

PLC BASICS COURSE

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Good Morning

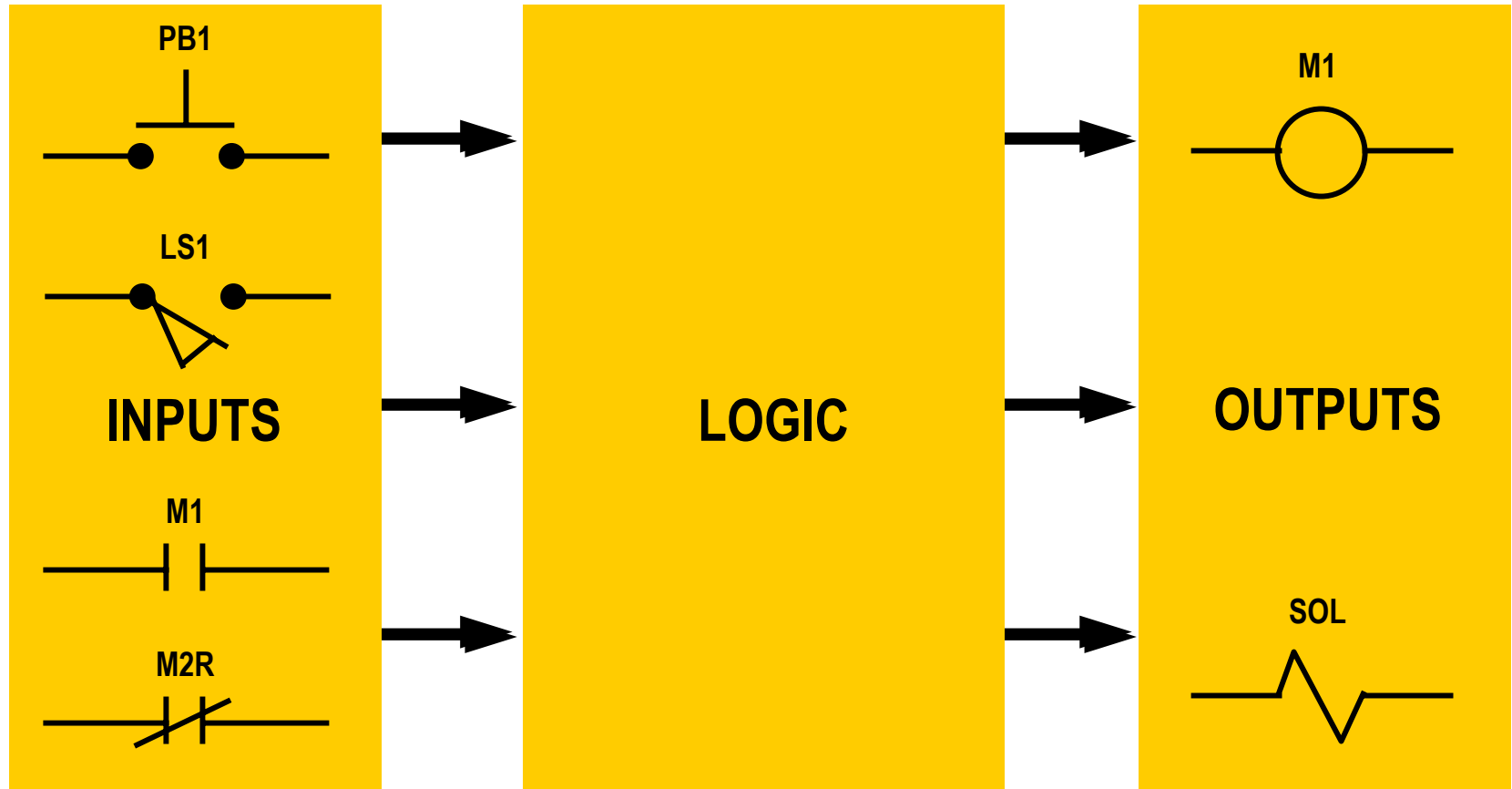
Questions to start with.....

- 1) Which Industry embraced PLC Globally & how was it different in India?
- 2) Who was the first user of PLC? When & why?
- 3) Who was the first vendor?
- 4) What were the alternate technologies in other parts of the world?
- 5) What is the common language of PLC programming & why ?
- 6) What's traditional PLC applications? Why was the suffix "L" dropped from PLC ?
- 7) Which brands product starts with PLC? What will you compete against?
- 8) What makes a PLC Micro or Nano?
- 9) What are the possible Instruction features of Nano & Micro? Calculator example.
- 10) What's the market size of Nano+ Micro in India? Micro goes upto ?
- 11) What are the constituents of PLC's?
- 12) List down the Inputs & Outputs you are aware of?
- 13) How many types of output cards are there?
- 14) What's a volatile memory? What's EEPROM, PCMCIA?
- 15) What's a bit in PLC parlance? Relationship of a bit, byte & word?
- 16) How does a PLC operate?
- 17) What is RS 232 C?
- 18) What is data table?
- 19) What is a EOI ? Does it save I/O's? How many types are there?
- 20) How do I size & select a PLC?

PLC Workshop

- ❖ Upon completion:
- ❖ The student will be familiar with the basic structure, operation, and optional interfaces of a PLC
- ❖ Have an understanding of the Central Processing Unit, the structure of User Memories, Program Protection options, the CPU and I/O System Scans will also be explained.
- ❖ The student will be able to :
 - Describe the Input/Output interface;
 - Describe the functional operation;
 - Describe the PLC components.

Block Diagram of a Control System

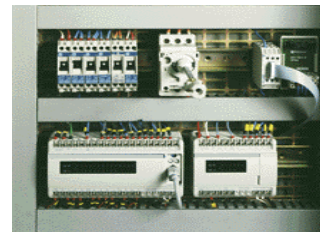
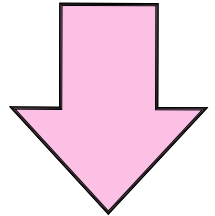
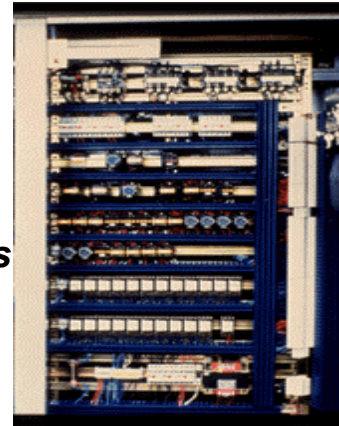


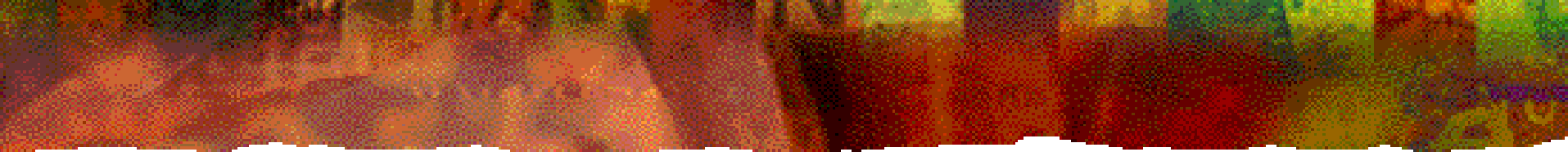
What is a Logic?

- ❖ The first step involved in automating any industrial process or machine is to determine the **sequence of operation** or **events** which are specific to its operation. This sequence is then arranged into a set of logic functions.
- ❖ Logic functions are of two types:
 - **Combinatory**: Where results depends only on the present state of the inputs.
 - **Sequential**: Where results depends on the present and past state of the inputs
- ❖ Then this Logic scheme is turned into a physical system using the basic building blocks of the particular technology selected, i.e. **Mechanical, Fluidic, Pneumatic, Electromechanical, Electronics.**

Which Logic System and why?

- ❖ There are three basic system options that are open to a design engineer.
 - **Relay Logic**
 - *It has for many years been the work horse of most electrical installations.*
 - **Advantages:** *It was simple for small systems, hence cost advantages due to wide range of available coil voltages.*
 - **Disadvantages:** *As the number of relays increases, it requires larger physical area, coupled with costly enclosures, the labour charges, the schematic and connection diagrams, escalates the final cost.*
 - **Wired Logic**
 - **Programmable Logic**
 - Improved installation time
 - eliminate the need for extensive wiring of timers, relays and other components
 - Improved flexibility
 - enable control system changes simply by reprogramming
 - Much more compact than relay control panels, yet enables complex, high-level control
 - Improved reliability
- ❖ Selection of the most suitable system is largely dependent on the application, availability and acceptability.





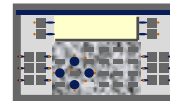
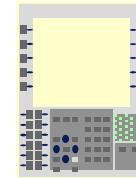
1. Programmable Controllers

The most significant development in the industrial control field in previous half-century

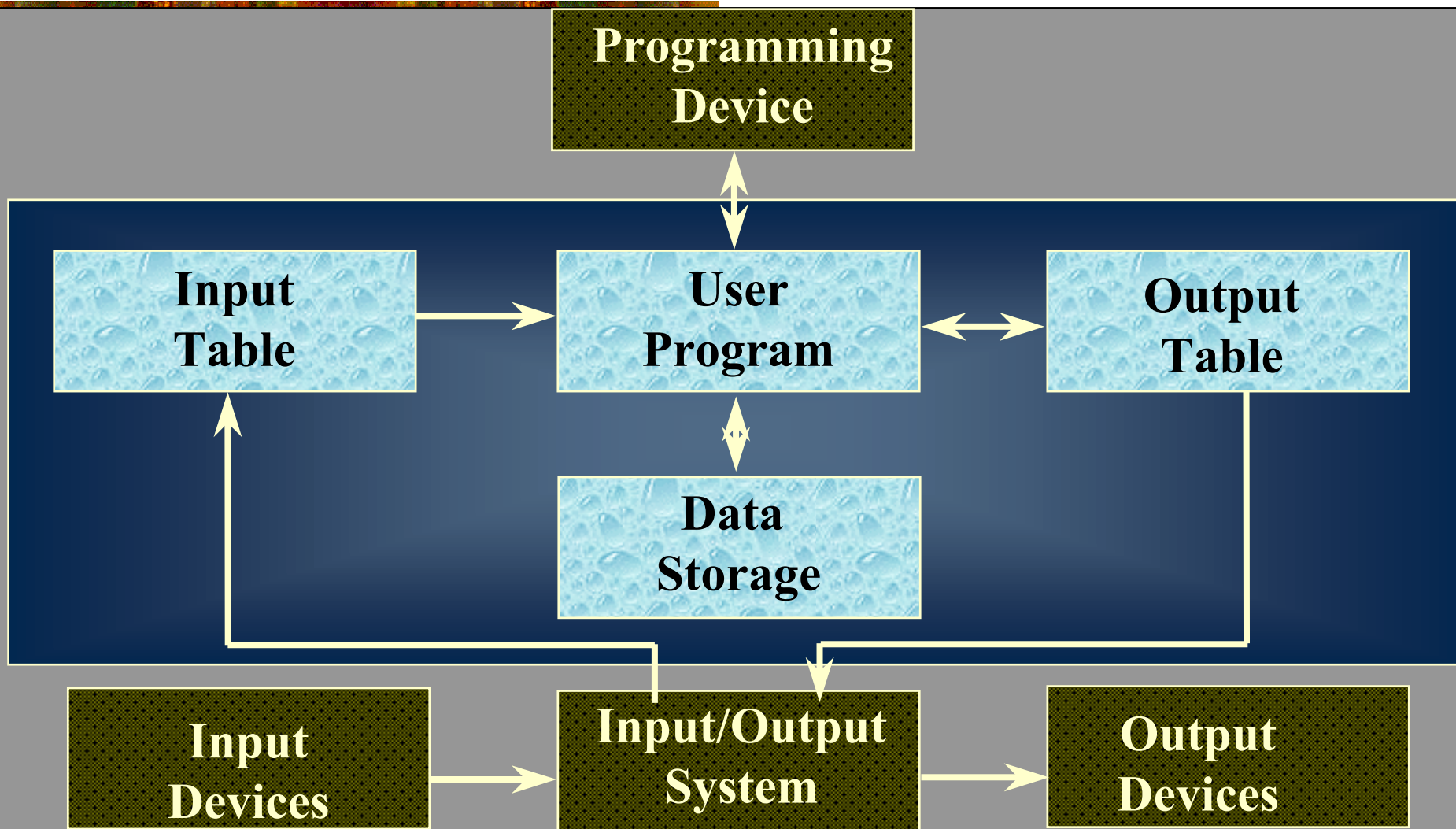
■ ■ ■ ■ ■ The Control of the

Future

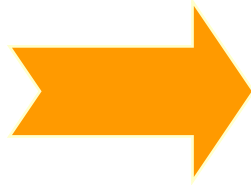
What is a Programmable Controller?



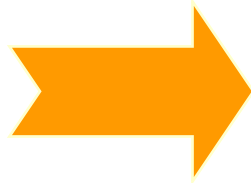
What is a PLC?



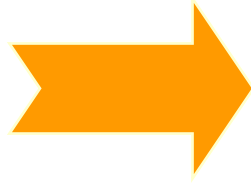
4 Basic PLC Parts



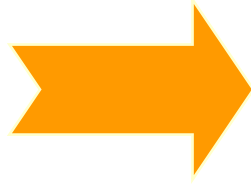
Processor



I/O Interface



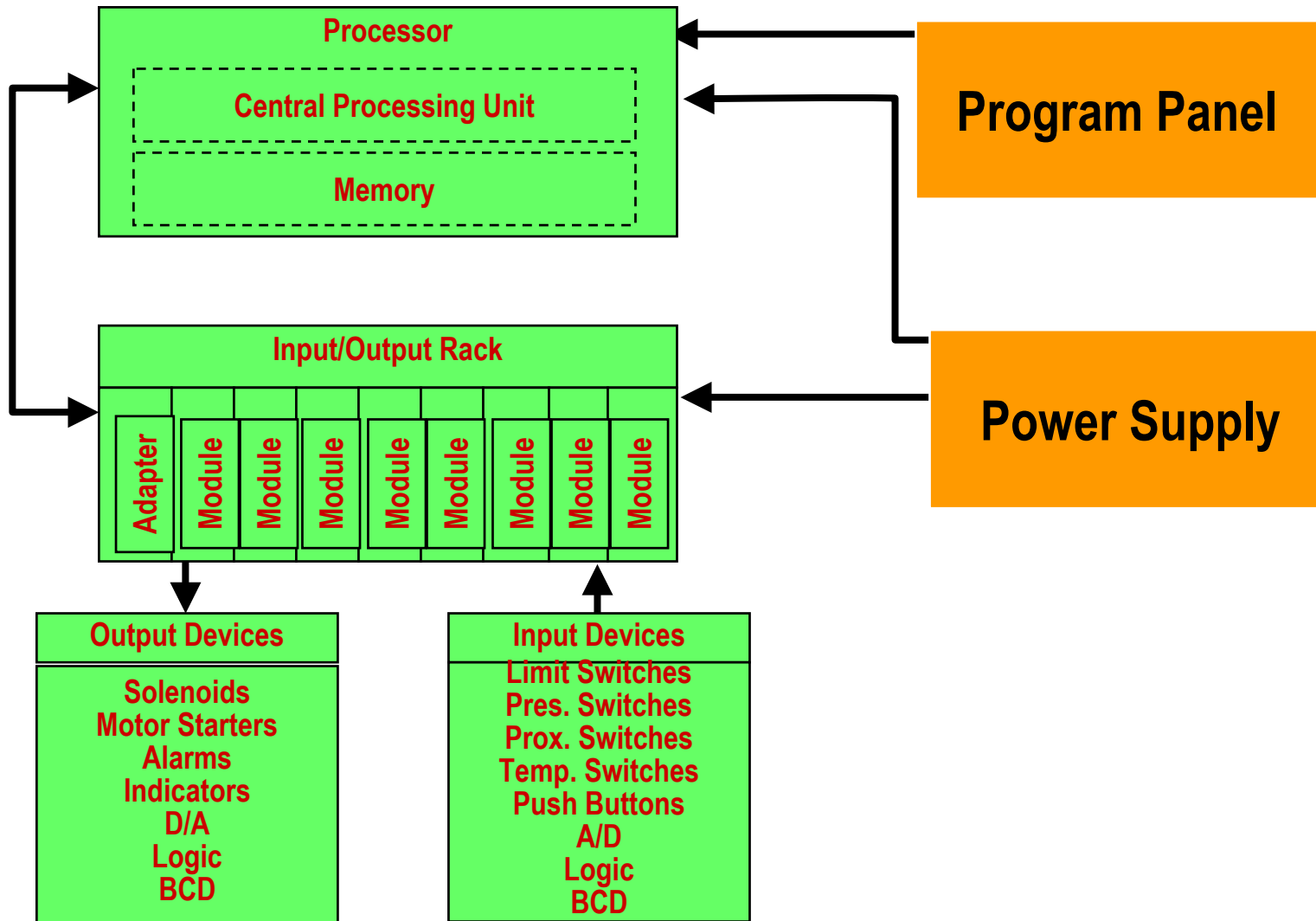
Power Supply



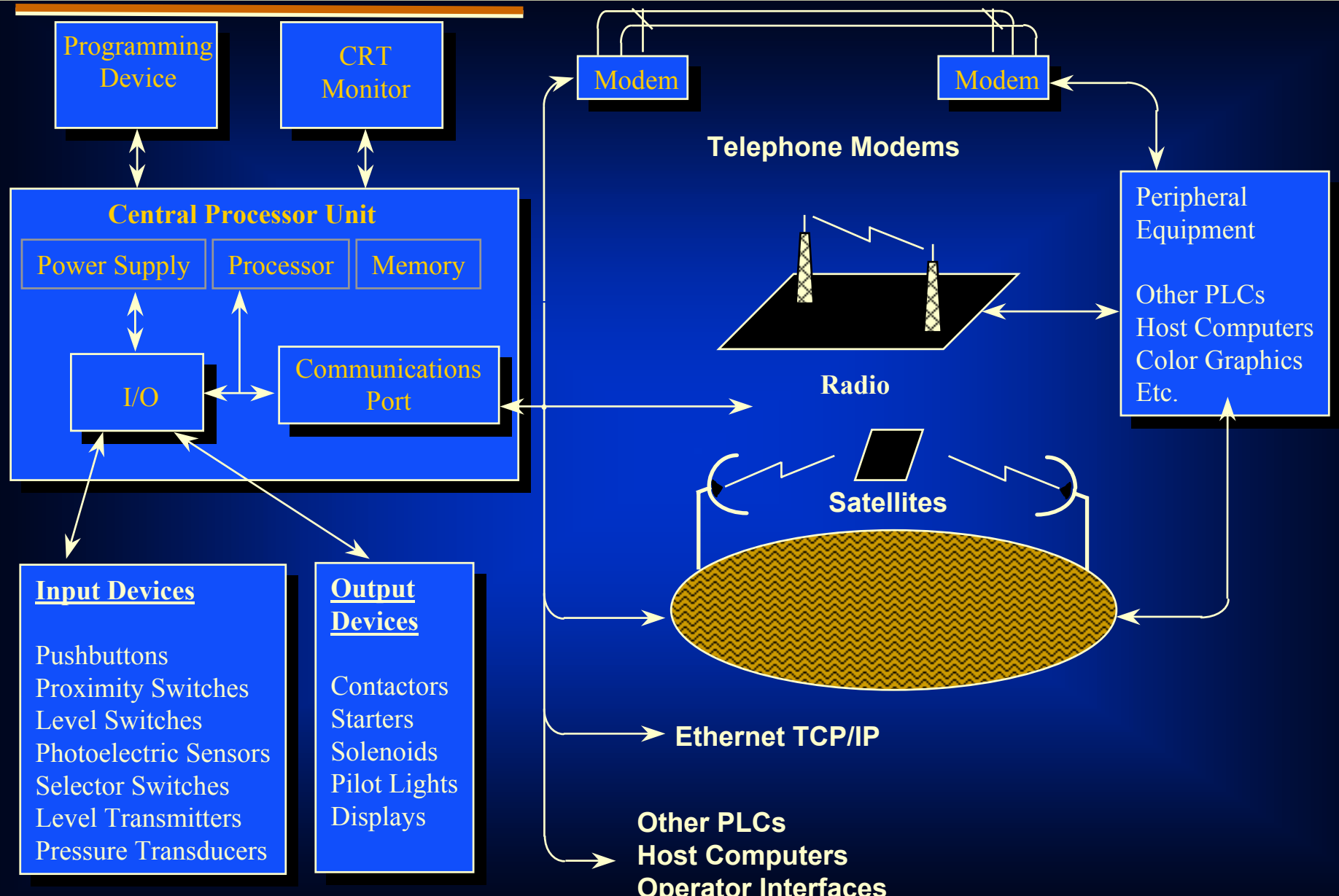
Programming Device

+ Electronic Operator Interface

4 Basic PLC Parts

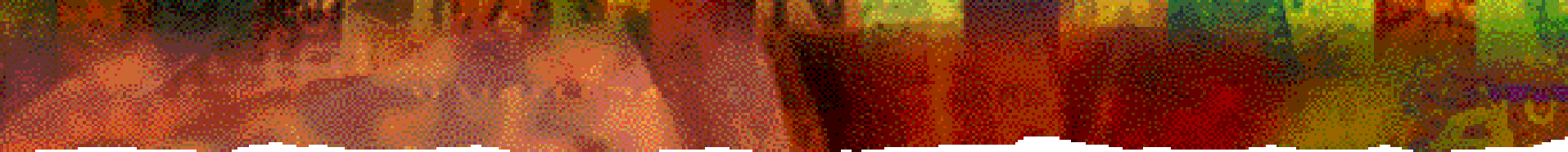


Optional Interfaces



PLC Definition

- ❖ A **Programmable Logic Controller (PLC)** is an industrial computer that accepts inputs from switches and sensors, evaluates these in accordance with a stored program, and generates outputs to control machines and processes.
- ❖ A **Programmable Logic Controller (PLC)** is a solid state device that uses soft wired logic contained in the controller's memory to duplicate the functions of relays and hardwired solid state control devices. In operation, the memory unit sequentially scans inputs(sensors, limit switches, push buttons, photocells) in cyclic fashion to determine which outputs(contacts, motor starters, solenoids, pilot lights, converters, etc.) should be turned on or off.
- A **Programmable Logic Controller (PLC)** is an electronic device that control machines and processes. It uses a programmable memory to store instructions and execute specific functions that include ON/OFF control, timing, counting, sequencing, arithmetic, and data handling.



2. Why Use a PLC ????????????????

Why Use a PLC?

- ❖ Reliability
- ❖ Flexibility
- ❖ Advanced Functions
- ❖ Communications
- ❖ Speed
- ❖ Diagnostics

PLC Advantages

- ❖ Ease of programming
- ❖ Ease of maintenance
- ❖ Designed for industrial environment
- ❖ Quick installation
- ❖ Adaptable to change

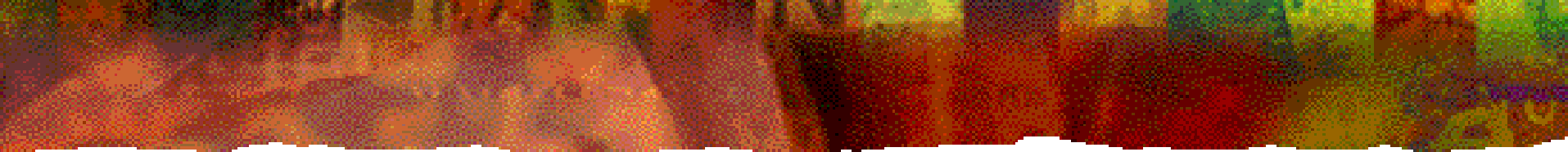
Traditional PLC Concept

- ❖ PLC performs relay equivalent functions
- ❖ PLC performs ON/OFF control
- ❖ Ladder diagram program representation
- ❖ Designed for industrial environment
- ❖ Designed for ease of use and maintenance

Traditional PLC Applications

- ❖ Packaging
- ❖ Bottling and canning
- ❖ Material Handling
- ❖ Power Generation
- ❖ HVAC/building control systems
- ❖ Security Systems
- ❖ Automated Assembly
- ❖ Water Treatment
- ❖ Food and Beverage
- ❖ Chemicals
- ❖ Pulp and Paper
- ❖ Pharmaceuticals
- ❖ Metals

Virtually any application that requires electrical control can use a PLC



3. History of PLC's

Historically

- ❖ Machines have been viewed as operational entities
- ❖ Processes have been viewed as functional entities

1978 1967 1958 1975

1971 1969 1963

1970 1979 1977

Evolution

1969

- PLC development began in 1968 in response to a request from Hydramatic Division of General Motors. At that time GM frequently spent days or weeks replacing inflexible relay-based control systems whenever it changed car models or made any line modifications. To reduce the high cost of rewiring, GM's control specs called for a solid state system that has the flexibility of a computer, yet could be programmed and maintained by plant engineers and technicians. It also withstand the dirty air, vibration, electrical noise, humidity and temperature extremes found in the industrial environment.

Evolution

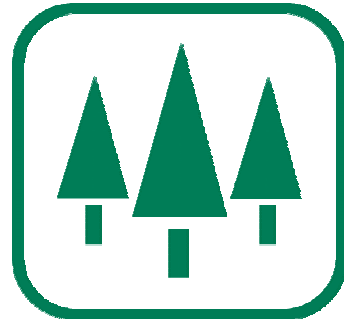
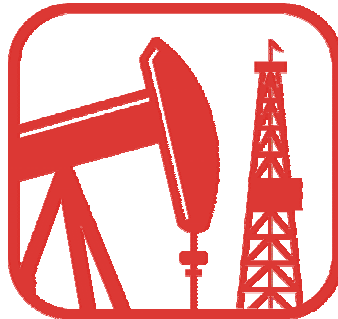
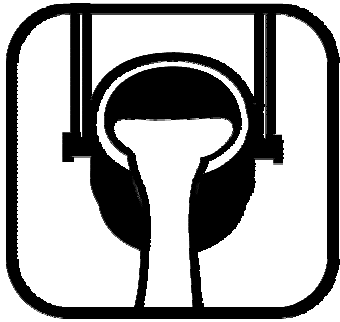
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- ❖ Proliferation into other industries
 - PLC performs relay-equivalent functions
 - PLC's applied in
 - Manufacturing industries
 - Food and beverage industries
 - Power industry
 - Process industries
 - Metals industry
 - Pulp and paper industries

Evolution

1990s
+
2000s

- ❖ PLC usage proliferates into other industries



Evolution

1
9
7
3

- ❖ Introduction of the “intelligent” Programmable Controller
 - PLC performs arithmetic and data manipulation functions
 - Applications expand in all industries

Evolution

1
9
7
5

- ❖ Introduction of “mini” Programmable Controllers
 - Intended for small scale dedicated applications

Evolution

1
9
7
5

- Expansion of capabilities
 - Operator communication
 - Analog control
 - Positioning control
 - Machine fault detection

Installations expand into minicomputer equivalent applications

Evolution

1
9
7
6

- ❖ Installation of manufacturing lines controlled by PLC networks

Evolution

1
9
7
8

- ❖ The year of PLC “Downsizing”
 - Microprocessor-based PLCs now cost effective in small-scale applications
 - Space-efficient, high-density I/O

Evolution

1979

- ❖ The year of PLC “Downsizing”
 - Microprocessor-based PLCs now cost effective in small-scale applications
 - Space-efficient, high-density I/O

Evolution

1
9
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9

- ❖ Introduction of fourth and future generations of PLCs providing continuing improvements in cost/performance effectiveness
 - Improved operator communication
 - Expanded capabilities
 - Extensive inter-control communication

Evolution

1979

- ❖ The advent of distributed control
 - Data Highways
 - Peer-to-peer PLC networks
 - Applications:
 - Material handling/tracking
 - Decentralized process control

Evolution

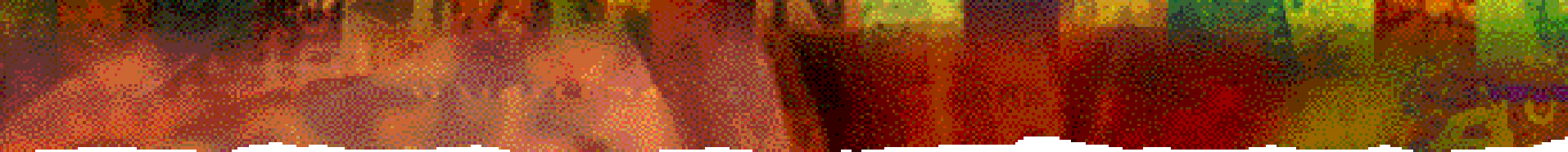
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- ❖ Smart I/O, more distributed intelligence
 - Processing power in I/O interface
 - Microprocessor CPUs increase functionality, at lower cost
 - PID control
 - Graphic operator interfaces

Evolution

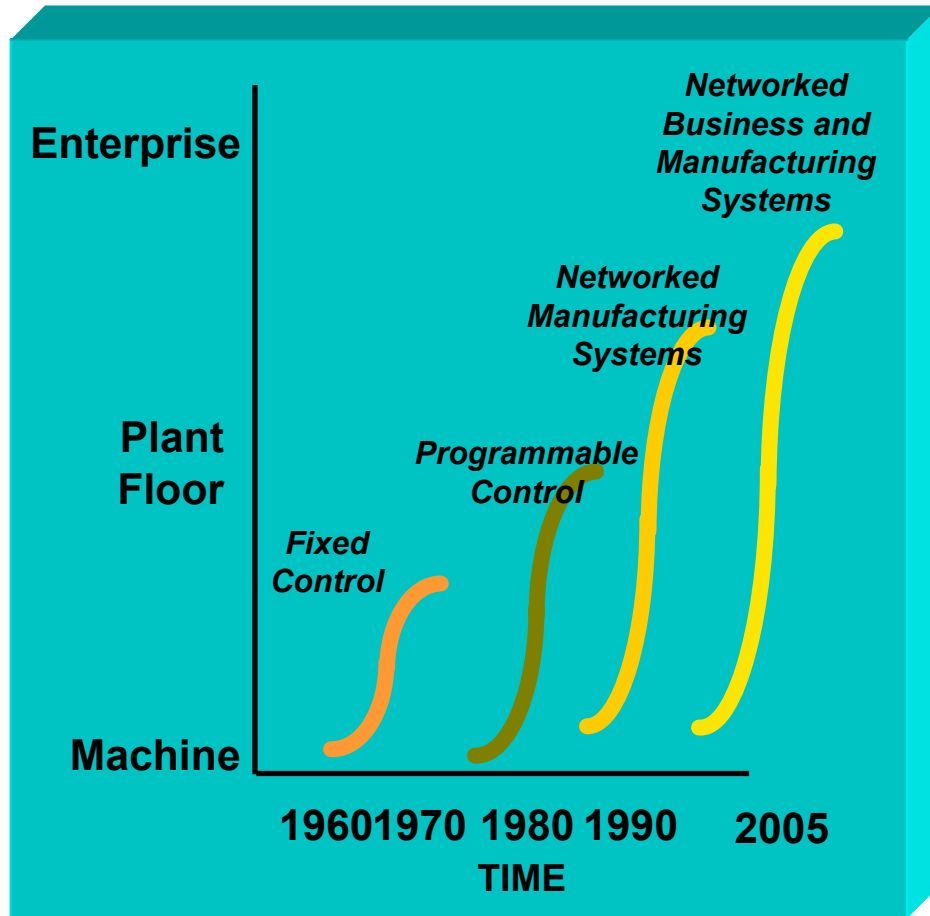
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- ❖ PLCs functionality expands into computer-like capability
 - Instruction sets expand to include floating point math, Boolean file manipulations
 - Microprocessor-based I/O performs sophisticated closed loop control
 - Use of Data Highways expand throughout industry

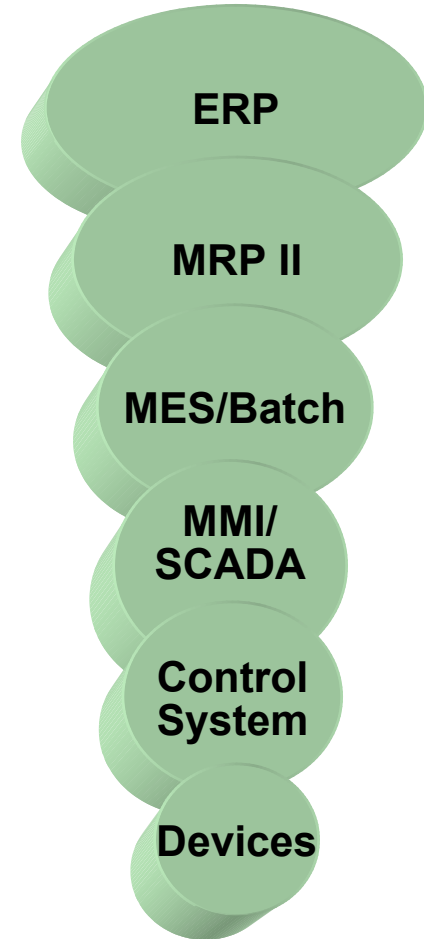
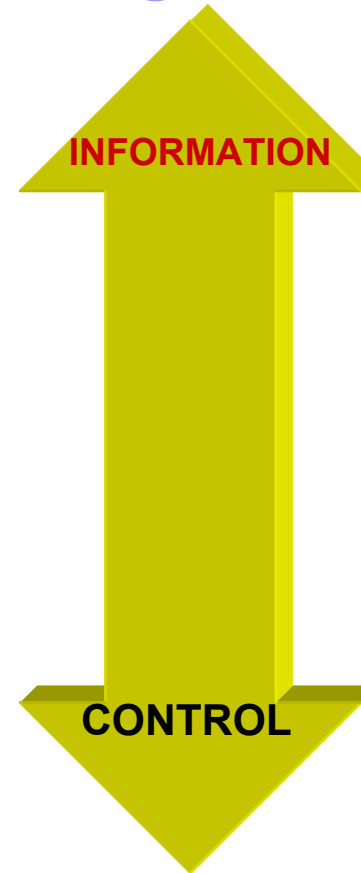


4. The Changing Face of Industrial Control

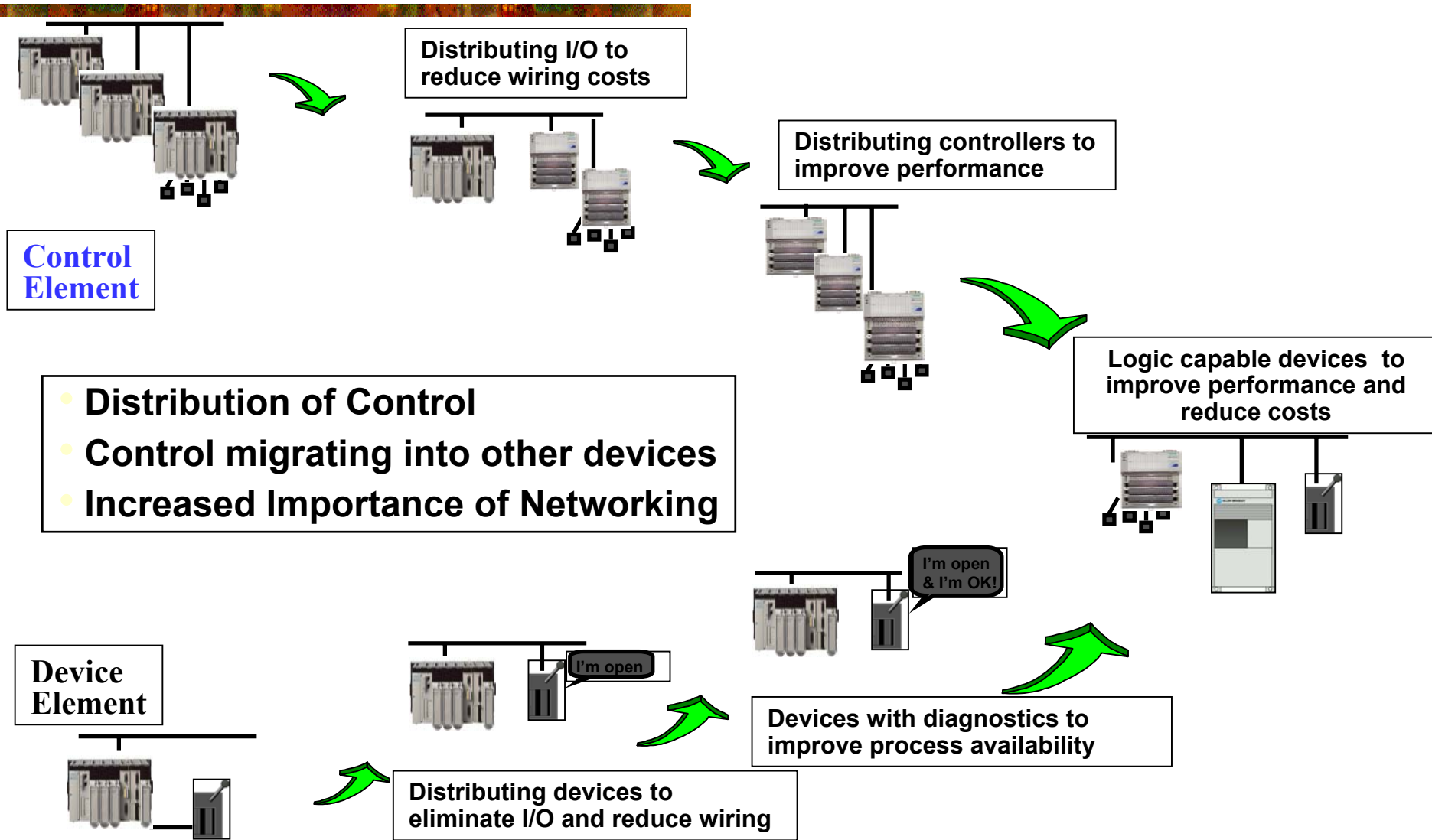
Business Is Driving the Integration of Plant Floor & Information



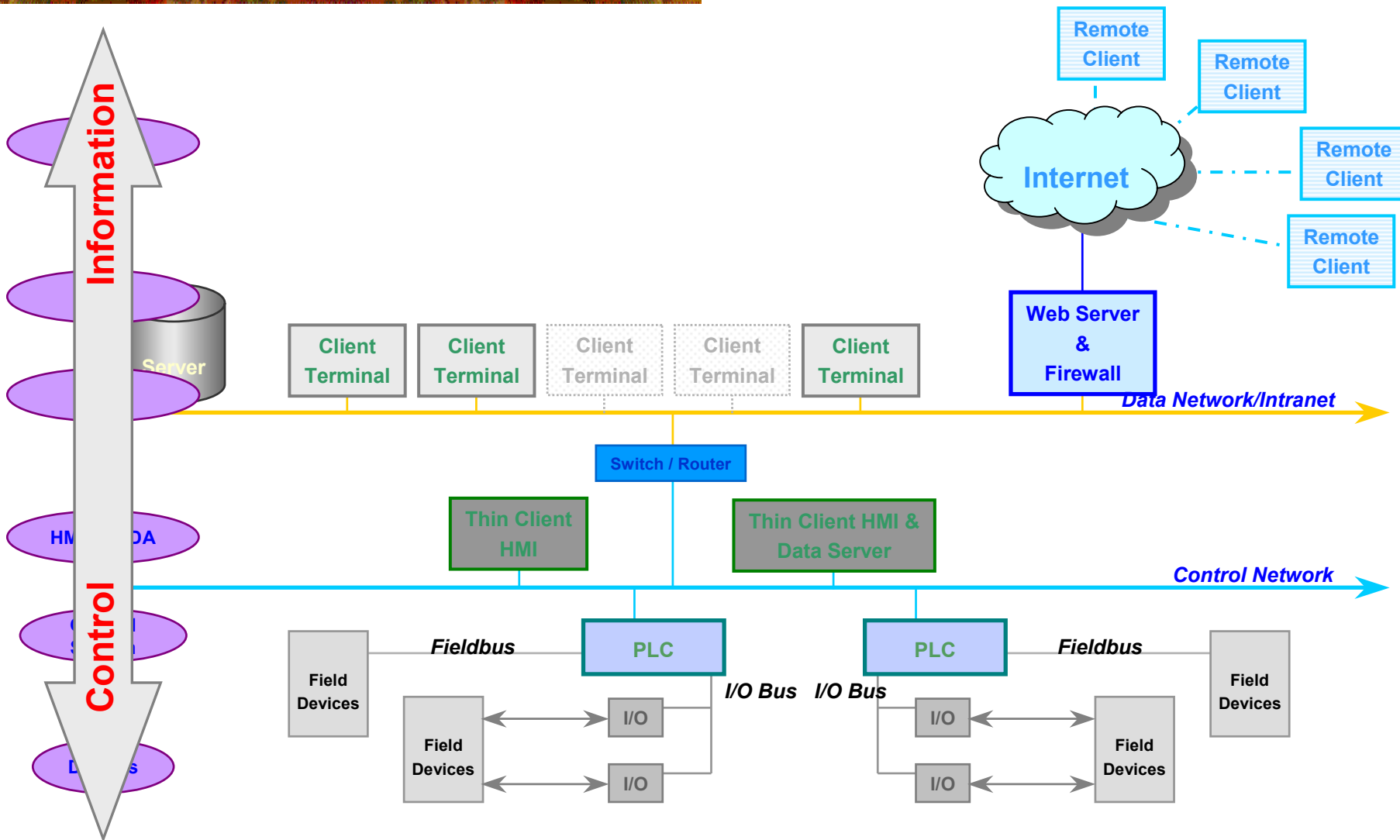
Integration



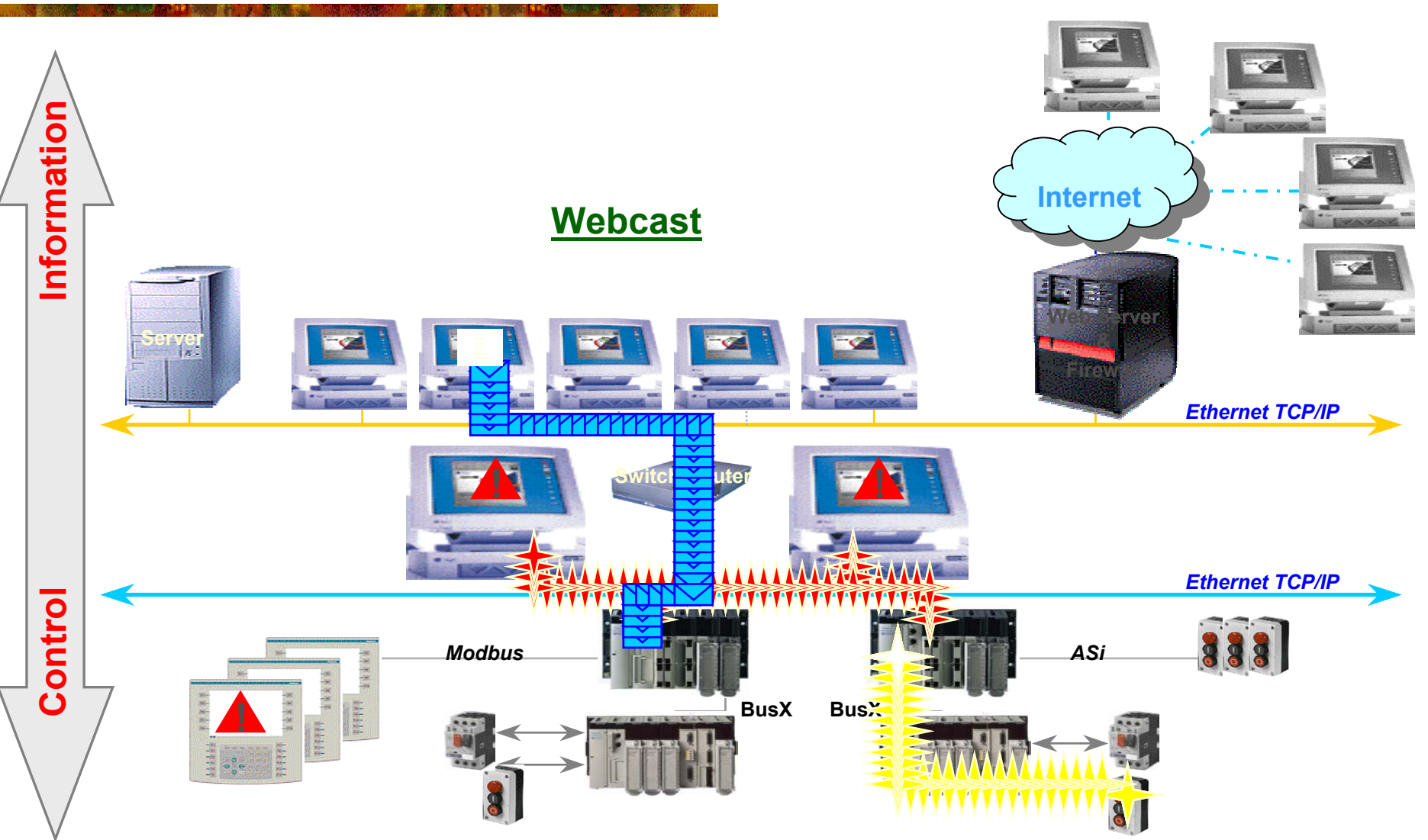
Distributed Control Market Trends



Information Flow...

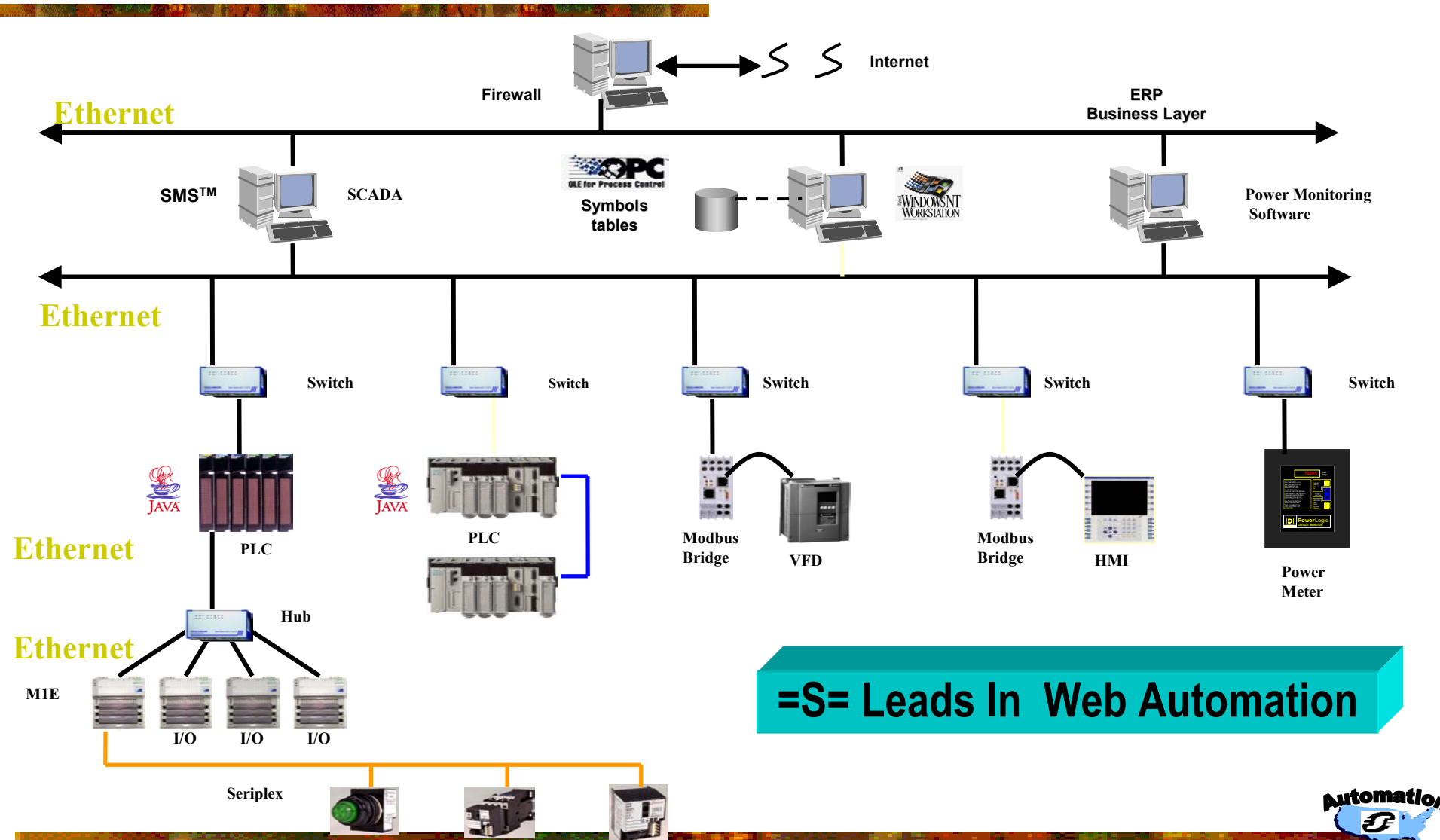


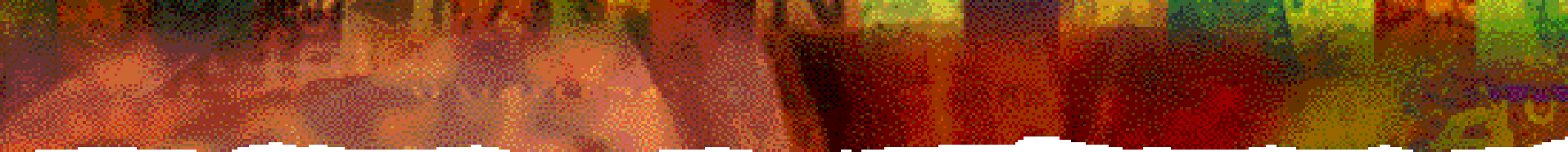
Information Flow...



Open Communications...

Transparent
FACTORY
Open for Business





2.The Micro PLC

Development of the PLC

- ❖ The driving force behind the development of the Micro PLC was the demand by OEM for a PLC.

Desired Features of Micro PLC

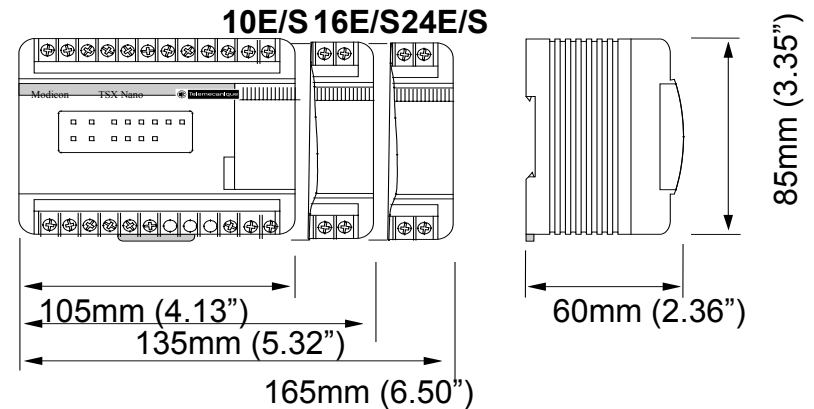
- Relay Logic Instructions.
- Math capabilities, +, -, *, /, Sq-root, =, <, >
- Timers-- On/Off Del, Retentive
- Data Handling instructions
- Up/Down Counters
- High-speed counting
- BCD to Binary conversion routines
- Drum timer and sequencer functionality
- Subroutines and interrupts
- Programmed with a personal computer
- Communication with other electronic devices
- Analogue Handling

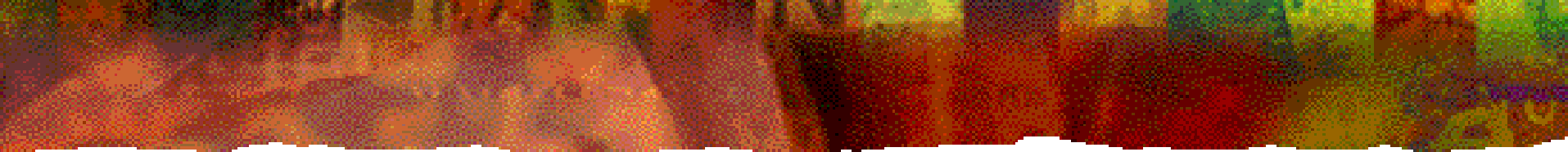
What makes micro PLC a micro?

- ❖ Micro PLC's are self-contained units with Processors, Power supply & I/O's in one package Hence often called Packaged Controller.

General Characteristics are --

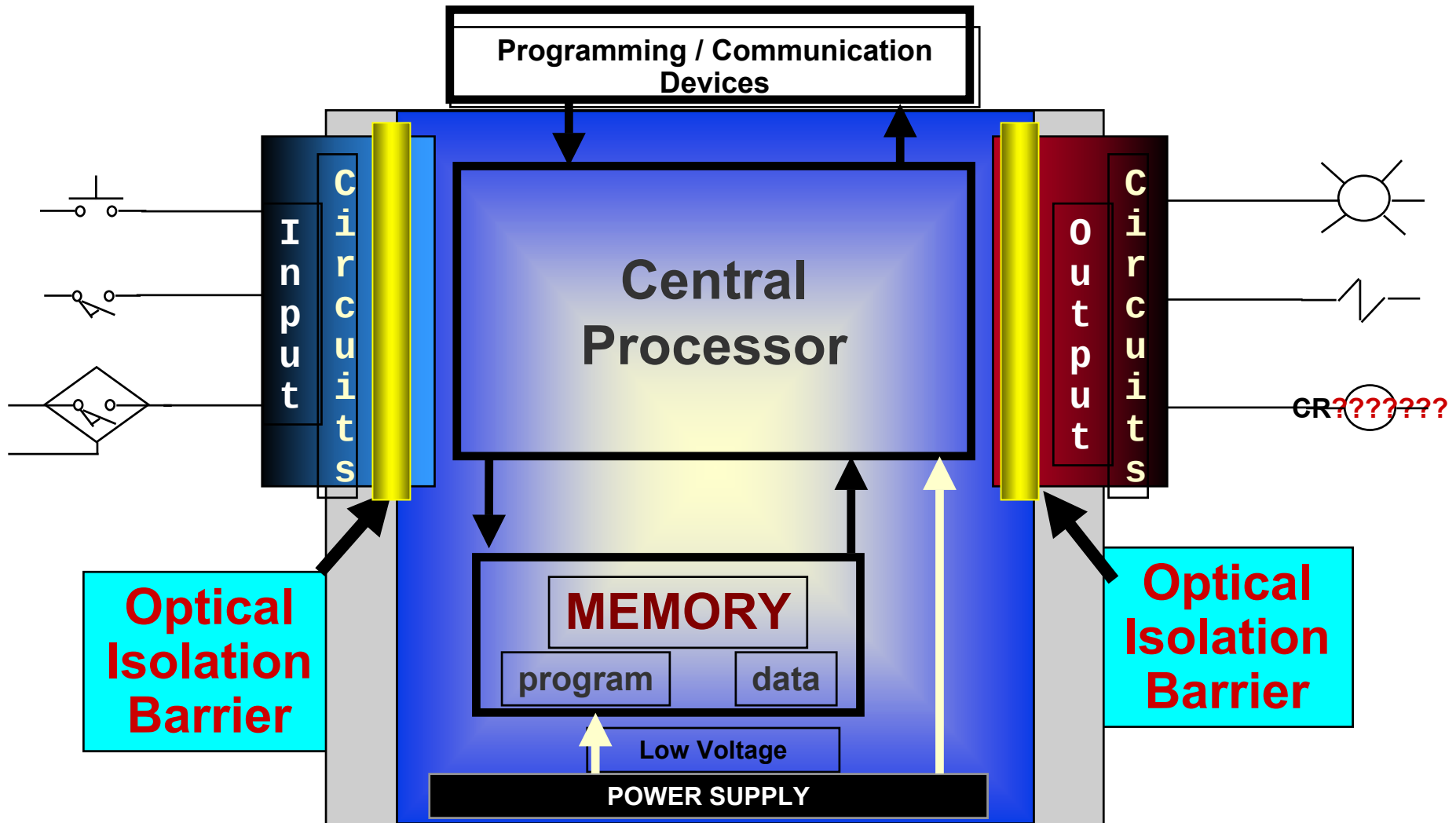
- ❖ Number of Inputs and Outputs ≤ 32 I/O's.
- ❖ Cost in four figures.
- ❖ Physical Size -- ever competing.





3. *Micro PLC Operation*

PLC Components Overview

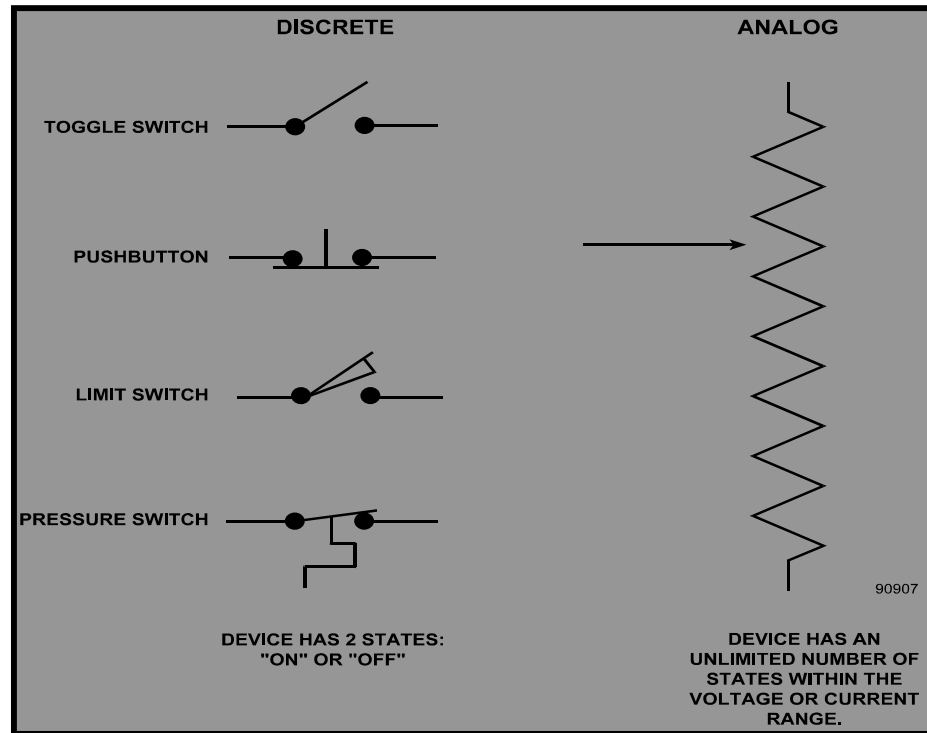


Input Devices

- ❖ Pushbuttons
- ❖ Selector Switches
- ❖ Limit Switches
- ❖ Level/Pressure/Temperature Switches
- ❖ Photoelectric Sensors
- ❖ Proximity Sensors
- ❖ Motor Starter Contacts
- ❖ Relay Contacts
- ❖ Thumbwheel Switches
- ❖ Transducers/Transmitters
- ❖ Encoders/Tachos/Resolvers

• 120 VAC

• 24 VDC

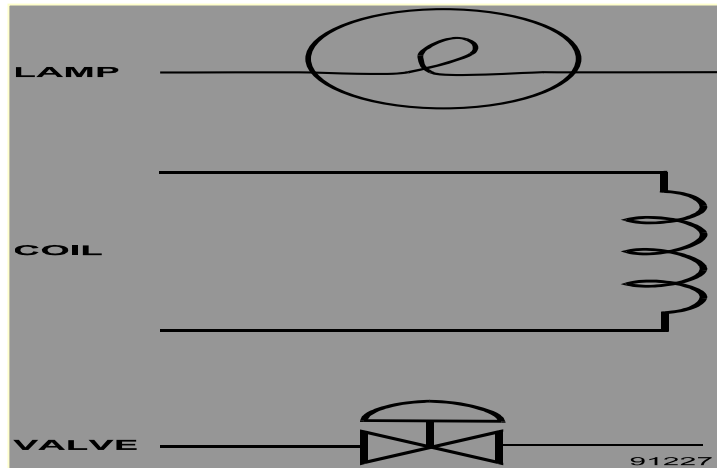


Points to know about Input Modules.

- ❖ Can be **Discrete or Analogue**.
- ❖ Can be varying voltages/ currents.
- ❖ **Field signals** are unfiltered. Conditioning of the signals are required because the internal components of a PLC operate on 5V DC. This minimizes the possibility of damage by shielding them.
- ❖ To **electrically isolate** the internal components from the input terminals, PLC employ an optical isolator -- a device which uses light to couple signals from one electrical device to another.
- ❖ The field signal needs to be qualified as valid which means it needs to be distinguished from the electrical noise.
- ❖ This activity is done by Input Filters which determine the validity of the signal of a signal by it's duration -- they wait to confirm that a signal is a reference from an input device rather than an electrical noise.
- ❖ Some PLC's have adjustable filter time ??(Question Higher/Lower)

Output Devices

- ❖ Valves
- ❖ Motor Starters
- ❖ Solenoids
- ❖ Control Relays
- ❖ Alarms
- ❖ Lights
- ❖ Fans
- ❖ Horns



Relays

- 120 VAC/VDC
- 240 VAC/VDC
- 24 VAC/VDC

Triac

- 120 VAC

MOSFET

- 24 VDC

Points to know about Output Modules.

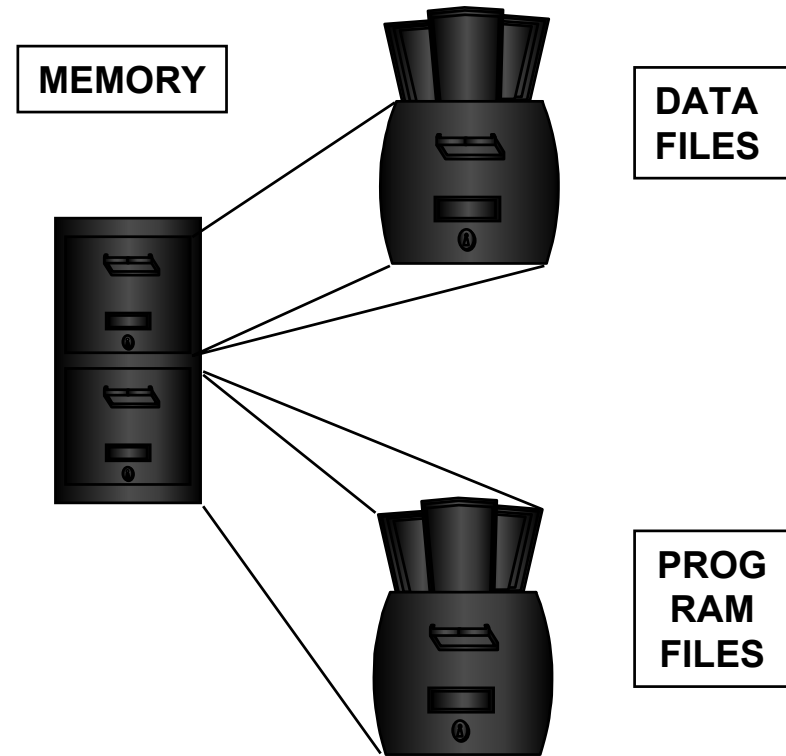
- ❖ Can be **Discrete or Analogue.**
- ❖ Can be varying voltages/ currents.
- ❖ Output circuits operate in a manner similar to the input circuits – signals from the CPU passes through an isolation barrier before energising outputs.
- ❖ Output Circuits can be
 - -- ..Relays ---can be either for AC/DC, handle higher amp,slow, wear & tear.
 - --- Transistors --Switches DC Power,Fast,lower Amp handling typically 0.5A.
 - Triacs -- Switches AC Power,other features same as Transistors.
- ❖ **Note**
 - -- Solid State Outputs (Triacs & Transistors) can be damaged by over voltage or over current.

Points to know about CPU's

- ❖ CPU, the primary component is made of a microprocessor & a memory system.
- ❖ CPU reads the inputs, executes logic as dictated by the **APPLICATION PROGRAM**, performs calculations & controls the outputs accordingly.
- ❖ PLC users work with 2 areas of the CPU : **Program Files & Data Files**.
- ❖ Program File stores an user application program, subroutines & the error files.
- ❖ Data files store data associated with the program, such as I/O status, counter/timer preset /accumulated values & other stored constants or variables.
- ❖ Together the above 2 areas are called Application or User Memory.
- ❖ CPU also has an executive program or system memory that directs & performs “operation” activities of the internal functions of the CPU's. This System Memory is Programmed by the manufacturer cannot be accessed by the user.

Points to know about Application Memory

- ❖ Memory is a physical space inside the CPU where the **Program files & Data information** are stored & manipulated.
- ❖ Memory are 2 types -- volatile & non-volatile.
 - **Volatile memory** can be easily altered or erased, it can be written to & read from. Without backup, the programmed contents will be lost in absence of Power. Best known form is RAM & is typically backed up by battery or capacitor.
 - **Non-volatile** memory retains its programmed contents without a backup. The EEPROM offers the same flexibility as RAM.



Knowing about Data, Memory & Addressing

- ❖ **Data** is a pattern of Electrical charges that represent a numerical value.
- ❖ **A bit** is the smallest unit of memory available. It is a discrete location within a silicon chip that has a voltage present(1--On) or absent (0--off).
- ❖ **16 bit** groups is known as a **WORD**. Generally CPU's process & store data in words, but the data can be manipulated at the bit level.
- ❖ Each **WORD** has a specific, physical location in the CPU called an **address or a register**.
- ❖ The address is related to the **terminal** where **input & output devices are connected**.
- ❖ **Thumbwheel switches require 4 bits per wheel** since they communicate in BCD format. Thus any PLC used with a thumbwheel must be able to accept a BCD input.

Memory & Data

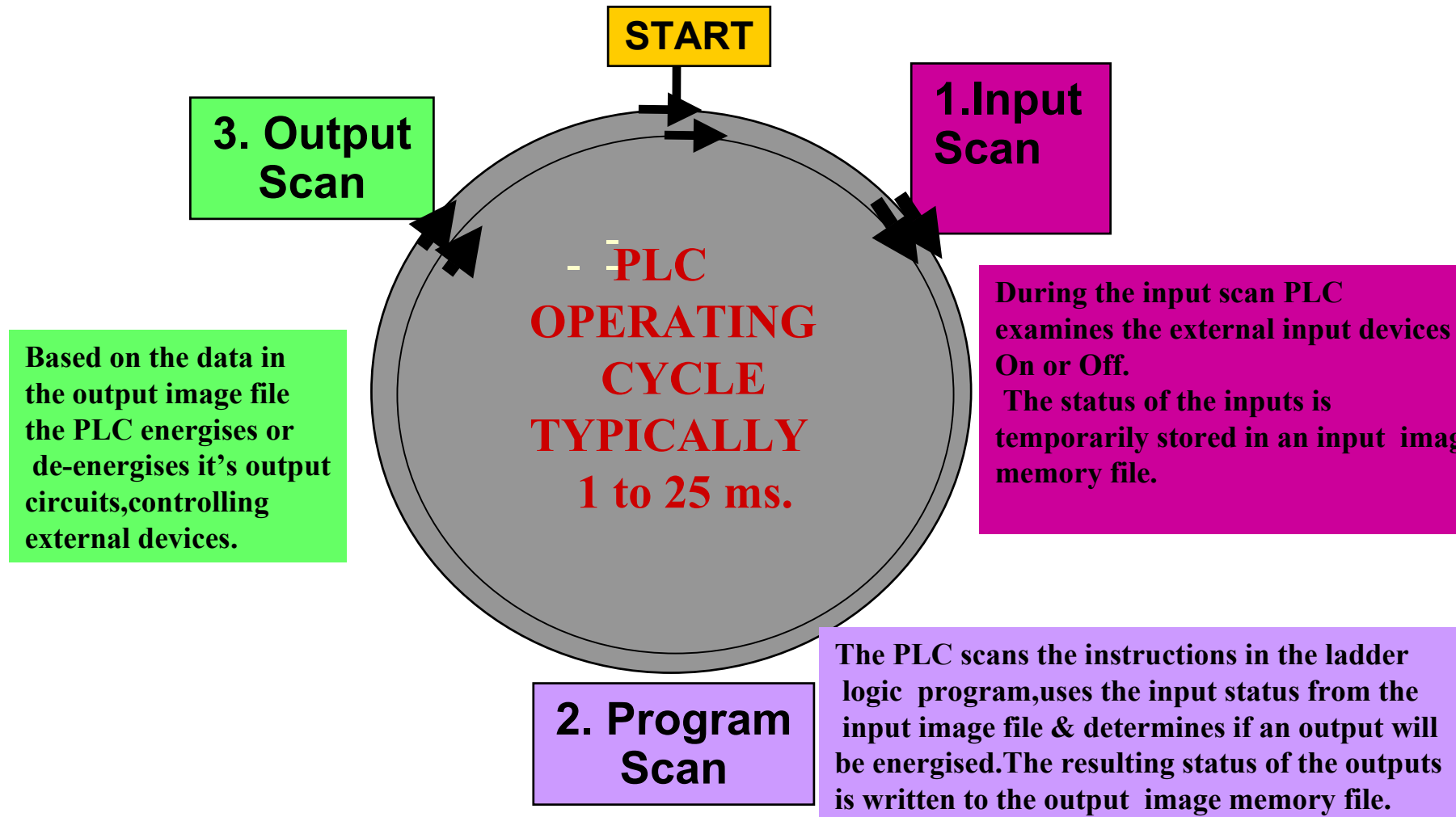
MEMORY

- ❖ Bit 1 or 0
- ❖ Nibble 4 bits
- ❖ Byte 2 nibbles
- ❖ Word 2 bytes
- ❖ Double Word 2 words
- ❖ Long Word 2 D words

DATA

- Octal 0-7
- BCD 0-9
- HEX 0-F (15)
- Integer (signed) -32767/ +32768
- Unsigned Integer 65,535
- Floating Point
IEEE $\pm 3.45 \times 10^{38}$
to
 $\pm 1.17 \times 10^{-38}$

What' happens in an operating cycle



Speed of a PLC or “the through put time”

- ❖ The throughput time includes the time for actuation of the physical input ; time for PLC's input circuit to sense the signal;time for input scan, program scan and output scan; time for actuation of the output circuit & corresponding field device;and time for the CPU's housekeeping or overhead functions.
- ❖ Therefore the formula is --
*Input scan time+Output scan time+housekeeping time+ **program scan time(addition of instruction execution times when all instructions are True)** +PLC input circuit filter time+PLC output circuit turn on time.*

Advanced Micros offer functions of high speed counting with direct control of outputs & immediate I/O update instructions. These functions enable the micro controller to detect & react quickly to changing conditions.

Power Supplies

- ❖ PLC Power supplies are typically designed to meet normal operation of +10 to -15%. *Fluctuation* in voltage.
- ❖ *Converts the incoming voltage* to a useable form for the internal electronics
- ❖ *Protects* the PLC 's components from voltage spikes. For voltage condition that are unstable insist on a CVT between PLC & primary power source.
- ❖ Operates either on 120VAC/ 240 VAC/ **24VDC**.
- ❖ PLC's Power Supply is designed to meet short power losses without affecting the operation of the system. PLC can operate for several "ms" without line power before the PS signals the processor that it can no longer provide adequate DC Power to the system. The CPU executes a controlled shut down which saves the users program & data in memory
- ❖ The other factor affecting the function of the PLC is *EMI or electrical noise*. Use an isolation transformer, take care of shielding from Drives, ensure proper earthing & cabling practices.

Programming Devices & HMI

❖ **Personal Computer**

- Run PLC Programming Software
- It creates, edits, document, store and troubleshoot ladder diagrams, and generates printed reports.

❖ **Hand Held Programmer**

- Mainly a troubleshooting tool.
- On factory floor you can modify the program, store the program and transfer the program to multiple machines.

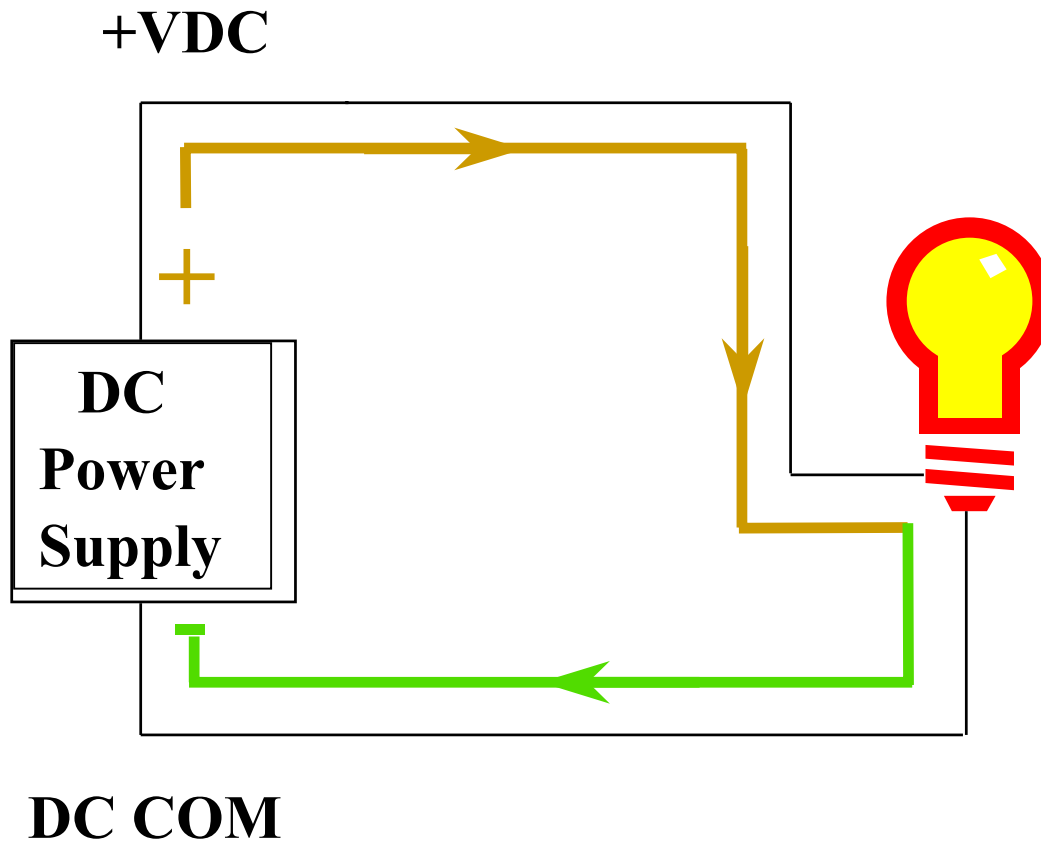
❖ **Operator Interfaces**

- These are not programming devices but graphic or alphanumeric displays & control panels that consolidate all the functions of traditional operator interface devices into a single panel.

These products communicate with the PLC through a RS232 communication port & thereby I/O's are not sacrificed.

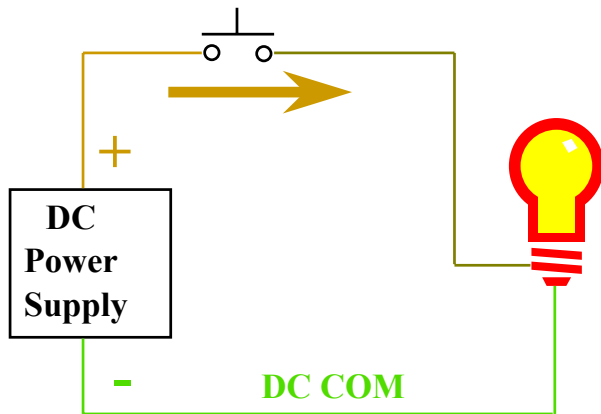


SOURCING vs. SINKING DC I/O (General)

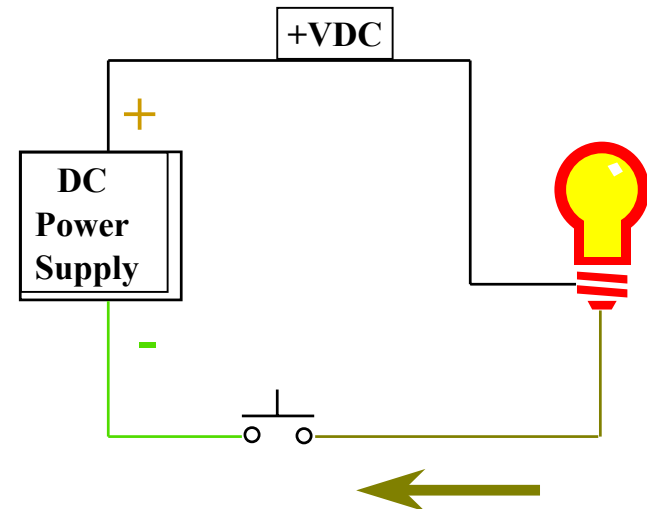


SOURCING vs. SINKING DC I/O (General)

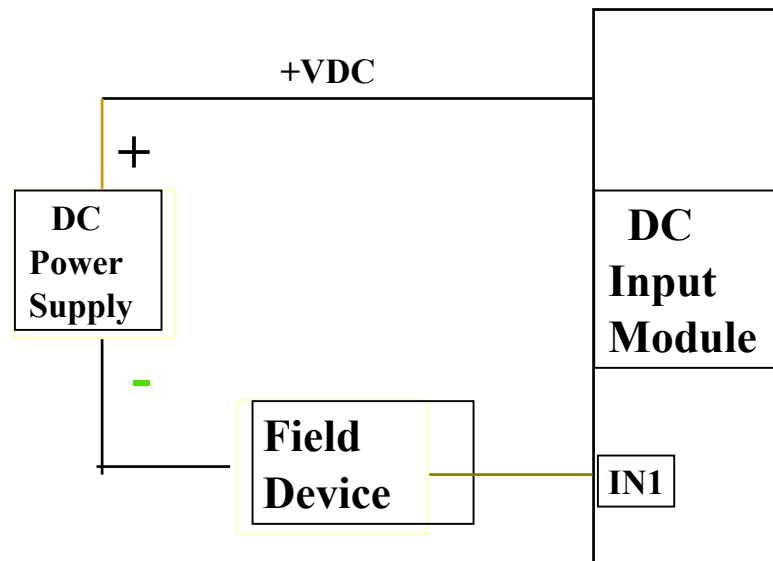
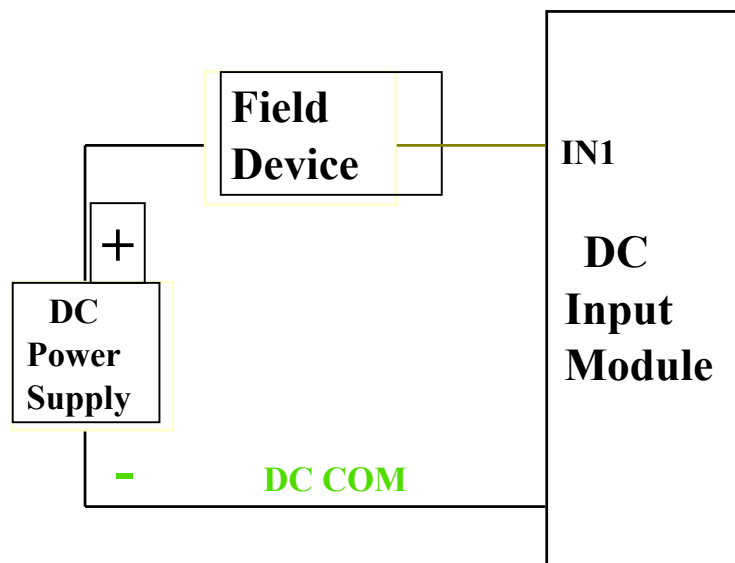
SOURCING Pushbutton



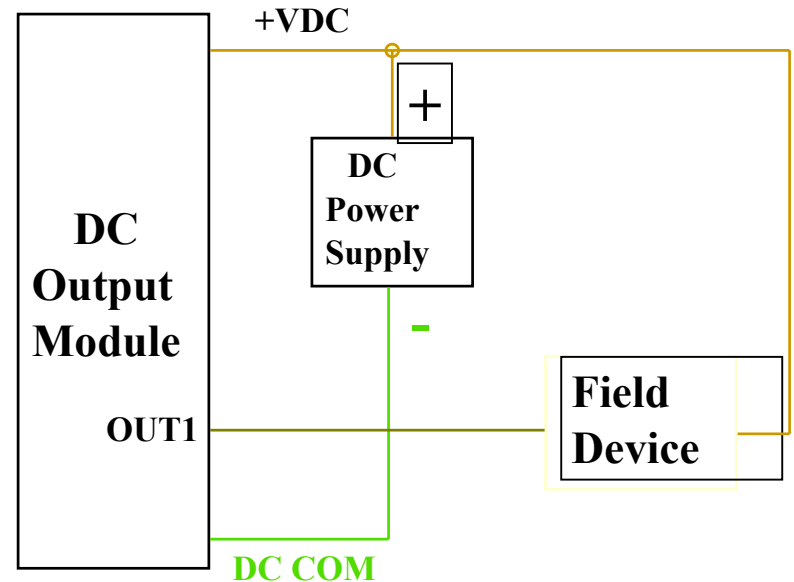
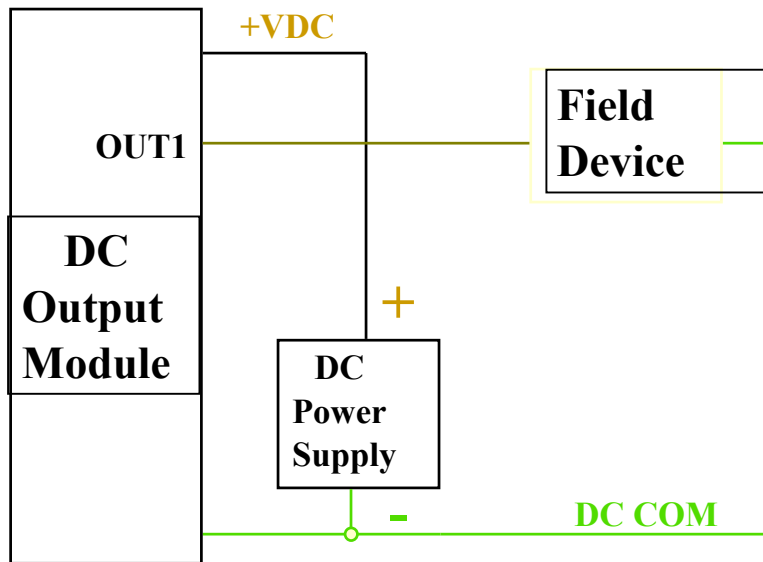
SINKING Pushbutton



SOURCING vs. SINKING DC Inputs



SOURCING vs. SINKING DC Outputs





Field devices on the positive side (+VDC) of the field power supply are **sourcing** field devices.



Field devices on the negative side (DC COM) of the field power supply are **sinking** field devices.

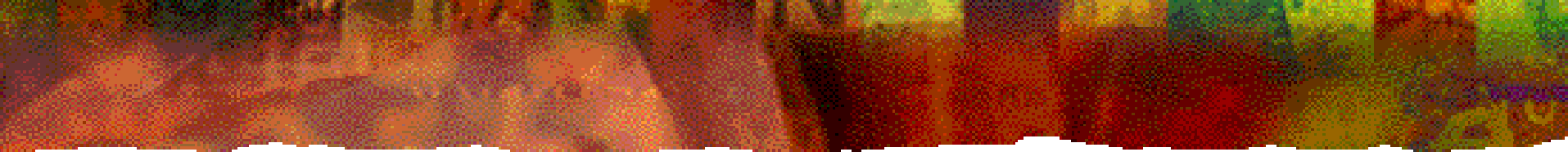


Sourcing field devices must be connected to sinking I/O cards and vice versa.



Sinking field devices must be connected to sourcing I/O cards and vice versa.

PLC Fundamentals Review



4. Ladder Logic Fundamentals

Programming Language

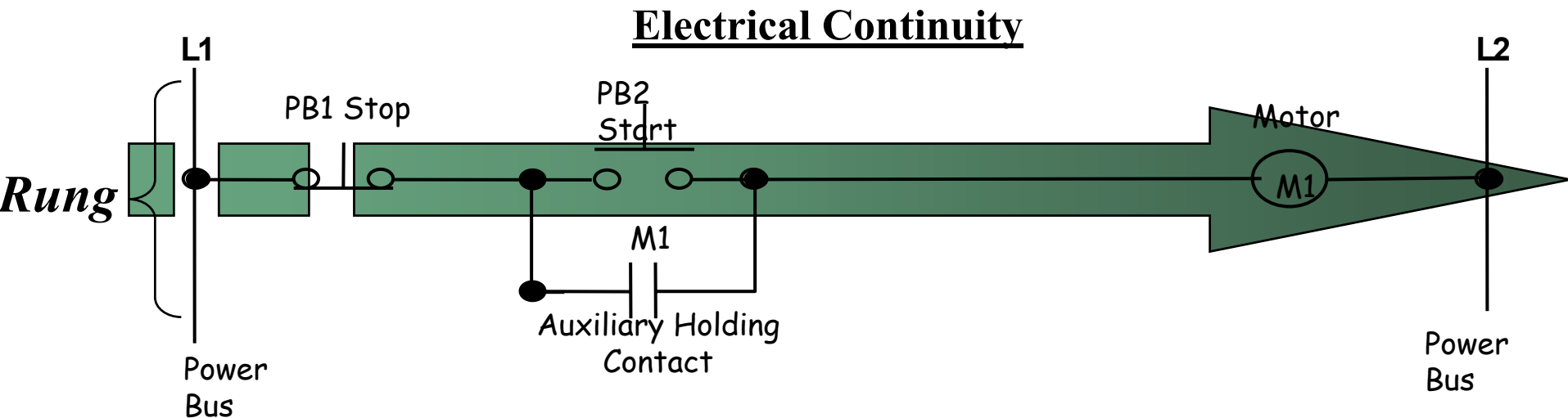
- ❖ A **Program** is a user developed series of instructions or commands that directs the PLC to execute actions.
- ❖ A **Programming Language** provides rules for combining the instructions so that they produce the desired actions.
- ❖ The most commonly used Programming Language is '**LADDER LOGIC**'
- ❖ Other Languages occasionally used to program the PLC's include BASIC, C and Boolean.

Why ladder logic?

- The Ladder logic programming language is an adaptation of an electrical relay wiring diagram, also known as ladder diagram.
- Ladder Logic is a graphical system of symbols and terms even those not familiar with relay wiring diagram can easily learn it.

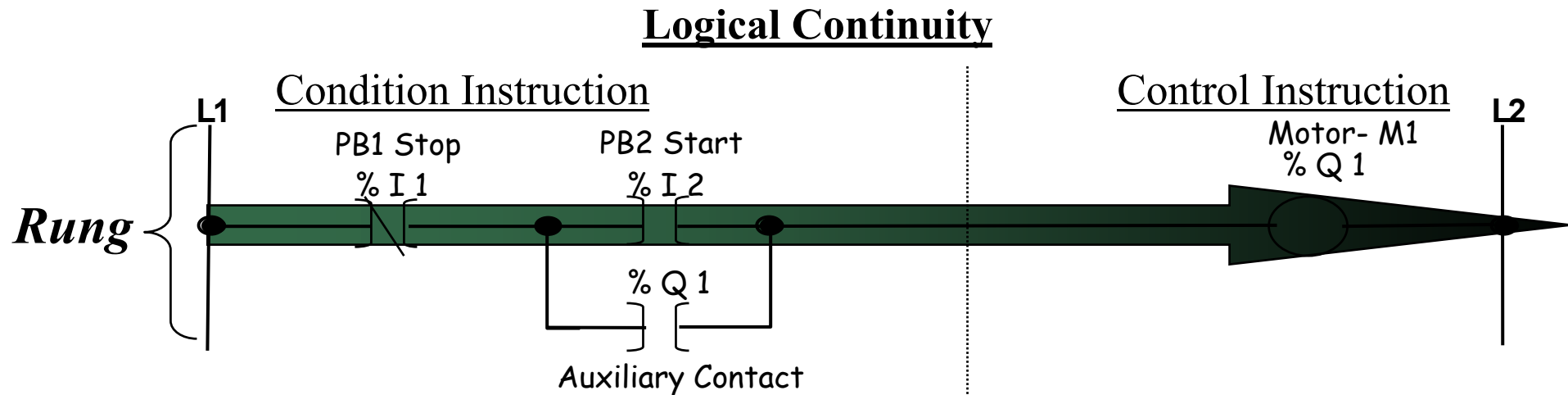
Electrical Ladder Diagram

- ❖ Ladder Logic is evolved from **electrical ladder diagrams**, which represents how electrical current flows thru the devices to complete an electrical circuit.
- ❖ An electrical diagram consists of two vertical bus lines or power lines, with current flowing from left bus to the right bus.
- ❖ Each electrical circuit in the diagram is considered a **rung**.
- ❖ Every rung has two components
 - It contains at least one device that is controlled
 - It contains the condition(s) that control the device.



Ladder Logic Program

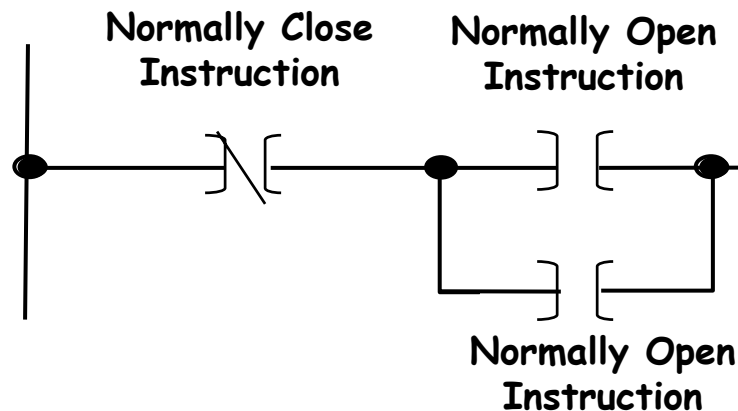
- ❖ Ladder Logic closely resembles electrical ladder diagrams
- ❖ A Ladder logic program exists only in the PLC's software.
- ❖ In ladder Logic it is not the actual flow of current thru circuits.
- ❖ In **electrical diagram** the devices are described as open or closed(**ON or OFF**), where as in **Ladder Logic**, instructions are either **TRUE or FALSE**.
- ❖ In Ladder Logic Program must contain at least one **control instruction (output)** and usually contains one or more **conditions (inputs)**.



Ladder Logic Instructions

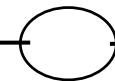
- ❖ The instructions in PLC ladder logic program are the **Normally open (N.O.)** instructions, the **Normally closed (N.C.)** instructions, and the **Output energized** instruction.

Condition Instruction



Control Instruction

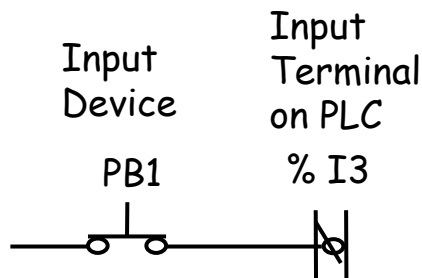
Output Energize Instruction



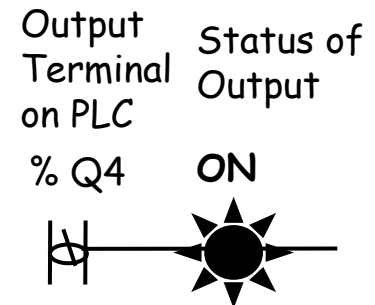
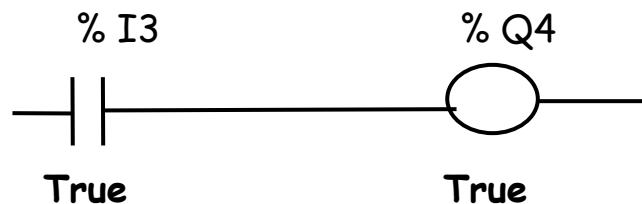
Normally Open Instruction (--I I--)

- ❖ A Normally Open instruction examines a PLC memory location for an ON condition. If PLC detects ON condition, the instruction is True and has Logical continuity.
- ❖ Let us take an example of a Push Button PB1.

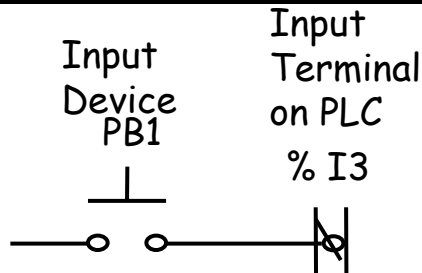
When PB1 is Pressed(ON)



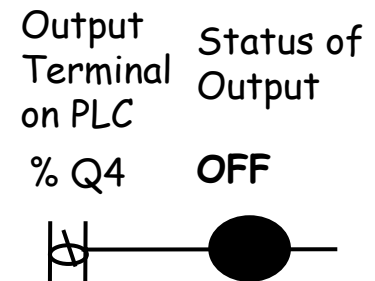
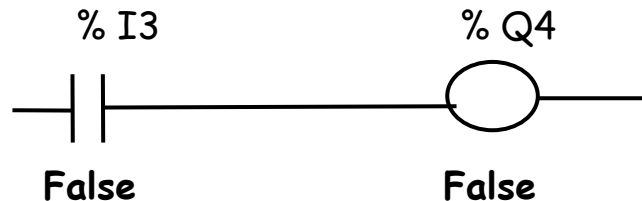
Ladder Program



When PB1 is Released(OFF)



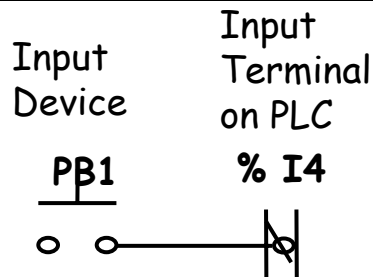
Ladder Program



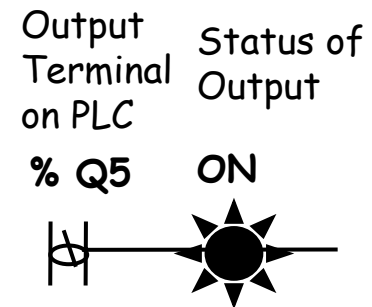
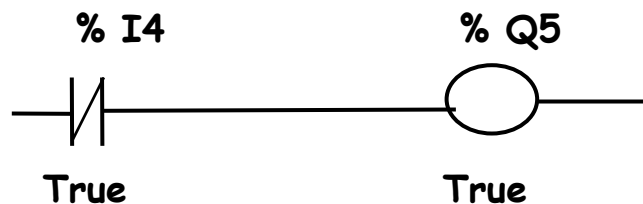
Normally Close Instruction (--N--)

- ❖ A Normally Open instruction examines a PLC memory location for an OFF condition. If PLC detects OFF condition, the instruction is True and has Logical continuity.
- ❖ Let us take an example of a Push Button PB1.

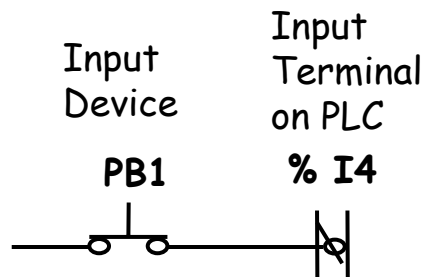
When PB1 is Released(OFF)



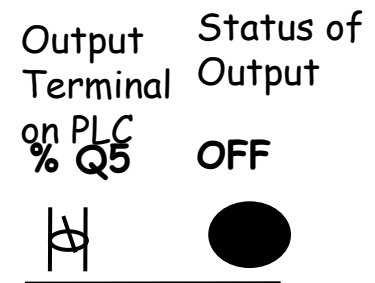
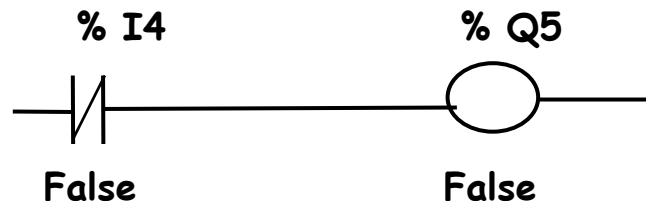
Ladder Program



When PB1 is Pressed(ON)



Ladder Program



Output Energize Instruction (--()--)

- ❖ When Logical continuity exists on a rung, the On condition (binary 1) is written to the location in the memory associated with the output energize instruction.

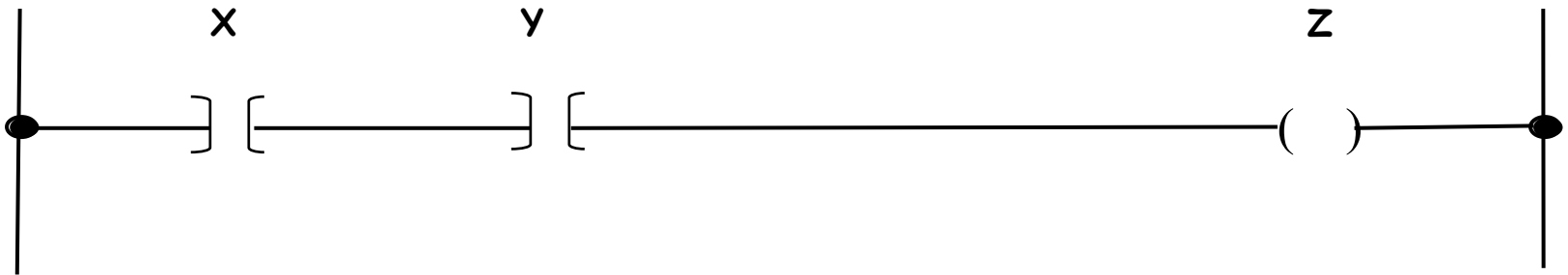
Higher Level Instruction

- While relay logic is suitable for simple On/Off sensing and control, many applications require more powerful instructions.
- These instructions deals with numerical data beyond simple 1s or 0s by manipulating data in bytes or words.
- Examples of higher level instructions include Counters, Timers, Sequencers, Math, Comparison and other operations.

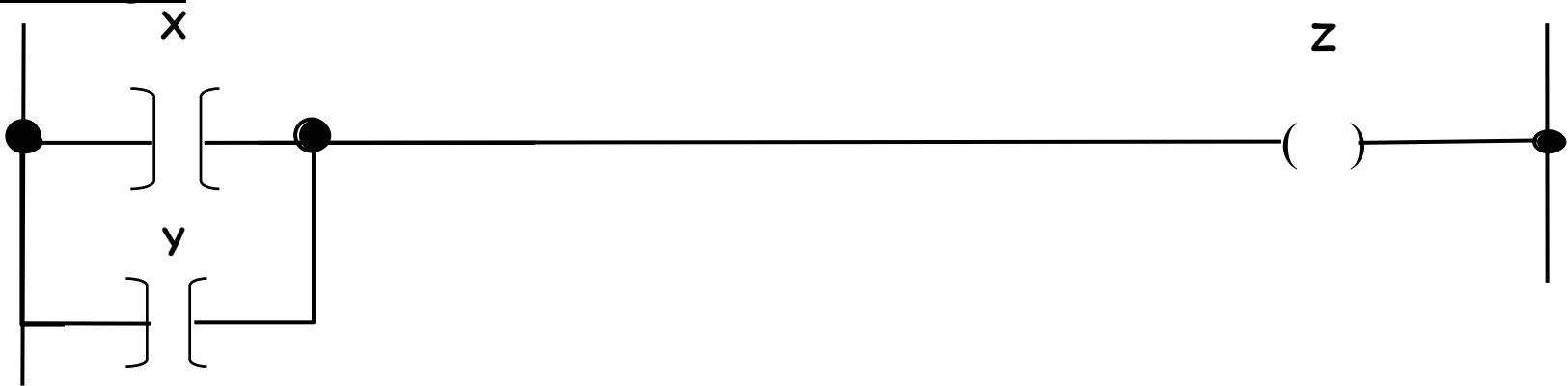
Combining Instructions

- ❖ Two fundamental logic operations – AND and OR provide the rules for governing how the instructions are combined.

AND Logic

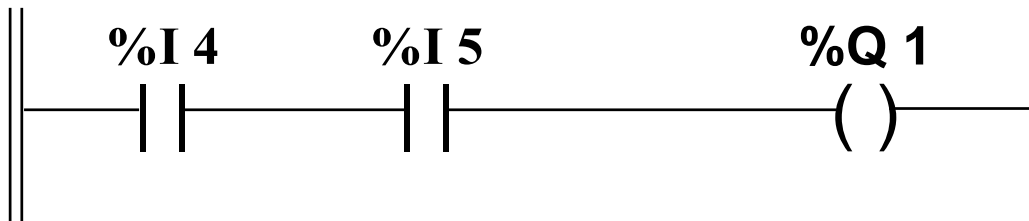


OR Logic



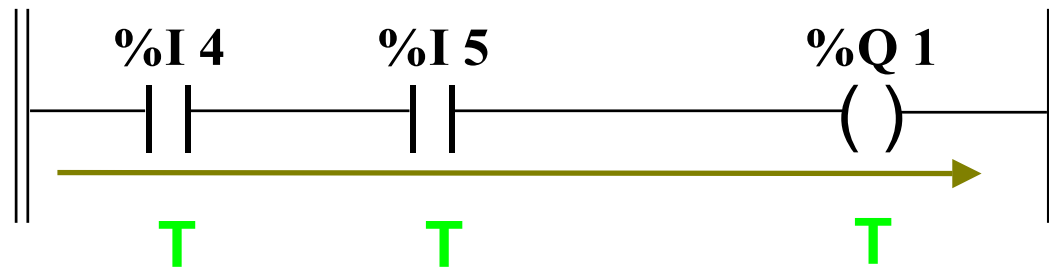
Logical AND Construction

IF input 004 **AND** input 005 have power
THEN energize output 1



Logical AND Construction

IF input **4** **AND** input **5** have power
THEN energize output **1**



Logical Continuity

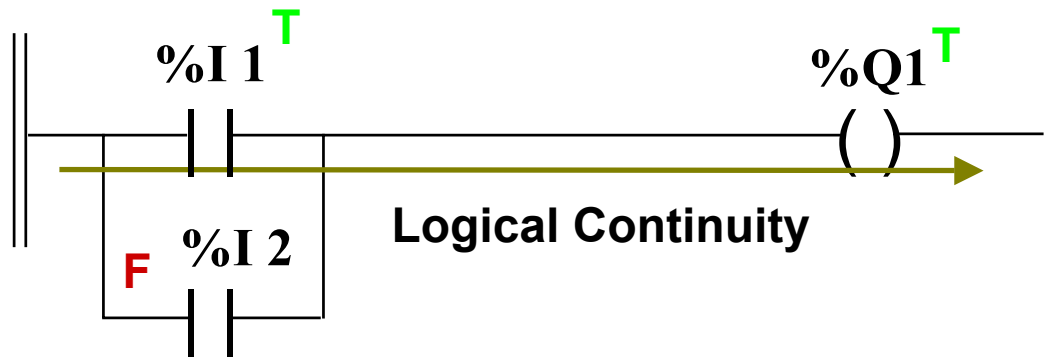
Logical OR Construction

IF input **4** **OR** input **5** have power
THEN energize output **1**



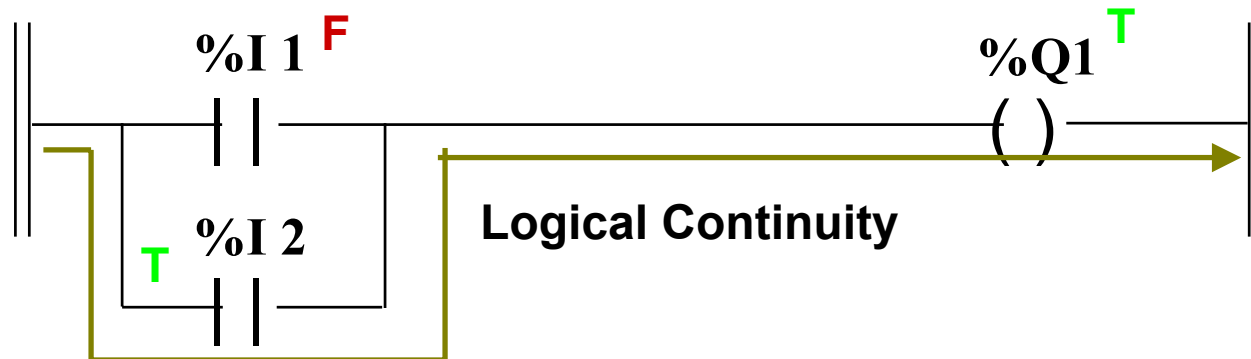
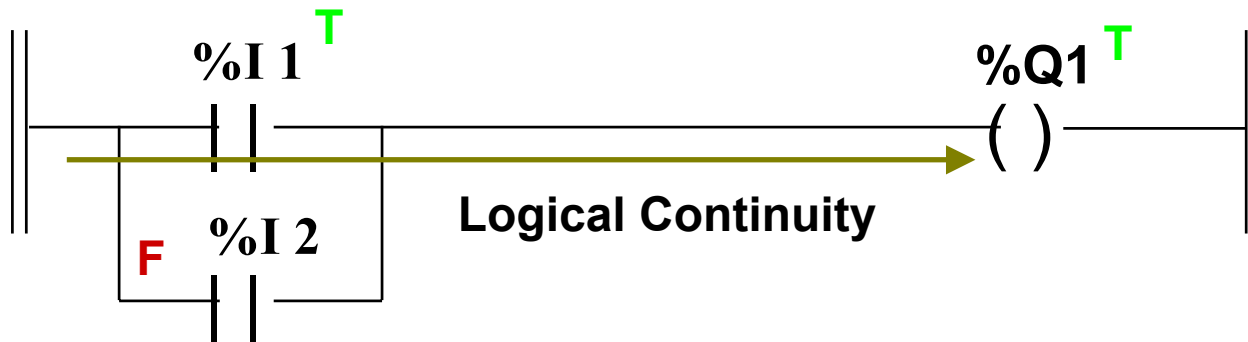
Logical OR Construction

IF input 1 **OR** input 2 have power **THEN** energize output 1



Logical OR Construction

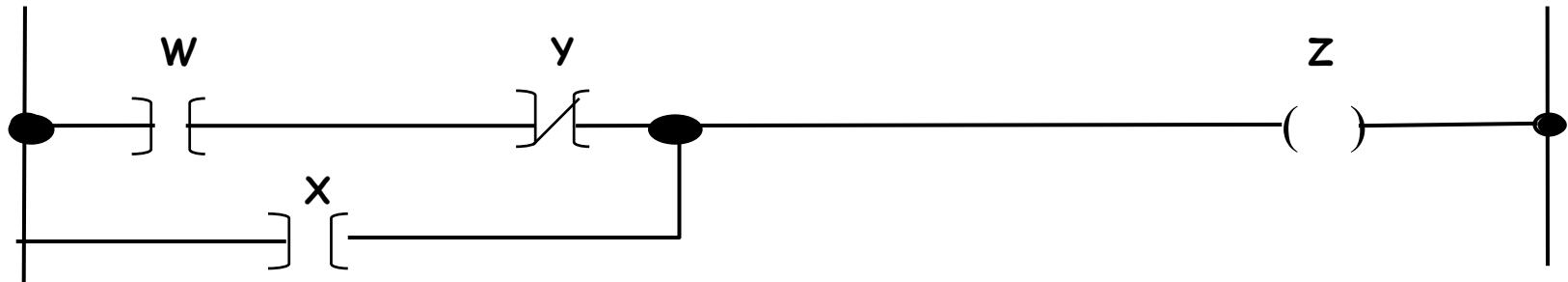
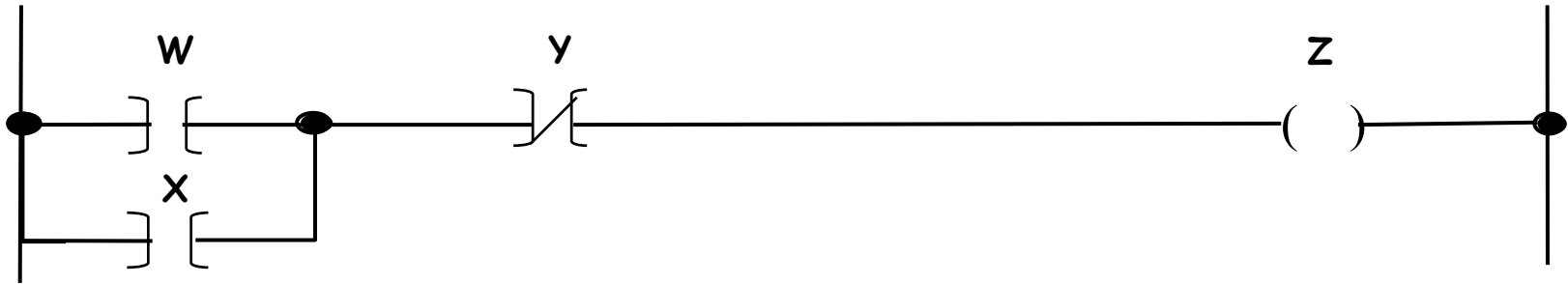
IF input 1 **OR** input 2 have power **THEN** energize output 1



Combining Instructions contd

Combining Series and Parallel Logic

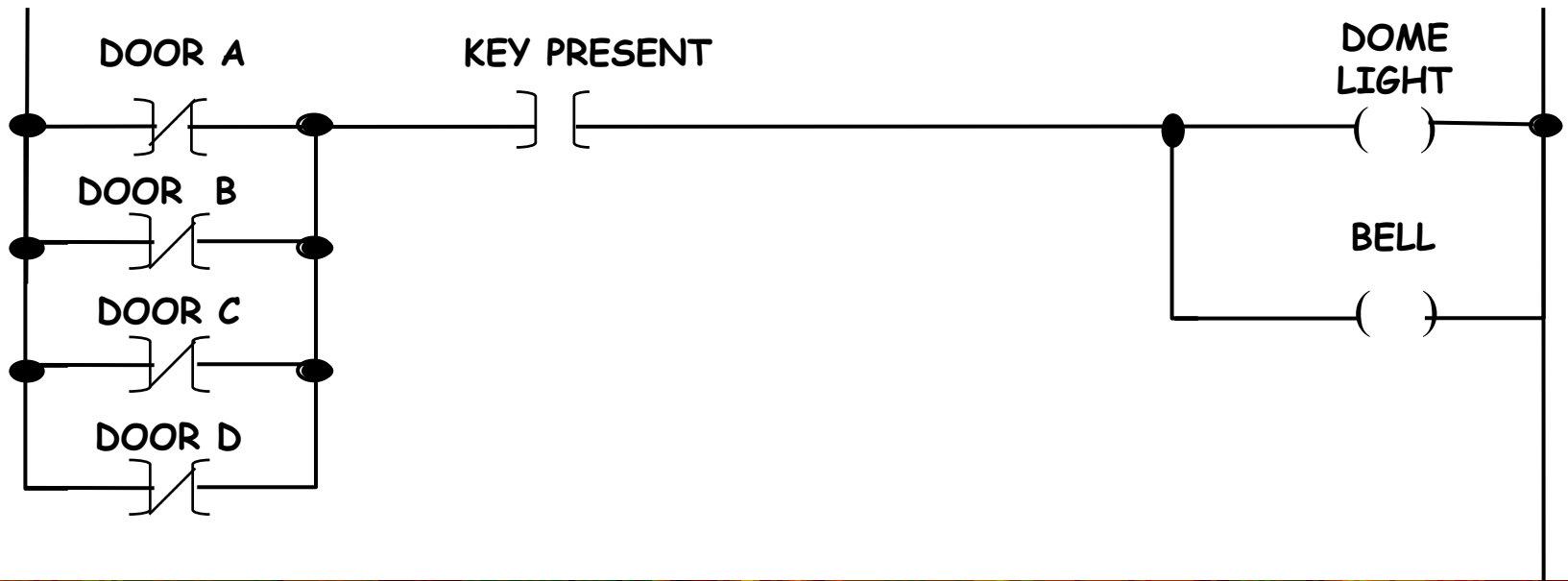
- ❖ AND and OR logic (series and parallel circuits) can be combined on a single rung.



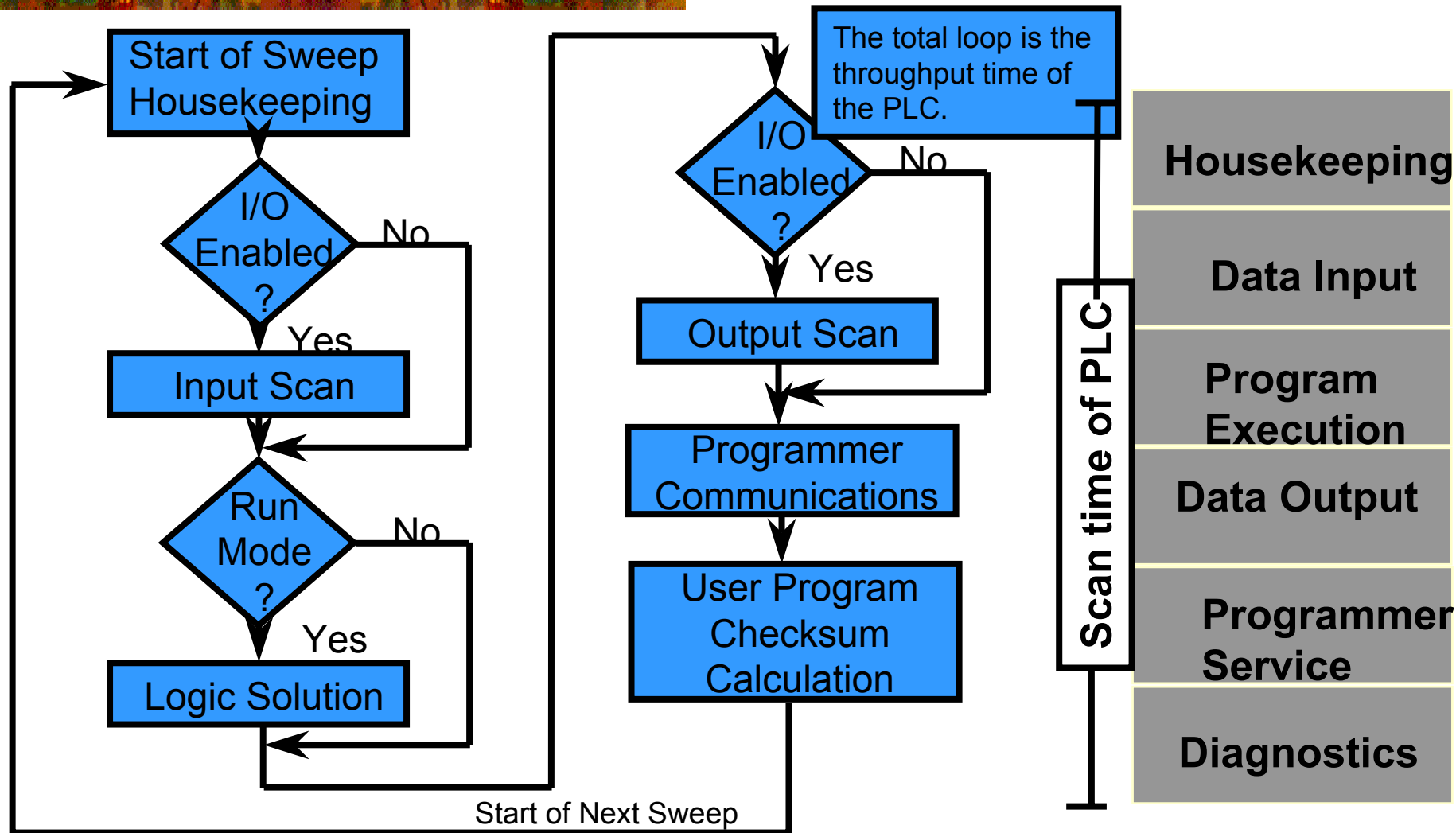
Combining Instructions contd

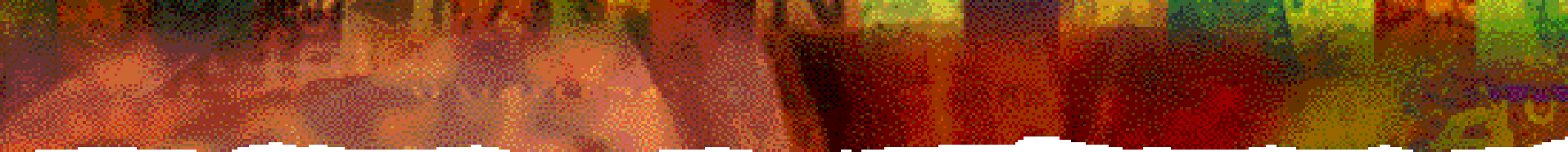
Branch Operations

- ❖ The Function of a branch is to allow both condition and control instructions to be programmed in parallel in a single rung
 - Condition instructions programmed in parallel are the equivalent of an OR operation.
 - Control instructions programmed in parallel are the equivalent of an AND operation.



Program Execution



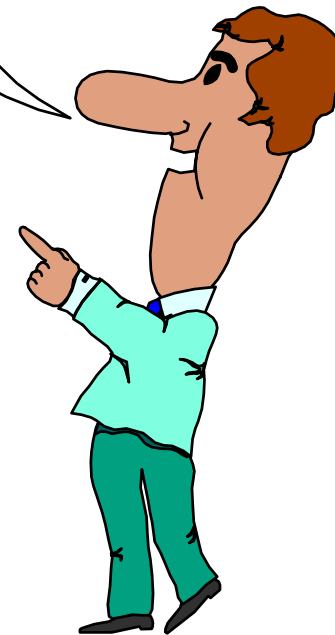


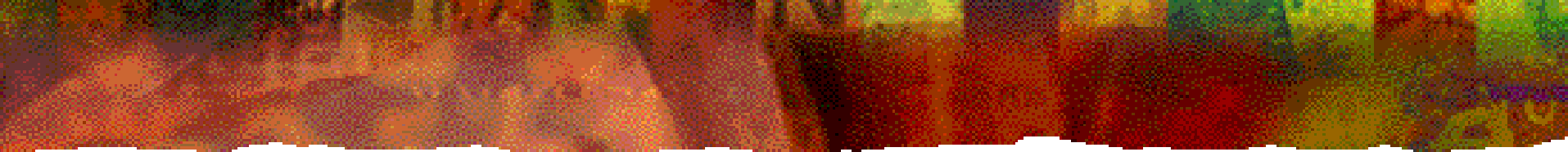
5. What's Networking & the Parlance

Schneider Communication Network Terms

- ❖ RS-232
- ❖ RS-422
- ❖ RS-485
- ❖ CL-20
- ❖ Fibre Optic
- ❖ Modbus
- ❖ Unitelway
- ❖ Modbus Plus
- ❖ FIPIO
- ❖ Fipway
- ❖ Ethernet TCP IP
- ❖ Profibus DP
- ❖ Interbus
- ❖ Lon Works

**What the hell do
all these mean?**





5. How to apply a micro PLC?

Do I need a Programmable Controller

1. Do you have any equipment or process controlled by 10 or more relays?
2. Are you satisfied with the reliability and uptime of relay controlled machine tools and processes?
3. Are you experiencing excessive downtime due to electrical problems?
4. Do relay control panels occupy floor space needed for other purposes?
5. Do existing relay control panel put a drain on energy consumption?
6. Do control requirements change frequently, say, once a month, and require rewiring or logic changes?
7. Is it must that you have to monitor operations presently controlled to detect and report malfunctions, part counts, machine uptime, etc.?
8. Does existing equipment have provisions for adding monitoring capability without major rework?
9. Do you operate equipment on a multi-shift basis, shortening relay life?
10. Do you anticipate extending, or having to extend, the capability of existing control by modifying them or by adding hardware?
11. Do you have any highly repetitive operations being performed by employees?
12. Do you have any operation repetitive in nature being handled by workers in an uncomfortable or hazardous environment?

Do I need a Programmable Controller

13. Do you inspect large quantities of raw materials or finished goods visually?
14. By weight?
15. By volume?
16. By dimensions?
17. Would automatic tabulation of inspection results be valuable under such circumstances?
18. Do you have process type operations requiring continuous or periodic monitoring of the pressure, flow rates, vacuum, leakage, spills, temperature, or humidity?
19. Is control of such variables required?
20. Is your maintenance staff knowledgeable in troubleshooting relay equipment?
21. Can you readily train new employees to use and maintain relay controls?
22. Do you use conveyor systems or stacker cranes for material handling?
23. Is speed of start up of new equipment critical?
24. Do you have a need to fine tune or optimize the performance of existing equipment to increase productivity?
25. Do present control systems permit equipment to be economically optimized?
26. Do you require data storage capabilities?
27. Do you plan to convert more than one or two machines to PCs at the time of re-mechanization?
28. Do you expect to add more PCs within the next three to five years?

What type of Programmable Controller do I need?

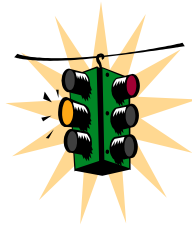
- ❖ Will your smallest control application require fewer than 20 inputs/ outputs (I/O)?
- ❖ 20 to 40 I/Os?
- ❖ Will your largest control application require 40 to 120 I/Os?
- ❖ More than 1000 I/Os?
- ❖ Do you require only digital I/O capability?
- ❖ Will your control application require analog I/O capability?
- ❖ Will your application involve pulse within a confined area, say, within a radius of 100 ft?
- ❖ Do you plan to include, or add at some future date, reporting or data displaying equipment such as CRT terminals or line printers?
- ❖ Is there the possibility the PC will be connected to a control computer in a hierarchical system?
- ❖ Will the application require programming equipment to diagnose faults, display status, generate documentation, or handle off-line programming?
- ❖ Will the controller need to have full range ac/dc capability?
- ❖ Will you require protection or limited access to information stored in the memory?
- ❖ Must the control retrofit to an existing machine or operation?
- ❖ Will you do the engineering installation, programming, and checkout using in-house personnel?
- ❖ Will you contract some of the work?
- ❖ Most of the work?
- ❖ All of the work?
- ❖ Do you presently have personnel knowledgeable in PC, or who can readily be trained?
- ❖ Do you have service/maintenance personnel familiar with ladder diagram logic?
- ❖ Do you have any severe environmental conditions which may affect equipment?
- ❖ Must you produce a cost justification to get the approval of purchase?
- ❖ Do you have any inherent resistance within your plant towards the use of PCs such as fear of programming, maintenance, or losing memory in the event of a power outage?

What are the Application's Requirements?

- ❖ The first step in approaching a control situation is to specify the application's requirements. This includes determining :
 - Input and Output **device requirements**.
 - The need for **special operation** in addition to discrete (ON/OFF) logic, including:
 - Timing
 - Counting
 - High speed counting
 - Sequencing
 - Data acquisition
 - Data calculations
 - The **electrical requirements** for inputs, outputs, and system power.
 - How fast the control system must operate (**speed of operation**).
 - If the application requires sharing data outside the process, i.e. **communication**.
 - If the system needs **operator control or interaction**.
 - The **physical environment** in which the control system will be located.

Example

Let us take an example, imagine designing a control system for a parking garage with a 500 car capacity. The first step is to define and describe the car parking process.



What is the desired operation for the parking garage?

- ❖ The car approaches an automated ticket machine at a gate.
- ❖ The driver pushes a button on the ticket machine to receive a ticket. If there is space left in the garage, the driver will receive a ticket. The machine should not provide a ticket if the garage is full or if the gate is already up.
- ❖ Removing the ticket raises the gate and turns on a green “enter”light.
- ❖ After the car clears the gate, the gate lowers and the green light shuts off.
- ❖ The number of vehicles in the garage needs to be known at any time.
- ❖ If maximum capacity is reached, a “Garage Full” sign is illuminated, the ticket machine will not provide a ticket, and the gate will not raise.
- ❖ An alarm must sound when the gate is obstructed.

1.Inputs and Output requirements

From the description, the following I/O requirements can be listed;

Functions(inputs)

- Ticket request
- Ticket taken
- Car cleared gate
- Car departed garage
- Gate obstructed
- Gate in up position
- Gate in down position

Functions(outputs)

- Provide Ticket
- Garage Full sign
- Green Light
- Alarm
- Raise gate
- Lower Gate

Device

- Push Button
- Limit switch
- Photoelectric sensor
- Photoelectric sensor
- Motor overload contact
- Proximity sensor
- Proximity sensor

Device

- Solenoid
- Light
- Light
- Horn
- Gear motor forward
- Gear motor reverse

The system requires seven inputs and six outputs

2. Advance Function Requirements

Functions(inputs)

- Up counter
- Down counter

Use

- Counts cars entering garage
- Counts cars leaving garage

3. Electrical Requirements

When determining the electrical requirements of a system, consider three items

- ❖ incoming power(power for the control system)
- ❖ Input device voltage
- ❖ Output voltage and current

To decide what type of voltage to use, consider the following:

- ❖ What type of power is available(e.g. 24Vdc, 120V or 240V ac)?
- ❖ How will the machine or process controlled be used?
- ❖ Will people come in contact with the machine?
- ❖ What power do the field devices use?
- ❖ What electrical codes apply?

3.Electrical Requirements contd...

Summarizing the electrical requirements for the parking garage:

Functions(inputs)

- Ticket request
- Ticket taken
- Car cleared gate
- Car departed garage
- Gate obstructed
- Gate in up position
- Gate in down position

Functions(outputs)

- Provide Ticket
- Garage Full sign
- Green Light
- Alarm
- Raise gate
- Lower Gate

Advanced Functions

- Up counter
- Down counter

Device

- Push Button
- Limit switch
- Photoelectric sensor
- Photoelectric sensor
- Motor overload contact
- Proximity sensor
- Proximity sensor

Device

- Solenoid
- Light
- Light
- Horn
- Gear motor forward
- Gear motor reverse

Device

- To be determined
- To be determined

Voltage

- 24V dc
- 24V dc
- 24V dc
- 24V dc
- 24V dc
- 24V dc
- 24V dc

Voltage

- 24V dc
 - 24V dc
 - 24V dc
 - 24V dc
 - 120 V ac
 - 120 V ac
- TBD
 - TBD

4.Speed of Operation

When determining the speed of operation, consider these points:

- ❖ How fast does the process occurs or machine operates?
- ❖ Are there “time critical “ operations or events that must be detected?
- ❖ In what time frame must the fastest action occur(input device detection to output device activation)?
- ❖ Does the control system need to count pulses from an encoder or flow meter and respond quickly?
- ❖ The control system selected needs to meet the speed demands of the process or machine, so knowing these criteria is important.

6. Operator Interfaces and Communication

❖ Operator Interfaces

- In order to convey information about machine or process status, or to allow an operator to input data, many applications require operator interfaces.
- Traditional Interfaces includes *push button*, *thumbwheel switches*, *pilot lights* and *LED numeric displays*. Electronic Operator interface devices like Magelis displays message about machine status, displays part count and track alarms. They are also used for data input.

❖ Communication

- Communication involves sharing application data or status with another devices such as computer or a monitor.
 - Communication takes place locally thru a twisted pair wire or remotely via telephone or radio modem.
- ❖ The parking control system does not require operator interface beyond the ticket request push button, the green light and the alarm horn.
- ❖ However communication capabilities could have provided the benefit, as if the portion of the garage was being repaired and 50 parking space were eliminated, it would be advantageous for the garage operator to change the capacity parameters from 500 to 450.

7.Environment

- ❖ Consider the environment where the control system will be located. Will it be subjected to Temperature extremes? Water? Humidity? Salt? Shock? Dust? Vibration?
- ❖ In harsh environments, house the control system in an appropriate NEMA- or IP- rated enclosure.
- ❖ For parking garage, the control system located in the ticketing machine needs to be housed into an enclosure to protect it against moisture and dirt.

Selecting a control Method

- ❖ The System designer can select from three types of control system: Relay, PLC'S, Wired(SBC).
- ❖ For the control method selection, the best method is to develop a chart which integrates application requirements with control methods.

Application Characteristics	Required?	Quantity	Can the control method accomplish task?		
			Relay	PLC	SBC
Inputs	Yes	7	Yes	Yes	Yes
Outputs	Yes	6	Yes	Yes	Yes
Timers	No	0	Yes	Yes	Yes
Counters	Yes	1 up/down	Yes	Yes	Yes
High Speed required?	No	0	No	Yes	Yes
Data Calculations?	No	0	No	Yes	Yes
Data acquisition	No	0	No	Yes	Yes
Communications	No	0	No	Yes	Yes
Operator interface	No	0	No	Yes	No

Selecting a control Method

- ❖ All the three control methods can accomplish the task, so the control system cannot be selected on the application requirement alone.
- ❖ To differentiate between control methods, we need to evaluate the relative cost impact of each method using the following criteria.

Application Characteristics	Relay	PLC	SBC
System design and development	Not applicable	Not applicable	****
Control System hardware	**/**	*/**	*
Panel Assembly	***	*	*
Panel Space	***	*	*
Implementing Logic	***	**	***
Duplicating Application	****	*	*
Documenting Logic	****	*	**
Modifying Logic	****	*	**
Maintenance	***	*	**

* = Low, ** = Moderate, *** = High, **** = Very High

Result of the Selection

- ❖ From the comparison we can see that PLC's are the easiest control system to support. **Assistance for programming and troubleshooting** is available at reasonable costs from many sources.
- ❖ And if the PLC fails, a **replacement** PLC can be purchased off the shelf from the nearest industrial electrical supplier--- there is no need to wait for a shipment from the factory. Furthermore, the **ruggedness** of the PLCs compared to SBCs gives them a definite advantage in harsh environment or when durability is a primary consideration.
- ❖ For all the criteria by which the control system are evaluated ---**Cost, Size, Flexibility, and Supportability**— micro PLC provide the user with distinct, advantages over other control options for many control applications. Thus, a micro PLC has been selected to provide the logic for the parking garage.

What are the PLC Specifications?

- ❖ After determining application requirements and selecting a method for providing system control, the next step is to determine specifications of a control system. Categories that can be considered for determining the PLC specifications are as follows:
 - **Total number of I/O**
 - **Electrical requirements**
 - **Output circuits**
 - **Memory requirements**
 - **Speed of operation**
 - **Communication**
 - **Operator interfaces**

Defined Specifications

- ❖ **Total number of I/O**
 - 7 Inputs and 6 Outputs
- ❖ **Electrical requirements**
 - Incoming Power – 24 VDC
 - Input Voltage – 24 VDC (7 Devices)
 - Output Voltage –120VAC (2 Devices) – 24VDC (4 Devices)
- ❖ **Output circuits**
 - Relay Outputs
- ❖ **Memory requirements**
 - $13 \text{ I/O} + 1 \text{ I/O} = 14 \text{ I/O}$, $14 \times 10 \text{ Words} = 140$ estimated words of memory required. Worksheet
- ❖ **Speed of operation**
 - Simplified program increases the performance.
- ❖ **Communication**
- ❖ **Operator interfaces**

Program Development Procedures

Three steps to develop a sequence of operation:

- ❖ **Define the rules of operation for each control point.**
- ❖ **Identify and label inputs and outputs.**
- ❖ **Convert the rules of operation to ladder logic.**

Program Development Procedures

Defining Rules of Operations

Recalling from the earlier section, the control for **Garage control system** was described like this

- ❖ The car approaches an automated ticket machine at a gate.
- ❖ The driver pushes a button on the ticket machine to receive a ticket. If there is space left in the garage, the driver will receive a ticket. The machine should not provide a ticket if the garage is full or if the gate is already up.
- ❖ Removing the ticket raises the gate and turns on a green “enter” light.
- ❖ After the car clears the gate, the gate lowers and the green light shuts off.
- ❖ The number of vehicles in the garage needs to be known at any time.
- ❖ If maximum capacity is reached, a “Garage Full” sign is illuminated, the ticket machine will not provide a ticket, and the gate will not raise.
- ❖ An alarm must sound when the gate is obstructed.

Program Development Procedures

Inputs

- Ticket request **pushbutton**
- Ticket taken **limit switch**
- Car cleared gate **photo sensor**
- Car departed garage **photo sensor**
- Gate obstructed (**Motor overload contact**)
- Gate in up position **proximity sensor**
- Gate in down position **proximity sensor**

Outputs

- Provide Ticket
- Raise gate
- Lower Gate
- Garage Full sign
- Green Light
- Alarm

Program Development

rung 1

Ladder Logic Development

The rules of operation converts easily to a ladder logic program, as follows:

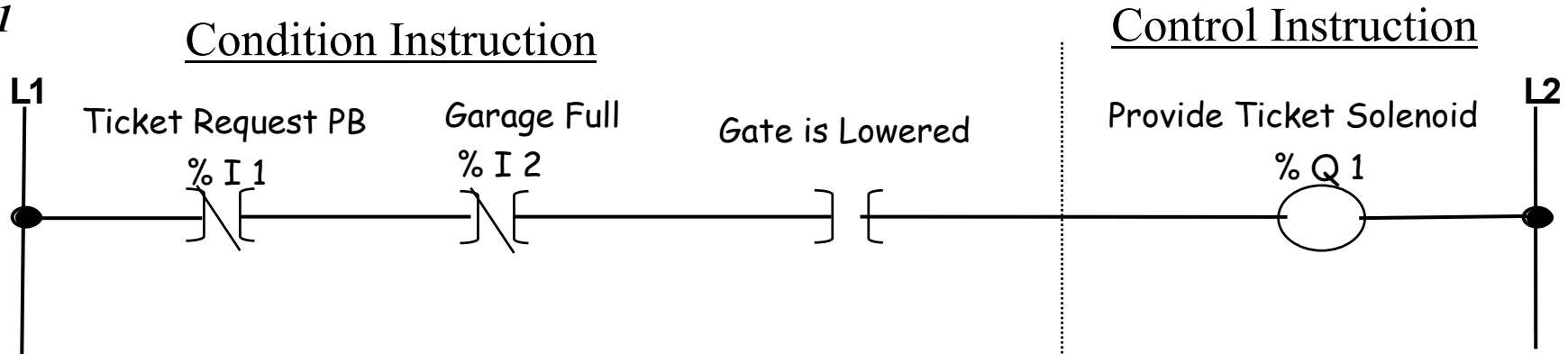
Rules of Operation

Control Point: ->>**The ticket machine will provide a ticket**

Conditions:

- >>If the driver presses the ticket request pushbutton
- >>AND the “Full” sign is NOT on
- >>AND the gate is lowered

Rung 1



Program Development

rung 2

- Control Point: ->>**Raise the gate un-till fully up**
- Conditions: ->>After the driver takes the ticket
->>AND the gate is NOT up
->>AND the “Full” sign is NOT on

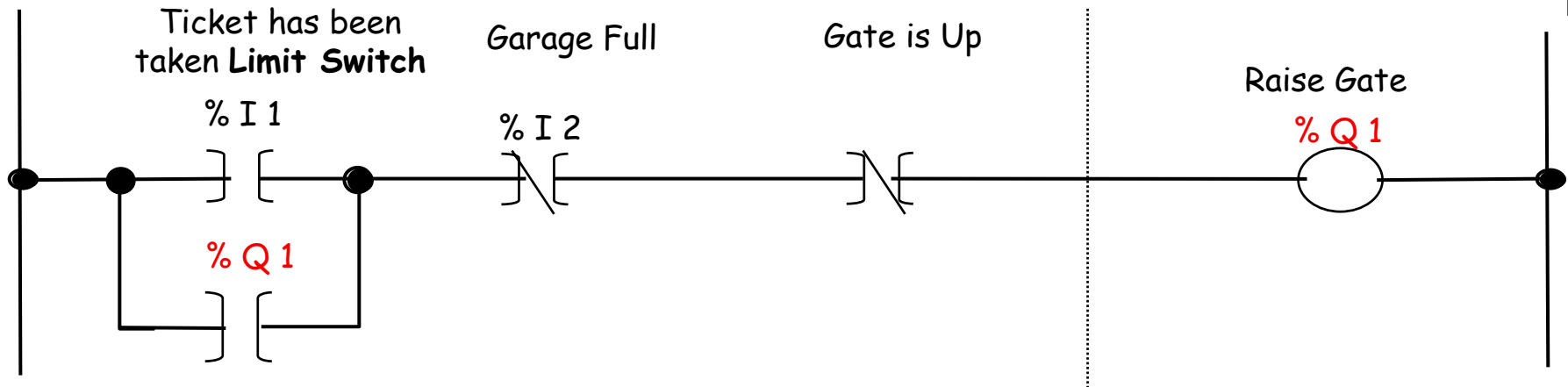
Rung 2

L1

Condition Instruction

Control Instruction

L2

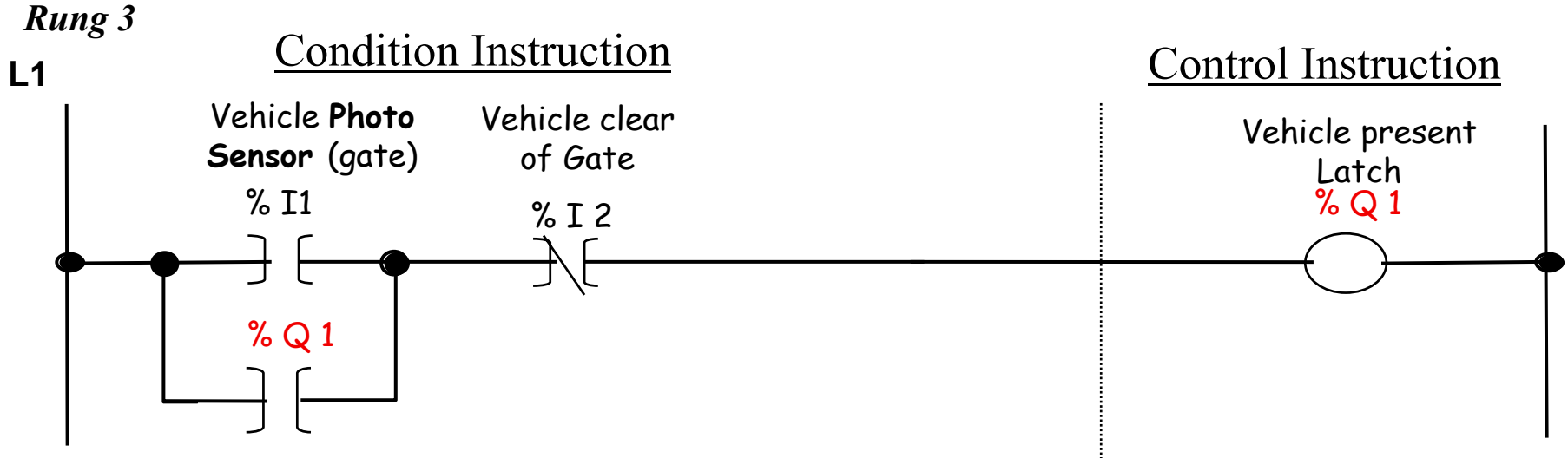


Program Development

rung 3

Control Point: ->>**Vehicle Present latch**

Conditions: ->>Vehicle has been detected.
->>AND the vehicle has NOT cleared the gate



Program Development

rung 4

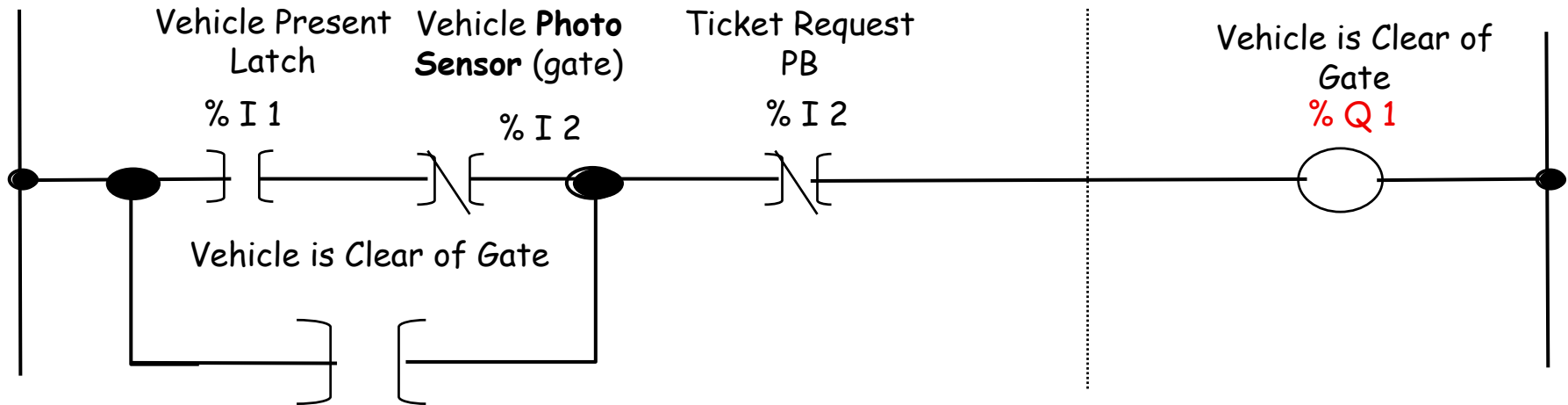
- Control Point:** ->>Vehicle clear of Gate
- Conditions:**
- >>Vehicle present latch is on.
 - >>AND a vehicle is NOT detected
 - >>AND the ticket request push button is NOT pressed

Rung 4

L1

Condition Instruction

Control Instruction



Program Development

rung 5

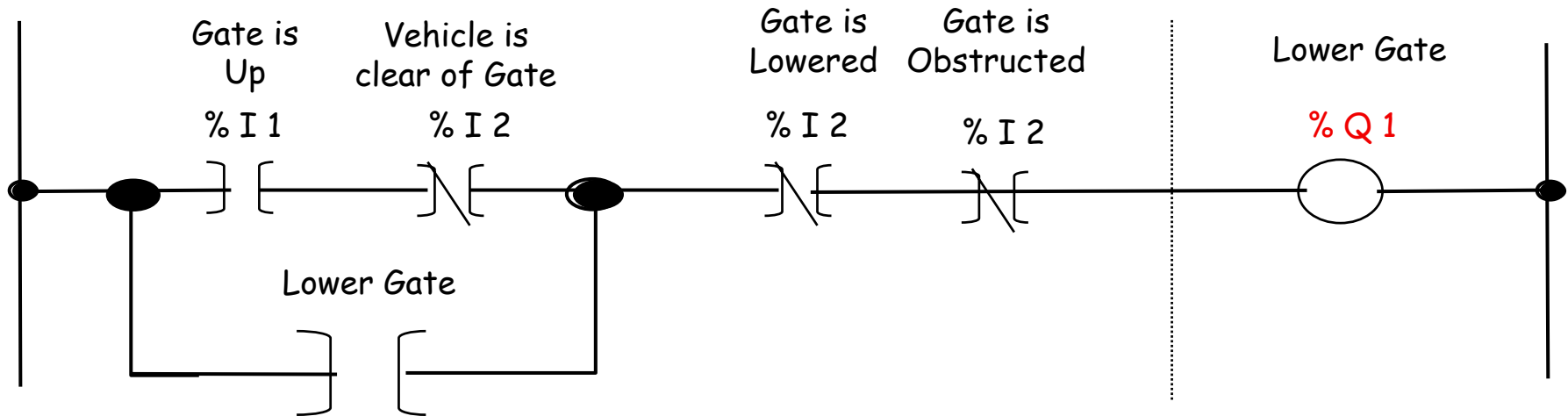
- Control Point:** ->>Lower the Gate until fully down
- Conditions:**
- >>If the Gate is up
 - >>AND the car has cleared the Gate
 - >>AND the Gate is NOT down
 - >>AND the Gate is not obstructed

Rung 5

L1

Condition Instruction

Control Instruction



Program Development

rung 6

Control Point: ->>Turn On the Green light

Conditions: ->>If the Gate is up

Rung 6

L1

Condition Instruction

Control Instruction



Program Development

rung 7

- Control Point:** ->>Count cars entering/turn on full sign at 500th car
- Conditions:** ->>If the Gate has been lowered
->>If accumulated counter value >/preset value of 500

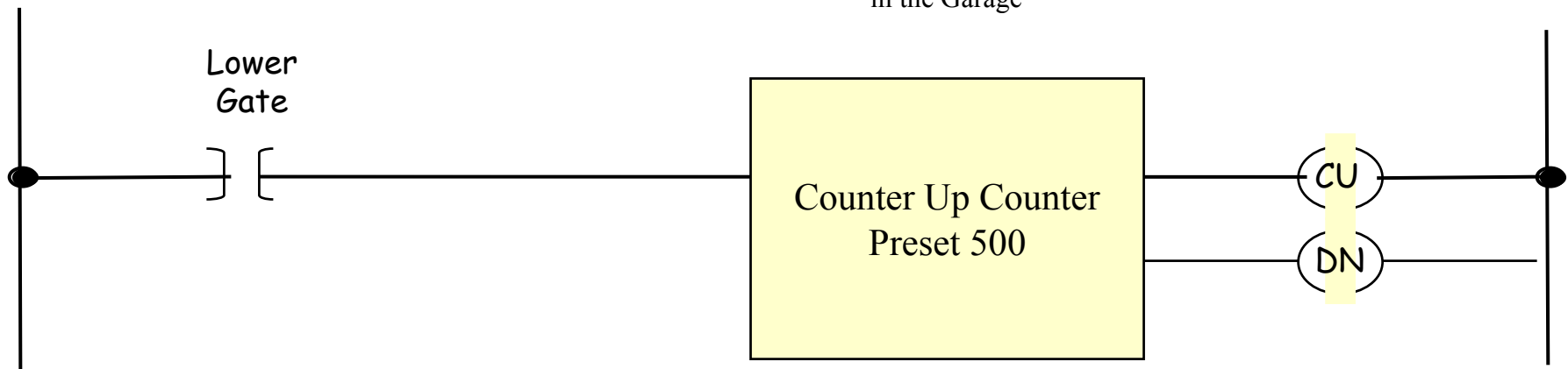
Rung 7

L1

Condition Instruction

Number of Vehicles
in the Garage

Control Instruction

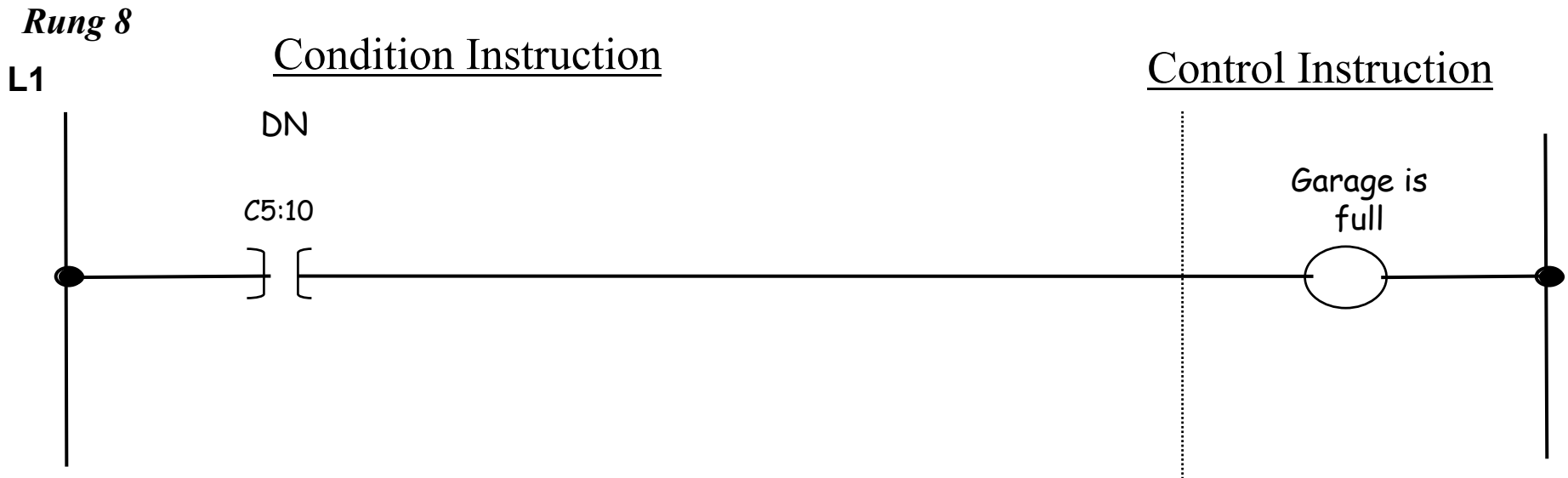


Program Development

rung 8

Control Point: ->> Turn On the Full sign

Conditions: ->> If accumulated counter value $\geq$ preset value of 500



Program Development

rung 9

Control Point: ->>Decrement the counter (count departing vehicle)
Conditions: ->>If a vehicle departs the garage

Rung 9

L1

Condition Instruction

Number of Vehicles
in the Garage

Control Instruction

Vehicle Photo Sensor
(Departing Garage)

Count Down
Preset 500

CU

DN

Program Development

rung 10

Control Point: ->>Sound Alarm

Conditions: ->>If the gate is obstructed

Rung 10

L1

Condition Instruction

Control Instruction

