

Industrial Automation

(Automação de Processos Industriais)

<http://users.isr.ist.utl.pt/~jag/courses/api1112/api1112.html>

Slides 2010/2011 Prof. Paulo Jorge Oliveira

Rev. 2011/2012 Prof. José Gaspar



A steam engine built to James Watt's patent in 1848 at Freiberg in Germany [wikipedia]

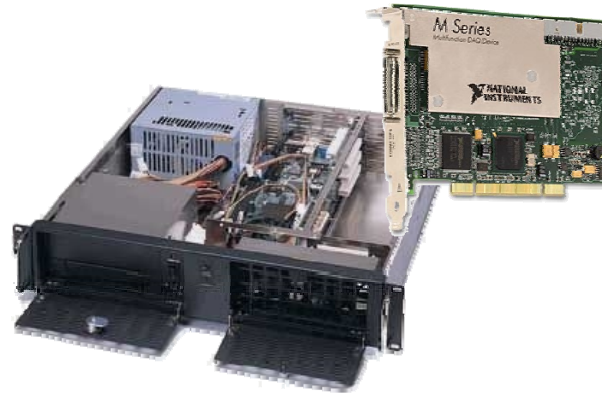
Microcontrollers



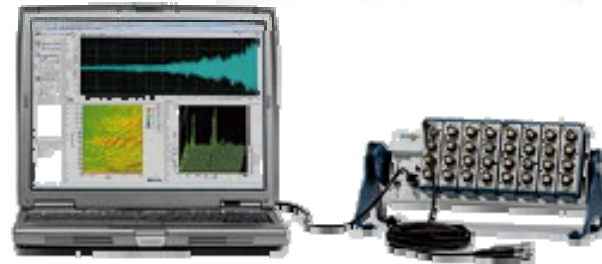
Arduino



Computer + IO



*National
Instruments
AD/DA*



PLC

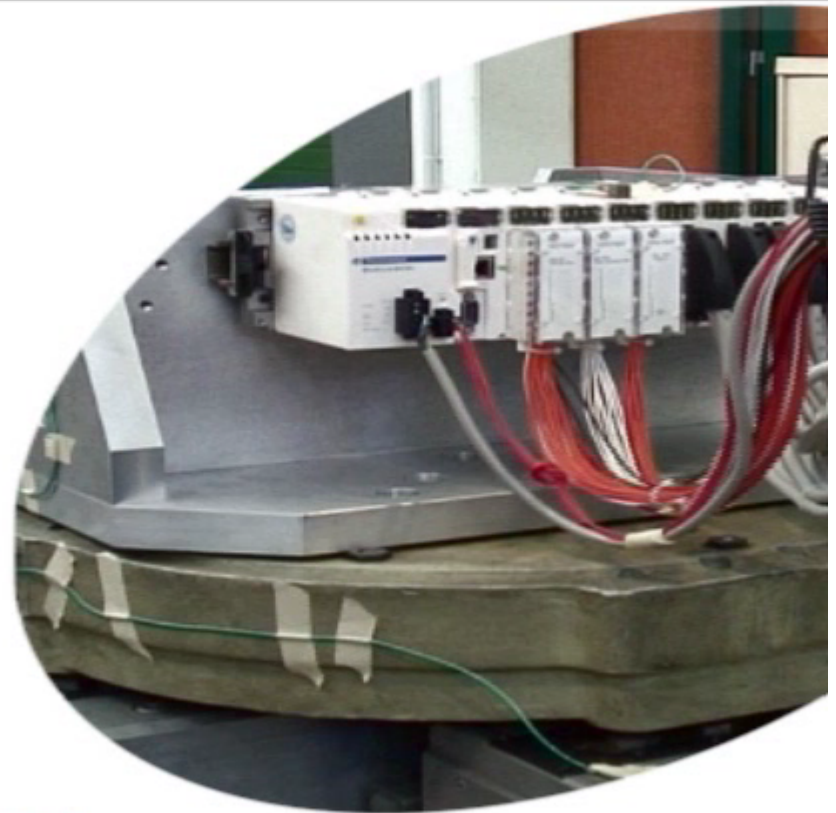


Premium P57



Many options for controlling real world devices! Why PLCs?

Robustness is not an Option



Objectives:

- *Analysis* of systems for industrial automation.
- Methodologies for the *implementation* of solutions in industrial automation.
- Programming *languages* of PLCs (*Programmable Logic Controllers*).
- CAD/CAM and Computerized Numerical Controlled machines.
- *Discrete Event Systems* Modeling.
- *Supervision* of Processes in Industrial Automation.

Program at a glance:

1. Introduction to Automation [1 week]

Introduction to components and methodologies.

2. Introduction to PLCs [2 weeks]

Components of Programmable Logic Controllers (PLCs). Architecture, functional structure, IO.

3. PLCs Programming Languages [2w]

Standard languages (IEC-1131-3): *Ladder Diagram*; *Instruction List* and *Structured Text*.

4. GRAFCET (*Sequential Function Chart*) [1 week]

Norm, elements of the language, modelling.

5. CAD/CAM and CNC Machines [1 week]

Types of Computerized Numerical Controlled machines. Interpolation of trajectories. Flexible fabrication cells.

6. Discrete Event Systems [1 week]

Modeling of discrete event systems (DESs). Automata. Petri networks. State and dynamics of PNs.

7. Analysis of DESs [2 weeks]

Properties of DESs. Methodologies for the analysis: reachability graph and matricial equation.

8. DESs and Industrial Automation [1week]

Relations GRAFCET / Petri networks. Analysis of industrial automation solutions as DESs.

9. Supervision of Industrial Processes [2w]

Methodologies for supervision. SCADA. Synthesis based on invariants. Examples of application.

Assessment and grading:

- *2 Preliminary laboratory assignments - training purposes (0% of the final grade).*
- *2 Laboratory assignments (20%+20% of the final grade). Groups of 3 students.*
- *1 Seminar (20% of the final grade). Topics to be selected with each group.*
- *Exams (40% of the final grade). Two written.*

Upon student choice, the second exam can be oral.

- *Minimum grade: 9.0/20.0 val. in each component.*

Extra 1 (one) valor for students attending more than 50% of recitations.

Schedule (laboratories & exam):

Lab. registration	First week	Fenix 14/09/2011
1 st preliminary lab.	1 week	26-30/09/2011
2 nd preliminary lab.	1 week	03-07/10/2011
1 st lab. assignment	4 weeks	10/10-04/11/2011
2 nd lab. assignment	4 weeks	07/11-02/12/2011
3 rd lab. assignment	0.5h seminar	One date \geq week 9
Exams	3h	9Jan, 30Jan 2012

Important: define the students' representative

Schedule (according to IST-GOP):

- Recitation classes

Monday 11.00 h – 12.30h **Ea5**

Friday 11.00 h – 12.30h **Ea4**

- Lab. Classes (once per week)

Monday 09.30h – 11.00h L1 **LSDC4 (room 5.21)**

Friday 09.30h – 11.00h L2 **LSDC4 (room 5.21)**

- Groups registration for the Laboratory

Bibliography:

- [Automating Manufacturing Systems with PLCs, Hugh Jack \(online version available\)](#).
 - Peterson, James L., "Petri Net Theory and the Modeling of Systems", Prentice-Hall, 1981.
 - Modeling and Control of Discrete-event Dynamic Systems with Petri Nets and other Tools, Branislav Hruz and MengChu Zhou, 2007. New reference...
- secondary---
- Programmable Logic Controllers, Frank D. Petruzella, McGraw-Hill, 1996.
 - Petri Nets and GRAFCET: Tools for Modeling Discrete Event Systems, R. DAVID, H. ALLA, New York : PRENTICE HALL Editions, 1992.
 - Computer Control of Manufacturing Systems, Yoram Koren, McGraw Hill, 1986.
 - Cassandras, Christos G., "Discrete Event Systems - Modeling and Performance Analysis", Aksen Associates, 1993.
 - Moody, J. e Antsaklis, Supervisory Control of Discrete Event Systems, Kluwer Academic Publishers, 1998.

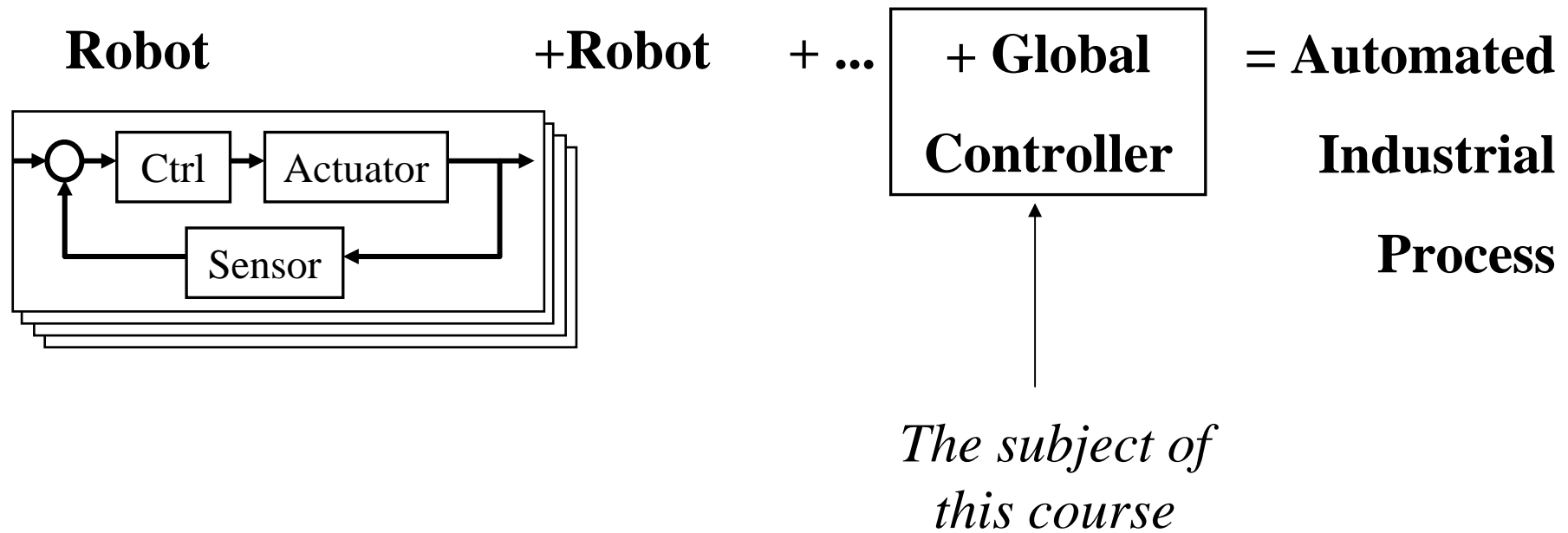
Industrial Automation

(Automação de Processos Industriais)

Introduction to Automation

<http://www.isr.ist.utl.pt/~jag/aulas/api1112/api1112.html>

Slides 2010/2011, Prof. Paulo Jorge Oliveira
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Cap. 1 – Introduction to Automation [1 week]

Introduction to components in industrial automation.

Cabled logic versus programmed logic versus networked logic.

Introduction to methodologies for problem modeling.
Methodologies of work.

Components used in industrial automation

The production of increasing amounts of goods requires the storage and handling of large quantities of resources.

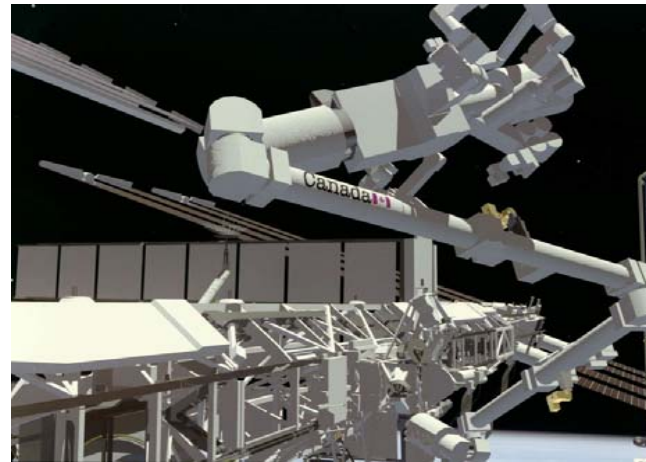
The use of **specialized, automatic tools are mandatory**.

Consistent trend in the last three centuries (since the Industrial Revolution).

Automation was also fostered by the invention of computers,



Robotic Manipulators

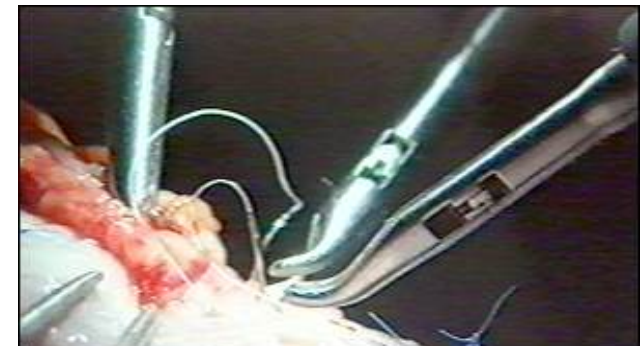
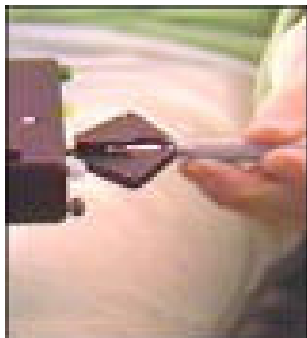
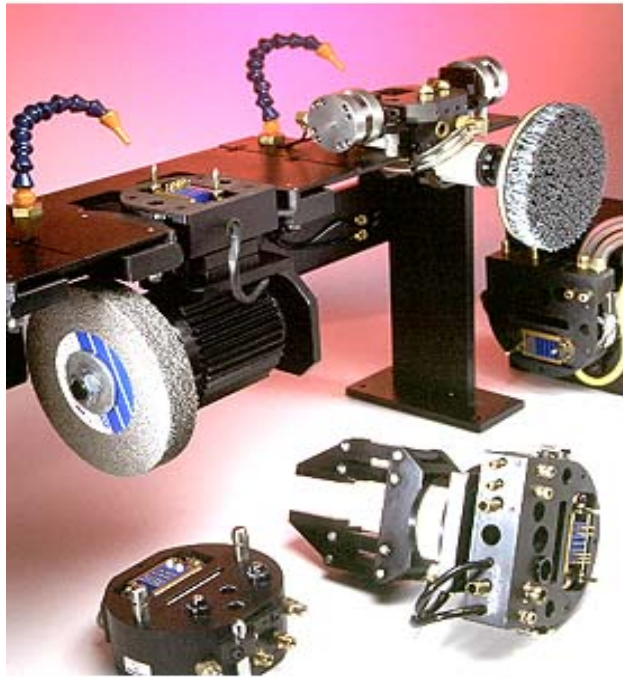




Riding an ABB IRB 6600 Robot 1 [Youtube]

API Note: please understand the power, and do not do this; keep always the safety!

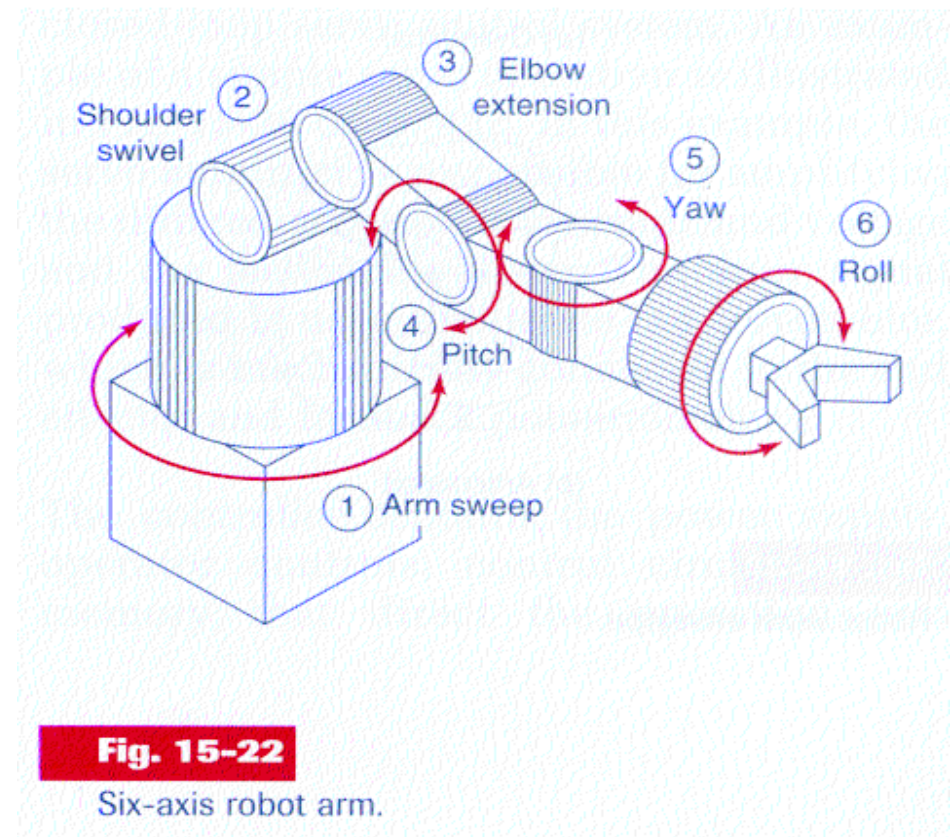
End Effectors



Robotic Manipulators

Major characteristics:

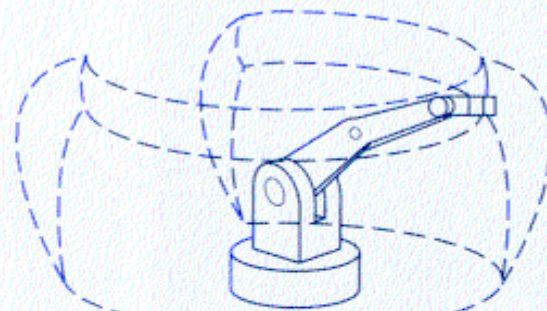
- Number of degrees of freedom
- Types of joints (prismatic/revolution/...)
- Programming tools and environments (high level languages, teach pendent, ...)
- Workspace
- Accuracy, fiability
- Payload and robustness



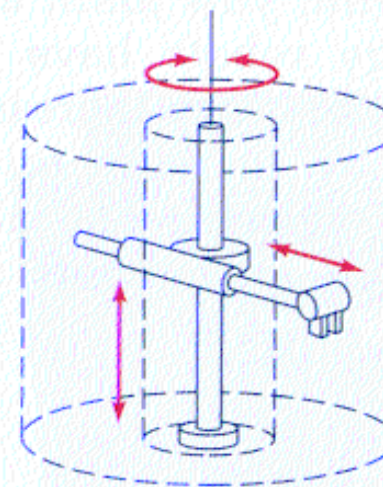
Robotic Manipulators

Workspace:

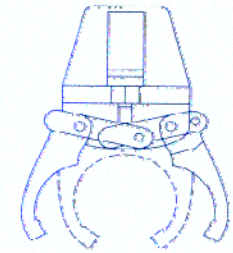
Examples



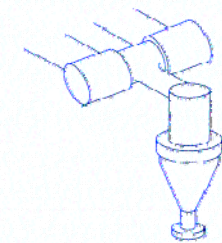
(b) Articulated



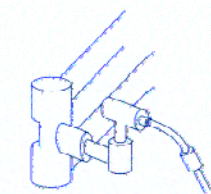
(a) Cylindrical



(a) Gripper



(b) Grinder



(c) Gas welding torch

Fig. 15-23

Robot work envelope.

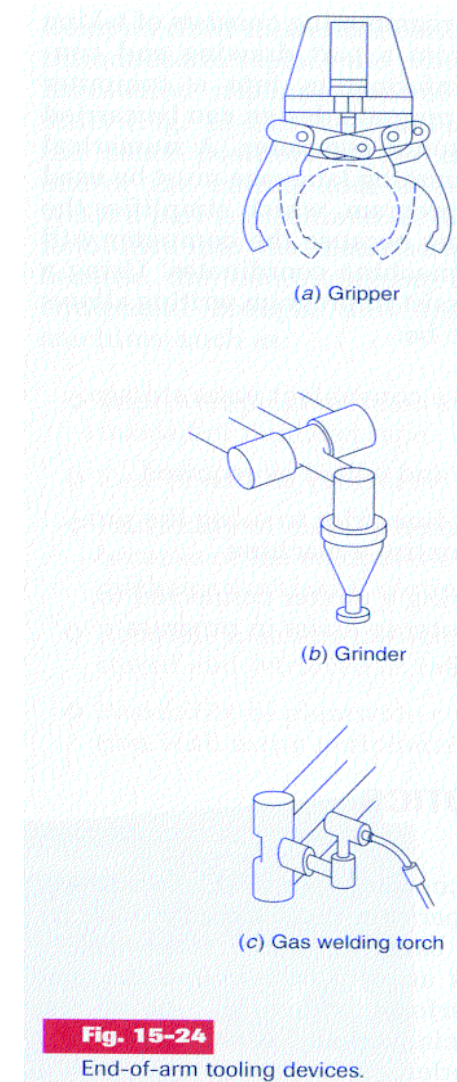
Fig. 15-24

End-of-arm tooling devices.

Robotic Manipulators

Central problems to address and solve:

- Direct / Inverse kinematics
- Trajectory generation
- Coordinate frames where tasks are specified
- Level of abstraction of the programming languages

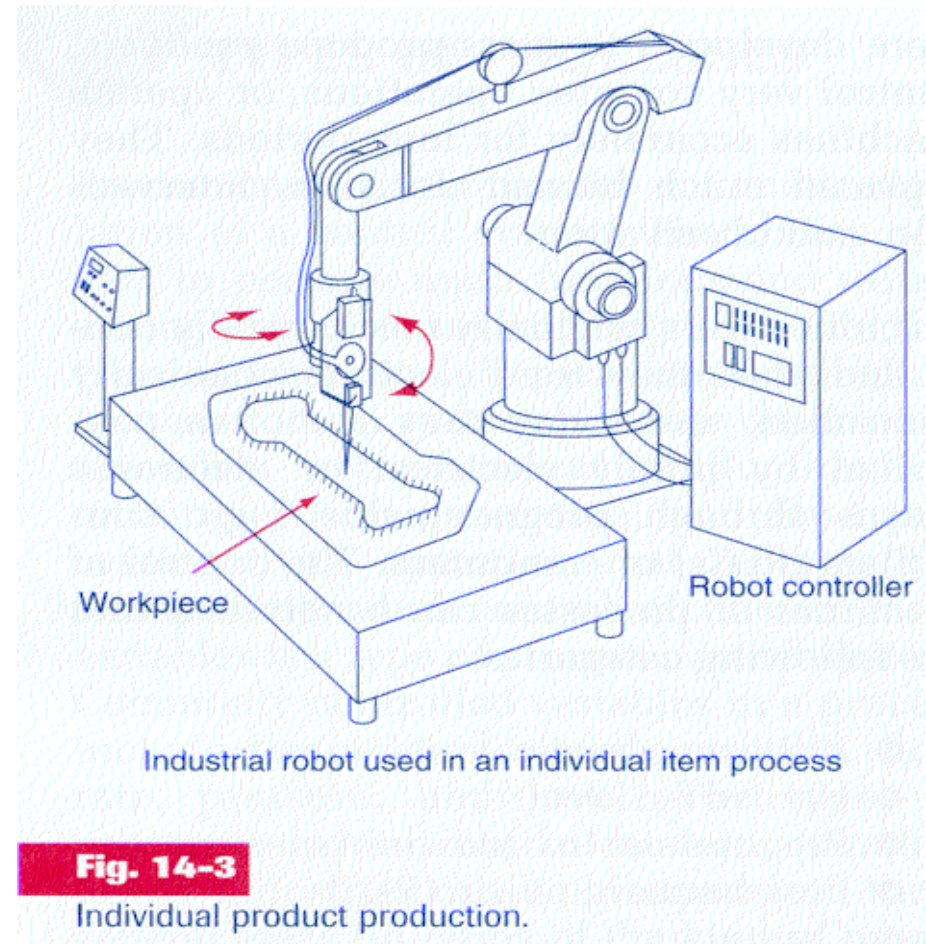


Robotic Manipulators

Use in Flexible

Cells of Fabrication:

it is required that the manipulators have correct interfaces for the synchronization and inputs for external commands.



Computerized Numerical Controlled Machines

Major characteristics:

- Number of degrees of freedom
- Interpolation methods
- Load/unload automation, and also in tool change
- Programming (high level languages, teach pendent, ...)
- Workspace
- Accuracy, reliability
- Payload and robustness
- Interface
- Synchronization with exterior

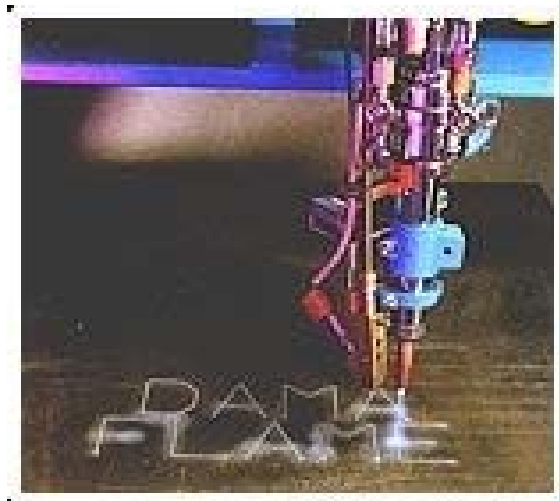
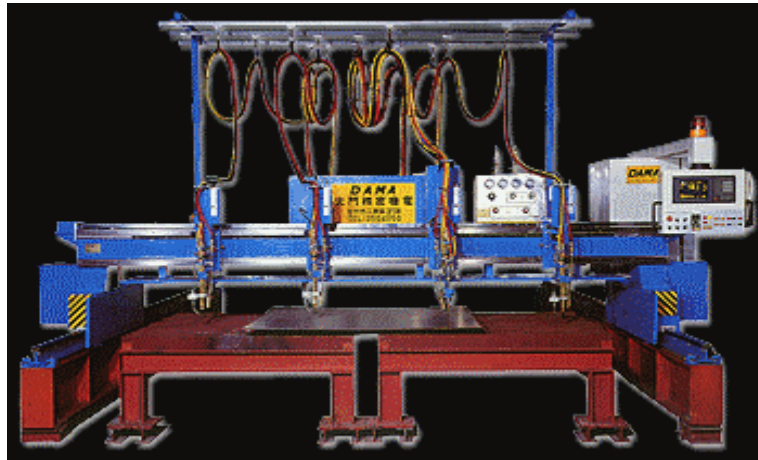
Examples:

Milling, Lathes, ...



MITSUI SEIKI Machining Center

Computerized Numerical Controlled Machines



Compact CNC plasma cutting machine
Effective cutting : 1.5 m X 3 m
Plasma torch cutting capacity up to 5cm (mild steel), Gas torch as option up to 10cm.

Solutions for Handling materials

For transport...

Major characteristics:

- Load/unload automation
- Accuracy, reliability
- Payload and robustness
- Interface
- Synchronization with exterior



AGVs (Automatic Guided Vehicles)

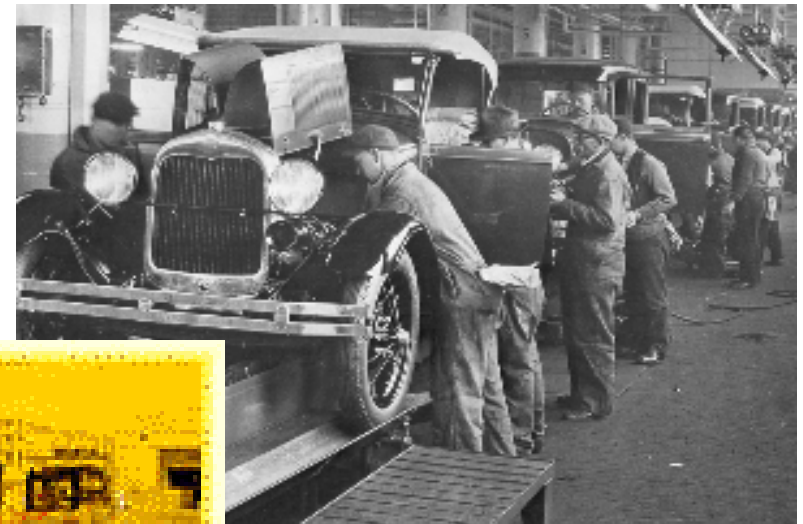
Major characteristics:

- Load/unload automation
- Accuracy, reliability
- Payload and robustness
- Interface
- Synchronization with exterior



AGVs (Automatic Guided Vehicles)

Example of fleet operating in industry



Actuation

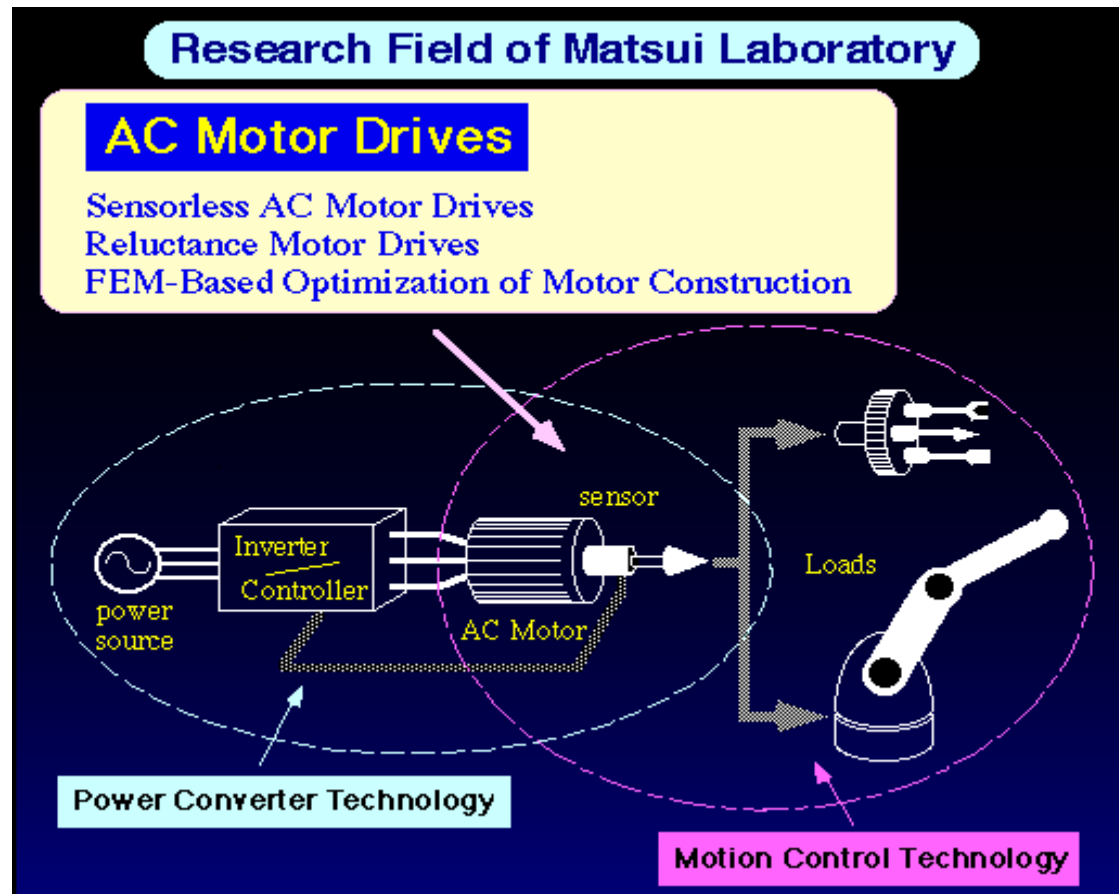
Motors

Major characteristics:

- Type of start
- Type of control
- Accuracy, reliability
- Payload and robustness
- Interface with exterior
- Synchronization



Exemple of AC motor, with driver



Specific Components

Factory example: production of aluminium packs



Cabled Logic versus ...

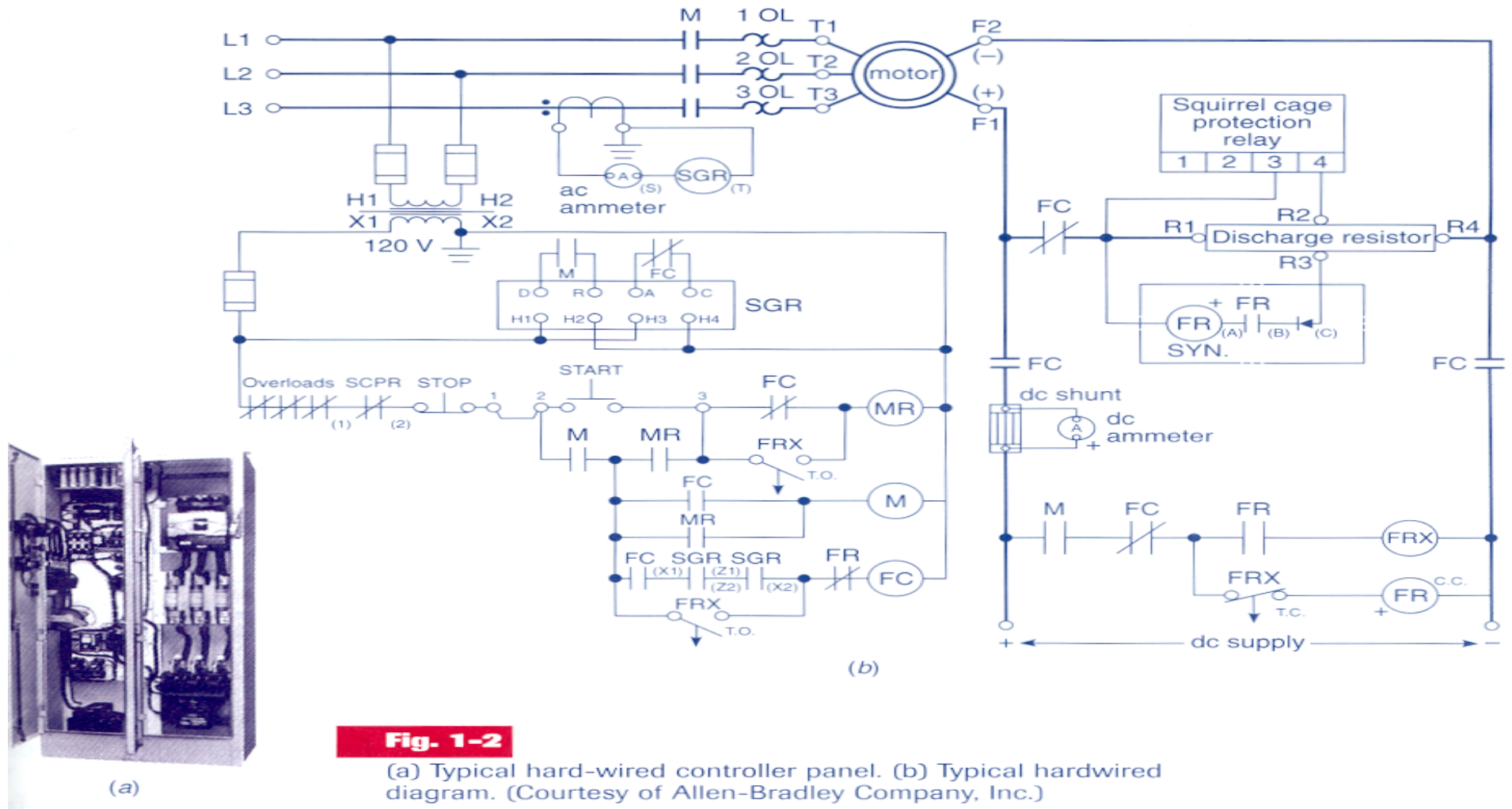
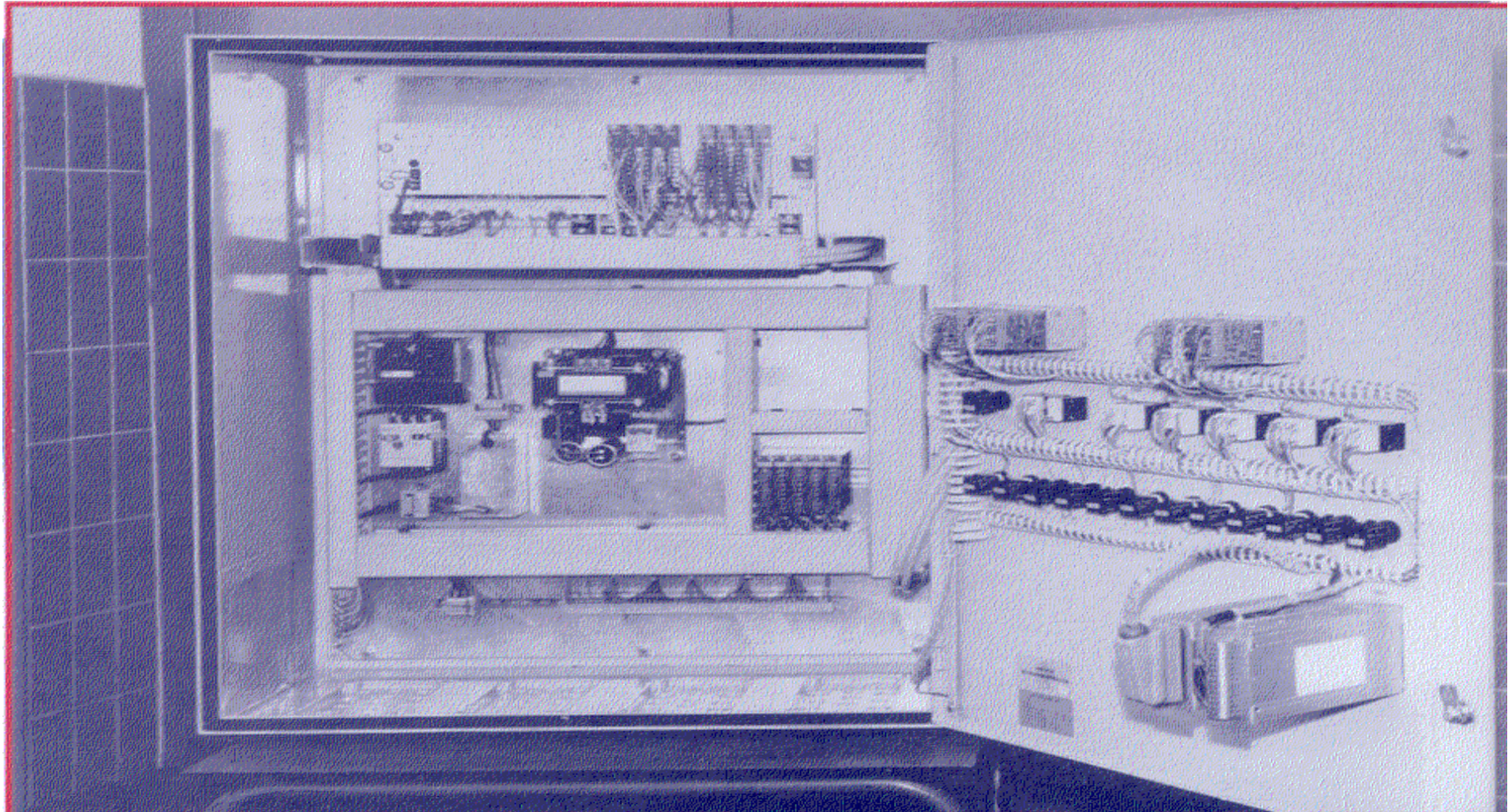


Fig. 1-2

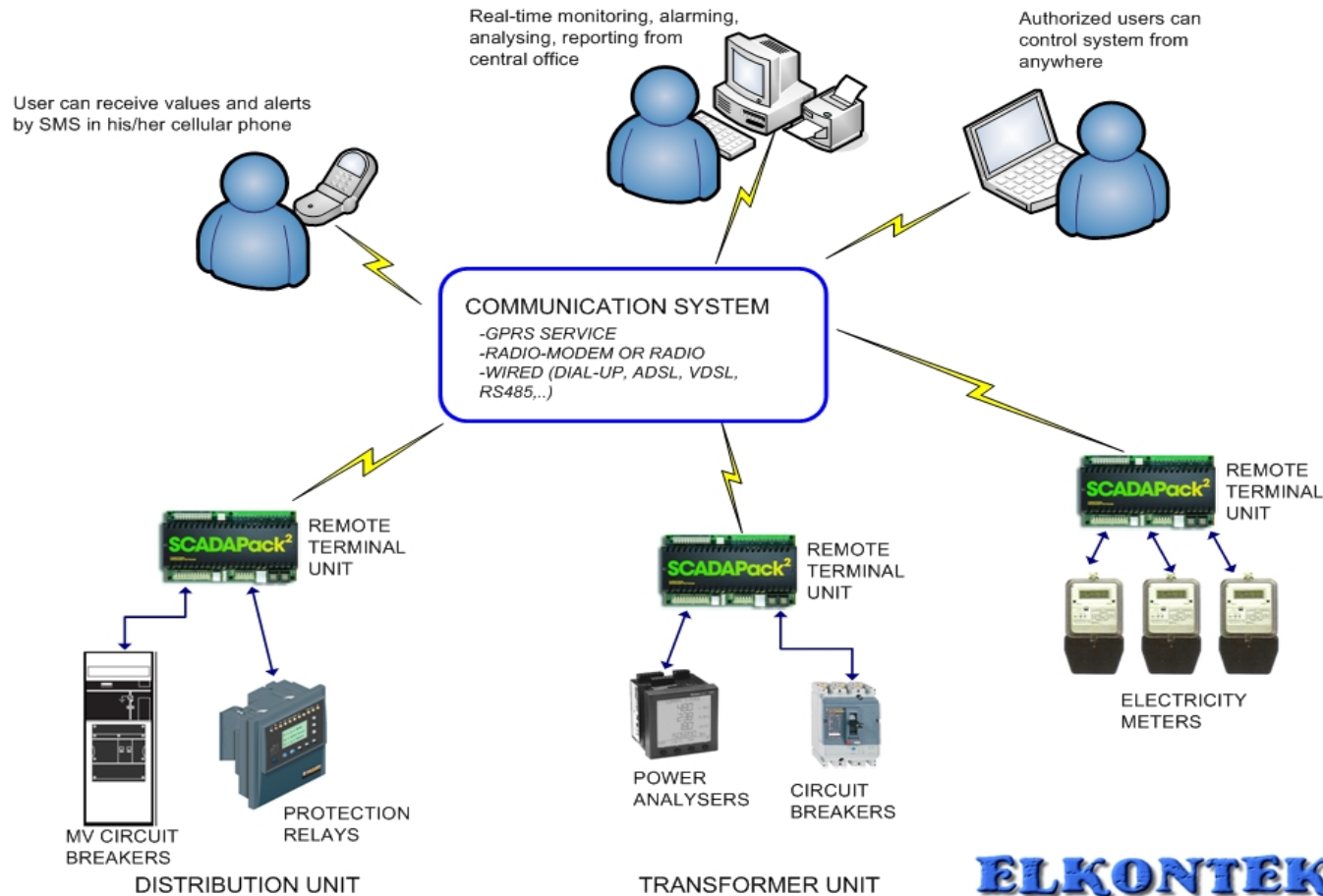
(a) Typical hard-wired controller panel. (b) Typical hardwired diagram. (Courtesy of Allen-Bradley Company, Inc.)

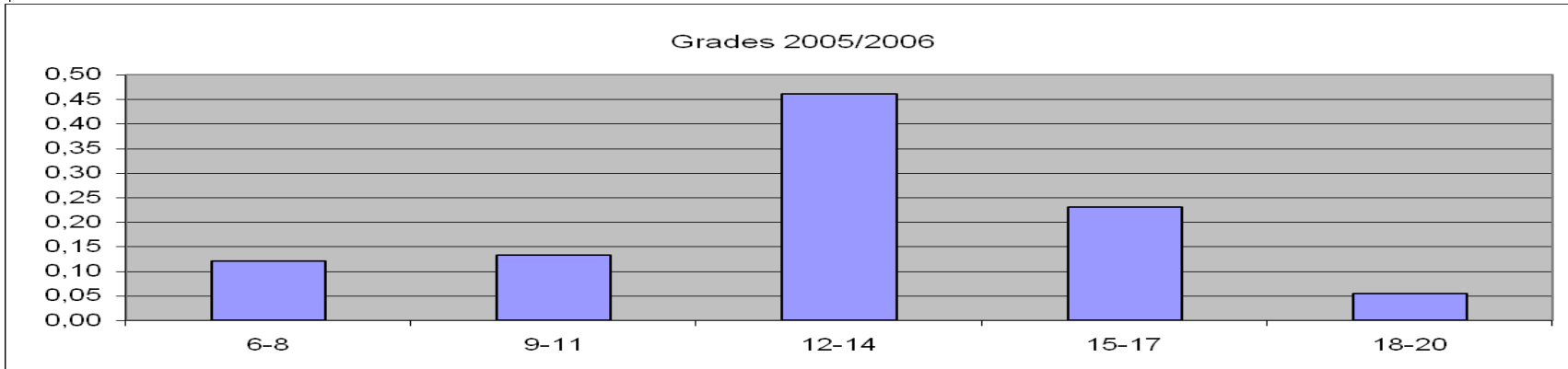
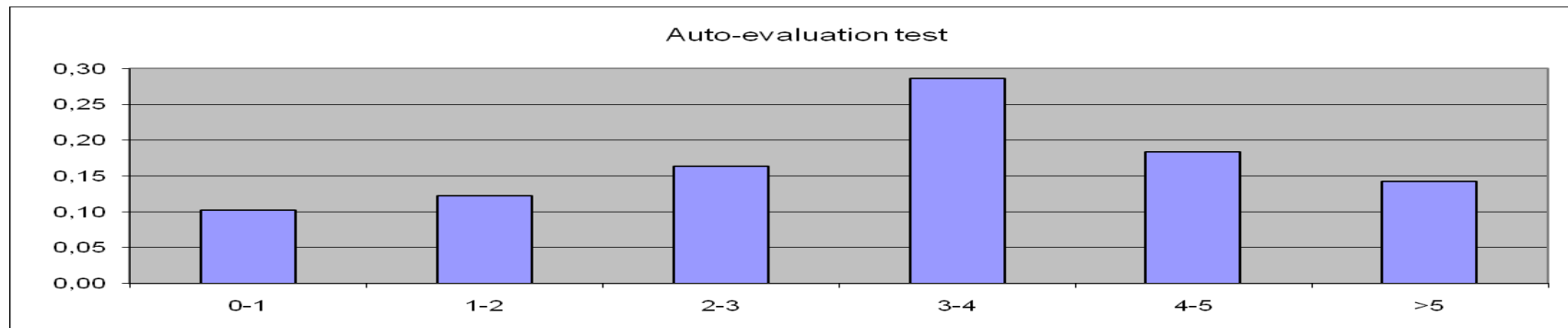
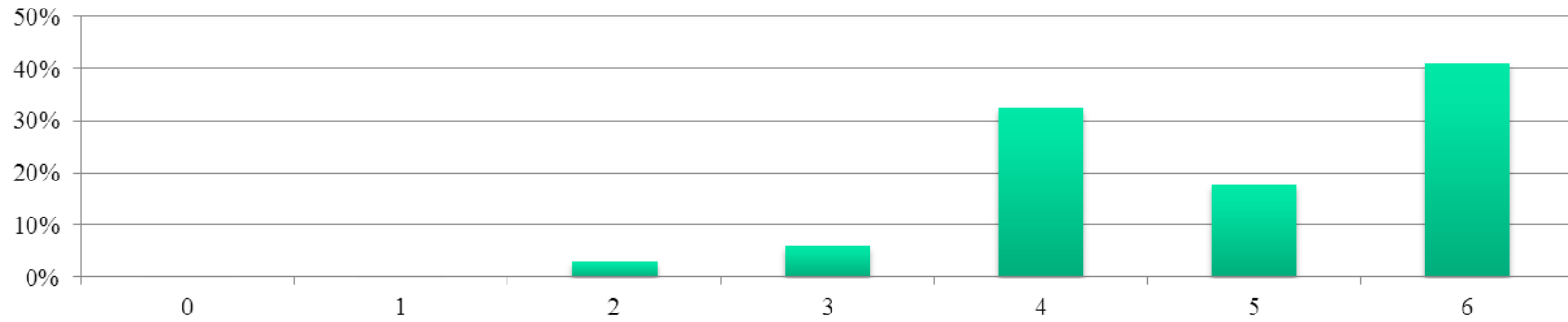
... versus Programmed Logic ...



... versus Networked Logic

MIDDLE AND LOW VOLTAGE
ELECTRICITY DISTRIBUTION NETWORKS
MONITORING VE CONTROL SYSTEM





**Introduction to methodologies
for problem modeling in
Industrial Automation**

Actuators

Solenoid valve

Command relay

Pneumatic cylinder

Electro pneumatic

Sensors

Pressure switch

Temperature sensors

Proximity sensors

Relay diagram / Ladder diagram

Refs: Programmable Logic Controllers, Frank D. Petruzella, McGraw-Hill, 1996.

Solenoid Valve

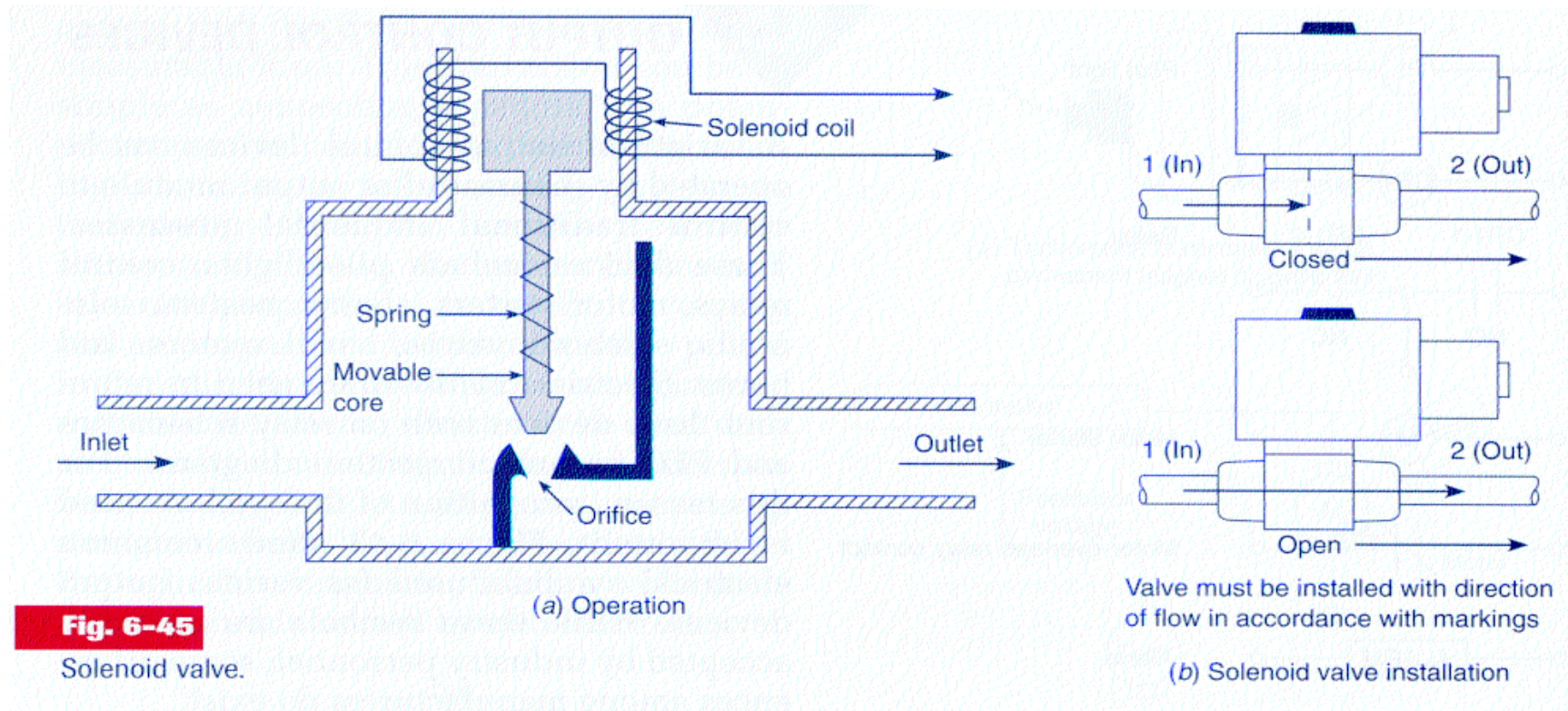


Fig. 6-45
Solenoid valve.

Command Relay

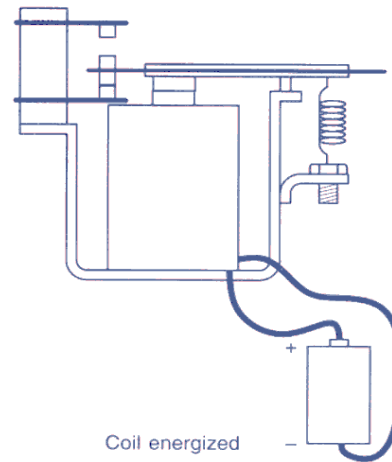
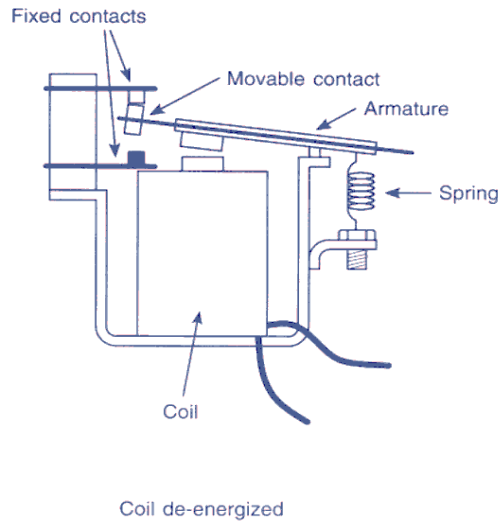


Fig. 6-1
Electromagnetic control relay operation.

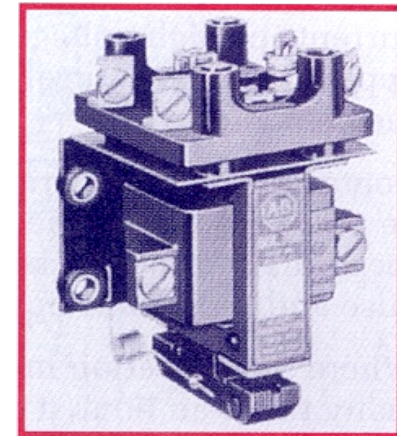
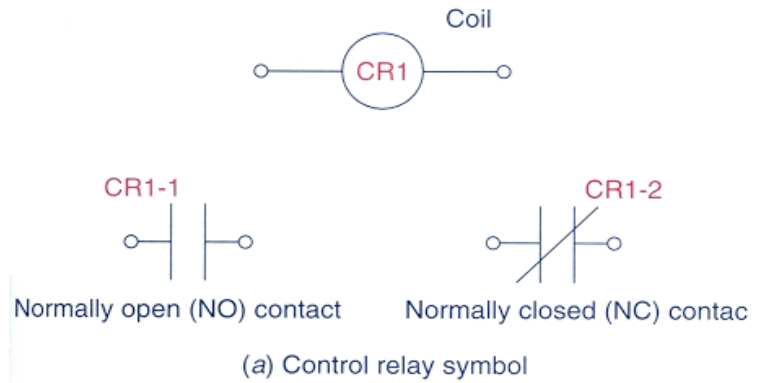
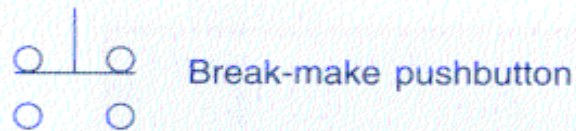
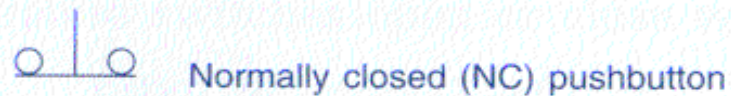
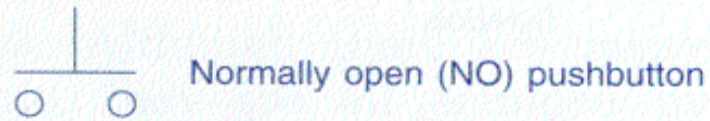


Fig. 6-2
Control relay.

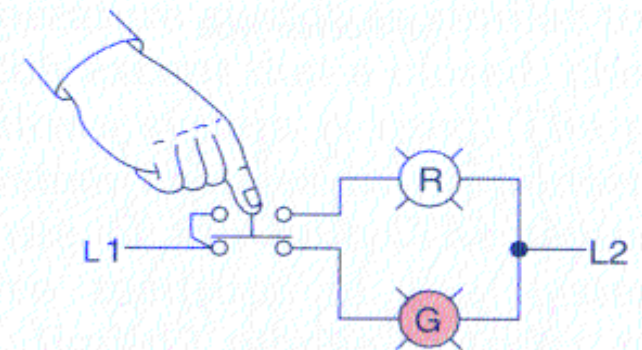
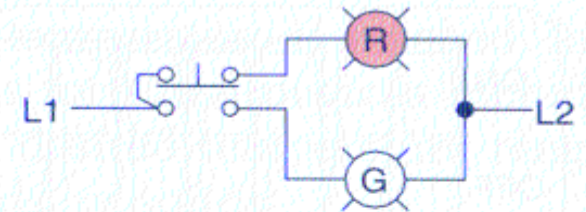
(b) Typical industrial control relay. (Courtesy of Allen-Bradley Company, Inc.)

Push buttons



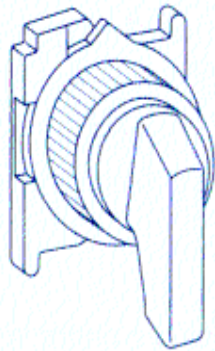
Note: The abbreviations NO and NC represent the electrical state of the switch contacts when the switch is not actuated.

(a) Pushbutton switches

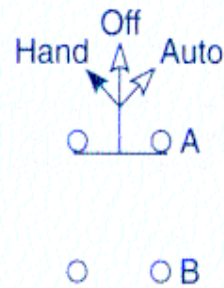


(b) Control circuit using a combination break-make pushbutton

Selector with three positions

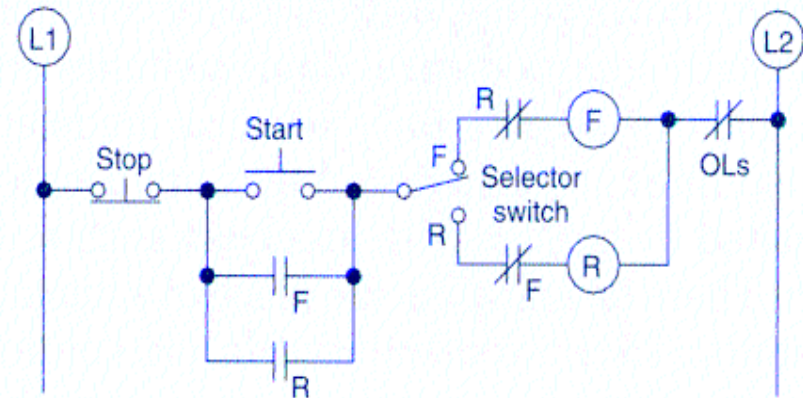


(a) Selector switch operator



Position	Contacts	
	A	B
Hand	X	
Off		
Auto		X

(b) Three-position selector switch and truth table

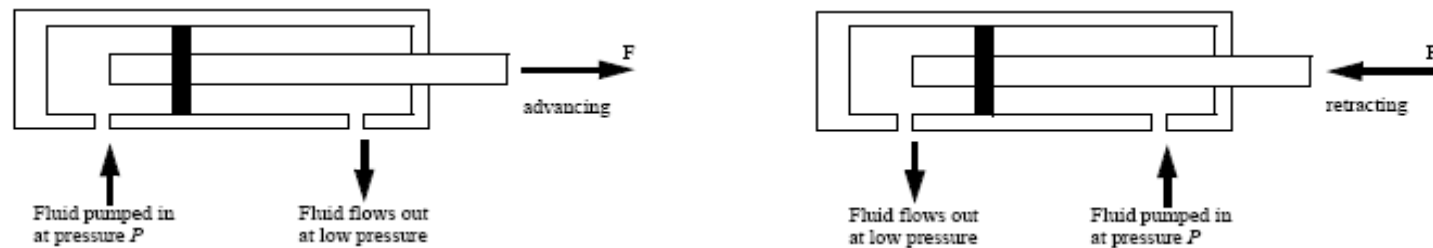


(c) Selector switch used in conjunction with a reversing motor starter to select forward or reverse operation of the motor

Fig. 6-11

Selector switch.

Cylinders (Pneumatics)



For Force:

$$P = \frac{F}{A} \quad F = P \cdot A$$

where,

P = the pressure of the hydraulic fluid

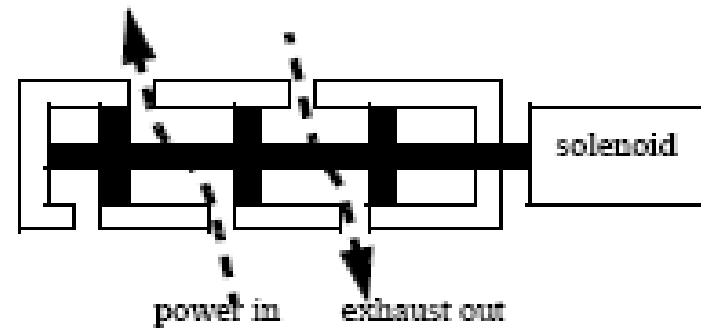
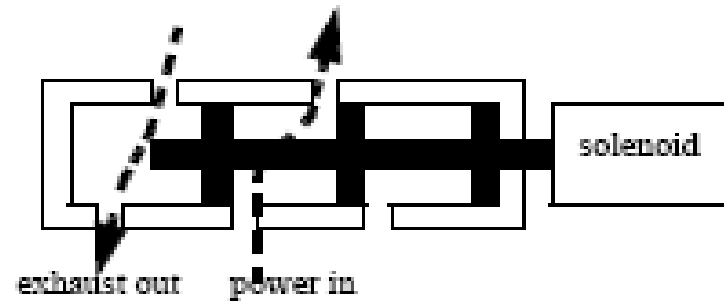
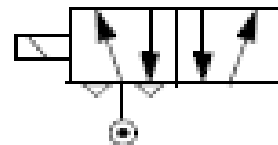
A = the area of the piston

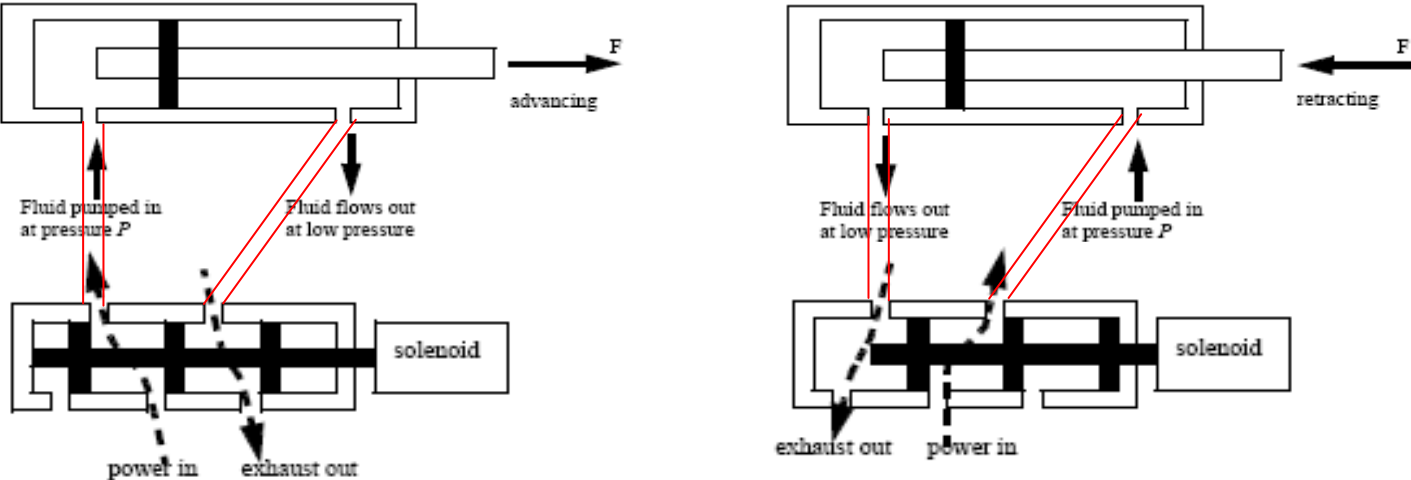
F = the force available from the piston rod

Valves (Electro-pneumatics)



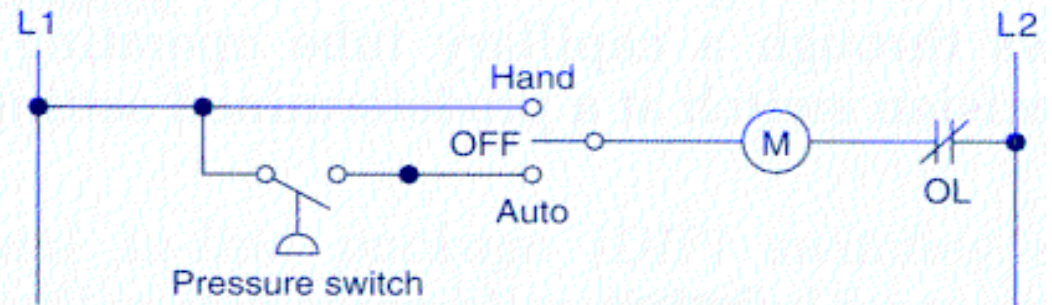
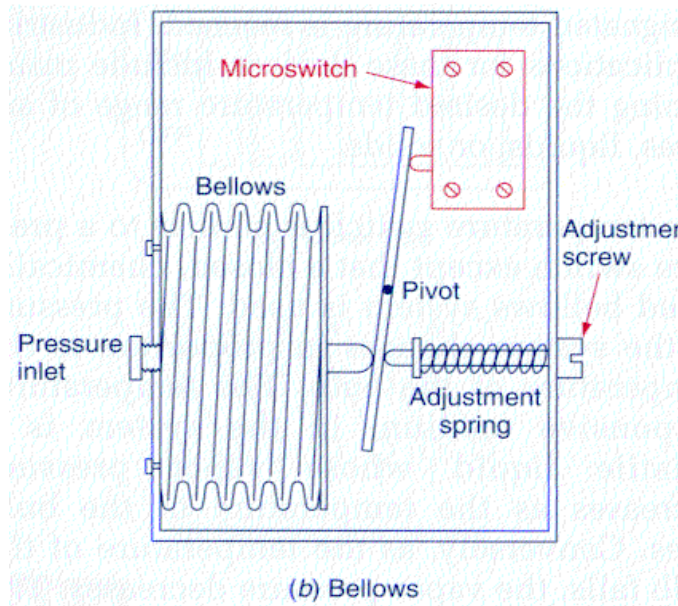
The solenoid has two positions and when actuated will change the direction that fluid flows to the device. The symbols shown here are commonly used to represent this type of valve.





Sensors

Pressure Switch



(c) Starter operated by pressure switch

Fig. 6-15 (continued)

Pressure switch.

Temperature Sensors





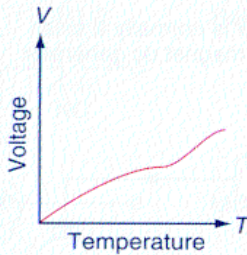
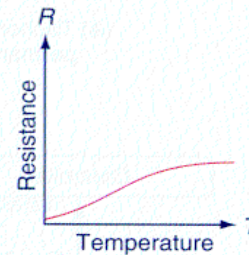
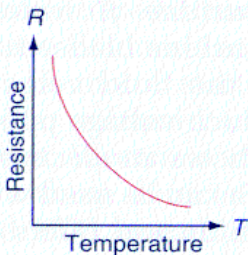
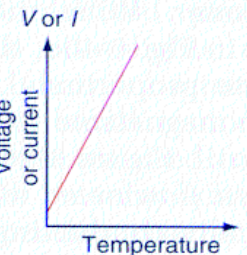
	Thermocouple	RTD	Thermistor	IC Sensor
				
				
Advantages	<ul style="list-style-type: none"> • Self-powered • Simple • Rugged • Inexpensive • Wide variety • Wide temperature range 	<ul style="list-style-type: none"> • Most stable • Most accurate • More linear than thermocouple 	<ul style="list-style-type: none"> • High output • Fast • Two-wire ohms measurement 	<ul style="list-style-type: none"> • Most linear • Highest output • Inexpensive
Disadvantages	<ul style="list-style-type: none"> • Nonlinear • Low voltage • Reference required • Least stable • Least sensitive 	<ul style="list-style-type: none"> • Expensive • Power supply required • Small ΔR • Low absolute resistance • Self-heating 	<ul style="list-style-type: none"> • Nonlinear • Limited temperature range • Fragile • Power supply required • Self-heating 	<ul style="list-style-type: none"> • $T < 200^{\circ}\text{C}$ • Power supply required • Slow • Self-heating • Limited configurations

Fig. 6-38

Common temperature sensors.

Thermocouple

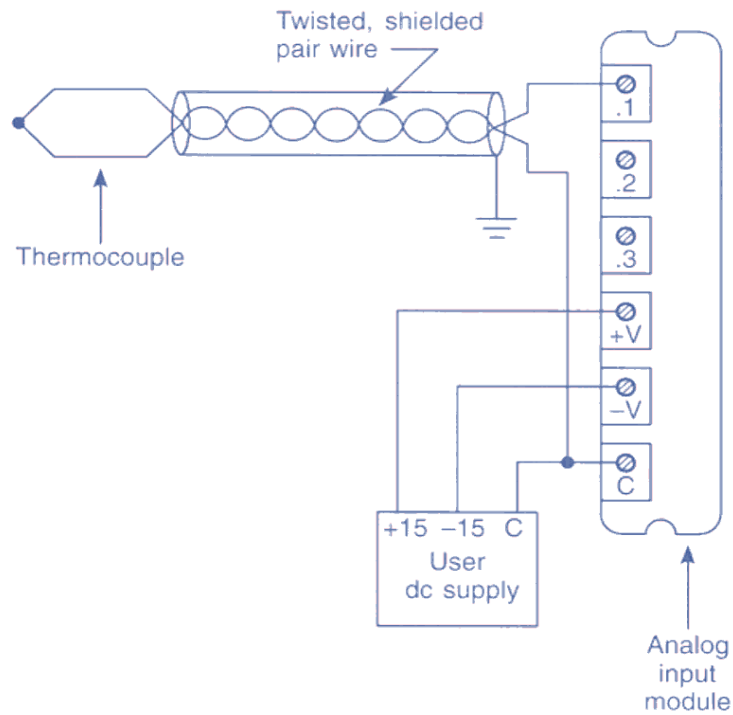


Fig. 2-12

Typical thermocouple connection to an analog input module.

Proximity detector

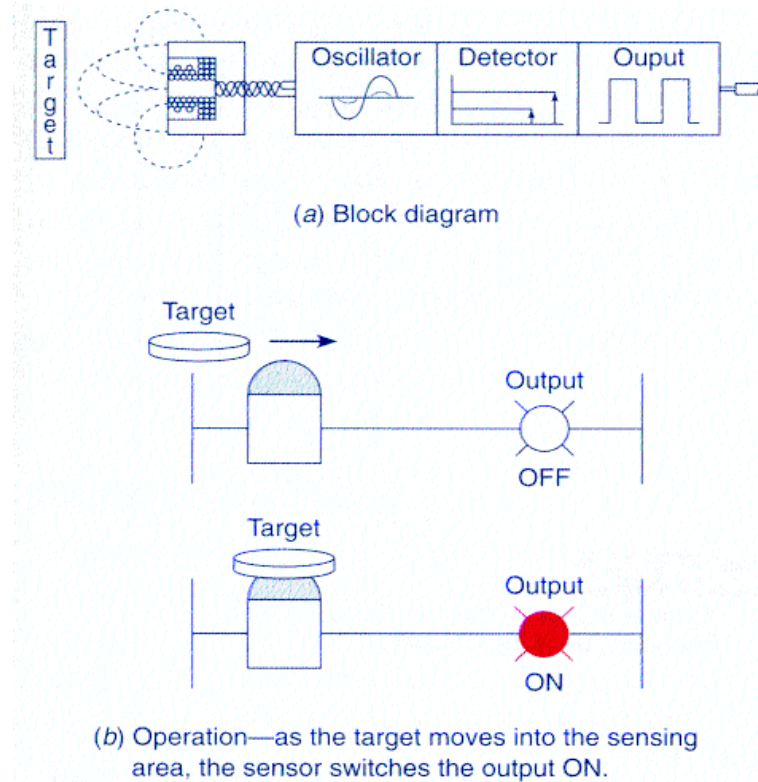


Fig. 6-20

Inductive proximity sensor.

Magnetic detector

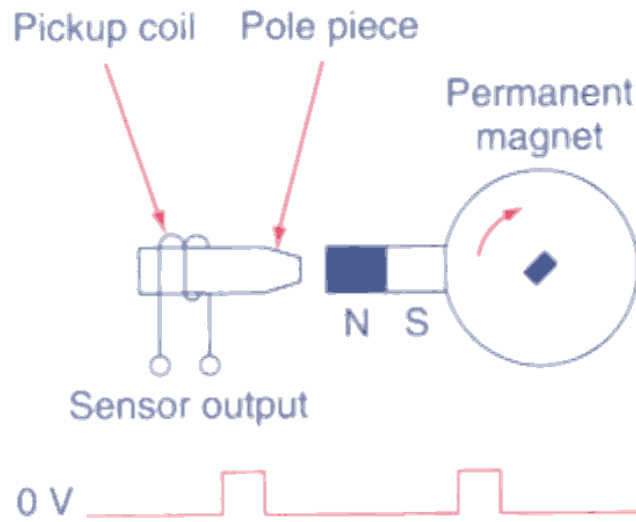


Fig. 6-42

Magnetic pickup sensor.

Magnetic switch

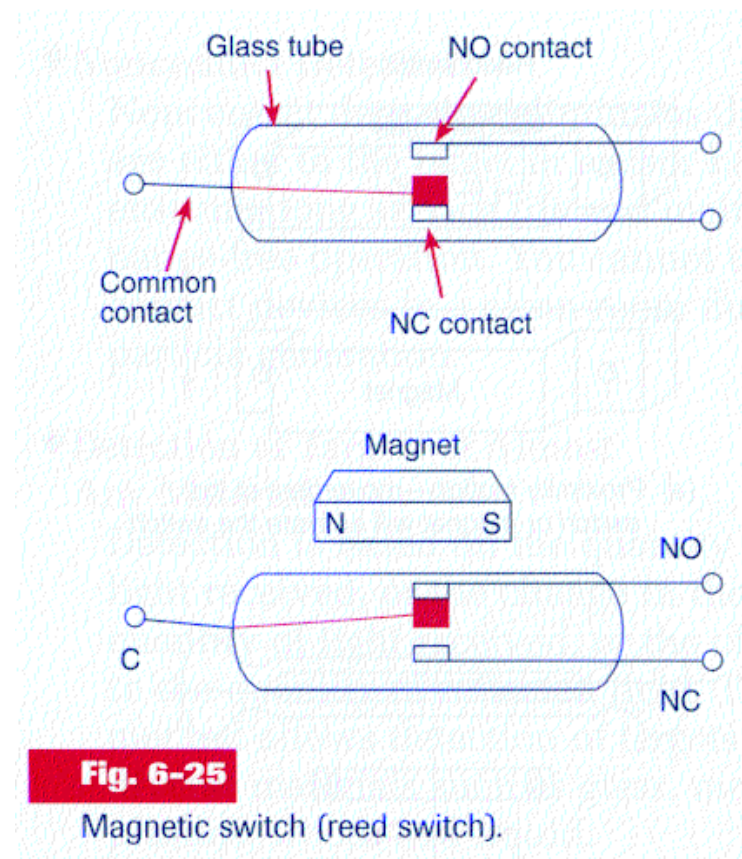


Fig. 6-25

Magnetic switch (reed switch).

Symbols associated to all components

Standards

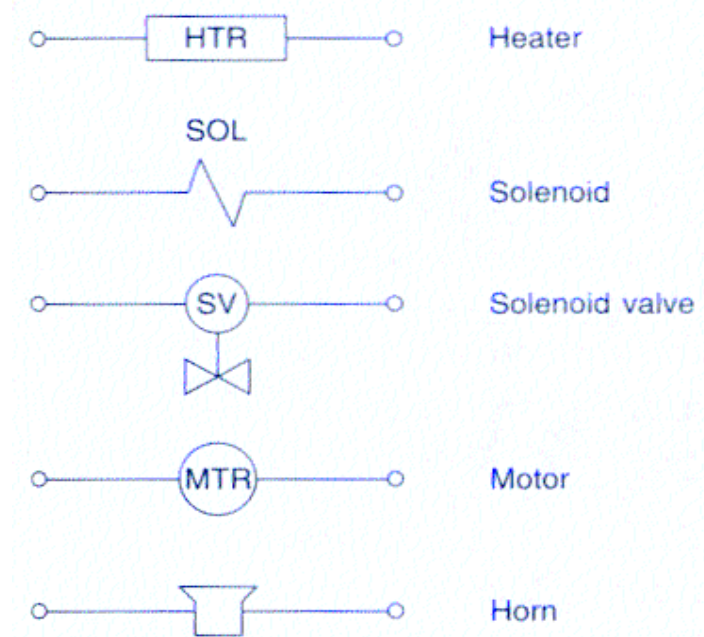
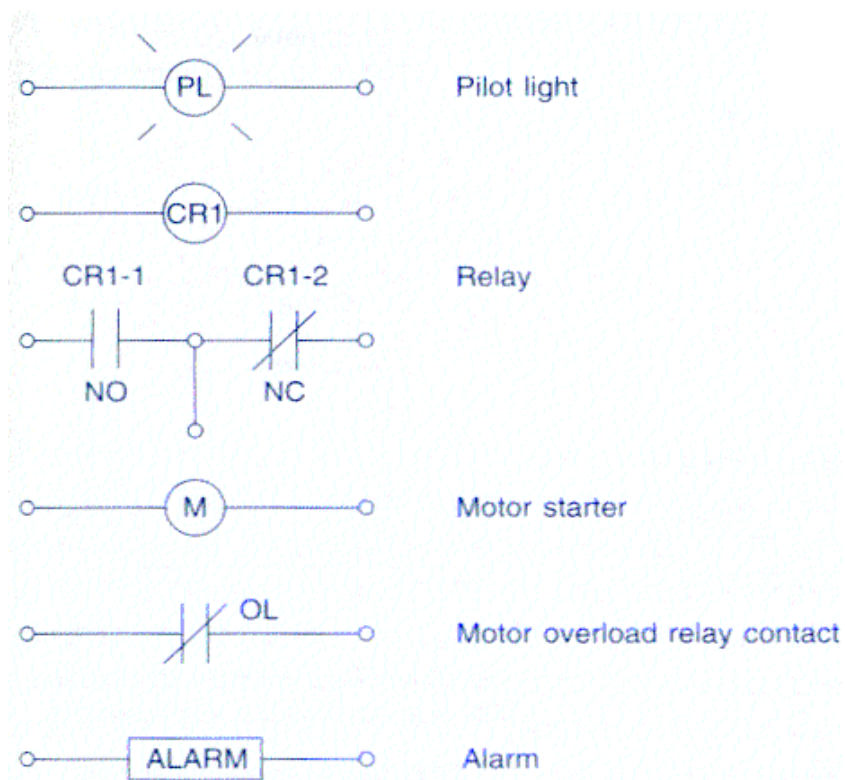


Fig. 6-43

Symbols for output control devices.

Methodologies for the implementation of solutions in industrial automation

Device: Relay

Contact Diagram or Ladder Diagram

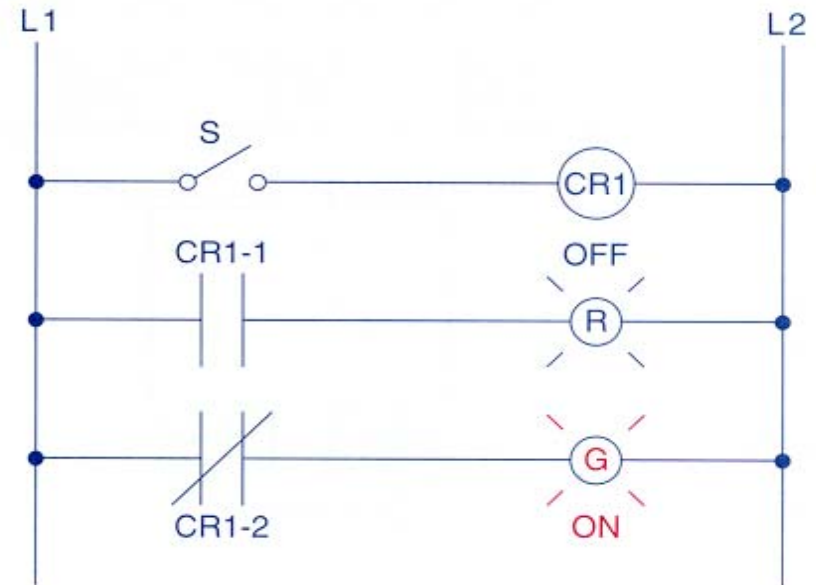
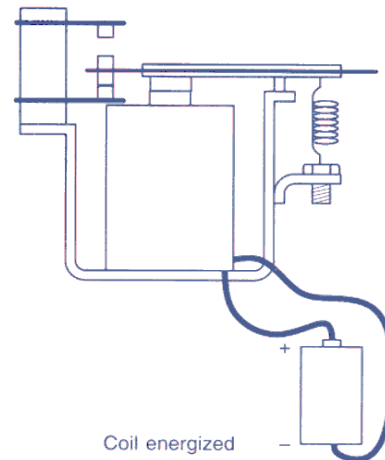
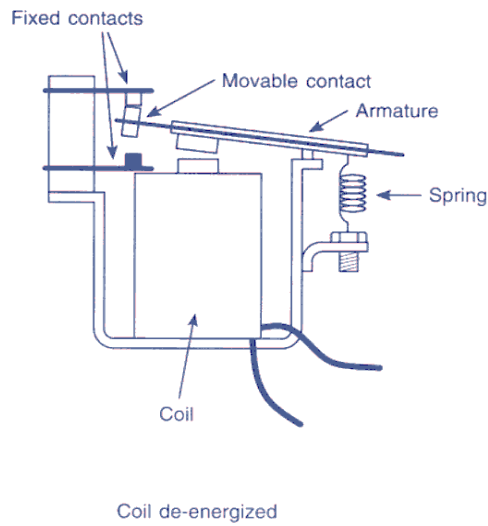


Fig. 6-3

Relay circuit—switch open.

Ladder Diagram

Or

Contact Diagram

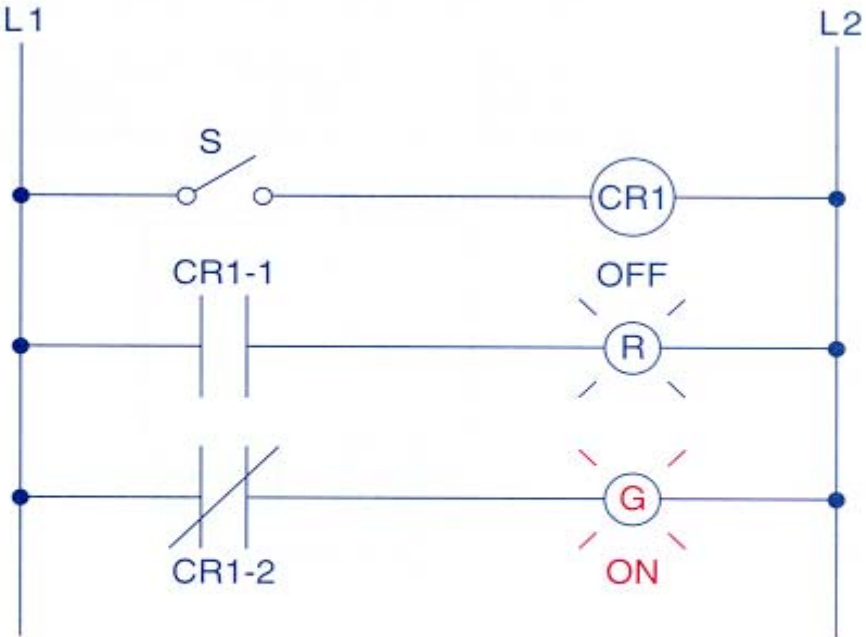


Fig. 6-3

Relay circuit—switch open.

Methodologies for the implementation of solutions in industrial automation

Contacts diagram

Example

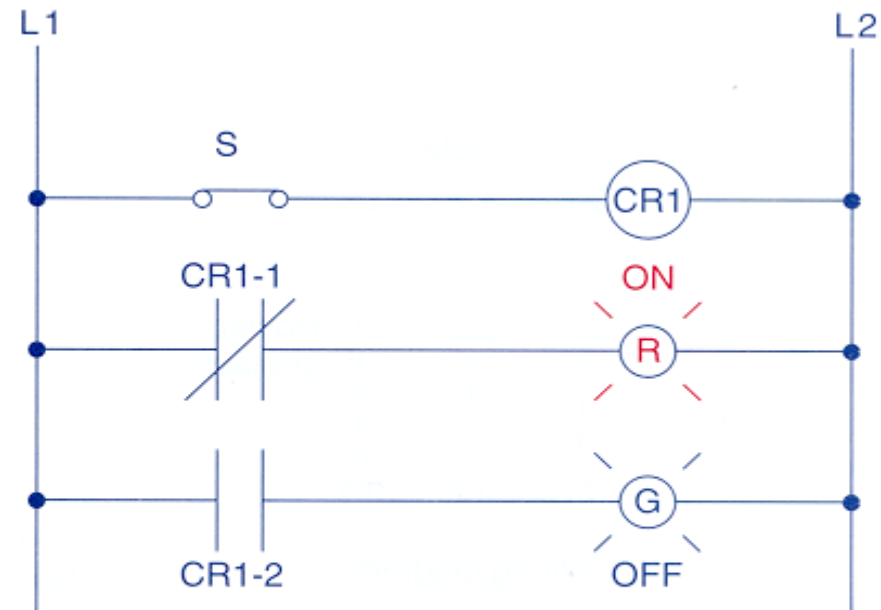


Fig. 6-4

Relay circuit—switch closed.

Example:

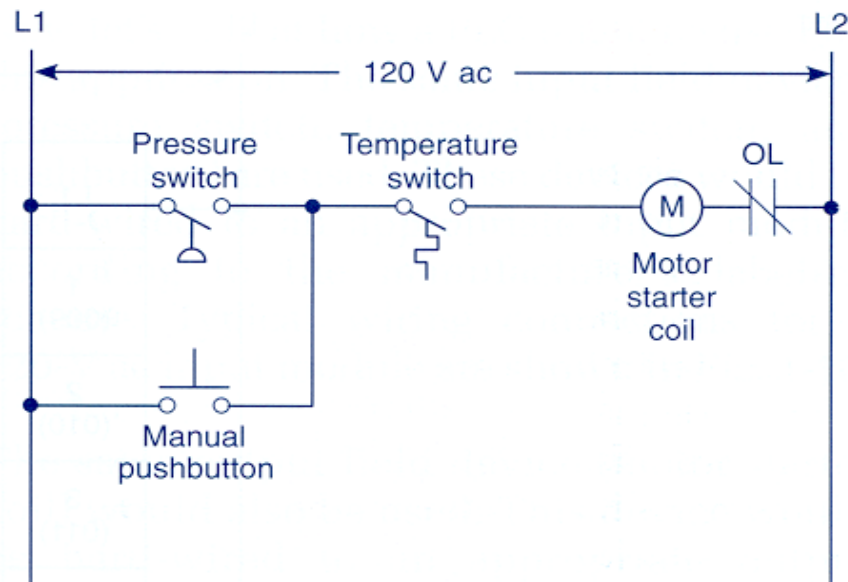


Fig. 1-13

Relay ladder diagram for modified process.

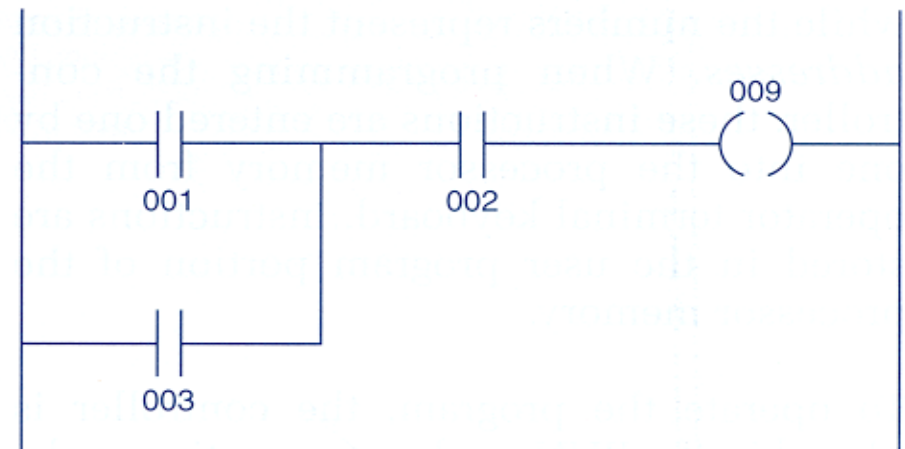
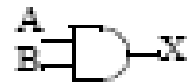


Fig. 1-14

PLC ladder logic diagram for modified process.

Logic Functions

AND



$$X = A \cdot B$$

A	B	X
0	0	0
0	1	0
1	0	0
1	1	1

OR



$$X = A + B$$

A	B	X
0	0	0
0	1	1
1	0	1
1	1	1

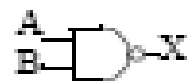
NOT



$$X = \bar{A}$$

A	X
0	1
1	0

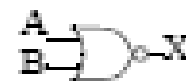
NAND



$$X = \overline{A \cdot B}$$

A	B	X
0	0	1
0	1	1
1	0	1
1	1	0

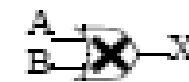
NOR



$$X = \overline{A + B}$$

A	B	X
0	0	1
0	1	0
1	0	0
1	1	0

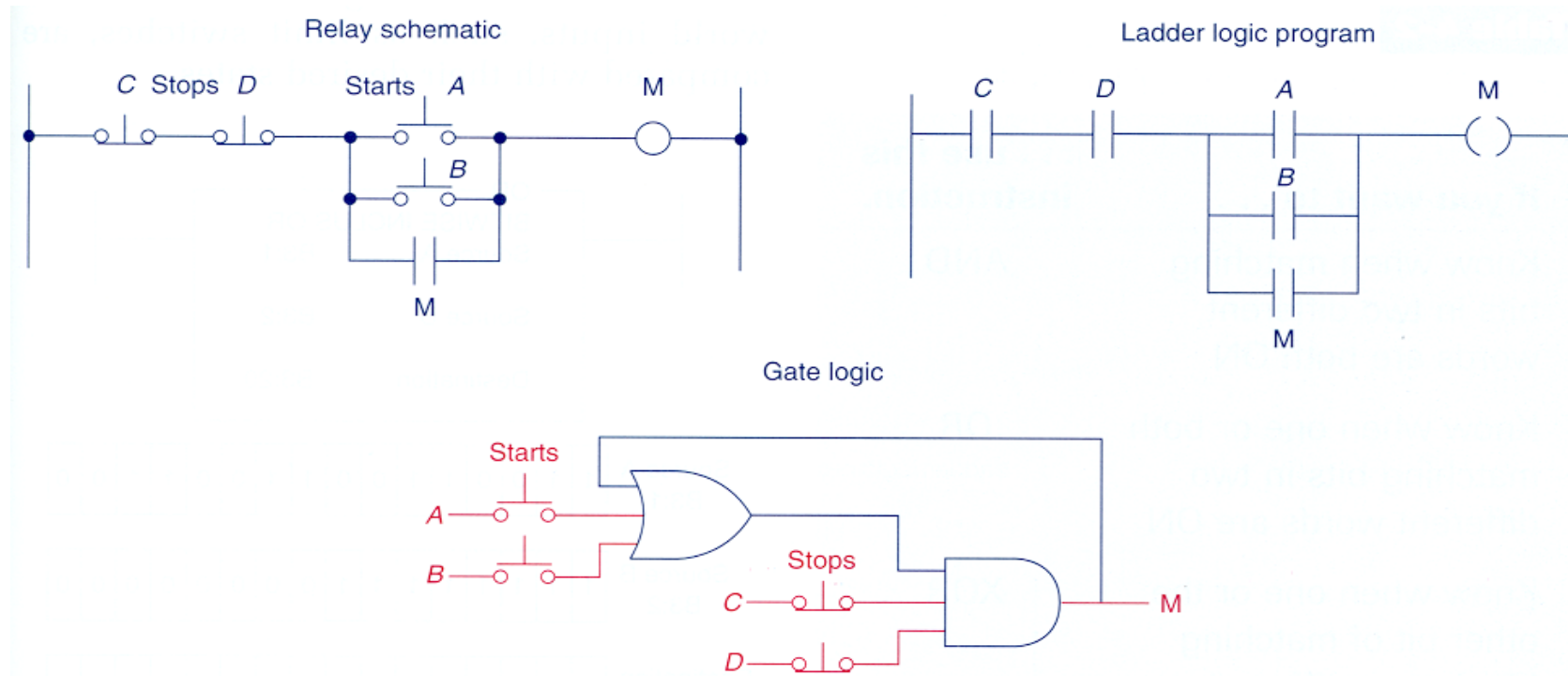
EOR



$$X = A \oplus B$$

A	B	X
0	0	0
0	1	1
1	0	1
1	1	0

Example:



Example 4-9

A motor control circuit with two stop buttons. When the start button is depressed, the motor runs. By sealing, it continues to run when the start button is released. The stop buttons stop the motor when they are depressed.

To exploit the advantages of Programmed Logic

