowledgeableConditionType*) is undefined and out of scope.

10 OPC UA DataTypes

10.1 MotionDeviceCategoryEnumeration

MotionDeviceCategoryEnumeration provides the kind of motion device based on ISO 8373. It is defined in Table 132.

Table 132 – MotionDeviceCategoryEnumeration Items

Name	Value	Description
OTHER	0	Any motion-device which is not defined by the MotionDeviceCategoryEnumeration
ARTICULATED_ROBOT	1	This robot design features rotary joints and can range from simple two joint structures to 10 or more joints. The arm is connected to the base with a twisting joint. The links in the arm are connected by rotary joints.
SCARA_ROBOT	2	Robot has two parallel rotary joints to provide compliance in a selected plane
CARTESIAN_ROBOT	3	Cartesian robots have three linear joints that use the Cartesian coordinate system (X, Y, and Z). They also may have an attached wrist to allow for rotational movement. The three prismatic joints deliver a linear motion along the axis.
SPHERICAL_ROBOT	4	The arm is connected to the base with a twisting joint and a combination of two rotary joints and one linear joint. The axes form a polar coordinate system and create a spherical-shaped work envelope.
PARALLEL_ROBOT	5	These spider-like robots are built from jointed parallelograms connected to a common base. The parallelograms move a single end of arm tooling in a dome-shaped work area.
CYLINDRICAL_ROBOT	6	The robot has at least one rotary joint at the base and at least one prismatic joint to connect the links. The rotary joint uses a rotational motion along the joint axis, while the prismatic joint moves in a linear motion. Cylindrical robots operate within a cylindrical-shaped work envelope.

Its representation in the AddressSpace is defined in the table below.

Table 133 – MotionDeviceCategoryEnumeration definition

Attribute	Value				
BrowseName	MotionDeviceCategoryEnumeration				
IsAbstract	False				
References	**NodeClass**	**BrowseName**	**DataType**	**TypeDefinition**	**Other**
Subtype of the 0:Enumeration type defined in OPC 10000-5					
0:HasProperty	Variable	0:EnumStrings	0:LocalizedText []	0:PropertyType	

10.2 AxisMotionProfileEnumeration

The *AxisMotionProfileEnumeration* provides the kind of axis motion as defined in Table 134.

Table 134 – AxisMotionProfileEnumeration

Name	Value	Description
OTHER	0	Any motion-profile which is not defined by the AxisMotionProfileEnumeration
ROTARY	1	Rotary motion is a rotation along a circular path with defined limits. Motion movement is not going always in the same direction. Control unit is degree.
ROTARY_ENDLESS	2	Rotary motion is a rotation along a circular path with no limits. Motion movement is going endless in the same direction. Control unit is degree.
LINEAR	3	Linear motion is a one-dimensional motion along a straight line with defined limits. Motion movement is not going always in the same direction. Control unit is mm.
LINEAR_ENDLESS	4	Linear motion is a one-dimensional motion along a straight line with no limits. Motion movement is going endless in the same direction. Control unit is mm.

Its representation in the AddressSpace is defined in the table below.

Table 135 – AxisMotionProfileEnumeration definition

Attribute	Value				
BrowseName	AxisMotionProfileEnumeration				
IsAbstract	False				
References	**NodeClass**	**BrowseName**	**DataType**	**TypeDefinition**	**Other**
Subtype of the 0:Enumeration type defined in OPC 10000-5					
0:HasProperty	Variable	0:EnumStrings	0:LocalizedText []	0:PropertyType	

10.3 ExecutionModeEnumeration

The ExecutionModeEnumeration is defined in Table 136.

Table 136 – ExecutionModeEnumeration

Name	Value	Description
CYCLE	0	Single execution of a task program according to ISO 8373
CONTINUOUS	1	Task program is executed continuously and starts again automatically
STEP	2	Task program is executed in steps

Its representation in the AddressSpace is defined in the table below.

Table 137 – ExecutionModeEnumeration definition

Attribute	Value				
BrowseName	ExecutionModeEnumeration				
IsAbstract	False				
References	**NodeClass**	**BrowseName**	**DataType**	**TypeDefinition**	**Other**
Subtype of the 0:Enumeration type defined in OPC 10000-5					
0:HasProperty	Variable	0:EnumStrings	0:LocalizedText []	0:PropertyType	

10.4 OperationalModeEnumeration

ISO 10218-1:2011 Ch.5.7 defines the different possible Operational Modes. This enumeration is defined in Table 138..

Table 138 – OperationalModeEnumeration

Name	Value	Description
OTHER	0	This value is used when there is no valid operational mode. Examples are: - During system-boot - The system is not calibrated (and hence cannot verify cartesian position values) - There is a failure in the safety system itself
MANUAL_REDUCED_SPEED	1	"Manual reduced speed" - name according to ISO 10218-1:2011
MANUAL_HIGH_SPEED	2	"Manual high speed" - name according to ISO 10218-1:2011
AUTOMATIC	3	"Automatic" - name according to ISO 10218-1:2011
AUTOMATIC_EXTERNAL	4	"Automatic external" - Same as "Automatic" but with external control, e.g. by a PLC

Its representation in the AddressSpace is defined in the table below.

Table 139 – OperationalModeEnumeration definition

Attribute	Value				
BrowseName	OperationalModeEnumeration				
IsAbstract	False				
References	**NodeClass**	**BrowseName**	**DataType**	**TypeDefinition**	**Other**
Subtype of the 0:Enumeration type defined in OPC 10000-5					
0:HasProperty	Variable	0:EnumStrings	0:LocalizedText []	0:PropertyType	

11 Profiles and ConformanceUnits

11.1 Conformance Units

This chapter defines the corresponding *Conformance Units* for the OPC UA Information Model for Robotics.

Table 140 – Conformance Units for Robotics

Category	Title	Description
Server	Rob MotionDeviceSystem Base	Supports the MotionDeviceSystemType with all its mandatory instance declarations and optionally the optional InstanceDeclarations with read access, thereby supporting the base functionality defined in the Robotics Information Model. There is at least one instance of the MotionDeviceSystemType (or a subtype) with all its mandatory elements. The mandatory elements shall in-turn implement all of their mandatory elements recursively.
Server	Rob MotionDevice AM Extended	Supports the MotionDeviceType with all its mandatory instance declarations and optionally the optional InstanceDeclarations with read access. There is at least one instance of the MotionDeviceType (or a subtype) with all its mandatory elements. The Properties 2:AssetId, 2:ComponentName and 2:DeviceManual shall be provided for at least one instance of the MotionDeviceType or its subtypes.
Server	Rob MotionDevice CM Extended	Supports the MotionDeviceType with all its mandatory instance declarations and optionally the optional InstanceDeclarations with read access. There is at least one instance of the MotionDeviceType (or a subtype) with all its mandatory elements. All Variables within the 2:ParameterSet of at least one MotionDeviceType instance shall also be implemented.
Server	Rob MotionDevice Flangeload	Supports the MotionDeviceType with all its mandatory instance declarations and optionally the optional InstanceDeclarations with read access. There is at least one instance of the MotionDeviceType (or a subtype) with all its mandatory elements. The FlangeLoad Object shall be provided for all instances of the MotionDeviceType or its subtypes.
Server	Rob TC Relationship	Supports the MotionDeviceType with all its mandatory instance declarations and optionally the optional InstanceDeclarations with read access. There is at least one instance of the MotionDeviceType (or a subtype) with all its mandatory elements. The Variable TaskControlReference shall be provided for all instances of the MotionDeviceType or its subtypes.
Server	Rob Axis AM Extended	Supports the AxisType with all its mandatory instance declarations and optionally the optional InstanceDeclarations with read access. There is at least one instance of the AxisType (or a subtype) with all its mandatory elements. The Property 2:AssetId shall be provided for at least one instance of the AxisType or its subtypes.
Server	Rob Axis CM Extended	Supports the AxisType with all its mandatory instance declarations and optionally the optional InstanceDeclarations with read access. There is at least one instance of the AxisType (or a subtype) with all its mandatory elements. All Variables within the 2:ParameterSet of at least one instance of AxisType shall also be implemented.
Server	Rob Axis AdditionalLoad	Supports the AxisType with all its mandatory instance declarations and optionally the optional InstanceDeclarations with read access. There is at least one instance of the AxisType (or a subtype) with all its mandatory elements. The AdditionalLoad Object shall be provided for at least one instance of the AxisType or its subtypes.
Server	Rob PowerTrain AM Extended	Supports the PowerTrainType with all its mandatory instance declarations and optionally the optional InstanceDeclarations with read access. There is at least one instance of the PowerTrainType (or a subtype) with all its mandatory elements. The Property 2:ComponentName shall be provided for at least one instance of the PowerTrainType or its subtypes.
Server	Rob Motor AM Extended	Supports the MotorType with all its mandatory instance declarations and optionally the optional InstanceDeclarations with read access. There is at least one instance of the MotorType (or a subtype) with all its mandatory elements. The Property 2:AssetId shall be provided for at least one instance of the MotorType or its subtypes.
Server	Rob Motor CM Extended	Supports the MotorType with all its mandatory instance declarations and optionally the optional InstanceDeclarations with read access. There is at least one instance of the MotorType (or a subtype) with all its mandatory elements. All Variables within the 2:ParameterSet of at least one instance of MotorType shall also be implemented.
Server	Rob Gear AM Extended	Supports the GearType with all its mandatory instance declarations and optionally the optional InstanceDeclarations with read access. There is at least one instance of the GearType (or a subtype) with all its mandatory elements. The Property 2:AssetId shall be provided for at least one instance of the GearType or its subtypes.
Server	Rob Gear CM Extended	Supports the GearType with all its mandatory instance declarations and optionally the optional InstanceDeclarations with read access. There is at least one instance of the GearType (or a subtype) with all its mandatory elements. The Property Pitch shall be provided for at least one instance of the GearType or its subtypes.
Server	Rob Emergency Stop Function	Supports the EmergencyStopFunctionType with all its mandatory instance declarations and optionally the optional InstanceDeclarations with read access. There is at least one instance of the EmergencyStopFunctionType (or a subtype) with all its mandatory elements in the EmergencyStopFunctions folder (instance of FolderType) of an instance of *SafetyStateType*.
Server	Rob Protective Stop Function	Supports the ProtectiveStopFunctionType with all its mandatory instance declarations and optionally the optional InstanceDeclarations with read access. There is at least one instance of the ProtectiveStopFunctionType (or a subtype) with all its mandatory elements in the ProtectiveStopFunctions folder (instance of FolderType) of an instance of SafetyStateType.

Category	Title	Description
Server	Rob Controller AM Extended	Supports the ControllerType with all its mandatory instance declarations and optionally the optional InstanceDeclarations with read access. There is at least one instance of the ControllerType (or a subtype) with all its mandatory elements. The Property 2:AssetId, 2:DeviceManual and 2:ComponentName shall be provided for at least one instance of the ControllerType or its subtypes.
Server	Rob Controller CM Extended	Supports the ControllerType with all its mandatory instance declarations and optionally the optional InstanceDeclarations with read access. There is at least one instance of the ControllerType (or a subtype) with all its mandatory elements. The 2:ParameterSet with all Variables within the 2:ParameterSet of at least one instance of ControllerType shall be implemented.
Server	Rob System Monitor	Supports the SystemOperationType with all its mandatory instance declarations and optionally the optional InstanceDeclarations. There is at least one instance of the SystemOperationType (or a subtype) connected to a ControllerType instance with a 0:HasAddIn Reference.
Server	Rob System Operation	Supports the SystemOperationType with all its mandatory instance declarations and optionally the optional InstanceDeclarations. There is at least one instance of the SystemOperationType (or a subtype) connected to a ControllerType instance with a 0:HasAddIn Reference. Each instance of the SystemOperationStateMachineType shall implement the methods defined within the SystemOperationStateMachineType.
Server	Rob RobAckCondInstance	Supports the SystemOperationType with all its mandatory instance declarations and optionally the optional InstanceDeclarations. There is at least one instance of the SystemOperationType (or a subtype) connected to a ControllerType instance with a 0:HasAddIn Reference. Each instance of the SystemOperationType shall implement the Conditions InstanceDeclaration defined within the SystemOperationType. The MultiAcknowledgeableConditionType is supported with all its mandatory instance declarations and optionally the optional InstanceDeclarations. At least once instance of MultiAcknowledgeableConditionType shall be provided within the Conditions InstanceDeclaration defined within the SystemOperationType.
Server	Rob System Events	The OPC UA Server supports eventing and shall support the Events from the MotionDeviceSystemType instance.
Server	Rob System IdleSubstate	Supports the SystemOperationStateMachineType with all its mandatory instance declarations and optionally the optional InstanceDeclarations. There is at least one instance of the SystemOperationStateMachineType (or a subtype). At least one instance of the SystemOperationStateMachineType shall implement the IdleSubstateMachine InstanceDeclaration defined within the SystemOperationStateMachineType.
Server	Rob System ExecutingSubstate	Supports the SystemOperationStateMachineType with all its mandatory instance declarations and optionally the optional InstanceDeclarations. There is at least one instance of the SystemOperationStateMachineType (or a subtype). At least one instance of the SystemOperationStateMachineType shall implement the ExecutingSubstateMachine InstanceDeclaration defined within the SystemOperationStateMachineType.
Server	Rob Task Control CM Extended	Supports the TaskControlType with all its mandatory instance declarations and optionally the optional InstanceDeclarations with read access. There is at least one instance of the TaskControlType (or a subtype) with all its mandatory elements. The Variable ExecutionMode within the 2:ParameterSet, shall be provided for at least one instance of instances of the TaskControlType or its subtypes.
Server	Rob Task Control Monitor	Supports the TaskControlOperationType with all its mandatory instance declarations and optionally the optional InstanceDeclarations. There is at least one instance of the TaskControlOperationType (or a subtype) connected to a TaskControlType instance with a 0:HasAddIn Reference.
Server	Rob Task Control Operation	Supports the TaskControlOperationType with all its mandatory instance declarations and optionally the optional InstanceDeclarations. There is at least one instance of the TaskControlOperationType (or a subtype) connected to a TaskControlType instance with a 0:HasAddIn Reference. Each instance of the TaskControlOperationStateMachineType shall implement the methods defined within the TaskControlOperationStateMachineType.
Server	Rob TC MD Relationship	Supports the TaskControlOperationType with all its mandatory instance declarations and optionally the optional InstanceDeclarations. There is at least one instance of the TaskControlOperationType (or a subtype) connected to a TaskControlType instance with a 0:HasAddIn Reference. Each instance of the TaskControlOperationType shall implement the MotionDevicesUnterControl Property defined within the TaskControlOperationType.
Server	Rob Task Control ReadySubstate	Supports the TaskControlOperationStateMachineType with all its mandatory instance declarations and optionally the optional InstanceDeclarations. There is at least one instance of the TaskControlOperationStateMachineType (or a subtype). At least one instance of the TaskControlOperationStateMachineType shall implement the ReadySubstateMachine InstanceDeclaration defined within the TaskControlOperationStateMachineType.

Category	Title	Description
Server	Task Control Ready Reset	Supports the TaskControlOperationStateMachineType with all its mandatory instance declarations and optionally the optional InstanceDeclarations. There is at least one instance of the TaskControlOperationStateMachineType (or a subtype). Each instance of the TaskControlOperationStateMachineType shall implement the ReadySubstateMachine InstanceDeclaration defined within the TaskControlOperationStateMachineType. At least one instance of the ReadySubstateMachine shall implement the ResetToProgramStart method defined within the ReadySubstateMachineType.
Server	Rob Program File Directory	At least one instance of the ControllerType shall implement the Programs InstanceDeclaration defined within the ControllerType.
Server	Rob Task Control Modules	At least one instance of the TaskControlType shall implement the TaskModules InstanceDeclaration defined within the TaskControlType. If a TaskControlType instance implements the TaskModules InstanceDeclaration (defined within the TaskControlType), then all TaskControlType instances (in the TaskControls folder) of that ControllerType instance, shall implement the TaskModules InstanceDeclaration.

11.2 Profiles

11.2.1 Profile list

Table 141 lists all Profiles defined in this document and defines their URIs.

Table 141 – Profile URIs for OPC UA for Robotics

Profile	URI
Robotics Base Server Facet	http://opcfoundation.org/UA-Profile/Robotics/Server/RobBase
Robotics MDS Operation Server Facet	http://opcfoundation.org/UA-Profile/Robotics/Server/RobOperation
Robotics AM Extended Server Facet	http://opcfoundation.org/UA-Profile/Robotics/Server/RobAMExtended
Robotics CM Extended Server Facet	http://opcfoundation.org/UA-Profile/Robotics/Server/RobCMExtended

11.2.2 Server Facets

11.2.2.1 Overview

The following sections specify the *Facets* available for *Servers* that implement the OPC UA for Robotics companion specification. Each section defines and describes a *Facet* or *Profile*.

11.2.2.2 Robotics Base Server Facet

Table 142 defines a *Facet* that describes the Robotics Base Server Facet.

Table 142 – Robotics Base Server Facet

Group	Conformance Unit / Profile Title	Mandatory / Optional
Address Space Model	0:Address Space Base	M
Address Space Model	0:Address Space Interfaces	M
Address Space Model	0:Address Space AddIn Reference	M
Address Space Model	0:Address Space AddIn DefaultInstanceBrowsename	M
View Services	0:View Basic	M
View Services	0:View TranslateBrowsePath	M
View Services	0:View Minimum Continuation Point 01	M
Attribute Services	0:Attribute Read	M
Robotics	Rob MotionDeviceSystem Base	M

11.2.2.3 Robotics MDS Operation Server Facet

Table 143 defines a *Facet* that describes the Robotics MDS Operation Server Facet.

Table 143 – Robotics MDS Operation Server Facet

Group	Conformance Unit / Profile Title	Mandatory / Optional
Profile	Robotics Base Server Facet	M
Robotics	Rob System Operation	M
Robotics	Rob Task Control Operation	O
Robotics	Rob RobAckCondInstance	O
Robotics	Rob Task Control ReadySubstate	O
Robotics	Task Control Ready Reset	O
Robotics	Rob Program File Directory	O
Robotics	Rob Task Control Modules	O

11.2.2.4 Robotics AM Extended Server Facet

Table 144 defines a *Facet* that describes the Robotics AM Extended Server Facet.

Table 144 – Robotics AM Extended Server Facet

Group	Conformance Unit / Profile Title	Mandatory / Optional
Robotics	Rob MotionDeviceSystem Base	M
Robotics	Rob MotionDevice AM Extended	M
Robotics	Rob MotionDevice Flangeload	O
Robotics	Rob TC Relationship	O
Robotics	Rob Axis AM Extended	M
Robotics	Rob Axis AdditionalLoad	O
Robotics	Rob PowerTrain AM Extended	M
Robotics	Rob Gear AM Extended	M
Robotics	Rob Emergency Stop Function	O
Robotics	Rob Protective Stop Function	O
Robotics	Rob Controller AM Extended	M
Robotics	Rob TC MD Relationship	O
Robotics	Rob Program File Directory	O
Robotics	Rob Task Control Modules	O

11.2.2.5 Robotics CM Extended Server Facet

Table 145 defines a *Facet* that describes the Robotics CM Extended Server Facet.

Table 145 – Robotics CM Extended Server Facet

Group	Conformance Unit / Profile Title	Mandatory / Optional
Robotics	Rob MotionDeviceSystem Base	M
Robotics	Rob MotionDevice CM Extended	M
Robotics	Rob Axis CM Extended	M
Robotics	Rob PowerTrain CM Extended	M
Robotics	Rob Gear CM Extended	M
Robotics	Rob Controller CM Extended	M
Robotics	Rob System Monitor	O
Robotics	Rob System Events	O
Robotics	Rob System IdleSubstate	O
Robotics	Rob System ExecutingSubstate	O
Robotics	Rob Task Control CM Extended	M
Robotics	Rob Task Control Monitor	O
Robotics	Rob RobAckCondInstance	O

12 Namespaces

12.1 Namespace Metadata

Table 146 defines the namespace metadata for this document. The *Object* is used to provide version information for the namespace and an indication about static *Nodes*. Static *Nodes* are identical for all *Attributes* in all *Servers*, including the *Value Attribute*. See OPC 10000-5 for more details.

The information is provided as *Object* of type *NamespaceMetadataType*. This *Object* is a component of the *Namespaces Object* that is part of the *Server Object*. The *NamespaceMetadataType ObjectType* and its *Properties* are defined in OPC 10000-5.

The version information is also provided as part of the ModelTableEntry in the UANodeSet XML file. The UANodeSet XML schema is defined in Table 146

Table 146 – NamespaceMetadata Object for this Document

Attribute	**Value**	
BrowseName	http://opcfoundation.org/UA/Robotics/	
Property	**DataType**	**Value**
NamespaceUri	String	http://opcfoundation.org/UA/Robotics/
NamespaceVersion	String	1.01
NamespacePublicationDate	DateTime	2025-03-17
IsNamespaceSubset	Boolean	False
StaticNodeIdTypes	IdType []	0
StaticNumericNodeIdRange	NumericRange []	
StaticStringNodeIdPattern	String	

Note: The *IsNamespaceSubset Property* is set to False as the UaNodeSet XML file contains the complete Namespace. *Servers* only exposing a subset of the Namespace need to change the value to True.

12.2 Handling of OPC UA Namespaces

Namespaces are used by OPC UA to create unique identifiers across different naming authorities. The *Attributes NodeId* and *BrowseName* are identifiers. A *Node* in the UA *AddressSpace* is unambiguously identified using a *NodeId*. Unlike *NodeIds*, the *BrowseName* cannot be used to unambiguously identify a *Node*. Different *Nodes* may have the same *BrowseName*. They are used to build a browse path between two *Nodes* or to define a standard *Property*.

Servers may often choose to use the same namespace for the *NodeId* and the *BrowseName*. However, if they want to provide a standard *Property*, its *BrowseName* shall have the namespace of the standards body although the namespace of the *NodeId* reflects something else, for example the *EngineeringUnits Property*. All *NodeIds* of *Nodes* not defined in this document shall not use the standard namespaces.

Table 147 provides a list of mandatory and optional namespaces used in an *OPC UA for Robotics Server*.

Table 147 – Namespaces used in a OPC Robotics Server.

NamespaceURI	Description	Use
http://opcfoundation.org/UA/	Namespace for *NodeIds* and *BrowseNames* defined in the OPC UA specification. This namespace shall have namespace index 0.	Mandatory
Local Server URI	Namespace for nodes defined in the local server. This namespace shall have namespace index 1.	Mandatory
http://opcfoundation.org/UA/DI/	Namespace for *NodeIds* and *BrowseNames* defined in OPC 10000-100. T*he namespace index is Server specific.*	Mandatory
http://opcfoundation.org/UA/Machinery/	Namespace for *NodeIds* and *BrowseNames* defined in OPC UA for Machinery. The namespace index is *Server* specific.	Optional
http://opcfoundation.org/UA/Robotics/	Namespace for *NodeIds* and *BrowseNames* defined in this document. The namespace index is *Server* specific.	Mandatory
Vendor specific types	A *Server* may provide vendor-specific types like types derived from *ObjectTypes* defined in this document in a vendor-specific namespace.	Optional
Vendor specific instances	A *Server* provides vendor-specific instances of the standard types or vendor-specific instances of vendor-specific types in a vendor-specific namespace. It is recommended to separate vendor specific types and vendor specific instances into two or more namespaces.	Mandatory

Table 148 provides a list of namespaces and their indices used for *BrowseNames* in this document. The default namespace of this document is not listed since all *BrowseNames* without prefix use this default namespace.

Table 148 – Namespaces used in this document.

NamespaceURI	Namespace Index	Example
http://opcfoundation.org/UA/	0	0:EngineeringUnits
http://opcfoundation.org/UA/DI/	2	2:DeviceRevision
http://opcfoundation.org/UA/Machinery/	3	3:MachineIdentificationType

Annex A (normative)

OPC UA for Robotics Namespace and mappings

A.1 Namespace and identifiers for Robotics Information Model

The Robotics *Information Model* is identified by the following URI:

http://opcfoundation.org/UA/Robotics/

Documentation for the NamespaceUri can be found here.

The *NodeSet* associated with this version of specification can be found here:

https://reference.opcfoundation.org/nodesets/?u=http://opcfoundation.org/UA/Robotics/&v=1.01&i=1

The *NodeSet* associated with the latest version of the specification can be found here:

https://reference.opcfoundation.org/nodesets/?u=http://opcfoundation.org/Robotics/&i=1

Supplementary files for the Robotics *Information Model* can be found here:

https://reference.opcfoundation.org/nodesets/?u=http://opcfoundation.org/Robotics/&v=1.01&i=2

The files associated with the latest version of the specification can be found here:

https://reference.opcfoundation.org/nodesets/?u=http://opcfoundation.org/Robotics/&i=2

A.2 Capability Identifier

The capability identifier for this document shall be:

```
Robotics
```

Annex B (informative)

Examples

B.1 Overview

This chapter describes examples for motion device systems, motion devices, axes, and power trains.

In addition, this chapter contains examples of how to use the references contained in this specification.

B.2 Example for motion device systems

Typically, a motion device system consists of at least one manipulator and one control unit. Manipulators shown in Figure B.1, Figure B.2, Figure B.3, Figure B.4, Figure B.5, Figure B.6 and Figure B.7 normally have only one control unit.

Figure B.8 shows an example with four motion devices which can be controlled by one control unit.

The motion device system illustrated in Figure B.9 consists of three motion devices and may have one or more control units regarding the motion devices. When a safety PLC is integrated in this motion device system, it can be described as an own instance of a *ControllerType*. This Instance would have no Reference to an instance of a motion device because the safety PLC doesn´t control a manipulator. It could however have a Reference to the instantiated *SafetyStates*.

B.3 Examples for motion devices and controllers in a motion device system

The motion devices shown in Figure B.8 are typically controlled by one controller unit. Each motion device *IsControlledBy* the same controller.

The system illustrated in Figure B.9 may have two control units. For example, one controller *Controls* both articulated robots and the mobile platform *IsControlledBy* the other controller.

B.4 Examples for motion devices

A motion device can be any manipulator e.g. a robot, a linear unit, or a turn table. For each motion device which has an own type plate an instance of a *MotionDeviceType* shall be created.

The kind of motion device shall be described with the *Property MotionDeviceCategory* of the *ParameterSet* of the *MotionDeviceType* by the *MotionDeviceCategoryEnumeration,* which is based on definitions of ISO 8373:2012.

The Figures Figure B.1 and Figure B.2 show examples of cartesian manipulators.

Figure B.2 shows a portal manipulator, a variant of a cartesian manipulator. Axis 1 in this example is driven with master-slave and a robot-hand is mounted at the flange of the cartesian manipulator.

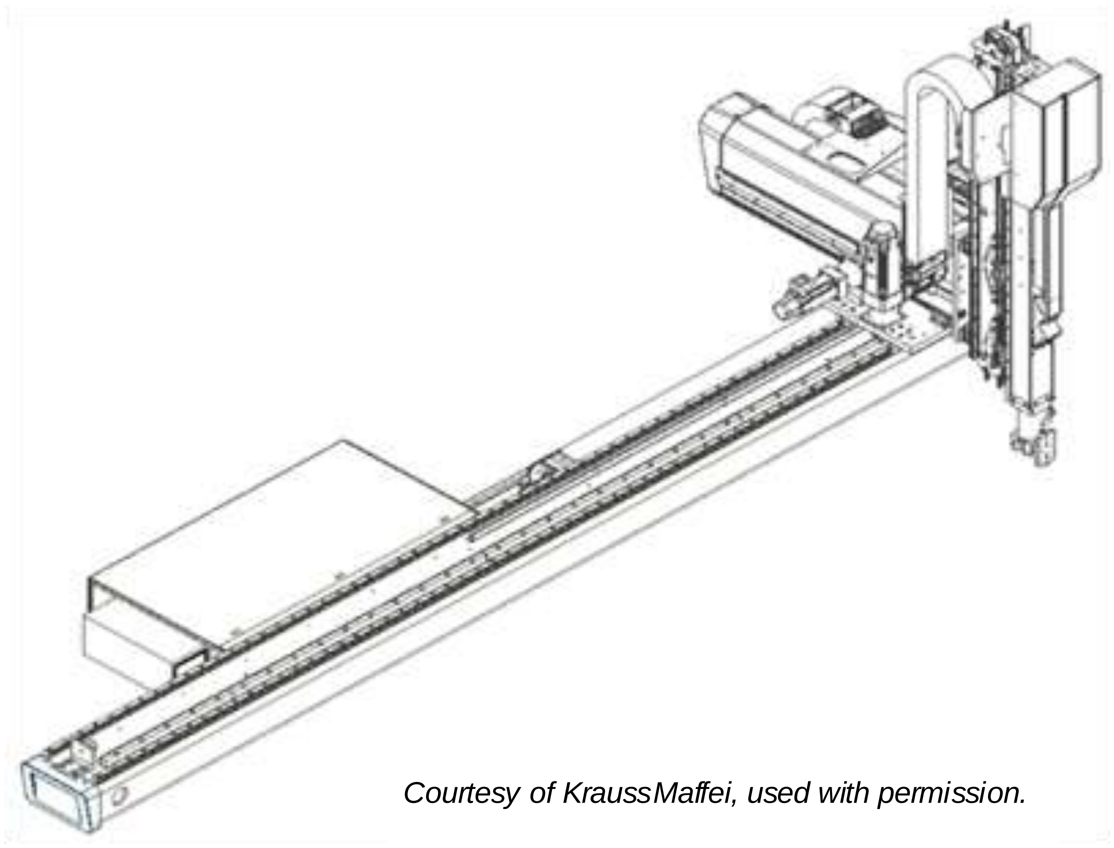


Figure B.1 – Cartesian manipulator

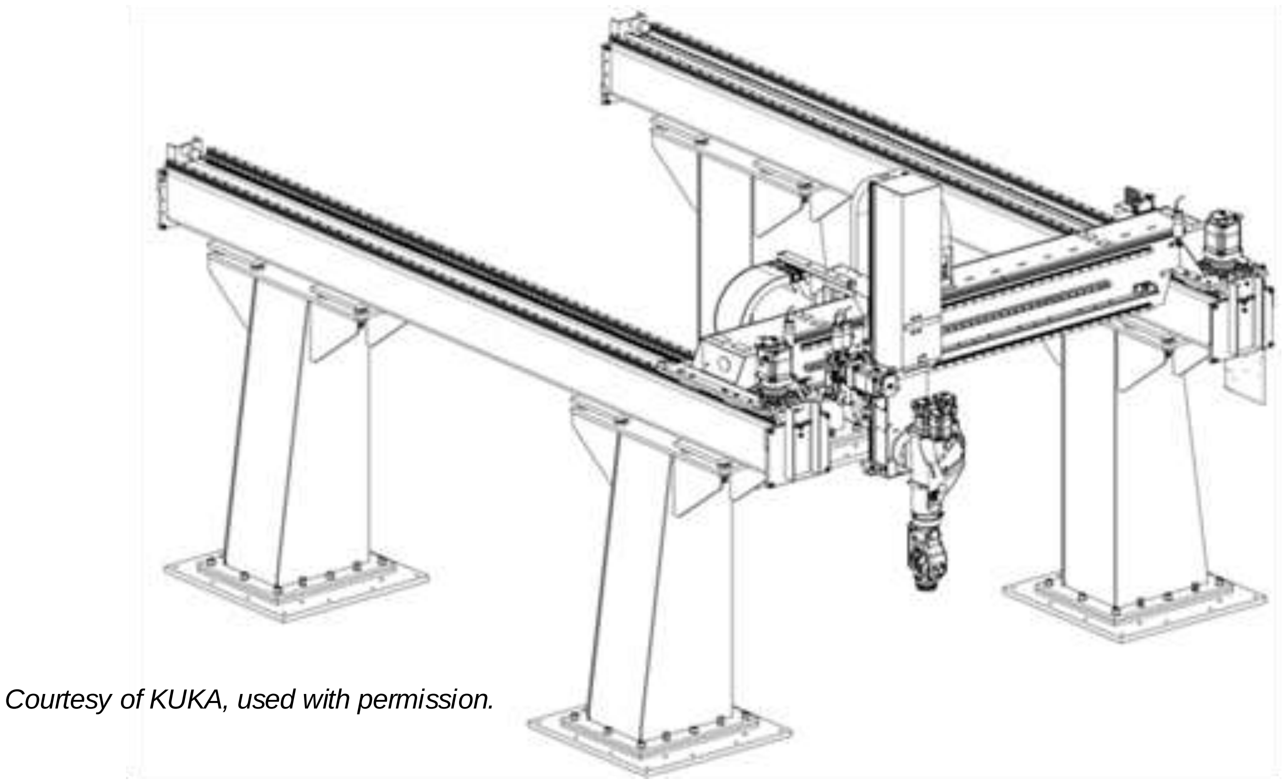
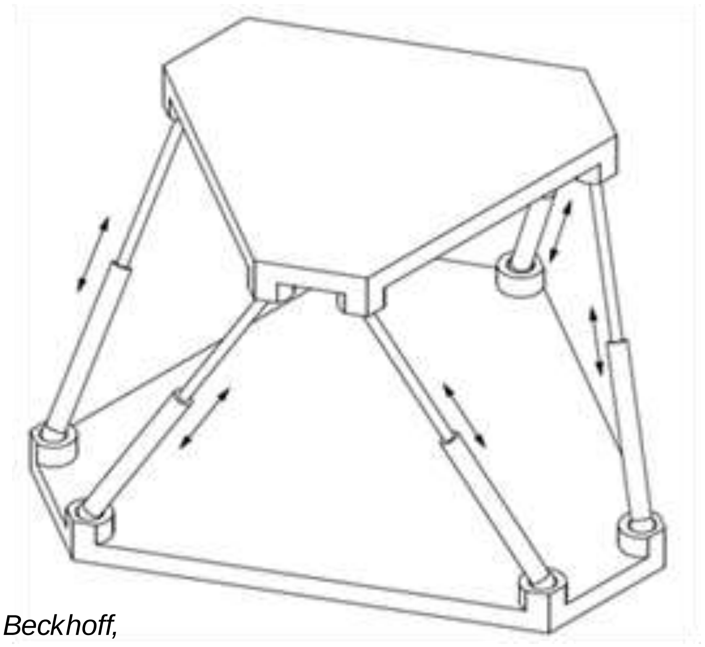


Figure B.2 – Portal manipulator

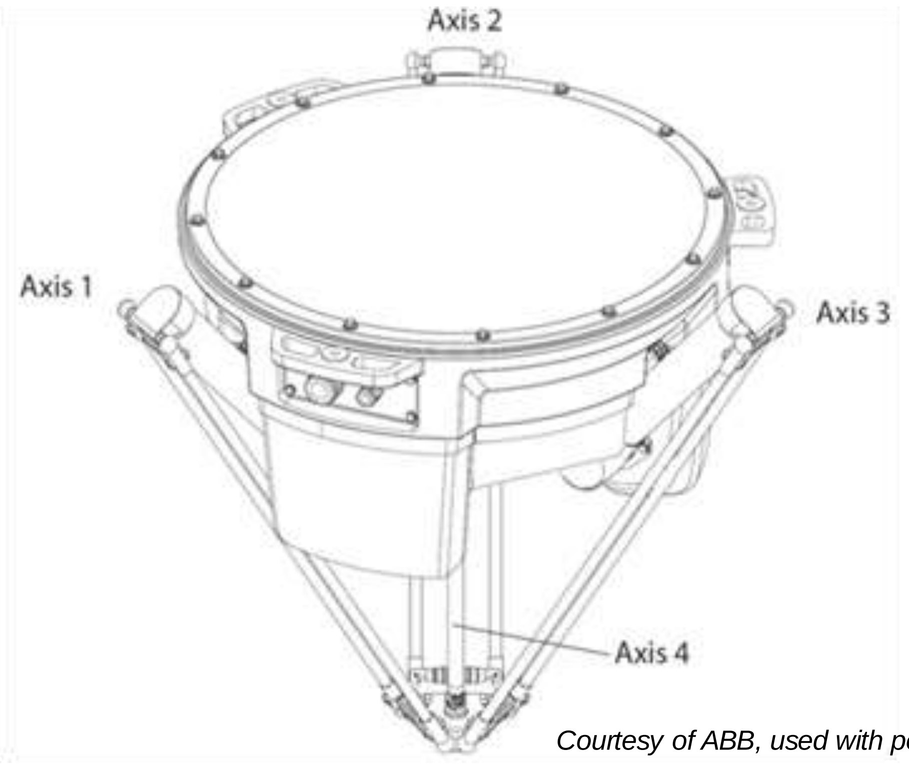
Figure B.3 shows an example of a parallel manipulator. So called delta robots, as shown in Figure B.4, are also parallel manipulators.



Courtesy of Beckhoff, used with permission.

Figure B.3 – Stewart platform or Hexapod

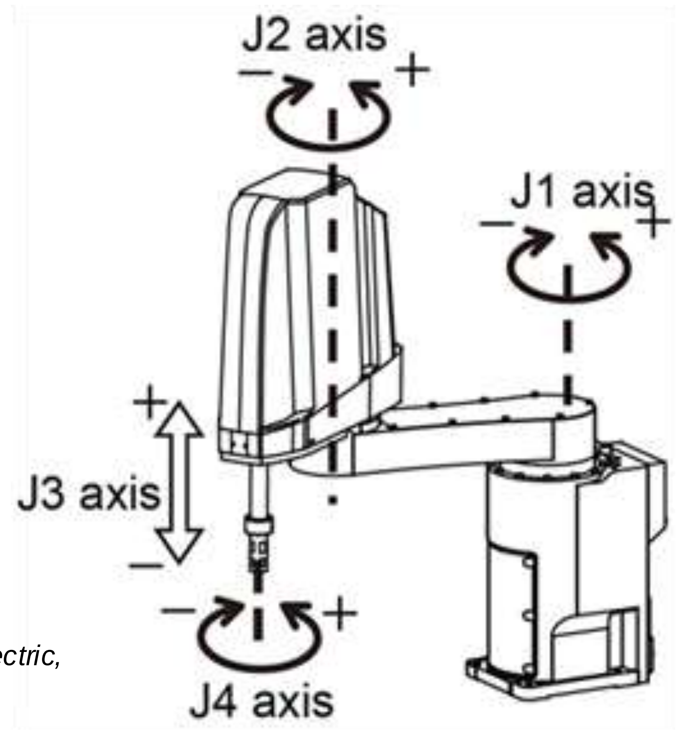
Figure B.4 shows an abstract example of a delta robot.



Courtesy of ABB, used with permission.

Figure B.4 – Delta robot

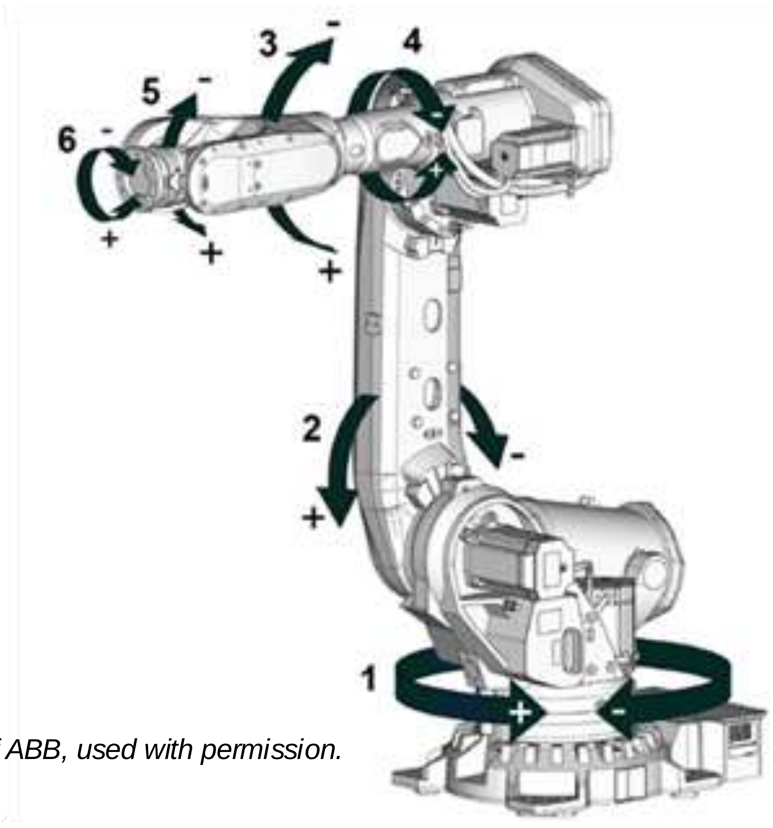
Figure B.5 shows an abstract example of a SCARA robot.



Courtesy of Mitsubishi Electric, used with permission.

Figure B.5 – Scara robot

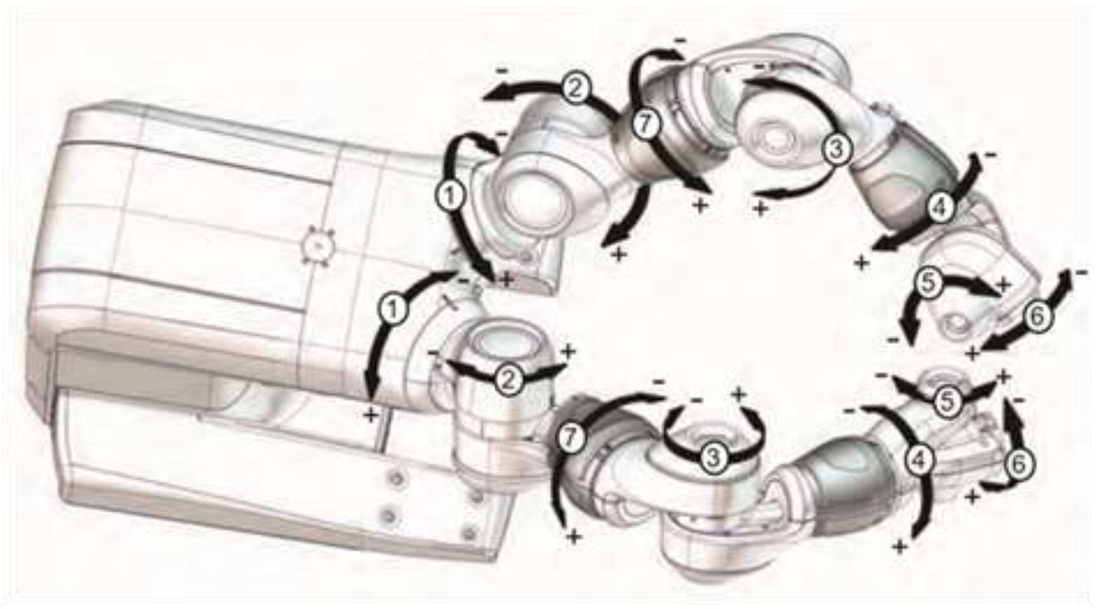
A typical example of an articulated robot is shown in Figure B.6.



Courtesy of ABB, used with permission.

Figure B.6 – Articulated robot

Another example of an articulated robot is a so-called humanoid robot as Figure B.7 schematically shows.

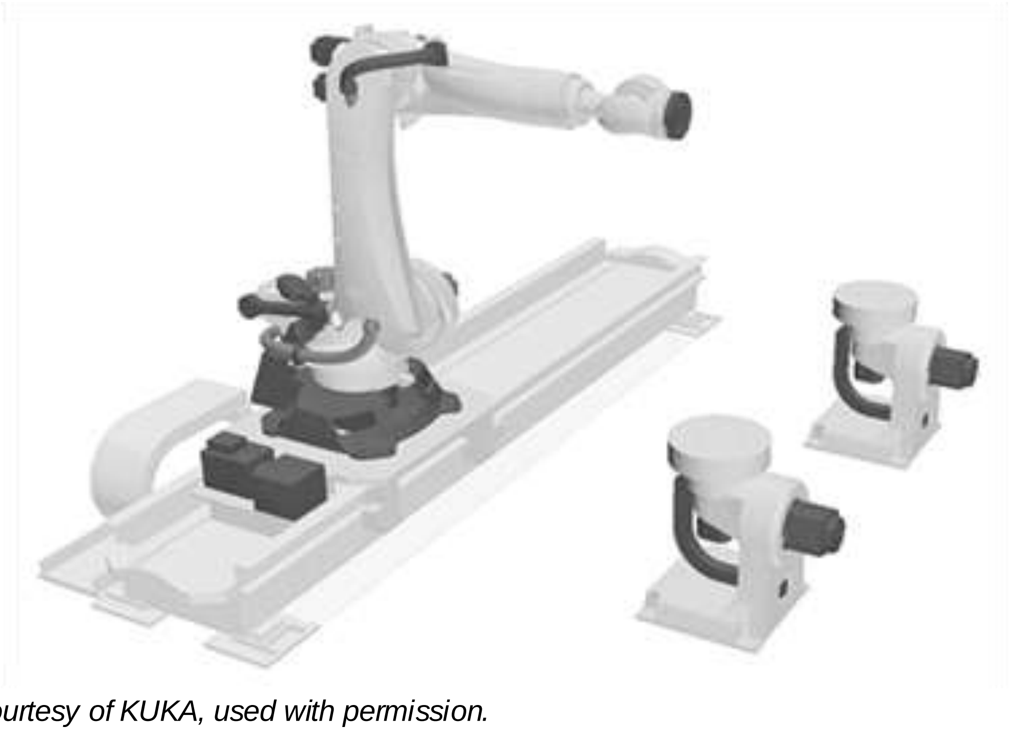


Courtesy of ABB, used with permission.

Figure B.7 – Schematic of a humanoid robot

B.5 Examples of combinations of motion devices in a motion device system

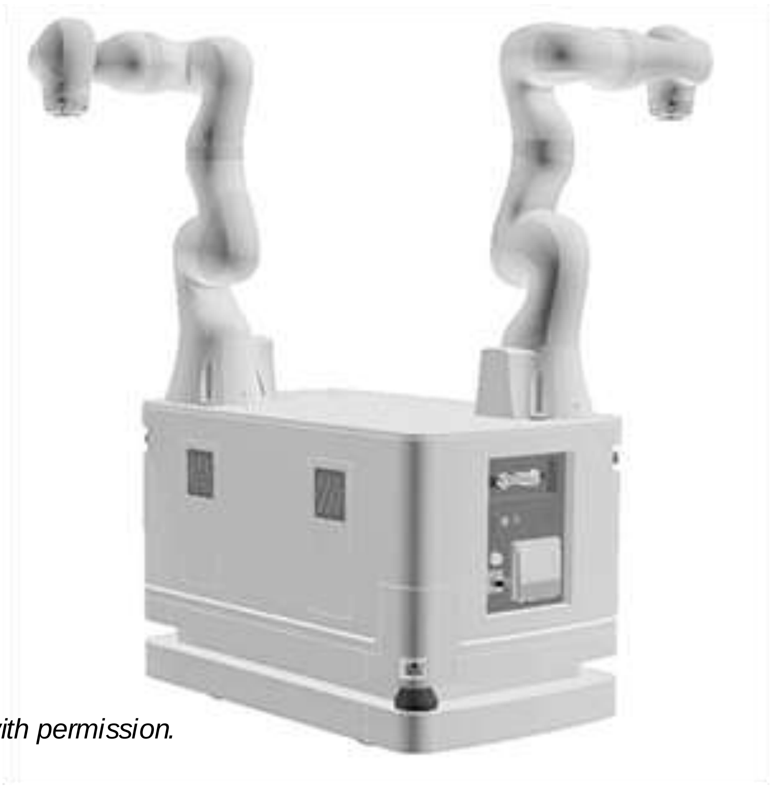
Figure B.8 shows four motion devices integrated in one motion device system: an articulated robot on a linear unit with two turntables.



Courtesy of KUKA, used with permission.

Figure B.8 – Motion device system 1

Figure B.9 shows three motion devices in one motion device system: two articulated robots on a mobile platform.



Courtesy of KUKA, used with permission.

Figure B.9 – Motion device system 2

B.6 Axes and power trains

An axis of a motion device is the mechanical joint of a manipulator that performs a linear or a rotational movement.

Power trains, consisting of gears, motors, and drives, are responsible for the movement of axes. Drives can be integrated in the manipulator or inside a controller cabinet. *References* describe the relationships between the components of the power train.

Figure B.10 shows two possibilities for a realization of a linear two-dimensional motion device. While in the left figure there is a 1:1 relation between power train and mechanical axis in the right figure power train 1 and power train 2 have effect on the movement of axis 1 and on axis 2. An additional load is located on the mechanical axis 2 but has effect on both power trains.

References describe the relationships between the movement of axes and the power trains that initiate the movement.

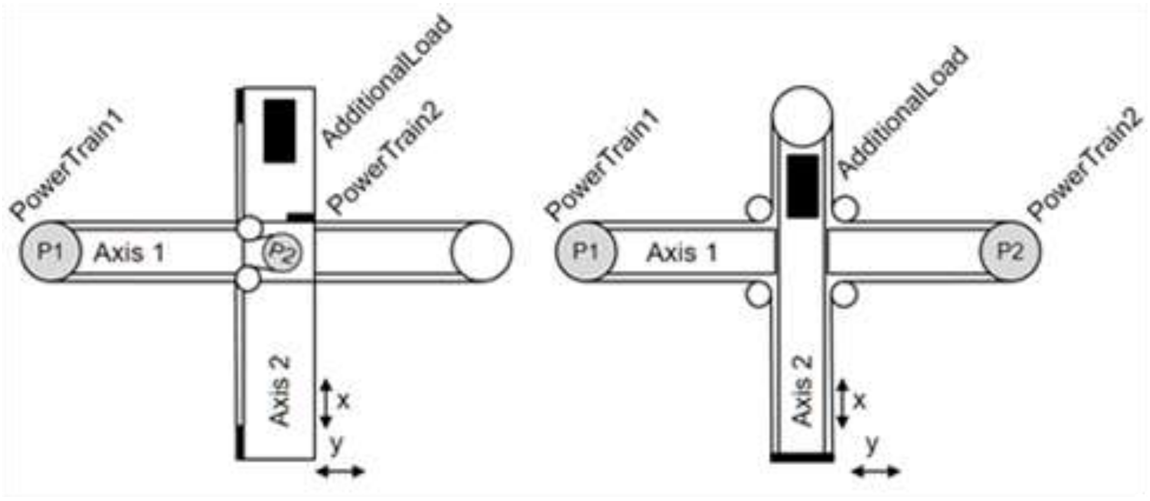


Figure B.10 – Axis and power train coupling

B.7 Virtual Axes

If there is the need to show information about virtual axes, which are not actively run by a power train, then these axes shall be provided, but they don´t have *References* to a power train. An example for a virtual axis is, when a robot control calculates the movement of an external axis in accordance with the robot movement, e.g. for a servo welding gun mounted at the robot flange, but doesn´t control actively the movement of this axis with an internal power train.

Another example for a virtual axis can be found in a delta robot. When the fourth axis is driven through a telescope shaft and cardan joints, then the length of the telescope shaft is depending on the positions of axes 1, 2 and 3. This length can be seen as a virtual axis, as it has constraints similar to a real axis, e.g. position limits. But it is not possible to actively move this axis.

B.8 Examples for axes and power trains

Figure B.1 and Figure B.2 show different versions of Cartesian robots. Figure B.1 shows a three-axis robot which has one dedicated power train for each axis: A power train *Moves* exactly one axis and so an axis only *Requires* one dedicated power train. One motor of a power train *IsDrivenBy* a drive and *IsConnectedTo* a gear.

Figure B.2 shows a three-axis robot with a master-slave driven axis 1. The first and second power train *Moves* axis 1. The first power train *HasSlave* the second power train. Axis 1 *Requires* the first and the second power train. For axis 2 and 3 one power train *Moves* exactly one axis and so an axis only *Requires* one dedicated power train.

B.9 Examples for the use of references regarding axes and power trains

B.9.1 Example articulated six-axis industrial robot.

The typical six-axis industrial robot shown in Figure B.6 normally has 6 power trains for the movement of the 6 axes. Due to the robot hand design, various power trains initiate internal compensation movements. When only the motor of power train 4 is rotating then axes 4, 5, and 6 are moving. When only axis 4 should be moved and axes 5 and 6 should stand still then power trains 5 and 6 must compensate the movement of these axes. Thus a movement of only axis 4 requires rotation of the motors of the power trains 4, 5 and 6. The complete set of references is depicted in Figure B.11.

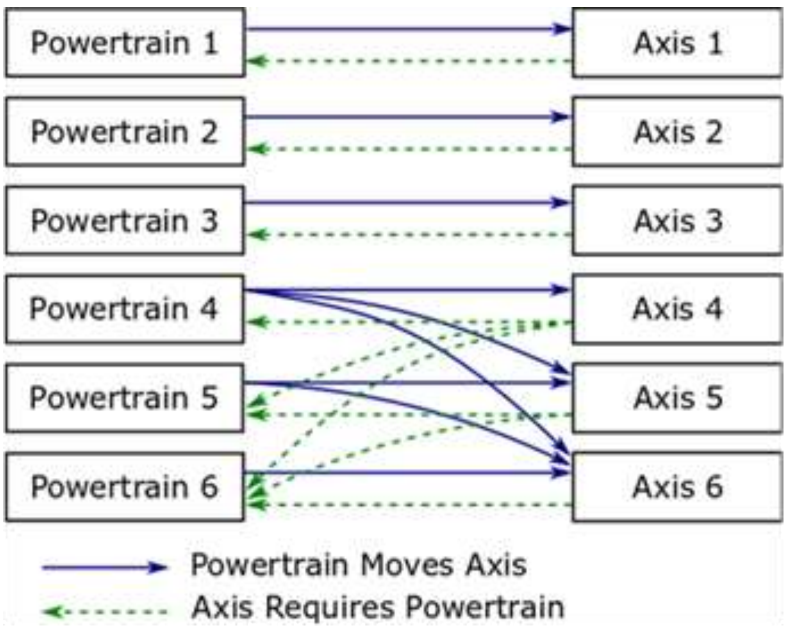


Figure B.11 – Coupling references for a typical six-axis industrial robot.

A power train *Moves* an axis means that if the motor of only this power train moves then there will be an effect on the position of the axis.

i. Power train 1 *Moves* axis 1
ii. Power train 2 *Moves* axis 2
iii. Power train 3 *Moves* axis 3
iv. Power train 4 *Moves* axis 4, axis 5 and axis 6
v. Power train 5 *Moves* axis 5 and axis 6
vi. Power train 6 *Moves* axis 6

Description regarding iv.: When only the motor of power train 4 is moving there is an effect on the position of axis 4, axis 5 and axis 6.

An axis *IsMovedBy* a power trains means, that actions of these power trains have an influence on the axis position. It is the inverse of the *Moves* reference.

i. Axis 1 *IsMovedBy* power train 1
ii. Axis 2 *IsMovedBy* power train 2
iii. Axis 3 *IsMovedBy* power train 3
iv. Axis 4 *IsMovedBy* power train 4
v. Axis 5 *IsMovedBy* power train 5 and power train 4
vi. Axis 6 *IsMovedBy* power train 6, power train 5 and power train 4

Description regarding vi.: Axis 6 movement is depending on movement from power train 6, power train 5 and power train 4.

An axis *Requires* the movement of a motor of a power train to position but also other power trains might be involved by this movement to compensation movements of affected axes.

i. Axis 1 *Requires* power train 1
ii. Axis 2 *Requires* power train 2
iii. Axis 3 *Requires* power train 3
iv. Axis 4 *Requires* power train 4, power train 5 and power train 6
v. Axis 5 *Requires* power train 5 and power train 6
vi. Axis 6 *Requires* power train 6

Description regarding iv.: When only axis 4 should be moved compensation movements of power train 5 and power train 6 are necessary to ensure a standstill of axis 5 and axis 6.

A power train *IsRequiredBy* axes means that this power train is active when only the referenced axis should be moved and all other axes should stand still. It is the inverse of the *Requires* reference.

i. Power train 1 *IsRequiredBy* axis 1
ii. Power train 2 *IsRequiredBy* axis 2
iii. Power train 3 *IsRequiredBy* axis 3
iv. Power train 4 *IsRequiredBy* axis 4
v. Power train 5 *IsRequiredBy* axis 4 and axis 5
vi. Power train 6 *IsRequiredBy* axis 4, axis 5 and axis 6

Description regarding vi: Power train 6 participates in positioning of axis 4, axis 5 and axis 6.

B.9.2 Example articulated six-axis industrial robot with 3 leader-follower axes

A high-payload six-axis industrial robot shown in Figure B.6 can have nine power trains for the movement of the six axes. In this example the axes 1 to 3 are each driven by two power trains with leader-follower configuration.

Figure B.12 shows the use of the *HasSlave* reference in addition to the power train to axis references.

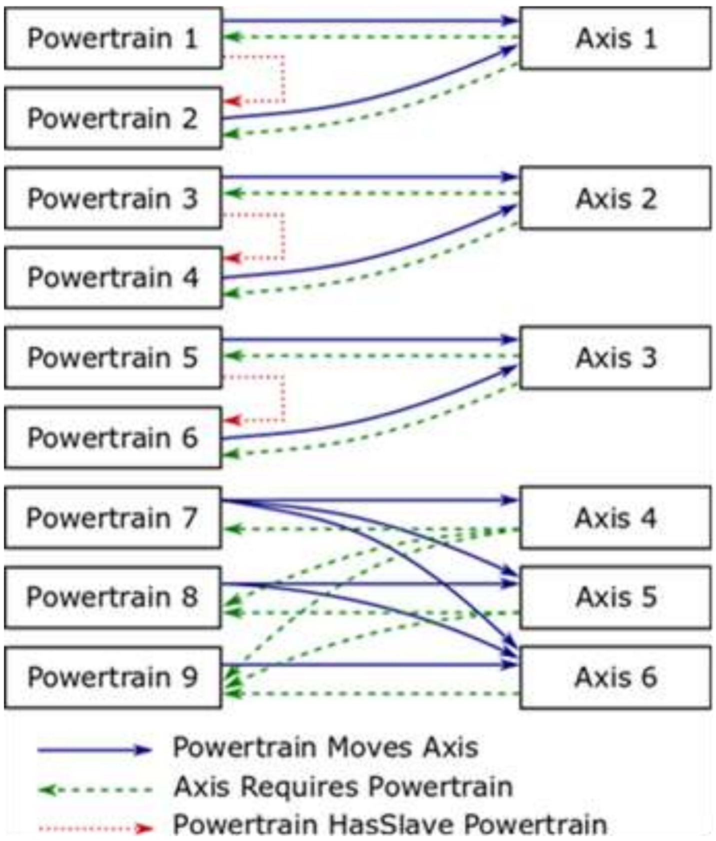


Figure B.12 – Coupling references for a six-axis industrial robot with leader-follower axes

A power train HasSlave a power train means that one power train is the master of a leader-follower-configuration and he references HasSlave to power train which is slave coupled.

HasSlave References:

i. Power train 1 *HasSlave* power train 2
ii. Power train 3 *HasSlave* power train 4
iii. Power train 5 *HasSlave* power train 6

For this leader-follower configuration the *Moves* and Requires references :

i. Power train 1 *Moves* axis 1
ii. Power train 2 *Moves* axis 1
iii. Power train 3 *Moves* axis 2
iv. Power train 4 *Moves* axis 2
v. Power train 5 *Moves* axis 3
vi. Power train 6 *Moves* axis 3
vii. Power train 7 *Moves* axis 4, axis 5 and axis 6
viii. Power train 8 *Moves* axis 5 and axis 6
ix. Power train 9 *Moves* axis 6

i. Axis 1 *Requires* power train 1 and power train 2
ii. Axis 2 *Requires* power train 3 and power train 4
iii. Axis 3 *Requires* power train 5 and power train 6
iv. Axis 4 *Requires* power train 7, power train 8 and power train 9
v. Axis 5 *Requires* power train 8 and power train 9
vi. Axis 6 *Requires* power train 9

B.9.3 Example linear two-dimensional motion device

For the left motion device in Figure B.10 the *References* between axes and power trains are shown in Figure B.13.

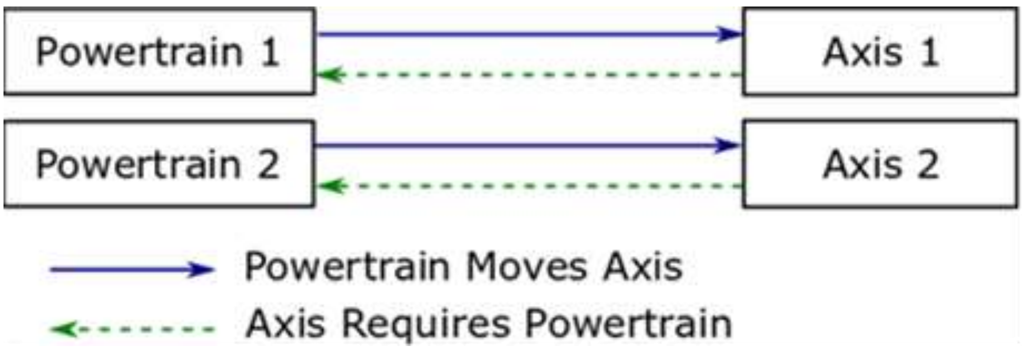


Figure B.13 – Coupling references for a simple linear two-dimensional motion device

Moves References:

iv. Power train 1 *Moves* axis 1
v. Power train 2 *Moves* axis 2

i. Axis 1 *IsMovedBy* power train 1
ii. Axis 2 *IsMovedBy* power train 2

Requires References from power train to axis

i. Axis 1 *Requires* power train 1
ii. Axis 2 *Requires* power train 2

i. Power Train 1 *IsRequiredBy* axis 1
ii. Power Train 2 *IsRequiredBy* axis 2

For the right motion device in Figure B.10 the *References* between axes and power trains are shown in Figure B.14.

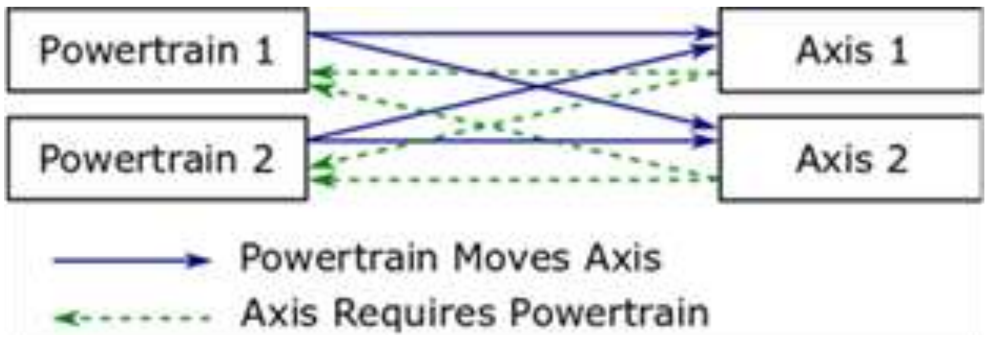


Figure B.14 – Coupling references for linear two-dimensional motion device

Moves References:

vi. Power train 1 *Moves* axis 1 and axis 2
vii. Power train 2 *Moves* axis 1 and axis 2

iii. Axis 1 *IsMovedBy* power train 1 and power train 2
iv. Axis 2 *IsMovedBy* power train 1 and power train 2

Requires References from power train to axis

iii. Axis 1 *Requires* power train 1 and power train 2
iv. Axis 2 *Requires* power train 1 and power train 2

iii. Power Train 1 *IsRequiredBy* axis 1 and axis 2
iv. Power Train 2 *IsRequiredBy* axis 1 and axis 2

B.10 Representations of exemplary server implementations

This chapter describes different examples for the usage of DriveType or a SubType of ComponentType defined in OPC 10000-100 inclusive the references described in this specification.

All views show only the instances and references necessary to better illustrate the examples described.

B.10.1 ObjectTypes and references used with DriveType instances

Figure B.15 describes the usage of *DriveType* as an instance of a single-slot drive regarding the manipulator showed Figure B.10 on the left side.

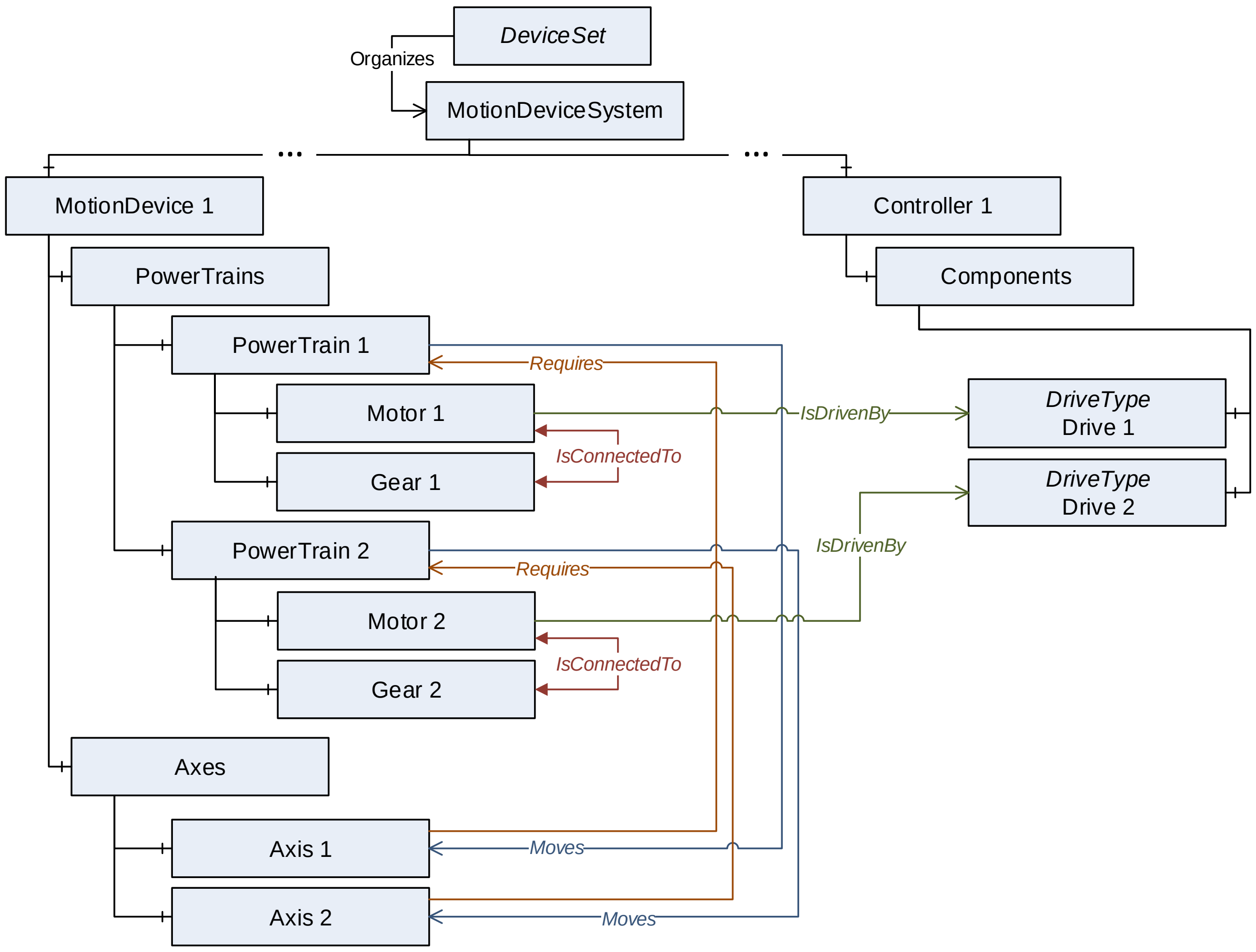


Figure B.15 – IsDrivenby references to DriveType instances

B.10.2 ObjectTypes and references used with instances of vendor specific subtypes of BaseObjectType for drive-channels

Figure B.16 describes the usage of slots or channels of a multi-slot-drive. The instance of the slot is a vendor specific subtype of *BaseObjectType*.

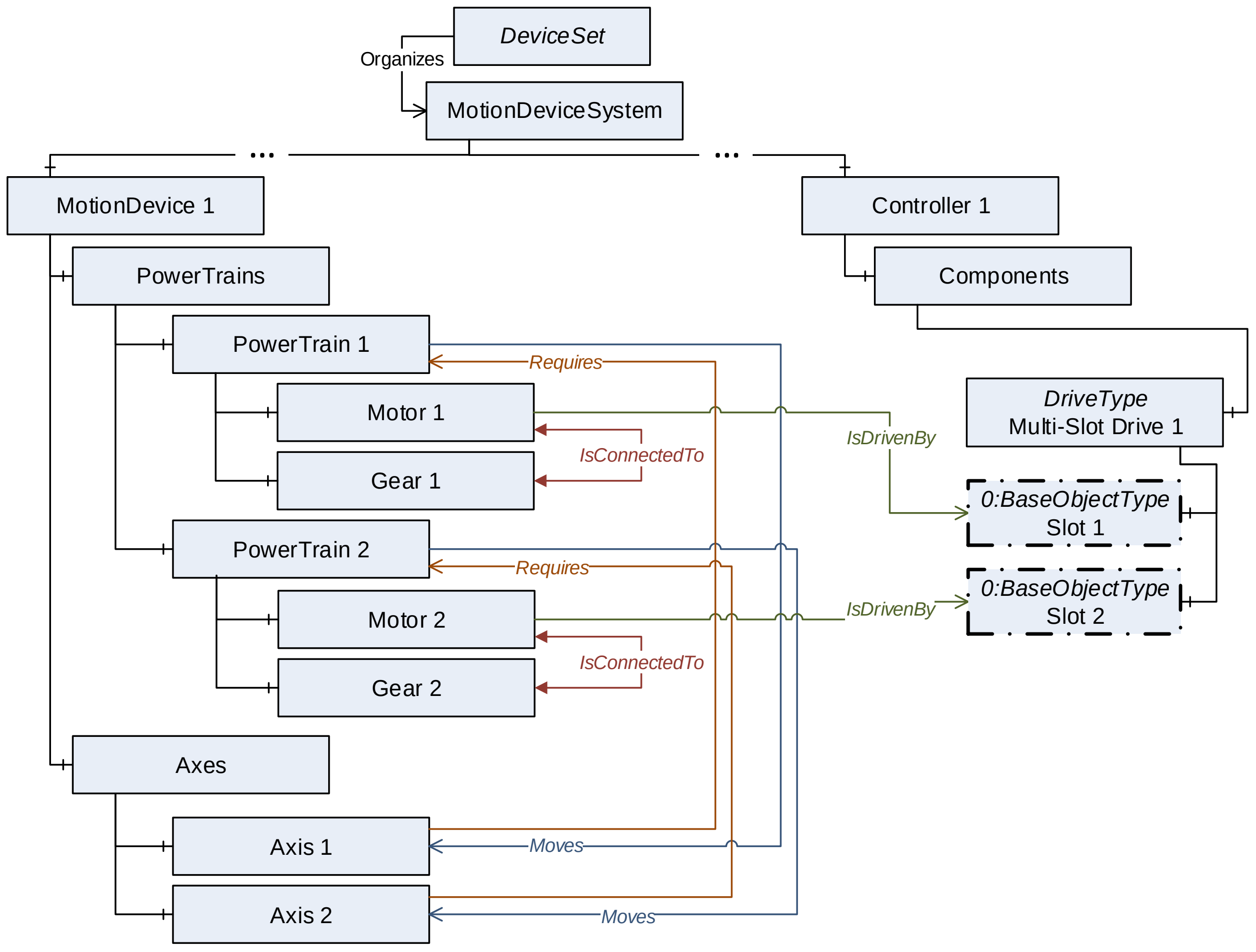


Figure B.16 – IsDrivenby references to vendor specific subtypes of BaseObjectType instances

B.10.3 ObjectTypes and references used with instances DriveType for drives with drive-channels

Figure B.17 describes the usage of *DriveType* for a multi-slot-drive if deeper information of slot definition is not available.

It is allowed that several instances of *MotorType* reference *IsDrivenBy* to one multi-slot-drive.

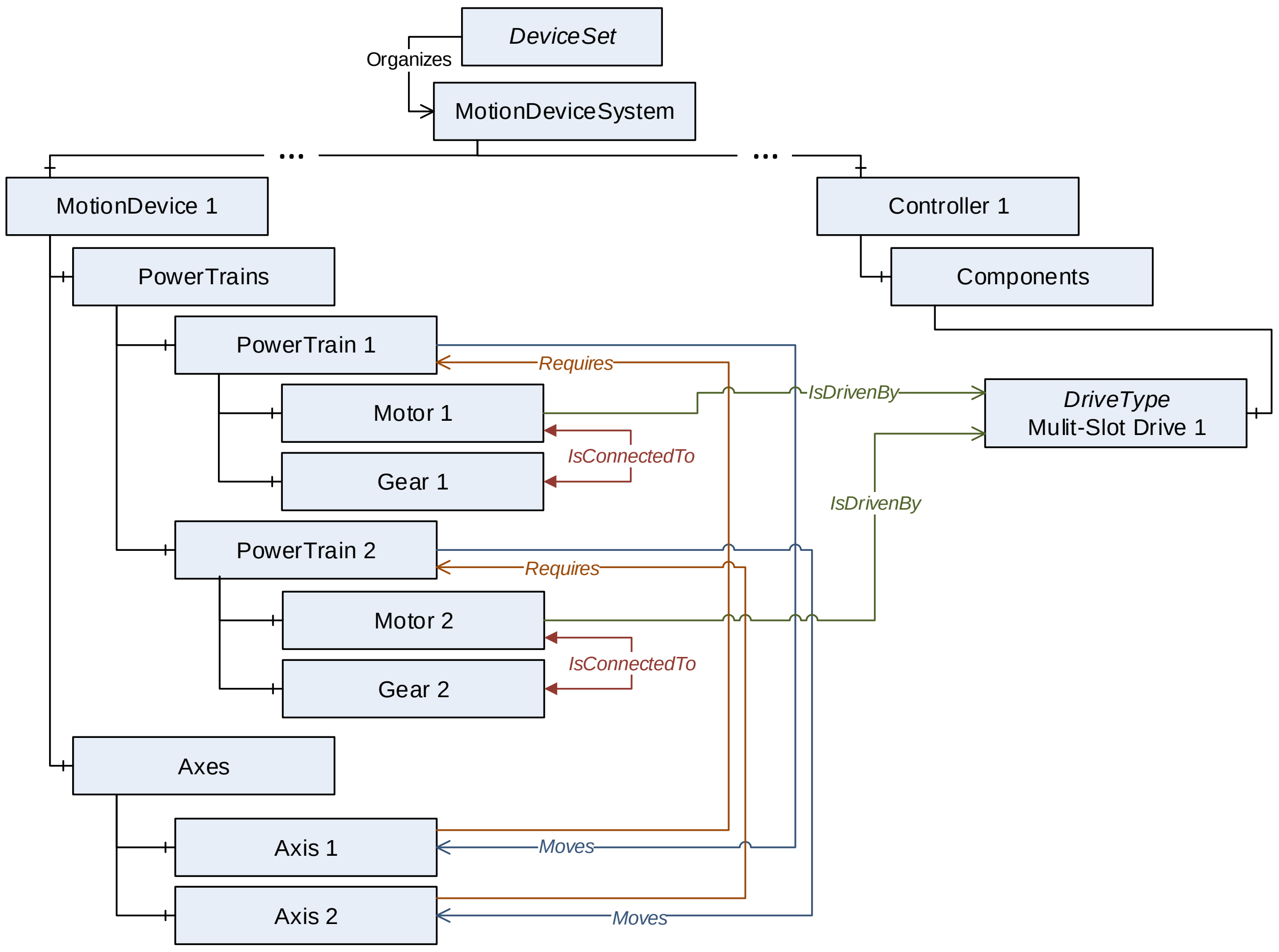


Figure B.17 – IsDrivenby references to DriveType instances for multi-slot drives w/o slots

B.10.4 ObjectTypes and references used with instances of vendor specific subtypes of BaseObjectType for motor-integrated-drives

Figure B.18 describes the usage with a motor-integrated-drive as one physical device. The instance MyDrive is a vendor specific subtype of *BaseObjectType*. Identification properties of this physical device shall be defined within the referenced *MotorType*.

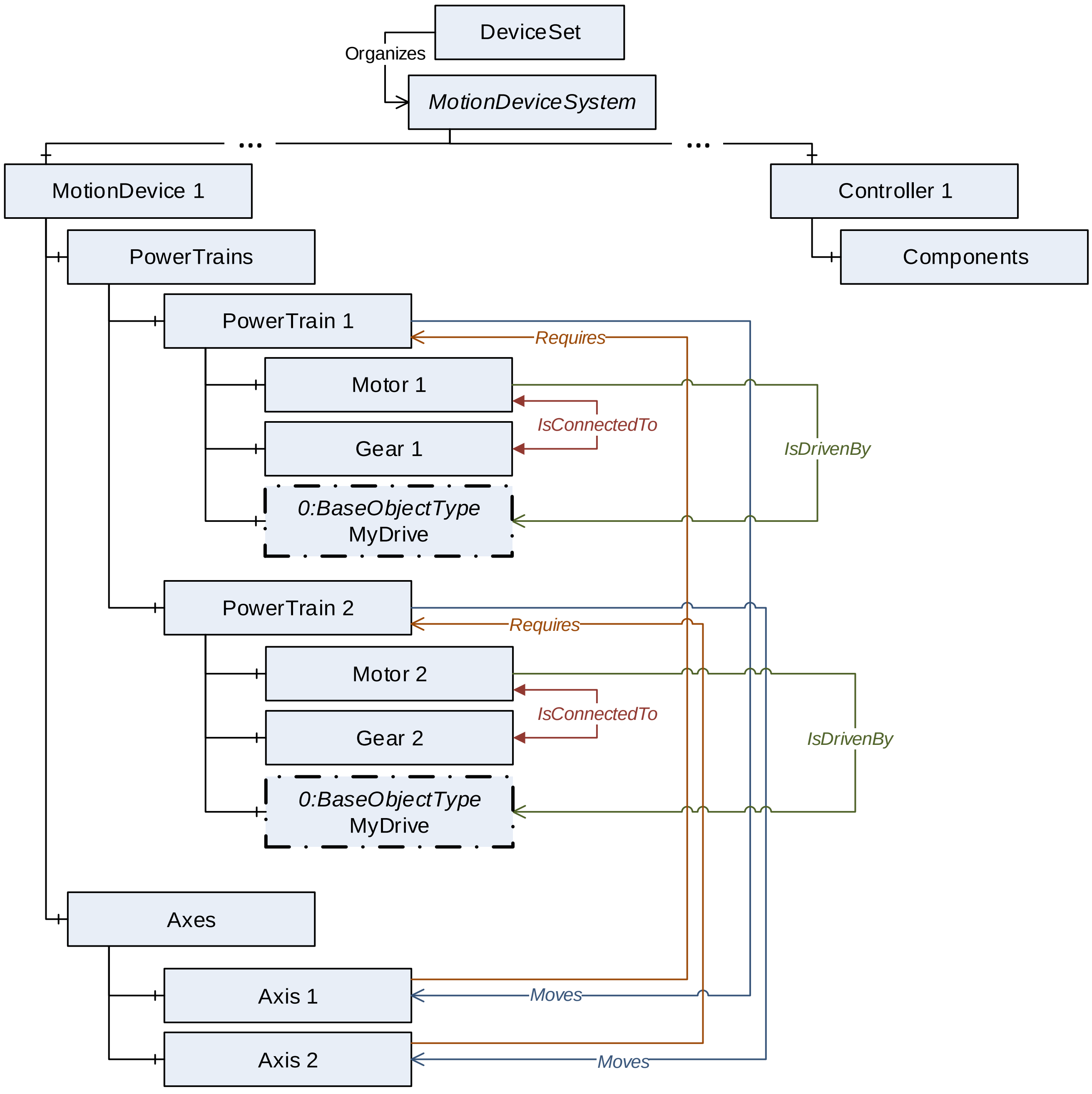


Figure B.18 – IsDrivenby used with motor-integrated-drives

B.10.5 Abstract example of a six-axis robot with master-slave axis and drive-slots

Figure B.19 describes an example view on a server with the instances of *ObjectTypes* and references of a six-axis robot with master-slave axis and drive-slots described in Annex B.9.2.

If a leader-follower configuration only has one gear this shall be placed inside the leader-powertrain.

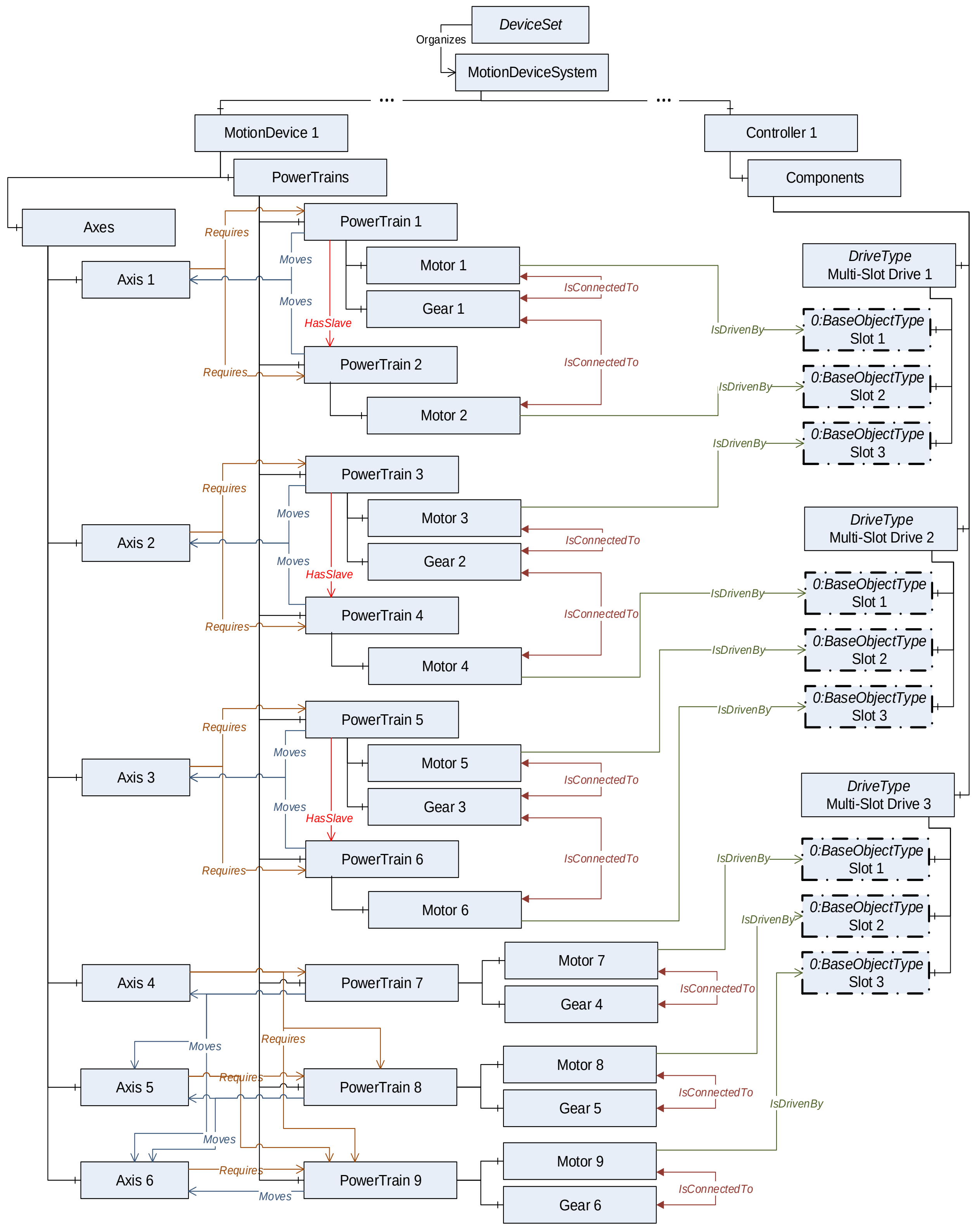


Figure B.19 – View on a six-axis robot with master-slave and drive-slots

B.10.6 Abstract example of a motion device system with three motion devices

Figure B.20 describes an example view on a server with the instances of *ObjectTypes* and references of a motion device system consisting of a six-axis robot, a linear unit and a turntable which are controlled by one controller.

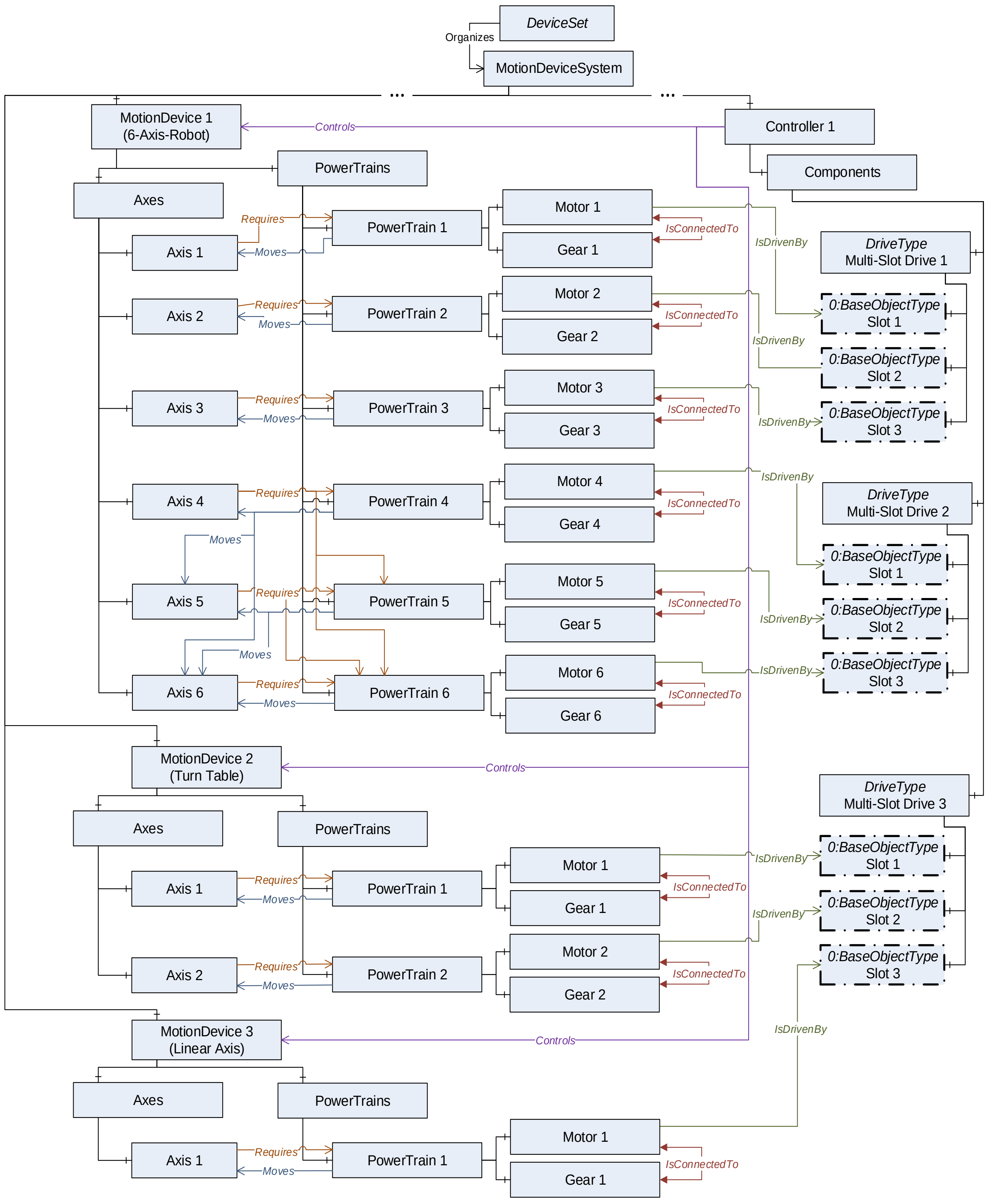


Figure B.20 – View on a motion device system with 3 motion devices controlled by one controller

Annex C
(informative)

Usage with OPC 40001-1 UA CS for Machinery Part 1 – Basic Building Blocks

C.1 Overview

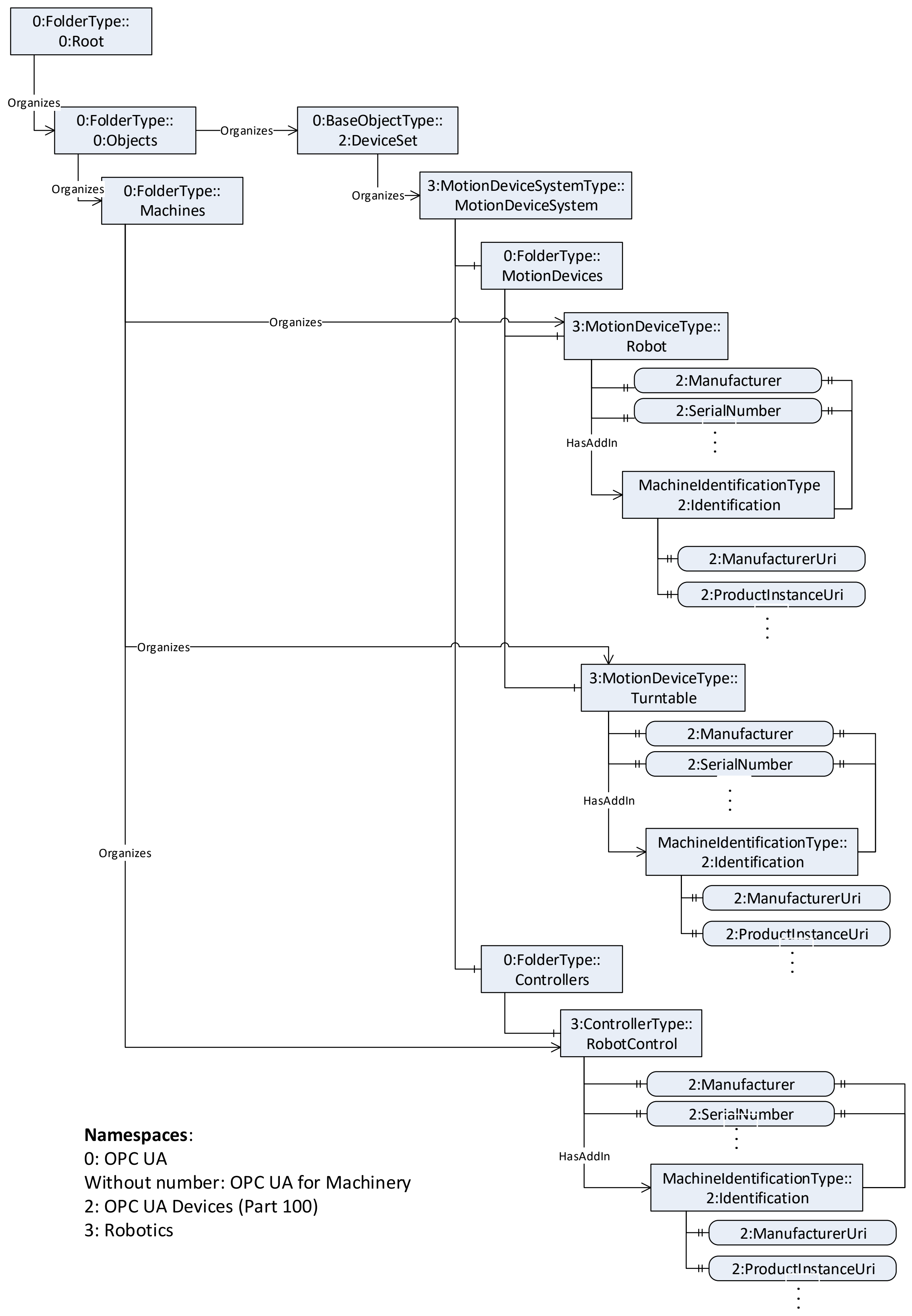
This appendix provides informal examples on how the building blocks defined in OPC UA for Machinery Part 1: Basic Building Blocks can be used merged with the Robotics Information Model.

C.2 Identification and Finding Machines

In **Fehler! Verweisquelle konnte nicht gefunden werden.** an example is given, showing the i dentification and Nameplate and Finding all *Machines* in Server use cases. The server provides information about a Robotics system.

As this Robotics specification Part 1 already defines some *Properties* for identification directly, those are only referenced from the Identification functional group.

Note that a Robotics system typically contains several machine parts with own nameplates. E.g. the Declaration of Incorporation of Partly Completed Machinery according Machinery Directive 2006/42/EU for robots provides the *Model* and the *SerialNumber* for the robot and for the controller.

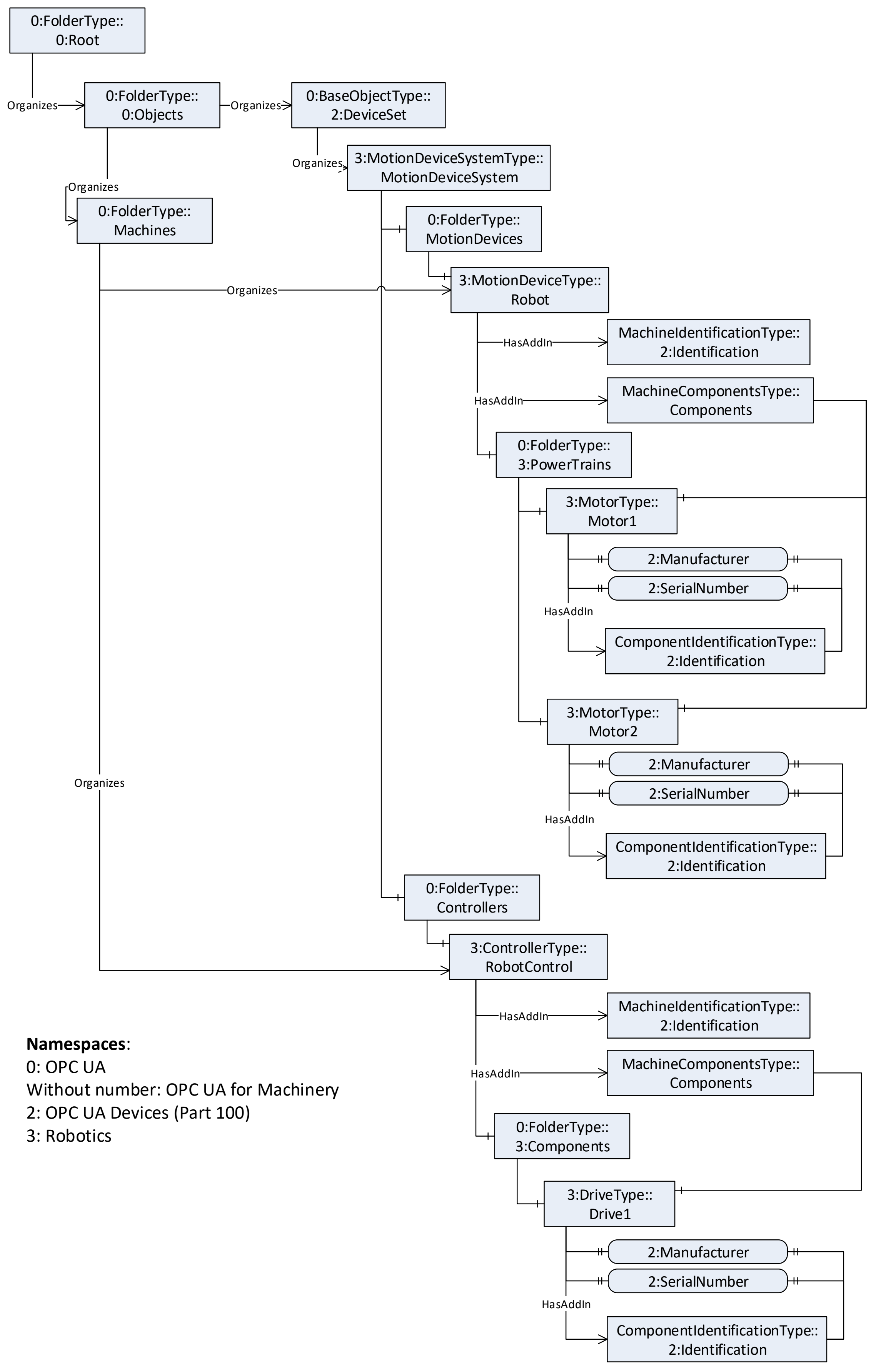


Namespaces:
0: OPC UA
Without number: OPC UA for Machinery
2: OPC UA Devices (Part 100)
3: Robotics

Figure C.1 – Example Finding all Machines and Machine Identification

C.3 Component Identification and Finding Components of a Machine

In **Fehler! Verweisquelle konnte nicht gefunden werden.**, a partially view on an example Robotics s ystem is shown and the components are organized according to the Robotics specification. And in addition, the figure shows according to the OPC UA for Machinery Part 1: Basic Building Blocks the Component Identification and Nameplate and Finding all Components and Machines of a Robotics system.



Namespaces:
0: OPC UA
Without number: OPC UA for Machinery
2: OPC UA Devices (Part 100)
3: Robotics

Figure C.2 – Example Finding all Machines and Components and Component Identification