ANSI/NEMA IA 2.1-1994 (R2002)

PROGRAMMABLE CONTROLLERS – GENERAL INFORMATION

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Programmable Controllers - General Information

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FOREWORD

This Standards Publication is a NEMA Adoptive Standard based on Part 1 of IEC 1131, "Programmable Controllers."

This Standards Publication was prepared by a technical committee of the NEMA Automation Products and Systems Section. It was approved in accordance with the bylaws of NEMA and supersedes NEMA Standards Publication ICS 3-1988, Part 3-304.

This Standards Publication provides practical information concerning ratings, construction, test, performance and manufacture of industrial control equipment. These standards are used by the electrical industry to provide guidelines for the manufacture and proper application of reliable products and equipment and to promote the benefits of repetitive manufacturing and widespread product availability.

NEMA Standards represent the result of many years of research, investigation and experience by the members of NEMA, its predecessors, its Sections and Committees. They have been developed through continuing consultation among manufacturers, users and national engineering societies and have resulted in improved serviceability of electrical products with economies to manufacturers and users.

One of the primary purposes of this Standards Publication is to encourage the production of reliable control equipment which, in itself, functions in accordance with these accepted standards. Some portions of these standards, such as electrical spacings and interrupting ratings, have a direct bearing on safety; almost all of the items in this publication, when applied properly, contribute to safety in one way or another.

Properly constructed industrial control equipment is, however, only one factor in minimizing the hazards which may be associated with the use of electricity. The reduction of hazard involves the joint efforts of the various equipment manufacturers, the system designer, the installer and the user. Information is provided herein to assist users and others in the proper selection of control equipment.

The industrial control manufacturer has limited or no control over the following factors which are vital to a safe installation:

a. environmental conditions
b. system design
c. equipment selection and application
d. installation
e. operating practices
f. maintenance

This publication is not intended to instruct the user of control equipment with regard to these factors except insofar as suitable equipment to meet needs can be recognized in this publication and some application guidance is given.

This Standards Publication is necessarily confined to defining the construction requirements for industrial control equipment and to providing recommendations for proper selection for use under normal or certain specific conditions. Since any piece of industrial control equipment can be installed, operated and maintained in such a manner that hazardous conditions may result, conformance with this publication does not by itself assure a safe installation. When, however, equipment conforming with these standards is properly selected and is installed in accordance with the National Electrical Code and properly maintained, the hazards to persons and property will be reduced.

To continue to serve the best interests of users, NEMA is actively cooperating with other standardization organizations in the development of simple and more universal metrology practices. In this Standards Publication, the U.S. customary units are gradually being supplemented by those of the modernized metric system known as the International Systems of Units (SI). This transition involves no changes in standard dimensions, tolerances, or performance specifications.

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Proposed revisions to this Standards Publication should be submitted to:

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National Electrical Manufacturers Association
2101 L Street, N.W.
Washington, DC 20037

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REFERENCED STANDARDS

The following standards contain provisions which, through reference in this text, constitute provisions of this NEMA Standard Publication. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.

International Electrotechnical Commission
1, rue de Varembé
Geneva, Switzerland

IEC 1131-1 — *Programmable Controllers • Part 1: General Information*

National Fire Protection Association
Publication Sales Department
Batterymarch Park
Quincy, MA 02269

ANSI/NFPA 70 — *National Electrical Code*

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AMENDMENTS

IEC 1131-1, "Programmable controllers • Part 1: General information," is adopted with the amendments noted below.
NEMA Adoptive Standard

Subclause 2.18:

Replace the definition in subclause 2.18 of IEC 1131-1 with the definition of *device* given in ANSI/NFPA 70, *National Electrical Code*.
NEMA Standard

Where a conflict exists between the provisions of IA 2.1 and other NEMA Standards Publications, the provisions of IA 2.1 shall govern in the area of programmable controllers and their associated peripherals.
NEMA Standard

Where a conflict exists between the provisions of IA 2.1 and ANSI/NFPA 70, *National Electrical Code*, the provisions of ANSI/NFPA 70 shall govern.
NEMA Standard

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INTERNATIONAL STANDARD

IEC 1131-1

First edition
1992-10

Programmable controllers –

Part 1:
General information

Automates programmables –

Partie 1:
Informations générales

Reference number
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PROGRAMMABLE CONTROLLERS –

Part 1: General information

FOREWORD

1) The formal decisions or agreements of the IEC on technical matters, prepared by Technical Committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.

2) They have the form of recommendations for international use and they are accepted by the National Committees in that sense.

3) In order to promote international unification, the IEC expresses the wish that all National Committees should adopt the text of the IEC recommendation for their national rules in so far as national conditions will permit. Any divergence between the IEC recommendation and the corresponding national rules should, as far as possible, be clearly indicated in the latter.

This part of the International Standard IEC 1131 has been prepared by sub-committee 65B: Devices, of IEC technical committee No. 65: Industrial-process measurement and control.

The text of this part is based on the following documents:

Six Months' Rule	Report on Voting
65A(CO)21	65A(CO)26

Full information on the voting for the approval of this part can be found in the Voting Report indicated in the above table.

IEC 1131 will consist of the following parts, of which this is the first, under the general title: Programmable controllers.

Part 1: 1992, General information.
Part 2: 1992, Equipment requirements and tests.
Part 3: Programming languages (being printed).
Part 4: User guidelines (under consideration).
Part 5: Messaging service specification (under consideration).

Annexes A and B form an integral part of this part.

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INTRODUCTION

This part of IEC 1131 constitutes part 1 of a series of standards on programmable controllers and their associated peripherals and should be read in conjunction with the other parts of the series.

Where a conflict exists between this and other IEC standards (except basic safety standards), the provisions of this standard should be considered to govern in the area of programmable controllers and their associated peripherals.

Compliance with parts 1 and 2 of this standard cannot be claimed unless *all tests and verifications required in part 2 are complied with.* See 6.2 of IEC 1131-2 for details.

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PROGRAMMABLE CONTROLLERS –

Part 1: General information

1 General

1.1 *Scope*

The International Standard IEC 1131 applies to programmable controllers and their associated peripherals such as programming and debugging tools (PADTs), test equipment (TE) and man-machine interfaces (MMIs), etc.

Equipment covered in this standard is intended for use in overvoltage category II (see IEC 364-4-443), in low voltage installations, where the rated mains supply voltage does not exceed 1 000 V a.c. (50/60 Hz), or 1 500 V d.c., for the control and command of machines and industrial processes.

Programmable controllers and their associated peripherals are considered as components of a control system and may be provided as enclosed or open equipment. Therefore, *this standard does not deal with the automated system* in which the programmable controller system is but one basic component among many others including its application program.

Since programmable controllers are component devices, overall automated system safety including installation and application is beyond the scope of this standard. For further information, refer to IEC 1131-4 which is intended to help users in reducing the risks. However, electrical noise immunity and error detection of the PC-system operation such as the use of parity checking, self-testing diagnostics, etc., are addressed.

1.2 *Object of the standard*

The purposes of this standard are:

– to establish the definitions and identify the principal characteristics relevant to the selection and application of programmable controllers and their associated peripherals;

– to specify the minimum requirements for the functional characteristics, service conditions, construction characteristics, general safety and tests applicable to programmable controllers and their associated peripherals;

– to define, for each of the most commonly used programming languages, major fields of application, syntactic and semantic rules, simple but complete basic sets of programming elements, applicable tests and means by which manufacturers may expand or adapt those basic sets to their own programmable controller implementations;

– to give general tutorial information and application guidelines to the user;

– to define the communication between programmable controllers and other electronic systems using the Manufacturing Message Specification (MMS) defined in ISO/IEC 9506.

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1.3 *Object of this part*

This part of IEC 1131 gives the definitions and contains a glossary of terms used in this standard. It identifies the principal functional characteristics of programmable controller systems.

1.4 *Normative references*

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 1131. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this part of IEC 1131 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 50(55): 1970, *International Electrotechnical Vocabulary – Chapter 55: Telegraphy and telephony.*

IEC 50(303): 1983, *International Electrotechnical Vocabulary – Chapter 303: Electronic measuring instruments.*

IEC 50(351): 1975, *International Electrotechnical Vocabulary – Chapter 351: Automatic control.*

IEC 271: 1974, *List of basic terms, definitions and related mathematics for reliability.*

IEC 364-4-443: 1990, *Electrical installations of buildings – Part 4: Protection for safety – Chapter 44: Protection against overvoltages – Section 443: Protection against overvoltages of atmospheric origin or due to switching.*

IEC 902: 1987, *Industrial-process measurement and control – Terms and definitions.*

ISO 2382-1: 1984, *Data processing – Vocabulary – Part 01: Fundamental terms.*

ISO 2382-4: 1987, *Information processing systems – Vocabulary – Part 04: Organization of data.*

ISO 2382-5: 1989, *Information processing systems – Vocabulary – Part 05: Representation of data.*

ISO/IEC 2382-7: 1989, *Information technology – Vocabulary – Part 07: Computer programming.*

ISO 2382-11: 1987, *Information processing systems – Vocabulary – Part 11: Processing units.*

ISO 2382-15: 1985, *Data processing – Vocabulary – Part 15: Programming languages.*

ISO 8601: 1988, *Data elements and interchange formats – Information interchange – Representation of dates and times.*

ISO/IEC 9506-1: 1990, *Industrial automation systems – Manufacturing message specification – Part 1: Service definition.*

ISO/IEC 9506-2: 1990, *Industrial automation systems – Manufacturing message specification – Part 2: Protocol specification.*

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2 Definitions

Terms not found in the International Electrotechnical Vocabulary (IEV) and of general use in IEC 1131 are defined in this clause. Terms which are more specific to programming languages, equipment characteristics or test procedures are defined in the corresponding parts in order to make them self-readable.

2.1 *Application program*

A logical assembly of all the programming language elements and constructs necessary for the intended signal processing required for the control of a machine or process by a PC-system. (See Automated system, 2.3.)

2.2 *Assignment list*

A list showing the correspondences between absolute or logical addresses and the symbolic addresses assigned to them.

2.3 *Automated system*

A control system beyond the scope of IEC 1131 in which PC-systems are incorporated by or for the user, but which also contains other components including their application programs.

2.4 *Availability*

The fraction of time that the system is actually capable of performing its mission.

2.5 *Binary coded decimal (BCD)*

A numerical representation in which each decimal digit is represented by a group of four bits (binary digits). The bits are assigned the respective weights 8-4-2-1. For example, in binary coded decimal, the number 14 is represented as 0001 0100.

2.6 *Boolean data*

Data represented as a single binary digit.

2.7 *Bus*

One or more conductors used for transmitting signals or power from one or more sources to one or more destinations.

2.8 *Byte*

A data element of length 8 bits.

2.9 *Catalogued device*

A device that is listed in the manufacturer's catalogue of PC components.

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2.10 *Component*

Any device, unit, or application program which is a part of an automated system. However its use in IEC 1131 is limited to manufacturer's catalogued parts of PC-system.

2.11 *Connect/disconnect*

Make/break a *logical* link (such as between a MMI and a MPU, eventually through communication devices). See Plug/unplug (2.47) for *physical* connection/disconnection.

2.12 *Coupling (for interference)*

The mechanism by which an interference source produces interference in a signal circuit.

2.13 *Cross-reference list*

A list showing all the locations in a PC program at which a selected list of data objects is operated upon.

2.14 *Current sinking*

The act of receiving current.

2.15 *Current sourcing*

The act of supplying current.

2.16 *Data communication equipment (DCE)*

The equipment that provides the functions required to establish, maintain, and terminate a connection, as well as the signal conversion, and the coding required for communication between data terminal equipment and data circuit.

2.17 *Data terminal equipment (DTE)*

Equipment consisting of digital devices and instruments that convert the user information into data signals for transmission, or reconvert the received data signals into user information.

2.18 *Device*

Part of a PC-system

2.19 *Disconnect*

See connect (2.11).

2.20 *Duration*

The amount of time taken by an event, action, etc.

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2.21 *Element*

The portion of a graphical language corresponding to an instruction in textual language. The operation part and the operand part as specified by appropriate combination of graphic and character symbols.

2.22 *Execution*

The process of performing the operations of a specified portion of an application program.

2.23 *Fail-safe shutdown*

The ability of a PC-system to have its outputs assume a predefined state within a specified delay after detecting the occurrence of a power supply voltage drop or an internal failure.

2.24 *Image (input/output (I/O image), image register)*

A portion of memory where I/O status (the image) is maintained.

2.25 *Input*

1) The current, voltage, power or driving force applied to a circuit or device; also called input value or input data.

2) The terminals or other places where current, voltage, power or driving force may be applied to a circuit or device; also called input terminal.

3) Data which can be read by the application program from an interface between the user program execution function and another functional unit of the PC-system, as defined in this part of IEC 1131. Also called program input.

(See also in IEC 1131-2: Input, digital, type 1/type 2.)

2.26 *Instruction*

A programming language element that specifies an operation and the values or location of its operands. [ISO/IEC 2382-7/07.06.01 modified.]

2.27 *Internal failure*

A failure involving the manufacturer-supplied hardware or software of the PC-system, excluding the application program.

2.28 *Isolated (devices, circuits)*

Devices, circuits are said to be isolated where there is no galvanic connection between them.

2.29 *Ladder diagram (relay ladder diagram)*

One or more networks of contacts, coils, graphically represented functions, function blocks, data elements, labels, and connective elements, delimited on the left and (optionally) on the right by power rails.

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2.30 *Language*

1) Function block diagram (FBD) language

A programming language using function block diagrams for representing the application program for a PC-system.

2) Graphical language

A programming language based upon graphical representation.

3) Instruction list (IL) language

A textual programming language using instructions for representing the application program for a PC-system.

4) Ladder diagram (LD) language

A programming language using ladder diagrams for representing the application program for a PC-system

5) Structured text (ST) language

A textual programming language using assignment, sub-program control, selection and iteration statements to represent the application program for a PC-system.

6) Textual language

A system consisting of a well-defined, usually finite, set of characters; rules for combining characters with one another to form words or other expressions; and a specific assignment of meanings to some of the words or expressions.

2.31 *Logic control system*

A control system in which definite output signal states are functions of the states of the input signals in keeping with the rules of Boolean algebra.

2.32 *Main processing unit (MPU)*

The portion of the PC-system which interpretes or executes the (main part of the) application program. The MPU may include power supply, memory, and I/Os. See annex B of this part and also 3.1 and 3.6 of IEC 1131-2.

2.33 *Man-machine interface (MMI)*

A manufacturer's catalogued peripheral equipped with pushbuttons, lamps, keyboards, displays or equivalent, intended as operator interface, such as motor control/monitor panel, general purpose operator interface, etc.

MMIs may be part of the permanent installation (e.g. mounted on front panels, doors, boards, etc.) or not.

2.34 *Mean time between failure (MTBF)*

For a stated period in the life of a functional unit, the mean value of the length of time between consecutive failures under stated conditions. [IEC 902/P5.3.0.08]

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2.35 *Memory utilization*

The amount of memory required for a specified part of a program.

2.36 *Network*

A maximal interconnected group of graphical language elements, excluding the left and right power rails of ladder diagrams.

2.37 *On-line*

A PC-system is said to be "on-line" when it is in active control of a machine or process.

2.38 *Operating system*

Manufacturer's provided functions intended to manage internal PC-system interdependent functions (see 4.2.1).

2.39 *Operation*

A defined action, namely, the act of obtaining a result from one or more operands in accordance with a rule that completely specifies the result for any permissible combination of operands (see Instruction, 2.26).

2.40 *Output*

1) The current, voltage, power or driving force delivered by a circuit or device, also called output value.

2) The terminals or other places where current, voltage, power or driving force may be delivered by a circuit or device, also called output terminals.

3) Data which can be written by the application program to an interface between the user program execution function and another functional unit of the PC-system, as defined in this part of IEC 1131. Also called program output.

2.41 *Overvoltage category*

See 1.4.39 of IEC 1131-2 and IEC 364-4-443.

2.42 *PC program*

Synonymous with application program.

2.43 *PC-system*

Synonymous with programmable controller system.

2.44 *Peripheral*

Catalogued device internal or external to the permanent programmable control system, the function of which is to program, supervise, monitor, test and record the operation of the PC-system.

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2.45 *Peripheral (permanent, transportable, portable, hand-held portable, on-line pluggable)*

1) Permanent peripheral (permanently installed)

Peripheral which is a part of the permanent installation of the PC-system.

2) Transportable peripheral

Peripheral which is not a permanent part of the installation and which is connectable to the system by means of cables or cords with connectors or other means to establish communication with the system.

3) Portable peripheral

Peripheral specifically designed to be carried by hand.

4) Hand-held portable

See Equipment, hand held portable 1.4.19 of IEC 1131-2.

5) On-line pluggable

See Equipment, on-line pluggable 1.4.21 of IEC 1131-2.

2.46 *Permanent installation*

The portion of the PC-system which must be present to perform the intended application functions (see annex A).

2.47 *Plug/unplug*

Make/break a *physical* connection (e.g. use a physical connector for interfacing a peripheral or a module to the rest of the PC-system). See Connect/disconnect (2.11) for *logical* connection/disconnection.

2.48 *Power rail*

Vertical lines bounding and connected to ladder diagrams on the left and, optionally, on the right.

2.49 *Pluggable*

See Equipment, on-line pluggable 1.4.21 of IEC 1131-2.

2.50 *Programmable controller (PC)*

A digitally operating electronic system, designed for use in an industrial environment, which uses a programmable memory for the internal storage of user-oriented instructions for implementing specific functions such as logic, sequencing, timing, counting and arithmetic, to control, through digital or analog inputs and outputs, various types of machines or processes. Both the PC and its associated peripherals are designed so that they can be easily integrated into an industrial control system and easily used in all their intended functions.

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2.51 *Programmable controller system (PC-system)*

A user-built configuration, consisting of a programmable controller and associated peripherals, that is necessary for the intended automated system. It consists of units interconnected by cables or plug-in connections for permanent installation and by cables or other means for portable and transportable peripherals (see annex A).

2.52 *Programming and debugging tool (PADT)*

A catalogued peripheral to assist in programming, testing, commissioning and troubleshooting the PC-system application, program documentation and storage and possibly to be used as MMIs. PADTs are said to be pluggable when they may be plugged or unplugged at any time into their associated interface, without any risk to the operators and the application. In all other cases, PADTs are said to be fixed.

2.53 *Real number*

A number with a decimal point.

2.54 *Relay ladder diagram*

Synonymous with ladder diagram (2.29).

2.55 *Remote input/output station (RIOS)*

A manufacturer's catalogued part of a PC-system including input and/or output interfaces allowed to operate only under the hierarchy of the main processing unit (MPU) for I/O multiplexing/demultiplexing and data preprocessing/postprocessing. The RIOS is only permitted limited autonomous operation, e.g. under emergency conditions such as breakdown of the communication link to the MPU or of the MPU itself, or when maintenance and troubleshooting operations are to be performed.

2.56 *Restart (cold r., hot r., warm r.)*

1) Cold restart

Restart of the PC-system and its application program after all dynamic data (variables such as I/O image, internal registers, timers, counters, etc., and program contexts) are reset to a predetermined state. A cold restart may be automatic (e.g. after a power failure, a loss of information in the dynamic portion(s) of the memory(ies), etc.) or manual (e.g. push-button reset, etc.).

2) Hot restart

Restart after power failure which occurs within the process dependent maximum time allowed for the PC-system to recover as if there had been no power failure.

All I/O information and other dynamic data as well as the application program context are restored or unchanged.

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Hot restart capability requires a separately powered real time clock or timer to determine elapsed time since the power failure was detected and a user accessible means to program the process dependent maximum time allowed.

3) Warm restart

Restart after a power failure with a user programmed predetermined set of dynamic data and a system predetermined application program context. A warm restart is identified by a status flag or equivalent means made available to the application program indicating that the power failure shut down of the PC-system was detected in the run mode.

2.57 *Restart (automatic, controlled, manual of protected output)*

See 3.3.2.2 of IEC 1131-2.

2.58 *Rung*

A network in a ladder diagram program with its attached left power rail and optionally attached right power rail.

2.59 *Scan time*

See Time (2.68).

2.60 *Sequential control system*

A control system in which the individual steps are processed in a predetermined order, progression from one sequence step to the next being dependent on defined conditions being satisfied. Such a system may be time-dependent, in which the step transition conditions are functions of time only or external-event dependent, where the conditions are functions of input signals only or combinations of these (and perhaps more complex) conditions.

2.61 *Sequential function chart (SFC)*

A graphical representation of a sequential program consisting of interconnected steps, actions and directed links with transition conditions.

2.62 *Serial (data transmission)*

A system wherein the bits of a character occur serially in time. Implies only a single transmission channel.

2.63 *Sink mode output*

A mode of operation of solid state output devices in which the device controls the current from the load, i.e. when the output is energized it connects the load to the negative polarity of the supply.

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2.64 *Software*

1) Computer programs, routines, programming languages and systems.

2) The collection of related utility, assembly and other programs that are desirable for properly presenting a given machine to a user.

3) Detailed procedures to be followed, whether expressed as programs for a computer or as procedures for an operator or any other person.

4) Documents, including hardware manuals and drawings, computer program listings and diagrams, etc.

5) Items such as those listed above, as contrasted with hardware.

2.65 *Source mode output*

A mode of operation of solid state output devices in which the device controls the current to the load, i.e. when the output is energized, it connects the load to the positive polarity of the supply.

2.66 *System software*

Software written by the device manufacturer which defines the operation of the device with or without an application program. Typically a collection of subroutines which acts as an interpreter in converting the instructions of the user-entered application program into the machine code required by the device hardware.

2.67 *Test equipment (TE)*

A manufacturer's catalogued peripheral equipped with pushbuttons, lamps, keyboards, displays, or equivalent, etc., for troubleshooting of the PC-system and/or the controlled application. TEs are said to be pluggable when they may be plugged or unplugged at any time into their associated interface, without any risk to the operators and the application. In all other cases TEs are said to be fixed. TEs may be permanently installed or not. TEs are intended for use by authorized personnel.

2.68 *Time (delay, execution, response, scan, transfer)*

1) Delay time, digital input (TID), analog input (TAID)

The delay encountered by the signal* as it passes through the input filter (from the field input terminal(s) to the input conversion circuit boundary).

2) Delay time, digital output (TQD), analog output (TAQD)

The delay encountered by the signal* as it passes through the output filter (from the output interface boundary to the field output terminal(s).

* For digital input or output, signal is synonymous with 0/1 or 1/0 transition. For analog input, signal is synonymous with noticeable change of analog value of the measured signal. For analog output, TAQD is the analog response time of the digital-to-analog output circuitry.

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3) Response time, analog

The time required, following the initiation of a specified stimulus to a system, for an output going in the direction of necessary corrective action to first reach a specified value.

4) Scan time (TSC)

The time elapsed between two subsequent initiations of the same portion of the application program, including the time required to update the I/O image table, where applicable.

5) Total system response time, digital (TRT)

The time elapsed between a change in input signal state at the field input terminals and the corresponding change in the output signal(s) state(s) at the field output terminals. TRT is the sum of all individual (partial) times encountered by the signal (information) as it passes through the PC-system from the field input interface to the field output interface.

Generally all partial times may vary depending upon many conditions such as the hardware configuration, e.g. RIOS communication links that may affect TIT and TQT, the method used to acquire and process data (periodic scan, interrupts, etc.), the instantaneous load of the application program, etc.

6) Transfer time, digital input (TIT), analog input (TAIT)

The time required by the signal* to pass (transfer) from the input conversion circuit boundary to the data storage in a MPU memory (e.g. to be made available to the application program).

7) Transfer time, digital output (TQT), analog output (TAQT)

The time required by the signal* to pass (transfer) from the data storage in a MPU memory (since it was elaborated by the application program) to the output storage at the output interface boundary.

8) User task execution time (TUT)

The time required by a MPU to carry out a specified portion of a user's application program (e.g. a statement, a program module, etc.), including reading from memory and storing the result, and additional time required by the system software.

9) Total input system transfer time

- For digital input: sum of TID and TIT.
- For analog input: sum of TAID and TAIT.

10) Total output system transfer time

- For digital output: sum of TQT and TQD.
- For analog output: sum of TAQT and TAQD.

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* See footnote on page 17.

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2.69 *Time of day*

The time within a 24-hour day, represented according to ISO 8601.

2.70 *Timer (off-delay timer, on-delay timer)*

1) Off-delay timer

A function block delaying a Boolean input for a specified duration when changing from one to zero.

2) On-delay timer

A function block delaying a Boolean input signal for a specified duration when changing from zero to one.

2.71 *User program*

Synonymous with application program (2.1).

2.72 *User program memory*

The portion of the PC memory reserved for the storage of application programs.

2.73 *Voltage – common mode*

The voltage common to all conductors of a group as measured between that group at a given location and an arbitrary reference (usually earth).

2.74 *Voltage – transverse mode (differential mode)*

The voltage at a given location between two conductors of a group.

2.75 *Watchdog*

1) A manufacturer-provided means performing specific actions if the integrity of the PC-system is violated.

2) A manufacturer-provided means which independently monitors the duration of internal hardware functions, and/or application program functions, and/or operating system software functions, and which will cause specific actions to be performed if not periodically reset at a predetermined interval.

2.76 *Word*

A data element of length 16 bits.

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3 Glossary

Terms already defined in the IEV or in other IEC and ISO documents which are frequently used in IEC 1131 are listed in this clause for convenience and comprehension.

3.1 *Baud*

Unit of modulation speed corresponding to a unit of interval lasting one second. [IEV 55-50-20 modified]

3.2 *Binary character*

Either of the characters of a character set consisting of two characters. Example: a binary digit. [ISO 2382-4/04.03.08 modified]

3.3 *Binary digit (bit)*

Either of the digits 0 and 1 when it is used in the pure binary numeration system. [ISO 2382-4/04.03.07, modified]

3.4 *Bit*

1) An abbreviation for a binary digit
2) A single character in a binary number
3) A single pulse in a group of pulses
4) A unit of information capacity of a storage device. [IEC 902/P4.0.0.01]

3.5 *Character*

Element of a finite set of different elements, called the character set, defined for representation of information, and usually represented by a letter, number or symbol. [IEC 902/P4.0.0.03]

3.6 *Character set*

A defined set of representations, called characters, from which selections are made to denote and distinguish data. Each character differs from all others, and the total number of characters in a given set is fixed, e.g. letters A to Z, punctuation marks and blank (space) characters. [IEC 902/P4.0.0.04]

3.7 *Data*

1) A representation of facts, concepts or instructions in a formalized manner suitable for communication, interpretation or "processing" by human or by "automatic" means. [ISO 2382-1/01.01.01]

2) Characters or continuous functions representing information due to known or supposed arrangement. [IEC 902/P1.1.0.01]

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3.8 *Direct address*

An address that designates the storage location of an item of data to be treated as an operand. [ISO/IEC 2382-7/07.06.22, modified]

3.9 *Direct addressing*

A method of addressing in which the address part of an instruction contains a direct address [ISO/IEC 2382/7]

3.10 *Feedback control*

A method by which one or more controlled variables (pressure, temperature, current, speed, power, etc.) are made to obey a command signal, whether constant or varying, according to a prescribed law, as a result of measurement of the variable(s) in question. [IEV 351-01-10 modified]

3.11 *Hardware*

Physical equipment used in data processing as opposed to computer program, procedures, rules and associated documentation. [ISO 2382-1/01.03.01 modified]

3.12 *Hexadecimal*

Pertaining to the numeration system with a radix of sixteen. [ISO 2382-5/05.03.13 modified]

3.13 *Initialization*

Originating or establishing basic conditions or startup state. [IEC 902/P1.0.0.24]

3.14 *Interrupt*

A break in the normal flow of a system or program occurring in such a way that the flow can be resumed from that point at a later time. [IEC 902/P4.2.0.11]

3.15 *Jump (unconditional jump, conditional jump)*

1) Unconditional jump

In the execution of a computer program, a departure from the implied or declared order in which instructions are being executed. [ISO/IEC 2382-7/07.02.14 and 07.06.14 modified]

2) Conditional jump

A jump that takes place only when the instruction that specifies it is executed and specified conditions are satisfied. [ISO/IEC 2382-7/07.02.14 and 07.06.15 modified]

3.16 *Open loop control*

Control which does not utilize the measurement of the controlled variable. [IEV 351-01-09]

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3.17 *Parameter*

A quantity describing the relation of variables within a given system.

NOTE - A parameter may be a constant or depend on the time or the magnitude of some system variables. [IEC 902/P1.0.0.15 modified]

3.18 *Program*

A series of actions proposed in order to achieve a certain result. [IEC 902/P1.0.0.17]

3.19 *Redundancy*

In an item, the existence of more than one means for performing a given function. [IEC 271/16.1]

3.20 *Register*

A storage device having a specified storage capacity such as a bit, a byte or a computer word and usually intended for a special purpose. [ISO 2382-11/11.01.19 modified]

3.21 *Reliability*

The ability of a functional unit to perform a required function under stated conditions for a stated period of time. [IEV 303-08-12 modified]

3.22 *Sequential program*

A plan which prescribes the actions on a system in a predetermined order and in which some actions depend on the execution of preceding ones or on the fulfilment of certain conditions. [IEV 351-01-14]

3.23 *Statement*

A programming language construct that represents a set of declarations or a step in a sequence of actions. [ISO 2382-15/15.01.06 modified]

3.24 *Syntax*

The rules governing the structure of a language.

3.25 *Variable*

1) A quantity or condition whose value is subject to change and can usually be measured. [IEC 902/P1.1.0.04]

2) A language object that may take different values, one at a time.

NOTE - The values of a variable are usually restricted to a certain data type. [ISO 2382-15/15.03.01]

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4 Functional characteristics

4.1 *Basic functional structure of a programmable controller system*

4.1.1 *General structure*

In a programmable controller system, the

- signal processing function,
- interface function to sensors and actuators,
- communication function,
- man-machine interface function,
- programming, debugging, testing and documentation functions,
- power supply functions,

communicate with each other and with the signals of the machine/process to be controlled so that the required control function can be implemented (see figure 1).

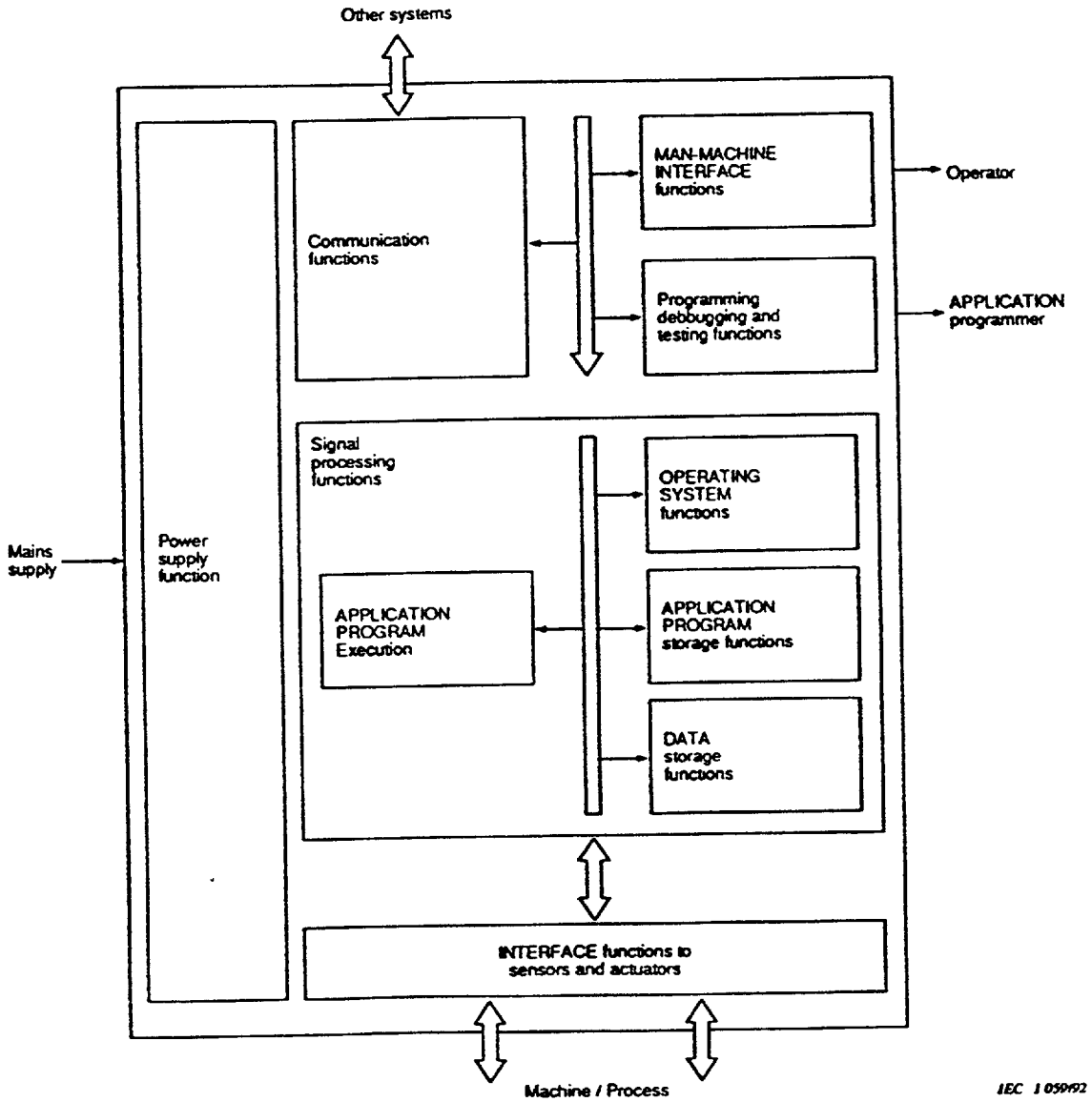


Figure 1 – Basic functional structure of a PC-system

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4.1.2 *Signal processing function*

The signal processing function consists of the application program storage, the data storage, the operating system, the execution of the application program functions.

It processes signals obtained from sensors as well as internal data storage and generates signals to actuators as well as internal data storage in accordance with the application program.

4.1.3 *Interface function to sensors and actuators*

The interface function to sensors and actuators converts:

- the input signals and/or data obtained from the machine/process to appropriate signal levels for processing;
- the output signals and/or data from the signal processing function to appropriate signal levels to drive actuators and/or displays.

4.1.4 *Communication function*

The communication function provides the data exchange with other systems (third party devices) such as other PC-systems, robot controllers, computers, etc.

4.1.5 *Man-machine interface (MMI) function*

The MMI function provides for interaction between the operator, the signal processing function and the machine/process.

4.1.6 *Programming, debugging, testing and documentation functions*

These functions provide for application program generation and loading, monitoring, testing and debugging as well as for application program documentation and archiving.

4.1.7 *Power supply functions*

The power supply functions provide for conversion and isolation of the PC-system power from the mains supply.

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4.2 *Characteristics of the signal processing function*

The capabilities of the programmable controllers are determined by programmable functions which are summarized in table 1. They are subdivided for ease of use into application-oriented groups.

Table 1 – Summary of programmable functions

Function group	Examples
Logic control – Logics – Timers – Counters	 AND, OR, NOT, XOR, flip-flops On-delay, off-delay, timed pulse Up and/or down counting of pulses
Sequential control	Sequential function chart
Signal/data processing – Mathematical functions – Data handling – Analog data processing	 Basic arithmetic: ADD, SUB, MUL, DIV Extended arithmetic: SQRT, trigonometric functions Comparisons: greater, smaller, equal Selecting, organizing, formatting, moving PID, integration, filtering
Interfacing functions – Input/output – Other systems – MMI – Printers – Mass memory	Analog, digital I/O modules BCD conversion *Communication protocols* Display, commands Messages, reports Logging
Execution control	Periodic, event-driven execution
System configuration	Status checking

4.2.1 *Operating system*

The operating system function is responsible for the management of internal PC-system interdependent functions (configuration control, diagnostics, memory management, application program execution management, communication with peripherals and with the interface functions to sensors and actuators, etc.).

4.2.2 *Memory for application program and application data storage*

4.2.2.1 *Application program storage*

The application program storage provides for memory locations to store a series of instructions whose periodic or event-driven execution determines the progression of the machine or the process.

4.2.2.2 *Application data storage*

The application data storage provides for memory locations to store I/O image table and data (e.g. set values for timers, counters, alarm conditions, parameters and recipes for the machine or the process) required during the execution of the application program.

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4.2.2.3 *Memory type, memory capacity, memory utilization*

Various types of memory are in use: read/write (RAM), read-only (ROM), programmable read-only (PROM), reprogrammable read-only (EPROM/UV-PROM, EEPROM). Memory retention at power failure is achieved by a proper selection of the memory type where applicable (e.g. EPROM, EEPROM) or the use of memory back-up for volatile memories (e.g. a battery).

Memory capacity relates to the number of memory locations in kbytes which are reserved to store both the application program and the application data. Memory capacity measurements are:

- capacity in the minimum useful configuration (e.g. 1 kbyte RAM + 4 kbytes EPROM);
- size(s) for expansion increments;
- capacity(ies) at maximal configuration(s).

Each programmable function used by the application program occupies memory locations. The number of locations required generally depends on the programmable functions and the type of programmable controller.

Application data storage requires memory capacity depending on the amount and format of data stored.

4.2.3 *Execution of the application program*

An application program may consist of a number of tasks. The execution of each task is accomplished sequentially, one programmable function at a time until the end of the task. The initiation of a task, periodically or upon the detection of an event (interrupt condition), is under the control of the operating system.

The total response time (TRT) of a PC-system executing the application program is the sum of all individual (partial) times encountered by the signal (information) as it passes through the PC-system from the field input terminal(s) to the field output terminal(s). See clause 2 for all definitions.

For periodic execution: TRT = TID + TIT + r.TSC + TUT + TQT + TQD

- rmin. ≤ r ≤ rmax.;
- r = rmin. if input information is available for processing just before initiation of the task;
- r = rmax. if input information is available for processing just after the initiation of the task.

NOTE - *rmin. and rmax. depend on the organization of the user's application program;* their minimum values are respectively 0 and 1.

For event-driven execution:

- In the above formula replace r.TSC by the time needed by the operating system to initialize the interrupt task.

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4.3 *Characteristics of the interface function to sensors and actuators*

4.3.1 *Types of input/output signals*

Status information and data from the machine/process are conveyed to the I/O system of the programmable controller by binary, digital, incremental or analog signals. Conversely, decisions and results determined by the processing function are conveyed to the machine/process by use of appropriate binary, digital, incremental or analog signals. The large variety of sensors and actuators used requires accommodating a wide range of input and output signals.

4.3.2 *Characteristics of the input/output system*

Various methods of signal processing, conversion and isolation are used in input/output systems. The behaviour and performance of the PC-system depend on the static/dynamic evaluation of the signal (detection of events), storing/nonstoring procedures, opto-isolation, etc.

Input/output systems in general display a modular functionality which allows for configuration of the PC-system according to the needs of the machine/process and also for later expansion (up to the maximum configuration).

The input/output system may be located in close proximity to the signal processing function or may be mounted close to the sensors or actuators of the machine/process, remotely from the signal processing function.

4.4 *Characteristics of the communication function*

The communication function serves the program and data exchange between external devices and the signal processing unit of the programmable controller to effect such functions as program transfers, data file transfers, monitoring, diagnostics.

The transfer of programs and/or data is generally accomplished by serial data transmission over local area networks or point-to-point links.

4.5 *Characteristics of the man-machine interface (MMI) function*

The MMI function has two purposes:

- to provide the operator with the information necessary for monitoring the operation of the machine/process;
- to allow the operator to interact with the PC-system and its application program in order to make decisions and adjustments beyond their individual scope.

4.6 *Characteristics of the programming, debugging, monitoring, testing and documentation functions*

These functions are implemented as either an integral or an independent part of a programmable controller and provide for code generation and storage of the application program and application data in the programmable controller memory(ies) as well as retrieving such programs and data from memory(ies).

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4.6.1 *Writing the application program*

4.6.1.1 *Generating the application program*

The application program may be entered via alphanumeric or symbolic keyboards and, when menu-driven displays are used, via cursor keys, joystick, mouse, etc. All program and data entries are generally checked for validity and internal consistency such that the entry of incorrect programs and data is minimized.

4.6.1.2 *Displaying the application program*

During application program generation all instructions are displayed immediately, statement by statement (in case of line display) or segment by segment (in case of video or other large display). In addition, the complete program can generally be printed. If alternative representation of programming language elements is available, then the display representation is generally user-selectable.

4.6.2 *Automated system startup*

4.6.2.1 *Loading the application program*

The generated program resides either in the memory of the programmable controller or in the memory of the PADT. The latter requires a program transfer via down load or memory cartridge insertion into the programmable controller before startup.

4.6.2.2 *Accessing the memory*

During startup or trouble-shooting operations, the application program and application data storages are accessed by the PADT as well as by the processing unit to allow program monitoring, modification and correction. This may be done "on-line" (i.e. while the PC-system is controlling the machine/process).

4.6.2.3 *Adapting the programmable controller system*

Typical functions for adapting the PC-system to the machine/process to be controlled are:

- test functions which check the sensors and actuators connected to the PC-systems (e.g. forcing the outputs of the PC-system);
- test functions which check the operation of the program sequence (e.g. setting of flags and forcing the inputs);
- setting or resetting of constants (e.g. timers, counters, etc.).

4.6.2.4 *Indicating the automated system status*

The ability to provide information about the machine/process and the internal status of the PC-system and of its application program facilitates the startup and debugging of a PC application. Typical means are:

- status indication for inputs/outputs;
- indication/recording of status changes of external signals and internal data;

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- scan time/execution times monitoring;
- real time visualization of program execution and data processing;
- fuse/short-circuit protections status indicators.

4.6.2.5 *Testing the application program*

Test functions support the user during writing, debugging and checking the application program. Typical test functions are:

- checking the status of inputs/outputs, internal functions (timers, counters);
- checking program sequences, e.g. step-by-step operations, variations of program cycle time, halt commands;
- simulation of interface functions, e.g. forcing of I/Os, of information exchanged between tasks or modules internal to the PC-system.

4.6.2.6 *Modifying the application program*

Functions for modification provide for changing, adjusting and correcting application programs. Typical functions are search, replace, insert, delete, add; they apply to characters, instructions, program modules, etc.

4.6.3 *Documentation*

A documentation package should be provided to fully describe the PC-system and the application. The documentation package may consist of:

- description of the hardware configuration with project-dependent notations, and
- application program documentation consisting of:
  - program listing, with possibly mnemonics for signals and data processed;
  - cross-reference tables for all data processed (I/Os, internal functions such as internal stored data, timers, counters, etc.);
  - comments;
  - description of modifications;
- maintenance manual.

4.6.4 *Application program archiving*

For rapid repair and to minimize downtime, the user may want to store the application program in nonvolatile media such as EPROM, disks, tapes, etc. Such a record needs to be updated after every program modification so that the program executing in the PC-system and the archived program remain the same.

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4.7 *Characteristics of the power supply functions*

The power supply functions generate voltages necessary to operate the PC-system and generally also provide control signals for proper start/stop synchronization of the equipment. Various power supplies may be available depending on supply voltages, power consumption, requirements for uninterruptable operation, etc.

4.8 *Availability and reliability*

Every automated system requires a certain level of availability and reliability of its control system. It is the user's responsibility to ensure that the architecture of the overall automated system, the characteristics of the PC-system and its application program will jointly satisfy the intended application requirements.

4.8.1 *Architecture of the automated system*

Techniques such as redundancy, fault tolerance and automatic error checking, as well as machine/process diagnostic functions can provide enhancements in the area of availability of the automated system.

4.8.2 *Architecture of the programmable controller system*

A modular construction in conjunction with suitable internal self-tests allowing rapid fault identification may provide enhancements in the area of maintainability of the PC-system and therefore of the availability of the automated system. Techniques such as redundancy and fault tolerance may also be considered for special applications.

4.8.3 *Design, testing and maintenance of the application program*

The application program is a key component of the overall automated system. Most programmable controllers provide enough computing power to permit implementation of diagnostic functions in addition to the minimum control function. Machine/process behaviour modelling and subsequent identification of faulty conditions should be considered.

Adequate testing of the application program is mandatory. Every modification implies proper design and testing such that the overall availability and reliability are not impaired. The program documentation shall be maintained and annotated accordingly.

4.8.4 *Installation and service conditions*

PC-systems are typically of rugged design and intended for general purpose service. However, as for any equipment, the more stressing the service conditions, the worse is the reliability, and benefit in this area may be expected when real service conditions are better than the normal service conditions specified in IEC 1131-2. Some applications may require consideration of special packaging, cooling, electrical noise protection, etc., for reliable operation.

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4.9 *Ergonomic characteristics*

4.9.1 *General*

This subclause provides recommendations which are intended to promote the efficient use of the PC-system and its peripherals (PADTs, TE, MMIs, etc.) and to minimize the possibility of human error, fatigue and operator risk.

4.9.2 *Status indicators*

The power supplies, MPUs, I/O modules and RIOSs should provide status indicators.

4.9.3 *Displays*

1) Displays should be unambiguous and easily readable up to 1 m at an angle of up to 30° from the normal of the display.

2) There should be means of varying brightness of displays.

3) The displays should have good contrast between light and dark areas.

4.9.4 *Keyboards*

1) Keyboards should be capable of being positioned so that the operator's hands do not obstruct his view of the display.

2) Keys should be arranged in a logical manner and groups of keys with the same classification should be together (e.g. all numbers in one area, all letters in another, all cursor keys in another etc.).

3) Key spacing should allow two adjacent keys to be simultaneously pressed with any two fingers without either of those two fingers touching any surrounding keys.

4) A keystroke response should be provided (e.g. tactile, bleeper, etc.). Auditory bleepers should have a means of adjusting or disabling.

4.9.5 *Other recommendations*

1) Fans: if fans or devices which cause vibration are contained in PC equipment, they should not cause the keyboard or display to vibrate.

2) Surface finishing: the outer surfaces of the PC-system which are visible from a normal operating position and are in the field of vision when operating should not be reflective.

3) Sharp edges: there should be no sharp edges which could cause cuts or abrasions to the operator.

4) Portability: a device which is designated portable by the manufacturer and weighs over 3 kg should have a handle. Its construction should be such that protection is provided for keyboards and displays when being transported.

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Annex A
(normative)

Illustration of programmable controller system hardware definitions

Figure A.1 illustrates the hardware in the PC-system as defined for the purposes of IEC 1131-1 and IEC 1131-2.

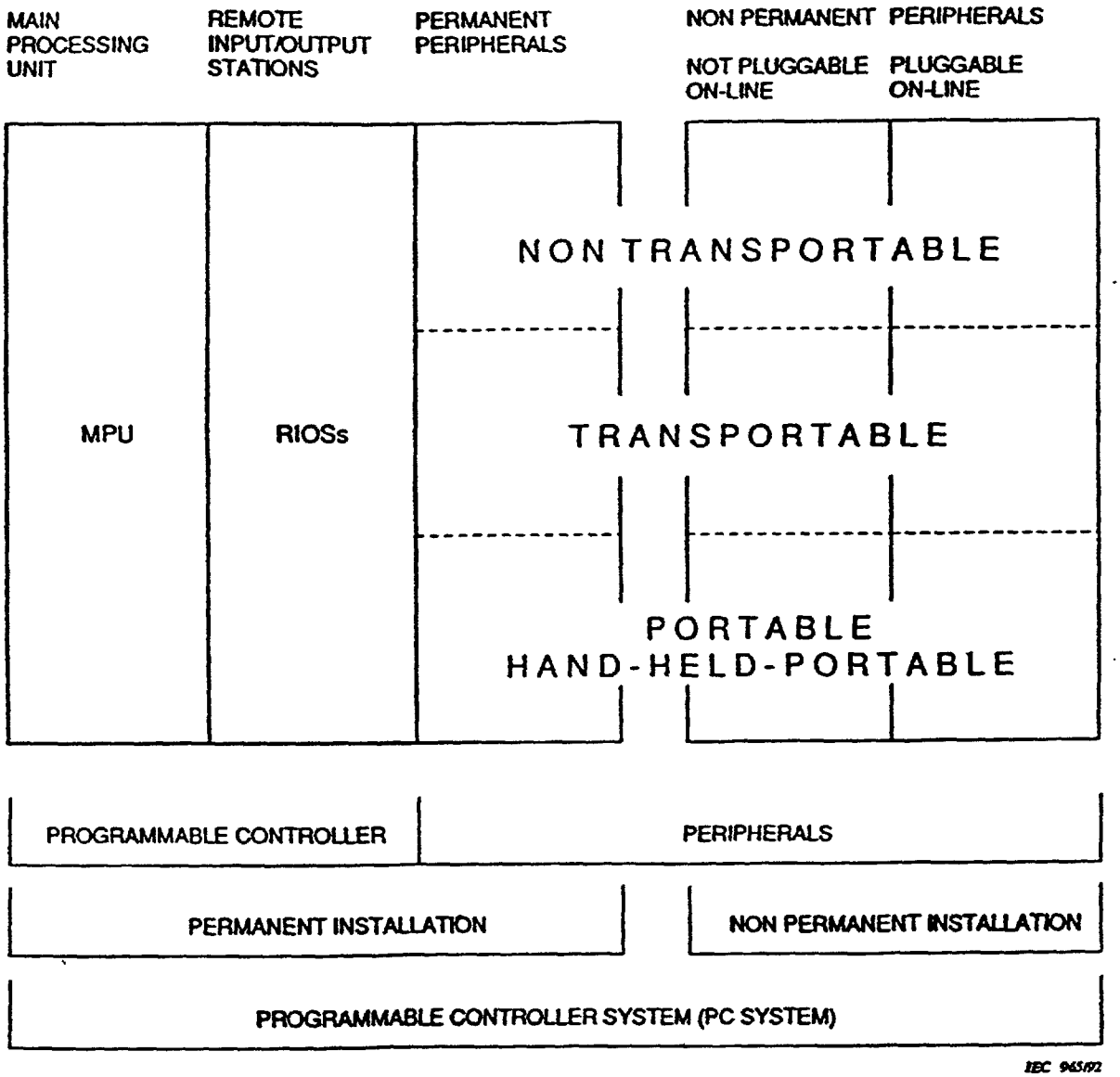


Figure A.1 – Programmable controller system (PC-system)

Transportable, portable and hand-held portable peripherals have specific requirements and have to be distinguished from permanently installed peripherals (see 2.1.3.3, 3.9.2 and 4.5.3 of IEC 1131-2).

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Annex B
(normative)

Typical interface diagram of a programmable controller system

A typical PC-system and its interfaces are shown in figure B.1. Functional requirements for PC-systems including those relating to basic and advanced functions of PADTs are given in IEC 1131-2.

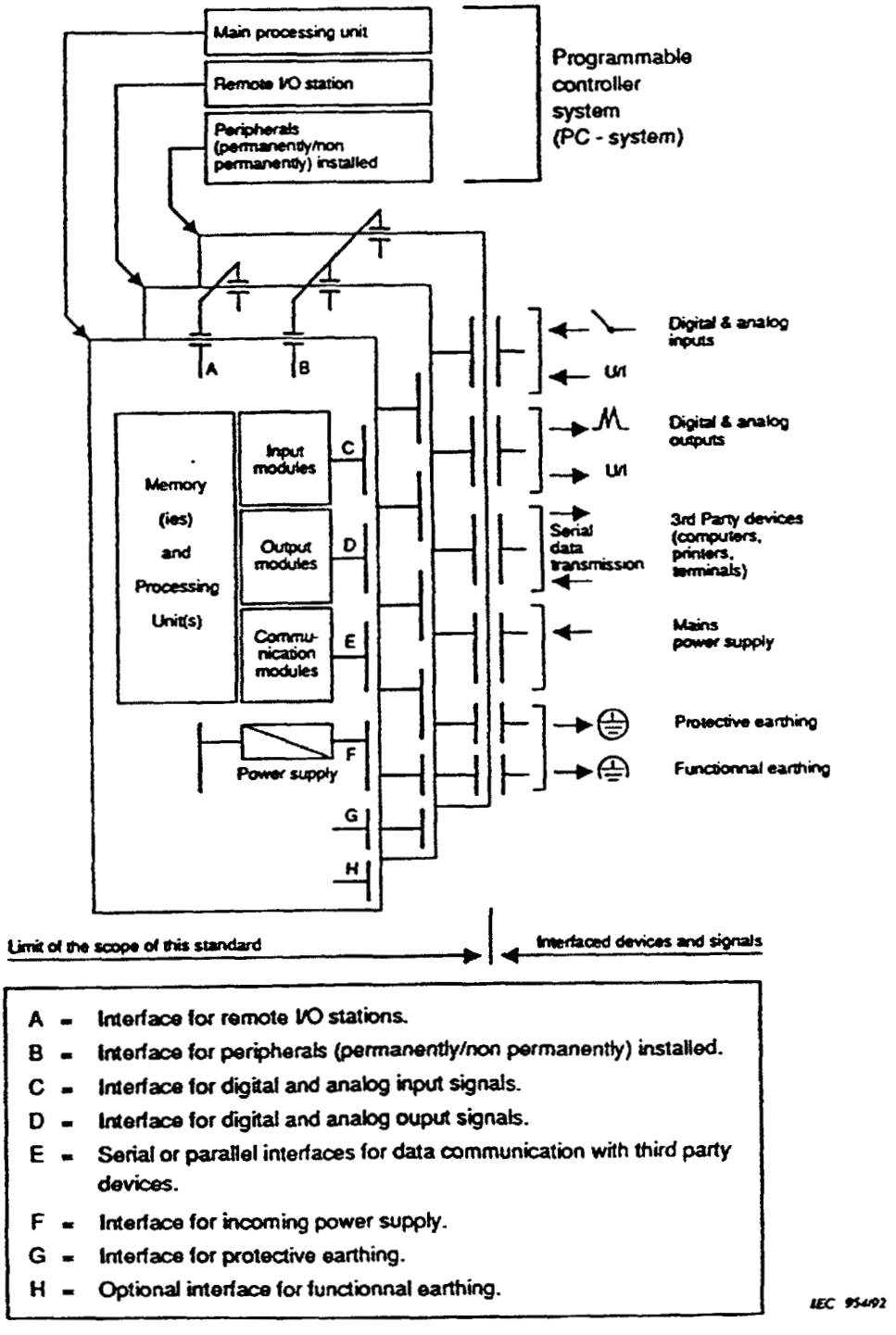


Figure B.1 – Typical interface diagram of a programmable controller system

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NEMA STANDARDIZATION BACKGROUND

The purpose of NEMA standards, their classification, and status are set forth in certain clauses of the NEMA *Standardization Policies and Procedures* manual and are referenced below:

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(Standardization Policies and Procedures, p. 1)

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Where dimensions are given for interchangeability purposes, alternate dimensions satisfying the other provisions of the Standards Publication may be capable of otherwise equivalent performance.

(Standardization Policies and Procedures, p. 6)

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National Electrical Manufacturers Association Standards are of three classes, which have received the affirmative vote of at least two-thirds of the Subdivision votes cast in the affirmative or negative:

1. NEMA Standard, which relates to a product, process, or procedure commercially standardized and subject to repetitive manufacture.
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3. Adoptive Standard, which is adopted in whole or in part from the standards of another organization, either domestic, regional, or international.

(Standardization Policies and Procedures, pp. 5)

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Authorized Engineering Information consists of explanatory data and other engineering information of an informative character not falling within the classification of NEMA Standard or Suggested Standard for Future Design, which standard has received the affirmative vote of at least two-thirds of the Subdivision votes cast in the affirmative or negative.

(Standardization Policies and Procedures, pp. 5)

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Standards in NEMA Standards Publications are identified as "NEMA Standard," "Suggested Standard for Future Design," or "Adoptive Standard." These indicate the status of the standard. A statement incorporating the auxiliary verb "shall" indicates that compliance with a requirement is mandatory for compliance with the standard. These classes of standards are identified in the foreword or throughout the text.

The material identified as "Authorized Engineering Information" is designated similarly. Statements incorporating other auxiliary verbs such as "should," "may," etc. refer to the authorized engineering information and not to procedures required for compliance with the standard.

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