Industrial Automation

(Automação de Processos Industriais)

http://users.isr.ist.utl.pt/~pjcro/courses/api1011/api1011.html

Faculty:

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Prof. José Gaspar jag @ isr.ist.utl.pt Tel: 21 8418293

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.

Syllabus:

Chap. 1 – Introduction to Automation [1 week]

Introduction to components in industrial automation.
Introduction to methodologies for problem modeling.
Cabled logic versus programmed logic.

Chap. 2 – Introduction to PLCs [2 weeks]

Components of Programmable Logic Controllers (PLCs).
Internal architecture and functional structure.
Input / output Interfaces. Interconnection of PLCs .

Chap. 3 – PLCs Programming Languages [2 weeks]

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

Syllabus (cont.):

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

The GRAFCET norm. Elements of the language.
Modeling techniques using GRAFCET.

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

Methodology CAD/CAM. Types of Computerized Numerical Controlled machines. Interpolation of trajectories.
Flexible fabrication cells.

Chap. 6 – Discrete Event Systems [1 week]

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

Syllabus (cont.):

Chap. 7 – Analysis of DESs [2 weeks]

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

Chap. 8 – DESs and Industrial Automation [1 week]

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

Chap. 9 – Supervision of Industrial Processes [2 weeks]

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: 9.5/20.0 val. in each component.

- ~~Oral discussion for students with grade > 17/20 valores .~~

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

Schedule (suggested)

October 1st 2010

Schedule (according to IST-GOP):

- Recitation classes

Monday	11.00 h – 12.30h	Ea5
Friday	11.00 h – 12.30h	Ea4

- Lab. Classes

Monday	09.30h – 11.00h L1	LSDC4
Friday	09.30h – 11.00h L2	LSDC4

Third session needed?

- Groups register 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.

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Introduction to Automation

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Cap. 1 – Introduction to Automation [1 week]

Introduction to components in industrial automation.

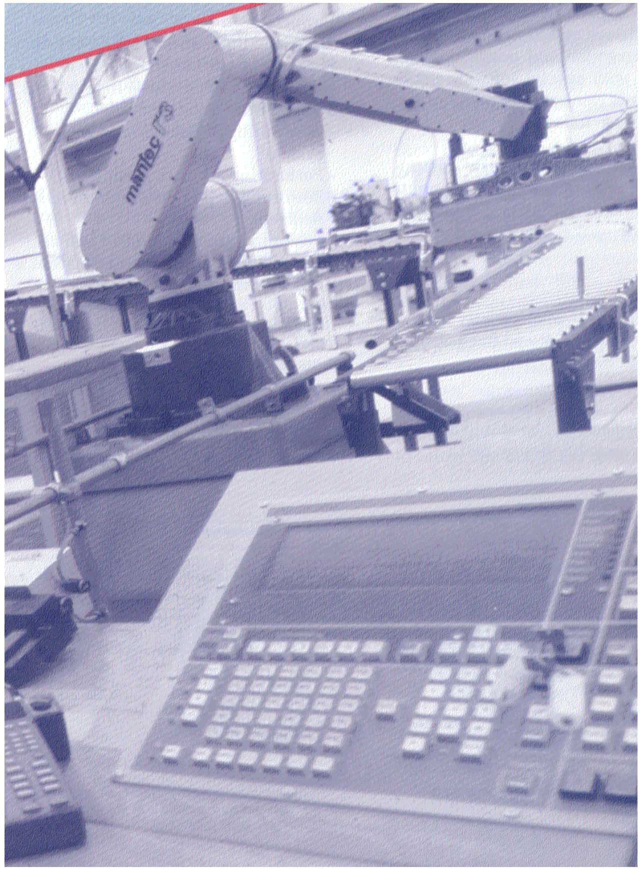
Introduction to methodologies for problem modeling.

Cabled logic versus programmed logic versus networked logic.

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.

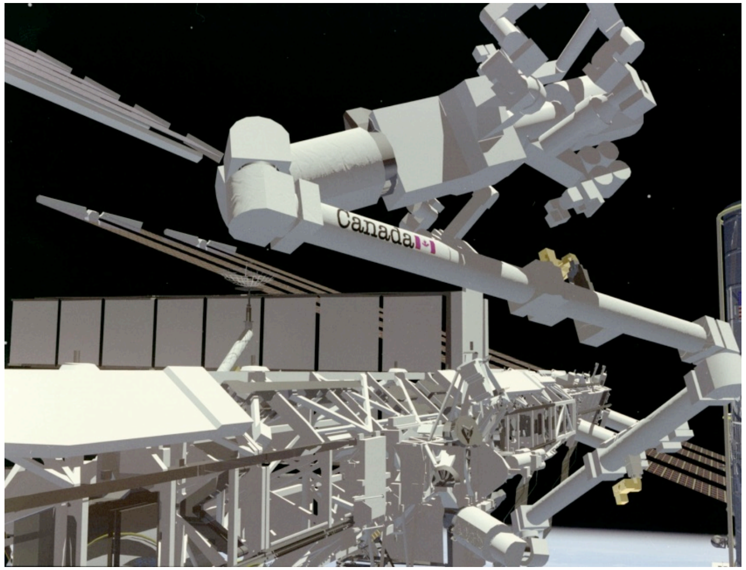


The use of specialized, automatic tools are mandatory.

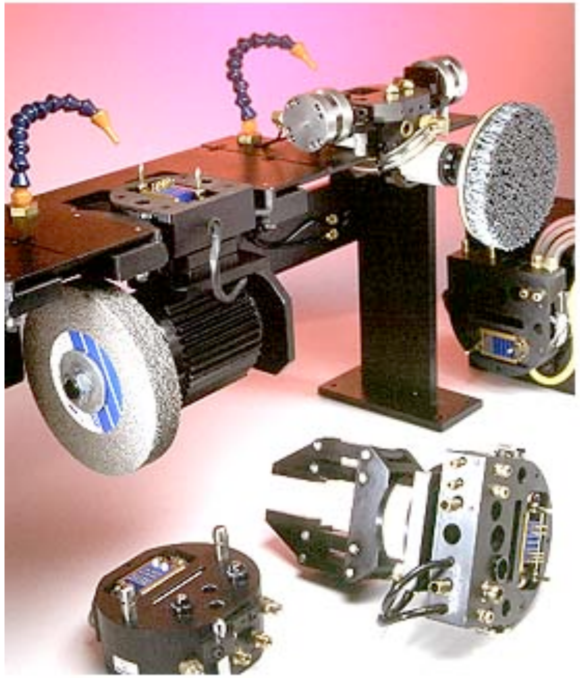
Consistent trend in the last three centuries (since the Industrial Revolution).

Automation was also fostered by the invention of computers,

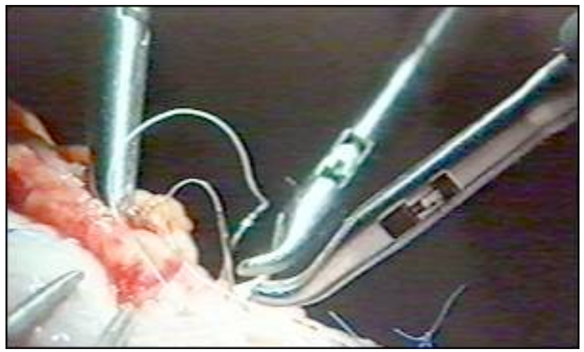
Robotic Manipulators



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

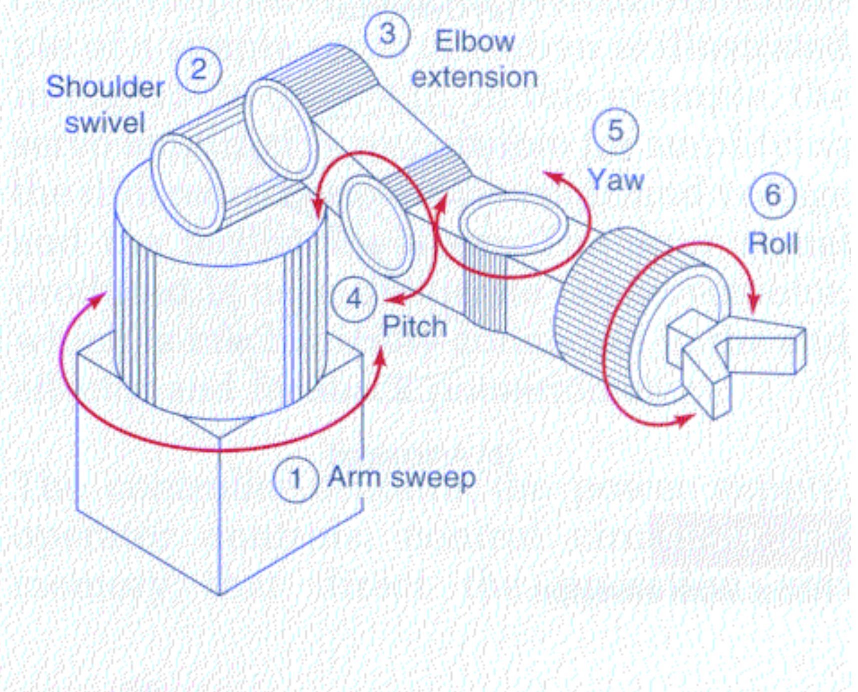


Fig. 15-22
Six-axis robot arm.

Robotic Manipulators

Workspace:

Examples

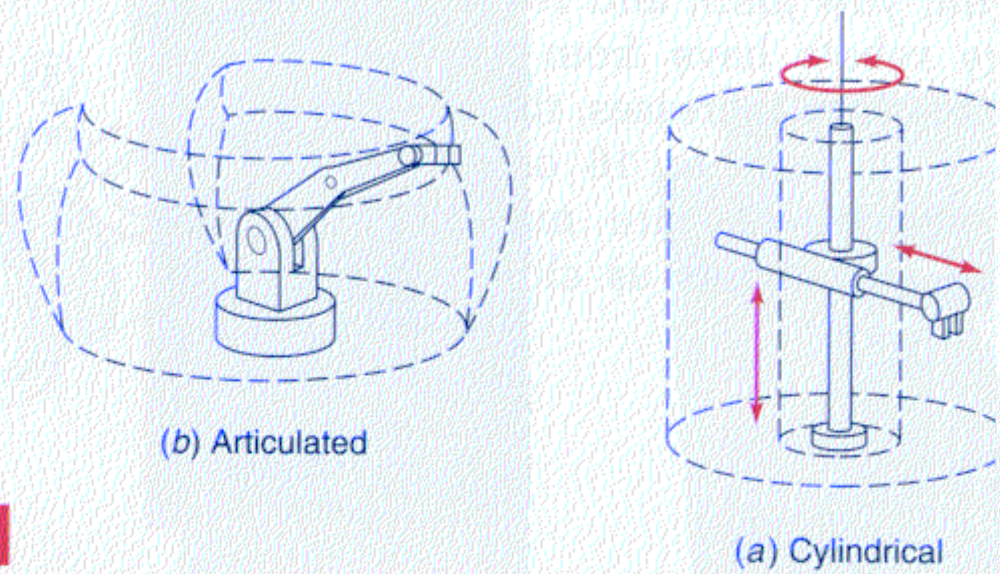


Fig. 15-23
Robot work envelope.

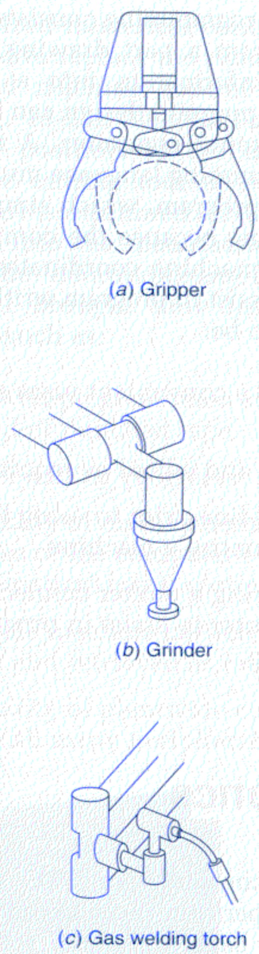


Fig. 15-24
End-of-arm tooling devices.

Robotic Manipulators

Central problems to adress and solve:

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

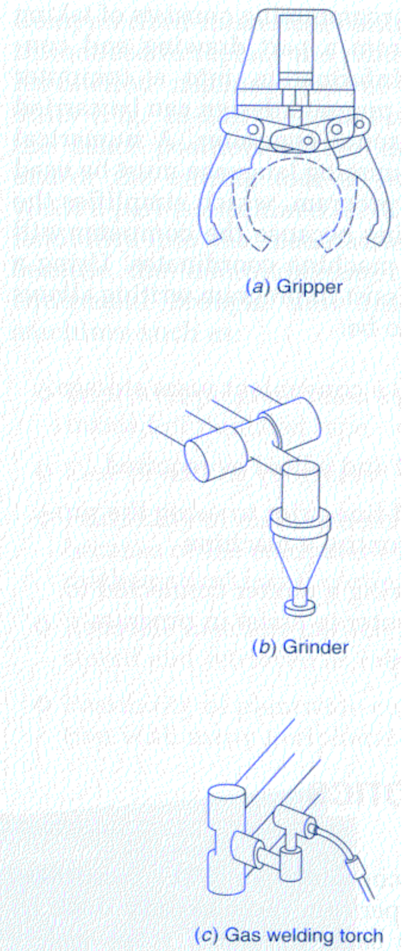


Fig. 15-24
End-of-arm tooling devices.

Robotic Manipulators

Use in Flexible

Cells of Fabrication:

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

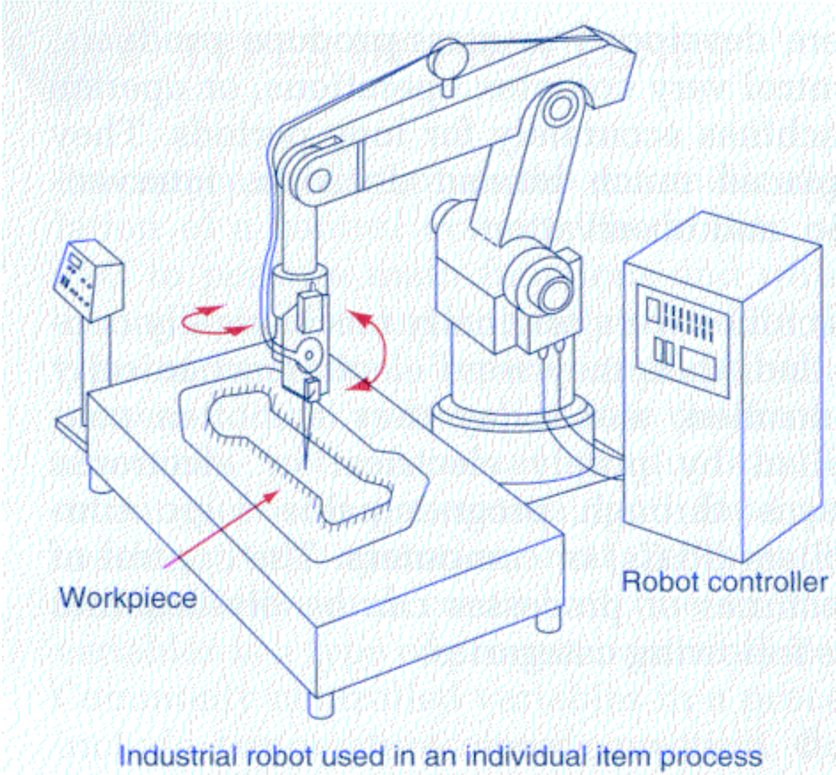


Fig. 14-3
Individual product production.

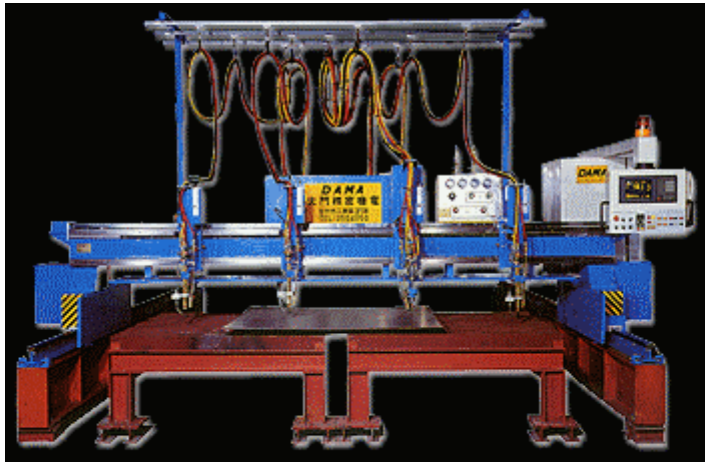
Computerized Numerical Controlled Machines

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, ...

Computerized Numerical Controlled Machines



Solutions for Handling materials

For transport...

Major characteristics:

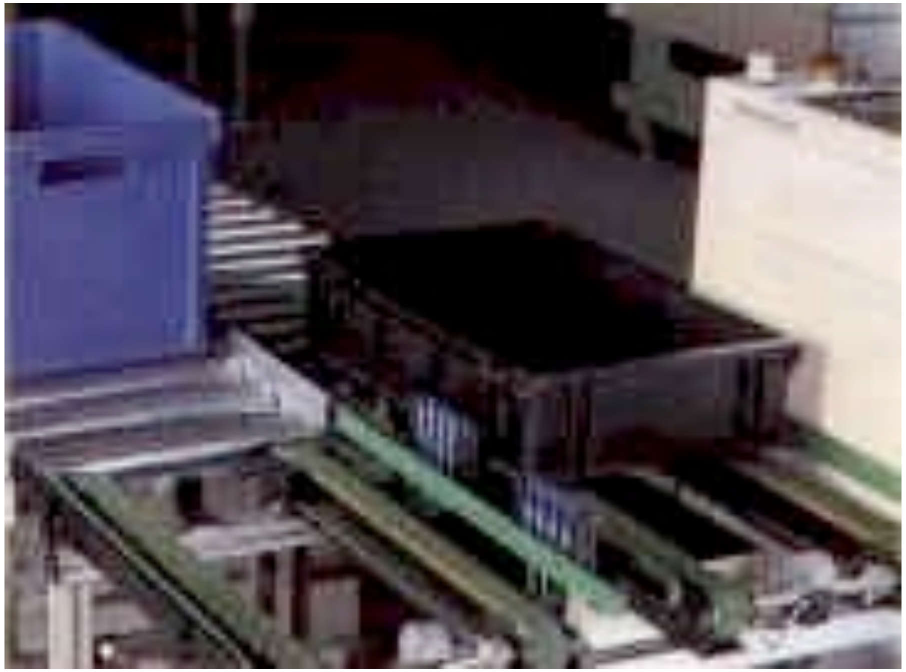
• Load/unload automation

• 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

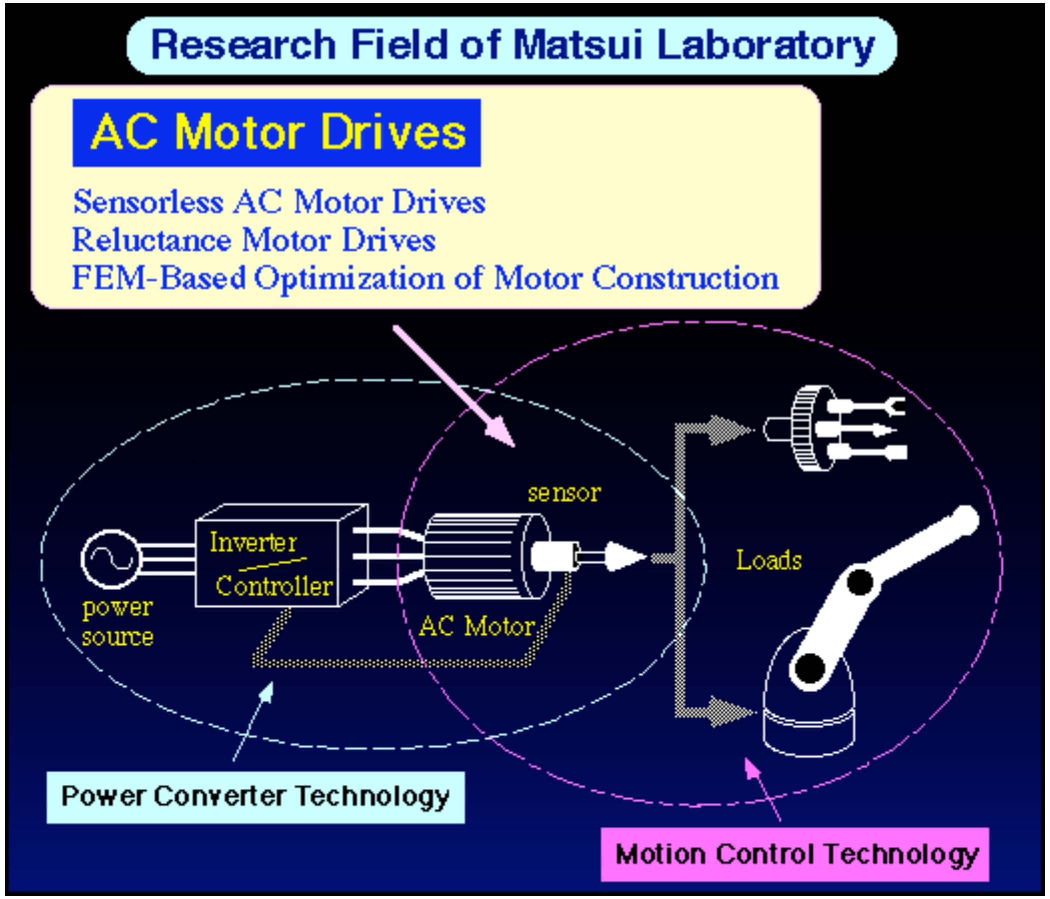
Actuation

Motors

Major características:

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

Exemple of AC motor, with driver



Specific Components

Factury example: production of aluminium packs

Cabled Logic versus ...

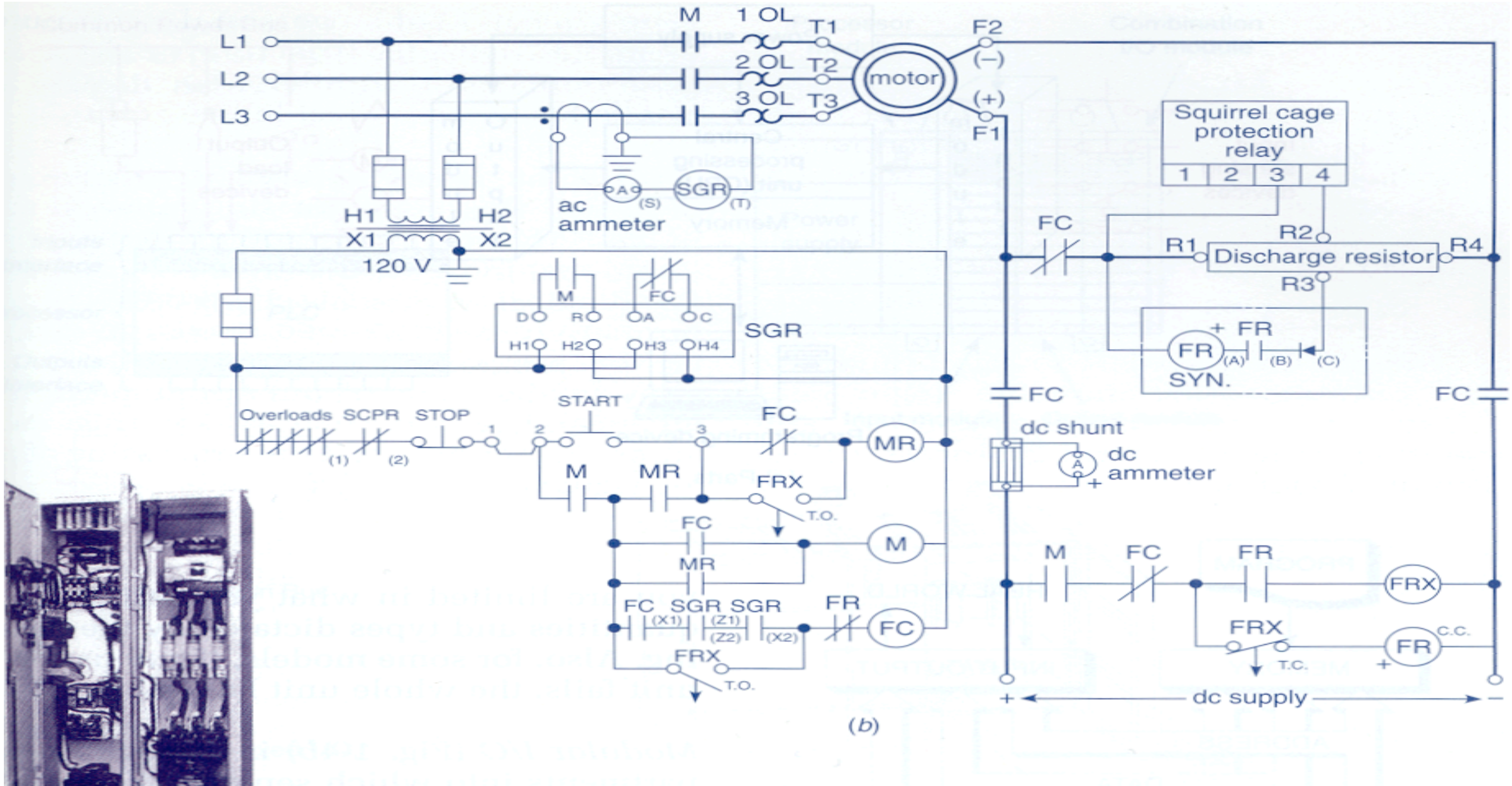
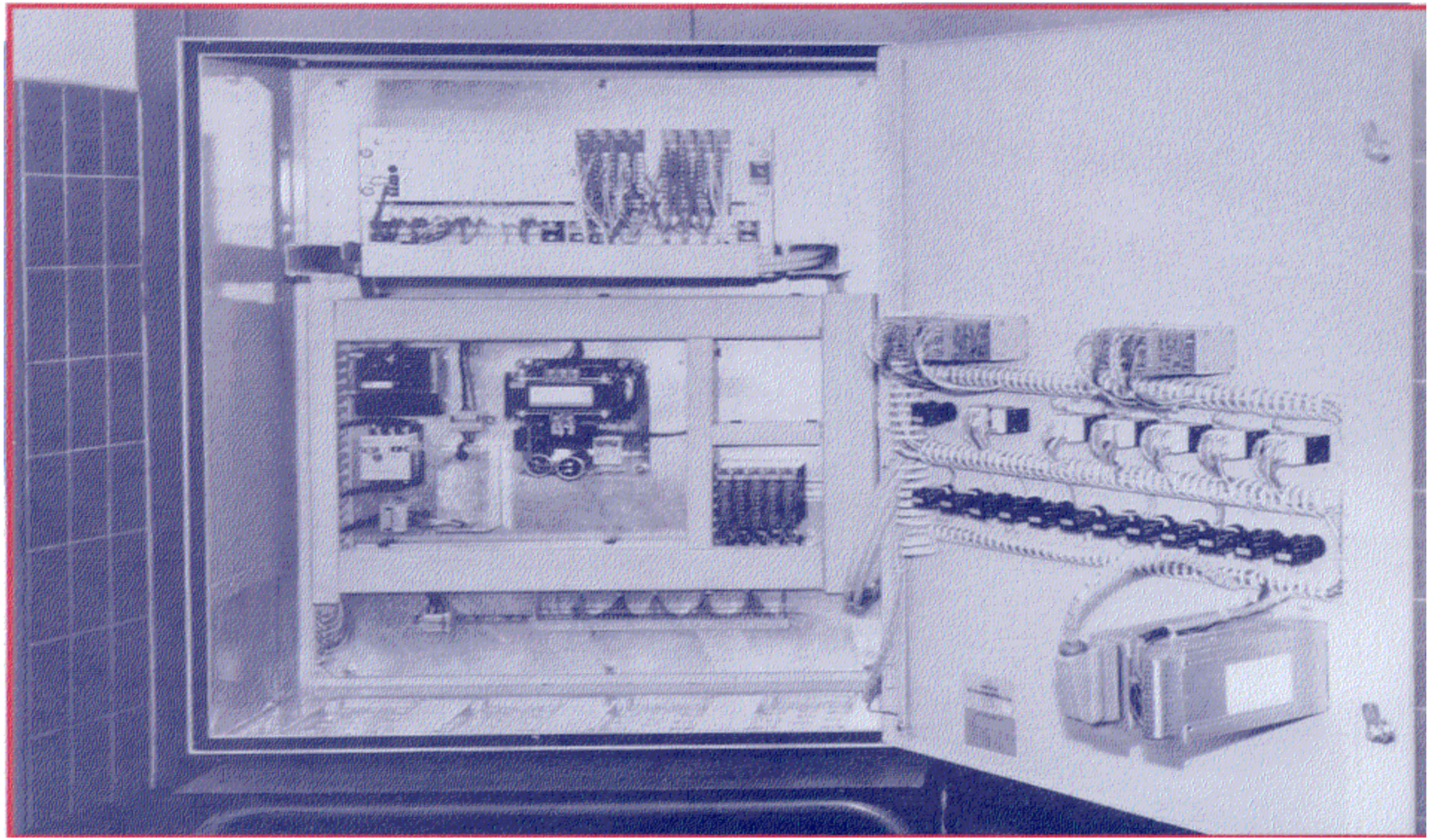


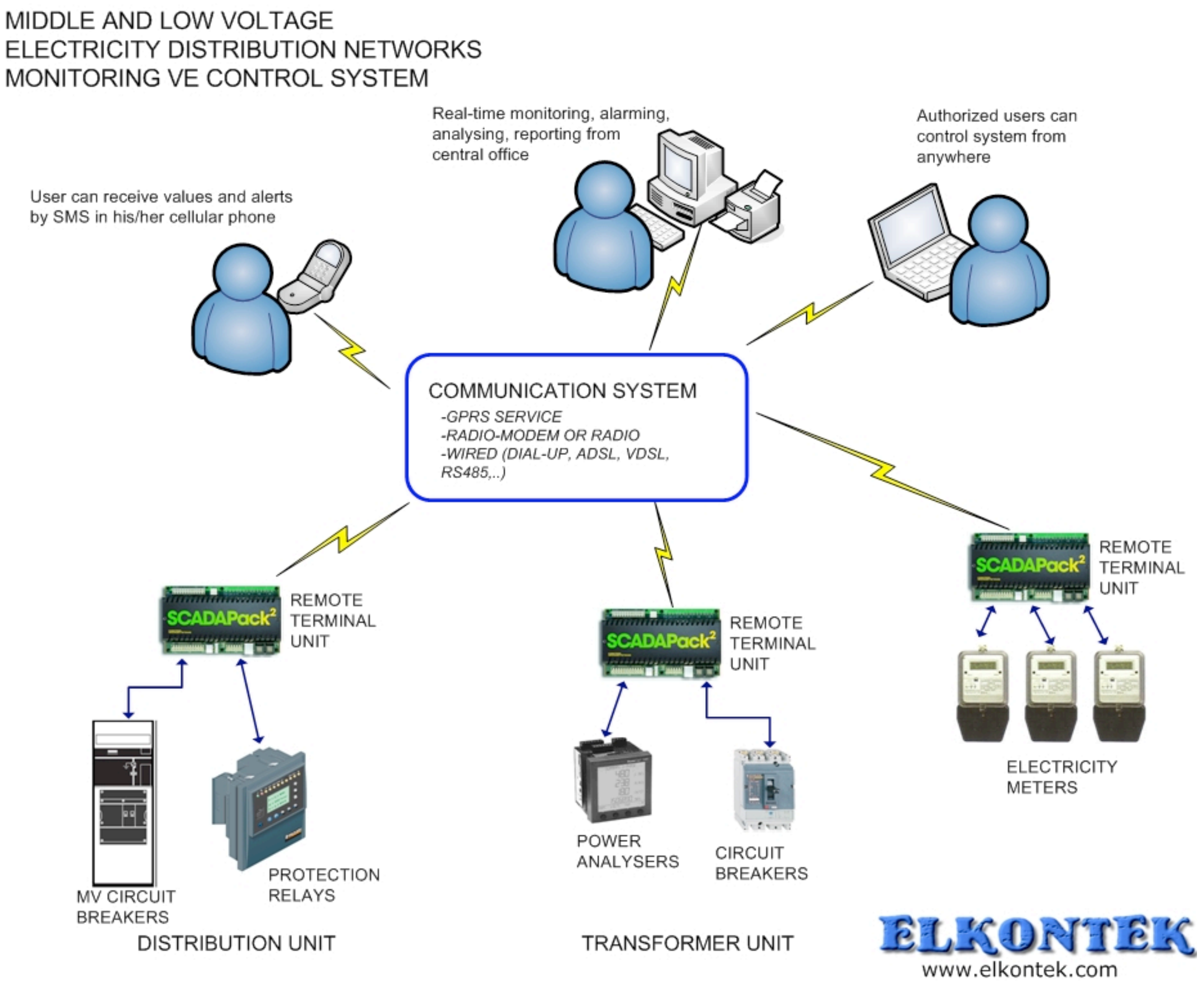
Fig. 1-2

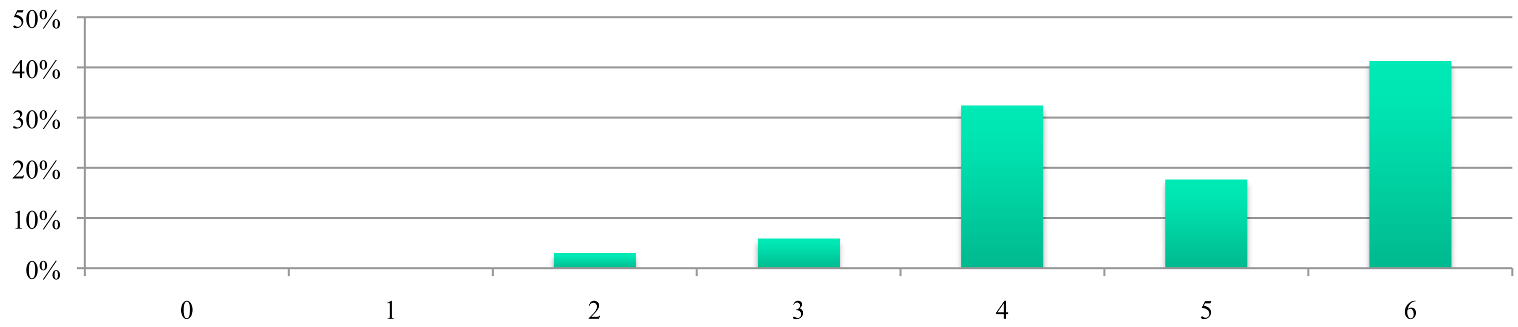
(a) Typical hard-wired controller panel. (b) Typical hardwired diagram. (Courtesy of Allen-Bradley Company, Inc.)

... versus Programmed Logic …



... versus Networked Logic

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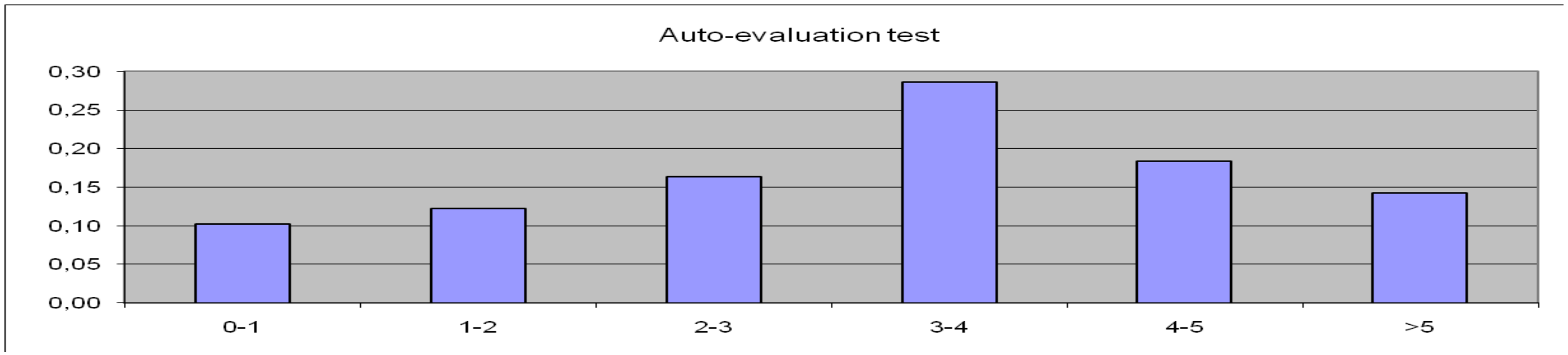
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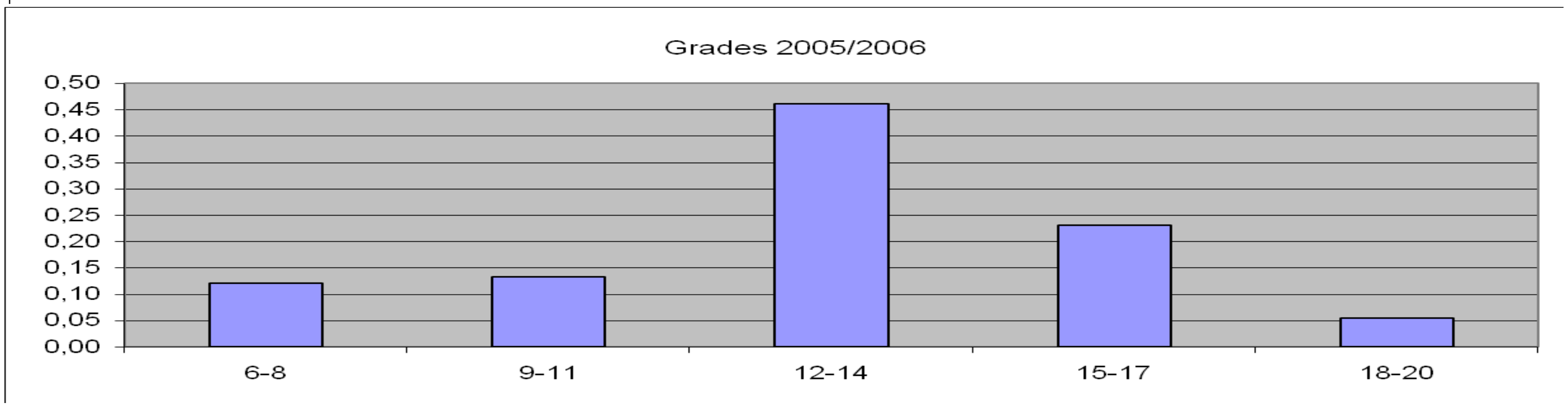
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18-20

Introduction to methodologies for problem modeling in Industrial Automation

Solenoide Valve

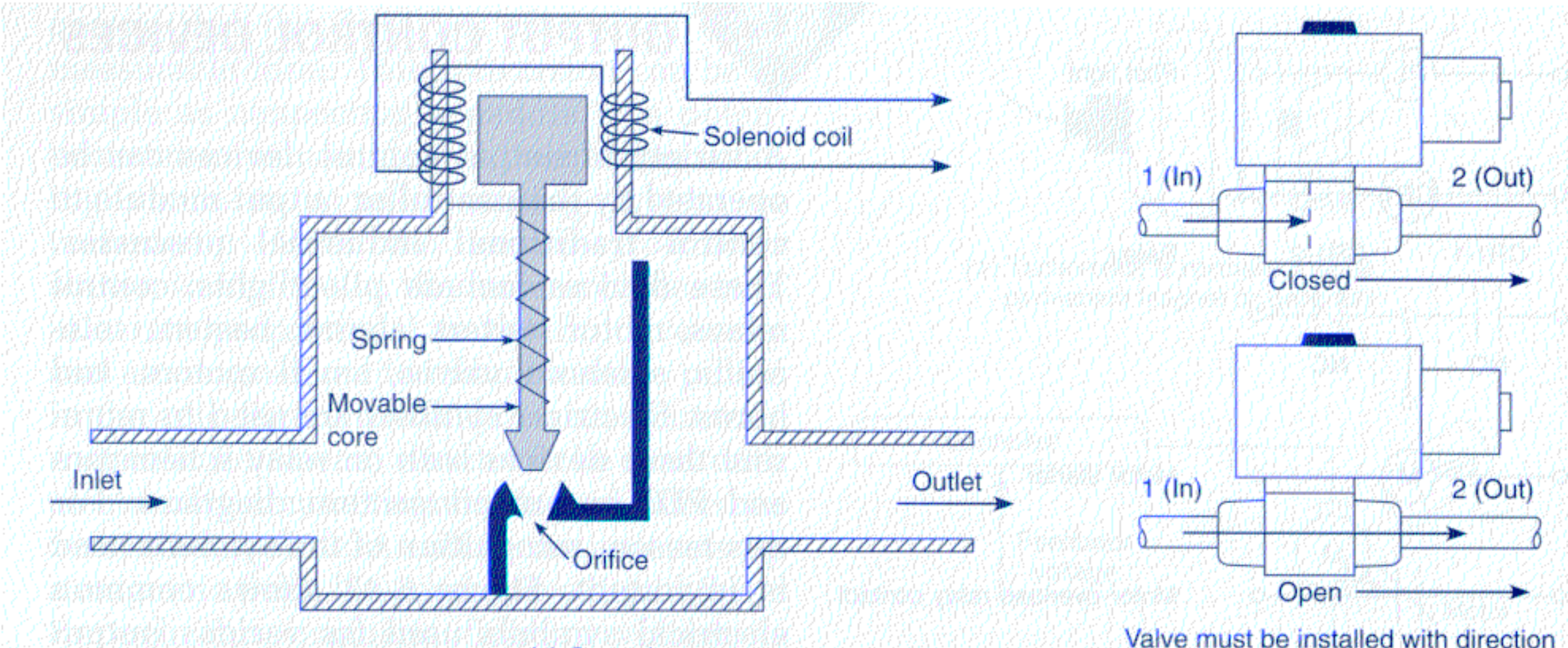


Fig. 6-45
Solenoid valve.

Command Relay

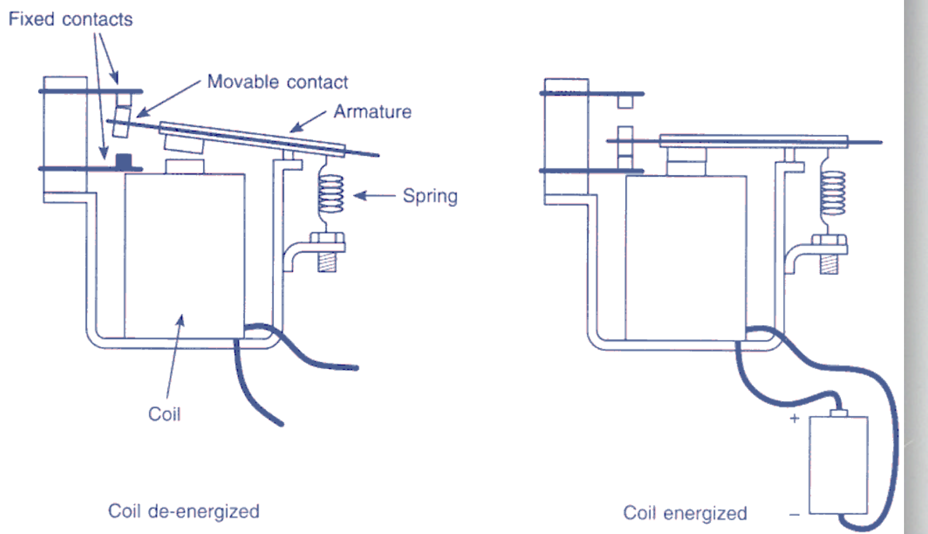


Fig. 6-1
Electromagnetic control relay operation.

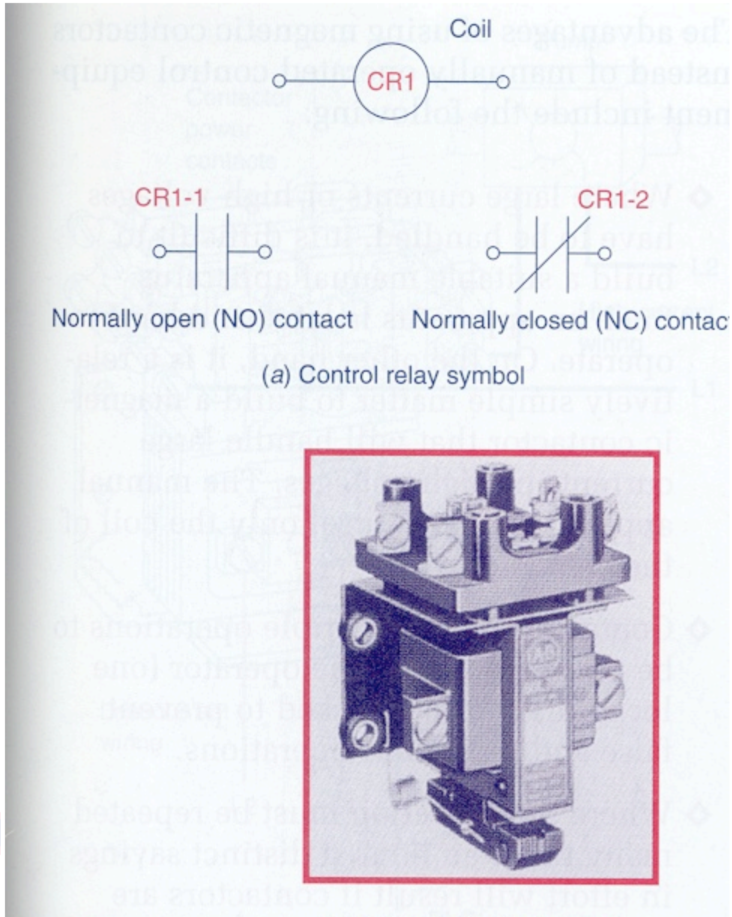
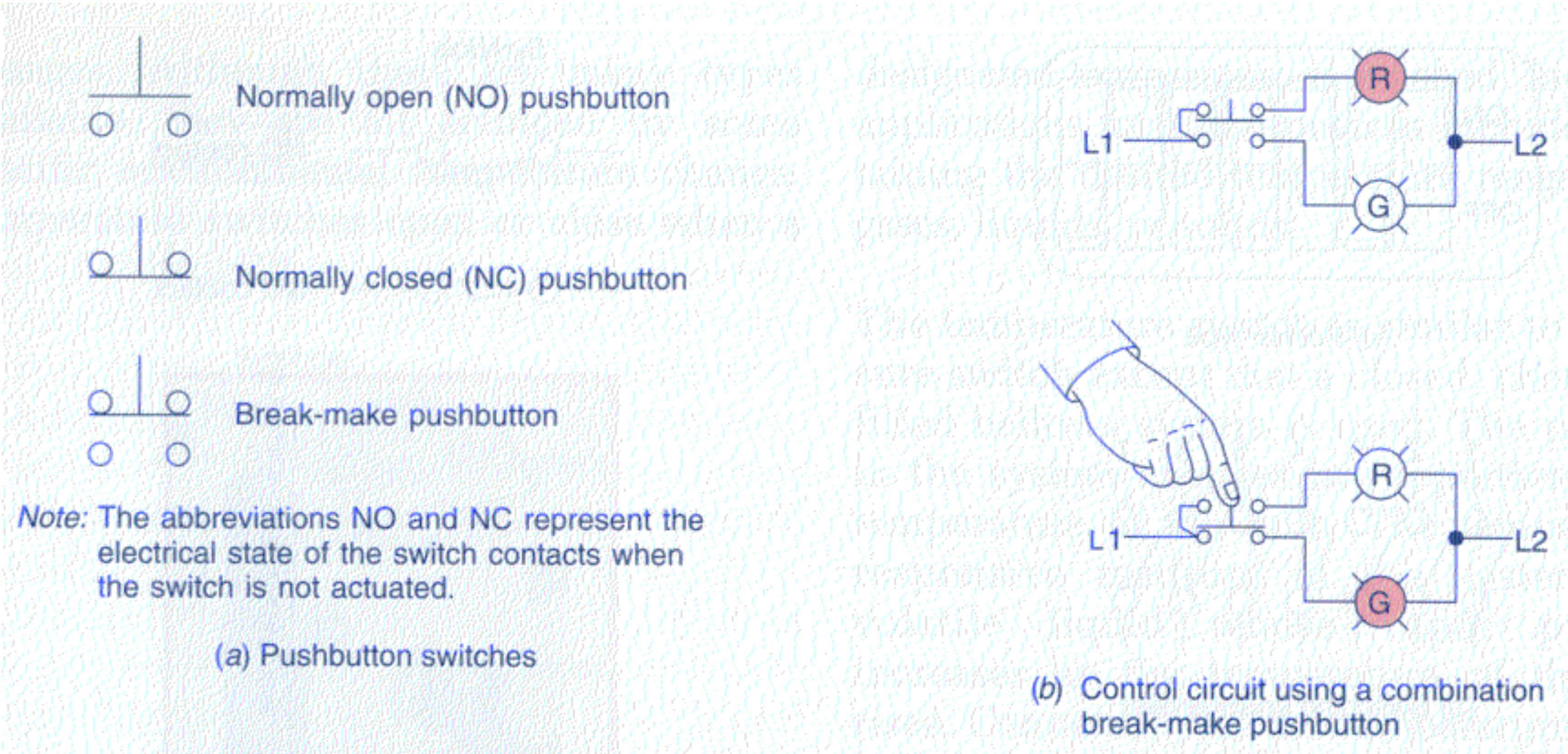


Fig. 6-2
Control relay.

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

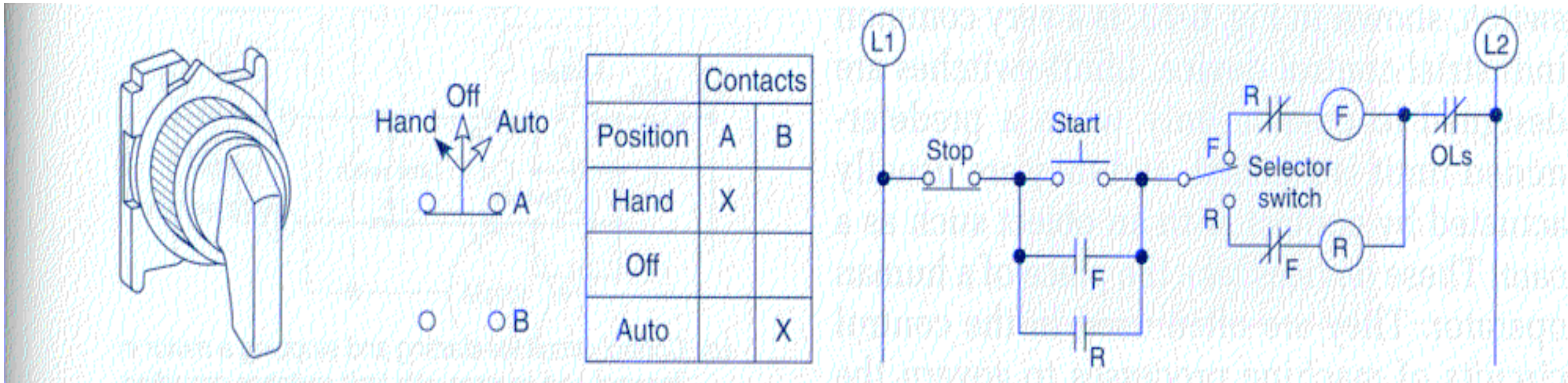
Push buttons



(*a*) Pushbutton switches

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

Selector with three positions



	Contacts	
Position	A	B
Hand	X	
Off		
Auto		X

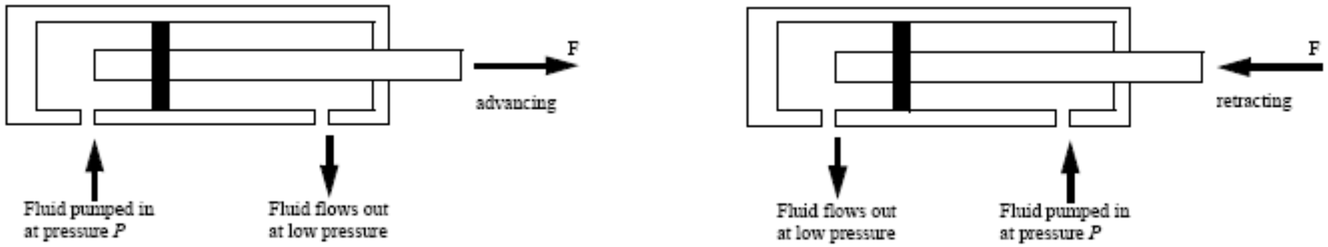
(a) Selector switch operator

(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)



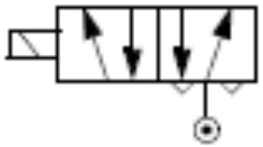
For Force:

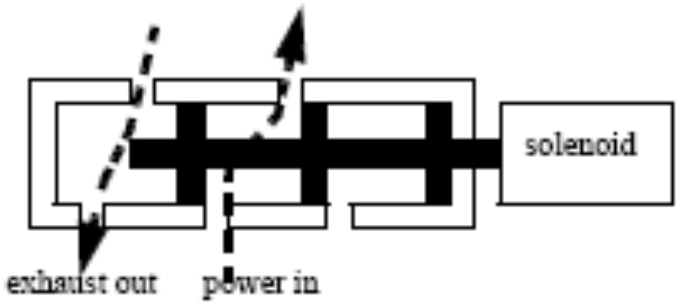
$$P = \frac{F}{A} \qquad F = PA$$

where,

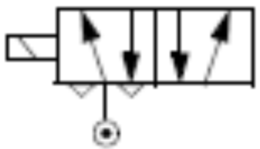
P = the pressure of the hydraulic fluid
A = the area of the piston
F = the force available from the piston rod

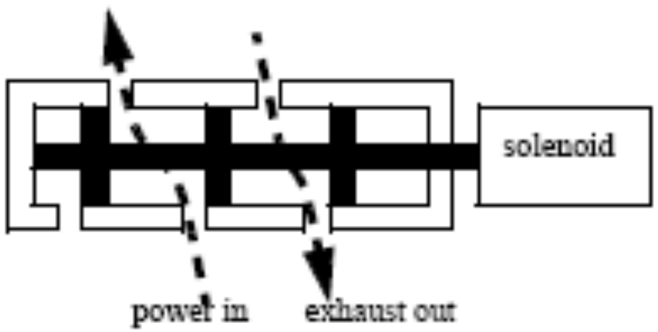
Valves(Electro-pneumatics)





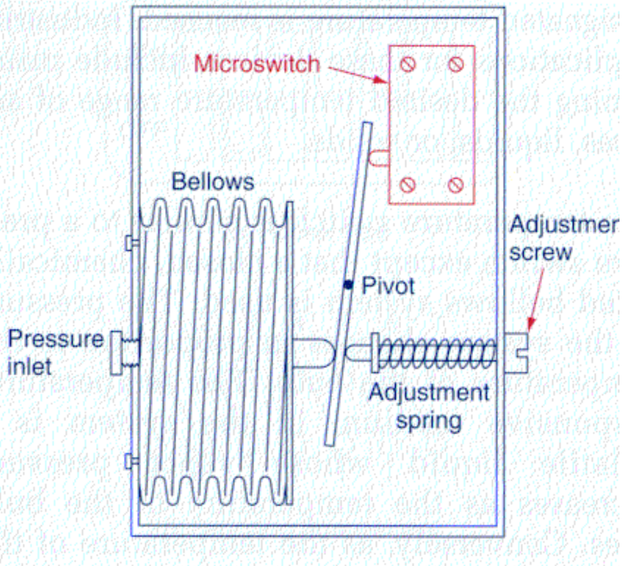
The solenoid has two positions and when actuated will change the direction that fluid flows to the device. The symbols shown here are commonly used to represent this type of valve.



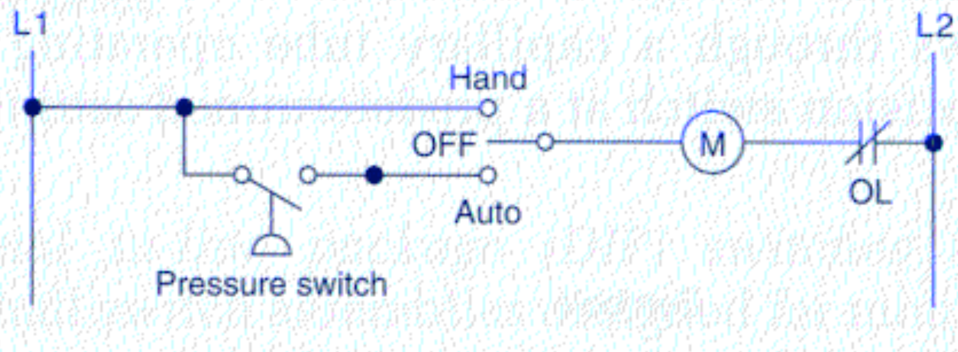


Sensors

Pressure Switch



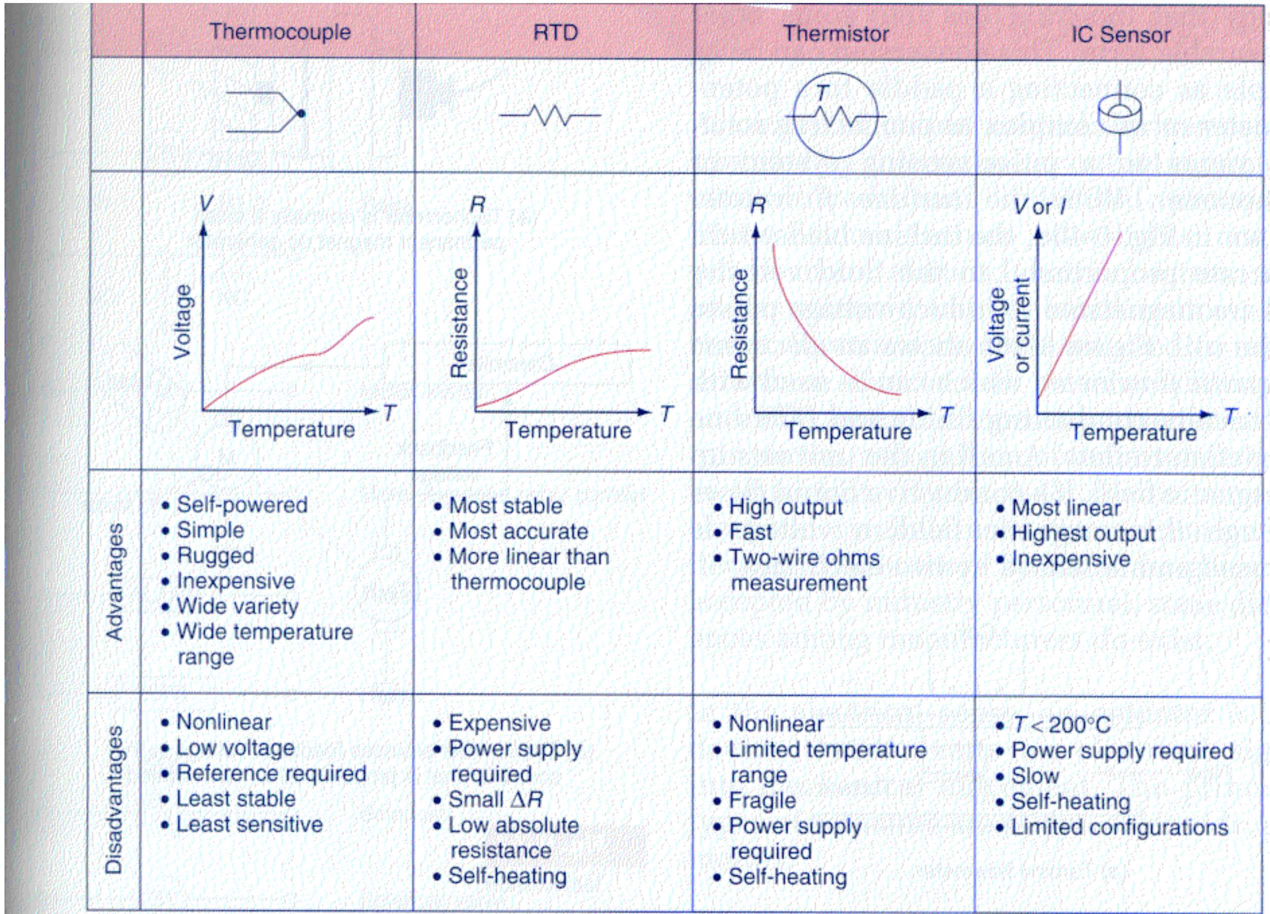
(b) Bellows



(c) Starter operated by pressure switch

Fig. 6-15 (continued)
Pressure switch.

Temperature Sensors



	Thermocouple	RTD	Thermistor	IC Sensor
Graph	Voltage (V) vs Temperature (T)	Resistance (R) vs Temperature (T)	Resistance (R) vs Temperature (T)	Voltage or current (V or I) vs Temperature (T)
Advantages	• Self-powered • Simple • Rugged • Inexpensive • Wide variety • Wide temperature range	• Most stable • Most accurate • More linear than thermocouple	• High output • Fast • Two-wire ohms measurement	• Most linear • Highest output • Inexpensive
Disadvantages	• Nonlinear • Low voltage • Reference required • Least stable • Least sensitive	• Expensive • Power supply required • Small ΔR • Low absolute resistance • Self-heating	• Nonlinear • Limited temperature range • Fragile • Power supply required • Self-heating	• $T < 200°C$ • Power supply required • Slow • Self-heating • Limited configurations

Fig. 6-38
Common temperature sensors.

Termocouple

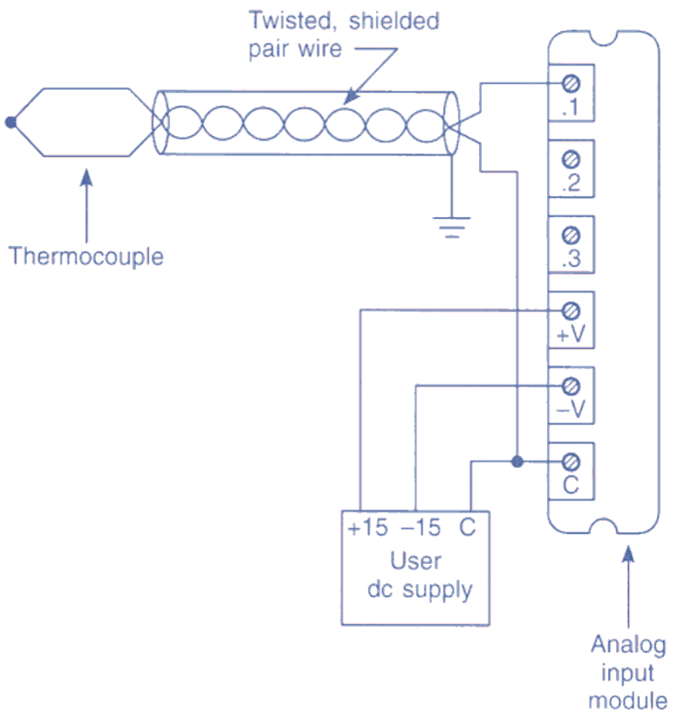


Fig. 2-12
Typical thermocouple connection to an analog input module.

Proximity detector

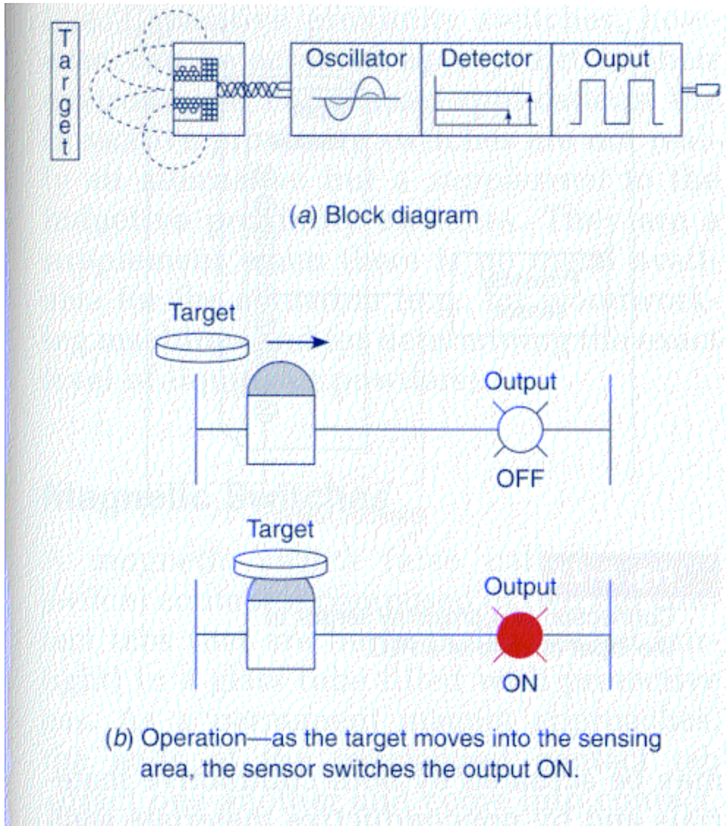


Fig. 6-20
Inductive proximity sensor.

Magnetic detector

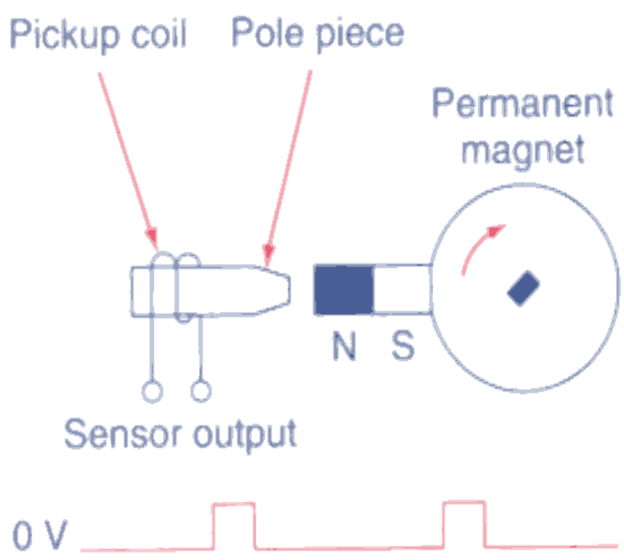


Fig. 6-42
Magnetic pickup sensor.

Magnetic switch

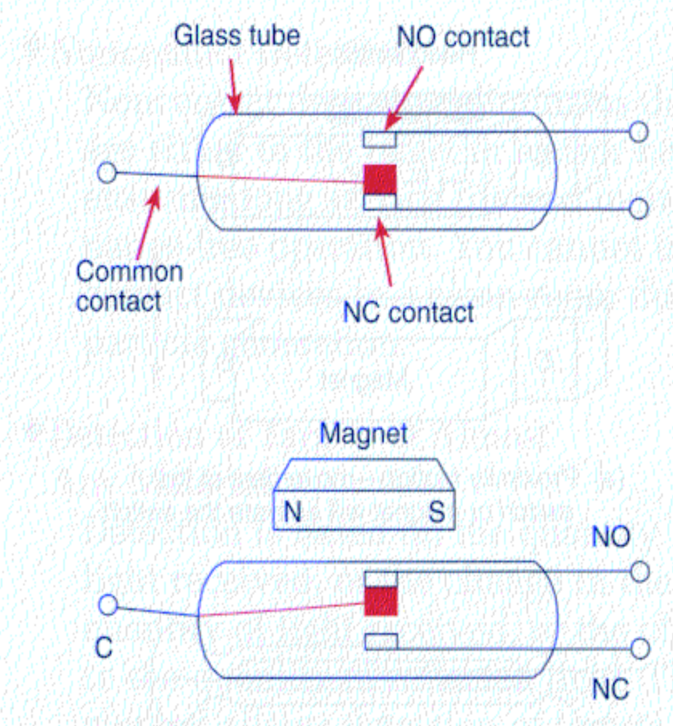
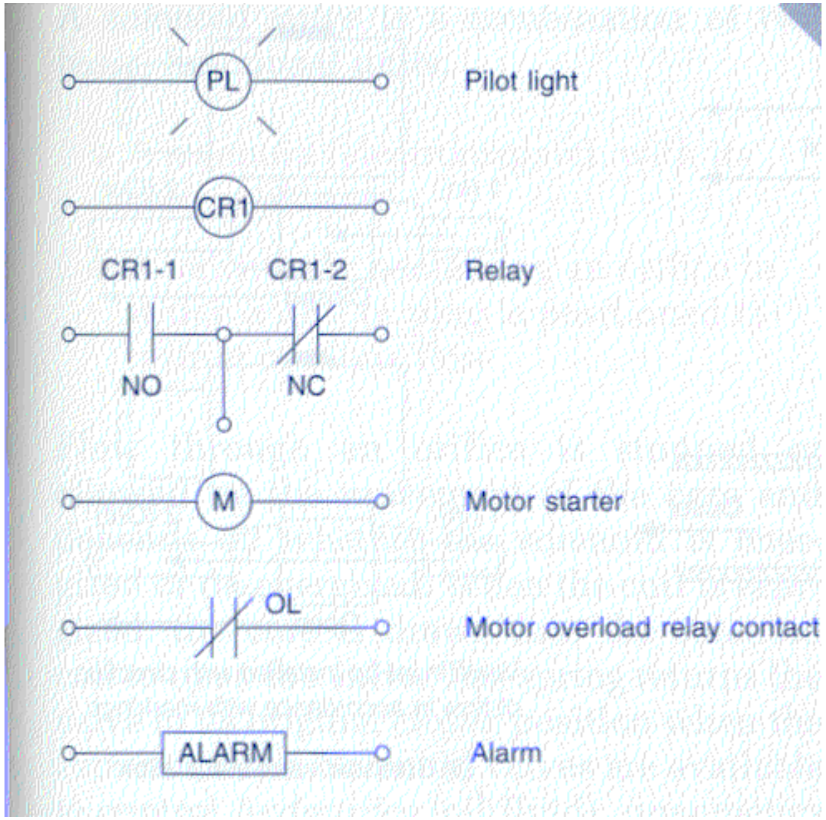


Fig. 6-25
Magnetic switch (reed switch).

Symbols associated to all components

Standards



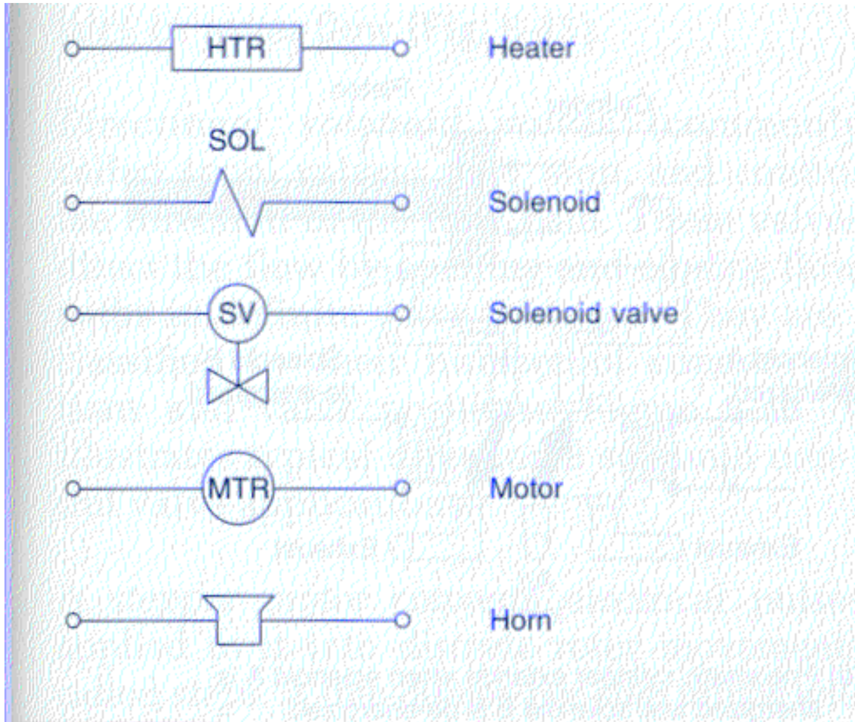


Fig. 6-43
Symbols for output control devices.

Ladder Diagram

Or

Contact Diagram

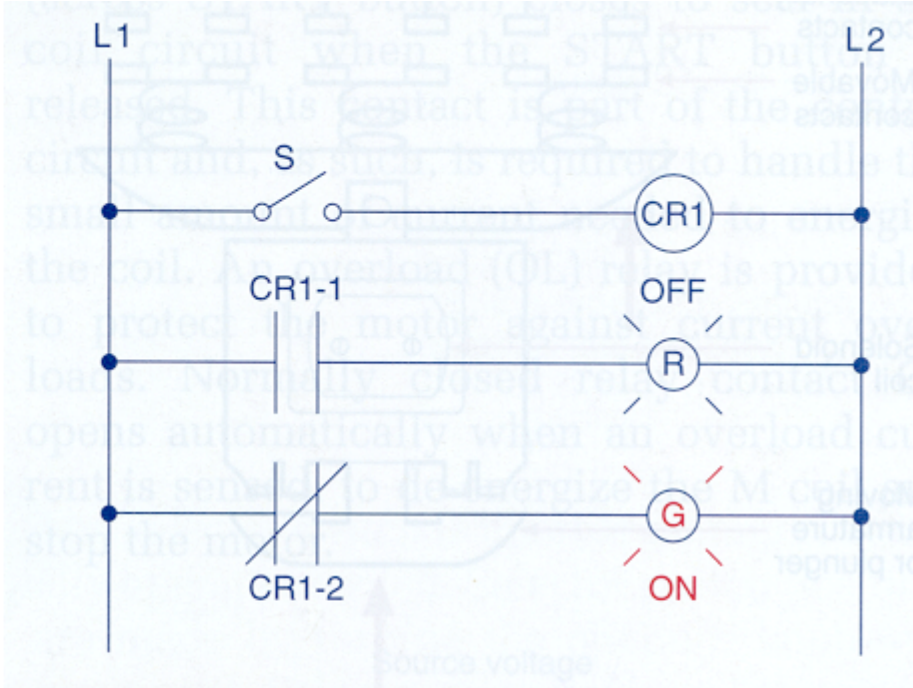


Fig. 6-3
Relay circuit—switch open.

Methodologies for the implementation of solutions in industrial automation

Contacts diagram

Example

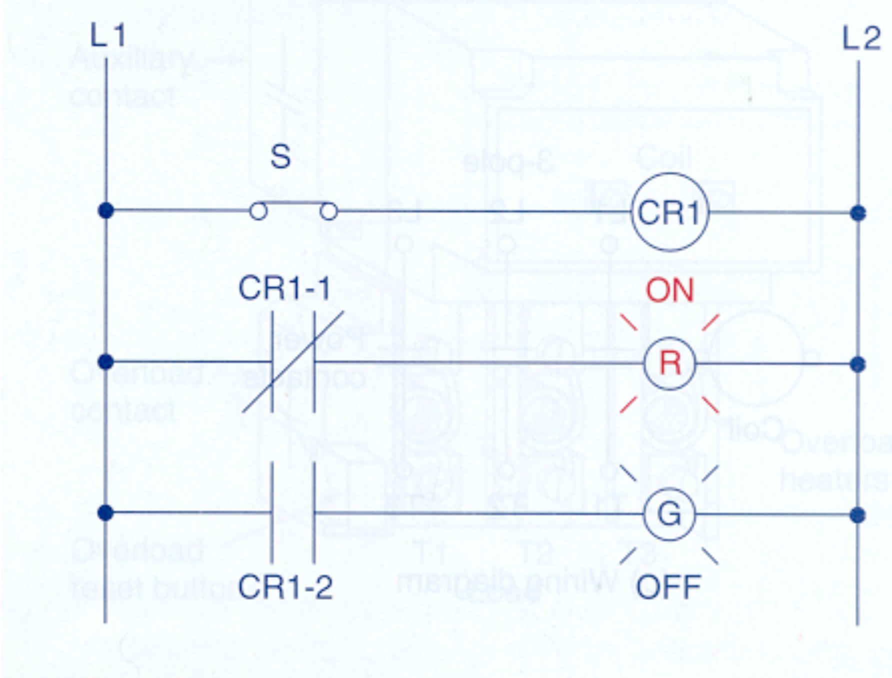


Fig. 6-4
Relay circuit–switch closed.

Example:

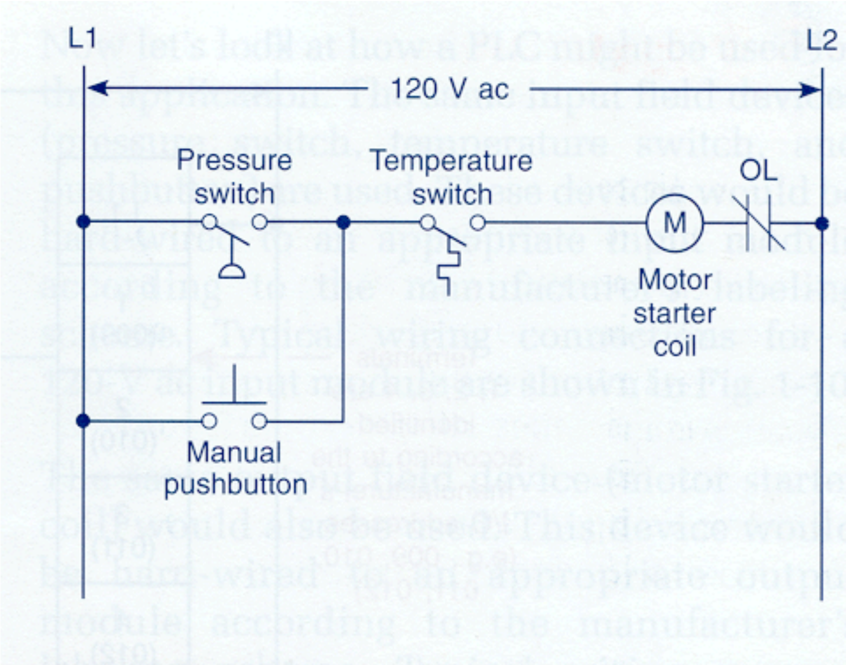


Fig. 1-13 Relay ladder diagram for modified process.

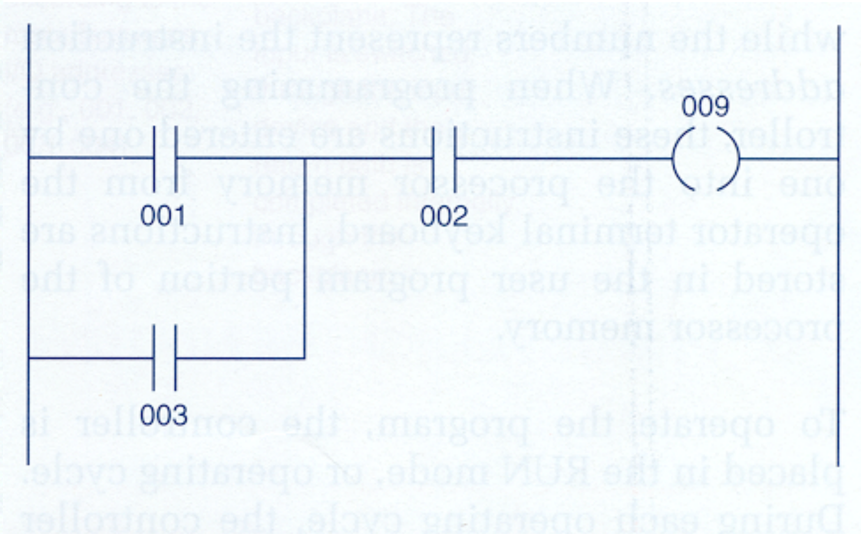


Fig. 1-14 PLC ladder logic diagram for modified process.

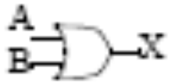
Logic Functions

AND

$X = A \cdot B$

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

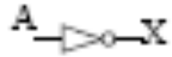
OR



$X = A + B$

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

NOT



$X = \overline{A}$

A	X
0	1
1	0

NAND

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

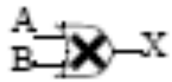
A	B	X
0	0	1
0	1	1
1	0	1
1	1	0

NOR

$X = \overline{A + B}$

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

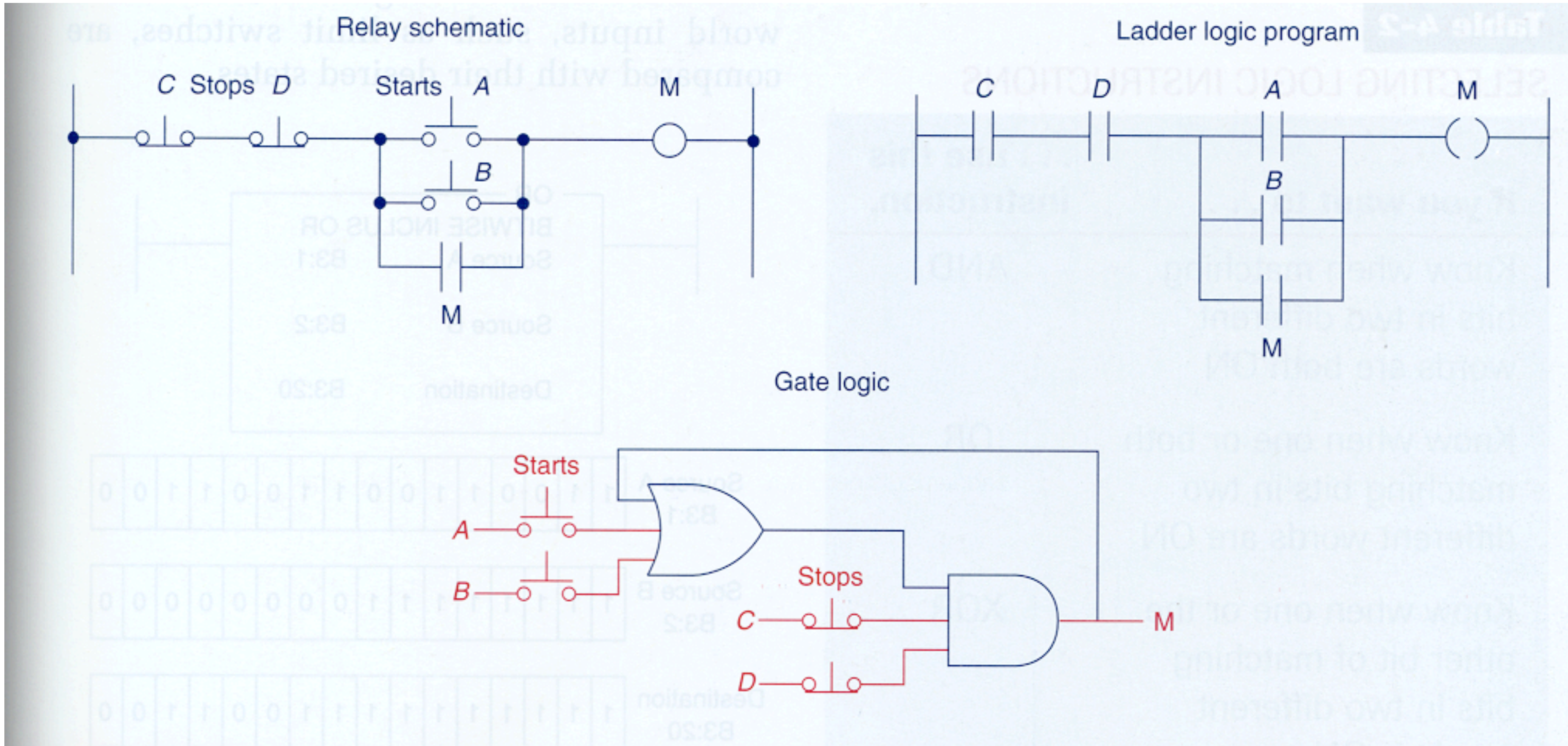
EOR



$X = A \oplus B$

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