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Australian/New Zealand Standard[®]

Preparation of function charts for control systems

[IEC title: Preparation of function charts for control systems]

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Australian/New Zealand Standard[®]

**Preparation of function charts
for control systems**

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PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee TE/13 on Symbols, Units and Quantities for Electrotechnology, as a Joint Standard.

The objective of this Standard is to provide developers of control systems with methods and symbols for preparing function charts for control systems to facilitate the clear, consistent and unambiguous presentation of the charts. The Standard may be applied to non-electrical systems.

This Standard is identical with and has been reproduced from IEC 848, *Preparation of function charts for control systems*. The Corrigendum:1990 to the Standard has been included at the rear of this Standard and text affected is marked by a marginal bar.

The term 'informative' has been used in this Standard to define the application of the annex to which it applies. An 'informative' annex is only for information and guidance.

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Reference to International Standard		Australian Standard	
IEC		AS	
50	International Electrotechnical Vocabulary	1852	International Electrotechnical Vocabulary
50(351)	Chapter 351: Automatic control	1852.351	Automatic control
ISO			
5807	Information processing— Documentation symbols and conventions for data, program and system flowcharts, program network charts and system resources charts	2645	Information processing— Documentation symbols and conventions for data, program and system flowcharts, program network charts and systems resources charts

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CONTENTS

Clause	Page
1 Scope	1
2 Normative references	1
3 General principles	1
4 General description of the function chart	6
5 Detailed commands (actions) and detailed transition conditions .	22
6 Re-use of the same sequence	32
7 Detailed representation of a step	33
8 Examples of function charts	33
Annex A - Mathematical description of the function chart	44
Annex B - Bibliography	45
Annex C - Index of symbols	46

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AUSTRALIAN/NEW ZEALAND STANDARD

Preparation of function charts for control systems

1 Scope

This standard applies to the preparation of descriptions of the function and behaviour of control systems by establishing an implementation-independent graphical representation. It includes the symbols required as well as rules for their use.

This standard has been prepared with a view to electrotechnical applications (especially industrial ones, including electric power generation and distribution), but as it provides a general process orientated way of describing control functions, independent of their technological implementation, no field of application is explicitly excluded. It may also be applied to non-electrical systems (for example pneumatic, hydraulic or mechanical) or to parts of systems.

The described method of representation should serve as a communication tool between different parties often representing different technological disciplines, involved in the engineering and use of control systems.

NOTE - The method of representation described can be considered as an industrial application of "Petri nets" used for the study of the co-ordination of asynchronous events. Compared to "Petri nets", it offers the possibility to start with an overall description of a control system and may, via progressive levels of description, proceed to a description in which all the details of the system are revealed.

A mathematical description of the function chart is given in Annex A.

2 Normative references

- ISO 5807 (1985): Information processing -
Documentation symbols and conventions for data,
program and system flowcharts, program network charts
and system resources charts.
- IEC 50(351) (1975): International Electrotechnical Vocabulary (IEV),
Chapter 351: Automatic control.

3 General principles

3.1 Description of a control system

The first step in the production of a control system for a process is the transfer to the designer of detailed information about the process. A written text is seldom satisfactory for the precise description of control actions which may be complicated and can include choices between several possible progressions and simultaneous actions.

In general, graphical representations are more easily understood, but it is often difficult to find a representation that will be readily accepted by all the parties involved and is not too orientated towards a specific technology or implementation. In addition, it is sometimes difficult to find a graphical symbol for each function that has to be represented. This suggests a method of representation which combines graphical symbols and textual statements.

Such a representation should allow an overall description of the process and its associated control, independent of the future implementation, as well as a description that takes into account the technological properties of the components used.

The function chart, described in this standard, meets these requirements. It can be used for a precise description of the relationship between the input (conditions) and output (actions) of a process as well as for an overall description.

This is achieved by dividing the process cycle into a number of well-defined, successive steps (steady situations), separated by transitions. The end of a step is marked by the appearance of the process information satisfying the transition condition to the next step. In consequence steps do not overlap. During a step, actions may be started, continued or finished. The precision of the description will be increased when the process cycle is divided into more steps.

3.2 Control, controlling and controlled system

In order to prepare a clear and unambiguous function chart of a system, it is of vital importance that the boundary of the system, and thus the scope of the chart, is clearly defined. As a pure functional description does not present any details regarding physical boundaries or the internal structure of the system, this definition shall be given by means of an adequate description of the inputs and outputs at the assumed boundary.

In accordance with IEC 50(351), a control system may be divided into two interdependent parts:

- the controlled system, which comprises the operative equipment executing the physical process, and
- the controlling system, which is the equipment receiving information from the supervisor, the process to be controlled, etc., and issuing orders to the controlled system.

Figure 1 shows this division and illustrates the boundary of the function chart for any one of these systems. The three function charts that may be prepared describe different relationships and usually serve different purposes.

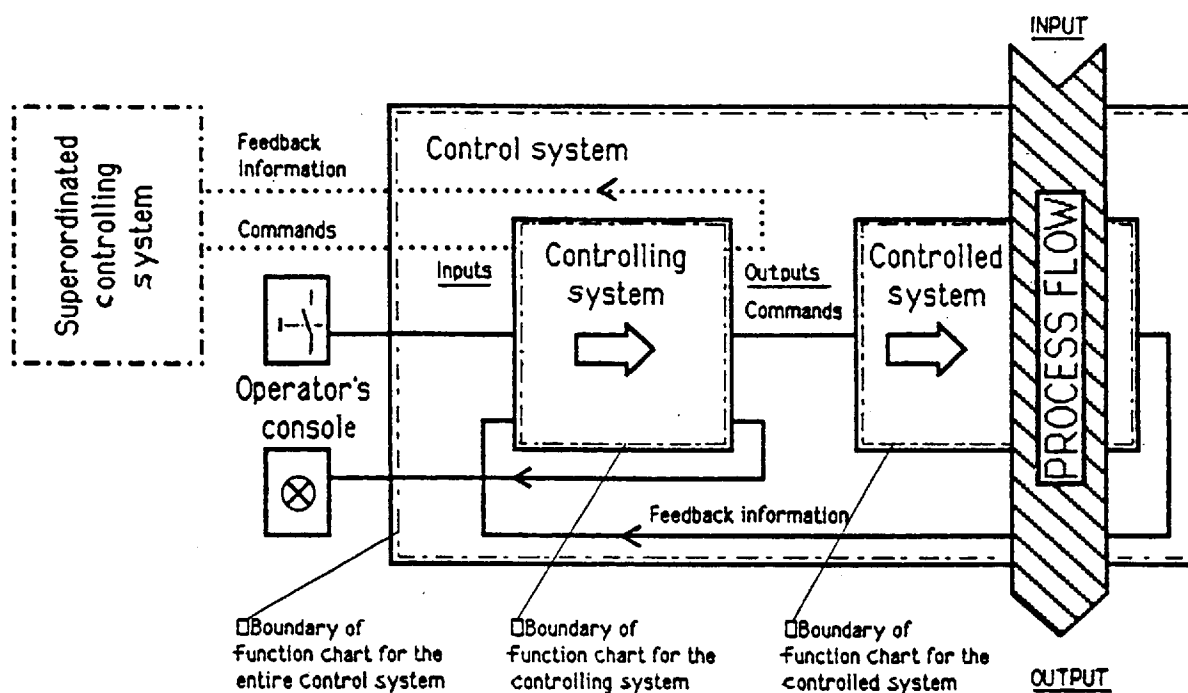


Figure 1 - Control system

3.2.1 Function chart for controlled system

The boundary indicated for the function chart of the controlled system shows that the input conditions consist of the output commands from the controlling system and (varying) properties of the input process flow. The output consists of feedback information to the controlling system and actions executed on the process flow giving it other (desired) properties.

A chart with this scope thus describes the functions of the process equipment, what commands it will take into account and what information and actions will be presented in return. It can be prepared by the process designer and may serve as a basis for the detailed design of the process equipment, and also for the preparation of the function chart for the controlling system.

3.2.2 Function chart for controlling system

The boundary indicated for the function chart of the controlling system shows that the input conditions consist of commands from the supervisor and a possible superordinated controlling system and feedback information from the controlled system. The output consists of information to the supervisor and to the superordinated controlling system and commands to the controlled system. A chart with this scope thus describes the function of the control equipment, what information will be available for it, and which commands and other information it will produce.

It can be prepared by a designer with knowledge about the process (for example through the function chart described above) and serve as a basis for the detailed design of the control equipment. In most cases this type of function chart is sufficient to describe non-complex systems.

3.2.3 Function chart for control system

The boundary indicated for the function chart of the entire control system shows that the input conditions consist of commands from the super-ordinated controlling system, the supervisor, and (varying) properties of the input process flow. The output consists of feedback information to the superordinated controlling system, the operator, and actions executed on the process flow. In this case no internal details can be given regarding the interaction between the controlled and the controlling system.

A chart of this extent thus describes the control system as one entity. This may be useful at an early stage in the design of the system. It may also be advantageous if the system considered belongs to a process plant in which it is just one out of several systems to which it has to be co-ordinated. The control system may then be considered as a part of the controlled system, when the co-ordinating controlling system is designed.

The following two examples give an impression of the described division into a controlled, and a controlling system, when existing control systems are chosen.

Example 1:

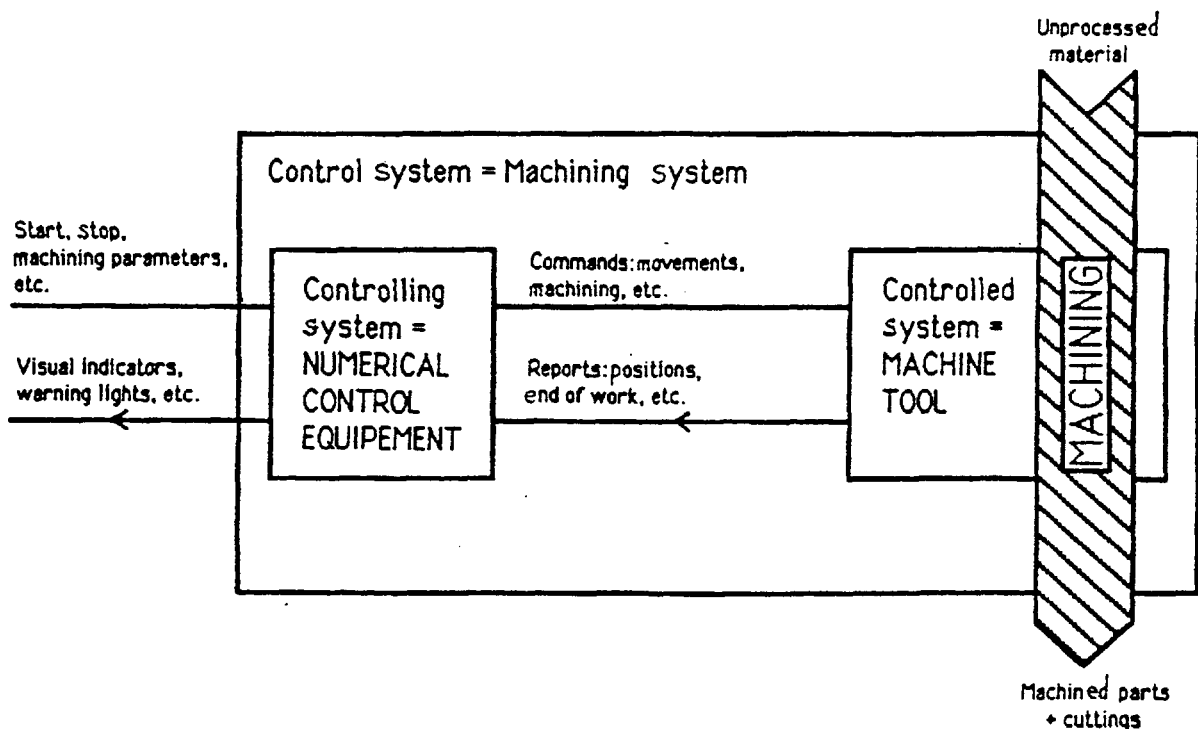


Figure 2 - Numerically controlled machine tool

In example 1 the process is the machining of raw material to produce finished parts. The controlled system is the operative machine tool proper and the controlling system is the numerical control equipment.

Example 2:

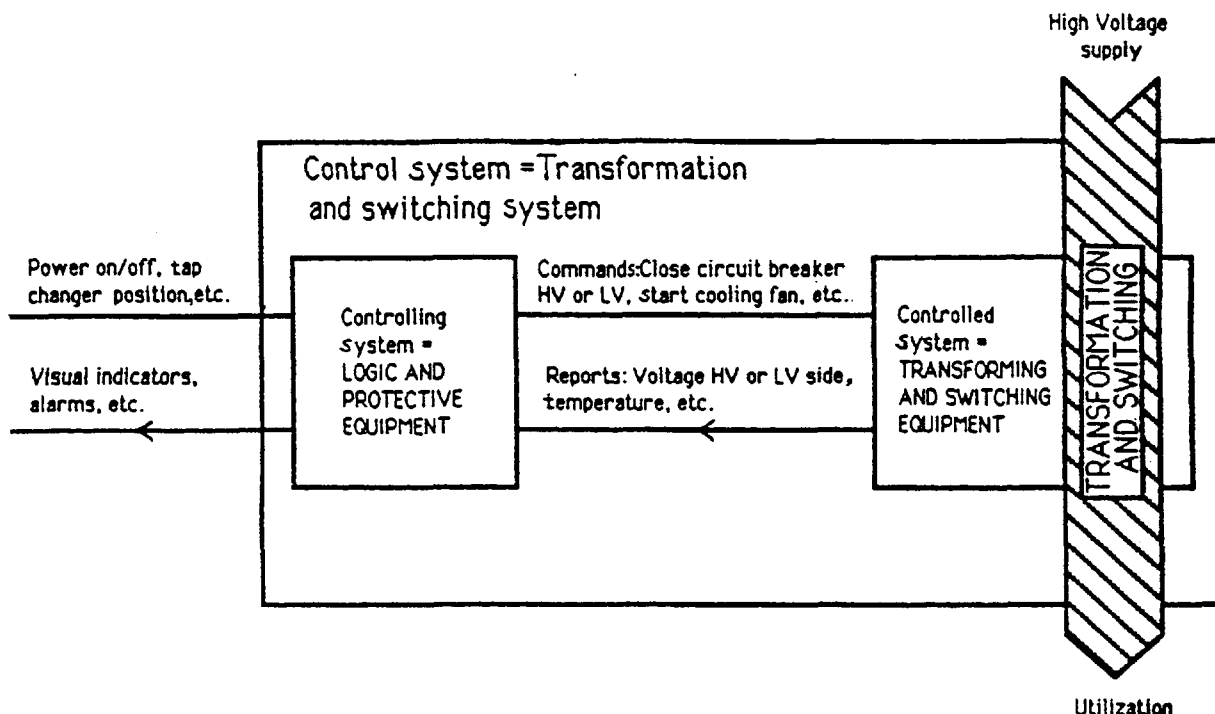


Figure 3 - Power distribution in sub-station

In example 2 the process is the transformation and distribution of electric energy.

If the sub-station is equipped with one transformer, the controlled system consists of the transformer, the circuit-breakers on the high and low voltage side, auxiliary equipment for cooling, etc. The controlling system consists of associated logic and protective equipment.

If the sub-station is equipped with two transformers working in parallel, each of these can be considered as a complete sub-ordinated control system (as described). In addition, a co-ordinating controlling system will be required, for example in load sharing.

3.2.4 Hierarchical representation levels

The technical specifications which have to be satisfied may be represented at several hierarchical levels, from a high descriptive level (macro-representation, see Figure 25 for an example) towards a complete detailed level at which all elementary commands and information are fully expressed in conformity with the technologies in use.

4 General description of the function chart

On the following pages the elements, rules and basic structures for function charts will be explained.

A function chart is defined by a set of symbols for:

- steps;
- transitions, and
- directed links, interconnecting steps and transitions.

If these symbols are combined in the prescribed way, a static representation is obtained. Due to the evolution rules, this representation also has a dynamic aspect, corresponding to the evolution of the control process.

Moreover, the static representation is interpreted meaning that:

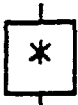
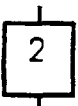
- with each step one or more commands or actions may be associated;
- with each transition a transition condition shall be associated.

The interpretation represents the functional aspect of the chart.

4.1 Steps

In order to describe the various steady situations of the control, controlling or controlled system the concept of a step is used.

A step characterizes an invariant behaviour of the system considered.

No.	Symbol	Description
1.1		Step, general symbol NOTE 1 - The length-width ratio of the rectangle is arbitrary, although a square is recommended. NOTE 2 - For identification, steps have to be labelled, for example, alphanumerical. The asterisk in the top centre of the general symbol has to be replaced by the label assigned to the step.
1.2		Example: Step 2

4.1.1 Active steps and inactive steps, initial steps

At a given instant a step may be either:

- active, or
- inactive.

The set of active steps defines the situation of the system considered.

The active or inactive state of a step may be represented respectively by the logic values "1" or "0" of a binary variable "X*", in which the asterisk (*) must be replaced by the relevant step label.

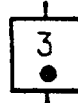
NOTE - This explains why a step symbol can be described logically by the symbol for a memory element.

When a step is active the associated commands are issued or actions are performed. During such a situation, the controlling system is only responding to signals related to the next relevant transition condition(s) or command enabling condition(s).

The steps which are active at the beginning of the control process correspond to the initial situation and are represented by initial steps, they characterize the initial behaviour of the controlling system.

No.	Symbol	Description
1.3		Initial step The notes to symbol 1.1 apply.
1.4		Example: Initial step 1

It is also possible to indicate which steps are active at a certain stage of the control process by marking these steps with a dot. This dot does not belong to the step symbol and is only used for explanatory purposes.

No.	Symbol	Description
1.5		Example: Step 3, depicted in its active state

4.1.2 Commands (actions) associated with steps

In control systems commands usually result in actions and actions may lead to steady state situations.

An active step can:

- issue one or more commands, if the function chart describes a controlling system, or
- cause one or more actions, if the function chart describes a control or a controlled system as explained in 3.2.

When in the following clauses the term command is used, it may be replaced by action when appropriate.

A command is specified by a written or a symbolic statement inside a rectangle connected to the step symbol with which it is associated.

When the written or symbolic statement is defined in the right way, it is possible to differentiate between a command (for example CLOSE VALVE 2) and an action (for example CLOSURE OF VALVE 2). Further it is possible to indicate a steady state situation (for example VALVE 2 OPEN). This is neither a command nor an action but a status indication.

It will be clear from the preceding paragraph that statements have to be formulated in a careful way to avoid misunderstanding. If however confusion about the nature of the statements could occur, an explanatory note should be put on the chart.

A command is issued when the step with which it is associated is active. When the step is deactivated, the command will:

- a) terminate, or
- b) maintain its state.

In case a), the command is not stored. In case b) the command is stored. A stored command only terminates if it is explicitly reset by a subsequent step.

Thus the statement specifying a command should also make clear whether the command is stored or not.

4.1.3 Examples

In a function chart describing a controlling system the following commands may be found.

a) PUT VALVE 2 IN SEMI-OPEN POSITION

During the time that the corresponding step is active, the command PUT VALVE 2 IN SEMI-OPEN POSITION is maintained.

When the corresponding step is deactivated, the command will terminate and the status of Valve 2 resulting from the de-activation of the step, e.g. the status VALVE 2 CLOSED, has to be presented in the relevant next step.

When instead of PUT VALVE 2 IN SEMI-OPEN POSITION a command with a clearly defined counterpart e.g. OPEN VALVE 2 (counterpart: CLOSE VALVE 2) is given and the status of Valve 2 resulting from the de-activation of the corresponding step is not indicated in the next relevant step, it may be assumed that the status of Valve 2 in the next relevant step is related to the counterpart of the command, so in this case the status will be: VALVE 2 CLOSED.

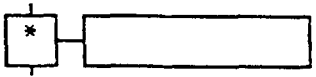
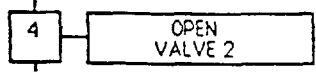
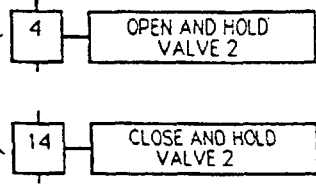
See symbol 2.2. The commands described are of the not stored type.

b) OPEN AND HOLD VALVE 2

During the time that the corresponding step is active the command OPEN VALVE 2 is issued. This command is maintained till a countermanding command is encountered. The command described is stored until then and is of the stored type. A status indication VALVE 2 OPEN may be associated with steps situated between the steps issuing the commands OPEN AND HOLD VALVE 2 and CLOSE AND HOLD VALVE 2, to emphasize the fact that valve 2 is open.

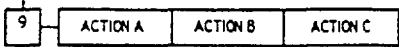
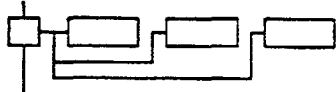
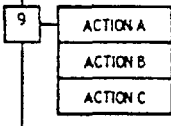
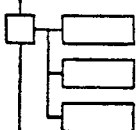
In general a verification of the status is necessary before a status indication is given. This can be achieved, for example, by incorporating a status check back signal in the transition condition preceding the step with the status indication. For the indication of check back signals, see clause 5.

Commands of the type mentioned in 4.1.3 are called common commands. They indicate which commands are issued during the respective steps of the control process, but give no information concerning the internal timing of the commands during the steps. The duration of each step is determined however by the clearing of the transitions between which the step is situated.

No.	Symbol	Description
2.1		Common command (action), general symbol, associated with a step NOTE - The written or symbolic statement inside the rectangle specifies the command issued by the controlling system or the action executed by the controlled system, when the corresponding step is active.
2.2		Examples: The command to open valve 2 is given when step 4 is active. The valve closes when step 4 is no longer active. Not stored command.
2.3		The command to open valve 2 is given when step 4 is active. The valve will be held open when step 4 is no longer active. An explicit command has to be specified in a subsequent step to close valve 2 (Ex.: step 14). Stored command.

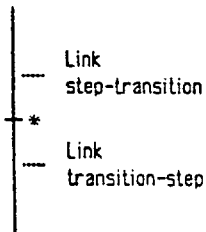
In this respect common commands and common transition conditions allow a general description of the relative timing of the control process. Detailed commands and detailed transition conditions, treated in clause 5, allow a more precise description of the timing.

If several commands (actions) are associated with the same step, the functional representation of these commands (actions) can be realized in the following ways:

No.	Symbol	Description
2.4		Three actions A, B and C associated with step 9, horizontal arrangement NOTE 1 - This symbol may be regarded as a simplification of:  NOTE 2 - The symbol does not imply any sequence between the actions.
2.5		Three actions A, B and C associated with step 9, vertical arrangement NOTE 1 - This symbol may be regarded as a simplification of:  NOTE 2 - The symbol does not imply any sequence between the actions.

4.2 Transitions

In order to describe a possible evolution of the active state from one step to another, routed by a directed link, the concept of a transition is used. A transition is symbolically represented by a dash which is shown in the directed link between the involved step symbols.

No.	Symbol	Description
3.1		TRANSITION symbol with DIRECTED LINKS and its associated TRANSITION CONDITION NOTE - The asterisk shall be replaced by a description of the associated transition condition, e.g. by a text, a Boolean expression or by graphical symbols.

4.2.1 Enabled transitions and clearing of transitions

A transition is enabled if all the immediately preceding steps, connected to its corresponding transition symbol by directed links are active.

Clearing of a transition occurs if it is enabled and its associated transition condition is true.

The clearing of a transition simultaneously leads to the activation of all the immediately following steps, connected to its corresponding transition symbol by directed links and the deactivation of the immediately preceding steps, connected to its corresponding transition symbol by directed links.

Figures 4 and 5 illustrate these concepts.

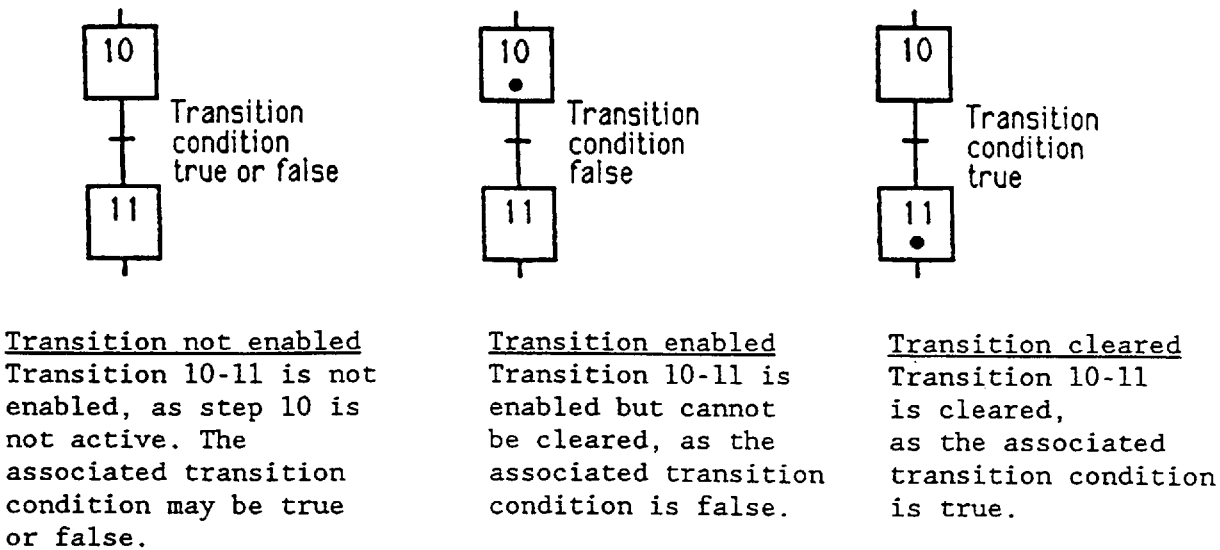
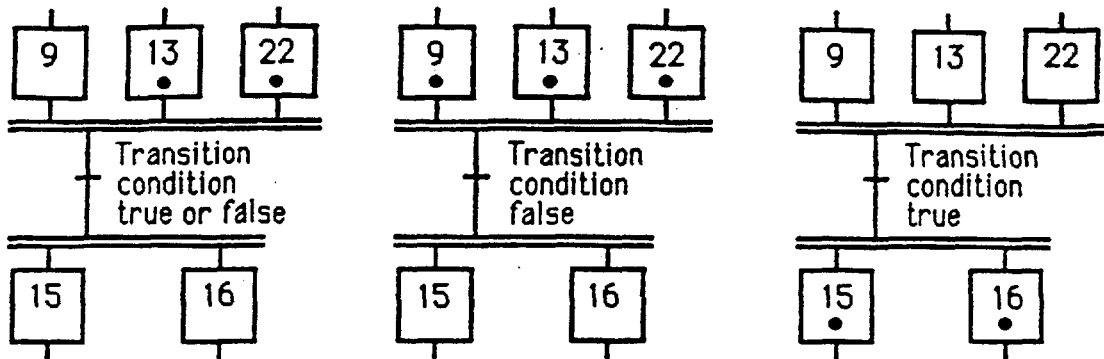


Figure 4 - Not enabled, enabled and cleared transition resulting from a single preceding step

12

Transition not enabled

The transition is not enabled, as step 9 is not active. The associated transition condition may be true or false.

Transition enabled

The transition is enabled but cannot be cleared, as the associated transition condition is false.

Transition cleared

The transition is cleared now, as the associated transition condition is true.

Figure 5 - Not enabled, enabled and cleared transition resulting from a number of preceding steps

To indicate the synchronizing property of the transition in this case, symbol No. 9.2.2.5 of ISO 5807 shall be used as shown in Figure 5.

4.2.2 Transition conditions

A logic proposition, called a transition condition, which can either be true or false, is associated with each transition.

If there exists a corresponding logic variable, it will be equal to 1 when the transition condition is true and equal to 0 when the transition condition is false.

Transition conditions may be represented by:

- textual statements;
- Boolean expressions;
- graphical symbols, etc.,

as shown in the following examples.