
**Industrial automation systems and
integration — Physical device control —
Data model for computerized numerical
controllers —**

Part 1:

Overview and fundamental principles

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*Systemes d'automatisation industrielle et integration — Commande des
dispositifs physiques — Modèle de données pour les contrôleurs
numériques informatisés —*

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Partie 1: Aperçu et principes fondamentaux



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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 14649-1 was prepared by Technical Committee ISO/TC 184, *Industrial automation systems and integration*, Subcommittee SC 1, *Physical device control*.

ISO 14649 consists of the following parts, under the general title *Industrial automation systems and integration — Physical device control — Data model for computerized numerical controllers*:

NOTE Phase numbers below refer to the planned release phases of ISO 14649 which are described in Annex D.

- *Part 1: Overview and fundamental principles* (Phase 1)
- *Part 10: General process data* (Phase 1)
- *Part 11: Process data for milling* (Phase 1)
- *Part 12: Process data for turning* (Phase 2)
- *Part 13: Process data for wire-EDM* (Phase 2)
- *Part 14: Process data for sink-EDM* (Phase 2)
- *Part 111: Tools for milling* (Phase 1)
- *Part 121: Tools for turning* (Phase 2)

Gaps in the numbering were left to allow further additions. ISO 14649-10 is the ISO 10303 Application Reference Model (ARM) for process-independent data. ISO 10303 ARMs for specific technologies are added after part 10.

This part of ISO 14649 has a strong relationship to ISO 10303 AP238, which is a one-to-one 100 % mapping of ISO 14649, where ISO 14649 represents the ARM and AP238 the AIM. This relationship is referenced in this document and in other parts of ISO 14649.

ISO 14649 is harmonized with ISO 10303 in the common field of Product Data over the whole life cycle. Figure D.1 shows the different fields of standardization between ISO 14649, ISO 10303 and CNC manufacturers with respect to implementation and software development.

Introduction

Modern manufacturing enterprises are built from facilities spread around the globe, which contain equipment from hundreds of different manufacturers. Immense volumes of product information must be transferred between the various facilities and machines. Today's digital communications standards have solved the problem of reliably transferring information across global networks. For mechanical parts, the description of product data has been standardized by ISO 10303. This leads to the possibility of using standard data throughout the entire process chain in the manufacturing enterprise. Impediments to realizing this principle are the data formats used at the machine level. Most computer numerical control (CNC) machines are programmed in the ISO 6983 "G and M code" language. Programs are typically generated by computer-aided manufacturing (CAM) systems that use computer-aided design (CAD) information. However, ISO 6983 limits program portability for three reasons. First, the language focuses on programming the tool center path with respect to machine axes, rather than the machining process with respect to the part. Second, the standard defines the syntax of program statements, but in most cases leaves the semantics ambiguous. Third, vendors usually supplement the language with extensions that are not covered in the limited scope of ISO 6983.

ISO 14649 is a new model of data transfer between CAD/CAM systems and CNC machines. It remedies the shortcomings of ISO 6983 by specifying machining processes rather than machine tool motion, using the object-oriented concept of Workingsteps. Workingsteps correspond to high-level machining features and associated process parameters. CNCs are responsible for translating Workingsteps to axis motion and tool operation. A major benefit of ISO 14649 is its use of existing data models from ISO 10303.

ISO/TC 184/SC 1/WG 7 envisions a gradual evolution from ISO 6983 programming to portable feature-based programming. Early adopters of ISO 14649 will certainly support data input of legacy "G and M codes" manually or through programs, just as modern controllers support both command-line interfaces and graphical user interfaces. This will likely be made easier as open-architecture controllers become more prevalent. Therefore, ISO 14649 does not include legacy program statements, which would otherwise dilute the effectiveness of the standard.

ISO 14649 is harmonized with ISO 10303 in the common field of Product Data by the ISO 10303-238 Application Interpreted Model (AIM) over the whole life cycle.

This document, ISO 14649-1, "Overview and fundamental principles," has five informative annexes. Annex A shows the use and assignment of features from ISO 10303-224 in ISO 14649, Annex B is the Application Activity Model that explains the environment and the activities of ISO 14649 in the manufacturing process. Annex C shows an overview of the data model structure as an EXPRESS-G diagram. Annex D describes the relationship of ISO 14649 to ISO 10303 (STEP). Annex E is a hypothetical scenario, intended to illustrate the life cycle application of ISO 14649 to a manufacturing enterprise. It is a vision of the future of manufacturing data transfer as intended by this International Standard.

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Industrial automation systems and integration — Physical device control — Data model for computerized numerical controllers —

Part 1: Overview and fundamental principles

1 Scope

This part of ISO 14649 provides an introduction and overview of a data model for Computerized Numerical Controllers and explains its advantages and basic principle, based on the concepts of Product Data.

2 Normative references

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

ISO 841:2001, *Industrial automation systems and integration — Numerical control of machines — Coordinate system and motion nomenclature*

ISO 2806:1994, *Industrial automation systems — Numerical control of machines — Vocabulary*

ISO 4342:1985, *Numerical control of machines — NC processor input — Basic part program reference language*

ISO 4343:2000, *Industrial automation systems — Numerical control of machines — NC processor output — Post processor commands*

ISO/TR 6132:1981, *Numerical control of machines — Operational command and data format*

ISO 6983-1:1982, *Numerical control of machines — Program format and definition of address words — Part 1: Data format for positioning, line motion and contouring control systems*

ISO 10303-1:1994, *Industrial automation systems and integration — Product data representation and exchange — Part 1: Overview and fundamental principles*

ISO 10303-11:1994, *Industrial automation systems and integration — Product data representation and exchange — Part 11: Description methods: The EXPRESS language reference manual*

ISO 10303-21:2002, *Industrial automation systems and integration — Product data representation and exchange — Part 21: Implementation methods: Clear text encoding of the exchange structure*

ISO 10303-22:1998, *Industrial automation systems and integration — Product data representation and exchange — Part 22: Implementation methods: Standard data access interface*

ISO 10303-41:2000, *Industrial automation systems and integration — Product data representation and exchange — Part 41: Integrated generic resource: Fundamentals of product description and support*

ISO 14649-1:2003(E)

ISO 10303-42:2000, *Industrial automation systems and integration — Product data representation and exchange — Part 42: Integrated generic resources: Geometric and topological representation*

ISO 10303-43:2000, *Industrial automation systems and integration — Product data representation and exchange — Part 43: Integrated generic resource: Representation structures*

ISO 10303-49:1998, *Industrial automation systems and integration — Product data representation and exchange — Part 49: Integrated generic resources: Process structure and properties*

ISO 10303-203:1994, *Industrial automation systems and integration — Product data representation and exchange — Part 203: Application protocol: Configuration controlled design*

ISO 10303-214:2001, *Industrial automation systems and integration — Product data representation and exchange — Part 214: Application protocol: Core data for automotive mechanical design processes*

ISO 10303-224:2001, *Industrial automation systems and integration — Product data representation and exchange — Part 224: Application protocol: Mechanical product definition for process planning using machining features*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply, some of which are defined in ISO 10303 and other standards.

3.1 Terms defined in ISO 10303-1

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application

application activity model

application interpreted model

application protocol

application reference model

data

data exchange

implementation model

information

information model

interpretation

model

product

product data

3.2 Terms defined in ISO 10303-11

attribute

entity

entity data type

entity instance

EXPRESS language

3.3 Terms defined in ISO 10303-21

physical file format

3.4 Terms defined in ISO 10303-224

fixture

machining features

manufacturing feature

3.5 Terms defined in ISO 2806

numerical control

computerized numerical control

tool path

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3.6 New definitions in ISO 14649

3.6.1

workingstep

machining information for one cutting tool acting on a feature

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NOTE It contains a Machining Operation.

3.6.2

machining operation

technological data for a Workingstep that details the operation

NOTE It is composed of cutting tool, toolpath strategy, machining function, cutting depth, finishing allowance, cutting speed, feed rate, retract plane, safety plane, approach strategy, and retract strategy.

3.6.3

workplan

collection of Workingsteps with an execution sequence

NOTE It contains a list of Executables.

3.6.4

executable

one of Workingstep, NC Function, or Program Structure

3.6.5

NC function

one of Display Message, Optional Stop, Program Stop, Exchange Pallet, Index Pallet, Index Table, Set Mark, Unload Tool, or Wait for Mark

3.6.6

program structure

one of Workplan, Parallel, If statement, While statement, or Assignment

3.6.7

project

entity which serves as a starting point for program execution

4 Symbols and abbreviated terms

For the purposes of this document, the following abbreviations apply.

AAM	Application Activity Model
AIM	Application Interpreted Model
AP	Application Protocol
ARM	Application Reference Model
CNC	Computerized Numerical Control

5 Overview of ISO 14649

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5.1 Purpose

The purpose of ISO 14649 is to:

- cover the current and expected future needs for data exchange; <https://standards.iteh.ai/catalog/standards/sist/d56e13fc-f1d6-4579-b884-aa865865276/iso-14649-1-2003>
- support the direct use of computer-generated product data from ISO 10303;
- create an exchangeable, workpiece-oriented data model for CNC machine tools;
- use standard, modern languages and libraries for the implementation of the data model;
- ensure compatibility of CNC input data.

ISO 14649 is applicable to advanced CNC machine tool and CAM systems.

5.2 The manufacturing cycle

Figure 1 shows the manufacturing life cycle, from design to fabrication, and how ISO 14649 is envisioned to be used within this cycle. The design phase results in CAD data (ISO 10303-203 geometry) and includes the definition of all the part features in ISO 10303-224. The process planning phase generates the resource requirements for part fabrication, using ISO 10303-213, and other results suitable for use in a Manufacturing Execution System (MES). Process planning also splits the ISO 10303-224 manufacturing features into sets suitable for various processes, e.g. milling, turning, electrical discharge machining (EDM), and inspection (which also uses ISO 10303-219). The ISO 10303-224 feature sets are used during the computer-aided manufacturing (CAM) phase. Based on this, ISO 14649 files are generated that are executed by CNC machine tools. At run time, each controller may access ISO 10303 integrated resources via the Standard Data Access Interface (SDAI) or EXPRESS-X queries in extensible markup language (XML), providing tight integration of ISO 10303 data with machining operations.

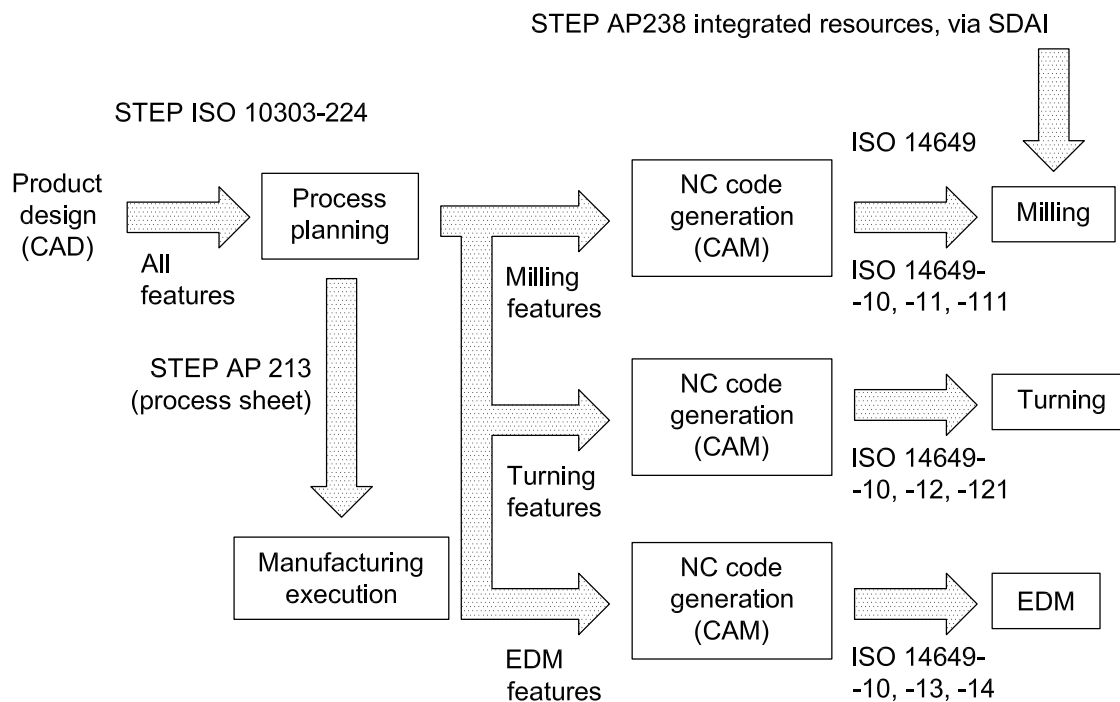


Figure 1 — The manufacturing cycle, from design to fabrication, and how ISO 14649 is envisioned to be used within this cycle

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The fundamental principle of the data model is the object-oriented view of programming in terms of manufacturing features, instead of direct coding of sequences of axis motions and tool functions. The objects in this case are manufacturing features and their associated process data. This does not mean that the programming language is object-oriented, in the sense that it provides classes, methods, or inheritance. Rather, the language is a procedural way to link together a sequence of feature objects.

The data model is composed of basic units called *entities*. Entities and the relationships between them are defined in the ISO 10303 EXPRESS data modelling language. Data in a particular ISO 14649 program consists of *instances* of these entities.

The data model contains geometry data, manufacturing feature data, and manufacturing process data. Geometry data typically originates from CAD, and is described in ISO 10303 AP 203. It includes all the information necessary to define the finished geometry of the workpiece. Manufacturing feature data typically originates from CAM. ISO 14649 defines manufacturing features that differ from, but are harmonized with, ISO 10303-224. Manufacturing process data also originates from CAM, and defines the technological parameters to be used during the cutting process such as tool feed and spindle speed, and descriptions of the tooling required for each of the machining operations. Manufacturing process data also includes the definitions of Workingsteps, one for each association of feature, of associated tool and its technological parameters, and the sequence of these Workingsteps. An overall Workplan lists this information. This is shown in Figure 2.

The division of information means that changing the sequence of Workingsteps or optimising tool paths can be done with minimal impact on the rest of the data. Graphical user interfaces are expected to be an excellent help.

Geometry, feature definitions, and process data are described in ISO 14649-10. Milling-specific data is described in ISO 14649-11 and ISO 14649-111. Data models for other technologies, such as turning and EDM, will be described in successive parts as they are completed.

Programming in legacy languages such as ISO 6983 is not part of the data model. CNCs should be able to handle legacy programs in a separate subsystem.

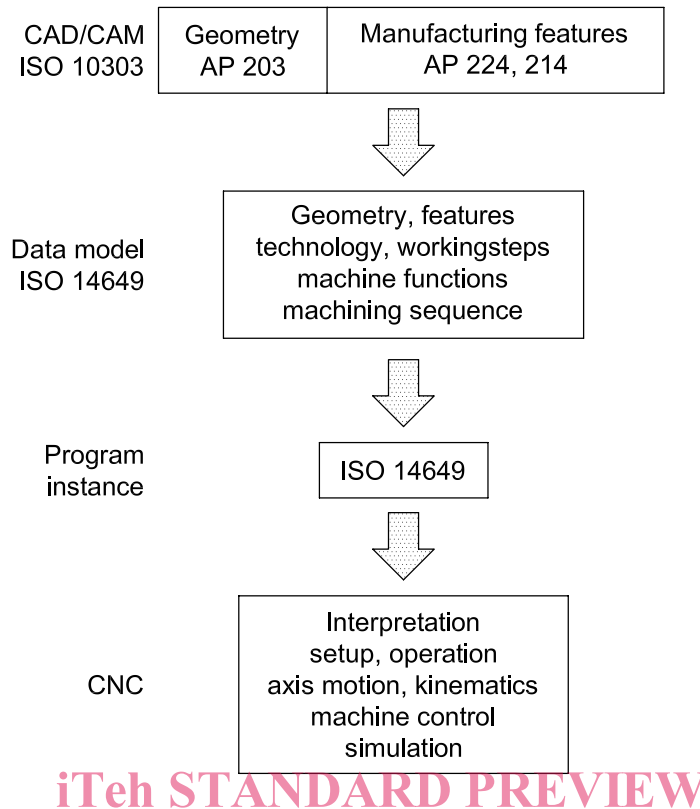


Figure 2 — General description of the data model

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5.3 Program organization

A part program is described in a Physical File Format according to ISO 10303-21. The first section of the part program is the header section marked by the keyword “HEADER”. In this header, some general information and comments concerning the part program are given, such as filename, author, date, organization, etc.

The second and main section of the program file is the data section marked by the keyword “DATA”. This section contains all information about geometry, features, and manufacturing tasks. The content of the data section is divided into three significant parts: Workplan and executables with its technology description, Manufacturing features and Geometry description. A Project entity serves as an explicit reference for the starting point of the manufacturing tasks. Figure 3 shows the relationship between these significant parts of an ISO 14649 data set. The structure and the purpose of the data sets that define features and process data are described in the following sections. (See ISO 14649-10 for more detailed definitions.)

5.4 Project description

The project entity in the DATA section serves as a starting point for executing the part program. This instance should contain a main workplan that contains sequenced subsets of executables (executable manufacturing tasks or commands) and may also include information of workpieces to be machined.

5.5 Executables and the Workplan

Executables initiate actions on a machine and are ordered by the workplan. There are three types of executables: Workingstep, program structure, and NC function. Workingsteps represent the essential building blocks of manufacturing tasks. Each workingstep describes a single manufacturing operation using one cutting tool. An example of a Workingstep is the roughing operation of a pocket or the finishing operation of a region of a freeform surface. The detailed information of workingstep is referenced from the technology description.