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Automation systems and integration — Numerical control of machines — Program format and definitions of address words —

Part 1: Data format for positioning, line motion and contouring control systems

Systèmes d'automatisation industrielle et intégration — Commande numérique des machines — Format de programme et définitions des mots adresses —

Partie 1: Format des données pour les systèmes de positionnement, de commande paraxiale de mouvement et de contourage

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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 6983-1 was prepared by Technical Committee ISO/TC 184, *Automation systems and integration*, Subcommittee SC 1, *Physical device control*.

This second edition cancels and replaces the first edition (ISO 6983-1:1982), which has been technically revised.

The following changes have been made to the first edition:

— the content has been restructured in a more logical order;

— the commonly used preparatory (G) and miscellaneous (M) function codes have been grouped in one standard (see Annex E);

— address indexing has been introduced (see 6.2);

— the equal (=) sign has been added to allow for axis indexing (see 6.2.1);

— new data formats have been specified to existing programming methods: helical interpolation (see 7.3); dwell time (see Clause 13); thread cutting (see Clause 11).

ISO 6983 consists of the following parts, under the general title *Automation systems and integration — Numerical control of machines — Program format and definitions of address words*:

— *Part 1: Data format for positioning, line motion and contouring control systems*

The following parts are under preparation:

— *Part 2: Coding of miscellaneous functions M (class 1 to 8)* [Technical Report]

Introduction

ISO 6983 describes a word address program format for machine control programs on different data storages, e.g. perforated tape, magnetic media, universal serial bus (USB) stick, hard disk, floppy disk, random-access memory (RAM), etc., or provided from a remote data source. ISO 6983 covers variable block format only and is not intended to specify machine design.

ISO 6983 is intended to specify the program format for the control program to be used for numerical controls (NC) on machines/machine tools. However, ISO 6983 can also be used for all kinds of geometric specifications and interactions with machines.

The program format specified by ISO 6983 is commonly referred to as “G code programming” or “ISO programming”.

Compliance with ISO 6983 does not guarantee interchangeability of machine control programs between different machines/machine tools. Annex D details some of the additional considerations necessary to ensure this interchangeability.

Automation systems and integration — Numerical control of machines — Program format and definitions of address words —

Part 1: Data format for positioning, line motion and contouring control systems

1 Scope

This part of ISO 6983 specifies requirements and makes recommendations for a data format for positioning, line motion and contouring control systems used in the numerical control of machines. This part of ISO 6983 helps the co-ordination of system design in order to minimize the variety of program manuscripts required, to promote uniformity of programming techniques, and to foster interchangeability of input programs between numerically controlled machines of the same classification by type, process, function, size and accuracy. It is intended that simple numerically controlled machines be programmed using a simple format, which is systematically extensible for more complex machines.

This part of ISO 6983 is not intended for use in the specialized cases of numerically controlled flame cutting machines and drafting machines used specifically and exclusively in the shipbuilding industry. In this application, a related format ("the ESSI Format") is specified in ISO 6582.

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2806 apply.

4 Program format

The machine program shall be structured in blocks of data, which contain sets of commands to the control system. A block shall consist of a number of words each of which is a specific instruction to the control system.

A character designated "end of block" shall terminate every block of data and in addition shall precede the first block of data.

A "program start" character shall precede all control data including "end of block". It is recommended that it should be used as an "absolute rewind stop" character.

All alphabetic, numeric and special characters shall conform to Annex A. Those characters required for reproducing a hard copy of the machine program, listed in Annex A as “non printing characters”, shall be ignored by the control equipment, with the exception of the LF/NL (end of block) character.

If there is any group of characters that is not to be processed in accordance with this part of ISO 6983, this group shall be within parenthesis characters (control out – control in). Any such group shall not contain either “:” or “%” characters. This group may be processed for display purposes, e.g. as instructions to an operator.

Where it is necessary to identify a machine program, this identification should be placed immediately after the program start character and before the first “end of block” character. If the identification contains alpha characters, the entire identification should be enclosed with parentheses. Where it is desired to identify a machine program number word, the program number word should be placed immediately after the first “end of block” for this identification. If the program number is greater than the system can store or display, the least significant digits shall be displayed.

It is recommended that the alignment code should be used at all positions in the program at which it is permissible to start the machine sequence. When used, this code shall be as defined in 6.3. The alignment function character “:” may be used as an intermediate rewind stop character.

The “/” (slash) character shall be used to provide an “optional block skip” function validated at the option of the operator. When used, this character shall immediately precede the “sequence number” word.

A general classification of the format shall be used to detail the capabilities of a system and machine configuration. This is called the general format classification and is defined in Annex B.

A classification of the data in a block shall be used to specify the programming detail for a system and machine configuration. This is called the detailed format classification and is described in Annex C.

For position values or length values, either metric or inch units of length shall be used.

When a system has the ability to use machine programs which have been prepared in either system of measurement, preparatory codes shall be used to signify whether the coded data is in metric or inch values. The mode of control shall be selected by one of the following G codes (preparatory function codes):

— G70 inch data input;

— G71 metric data input.

5 Format make-up

5.1 Data block

A block of data shall consist of the following:

a) the sequence number word;

b) the data word;

Tab characters, which are optional for the tabulation of a printed copy of the data, may be inserted between words but shall be ignored by the control system.

5.2 Data words

The data words shall be presented in the following sequence and shall be not repeated within one block. However, existing control systems may permit the repetition of non dimensional words, but it is recommended for maximum machine program interchangeability that this facility should not be used.

The sequence is as follows:

a) the preparatory words “G”;

b) the “dimension” words, which shall be arranged in the following sequence: X, Y, Z, U, V, W, P, Q, R, A, B, C;

c) the “interpolation or thread cutting lead words” I, J and K, which apply only to a specific group of axes and shall immediately follow that group; the words shall conform in detail to Clauses 7 or 11;

d) the “feed function” word (or words), which applies to one or more of several axes and shall follow the last dimension word to which it applies and immediately follow the applicable interpolation parameter words; the word shall conform in detail to 6.3;

e) the “spindle speed function” word (or words);

f) the “tool function” word (or words);

g) the “miscellaneous function” word (or words).

5.3 Omitted words

Words may be omitted in a specific block of data. This should be understood as meaning that there is no change in the condition of the machine with respect to the function denoted by the omitted word. Therefore, the “end of block” character may be used after any complete word. Instructions that are inherently executed in a single block shall be repeated whenever necessary.

6 Words

6.1 All words

The address character shall be the first in the word and it shall be followed by an algebraic sign, if required, and then by digital data. The address character shall be in accordance with Annex A.

The implicit position of the decimal sign shall be defined by the detailed format classification (see Annex C). All control systems shall accept implicit decimal sign programming. Optionally, the decimal sign character may be recognized.

Implicit decimal sign and explicit decimal sign format shall not be mixed in any machine program.

In the explicit decimal sign format mode, words from which the decimal sign is missing shall be interpreted as whole numbers. The procedure for recognition of explicit decimal sign format shall be defined in the detailed format classification (see Annex C).

In order to reduce the amount of data with the implicit decimal sign format, either leading zeros only, or trailing zeros only, shall be omitted. It is recommended that leading zeros should be omitted.

Zero omission shall be specified in the detailed format classification (see Annex C).

With explicit decimal sign format, both leading zeros before the decimal sign and trailing zeros after the decimal sign may be omitted.

EXAMPLE 1 X1030 represents a dimension of 1 030 mm in the X-axis.

EXAMPLE 2 X.03 represents a dimension of 0,03 mm in the X-axis.

In either decimal format, a dimension containing only zeros shall be expressed by at least one zero.

6.2 Address indexing

6.2.1 Axis indexing

For machine tools with a higher number of axes, the address indexing may be used. This index digit of the address shall follow directly after the address character. The index shall be an unsigned integer greater zero (0). The maximum index value is specified in the machine description. Leading zeros may be omitted.

For the separation of the index value and the address value, the equal (=) sign is used.

EXAMPLE G00 X1=123.456 Y1=234 Z2=10.1 F100 S1000.

Indexing of addresses may be mixed with non-indexed addresses if there are addresses which have no relation to any indexed address.

NOTE This axis indexing is used in ISO 841.

6.2.2 General indexing

For machine tools with a higher number of axes, auxiliary axis, spindles, tool magazines, etc., address indexing may be used. This index digit of the address shall follow directly after the address character. The index shall be an unsigned integer greater zero (0). The maximum index value is specified in the machine description. Leading zeros may be omitted. The indexing of G codes is not intended.

For the separation of the index value and the address value, the equal (=) sign is used.

EXAMPLE G00 X1=123.456 Y1=234 Z1=10.1 F1=100 M1=3 S1=1000.

Indexing of addresses may be mixed with non-indexed addresses if there are addresses which have no relation to any indexed address.

This indexing can also be used for machine tools with more work groups. This work grouping can be realized by grouping the axis systems using the address indexing, e.g.:

— X1=, Y1=, Z1=, G1=, M1=, S1=, … in the first axis system (work group 1);

— X2=, Y2=, Z2=, G2=, M2=, S2=, … in the second axis system (work group 2).

6.3 Dimension words

It shall be possible to use both absolute dimension words and incremental (relative) dimension words. The mode of the control shall be selected by one of the following G codes:

a) G90 Absolute dimension;

b) G91 Incremental dimensions.

All linear dimensions shall be expressed in millimetres or inches and decimal fractions thereof.

Angular dimensions shall be expressed either in degrees and decimal parts thereof, or in revolutions or decimal parts of a revolution. The use of degrees and decimal parts of a degree is recommended for the expression of all angular dimensions.

The algebraic sign (+ or −) is part of the dimension word, and shall follow the address character and shall precede the numerical character. If the sign is omitted, a plus (+) sign shall be assumed. The control system shall use the negative sign for a negative absolute dimension word and for a negative direction movement with an incremental word.

The resolution of the linear and angular dimensions used in the program shall be defined by the detailed format classification (see Annex C).

6.4 Non-dimensional words

6.4.1 Sequence number

The number of digits shall be specified by the detailed format classification (see Annex C). If a sequence number word in a machine program contains more digits than are specified by a particular control equipment, the least significant digits shall be displayed.

It is recommended that at all positions in the program at which it is permissible to start a machine sequence, the alignment code should replace the sequence number address character N.

6.4.2 Preparatory function

The preparatory function shall be expressed by the address character G followed by a coded number in accordance with Annex E.

6.4.3 Feed function

The number of digits shall be designated by the detailed format classification (see Annex C).

Selection of the type of feed function shall be by the following preparatory (G) codes:

a) G93 Inverse time;

b) G94 Feed per minute;

c) G95 Feed per revolution.

It is recommended that when the feed is independent of spindle speed, the digits should represent directly the vectorial motion in millimetres per minute or inches per minute.

When the feed is dependent on spindle speed, it is recommended that the digits should represent directly the vectorial motion in millimetres per revolution or inches per revolution.

When the feed is applied to a rotary motion only, it is recommended that the digits should represent directly the vectorial motion in degrees per minute.

When simultaneous interpolation in both linear and rotary axes are possible, independent of spindle speed, the rate of vectorial motion may be expressed as a feed command. This feed command shall be the reciprocal of time in minutes to execute the block and is equivalent to the vector velocity (expressed in millimetres or inches per minute) divided by the vector distance of the tool path (expressed in millimetres or inches). When this facility requires a change in the detailed format classification, the revised F word format should be specified. Alternatively, the feed can be specified by the speed of the vectorial motion along the tool path.

It is recommended that preparatory code G00 should be used for rapid positioning (see Annex E).

As an alternative, if the F word is used for traverse, the code shall be specified in the detailed format classification and it shall be defined as modal or non-modal.

For any combination of interdependent axes which can be moved simultaneously or sequentially with the principal axes, the F character shall be used as address for the feed word. An independent axis which can be moved simultaneously with the principal axes shall use the E character as address for the feed word.

As an alternative to the recommended practice, the feed function may consist of a two-digit code with increasing arbitrary values of feed rate represented by increasing code number.

6.4.4 Spindle function

The number of digits shall be designated by the detailed format classification (see Annex C). Where necessary, selection of the type of spindle speed function shall be made by the following preparatory (G) codes:

a) G96 Constant surface speed;

b) G97 Revolutions per minute.

It is recommended that when the digits represent RPM, they shall represent directly the spindle rotation in revolutions per minute.

When the digits represent surface speed (see Clause 12), the digits shall represent metres per minute or feet per minute.

As an alternative to the recommended practice, the spindle function may consist of a two-digit code, with increasing arbitrary values of spindle speed represented by increasing code number.

6.4.5 Tool function

The T word shall be used for tool selection and optionally the same word may select the tool compensation offset. When tool compensation offset is selected by a different word, the D word is recommended. The T word, and the D word if used, shall be designated by the detailed format classification (see Annex C).

6.4.6 Miscellaneous function

The miscellaneous function shall be expressed by a coded number in accordance with Annex E.

6.4.7 Parameters

For a flexible programming method, calculations of axis values or setting of parameters for a subroutine are necessary. The kind of use of these features shall be specified in the manual, i.e.

— which address character is used as parameter: P, Q or R;

— which operations are allowed, e.g. arithmetic, trigonometric, logical;

— which memory addresses are used for the parameters.

In these cases, the parameter index is the memory location of the parameter, and address indexing is mandatory.

EXAMPLE 1 R11 = 22.2 (The content of parameter R11 is set to 22.2)

EXAMPLE 2 R29 = R9 + R15 (Parameter content addition, result is stored in parameter R29)

EXAMPLE 3 X2 = 105 + R9 (X2-position results of addition of 105 and the content of R9)

7 Programming methods for interpolation

7.1 Principles

Interpolation is performed over a pre-determined portion of a given curve. The portion interpolated is called a “span” and may be covered by one or more blocks of information. Data necessary to define a “span” shall obey one or more of the principles below.

a) An appropriate G code shall be used to define the functional nature of the curve, i.e. linear, circular or parabolic.