International Standard 6983 / 1

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

Commande numérique des machines — Format de programme et définition des mots adresses — Partie 1 : Format de données pour les équipements de commande de mise en position, de déplacement linéaire et de contournage

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO member bodies). The work of developing International Standards is carried out through ISO technical committees. Every member body interested in a subject for which a technical committee has been set up 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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 6983/1 was developed by Technical Committee ISO/TC 97, *Computers and information processing*, and was circulated to the member bodies in May 1980.

It has been approved by the member bodies of the following countries :

Australia	Germany, F. R.	Spain
Belgium	Italy	Sweden
Cuba	Netherlands	United Kingdom
Czechoslovakia	Poland	USA
Finland	Romania	USSR
France	South Africa, Rep. of	

The member body of the following country expressed disapproval of the document on technical grounds :

Japan

Printed in Switzerland

Numerical control of machines — Program format and definition of address words — Part 1 : Data format for positioning line motion and contouring control systems

0 Introduction

A word address program format is described in this International Standard for machine control programs on perforated tape, magnetic media, or provided from a remote data source. The standards cover variable block format only and are not intended to specify machine design.

0.1 This International Standard will replace :

a) ISO 840, *Numerical control of machines — 7-bit coded character set.*

b) ISO 1056, *Numerical control of machines — Punched tape formats — Coding of preparatory functions G and miscellaneous functions M*

c) ISO 1057, *Numerical control of machines — Interchangeable punched tape variable block format for positioning and straight-cut machining.*

d) ISO 1058, *Numerical control of machines — Punched tape variable block for positioning and straight-cut machining.*

e) ISO 1059, *Numerical control of machines — Punched tape fixed block format for positioning and straight-cut machining.*

f) ISO 2539, *Numerical control of machines — Punched tape variable block format contouring and contouring positioning.*

0.2 Compliance with this International Standard does not guarantee interchangeability of machine programs between machines. Annex D details some of the additional considerations necessary to ensure this interchangeability.

The purpose of this revision of International Standards is :

a) to consolidate the previous format standards into one International Standard for positioning, line motion and contouring systems;

b) to remove outmoded provisions of the previous International Standards, where feasible;

c) to introduce format standards for new functions, not covered by the previous International Standards;

d) to reduce the difference in programming between different machine/control units;

e) to provide guidelines for achieving program interchangeability between machines of similar capacity;

f) to include the preparatory and miscellaneous codes.

This International Standard will consist of several parts; for the moment there are two parts : part 1, the details of data format, and part 2, the preparatory and miscellaneous codes.

1 Scope and field of application

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 International Standard 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 International Standard is not intended for use in specialized case of numerically controlled flame cutting machines and drafting machines used specifically and exclusively in the shipbuilding industry. In this specialized application a related format, the "ESSI Format", is specified in ISO 6582.

2 References

This part of ISO 6983 requires, and is based upon, conformance to the International Standards cited below, with the further requirements that character coding shall be selected to provide even parity and the characters used shall be limited to those identified in annex A of this part of ISO 6983.

ISO 646, *7-bit coded character set for information processing interchange.* [1)]

ISO 841, *Numerical control of machines — Axis and motion nomenclature.*

ISO 2806, *Numerical control of machines — Vocabulary.*

ISO 6983/2, *Numerical control of machines — Program format and definition of address words — Part 2 : Coding and maintenance of preparatory functions G and universal miscellaneous functions M.* [2)]

When punched tape is used, the following International Standards are also used :

ISO 1154, *Information processing — Punched paper tape — Dimensions and location of feed holes and codes holes.*

ISO 1729, *Information processing — Unpunched paper tape — Specification.*

ISO 6582, *Shipbuilding — Numerical control of machines — ESSI format.* [2)]

3 Program format

3.1 The machine program shall be in blocks of data, which are 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.

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

3.3 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.

3.4 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 exeception of the LF/NL (end of block) character.

3.5 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.

Any such group shall not contain either : ":" or "%" characters.

This group may be processed for display purposes, for example as instructions to an operator.

3.6 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 within parentheses. If the program number is greater than the system can store or display, the least significant digits shall be displayed.

3.7 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 5.3.1.1.

The alignment function character ":" may be used as an intermediate rewind stop character.

3.8 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.

3.9 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.

3.10 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.

3.11 Either metric or inch units of length shall be used.

3.11.1 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.

3.11.2 The mode of the control shall be selected by one of the following G codes :

— G70 inch data input;

— G71 metric data input.

4 Format make-up

4.1 A block of data shall consist of the following :

a) the sequence number word;

b) the data words.

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

1) See annex A.

2) At present at the stage of draft.

4.2 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.

a) the preparatory word;

b) the "dimension" words. These words 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. These words applying only to a specific group of axes shall immediately follow that group. The words shall conform in detail to paragraphs 6 or 10;

d) the "feed function" word or words. The feed function word applying to one or more of several axes 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 5.3.3;

e) the "spindle speed function" word;

f) the "tool function" word or words;

g) the "miscellaneous function" word.

4.3 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.

5 Words

5.1 All words

5.1.1 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.

5.1.2 The address character shall be in accordance with annex A.

5.1.3 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.

5.1.4 Optionally also, 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, annex C.

5.1.5 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.

NOTE — It is recommended that leading zeros should be omitted.

Zero omission shall be specified in the detailed format classification (see C.2.1).

With explicit decimal sign format both leading zeros before the decimal sign and trailing zeros after the decimal sign may be omitted. For example X1030 represents a dimension of 1 030 mm in the X-axis. 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.

5.2 Dimension words

5.2.1 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 :

— G90 absolute dimension;

— G91 incremental dimension.

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

5.2.3 Angular dimensions shall be expressed either in degrees and decimal parts thereof, or in decimal parts of a revolution.

NOTE — The use of degrees and decimal parts of a degree, is recommended for the expression of all angular dimensions.

5.2.4 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.

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

5.3 Non-dimensional words

5.3.1 Sequence number

The number of digits shall be specified by the detailed format classification, see annex C. If 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.

5.3.1.1 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.

5.3.2 Preparatory function

It shall be expressed by a coded number. For designation see part 2 of ISO 6983.

5.3.3 Feed function

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

Selection of the type of feed function associated with 5.3.3.1 to 5.3.3.4 shall be by the following preparatory (G) codes, detailed in part 2 of ISO 6983.

- G93 Inverse time;
- G94 Feed per minute;
- G95 Feed per revolution.

5.3.3.1 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.

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

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

5.3.3.4 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).

If this facility requires a change in the detailed format classification, the revised F word format should be specified.

5.3.3.5 It is recommended that preparatory code G00 should be used for rapid positioning (see part 2 of this International Standard).

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.

5.3.3.6 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.

5.3.3.7 As an alternative to the recommended practice, the feed function may consist of a two (2) digit code with increasing arbitrary values of feed rate represented by increasing code number.

5.3.4 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, detailed in part 2 of ISO 6983.

- G96 Constant surface speed;
- G97 RPM.

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

5.3.4.2 When the digits represent surface speed (see 11.1), the digits shall represent metres per minute or feet per minute.

5.3.4.3 As an alternative to the recommended practice, the spindle function may consist of a two (2) digit code, with increasing arbitrary values of spindle speed represented by increasing code number.

5.3.5 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).

5.3.6 Miscellaneous function

It shall be expressed by a coded number. For designation see part 2 of ISO 6983.

6 Programming methods for interpolation

6.1 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 following principles.

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

6.1.2 The starting point of each span shall be identical to the end point of the previous span and, therefore, it is not necessary to repeat this point in the new block. Each subsequent point on the span for which coordinates are specified shall require a separate block of information and shall use a valid dimension address such as X, Y or Z.

6.1.3 Interpolation parameters shall be addressed I, J or K and shall be used for defining the geometric properties of the curve as defined for each interpolation method.

6.1.4 In cases where an algebraic sign is required with the interpolation parameter word, it shall follow the address character and precede the numeric characters. If the sign is omitted, a plus sign shall be assumed.

6.2 Linear interpolation

A straight line span shall be defined in one block which contains :

a) the G function word (if not currently active);
G01 linear interpolation;

b) the coordinates of the end point, which shall be expressed as dimension words (see 5.2).

The example in figure 1 shows the geometric properties of the span and gives an example of the coordinate values to be programmed.

6.3 Circular interpolation

6.3.1 Circular interpolation defines a circular span lying in a plane parallel to one of the three principal planes of reference. The example in figure 2 shows the geometric properties of a typical circular span and gives an example of the coordinate and interpolation values to be programmed.

6.3.2 It is recommended that circular interpolation should be programmed by defining the span (up to full circle) in one block.

6.3.3 As an alternative, the programming of circular interpolation may be limited to a span lying in a quadrant for each block.

6.3.4 The block shall contain :

a) the G function word (if not currently active);
the G02 circular interpolation Arc CW;
the G03 circular interpolation Arc CCW;

b) The coordinates of the end point, which shall be expressed in either absolute or incremental dimensions and addressed by any valid motion address, such as X, Y or Z;

c) The interpolation parameters addressed I, J and K which define the centre of the arc.

6.3.5 It is recommended that the I, J and K words should be the incremental (relative) dimension from the starting point to the centre of the circle, irrespective of whether the dimension words are incremental or absolute.

I will be the dimension parallel to X.

J will be the dimension parallel to Y.

K will be the dimension parallel to Z.

Systems that do not require an algebraic sign for circular interpolation shall ignore any sign character in the interpolation word.

As an alternative the I, J and K words shall be programmed in the same mode as the dimension words.

6.3.6 When circular interpolation is to be combined with simultaneous linear interpolation, the plane for circular interpolation shall be selected by a preparatory function (see part 2). Interpolation blocks shall be as specified in 6.3.2 to 6.3.5 with the addition of a third dimension word, which shall indicate the end point of the linear motion, and a third interpolation parameter addressed by the letter allocated to dimensions parallel to the linear motion (I, J and K). The value assigned shall be the linear movement required per radian of arc.

6.3.7 If a preparatory function is required to select one of the three principal planes of reference, the code shall be selected from part 2 of ISO 6983.

6.4 Parabolic interpolation

6.4.1 Parabolic interpolation defines a parabolic span lying in any plane. It is recommended that the method of programming should be by definition of the span by three points. The intermediate point and the end point shall be programmed in successive blocks. The example in figure 3 shows the geometric properties of the span and gives examples of meanings of the coordinate values to be programmed. The first block shall contain :

a) The G-function word (if not currently active).
G06 parabolic interpolation;

b) The coordinates of the intermediate point.

The following block shall contain the coordinates of the end point.

The coordinates of all points shall be expressed in either absolute or incremental dimensions and addressed by any valid motion address such as X, Y or Z.

6.4.2 Alternatively, the span may be defined in one block using interpolation parameters. The block shall contain :

a) The G-function word (if not currently active).
G06 Parabolic interpolation;

b) The coordinates of the end point, which shall be expressed in either absolute or incremental dimensions and addressed by any valid motion address, such as X, Y or Z;

c) The interpolation parameters addressed by I, J, K.

I, J, K should be the coordinates of the tangent intersection point.

7 Tool length offset and tool offset

7.1 When tool length offset is included, it provides the possibility of moving a tool a distance along the Z-axis equal to the value entered into the control equipment. The offset distance, and where applicable the sign, may be inserted via manual data input switches or other means.

7.2 When tool offset is included, usually for lathes, it provides the possibility of moving a tool a distance along specified axes, normally X and Z. The value shall be inserted as specified in 7.1.

7.3 The offset move shall be possible without the use of any preparatory codes. Removal of the offset shall be accomplished by a zero (0) value in the digits of the tool function that are allocated to selection of the offset value.

8 Tool radius (diameter) offset

8.1 When this feature is included, it provides the possibility of moving a tool the same distance along both the X and Y-axes to the value entered into the control equipment (half for diameter offset). The offset distance, and where applicable the sign, may be inserted via manual data input switches or other means.

8.2 The control equipment shall provide preparatory codes to signify the block in which the offset has to be added.

8.3 It is recommended that the preparatory codes G43 (tool offset positive) and G44 (tool offset negative) be used, as defined in ISO 6983/2, to signify the block in which the offset has to be introduced and whether it has to be added to or subtracted from the commanded axis dimension. The offset can be cancelled by G40 as defined in ISO 6983/2.

9 Cutter compensation

9.1 When this feature is included in a control system, it provides the possibility of modifying the tool path to take into account the dimensions of the actual tool.

Compensation shall be applied to contouring modes : linear interpolation, circular interpolation. The compensation parameter shall be determined by values entered into the control system store, via manual data input or other means. The store position shall be identified by the T word unless a separate D address has been used. The range of compensation shall be specified in the control system specification. Cutter compensation may be applied to a succession of motion blocks which include circular interpolation. Compensation shall not, however, be introduced or removed in circular interpolation blocks.

9.2 The control system shall provide the following preparatory functions G40, G41, G42; the operation of these G-codes is specified in part 2 of ISO 6983. The compensation shall be applied to all motions generated from blocks containing G41 or G42 and all subsequent blocks until G40 is read, when the operational T word store identity has a value other than zero. Before a further T word, or D word, is programmed, a G40 shall be used to remove the original compensation.

10 Thread cutting

10.1 When this feature is incorporated in the control system, the data required shall be the axes move, the lead and a preparatory code.

10.2 The preparatory functions to commence constant lead thread cutting and at completion to reset the program are detailed in part 2.

10.3 The dimension words X, Y and/or Z shall be used as specified in 5.2.

10.4 The address characters to be used for the lead shall be I for the lead in the X axis, J for the lead in the Y axis, and K for the lead in the Z axis.

10.5 The lead dimension shall be expressed in millimetres or inches and the decimal fraction thereof for one revolution of the spindle.

The number of digits shall be designated by the detailed format classification (see annex C). There shall not be an algebraic sign.

10.5 The feed functions word is not required with constant lead and shall not be programmed.

10.6 For variable lead threads, the I, J and K words shall be the initial lead dimensions. The rate of increase or decrease in lead per revolution shall be expressed in millimetres per revolution squared or inches per revolution squared and addressed by character F.

If the F word is used as above, it shall be specified in the detailed format classification, see annex C.

11 Constant surface speed

11.1 When this feature is incorporated in the control system, a preparatory code shall be used to signify that the S word is the required surface speed (see 5.3.4).

11.2 The preparatory code G96 shall be used to start the constant surface speed operation and G97 shall revert the S word back to revolutions per minute.

11.3 If a limitation for spindle speed is necessary, it should be programmed by G92 and the S word. The digits of the S word define the maximum allowed spindle speed in RPM. The preparatory function G92 and the S word should be programmed in a block prior to that containing G96 calling for constant surface speed.

12 Dwells

12.1 A delay between moves shall be programmed in a separate block containing G04. It is recommended that the duration should be specified by the F word.

The delay shall be in seconds if G94 is operative and in revolutions of the spindle if G95 is operative.

It is recommended that the resolution of the F word should be 0,1 s or 0,1 revolutions, or as specified in the detailed format classification.

12.2 As an alternative, the delay may be set by other means.

A G04 word in a block without dimensional or feed data shall be used to initiate a dwell whose duration is controlled by a fixed or operator controlled variable device.

13 Reset states

13.1 It is recommended that the system should assume the following operation modes at power turn-on after the miscellaneous function M02 (end of program) or M30 (end of data) have been read. Exceptions shall be defined in the detailed format classification.

13.2 Point to point and line motion controls

The control system should have power-on with the following states operational :

G00 positioning

G40 cutter compensation/tool radius offset cancel

G71 metric data

G80 fixed cycle cancel

G90 absolute dimension data

G94 feed per minute

13.3 Contouring controls other than those on lathes

The control system should have power-on with the following states operational :

G01 linear interpolation

G17 XY plane selection

G40 cutter compensation/tool radius offset cancel

G71 metric data

G80 fixed cycle cancel

G90 absolute dimension data

G94 feed per minute

13.4 Contouring controls on lathes

The control system should have power-on with the following states operational :

G01 linear interpolation

G40 cutter compensation/tool radius offset cancel

G71 metric data

G90 absolute dimension data

G94 feed per minute

G97 revolutions per minute