



Automation & Control

The Process

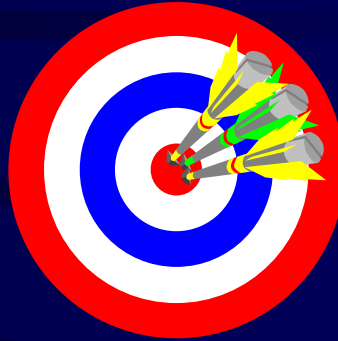
Any process consist of :-

- (1) Application
- (2) Control System



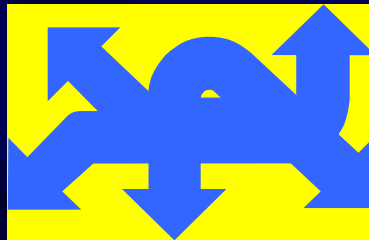
Automation Objectives

Directly



Reducing cost
Improving quality

Indirectly



Improving working
condition

Automatic Control

Control System is divided into



Processing section has the task to produce predetermined responses (in the form of outputs) as a result of information by the input signal measurements

Inputs

Input signals are provided by transducers / detectors that convert physical quantities into electrical signals. Depending on transducer used, the information detected can be discontinuous (binary) or continuous (analog) representation of the input quantity

<i>Transducers</i>	<i>Measured Quantity</i>	<i>Output Quantity</i>
Switch	Movement / Position	Binary Voltage
Limit Switch	Movement / Position	Binary Voltage
Thermostat	Temperature	Varying Voltage
Thermocouple	Temperature	Varying Voltage
Thermistor	Temperature	Varying Resistance
Strain Gauge	Pressure / Movement	Varying Resistance
Photo Cell	Light	Varying Voltage
Proximity Cell	Presence of Objects	Varying Resistance













Outputs

Output devices (like relays, pumps, motors..) are tools used by a control system to alter certain key element or quantities within the process. they are also transducers but contrary signals from the control system into other necessary. There are also discontinuous (binary) or continuous (analog) devices

<i>Output device</i>	<i>Quantity Produced</i>	<i>Input</i>
Motor	Rational motion	Electrical
Pump	Rational motion + product displacement	Electrical
Piston	Linear motion / pressure	Hydraulic / pneumatic
Solenoid	Linear motion / pressure	Electrical
Heater	Heat	Electrical
Valve	Orifice variation	Electrical/Hydraulic/pneumatic
Relay	Elec. Switching / limited physical movement	Electrical

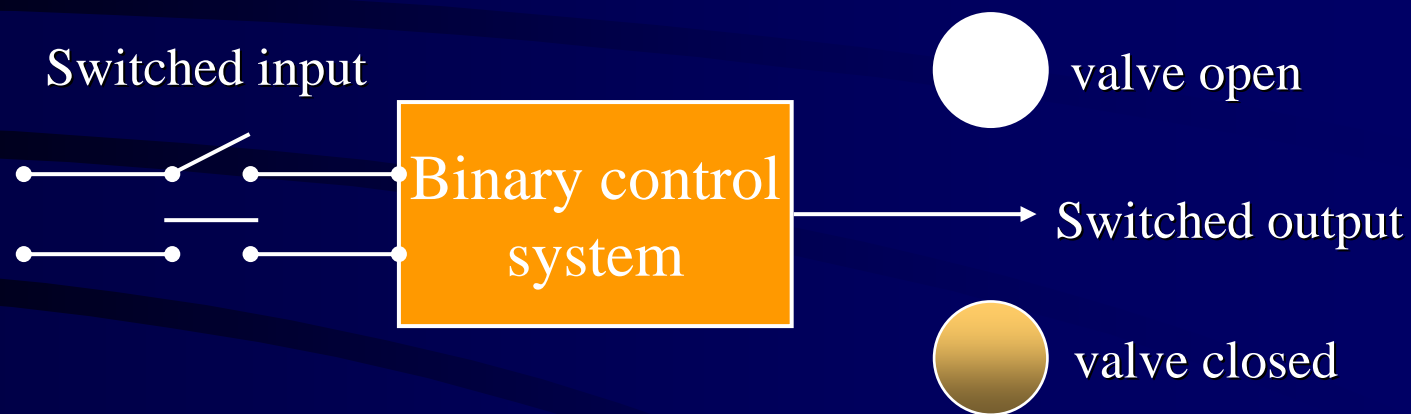
Processing Section

This corresponds to the operations required to keep process “in control” in conjunction obtained from input readings, producing resultant output action. input causes output action due to a control plan which can either hardwired or programmable

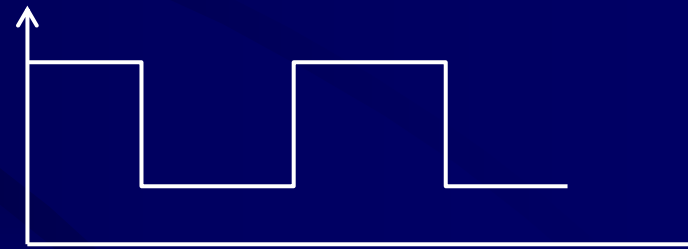
System	Type	Hard	program
Relay	Digital		
Electrical logic	Digital		
Pneumatic logic	Digital		
Analog logic	Digital		
Computers	Digital/analog		
PLCs	Digital		

Digital Systems

Discontinuous or on / off control is most common system, since many machines and processes consist of units controlled by a larger number of simple operation or sequence steps

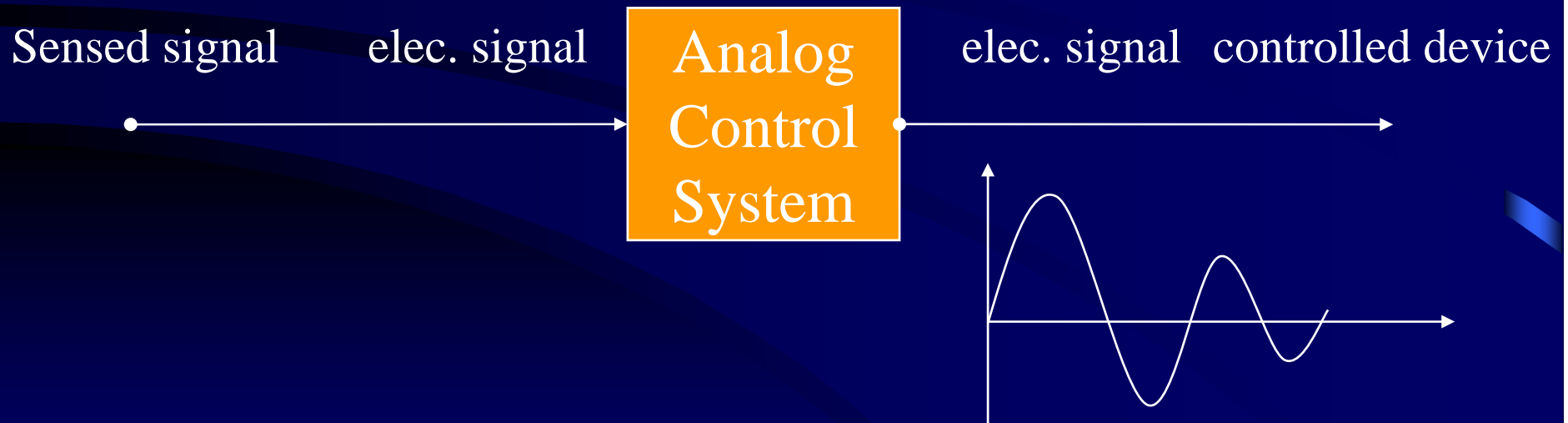


Many devices produce or respond to digital signals, where there are only one of two conditions



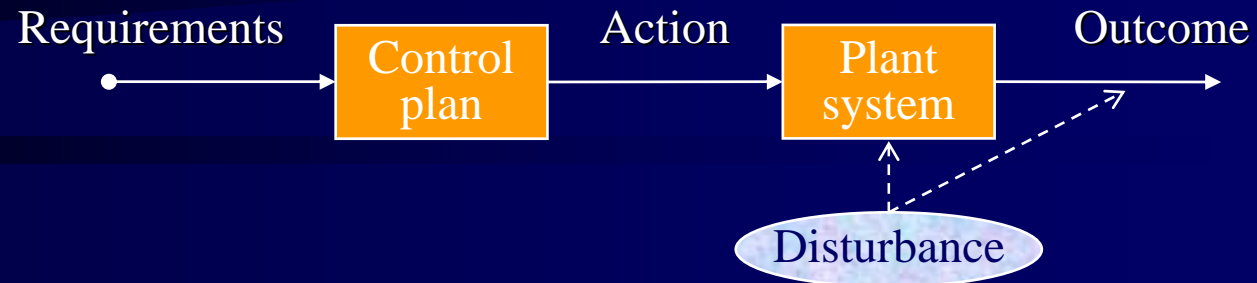
Analog Systems

Continuous or analog control is related to the varying quantities such as temperature, speed, ... change gradually and continuously across an infinite of values.

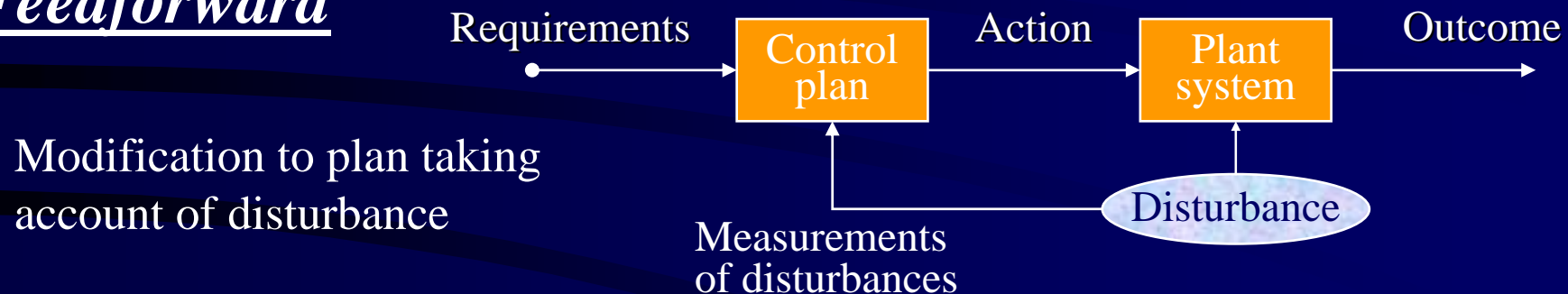


Control Strategies

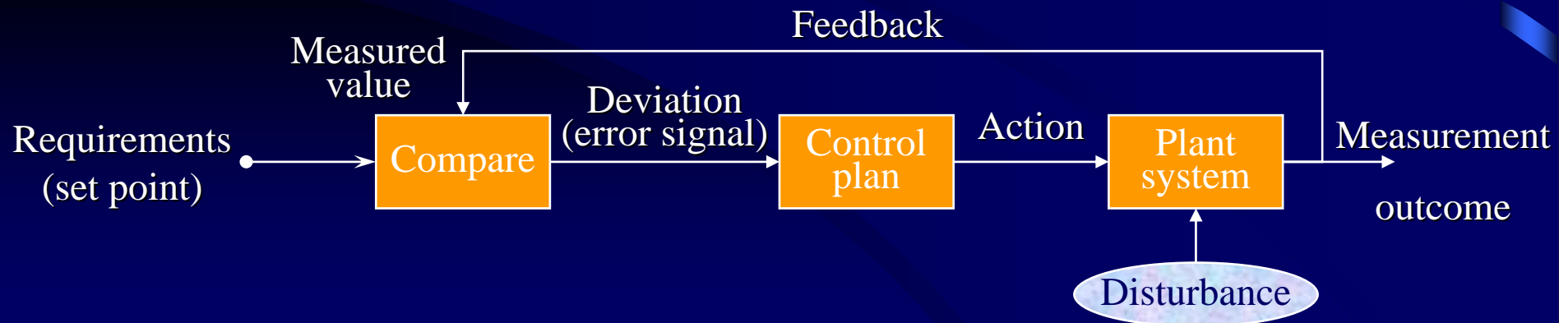
Open Loop



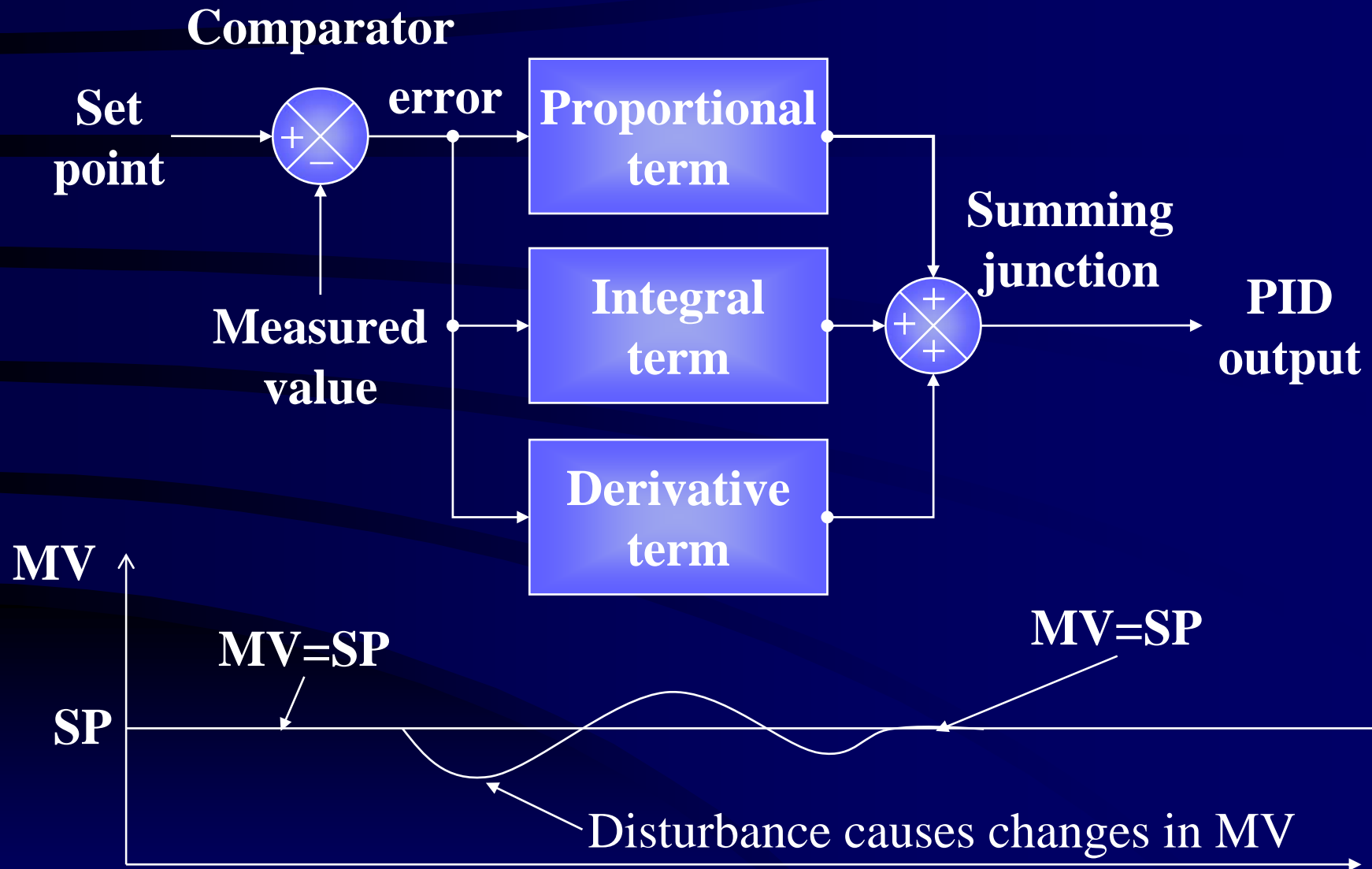
Feedforward



Closed Loop



PID Controller Structure



Industrial Processes

Continuous

I/P is introduced and runs continuously producing an O/P process may run for long period of time typically minutes hours or even weeks. (e.g steel sheet Production)

Batch

A batch process uses a set quantity of I/P material & performs process operations on this material .producing a specific quantity of finished O/P product that will undergo further stages of processing. (e.g food&beverage production)

Discrete

in this type of process an individual item under goes various operations before being produced in a final form alternatively, several components may be combined Within the process. to emerge as one unit

Relay Control

- ☺ Group of relays with large number of contacts .
- ☺ space required .
- ☺ Fixed application,
- ☺ Simple control tasks.
- ☺ Difficult expansion and/ or modification.
- ☺ Slow action.

relay diagram basic
design of any
control system

But!

Relays continue to be used as output device
another types of control systems, being ideal for the
conversion of small signals to higher current /
voltage driving signal

Electronic Control

Linear integrated circuits

- 📖 Handle analog signals.
- 📖 Important component "op-amp".
- 📖 Involve complex math (differentiation, integration, ...).
- 📖 Bases of loop controls.
- 📖 Limited fine tuning of feedback systems.

Digital integrated circuits

- ✎ Deal exclusively with binary signals.
- ✎ Process information through logic gates.
- ✎ Various logic families (CMOS, TTL, ...).
- ✎ Logic symbols & Boolean algebra...design&analysis.
- ✎ Large ICs with enormous number of gates.
- ✎ Heard of microprocessors.

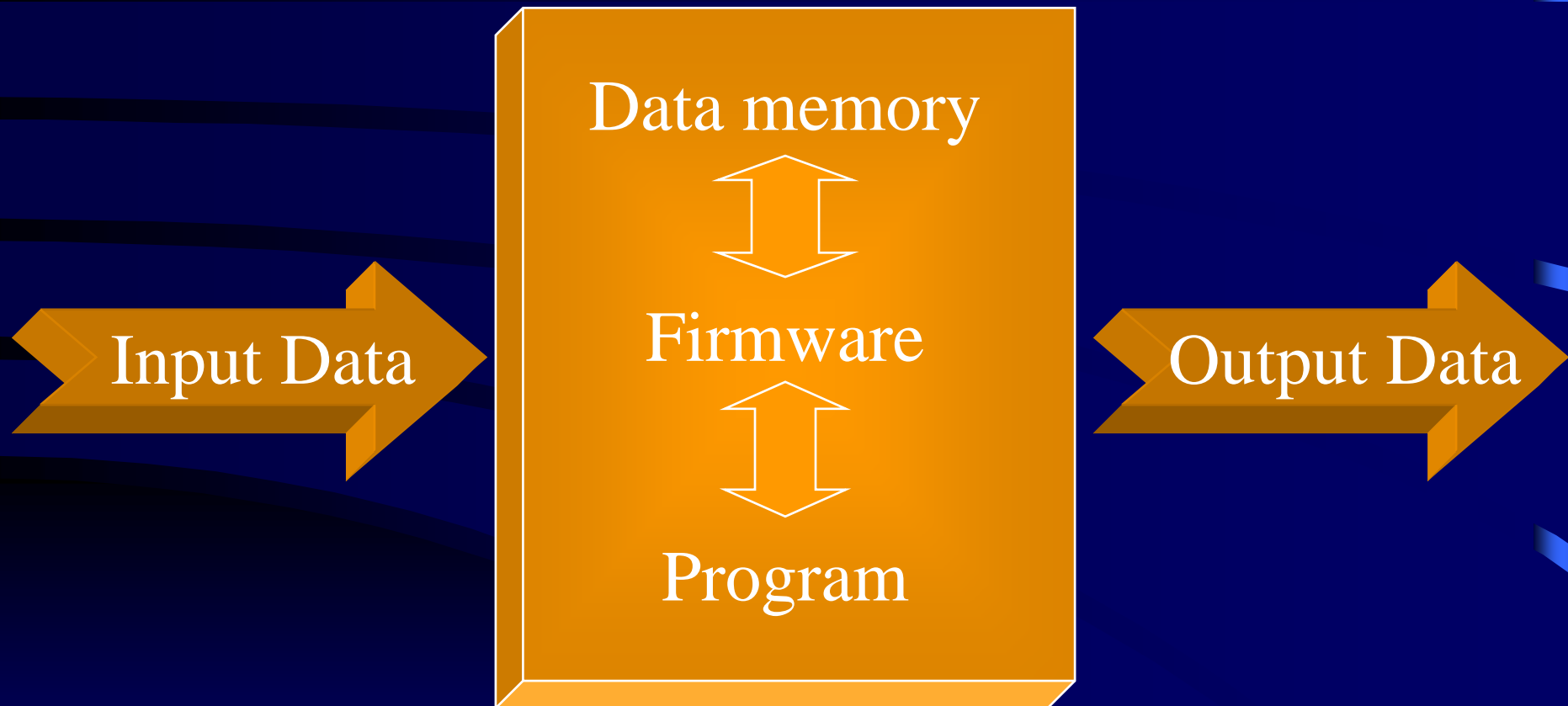
Sequential Control

✓ basis of computer operation.

✓ digital systems that have outputs dependent on previous system state

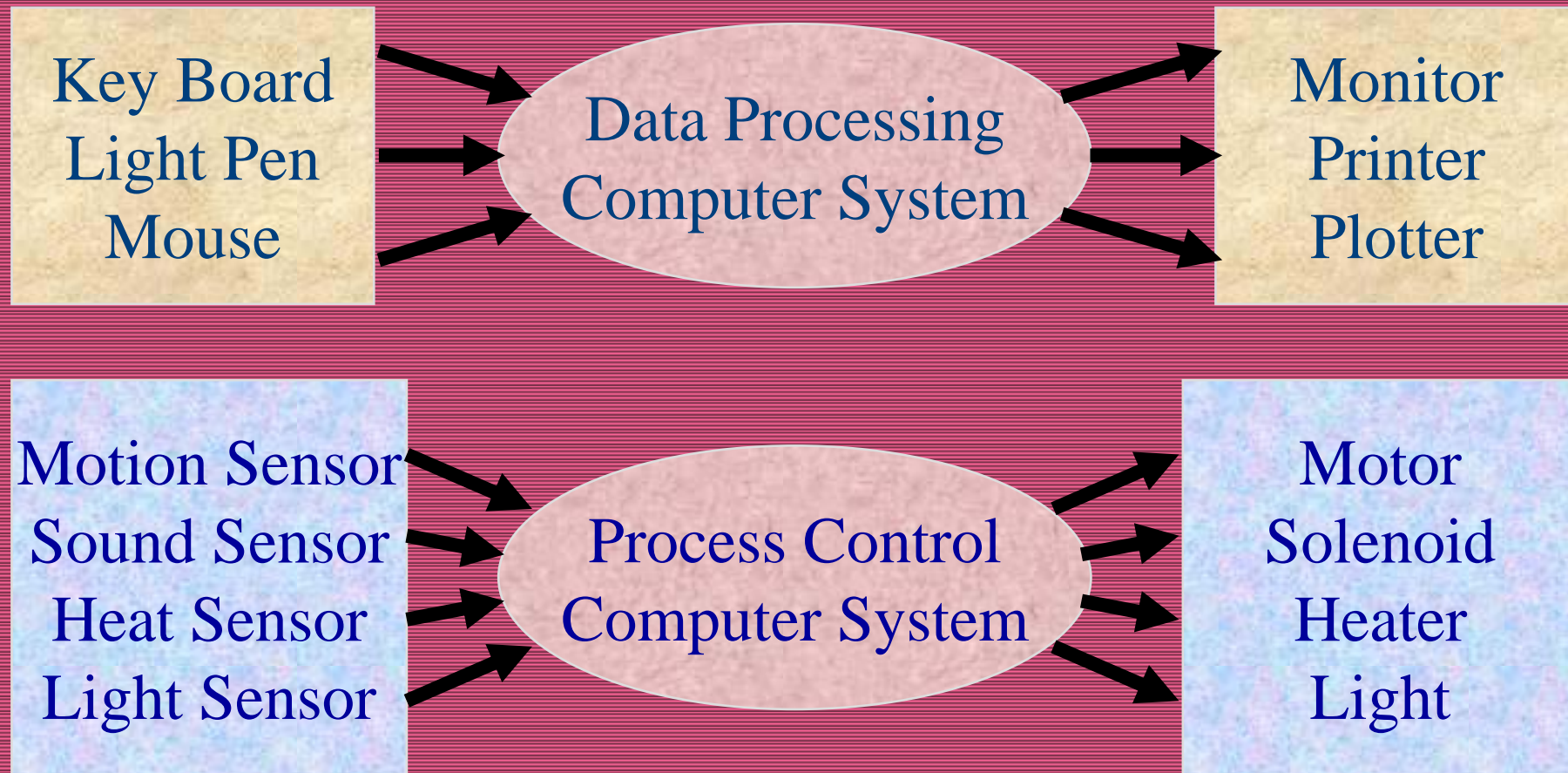


Programmable Computing Control Systems



Programmable logic control

PLC a Process Control Computer System



Definition & Advantages

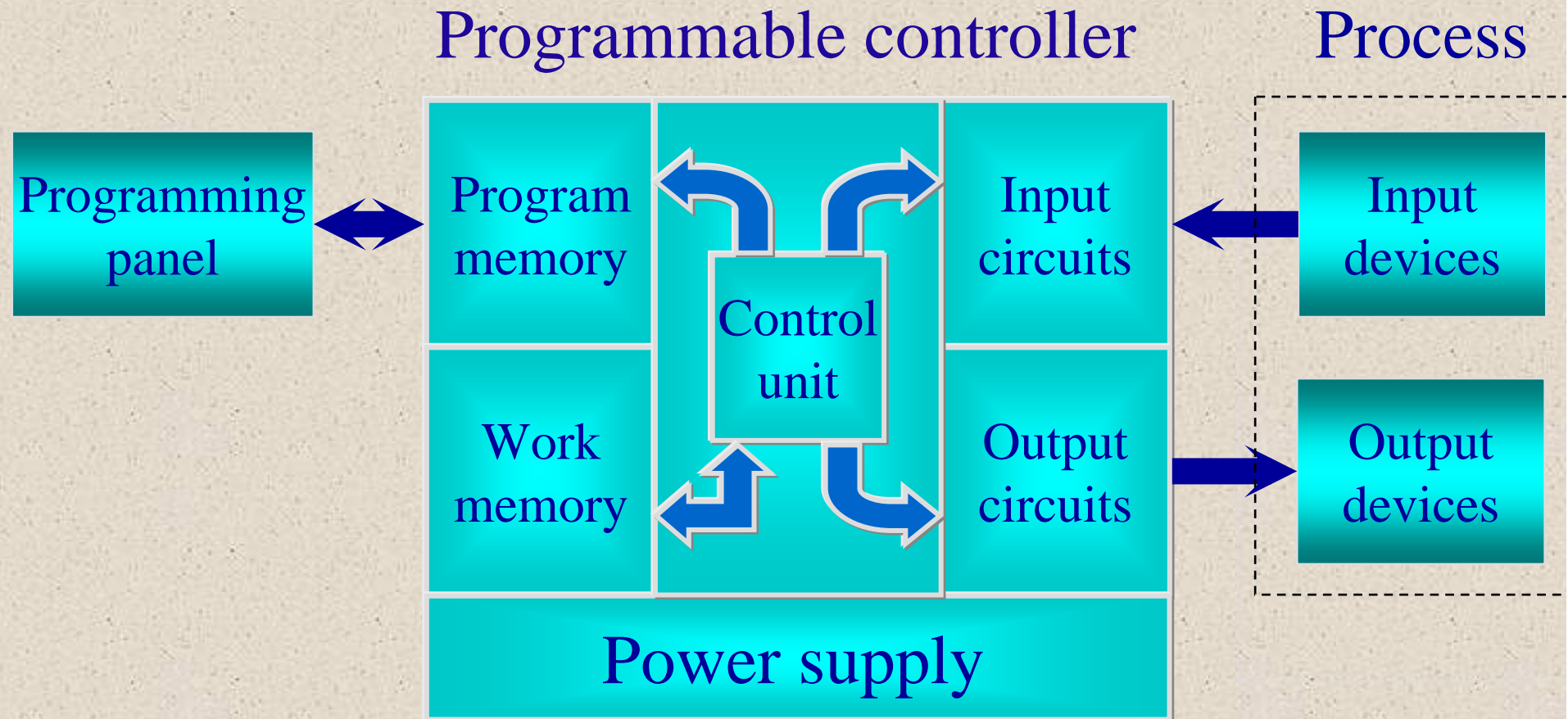
A **PLC** is user-friendly, microprocessor-based, specialized computer that carries out control schemes of many types and levels of complexity. It can be programmed, controlled and operated by person unskilled in computers

- rugged-noise immune equipment
- modular-easy installation/replacement
- standard I/O connections & signal levels
- simple programming.
- compact sizes.
- cost competitive

Comparison with Other Control Systems

C\Cs	Relay systems	Computers	PLC systems
Price Per Function	Fairly Low	High	Low
Physical Size	Bulky	Fairly Compact	Very Compact
Operating Speed	Slow	Fairly Fast	Fast
Noise Immunity	Excellent	Fairly Good	Good
Installation	Time Consuming in All Phases	Time Consuming in Programming	Easy in All Phases
Complex Operation	None	Yes	Yes
Ease of Changes	Very Difficult	Quite Simple	Very Simple
Easy of Maintenance	Poor-large No. Of Contacts	Poor-several Custom Boards	Good-few Standard Cards

Structure



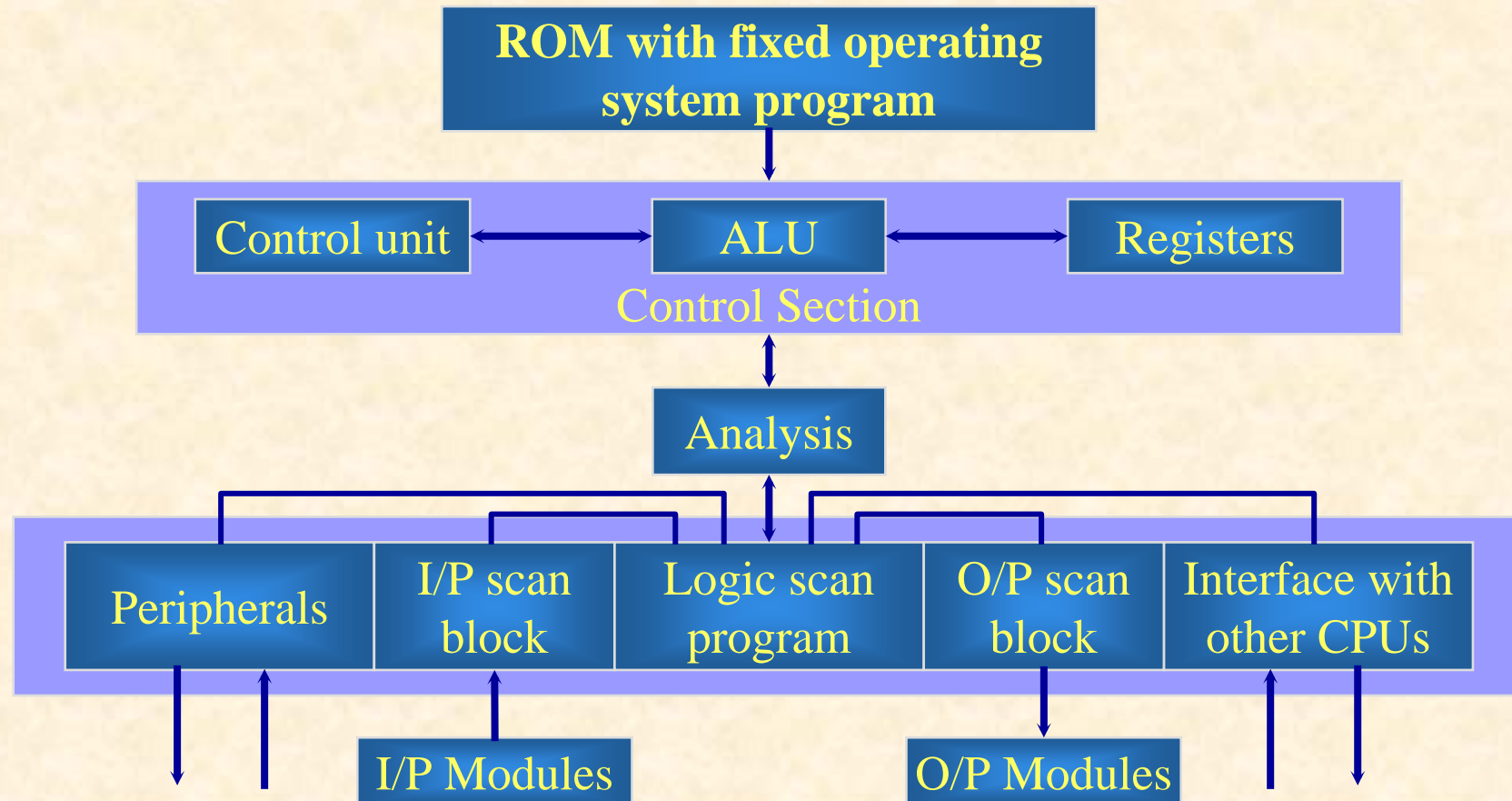
Central Processing Unit

“CPU”(1)

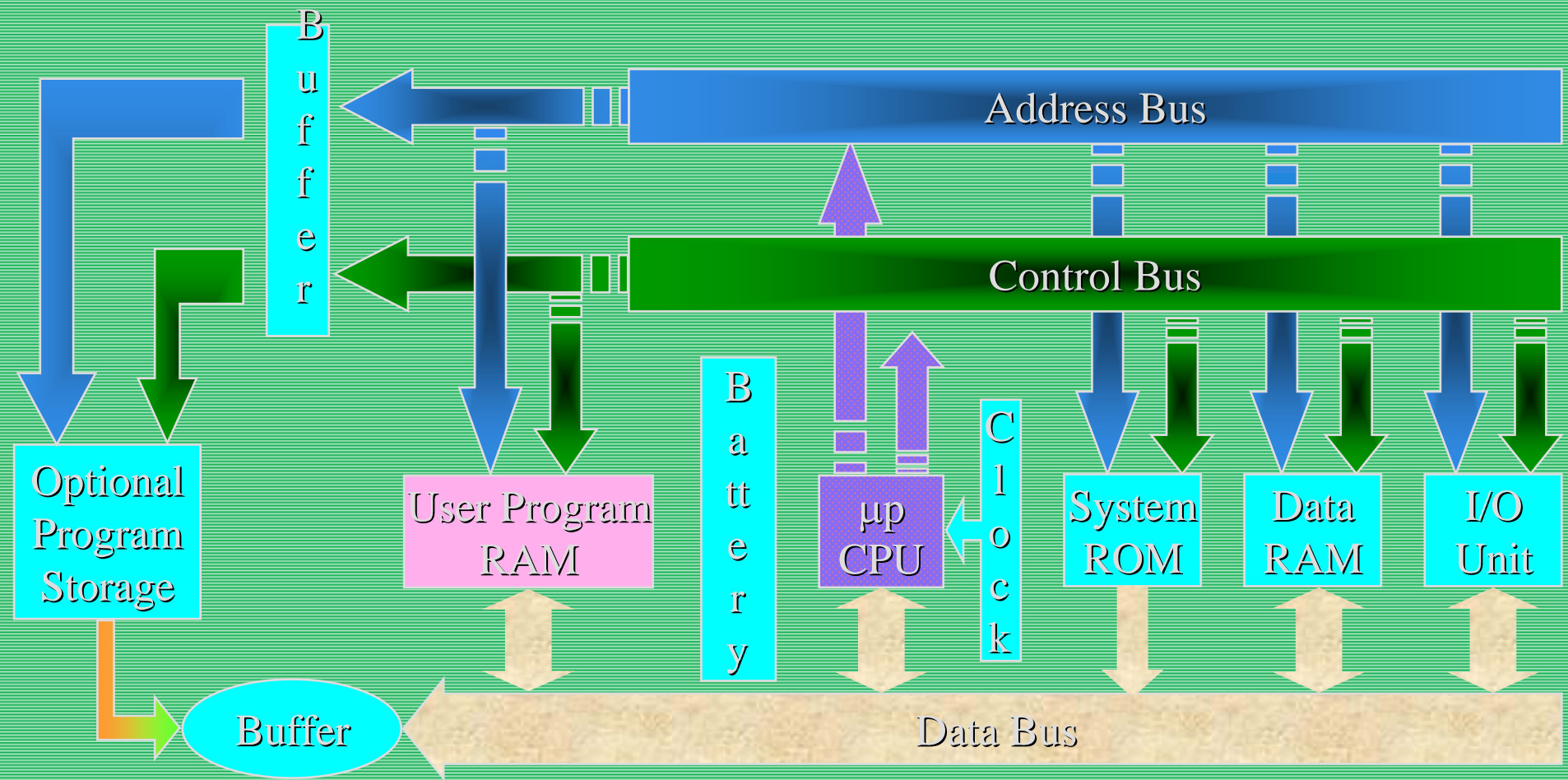
- ⌚ The CPU controls and supervises all operation within PLC, carrying out programmed instructions stored in the memory.
- ⌚ An internal communications highway or bus system carries information to and from CPU, memory and I/O units, under CPU control.
- ⌚ The CPU is supplied with a clock frequency by a quartz crystal or RC oscillator with speed depending on the microprocessor type.
- ⌚ The clock determines the operating speed of the PLC and provides timing/synchronization of all system elements.

Central Processing Unit

“CPU”(2)



Central processing unit “CPU” (3)



System memory

📖 Can be subdivided into two types :

Executive Memory and *Scratchpad Memory*.

📖 *Executive memory* contains the executive operating system .Such system is provided by PLC manufacturer and rarely changed, so it is loaded on a PROM.

📖 It provides the translation between the high level programming language and the binary machine language, scans PLC to update system status and reads inputs and updates outputs.

📖 During administration of these functions, the executive often needs an area of memory to store data temporarily: the memory is called *Scratchpad Memory*, it is a RAM which is not accessible by the user

I/O Status Memory

- & It is a portion of RAM dedicated for storage of current I/O status.
- & As the executive program requires I/O status update, the I/O status memory can be considered as part of system memory

Application Memory

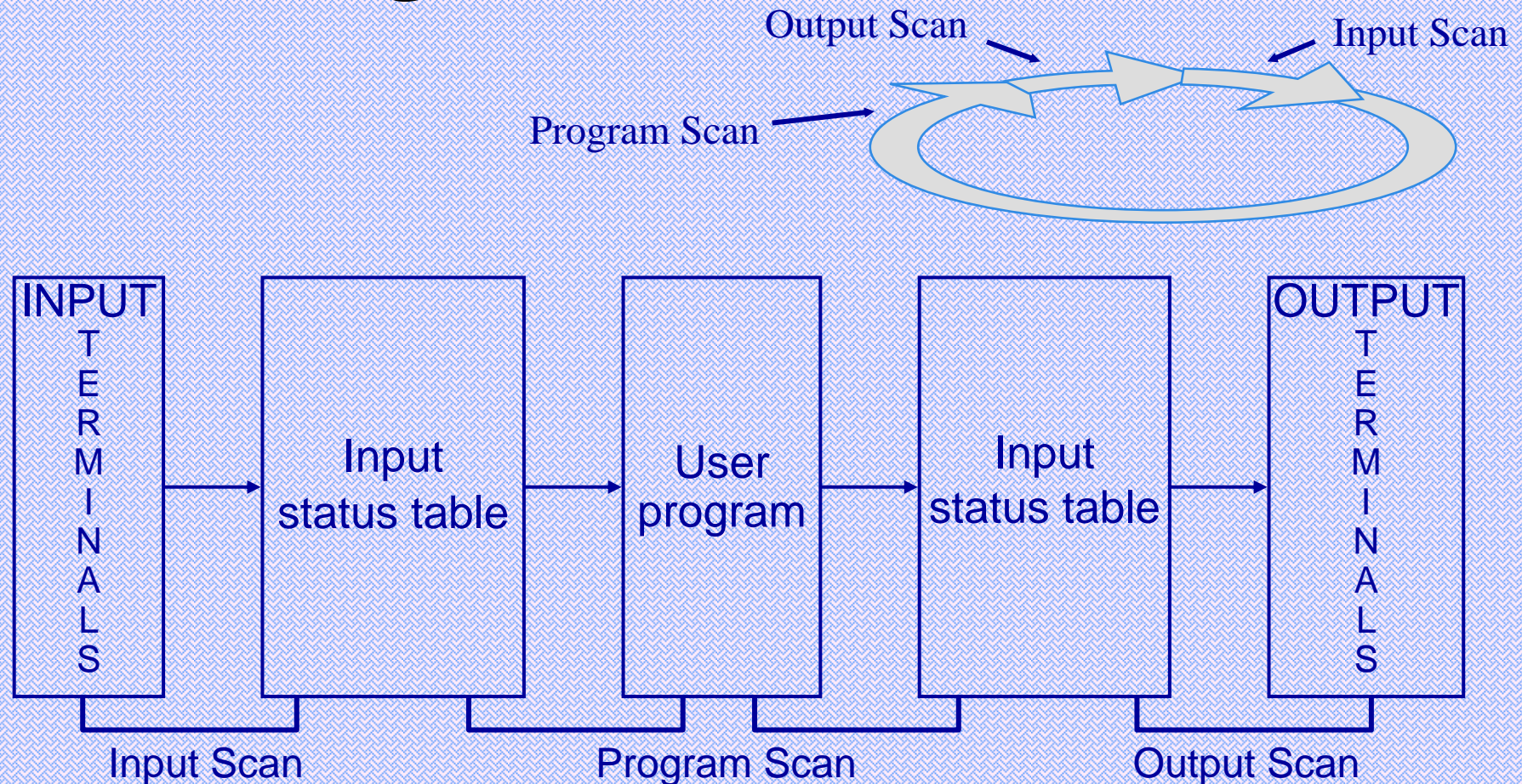
☞ It can be subdivided into two types :

Data memory & User memory.

☞ **Data memory** holds generally the preset values (like timers,...).

☞ **User memory** is the most accessible by the user where all program sequence and specific functions are handled. It is scanned by CPU for instructions when it is directed for scan by the executive.

I/O scanning



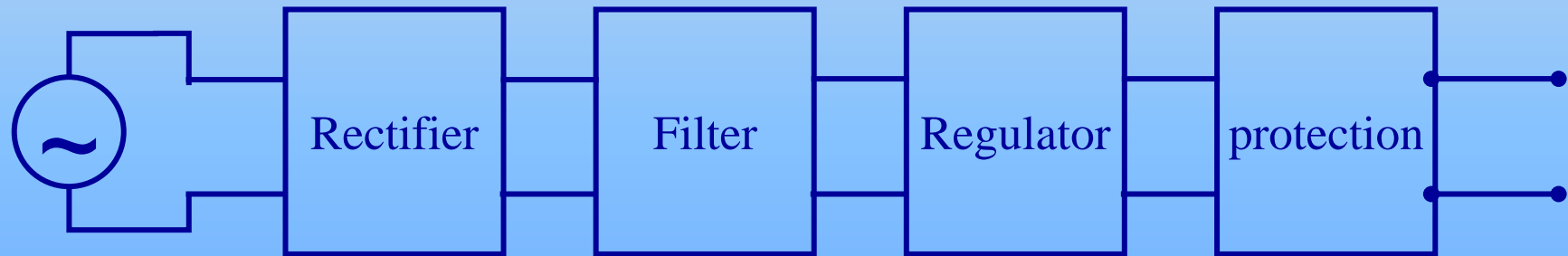
Output terminals are read and input status table is updated accordingly.

During program scan data in I/P table is applied to user program, program is executed and O/P table is updated accordingly.

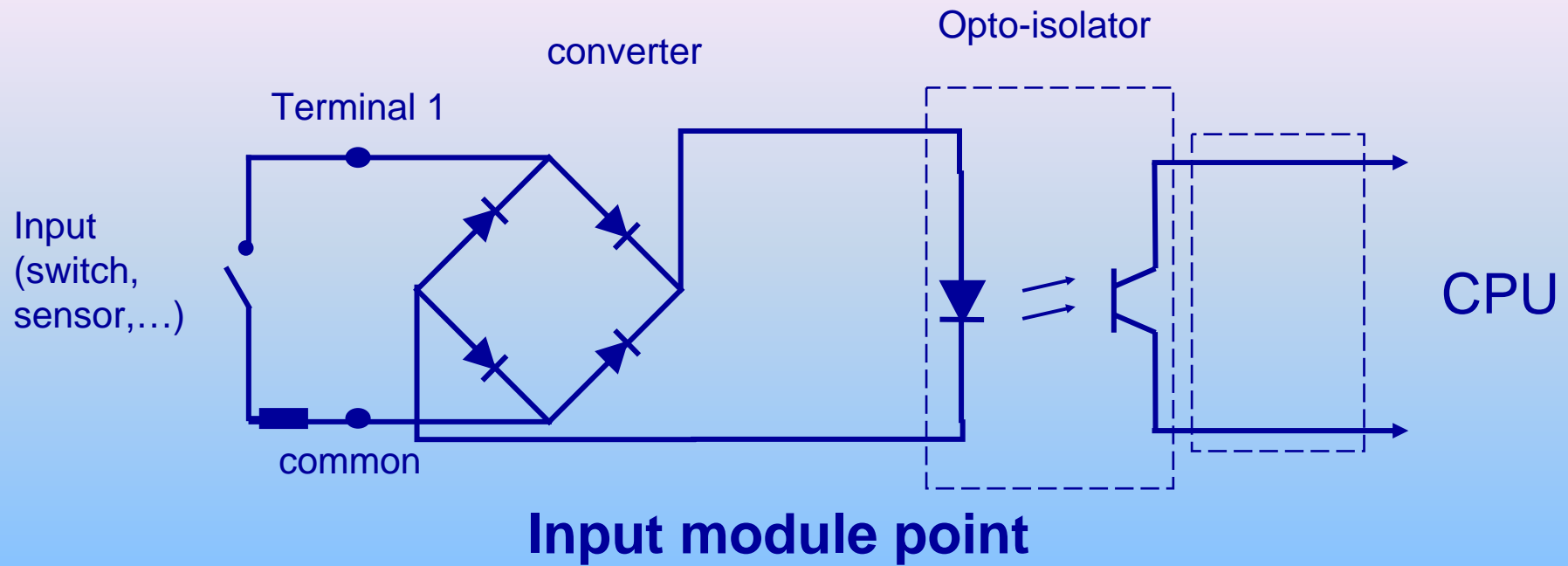
Data associated with O/P status table is transferred to O/P terminal.

Power Supply

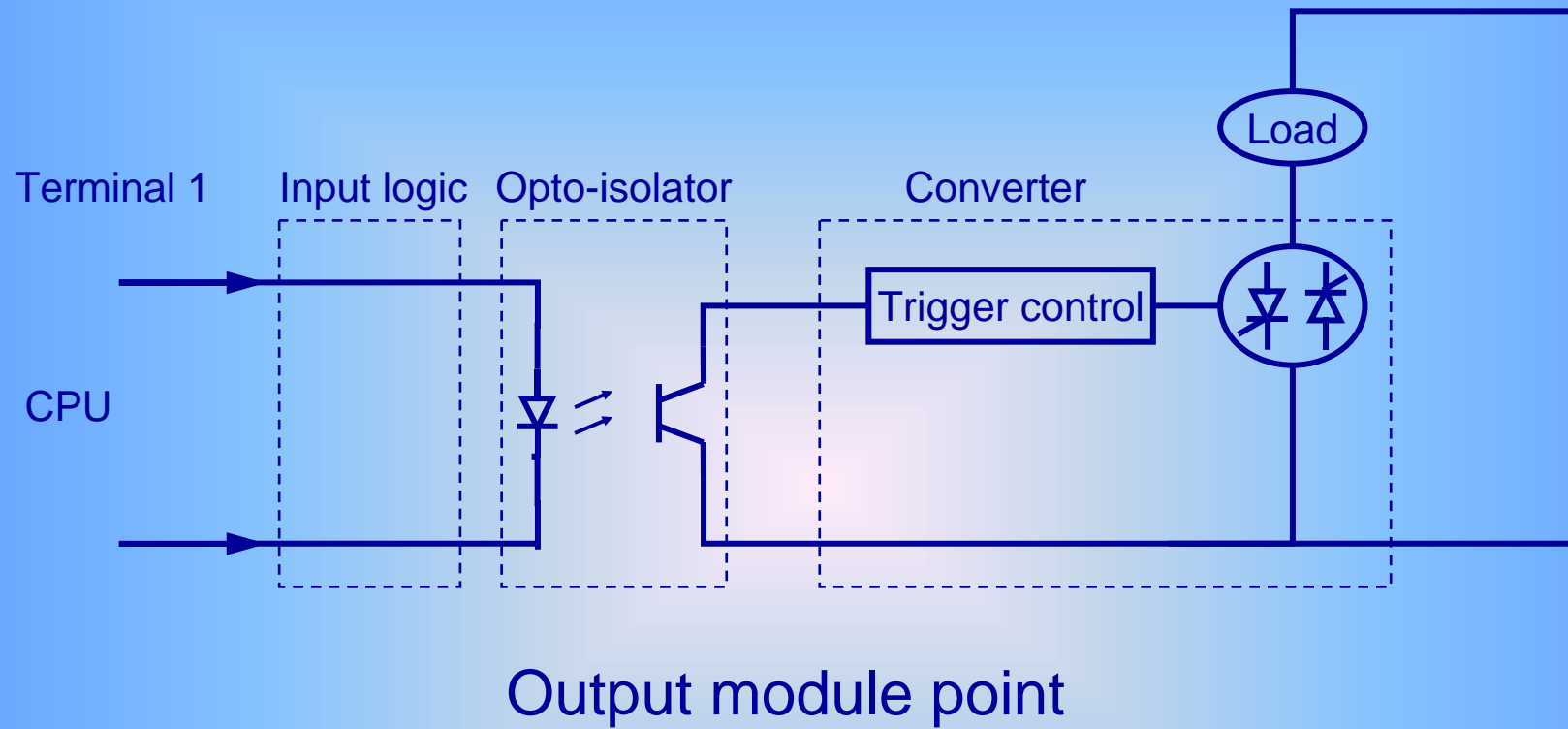
- PLCs internal circuitry operates at $\pm 5\text{V}$ DC.
- Whether the available supply is AC or DC, a power supply is required to condition, regulate, ... this supply to the adequate need of the circuitry.



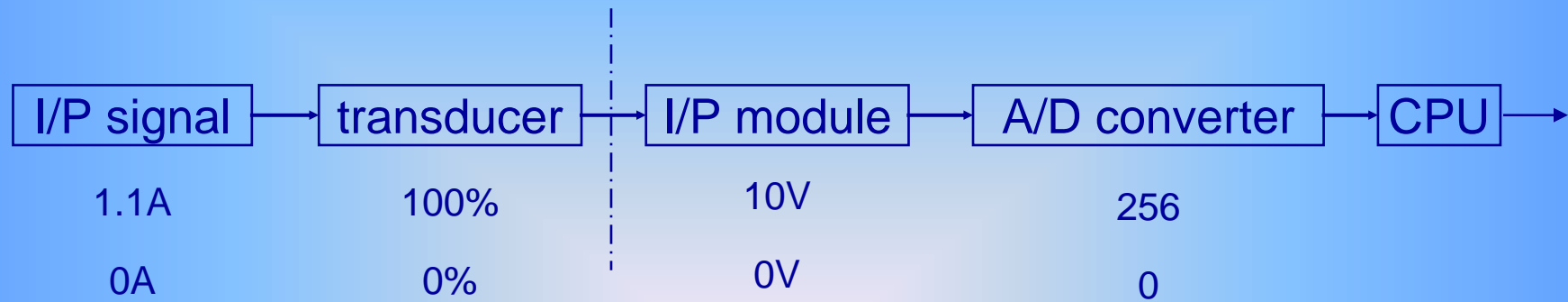
Discrete Input



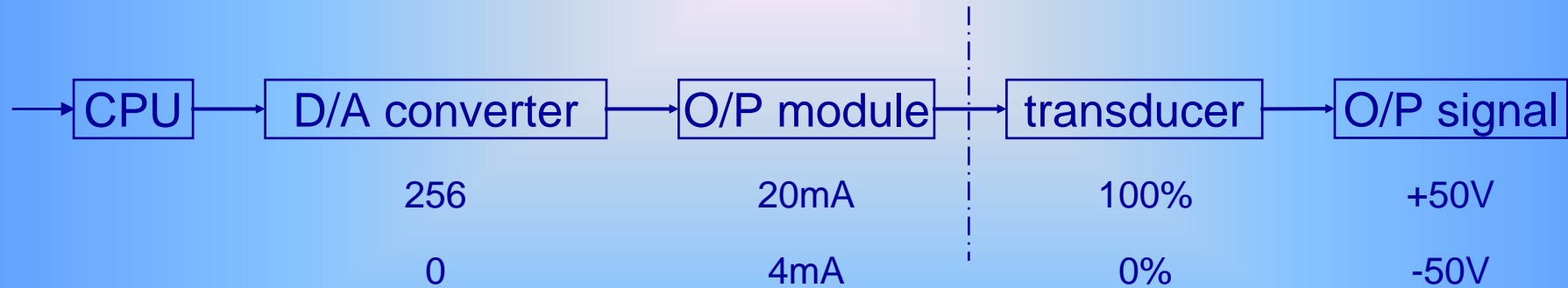
Discrete Output



Analog I/O



Analog Input



Analog Output

I/O Modules

- ❖ PLCs operate at 5V DC to 15V DC, whilst process signals can be much greater or of different levels.
- ❖ The I/O units form the interface between the microelectronics of PLC and the real world outside.
- ❖ These units provide all necessary signal conditioning and isolation functions.
- ❖ I/O modules are available (Digital, analog) with all different process signals which allow PLC to be directly connected to process.

Special Modules

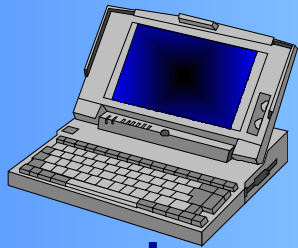
- These modules are intelligent ones which perform certain tasks independent of the CPU.
- The use of such modules in process control is Known as distributed processing.
- Such modules are dedicated computers that perform preset calculations on data received from detectors or other devices connected to it.
- PLC CPU is thus freed to handle larger control functions.

Housing

- ☞ Small PLCs are build of individual printed circuit cards within single compact unit
- ☞ small PLCs are constructed modular basis with function modules slotted into the back plane connectors of the mounting rack
- ☞ modular systems housing or mounting racks are equipped with buses to exchange all information required to run the system: data, control, address,....

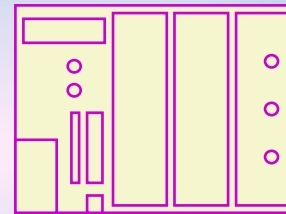
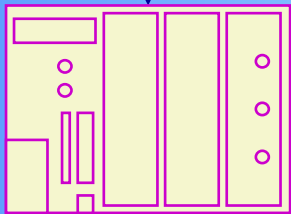
Communication - Point to Point

Between two intelligent devices - CPUs



Links:

- PLC w/ programming terminal.
- PLC w/ Man Machine Interface.



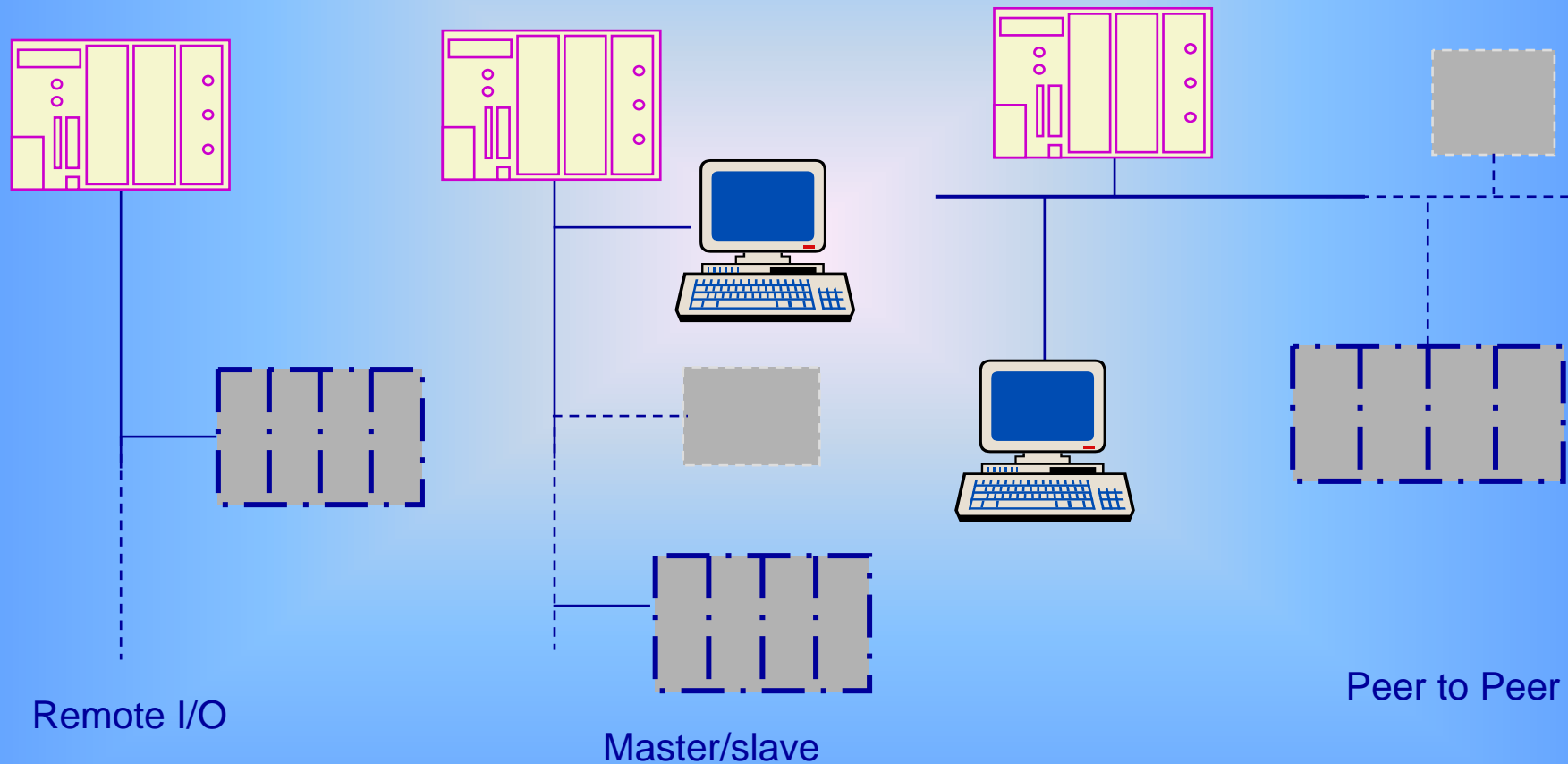
Links:

- PLC w/ other PLC.
- PLC w/ any intelligent device.



Communication - Networking

Between intelligent devices - CPUs & others



Programming Equipment

- ☞ Allowing writing, editing and monitoring a program as well as performing various diagnostic procedures.
- ☞ Three types of programming tools are in common use:
 1. Hand held programmer
 2. Portable programming terminal
 3. S/W to run on PC
- ☞ the third type is commonly used and have larger capabilities.



Programming Languages

IEC 1131

- 1979 :The International Electromechanical Commission assigned the research committee 65A to define a PLC standard.
- Objective :to meet the increasing complexity requirements of control and monitoring systems and the large number of PLCs which are incompatible with each other.
- Its contents :
 - IEC1131-1 :General information (1992).
 - IEC1131-2 :Specifications & equipment testing (1992).
 - IEC1131-3 : Programming languages (1993)
 - IEC1131-4 : Recommendation to the user.
 - IEC1131-5 :Message handling functions specifications.

IEC 1131-3

This standard describes:-

Two textual languages

- Instruction list **IL**
- structured Text **ST**

Two graphic languages

- Ladder Diagram **LD**
- Function Block **FB**

A graphic chart

- Sequential Fn. Chart **SFC**

Instruction List (IL)

- Series of instructions, each one must start on a new line.
- One instruction = operator + one or more operations separated by commas.
- Function Blocks lunched using a special operator.

Label	Operator	Operation	Comment
Run:	LD	%IX1	(*pushbutton*)
	ANDN	%MX5	
	ST	%QX2	(*run*)

Structured Text (ST)

- ☐ Syntax similar to that of Pascal enabling a description of complex algorithmic structure

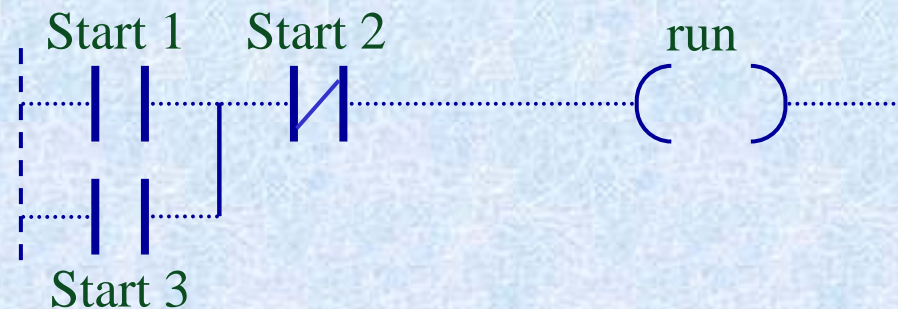
- ☐ succession of statements for assigning variables, controlling functions and function blocks, using operators, repetition, conditional executions.

- ☐ Function blocks launched using a special operator.

```
J:=1  
WHILE J<=100 & X1<>X2DO  
J:=J+2  
END_WHILE
```

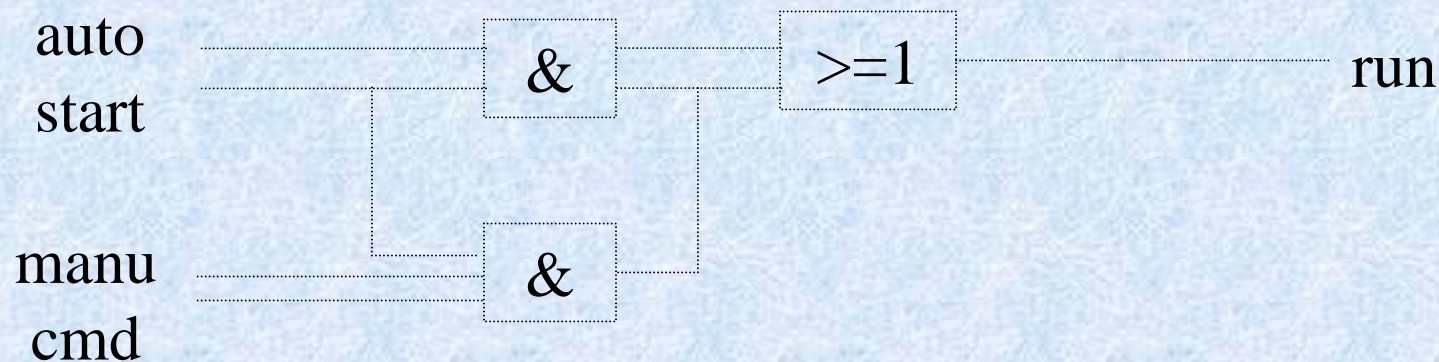
Ladder Diagram (LD)

- Graphic elements organized in networks connected by power supply rails.
- Elements used :contacts, coil, functions, function blocks control elements (jump, return, etc.)



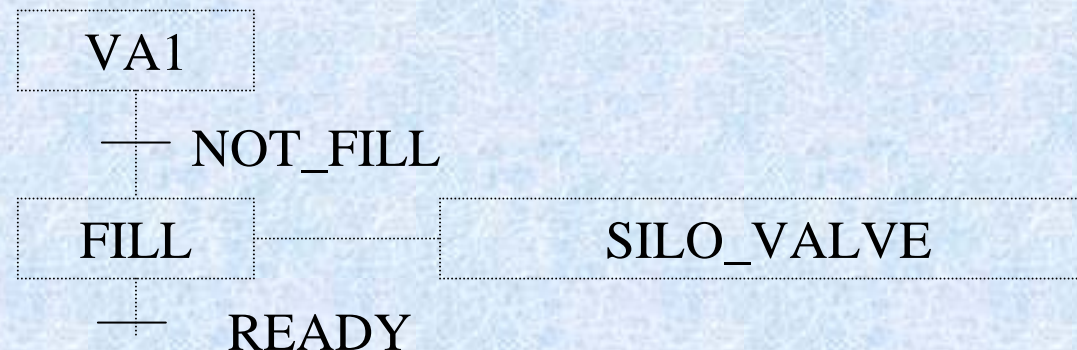
Function Block Diagram (FBD)

- ☐ Representation of functions by blocks linked to each other.
- ☐ Network evaluation :from the O/P of a function block to the I/P of the connected function block.


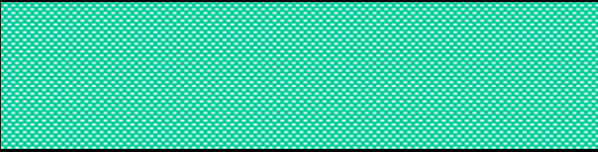





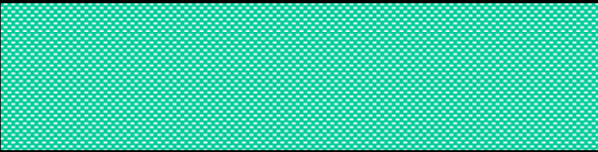






Sequential Function Chart (SFC)

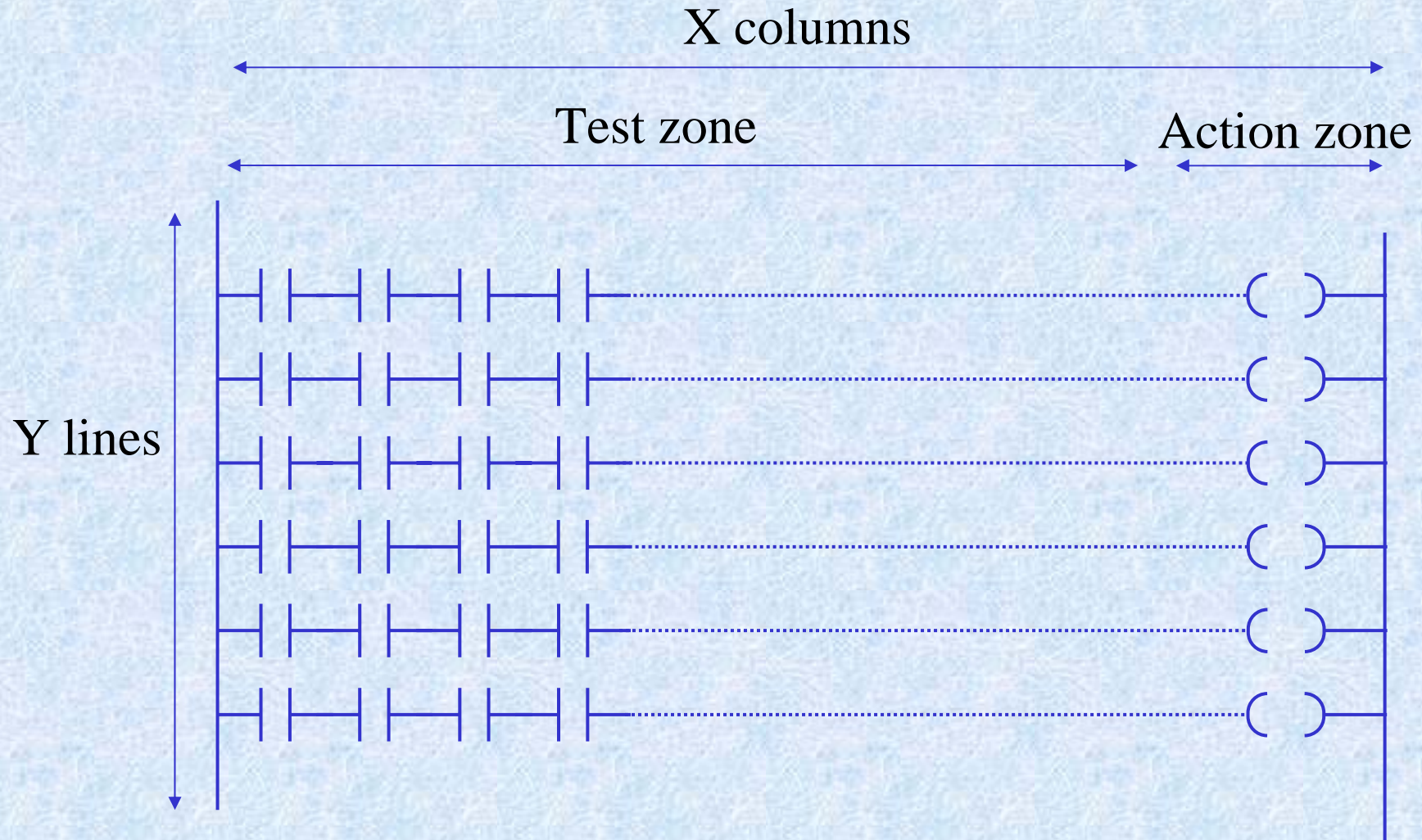
- ☐ To describe sequential control function.
- ☐ steps & transitions represented graphically by a block or literally.
- ☐ Transition conditions in LD, FBD, IL or ST languages.
- ☐ Actions associated with the steps : Boolean variables or a section of the program written in one of the five languages.
- ☐ Association between action and steps in graphical or literal form.



LD Language - Graphic Elements

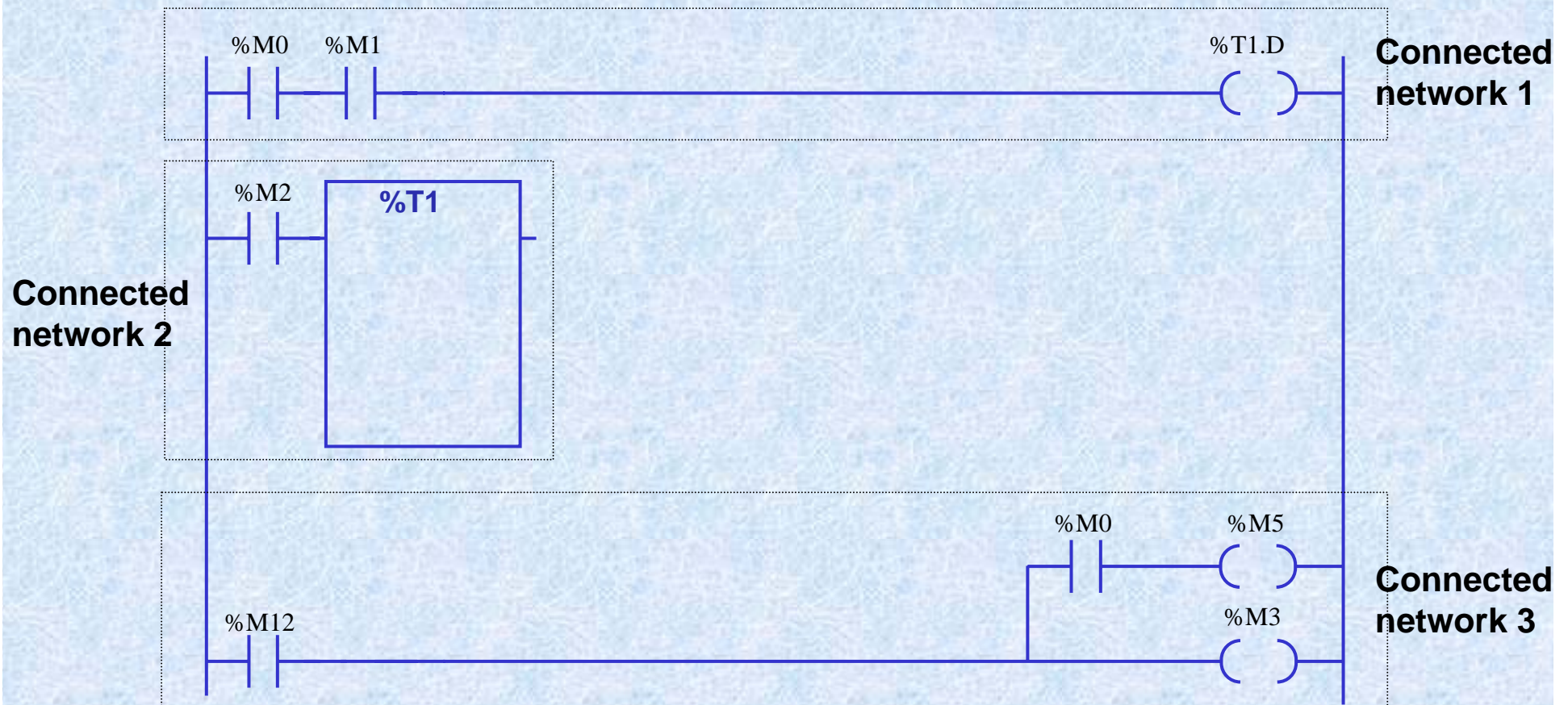
N/O contact		
N/C contact		
Rising edge detection		
Falling edge detection		
Direct coil		
Inverse coil		
Set coil		
Reset coil		

LD Language - Rung Structure



How a Ladder Rung is Executed

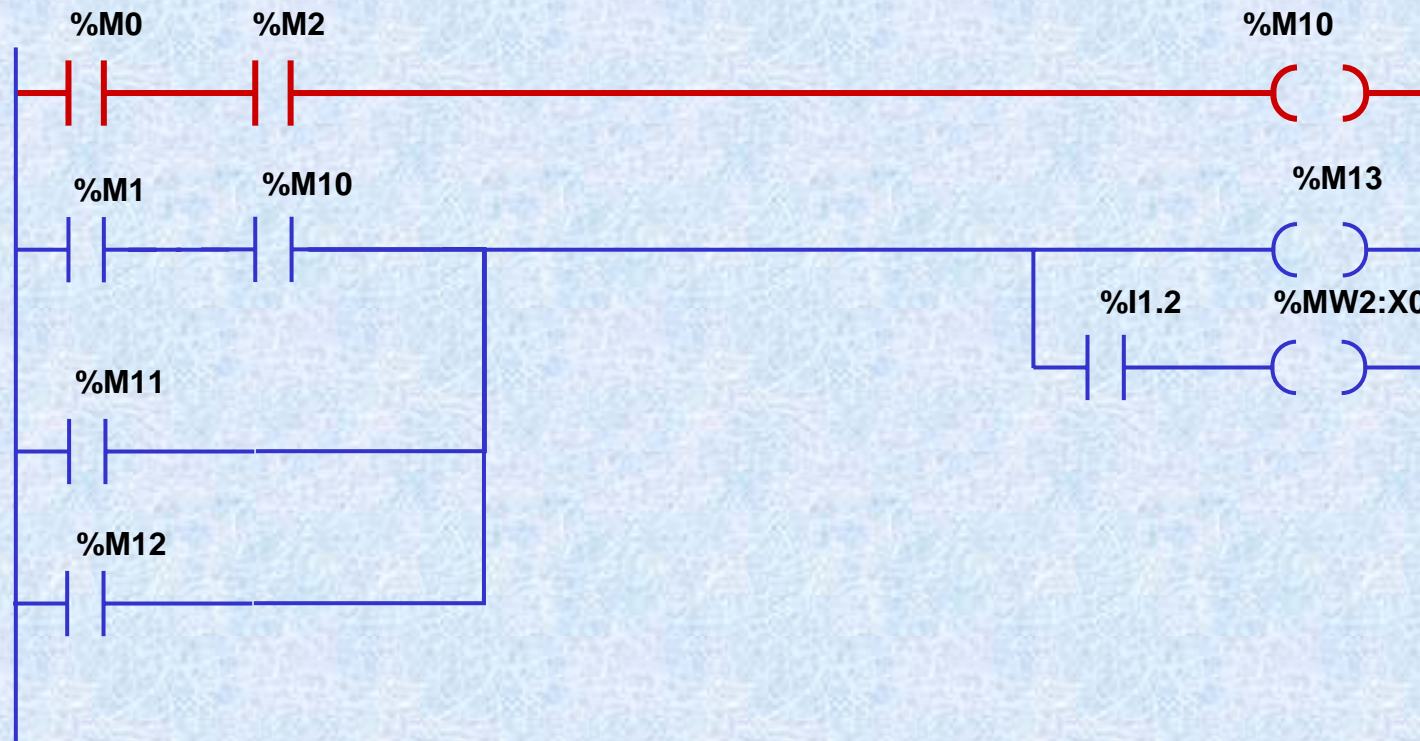
Connected network = independent equation



A network is executed from connected network, and within a connected network, in the direction of the equation: from top to bottom, line by line, and in each line from left to right

How a Ladder Rung is Executed

Example



First coil evaluation (%M10)

Second coil Evaluation (%M13)

Third coil evaluation (%MW2:X0)

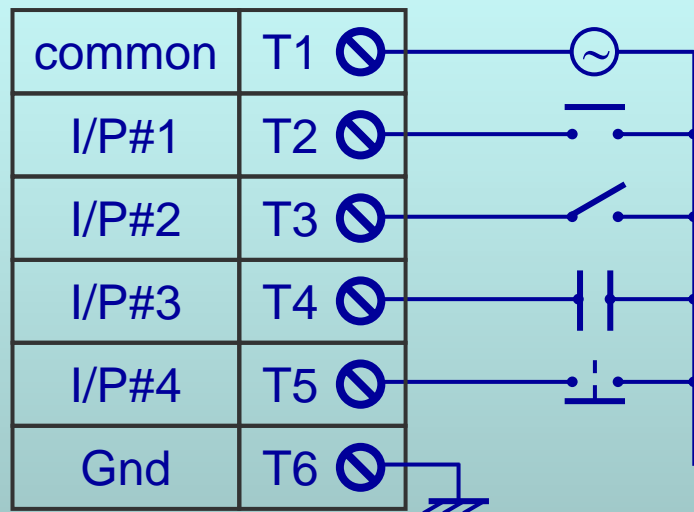
Basic Programming



I/P Addressing

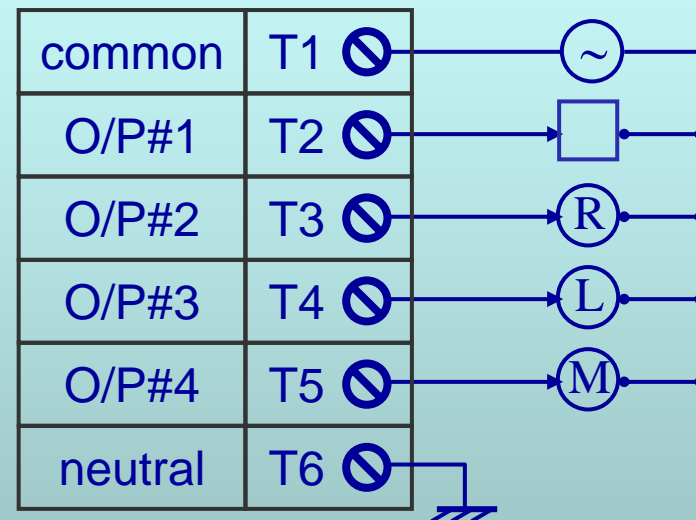
Each input or output is assigned a number on its module, which is referenced to within the program which is referred to as “address”.

I/P#1 physically
%I0.0



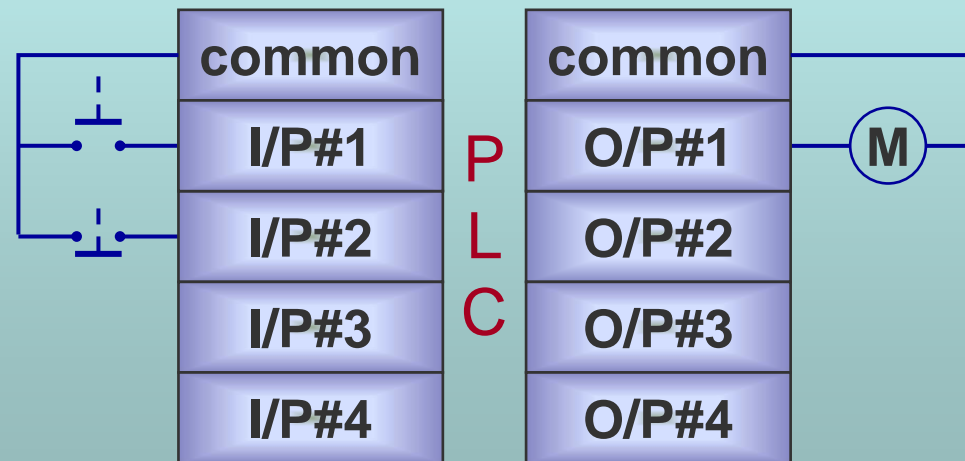
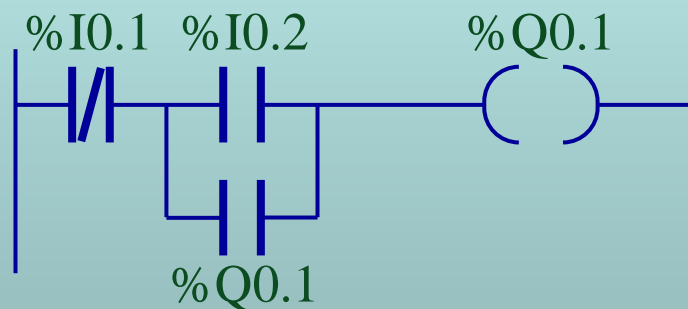
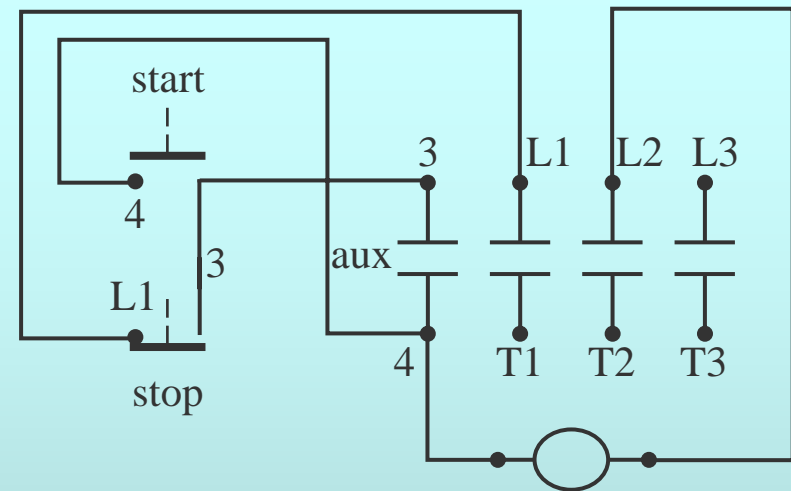
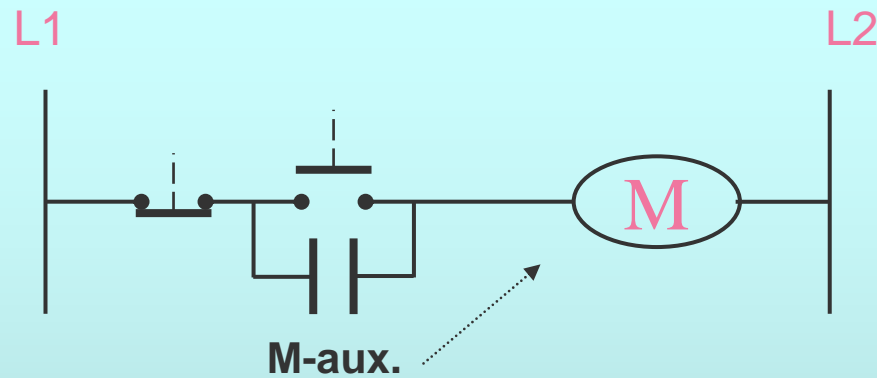
Group of I/Ps on
an AC I/P module

O/P#1 physically
%Q0.0



Group of O/Ps on
an AC I/P module

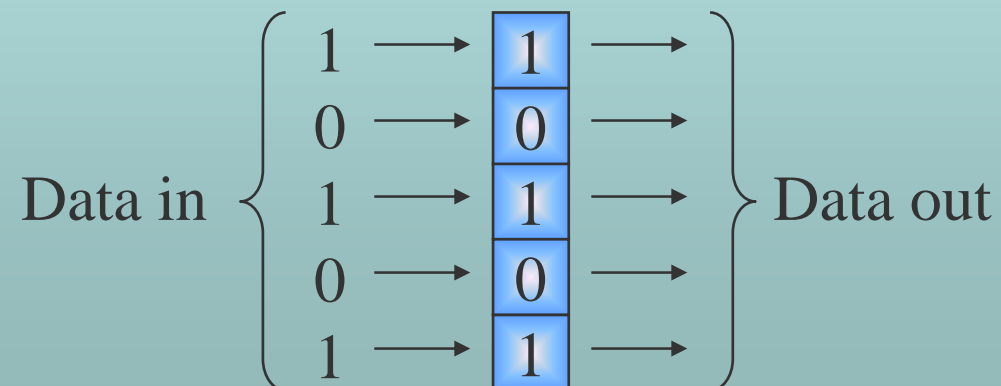
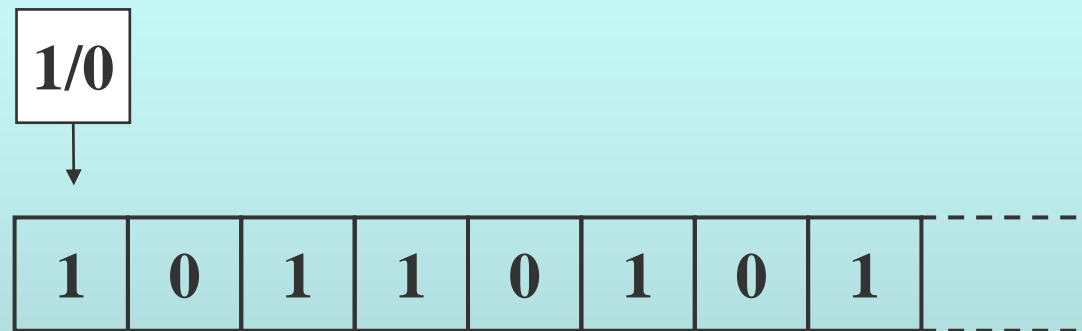
Ladder Logic Vs Conventional Control



Registers

Register is a storage of individual bits.

Data other than simple two state binary can be handled in and out by registers.



Timers

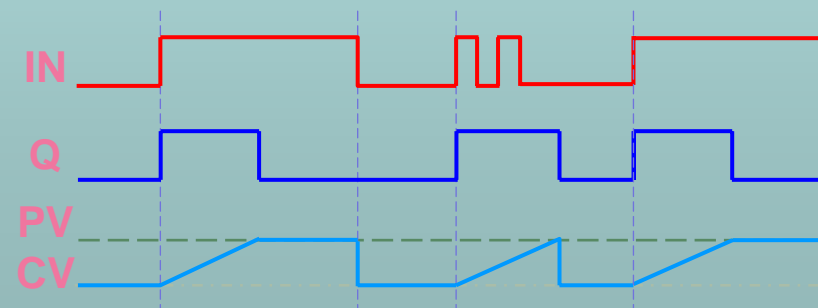
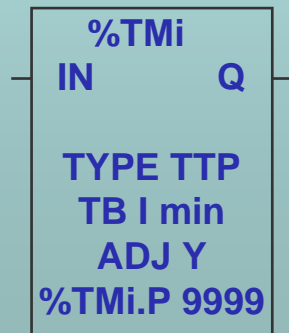
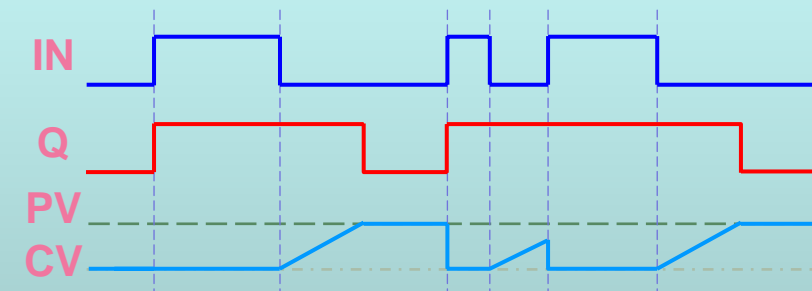
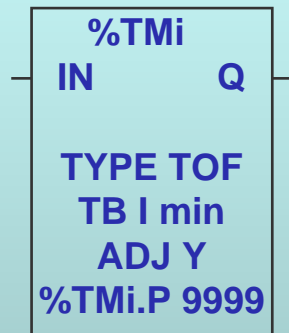
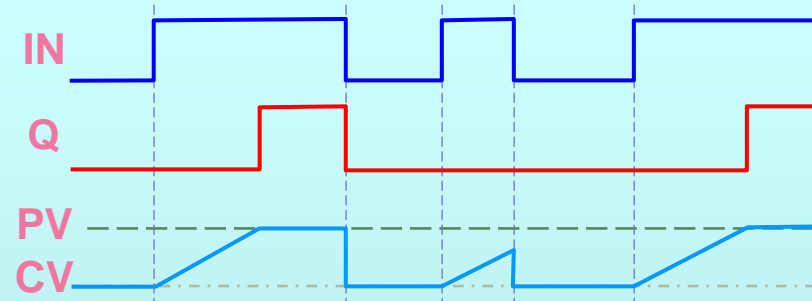
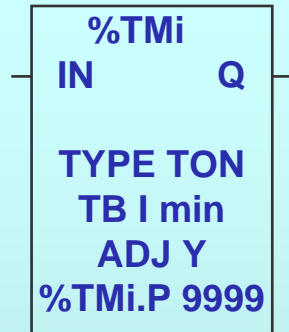
PLC TIMER

programmable variable time as well as fixed time with large time span

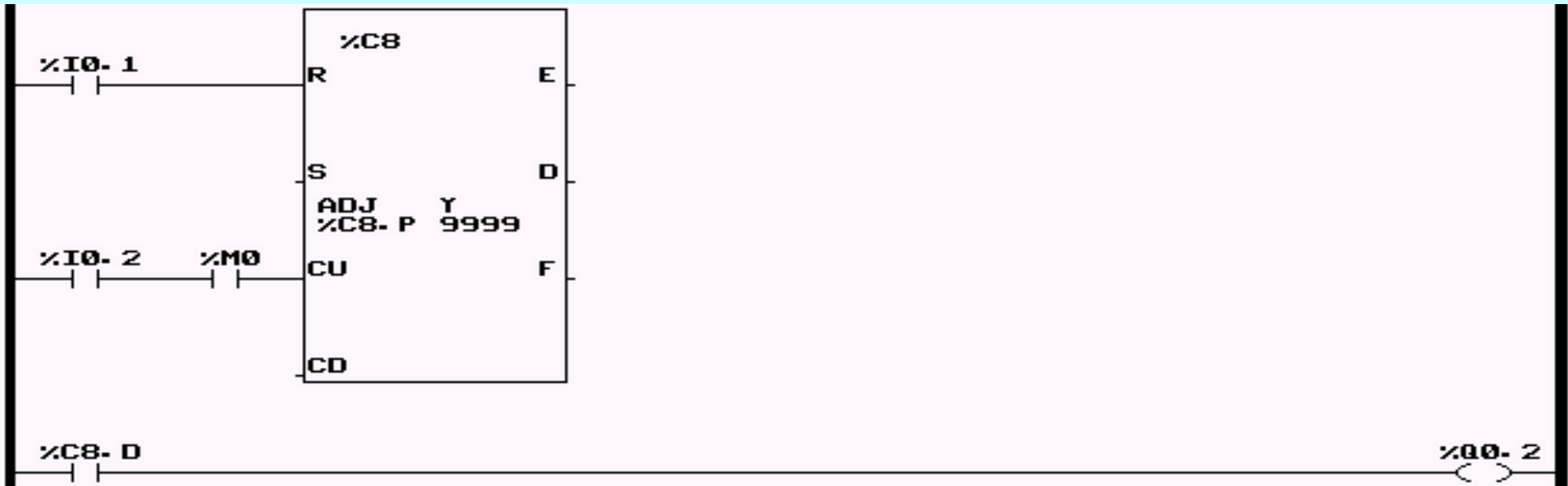


On DELAY.
OFF DELAY.
limited ON TIME.
“one shot” operation.
Multiple on delay.
Industrial timers.
Digital, Solid state.
Electronic timers.
etc.....

Time Charts



Counters



Count x

Reset

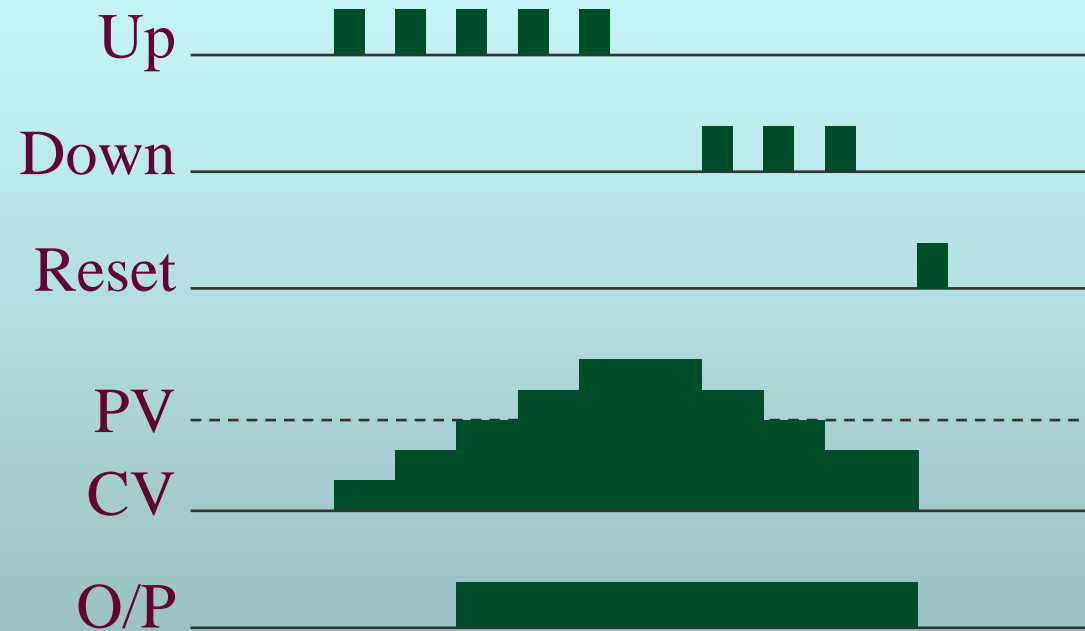
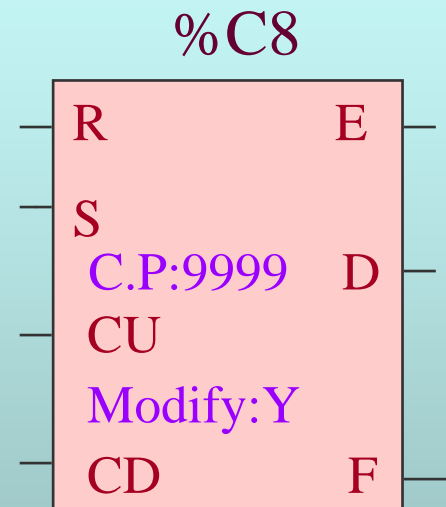
Pv

Cv

O/P

Up Counter

Up/Down Counters



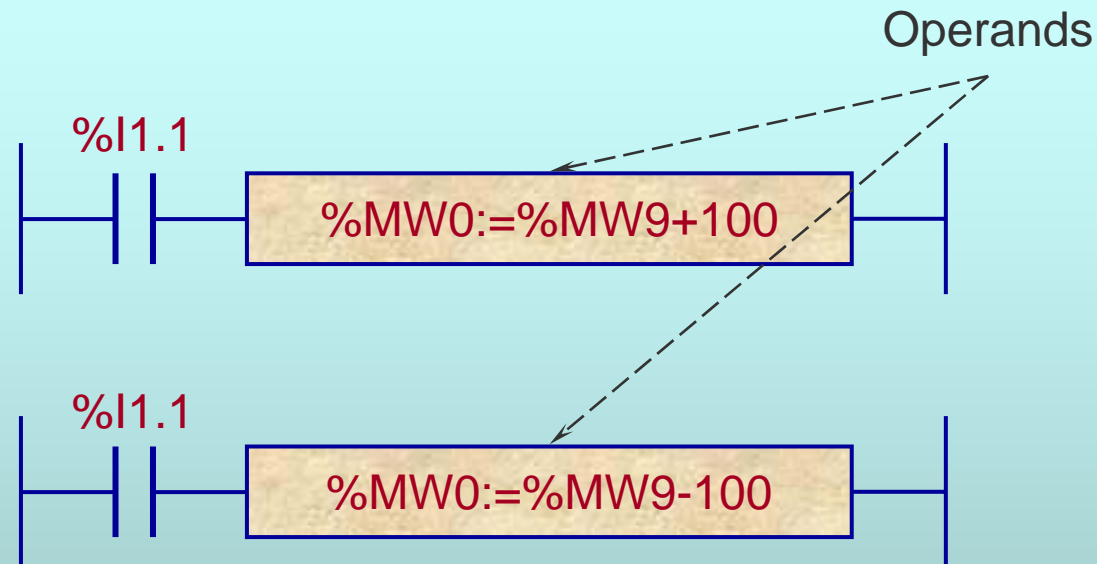
Arithmetic Functions

Addition
Subtraction

Multiplication
Division

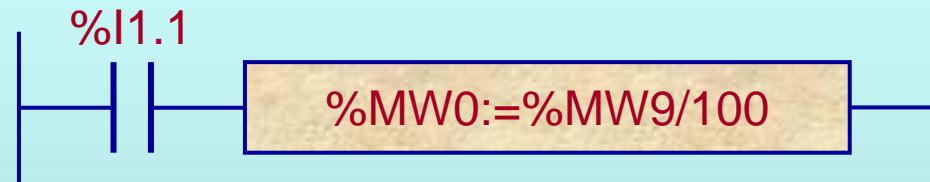
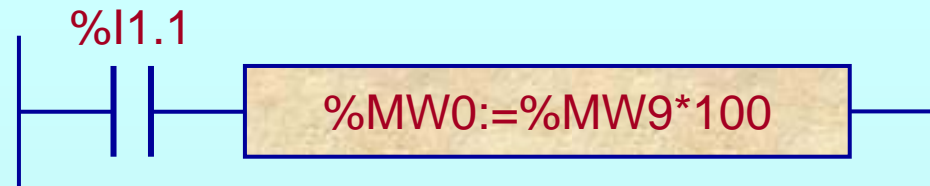
Square Root
etc.

Add & Subtract

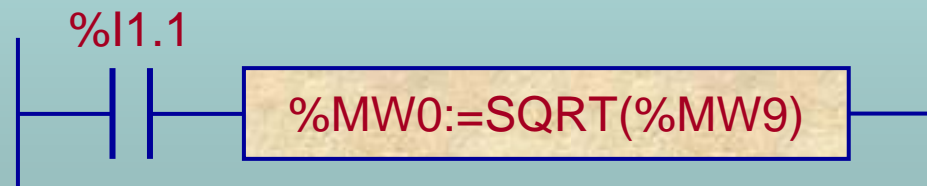


OPERAND: a register containing a numerical value used in an arithmetic operation as an input

Multiply & Divide

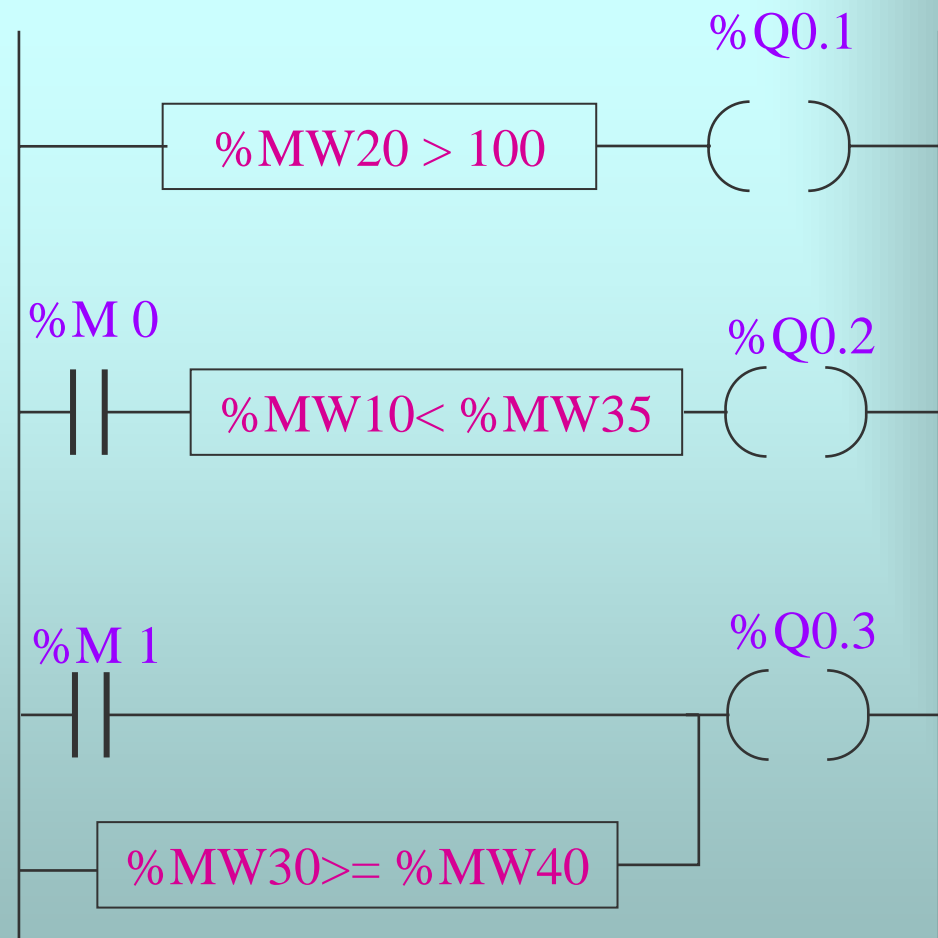


Square Root

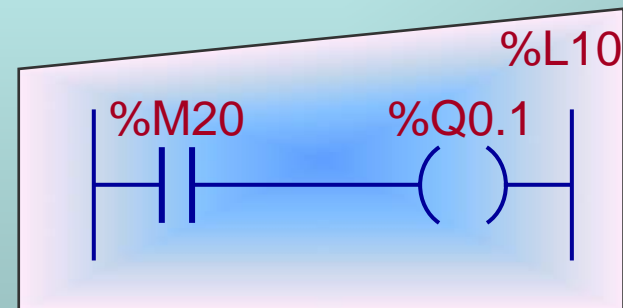
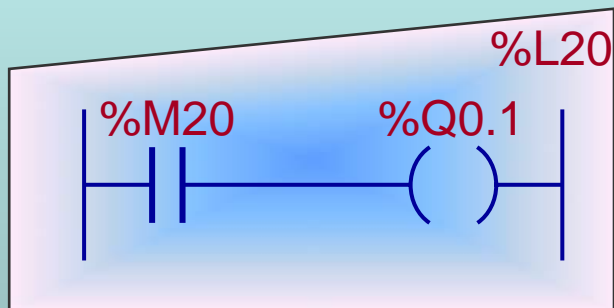
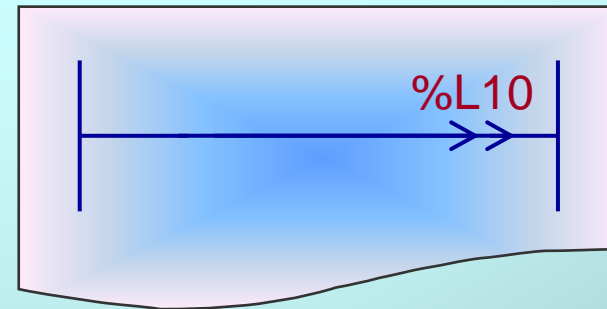
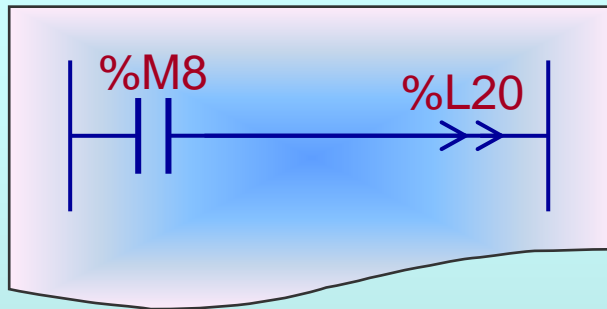


Comparison Instructions

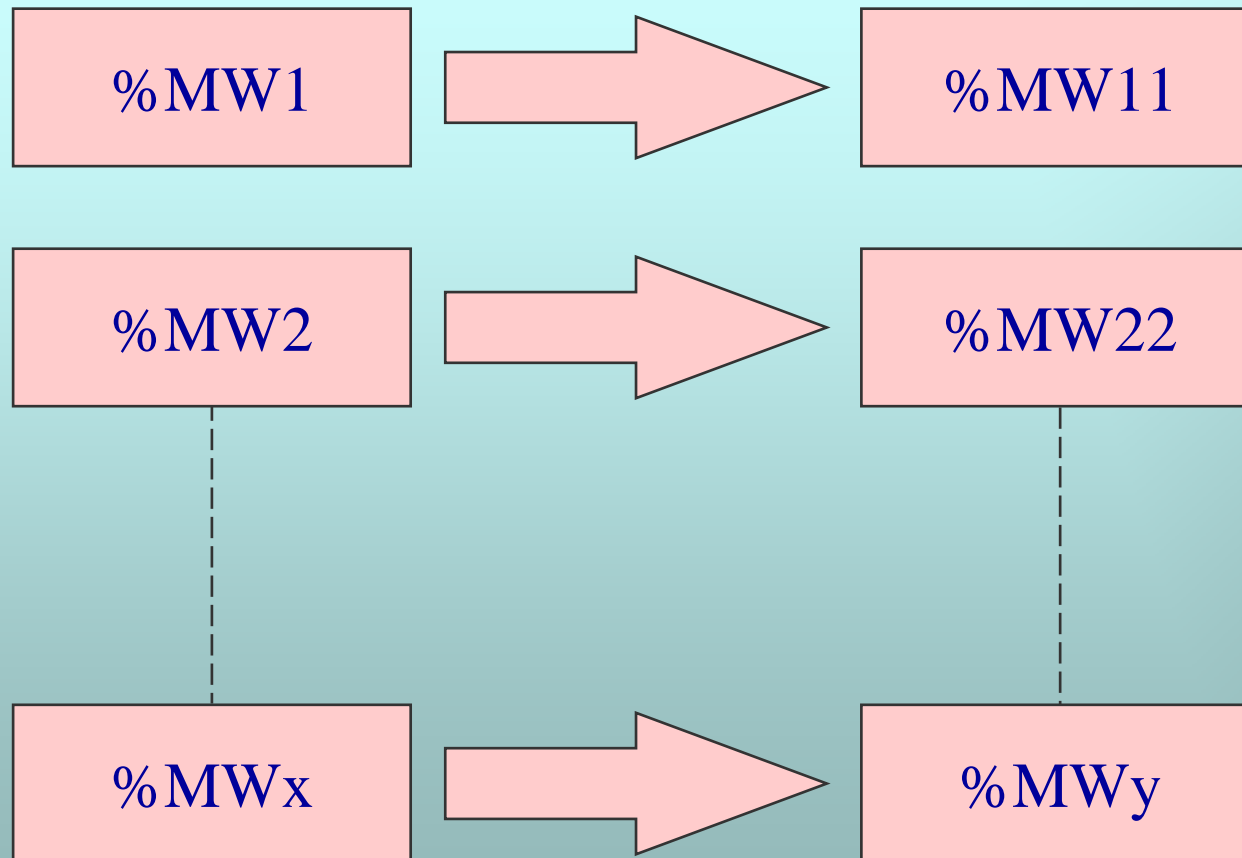
$\Pi >$	Greater Than
$\Pi \geq$	Greater Than or Equal
$\Pi <$	Less Than
$\Pi \leq$	Less Than or Equal
$\Pi =$	Equal
$\Pi \neq$	Different From



Jump Instructions



Data Move



%MW1

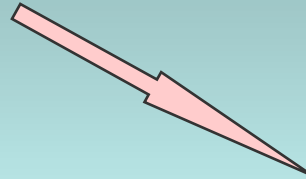
%MW2

%MW3

%MW4

%MW5

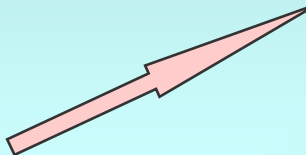
1st



2nd

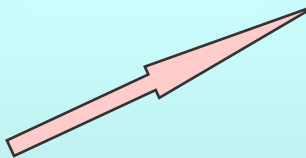


3rd

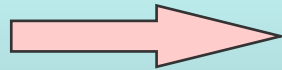


%MW9

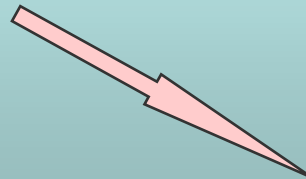
1st



2nd



3rd



%MW1

%MW2

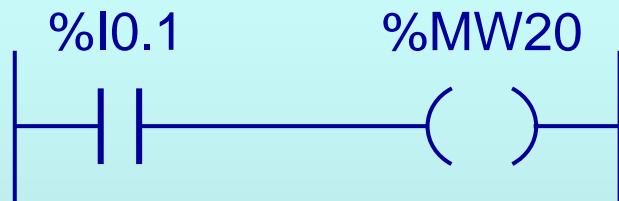
%MW3

%MW4

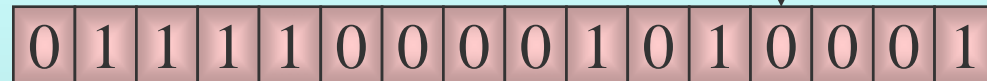
%MW5

%MW9

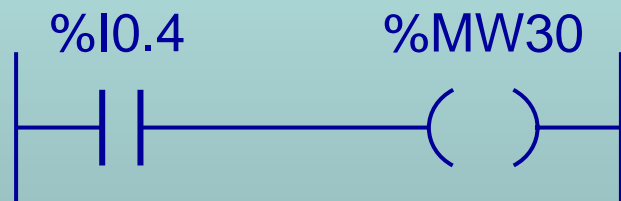
Bit Operations



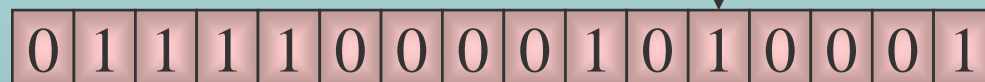
Permanently change to '1'
when %M20 is on



Bit set

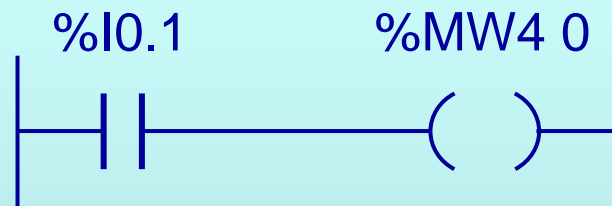


Permanently change to '0'
when %M30 is on



Bit clear

Bit Operations - Bit Follow

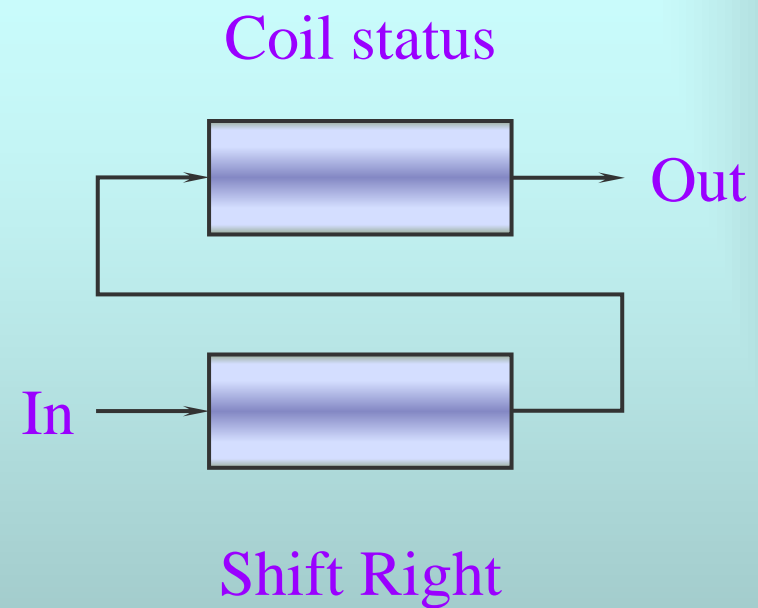
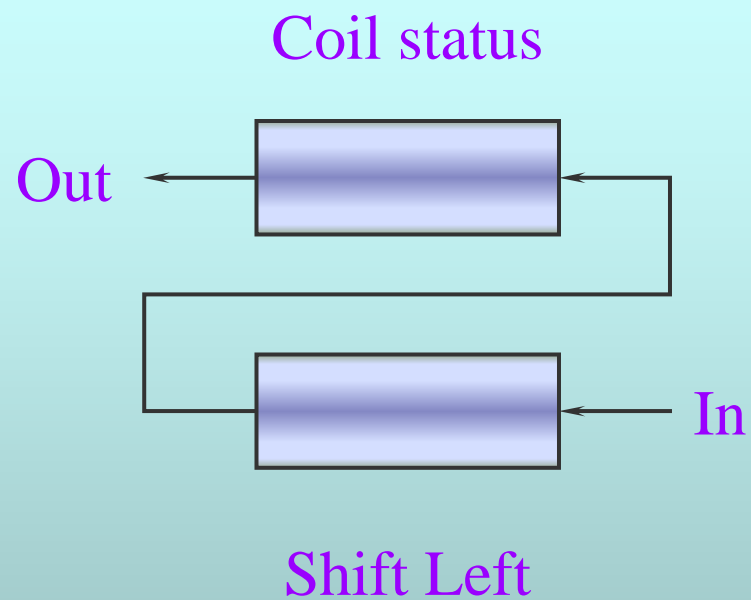


“ 0 ” when %MW40 is on

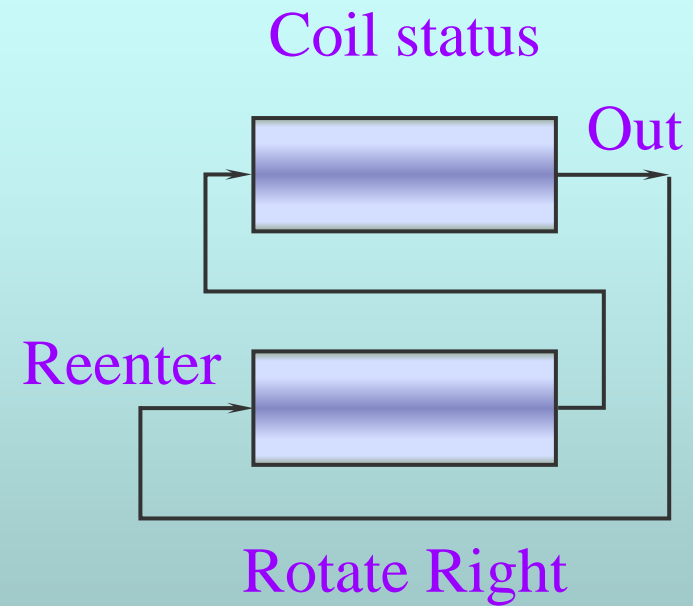
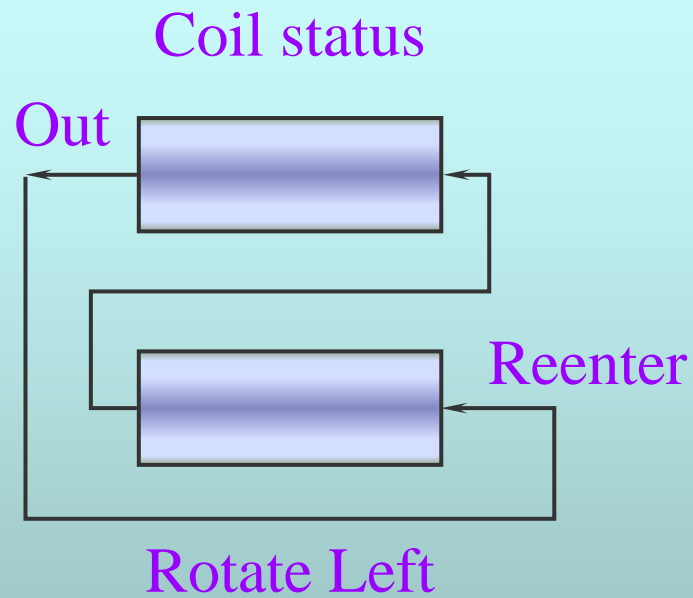
“ 1 ” when %MW40 is off

0	1	1	1	1	0	0	0	0	1	0	1	0	0	0	1
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

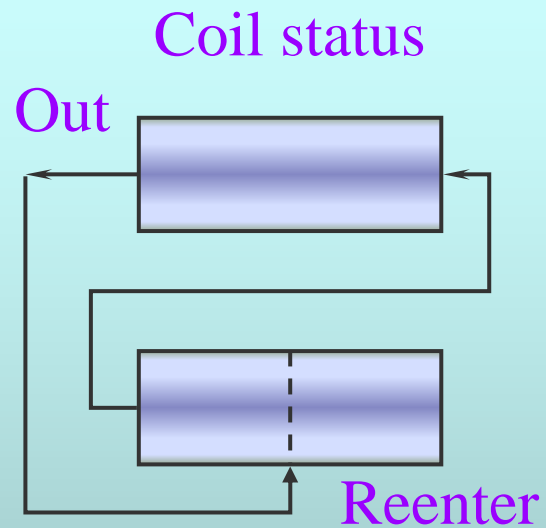
Shift Register



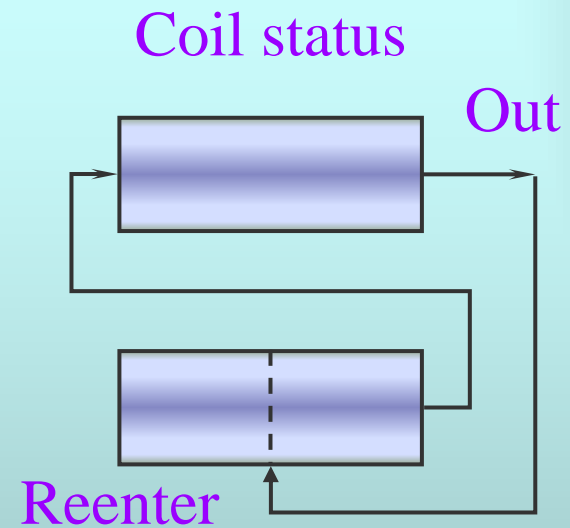
Shift Register - Rotate Full



Shift Register-Rotate Partial

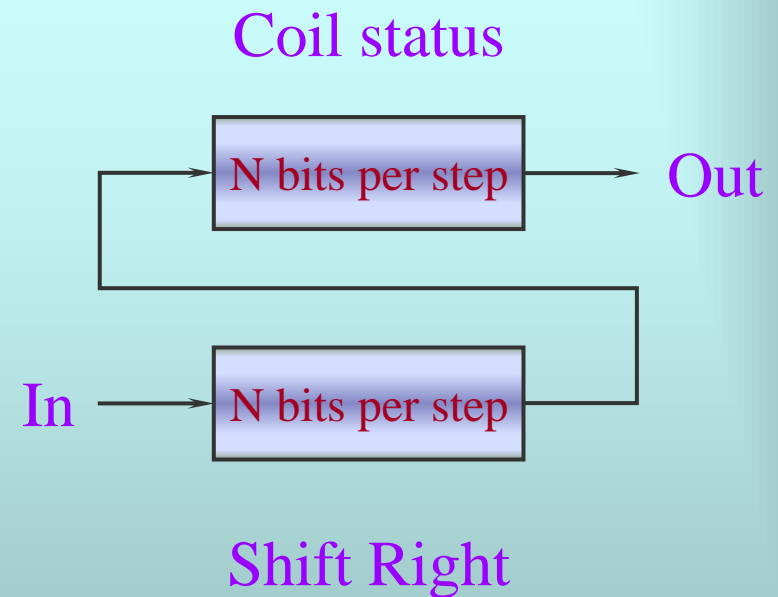
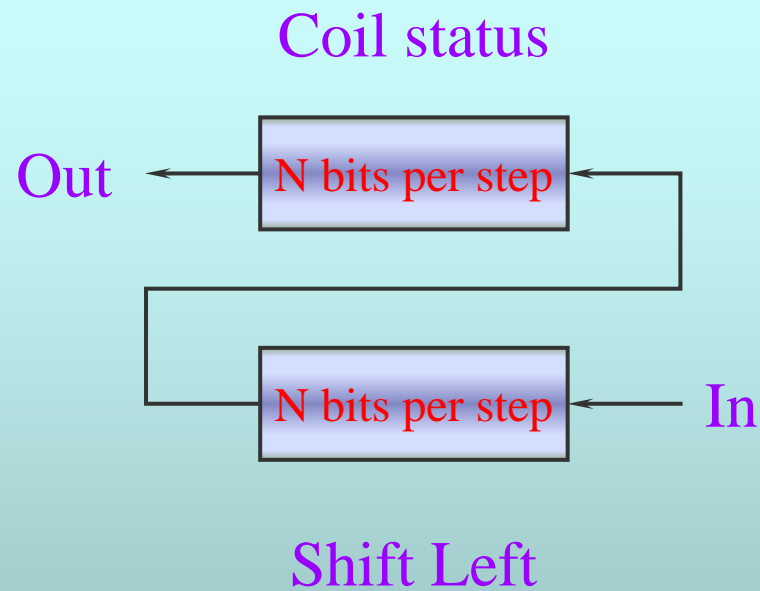


Rotate Left



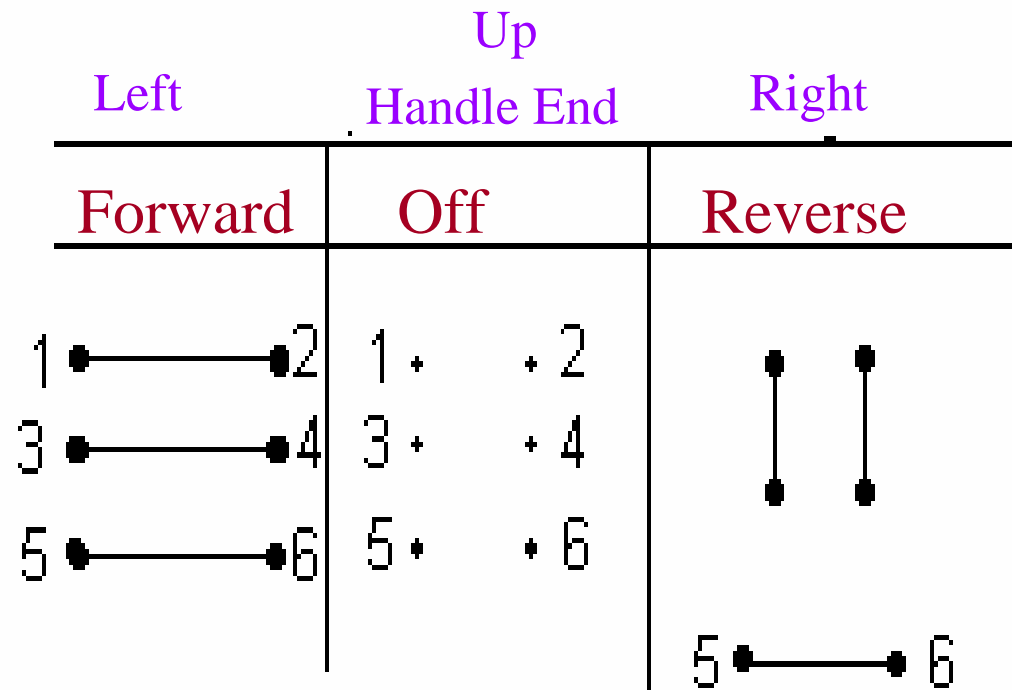
Rotate Right

Shift Register - Multi - bit

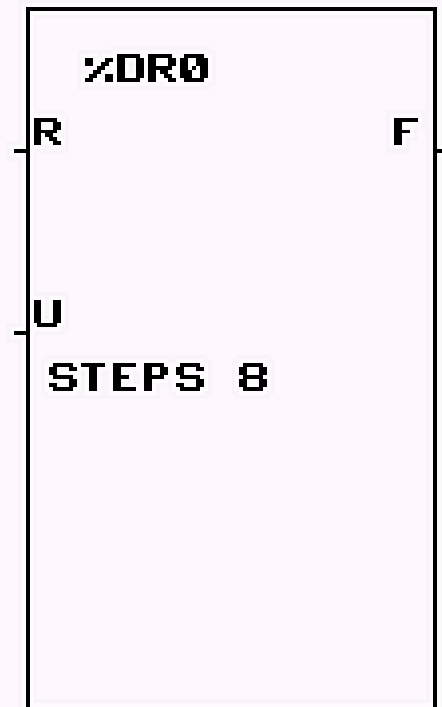


E/M Drum Sequencer

Electromechanical drum controller is a 3 position / 6 terminal device it is an economical control device for handling applications with a fixed sequence and a limited number of required contacts

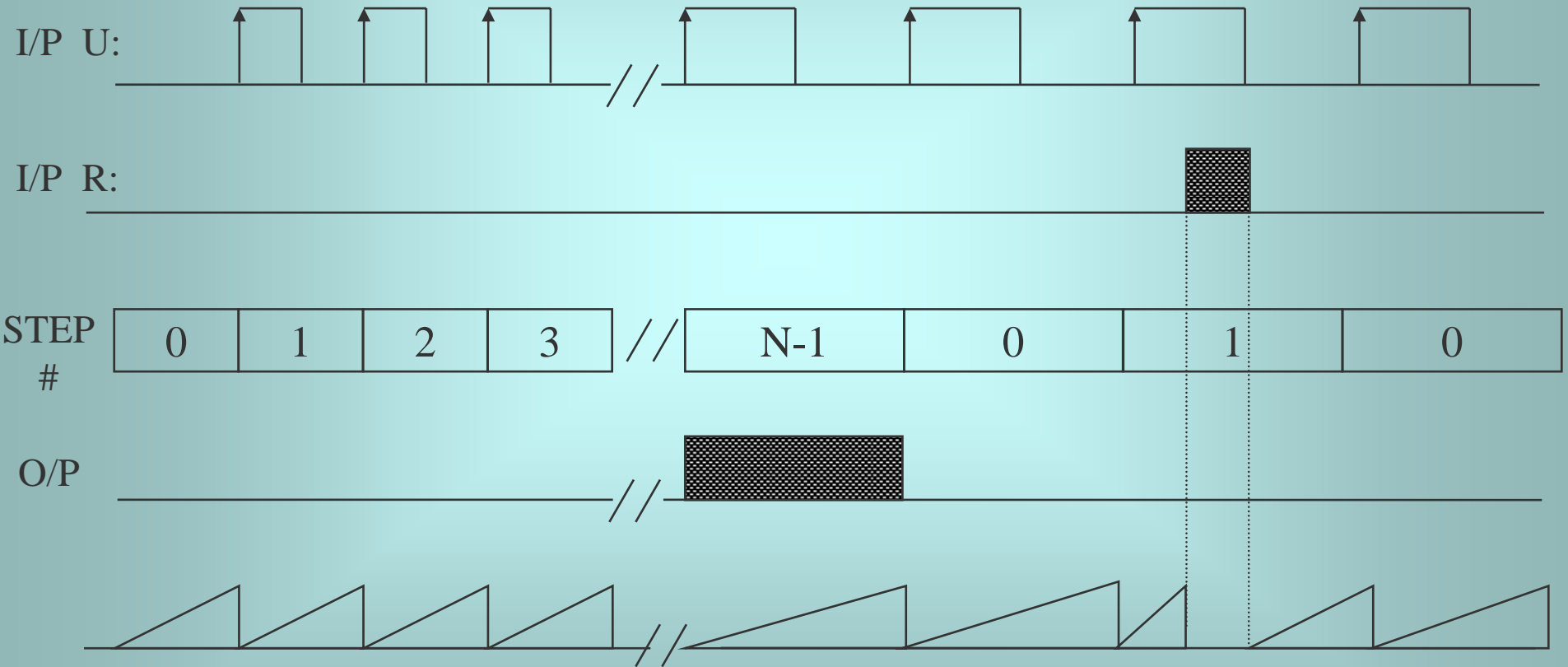


PLC Sequencer

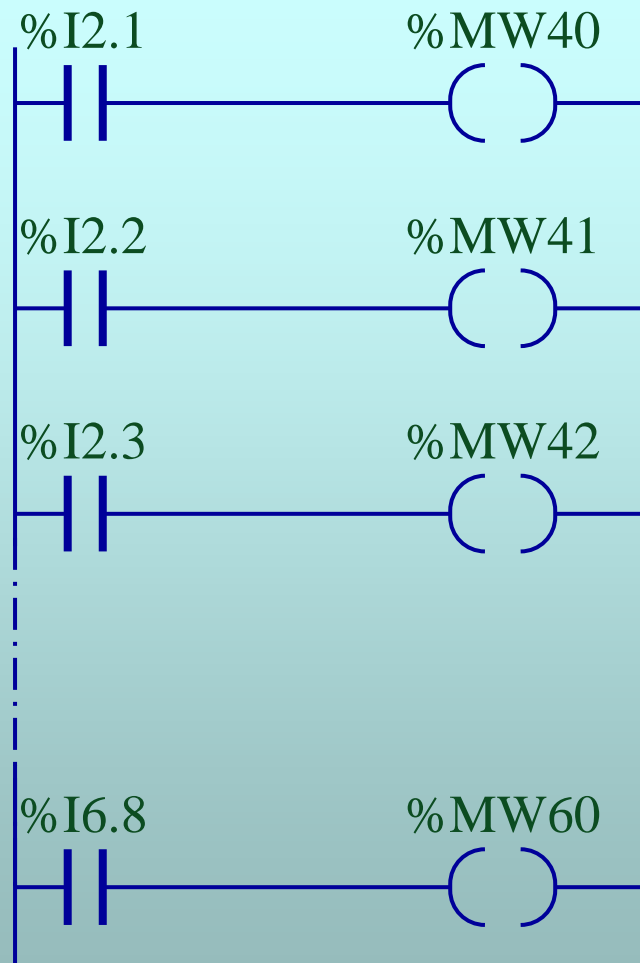


PLC sequencer operates on a similar principle to an electromechanical drum controller, which changes step according to external events. On each step, the high point of a cam gives a command which is executed by the control system. In the case of a drum controller (**PLC sequencer**), these high points are symbolized by state **1** for each step and are assigned to output bits or internal bits, known as control bits.

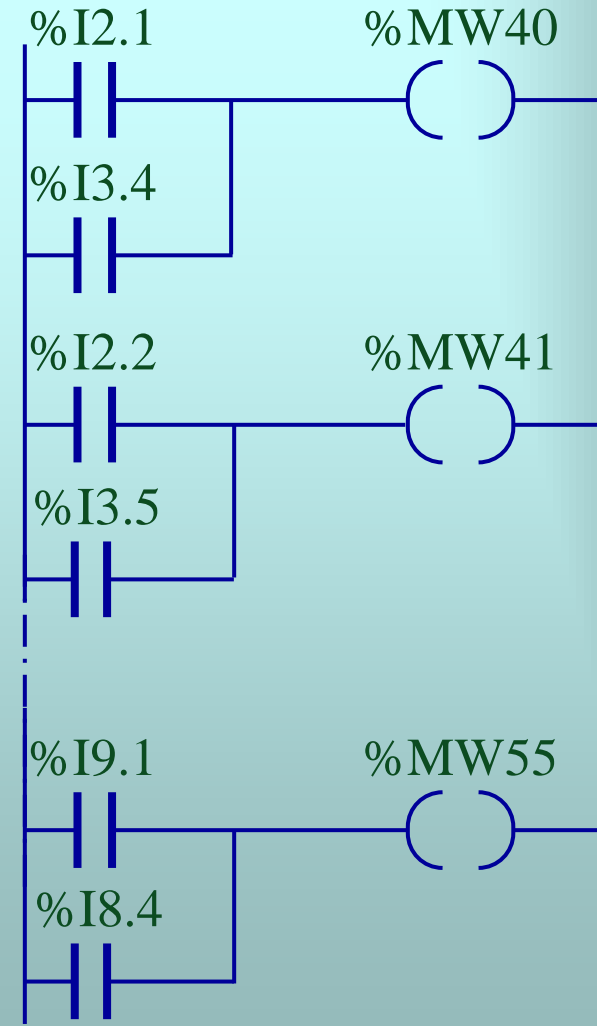
Operating Diagram



Matrix Function



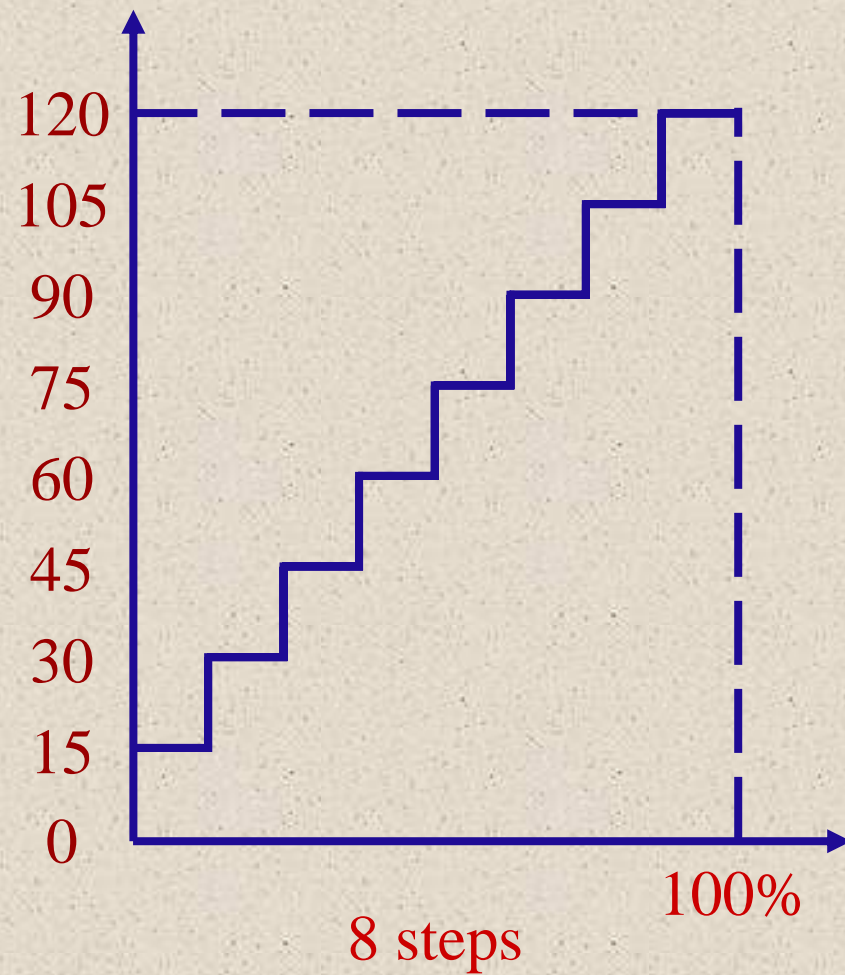
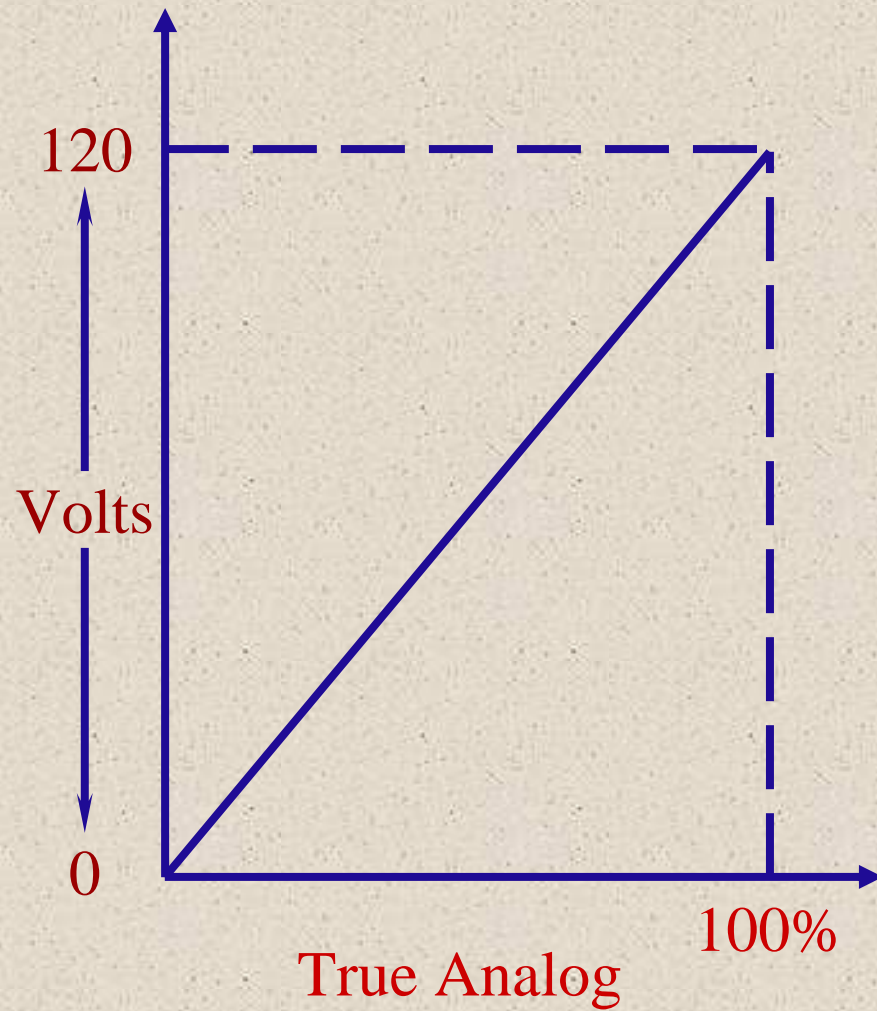
Reducing
Program
Length



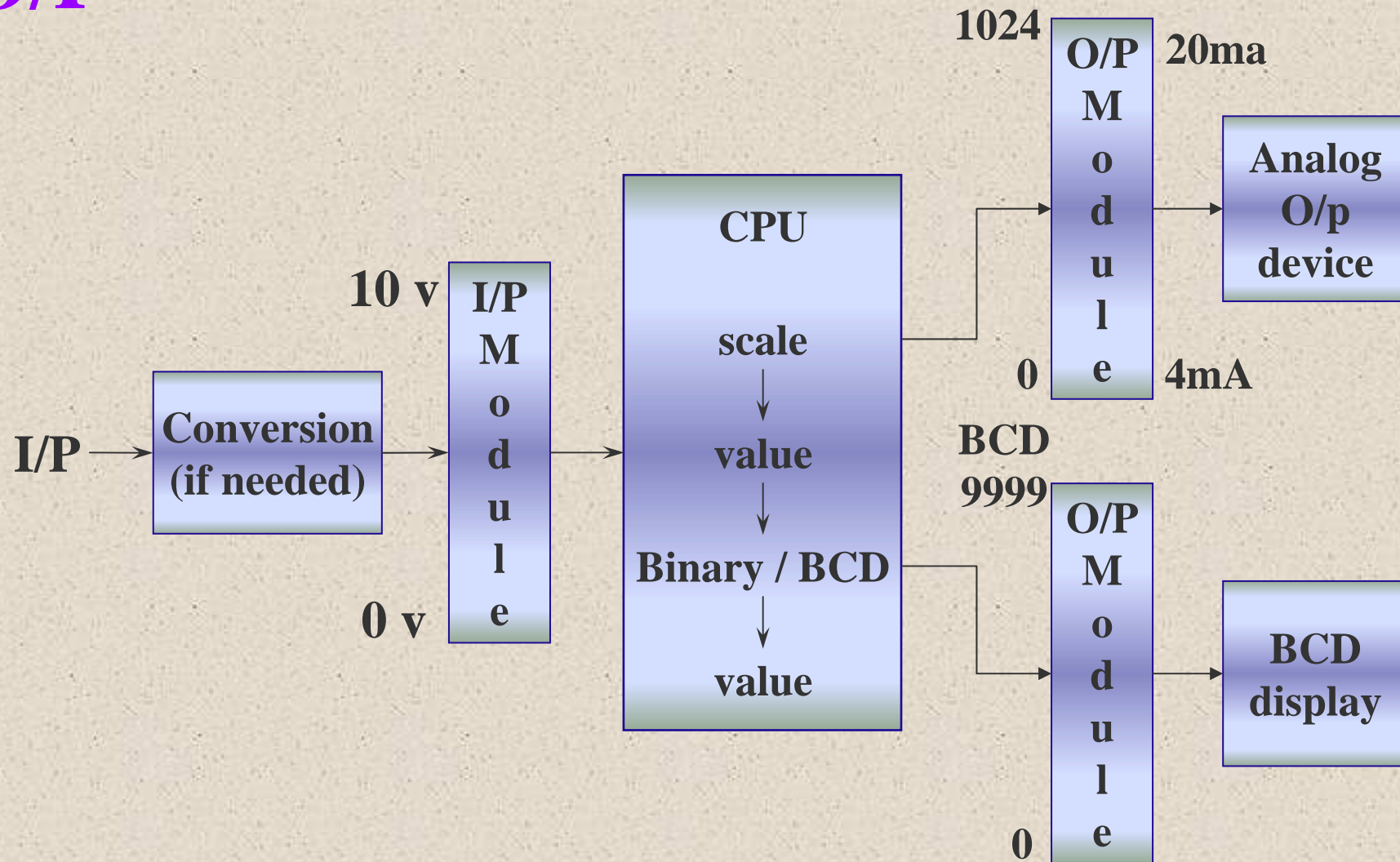


Advanced Programming

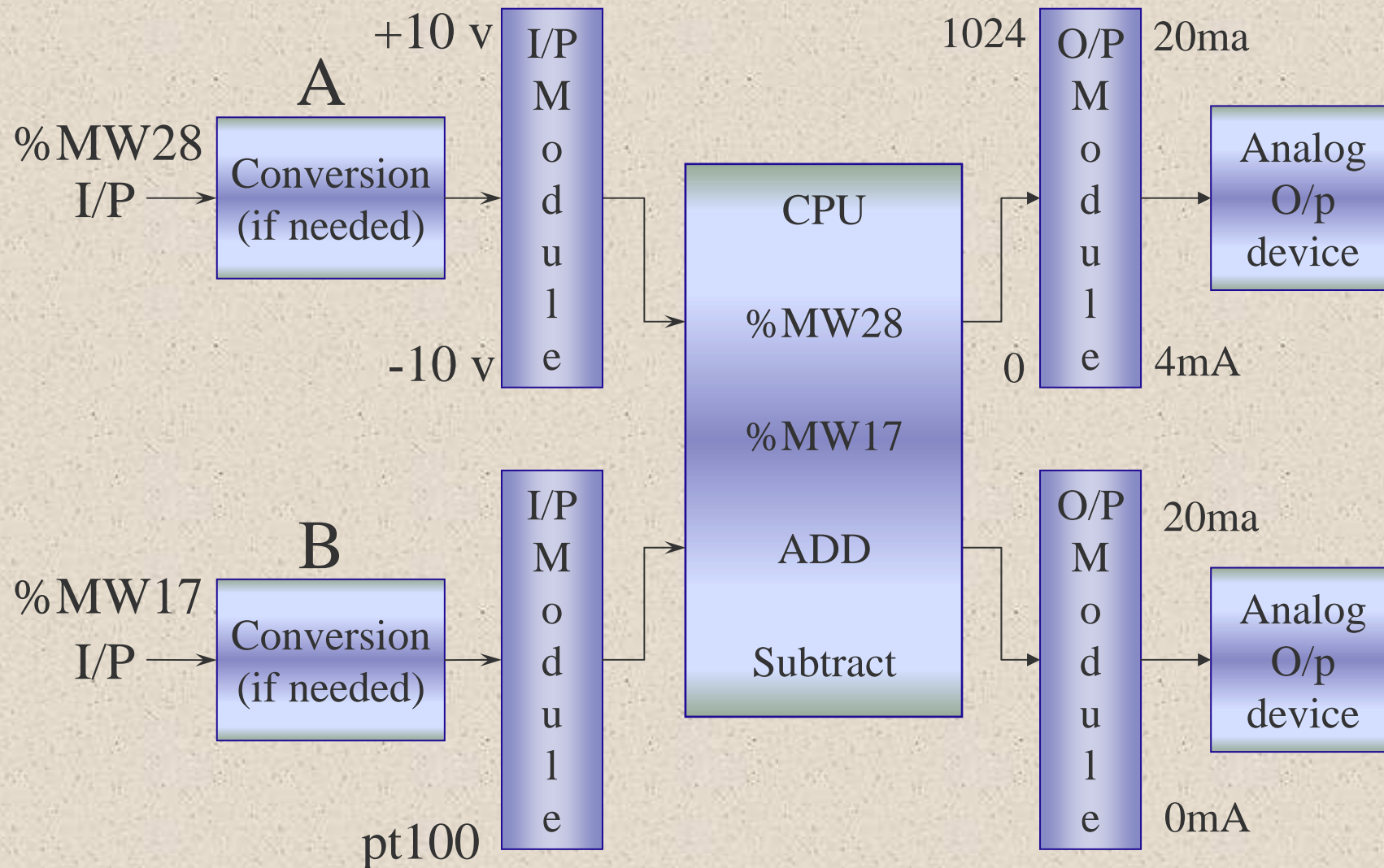
Analog Operation



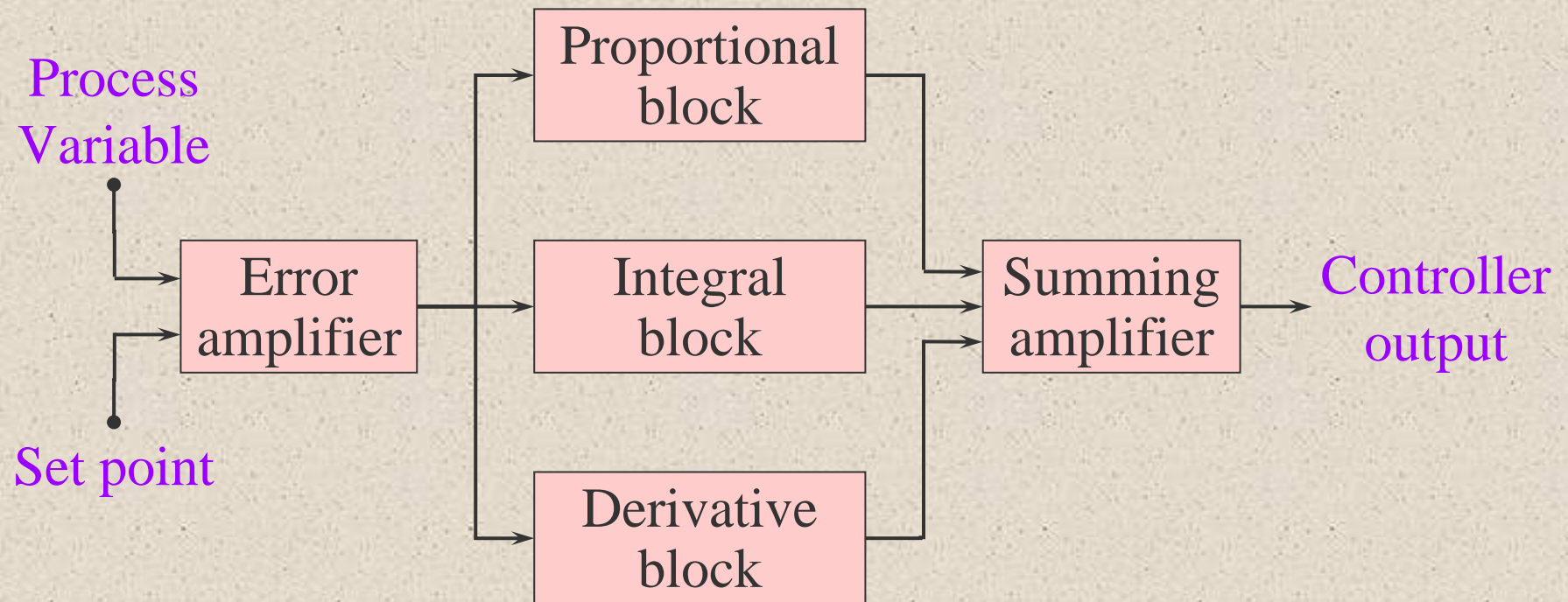
Examples:- Analog I/P / Analog or BCD O/P



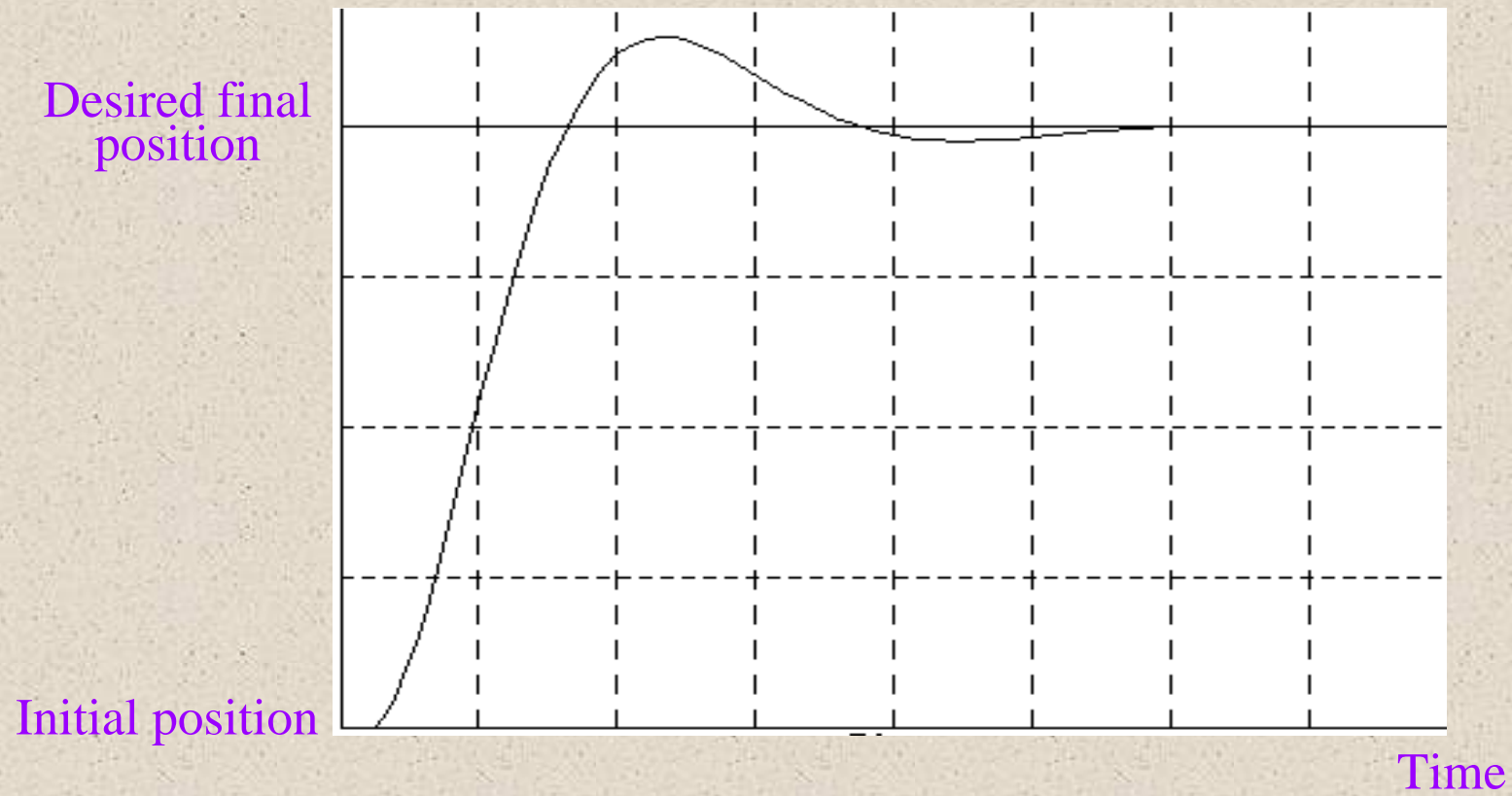
Examples:- 2 Analog In /2 Analog Out



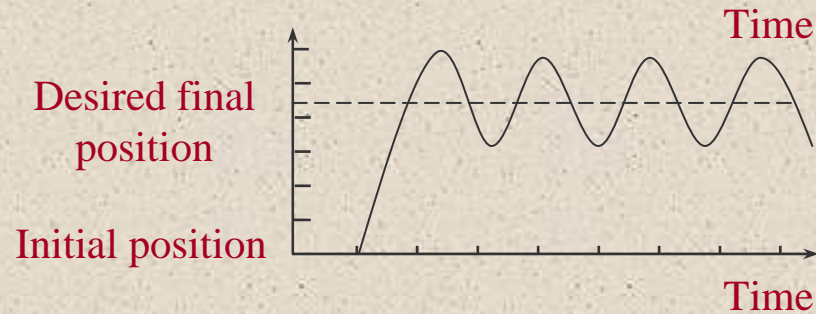
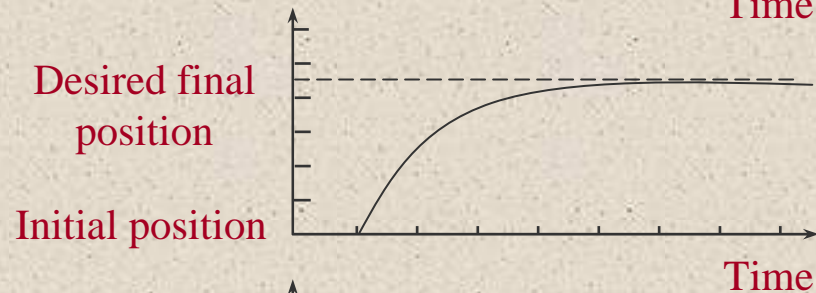
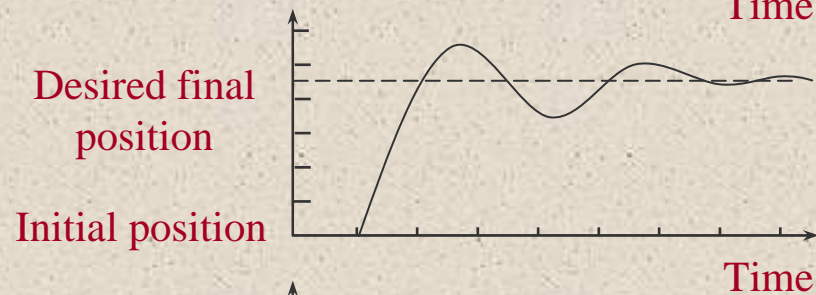
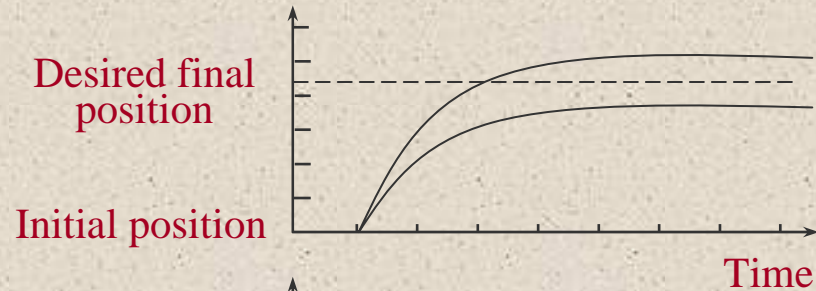
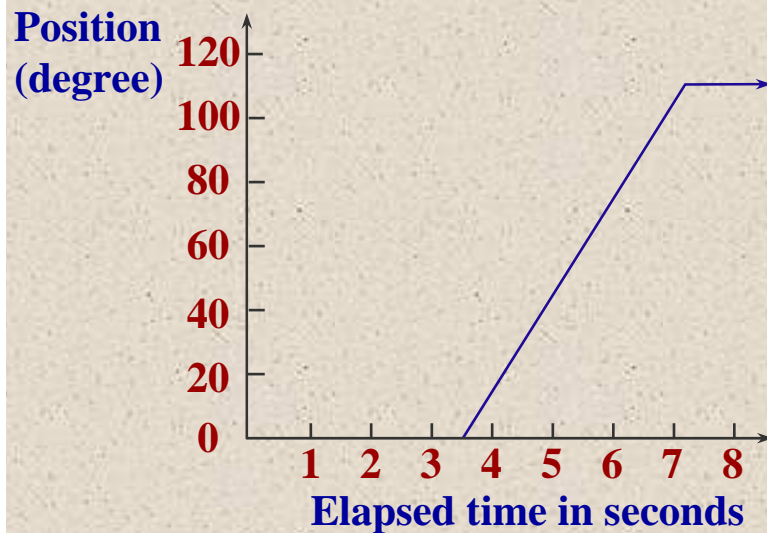
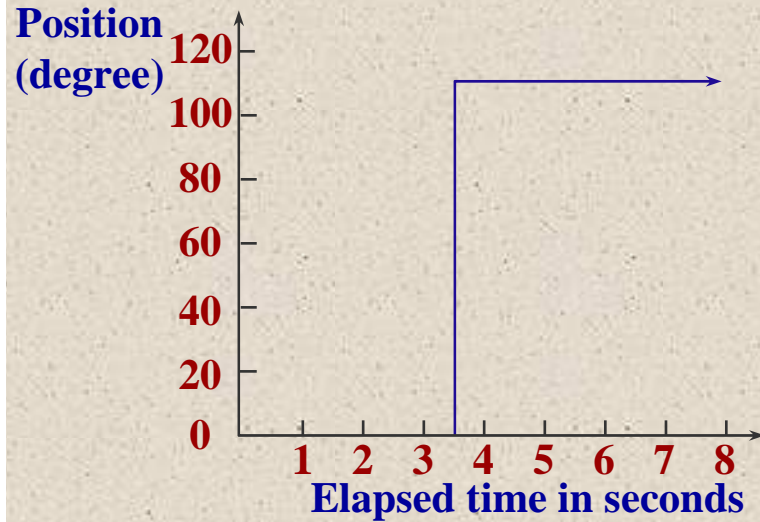
PID Principles



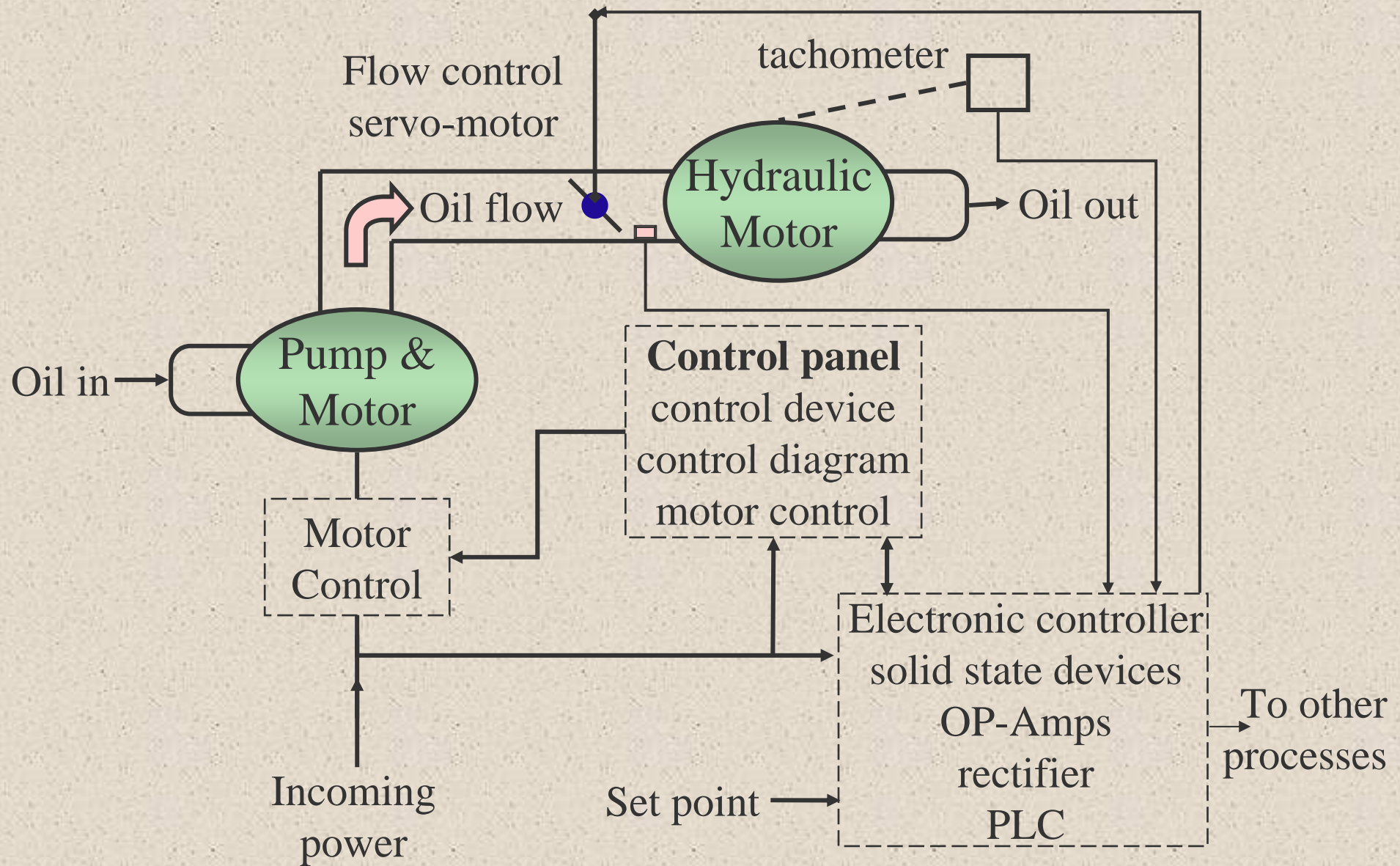
Ideal PID Control Curve



Typical Process Control Curves



PID Example



Position Indicator with PID Control

