Programmable Logic Controller

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About Me

- **Jie LING | 凌杰** **Associate Professor，PhD Supervisor, Department of Mechanical and Electronic Engineering**
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Personal Website

About My Research Group

1. Smart Material Actuator

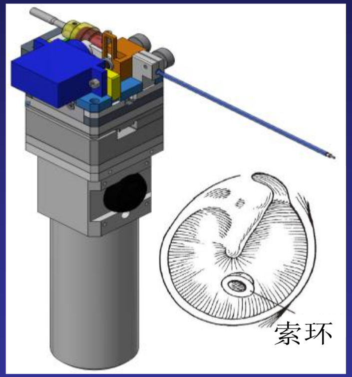
Piezoelectric motor、Piezoelectric energy harvester、Intelligent servo valve

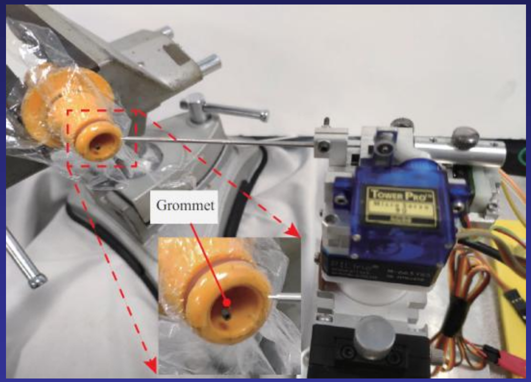
2. Micro/nano Manipulation

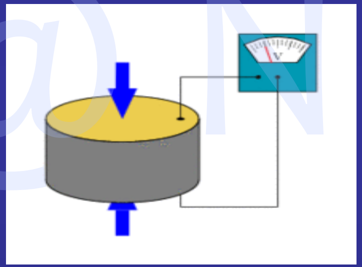
Percutaneous puncture 、Cell modeling and manipulation

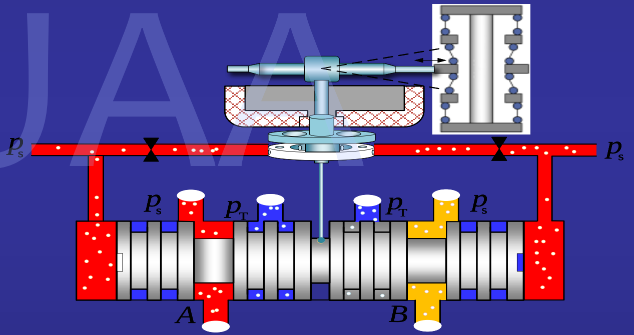
3. Precision Motion Control

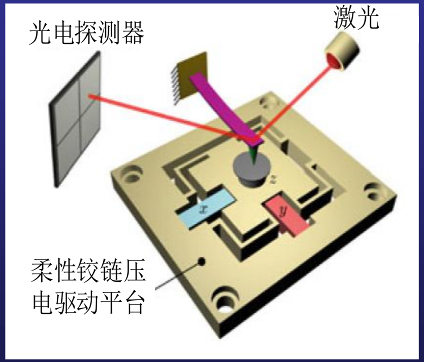
Multi-axis motion contour tracking、Nonlinear modeling and control

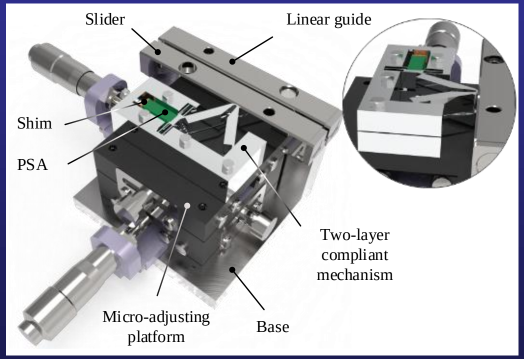


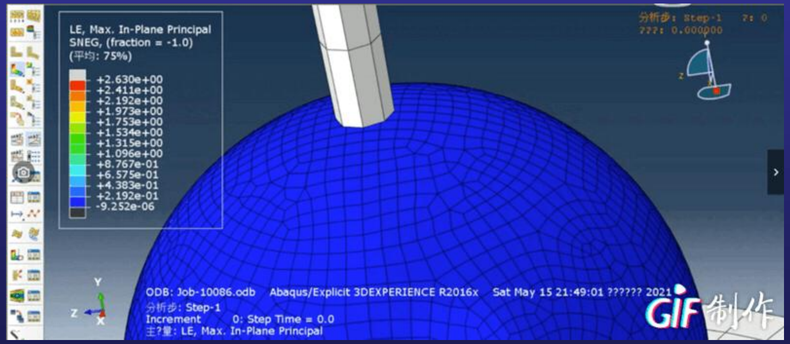












Course description

Overview

CH1 Introduction to PLCs (3 sessions)

CH2 CP1 PLC (1 sessions)

Review & Quiz 1 (1 session)

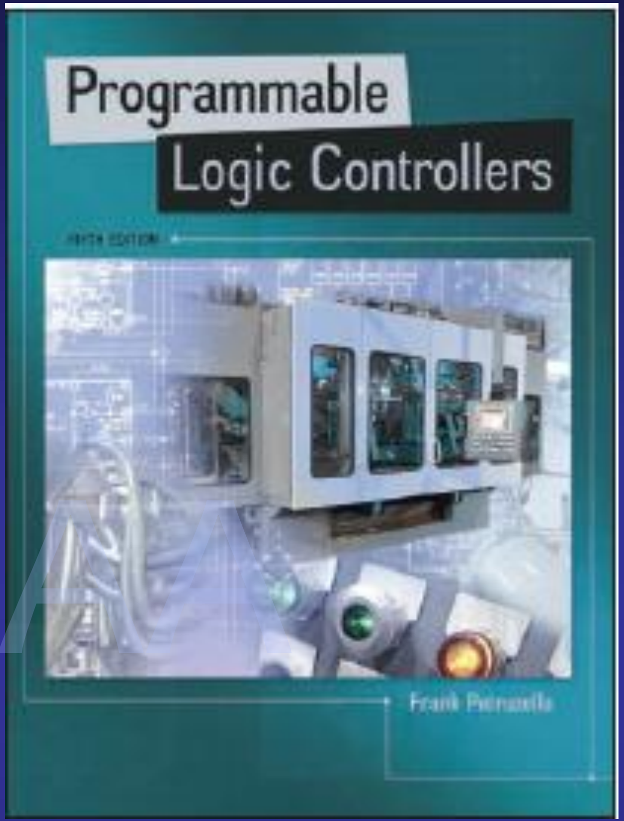
CH3 Instructions (3 sessions)

CH4 PLC programming (3 sessions)

Review & Quiz 2 (1 session)

Lab Experiments (2 session)

Course description



Objectives:

- Understand the working principle of PLC
- List the components and specifications of the PLC CP1
- Use the instructions of CP1
- Design PLC control systems

References:

Programmable Logic Controllers (5th Edition), Frank Petruzella

Programmable Controllers Theory and Implementation, L.A. Bryan

CP1H CPU Unit Operation Manual, OMRON, 2014

Course Grading and Policies

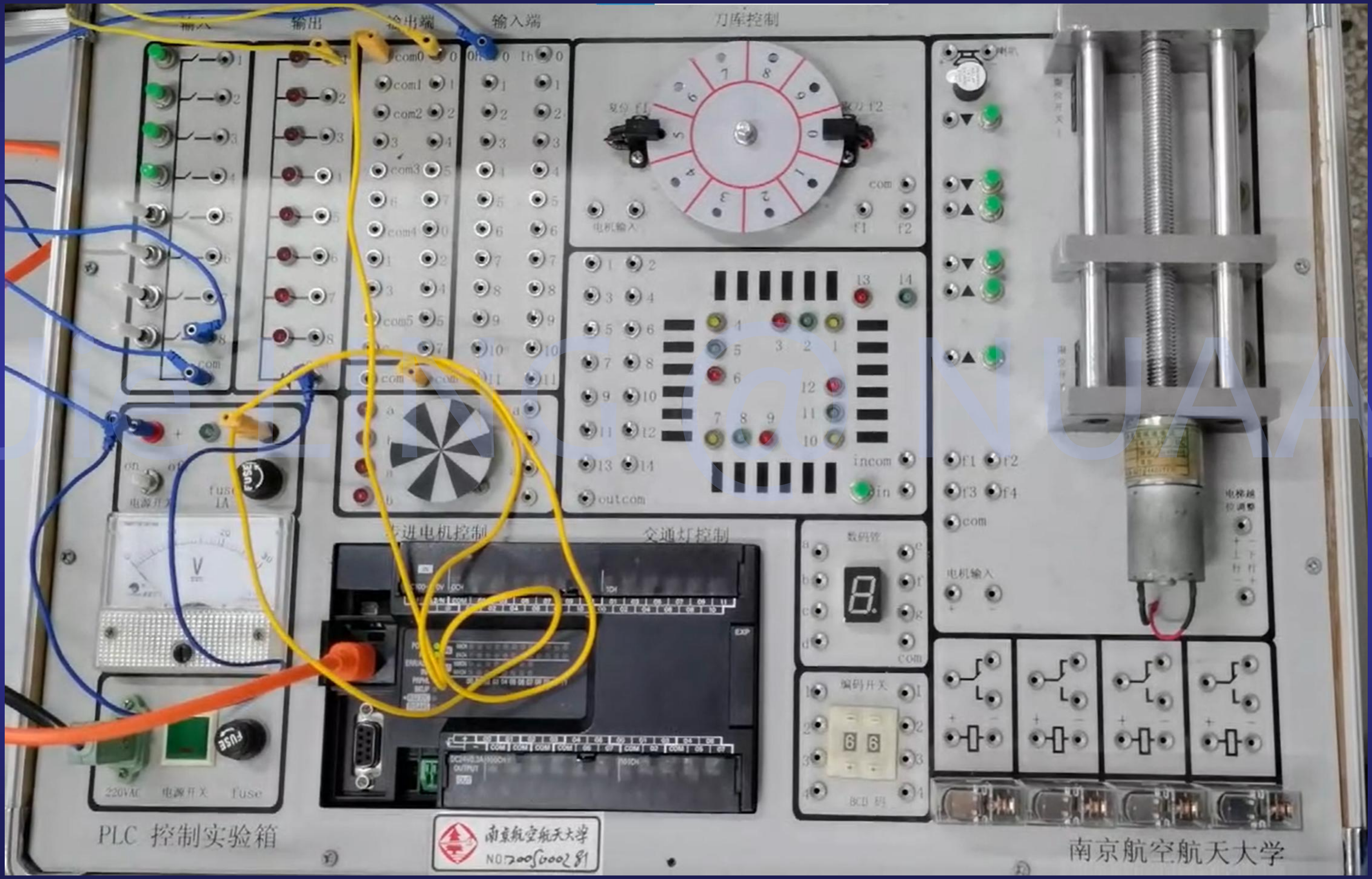
Course grade:

Attendance & Performance	10%
Quiz & Assignments	20%
Lab Experiments	10%
Final exam	60%

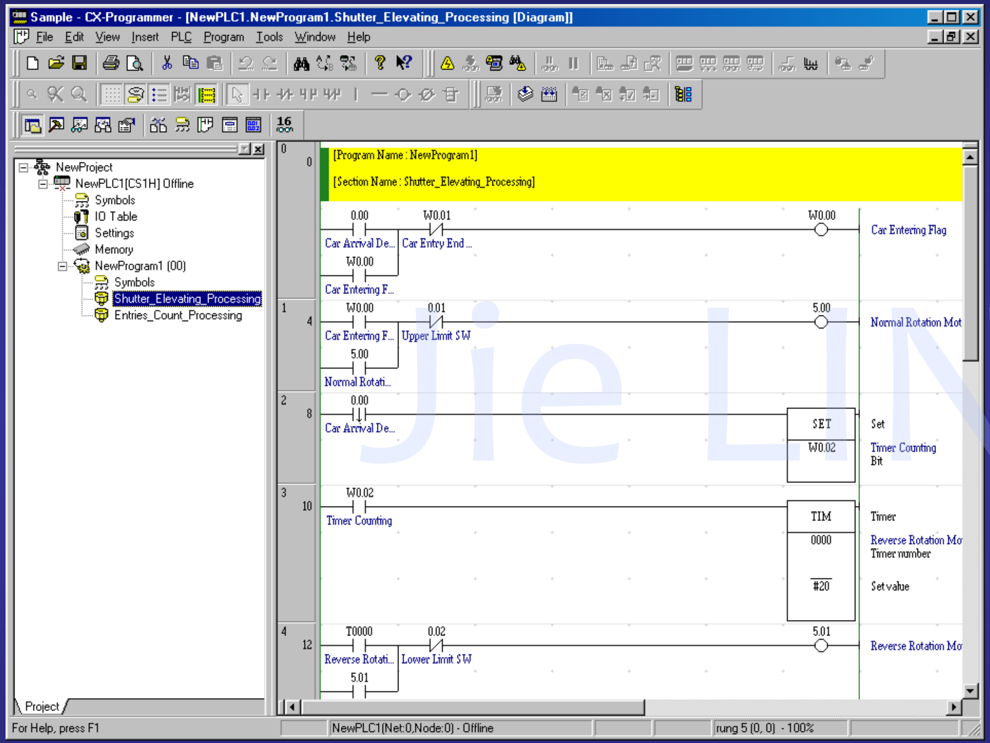
Policies:

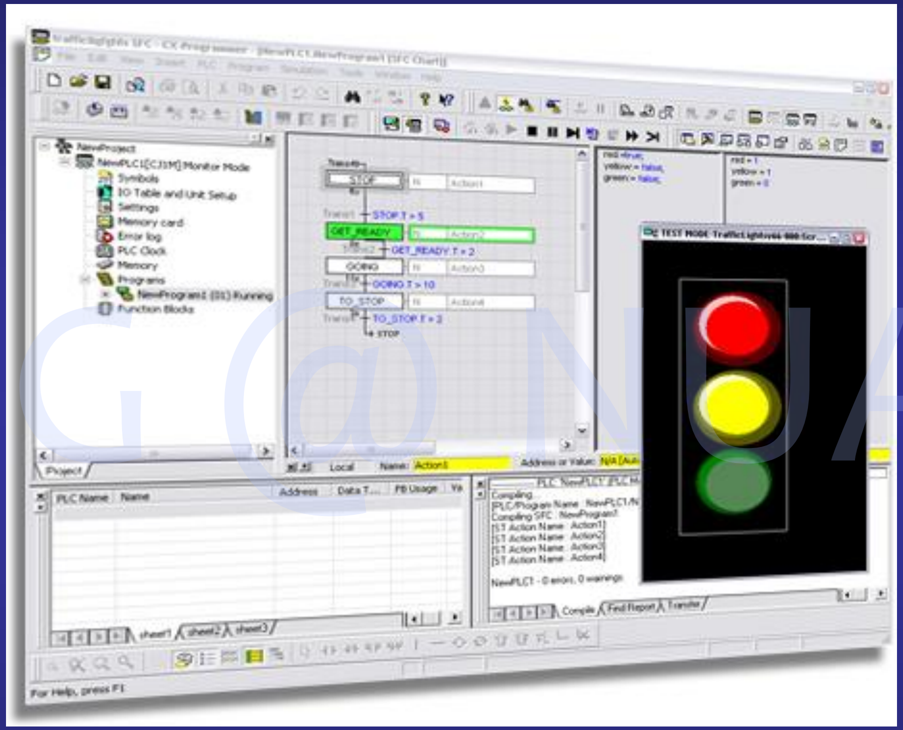
- Attendance will be taken at the beginning of every class
- Absence requests should be made one week in advance
- Each absence will be 5 deducted points of “Attendance & Performance”
- Open book exam

Lab Experiment



Simulation software





CX-one programmer
Software download from
NUAA cloud storage
Password: plc2025

CX-Simulator Introduction Guide R151-E1-01, OMRON

Ch1

Introduction to Programmable Logic Controllers

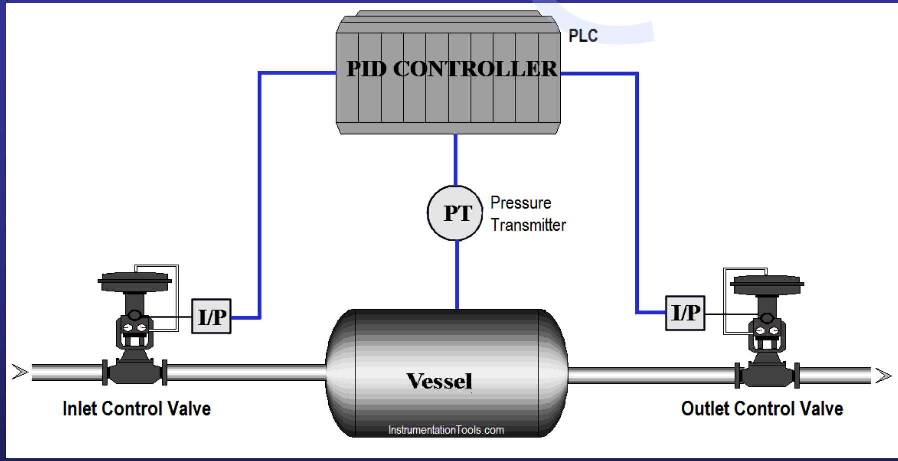
Ch1 Introduction to PLC

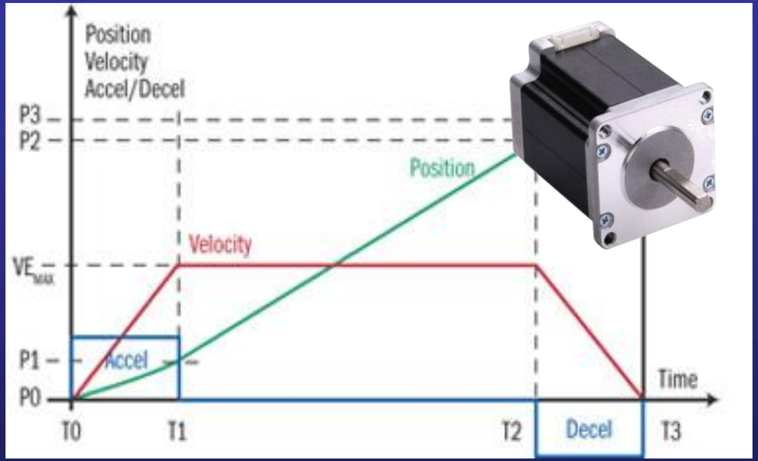
- **Controllers**
- **Relay logic and PLC logic**
- **Architecture of PLC**
- **Input devices and output actuators**
- **Programming Language**
- **Principle of Operation**
- **Application of PLC**
- **Development of PLC**

1.0 Controllers

1.0.1 Tasks of a control system

- control a sequence of events
- maintain some variable constant
- follow some prescribed change

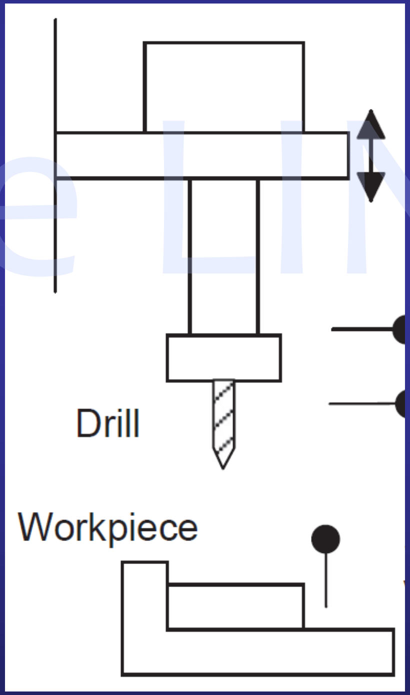




1.0 Controllers

1.0.1 Tasks of a control system

➢e.g. Automatic Drilling Machine

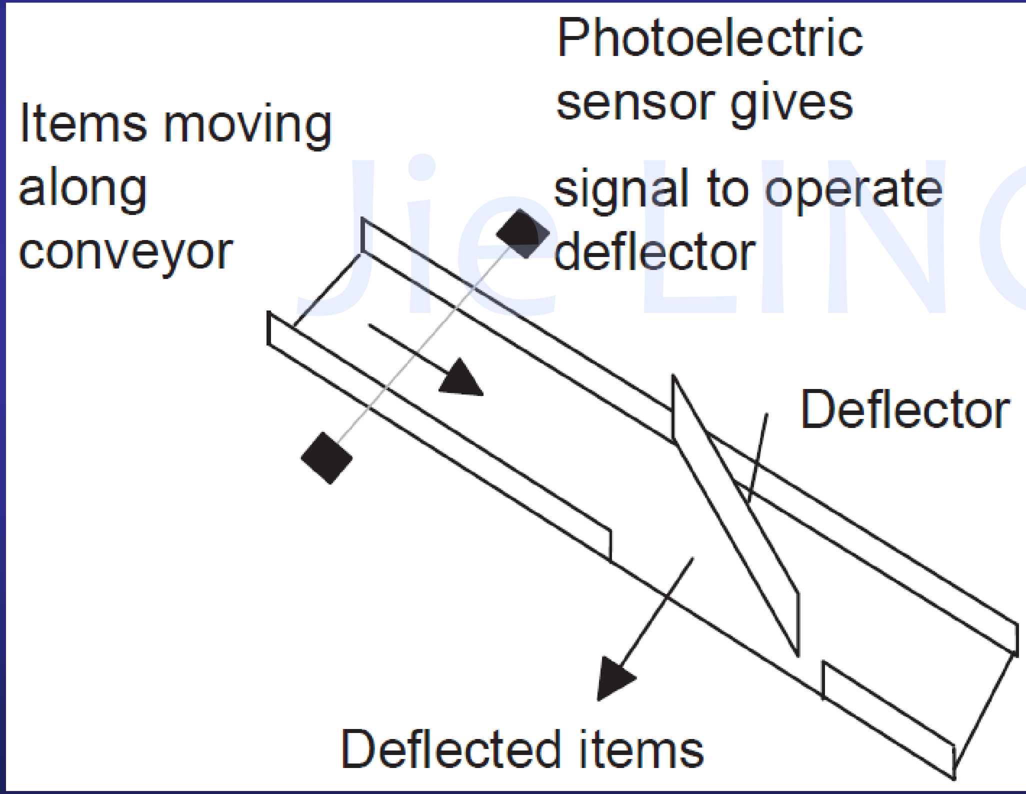


- Start lowering the drill when the workpiece is in position
- Start drilling when the drill reaches the workpiece
- Stop drilling when the drill has produced the Required depth of hole
- Retract the drill
- Switch off
- Wait for the next workpiece to be put in position
- Repeat the operation

1.0 Controllers

1.0.1 Tasks of a control system

- **e.g. Packing System**



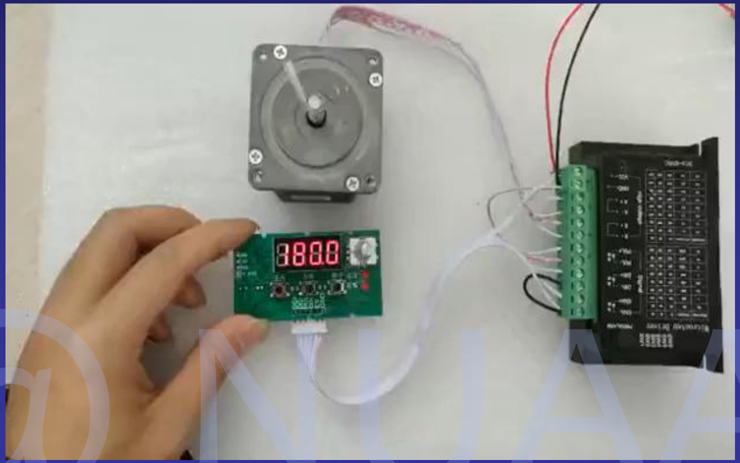
- Control the number of items moving along a conveyor belt
- Direct them into a packing case
- Inputs: switches , proximity sensors, etc.
- Outputs: motor, valve, etc.

1.0 Controllers

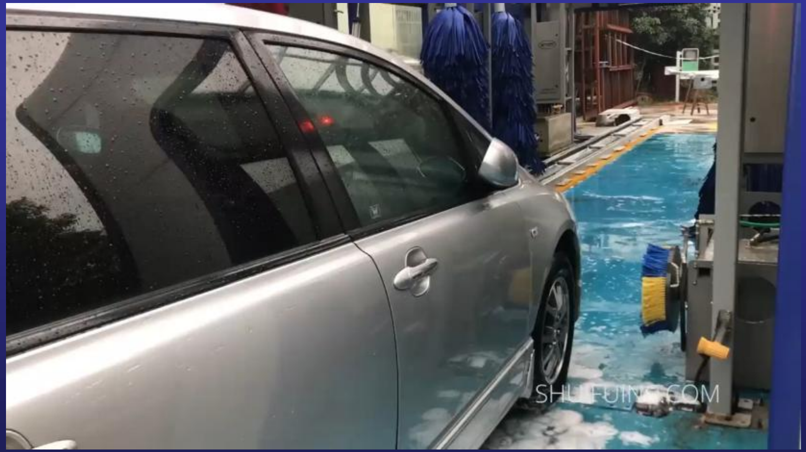
1.0.1 Tasks of a control system

Source: Youtube

Sorting machine



Stepper motor control



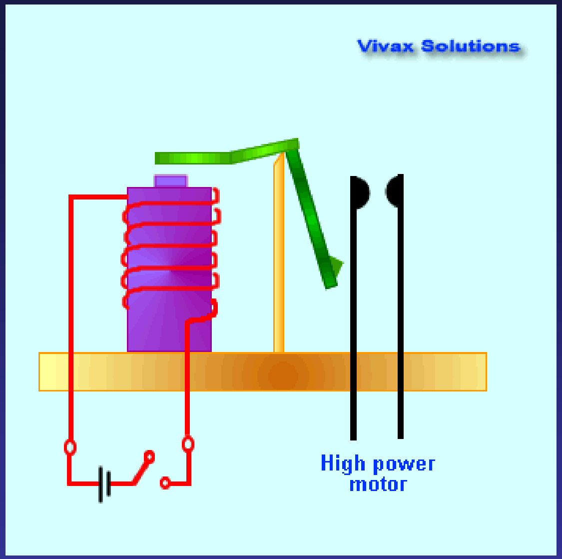
Car wash machine

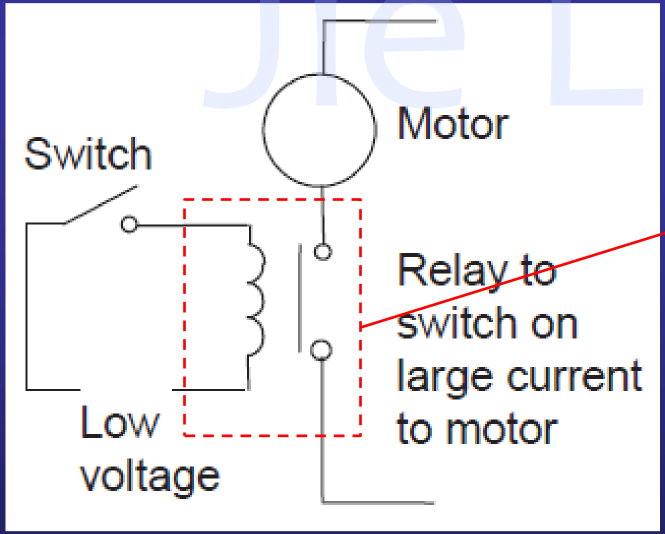
Filling machine

1.0 Controllers

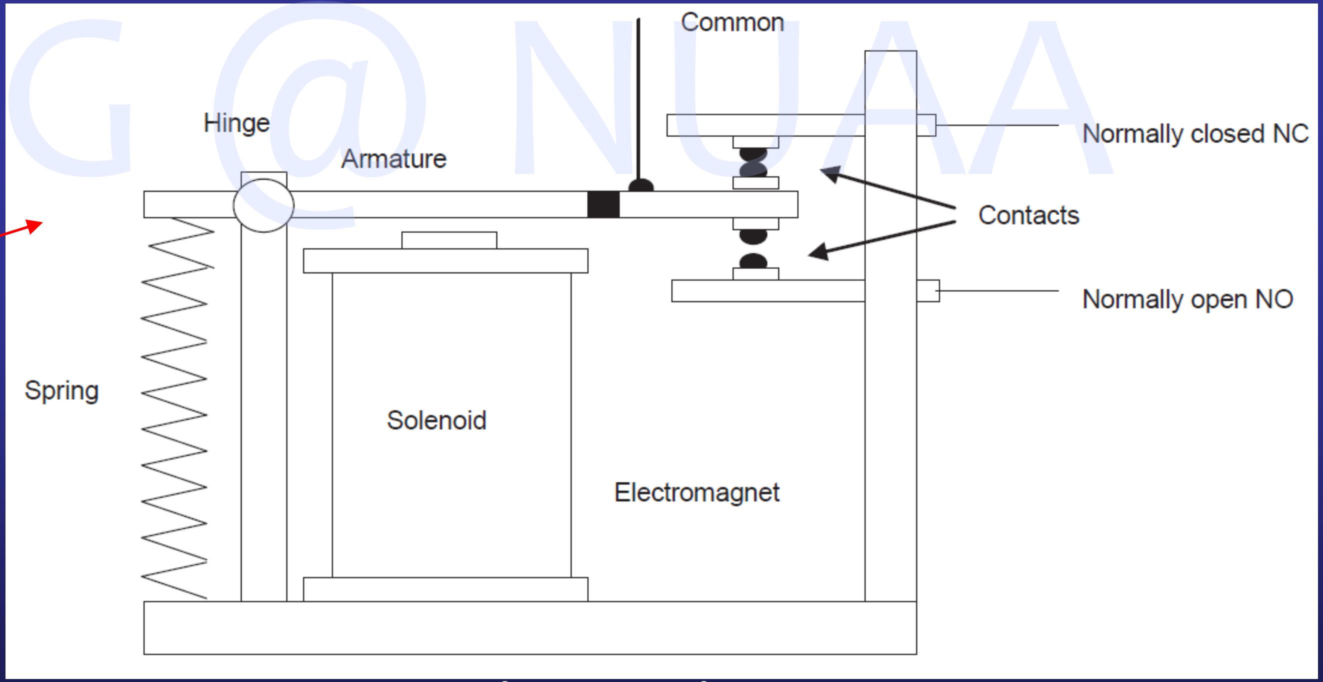
1.0.2 Relay controller

➢**When switched on, a current flows through the solenoid, normally closed (NC) contacts will open and normally-open (NO) contacts will close.**

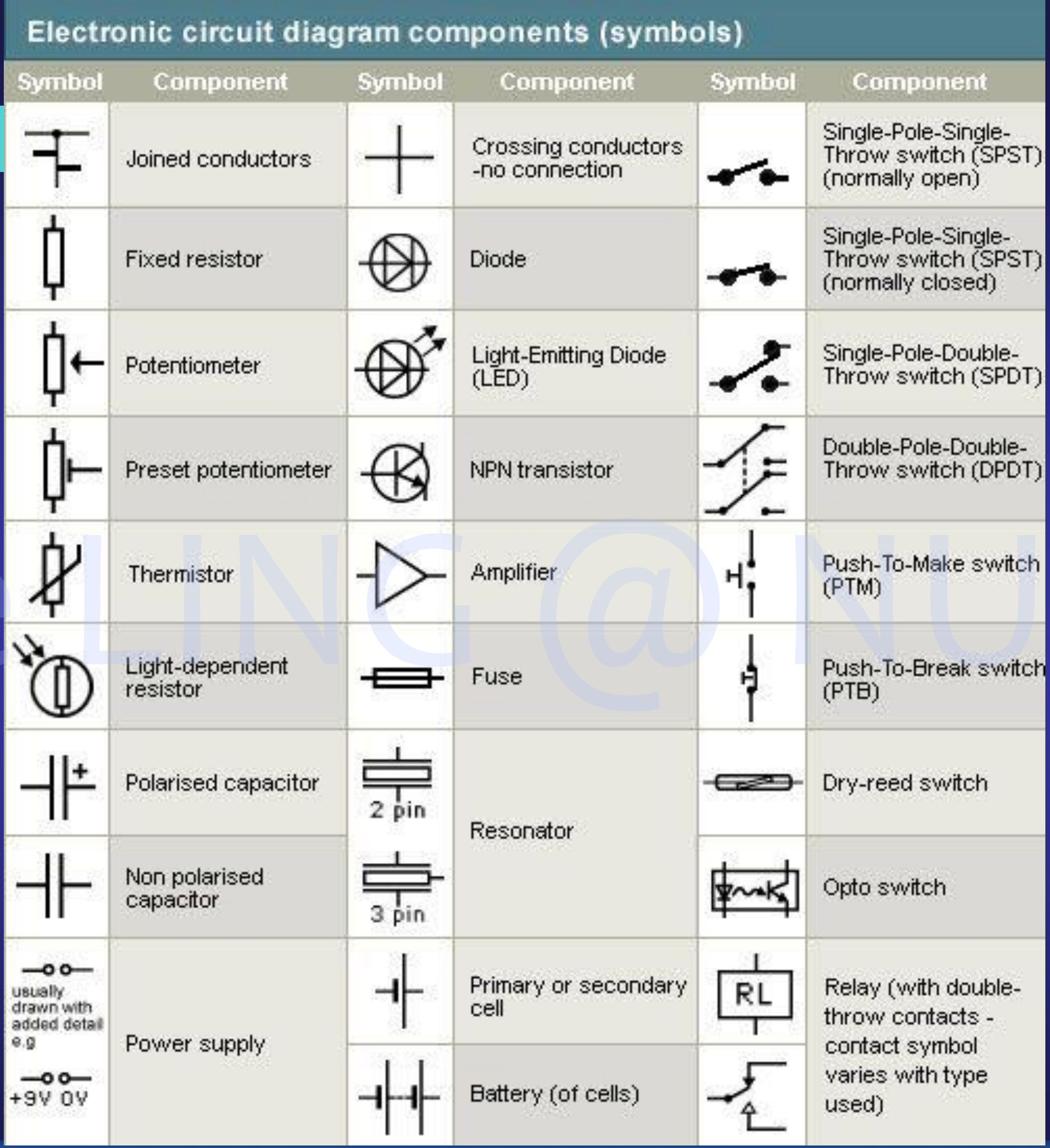




Control circuit



A basic relay

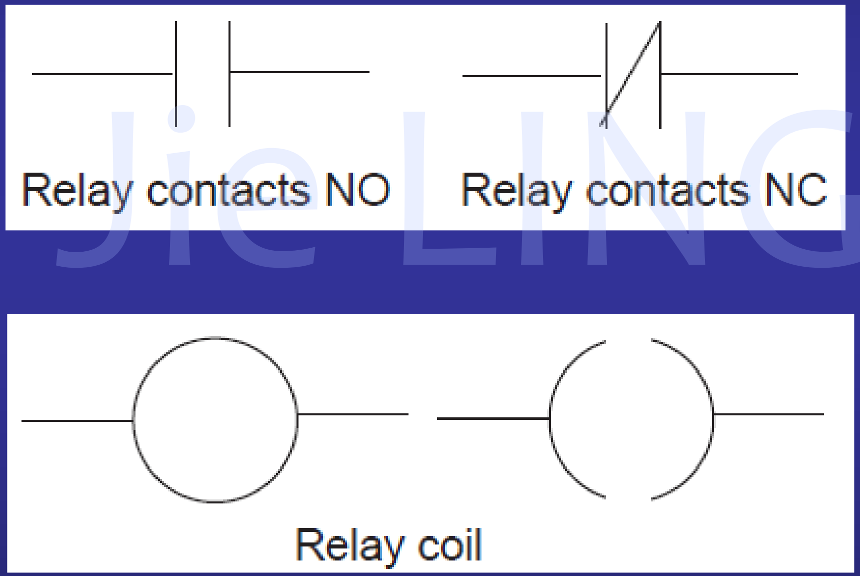


Electronic circuit diagram components (symbols)

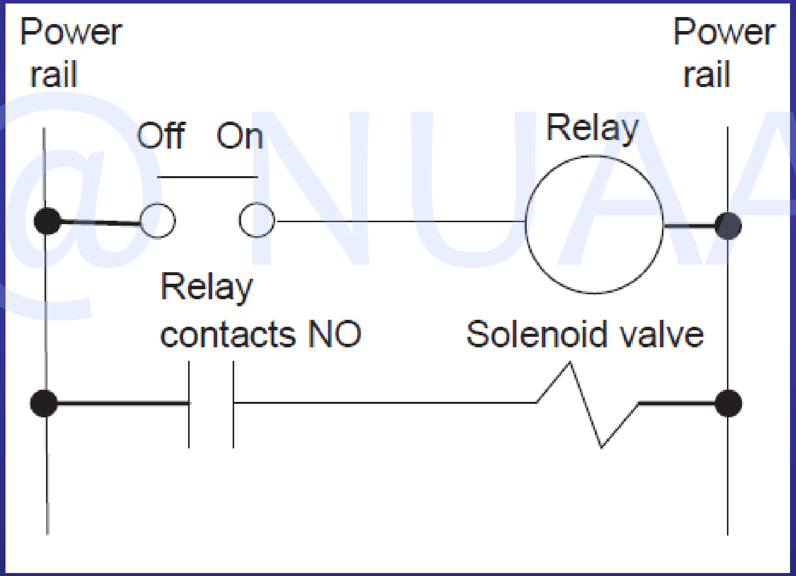
Symbol	Component	Symbol	Component	Symbol	Component
	Joined conductors		Crossing conductors -no connection		Single-Pole-Single-Throw switch (SPST) (normally open)
	Fixed resistor		Diode		Single-Pole-Single-Throw switch (SPST) (normally closed)
	Potentiometer		Light-Emitting Diode (LED)		Single-Pole-Double-Throw switch (SPDT)
	Preset potentiometer		NPN transistor		Double-Pole-Double-Throw switch (DPDT)
	Thermistor		Amplifier		Push-To-Make switch (PTM)
	Light-dependent resistor		Fuse		Push-To-Break switch (PTB)
	Polarised capacitor	2 pin	Resonator		Dry-reed switch
	Non polarised capacitor	3 pin			Opto switch
usually drawn with added detail e.g +9V 0V	Power supply		Primary or secondary cell	RL	Relay (with double-throw contacts - contact symbol varies with type used)
			Battery (of cells)		

1.0.2 Relay controller

➢**Control drawing**



Relay symbols

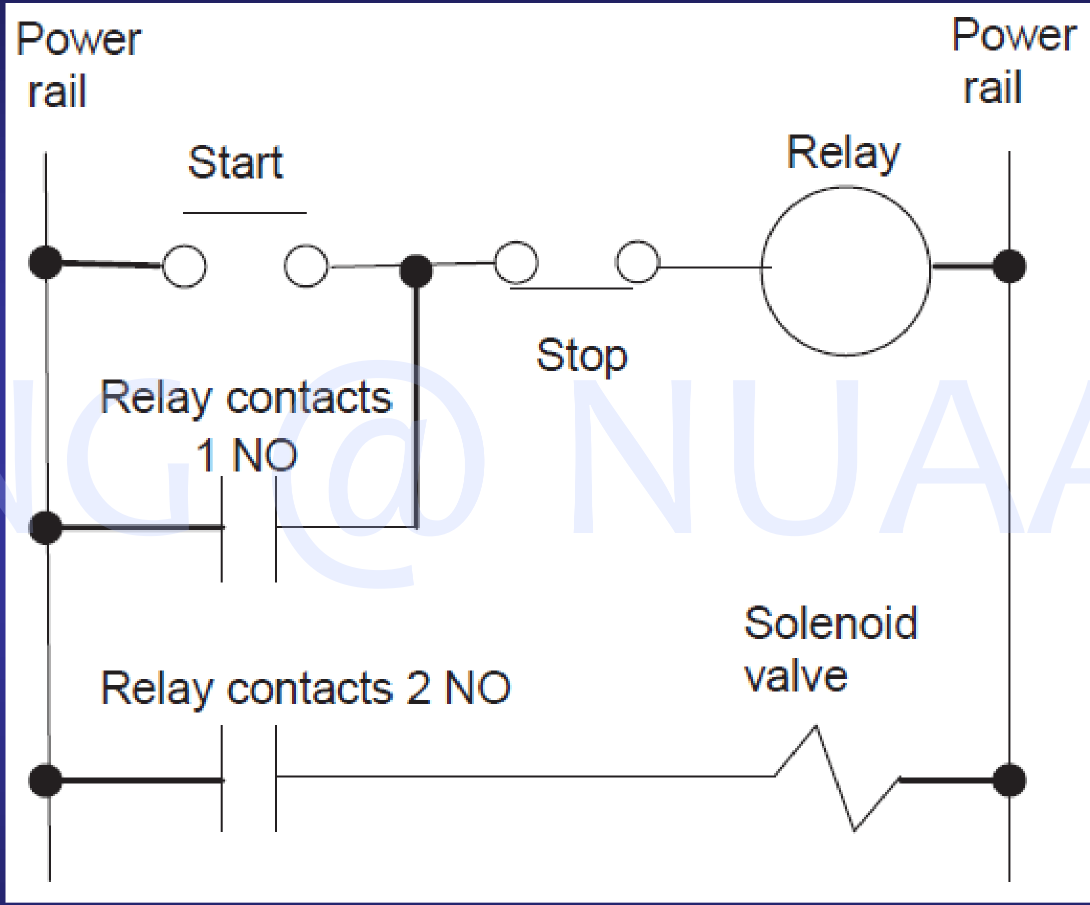


Relay-controlled system control drawings

1.0 Controllers

1.0.2 Relay controller

- ➢**Control drawing**



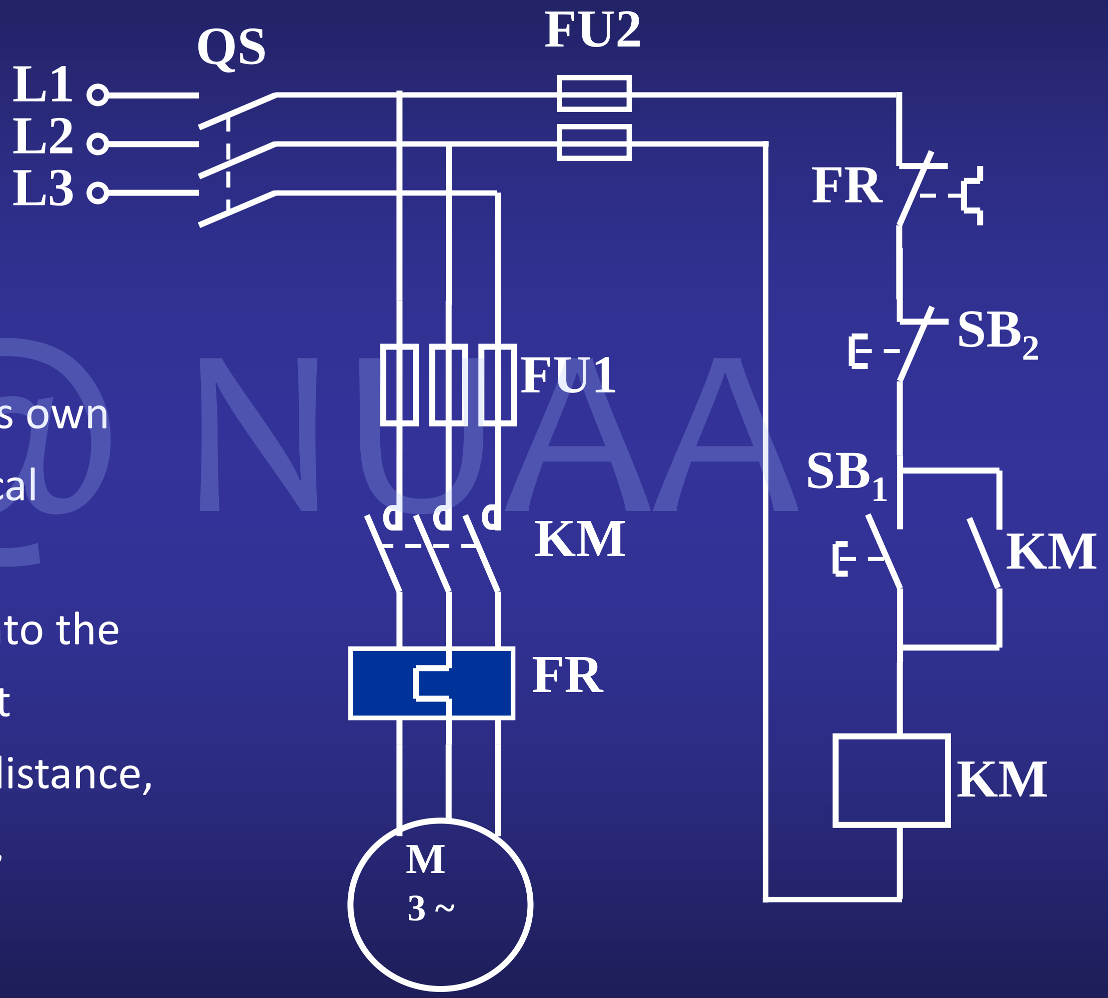
Relay-controlled system control drawings

(Start-Stop-Hold)

1.0.2 Relay controller

➢Power circuit and control circuit

Three phase alternating current motor



KM: Alternating current contactor

FU: Fuse, when the current exceeds the specified value, with its own heat to make the melt fuse, disconnect the circuit of an electrical appliance

FR: Thermal relay, to generate heat from the current flowing into the thermal element, which causes the bimetal sheet with different expansion coefficients to change, and after reaching a certain distance, the connection is promoted, the control circuit is disconnected, resulting in the contactor power off, forming circuit protection

QS: Knife switch

1.0 Controllers

1.0.3 Microprocessor Controller

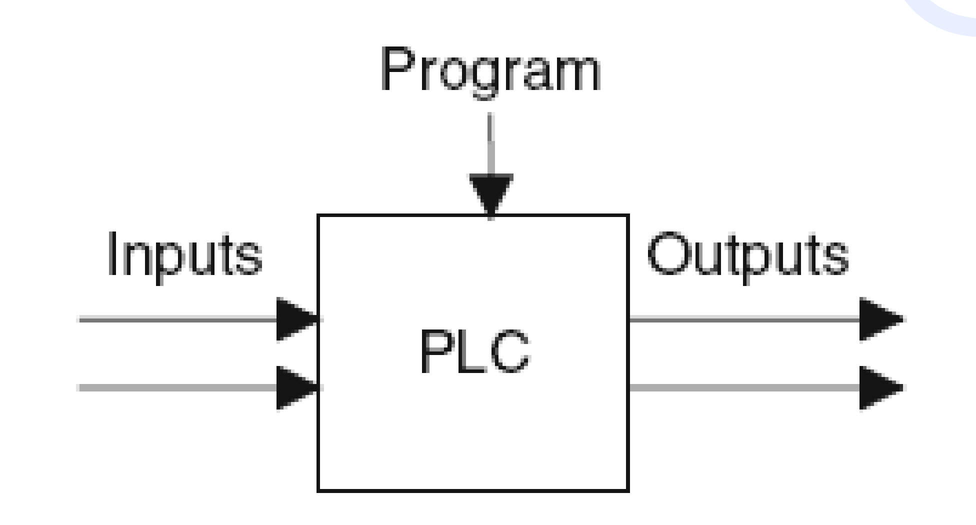
- **A microprocessor-based system**
- **A program to instruct the microprocessor how to react to each input signal and give the required outputs.**

```
If switch A closes
Output to motor circuit
If switch B closes
Output to valve circuit
```

- **Modify control rules by changing the instructions in the program**

1.0.4 Programmable Logic Controller (PLC)

A special form of microprocessor-based controller that uses programmable memory to store instructions and to implement functions such as logic, sequencing, timing, counting, and arithmetic in order to control machines and processes.



e.g. A+B=C

1.0 Controllers

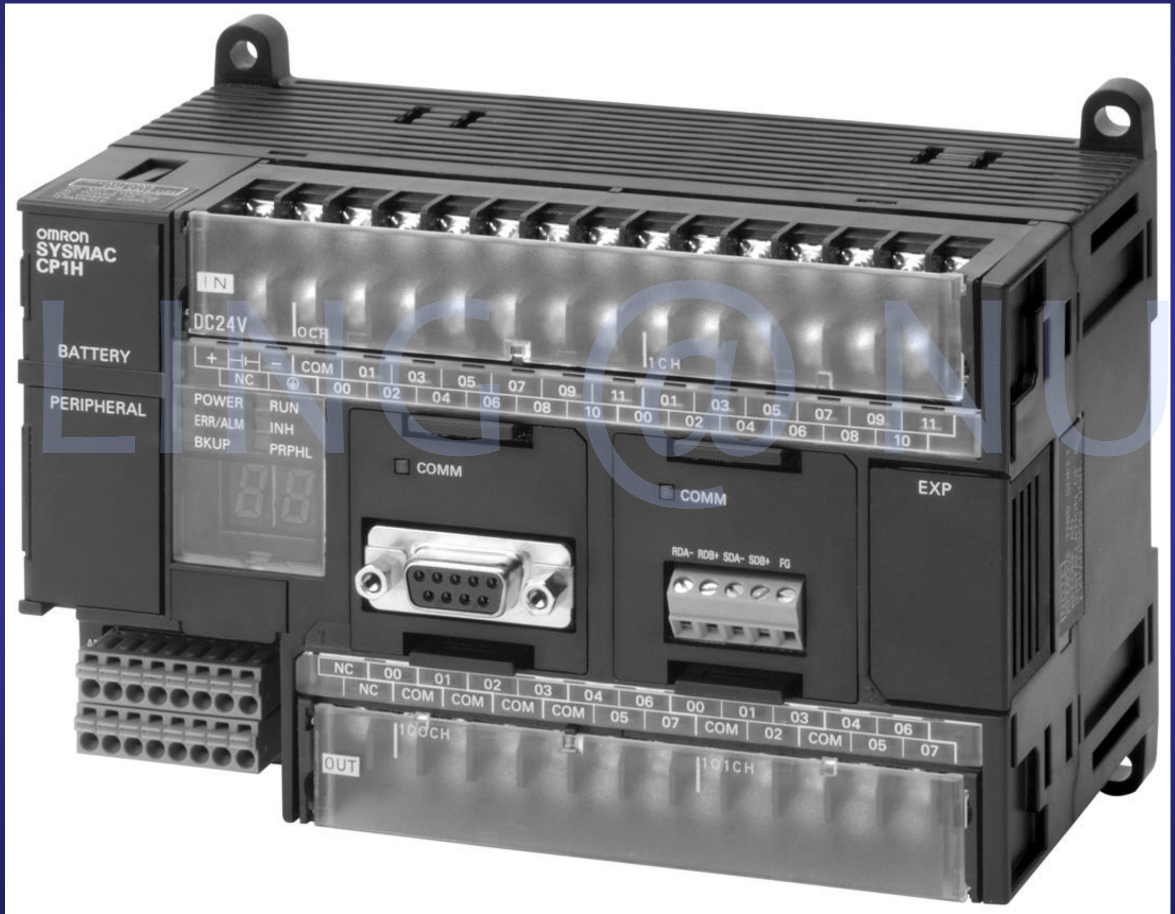
- A PLC is a specialized computer used to control machines and process.
- It uses a programmable memory to store instructions and specific functions that include On/Off control, timing, counting, sequencing, arithmetic and data handling.
- PLC is designed for control task and industrial environment.

1.0 Controllers

- Designed for engineers with a limited knowledge of computers and computing languages.
- Control program using a simple, intuitive form of language.
- "Logic" is used because it is primarily concerned with implementing logic and switching operations.
- The controller monitors the inputs and outputs and carries out the control rules

1.0 Controllers

1.0.4 Programmable Logic Controller (PLC)



OMRON CP1 PLC

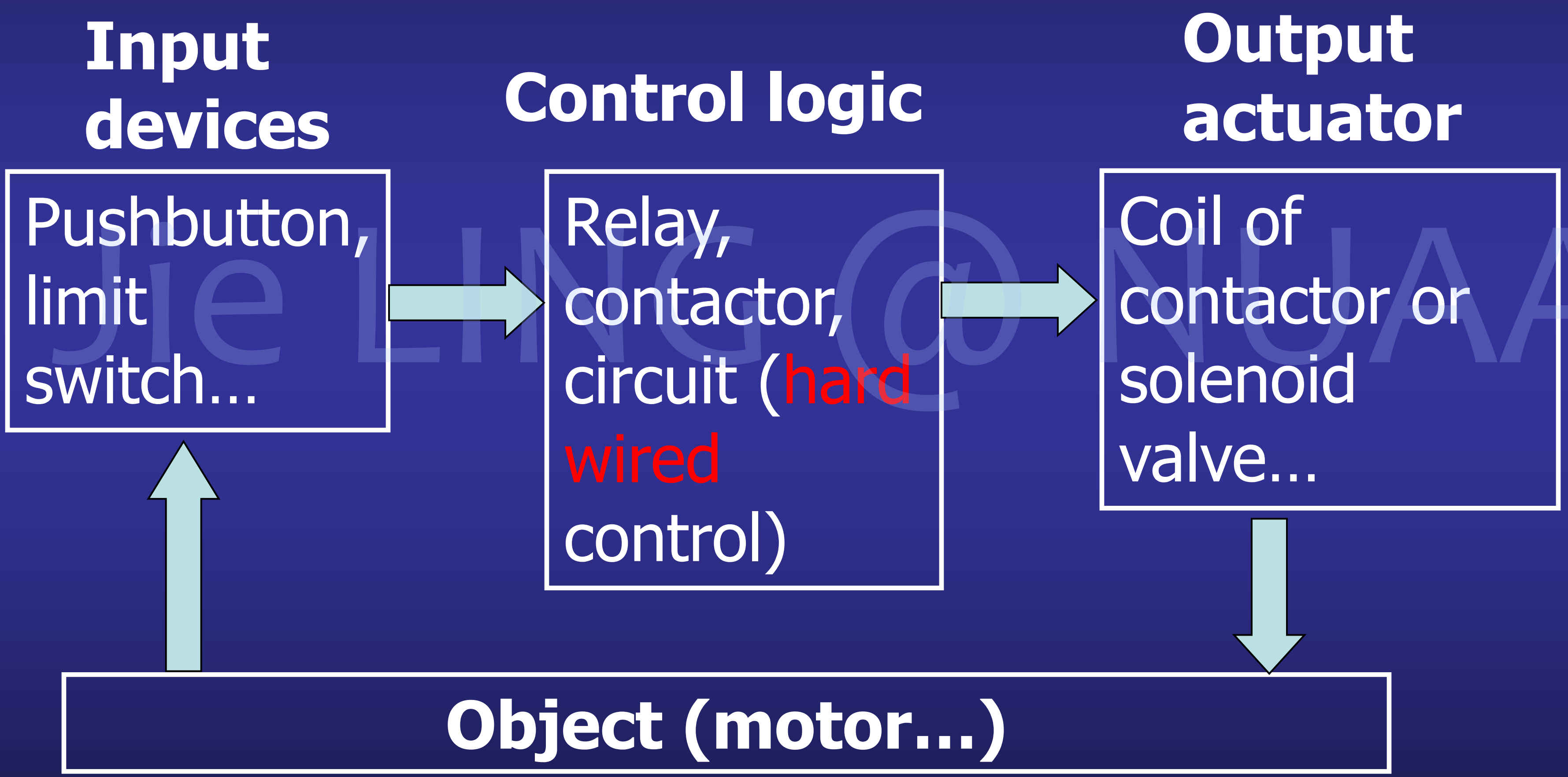
1.0.4 Programmable Logic Controller (PLC)

Introduction to OMRON PLCs

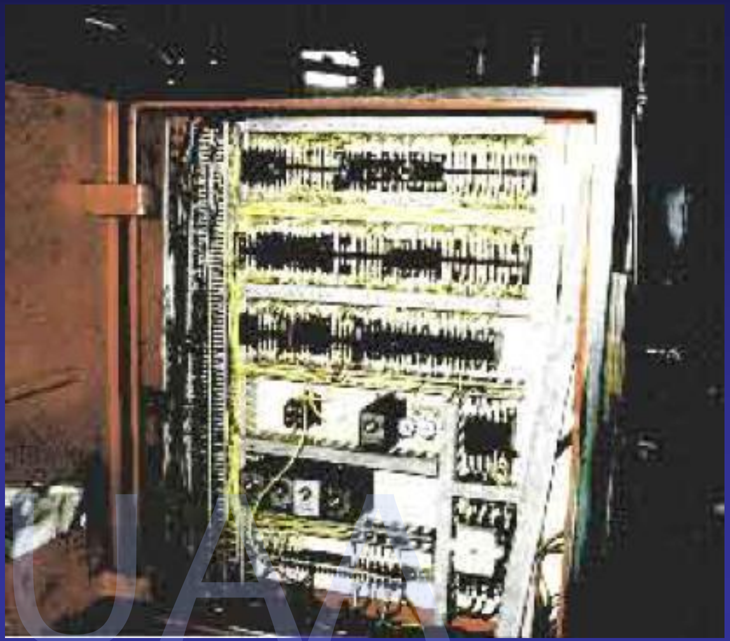
Source: OMRON@Youtube

1.1 Relay logic and PLC logic

1.1.1 Relay control



1.1 Relay logic and PLC logic

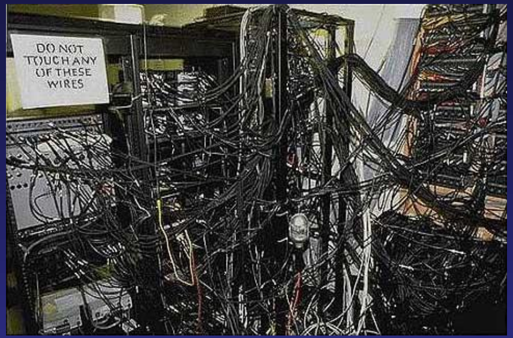


- Control panel based on relay logic

  - ✓ Inflexible: Difficulty with changes or replacements
  - ✓ Unreliable: Too many contacts
  - ✓ Too much work required in connecting wires
  - ✓ Difficulty in trouble-shooting; requiring skillful work force
  - ✓ Power consumption can be quite high as the coil consumes power
  - ✓ When a problem occurs, hold-up time is indefinite, usually long

1.1 Relay logic and PLC logic

1.1 Relay logic and PLC logic

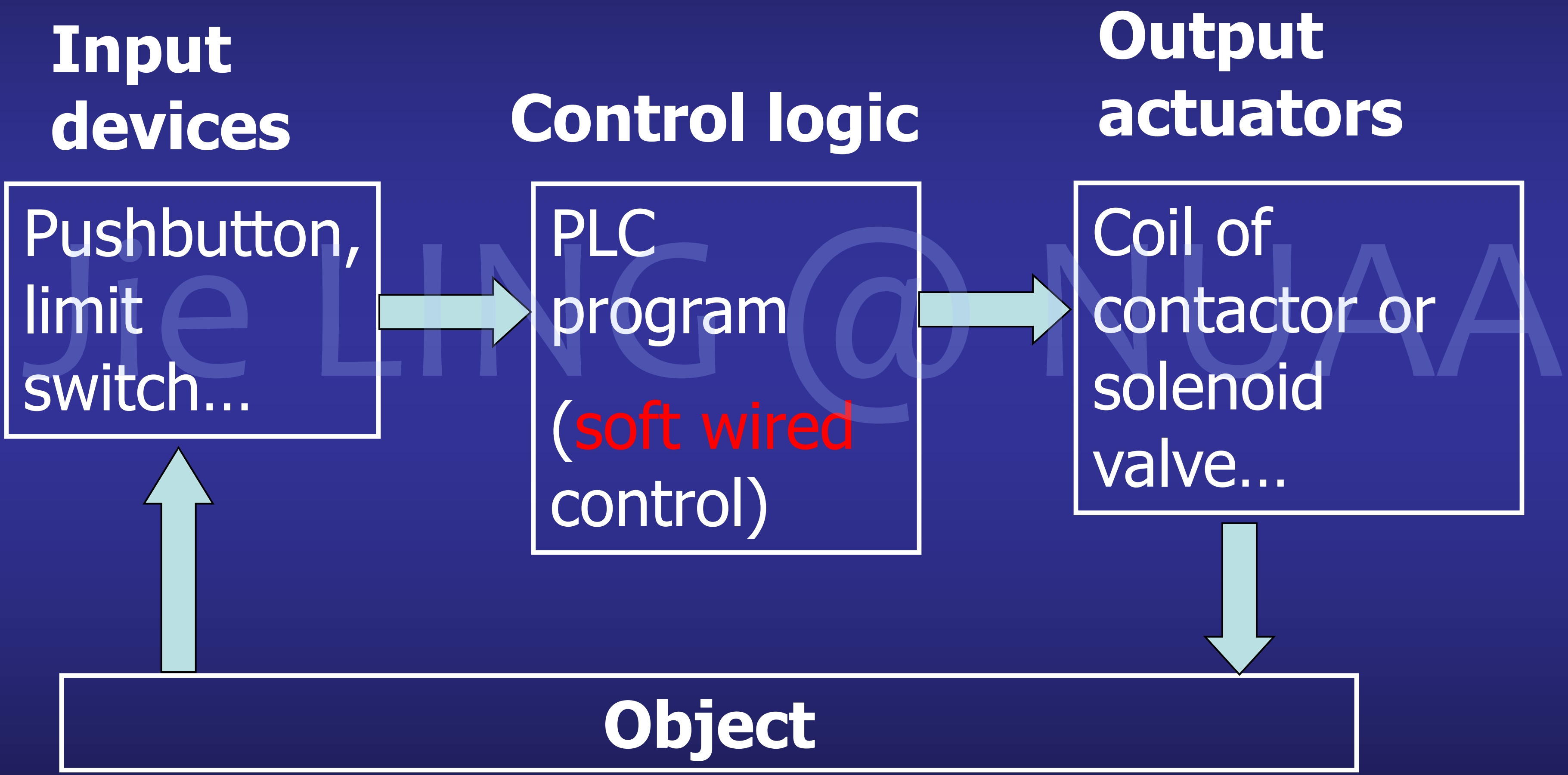


- Problems of Relay Logic
  - ✓ **Adaption to new requirements**: Industrial revolution→ To update the control panel frequently
  - ✓ **Limited lifetime** of a relay or contact
  - ✓ **Not enough room** for necessary changes: A control panel always convers an entire wall
  - ✓ **Fault diagnose**→Time consuming→ Production needs to be stopped

In 1968, General Motors Corp. proposed an idea to in integrate the computer technology with relay control.

1.1 Relay logic and PLC logic

1.1.2 PLC control

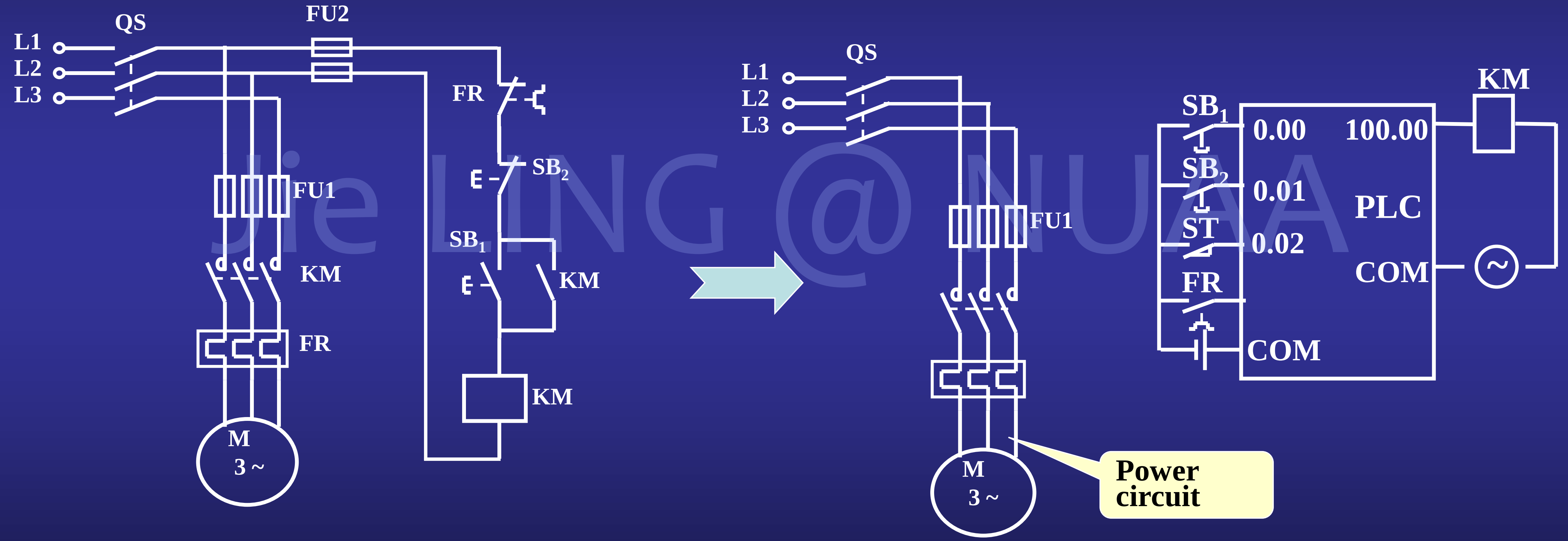


1.1 Relay logic and PLC logic

- Control panel on PLC
  - ✓ Reliable. No or fewer mechanical contacts, hardware and software measures
  - ✓ Flexible. Changeable in operating sequence or application
  - ✓ Easy to use. Hardware and software
  - ✓ Reduce the number of wires by 80%
  - ✓ Reduce the energy consumption
  - ✓ **F**ast and easy error detection
  - ✓ Cheaper, especially in cases of a large number of I/O instruments

1.1 Relay logic and PLC logic

1.1.3 Wiring



1.1 Relay logic and PLC logic

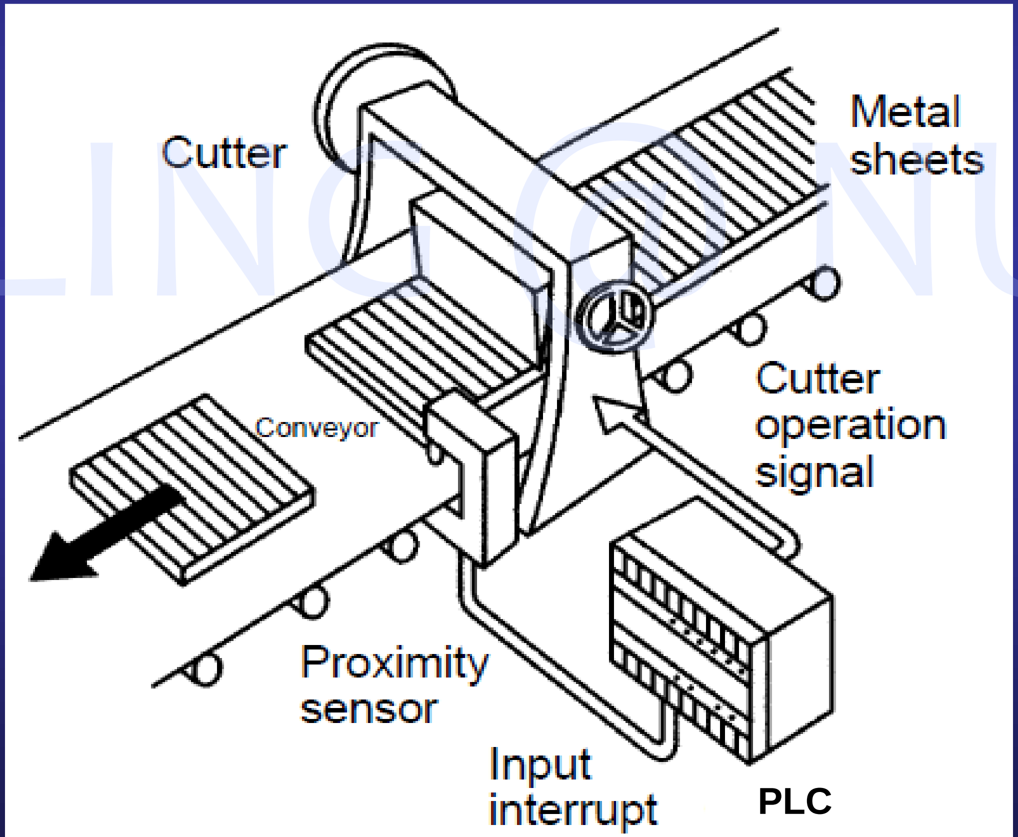
1.1.4 Comparison between PLC and relay control

Type	Sequence control	PLC
Logic type	Hard Logic	Soft Logic
Supported functions	Relay, Timer, Preset Counter	Relay (AND, OR, NOT), Up/down Counter, Shift register Arithmetic calculation, logic calculation
Control type	Contact type (limited life, slow control)	Non-contact type (long life, fast, high reliability)
How to change the logic	By changing wiring between hardware elements	By changing PLC program
Installation time	Building, inspection and test run take a long time.	The time for inspection and test run decreased
System charact-eristics	Stand-alone control equipment	It is easy to extend system. It is possible to connect to a computer.
Maintain-ability	For maintenance, long time is needed.	Due to high reliability and long life, the need for maintenance is small.
Volume	Miniaturization is difficult.	Miniaturization is possible.

PLC Application Example

Cutting Metal Sheets to Specified Lengths

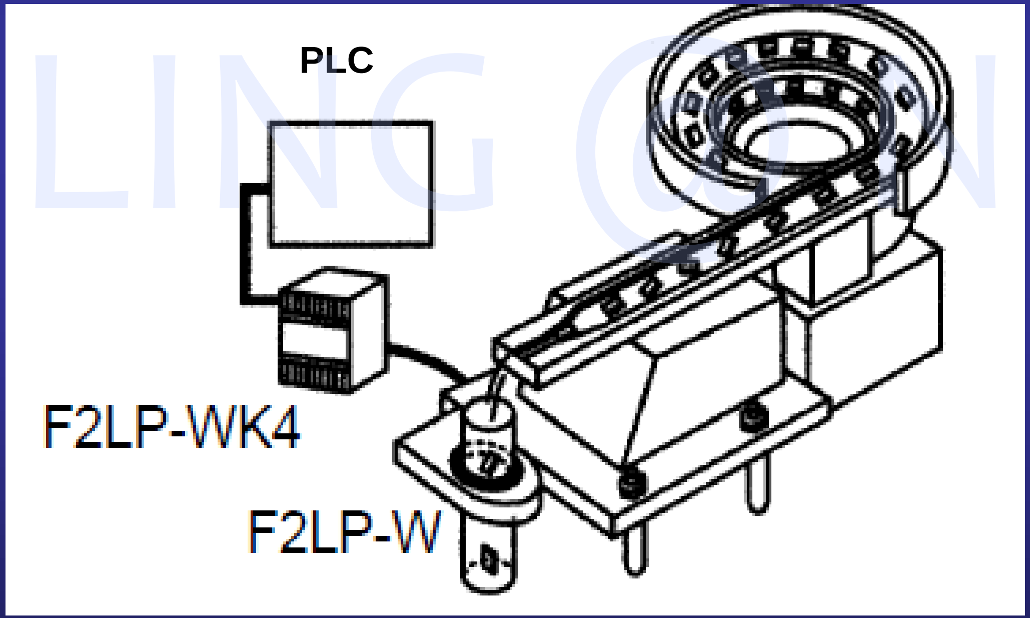
The proximity sensor detects the edge of a metal plate to operate the cutter. Metal sheets can be cut continuously to the specified lengths at a high speed.



PLC Application Example

Calculating the Number of Chips

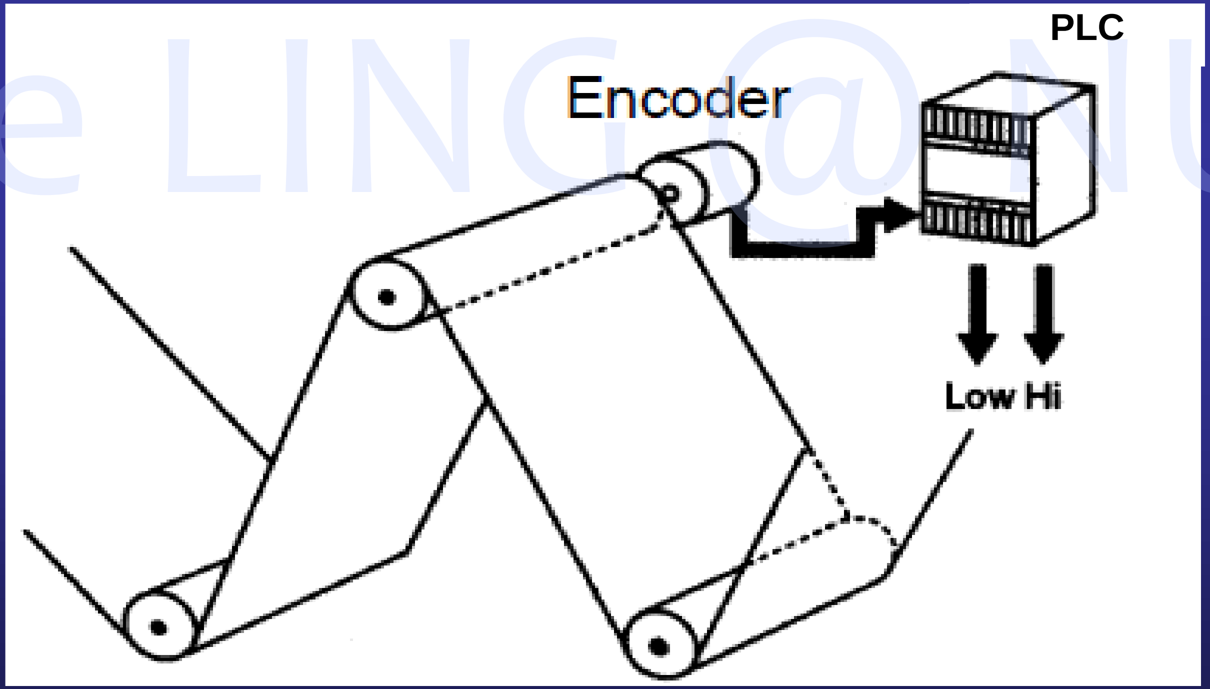
The metal sensor counts the number of parts that have passed. Steady counting can be achieved even when the input-ON time is short.



PLC Application Example

Computing the Sheet Speed

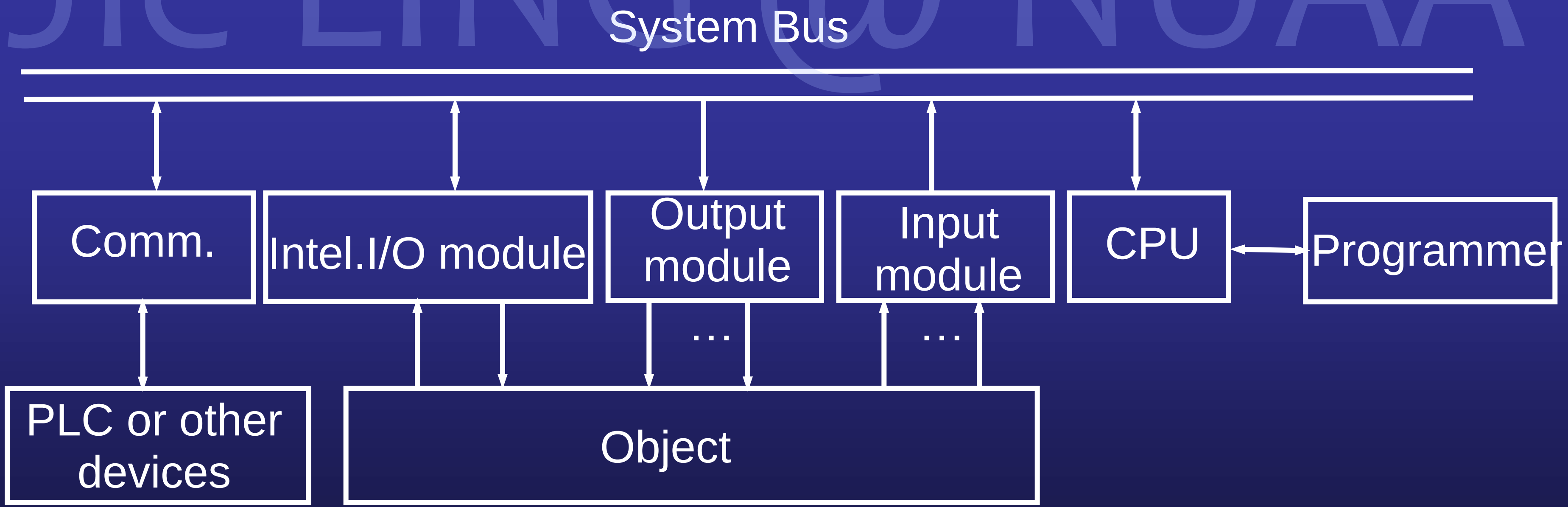
The number of pulse inputs is computed in the interrupt mode at a fixed time to calculate the speed.



1.2 Architecture of PLC

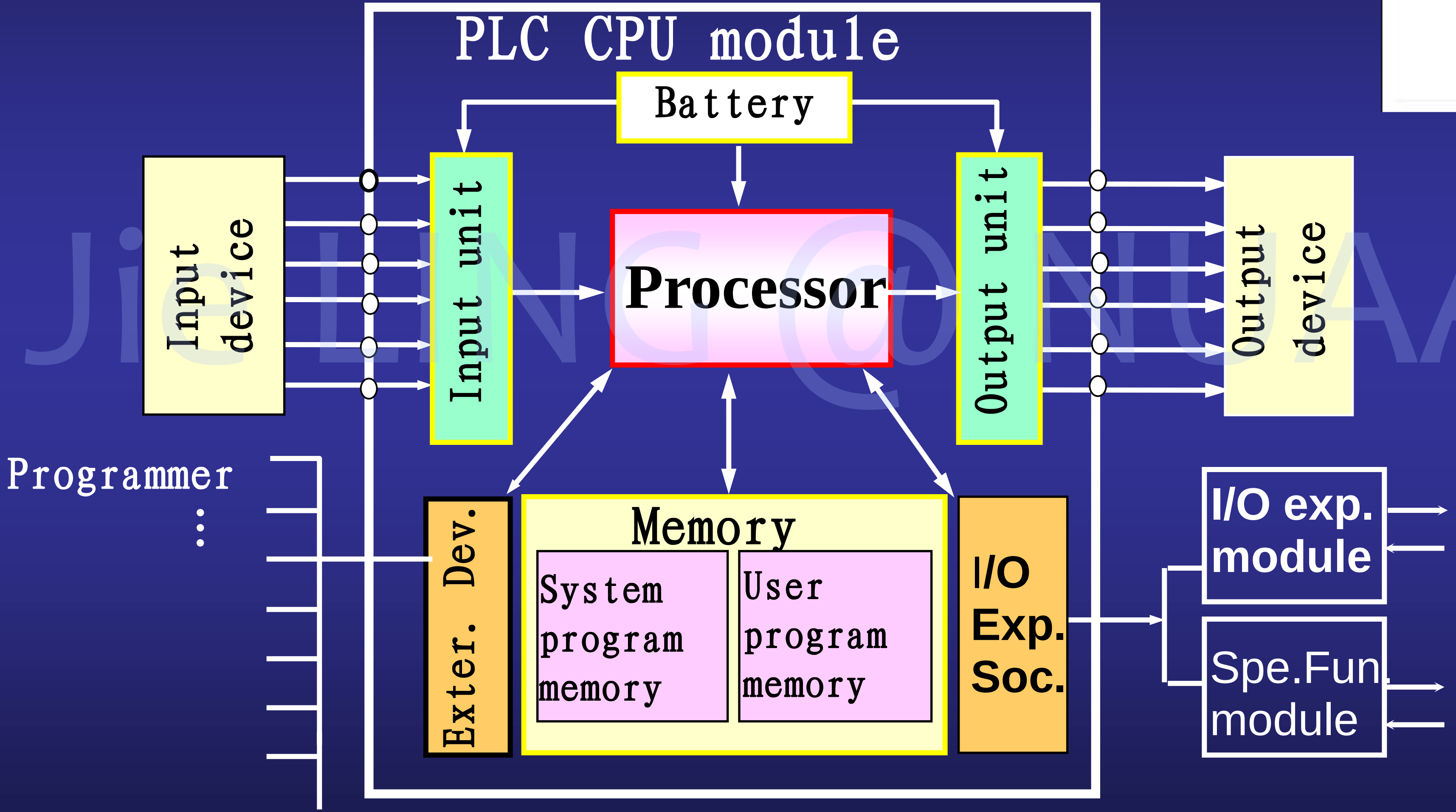
1.2.1 Type of PLC

- Modular PLC



1.2 Architecture of PLC

➢Integrated PLC (Micro PLC)



1.2 Architecture of PLC

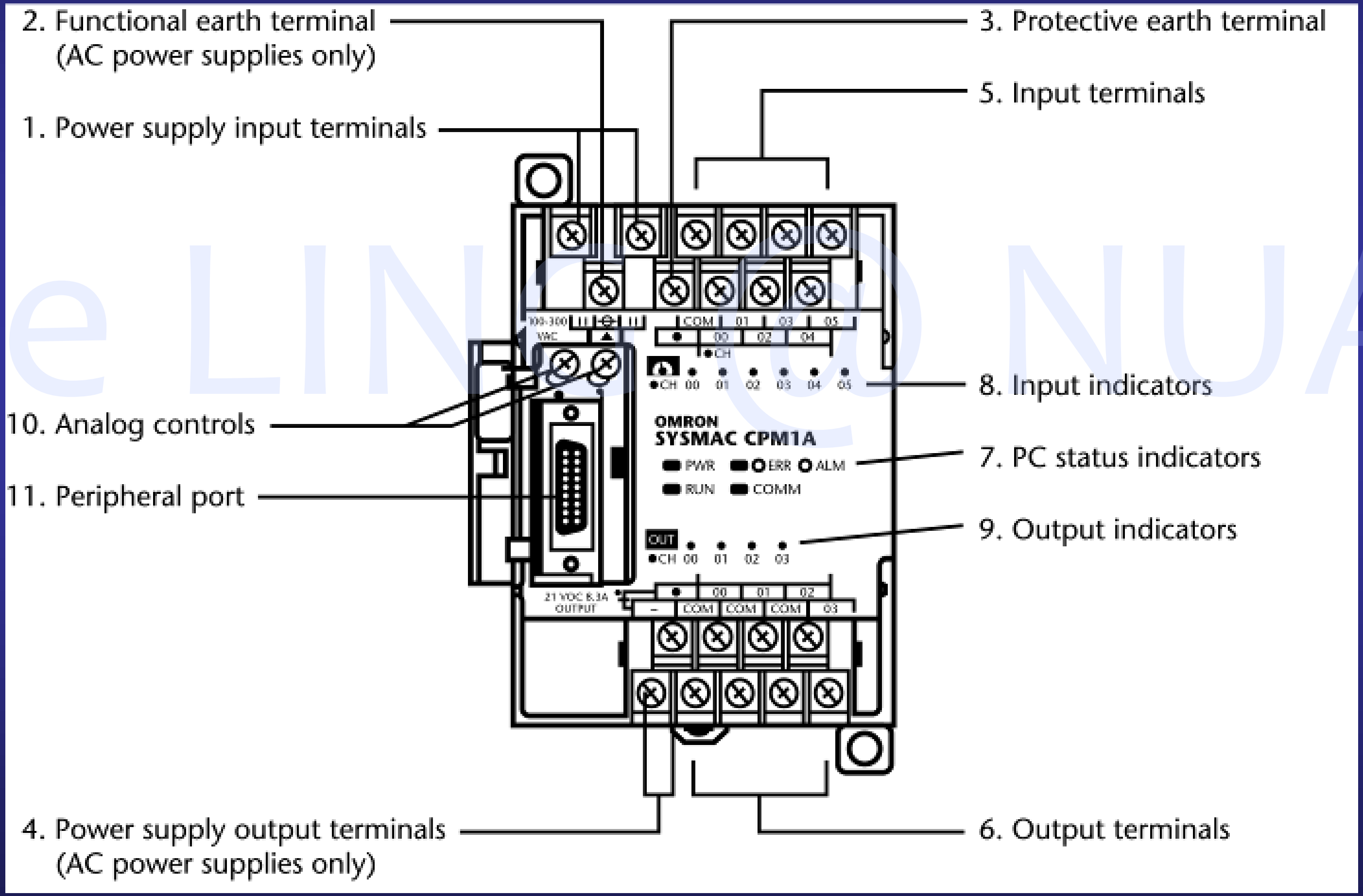
- Micro PLC Advantages

  Use when relay replacement and only basic control is desired.

  - ✓Package size smaller
  - ✓Lower cost
  - ✓Less complexity than larger PLCs
  - ✓Easy installation

1.2 Architecture of PLC

CPM1A Ten I/O Micro PLC Features



1.2 Architecture of PLC

MicroLogix 100 Micro Controllers (*Allen-Bradley*) and a Hand-held Programmer

1.2 Architecture of PLC

1.2.2 Components and systems of PLC

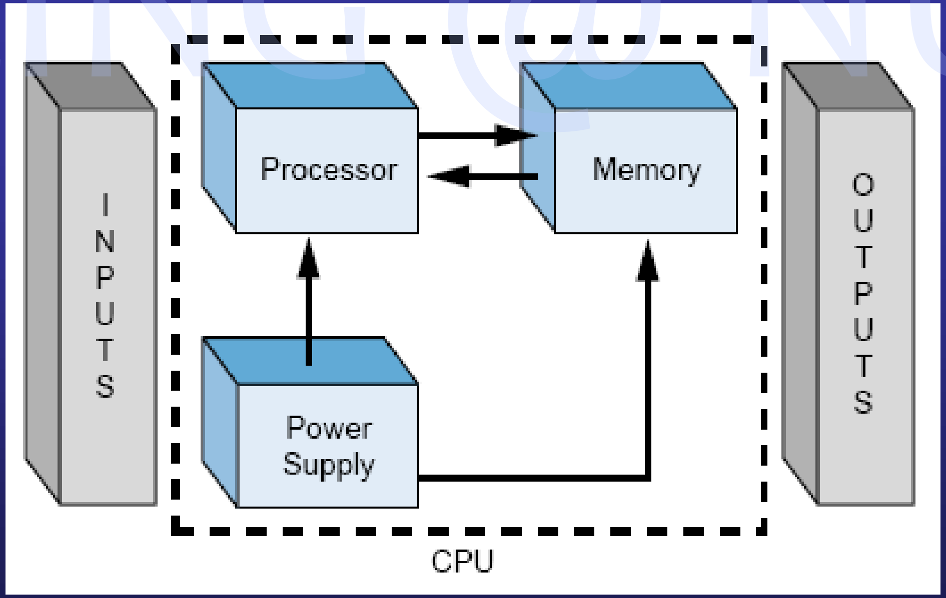
- Processor
- Power supply
- Programming device
- Memory system
- Discrete Input/output system
- Other components

1.2 Architecture of PLC

➢Overview

✓Two basic sections

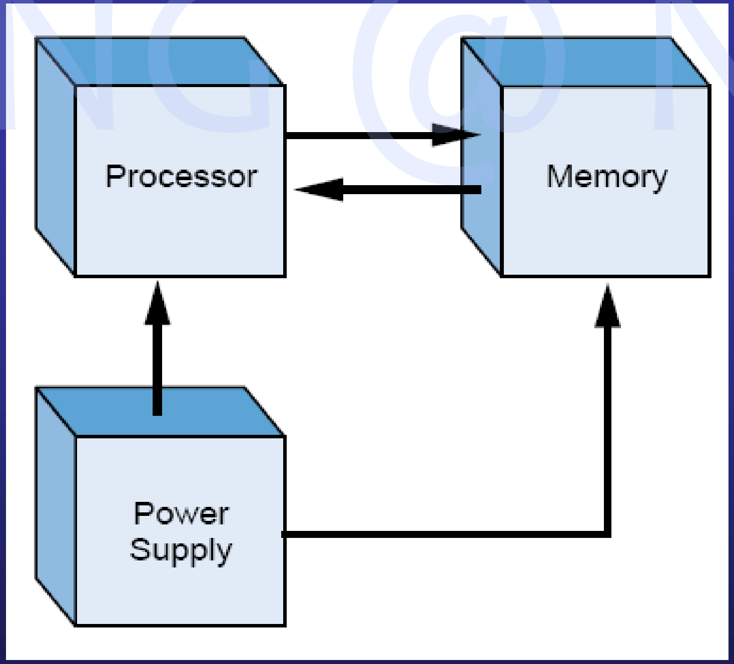
- Central processing unit
- Input/output interface system



1.2 Architecture of PLC

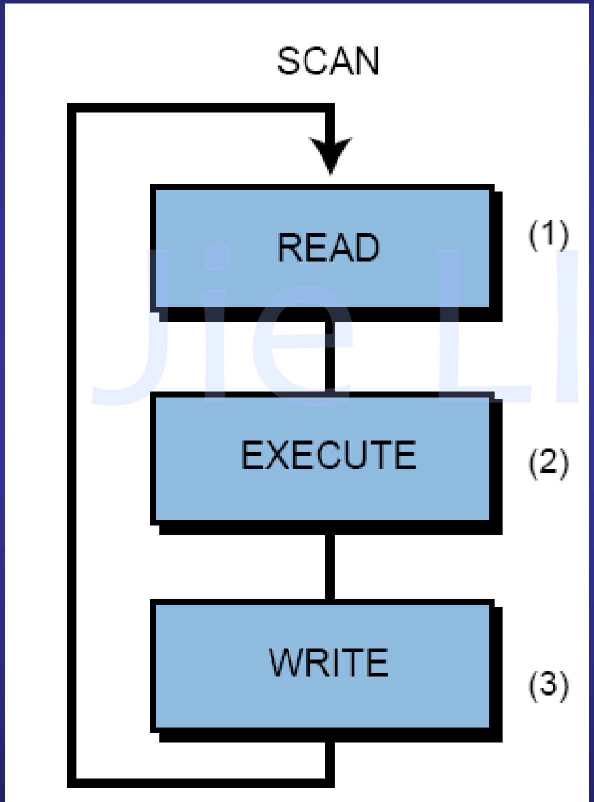
✓Components of CPU

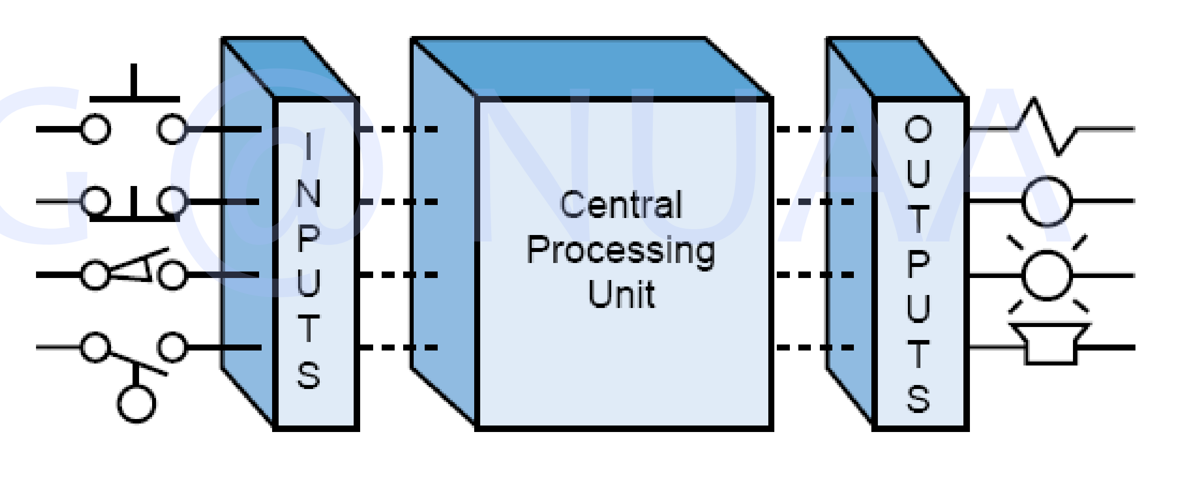
- the processor
- the memory system
- the system power supply



1.2 Architecture of PLC

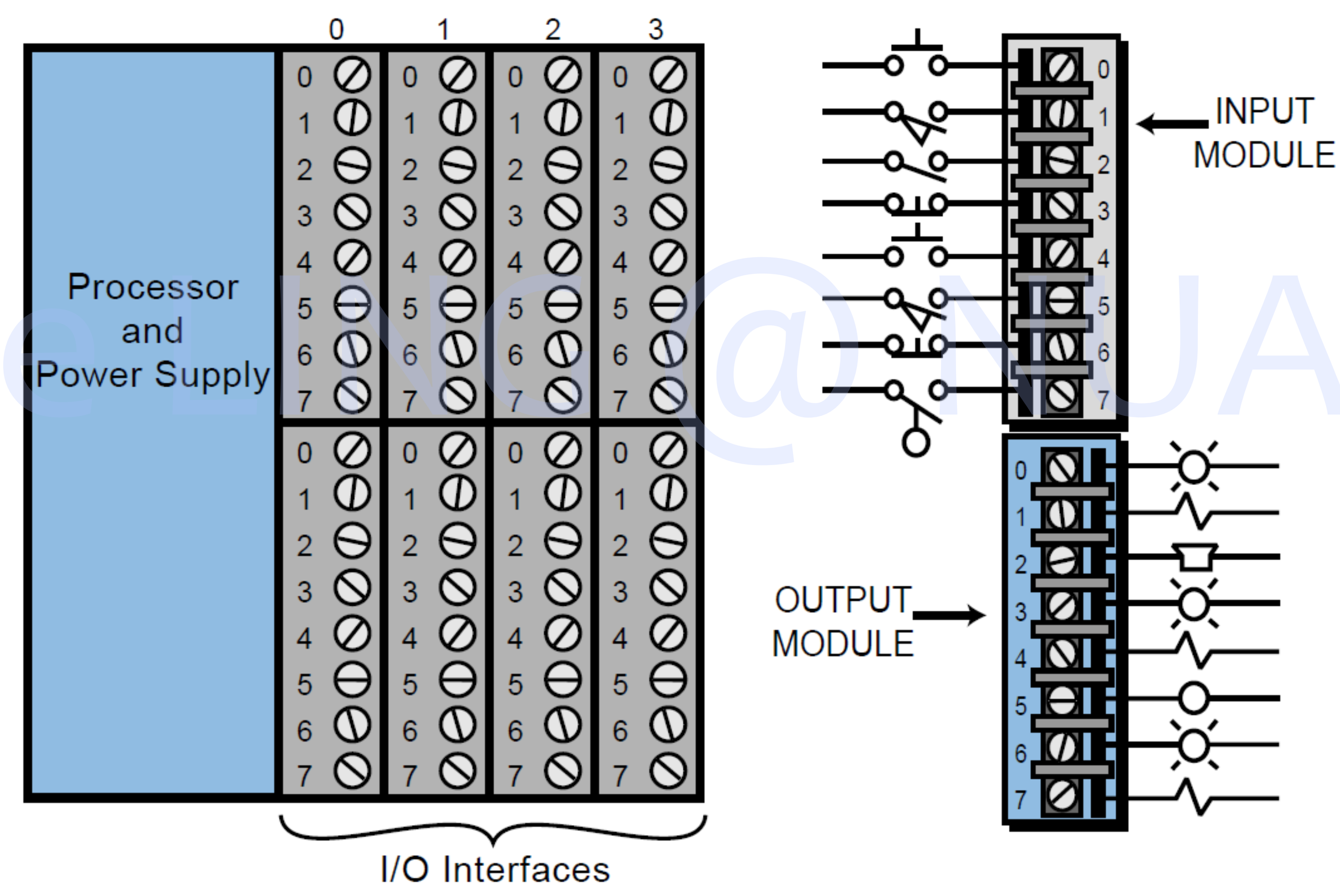
✓Function of CPU





1.2 Architecture of PLC

✓Function of Input/output interface



1.2 Architecture of PLC

➢**Processor**

✓Command and govern the activities of the entire system

✓Updating inputs and outputs

✓Performing logic and arithmetic operations

✓Communicating with memory

✓Scanning application programs

✓Communicating with a programming terminal

1.2 Architecture of PLC

- **Power supply**
  - Functions
    - ✓Provide internal DC voltages to the system components (i.e., processor, memory, and input/output interfaces)
    - ✓Monitor and regulate the supplied voltages and warn the CPU if something is wrong
    - ✓Supplying well-regulated power and protection for other system components

1.2 Architecture of PLC

✓Most PLCs require 120V/220V AC power source, some accept 24VDC

✓A constant **voltage transformer** compensates for input voltage changes to maintain a steady voltage output

1.2 Architecture of PLC

➢**Programming device**

— Used to edit program, debug program and supervise the operation of program, test the internal state and parameters of PLC online.

✓Two programming devices

- Hand-held mini-programmers
- Personal computers

1.2 Architecture of PLC

✓Hand-held miniprogrammers

1.2 Architecture of PLC

✓Hand-held Programming Terminal Advantages

- Compact size
- Easy to use and learn, no software required
- Low cost; cheaper than computer
- Easy to transport a program to the field
- Easy to transfer PLC program to HHT for editing or troubleshooting

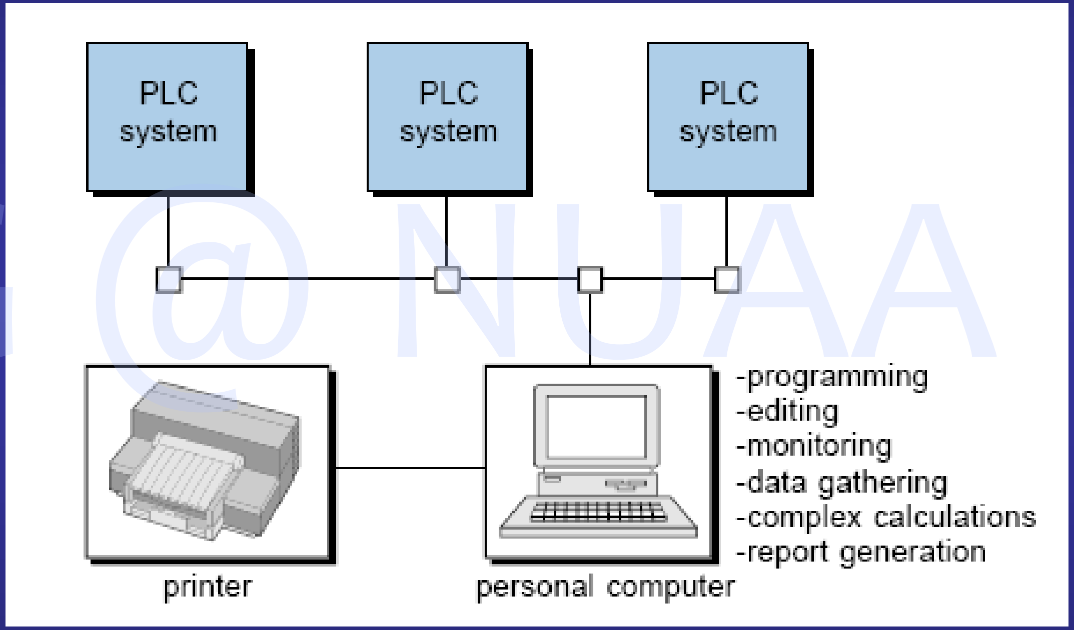
1.2 Architecture of PLC

✓Hand-held Programming Terminal Disadvantages

- Holds one program at a time
- Newer more complex processors do not support
- Limited capability to display ladder rungs
- Documentation not displayed
- Many keystrokes needed to program or edit ladder program
- Dead battery means program lost

1.2 Architecture of PLC

✓Personal computers



1.2 Architecture of PLC

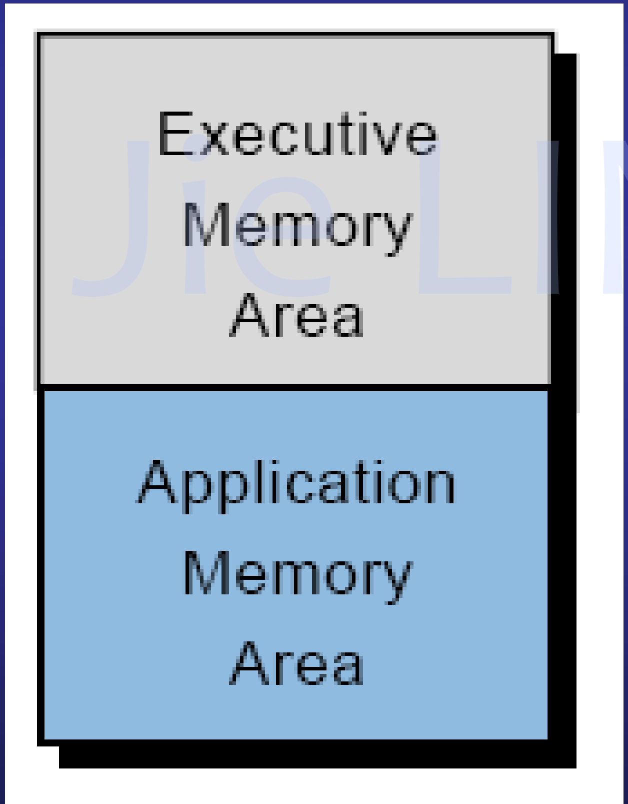
✓Software Programming Using PC Advantages

- Software Windows-based
- View or monitor multiple ladder rungs
- Documentation displayed
- Easy to scroll through rungs for troubleshooting
- Programs stored on computer's hard drive
- Programs transferred to floppy or CD-ROM
- Easy editing and programming, drag and drop, cut and paste, etc.

1.2 Architecture of PLC

➢Memory system

✓Memory sections

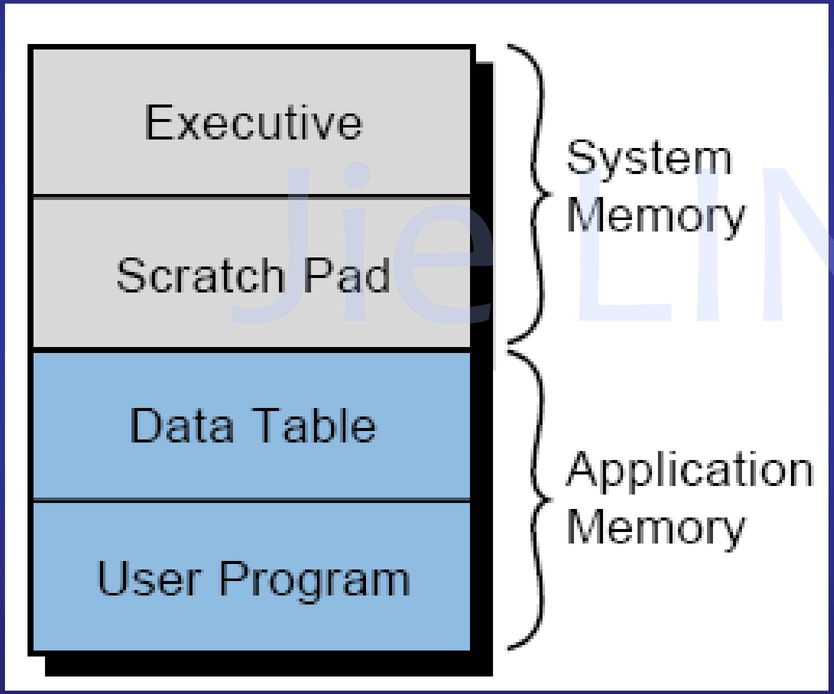


System memory → Permanently stored programs-direct all system activities. Not accessible to user.

Application memory → Store user program. Accessible to user.

1.2 Architecture of PLC

✓Memory map



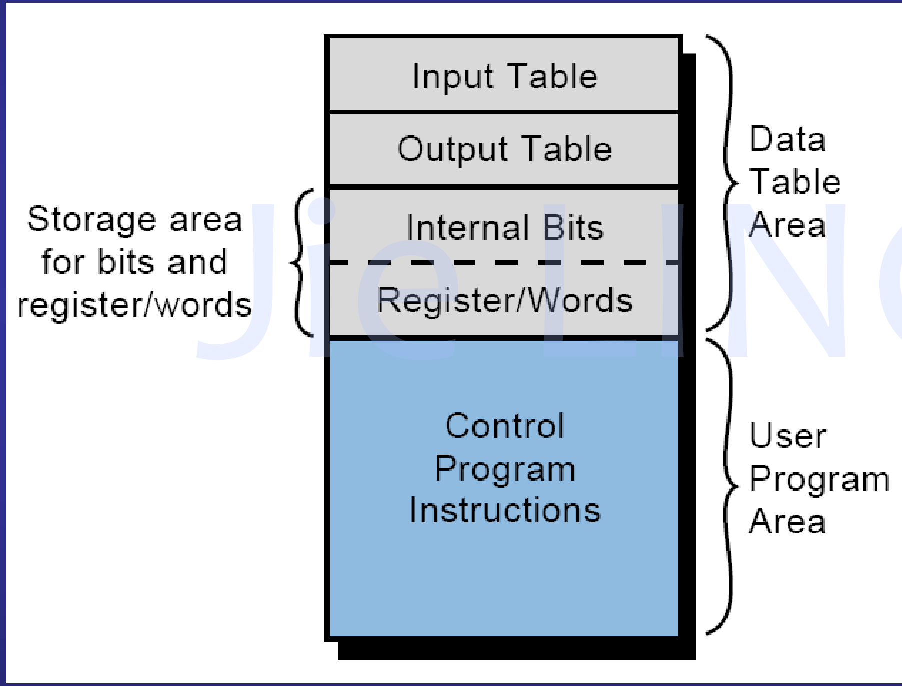
•Supervisory programs-direct systems activities

•Temporary storage area used to store a relatively small amount of data for interim calculations and control

•All data associated with the control program.

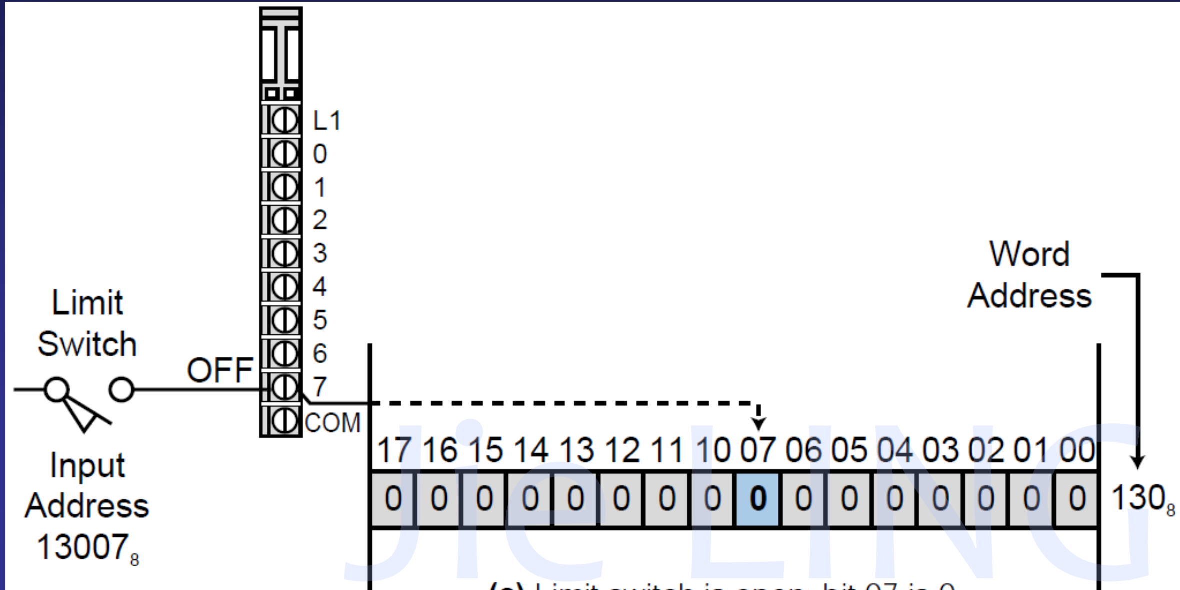
•Programmed instructions

✓Application Memory

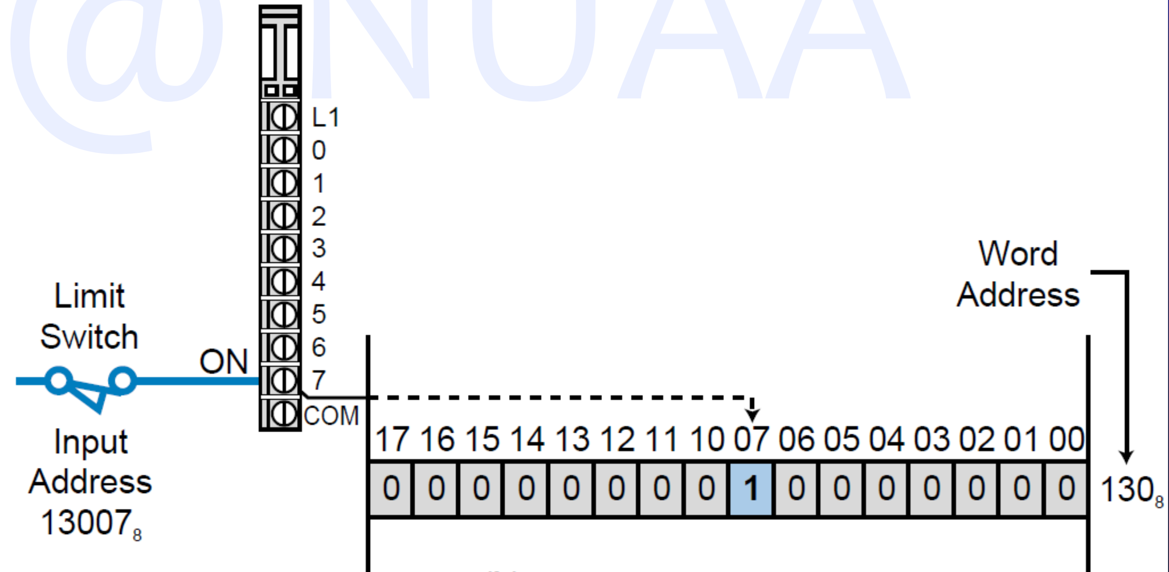


- An array of bits that stores status of digital inputs connected to input interface
- Bits that controls the status of digital output devices.
- Store changeable data, in a bit (e.g. internal relays) or a word (input data from devices, e.g. analog inputs; output data to output modules; hold fixed constants, e.g. T/C).

1.2 Architecture of PLC

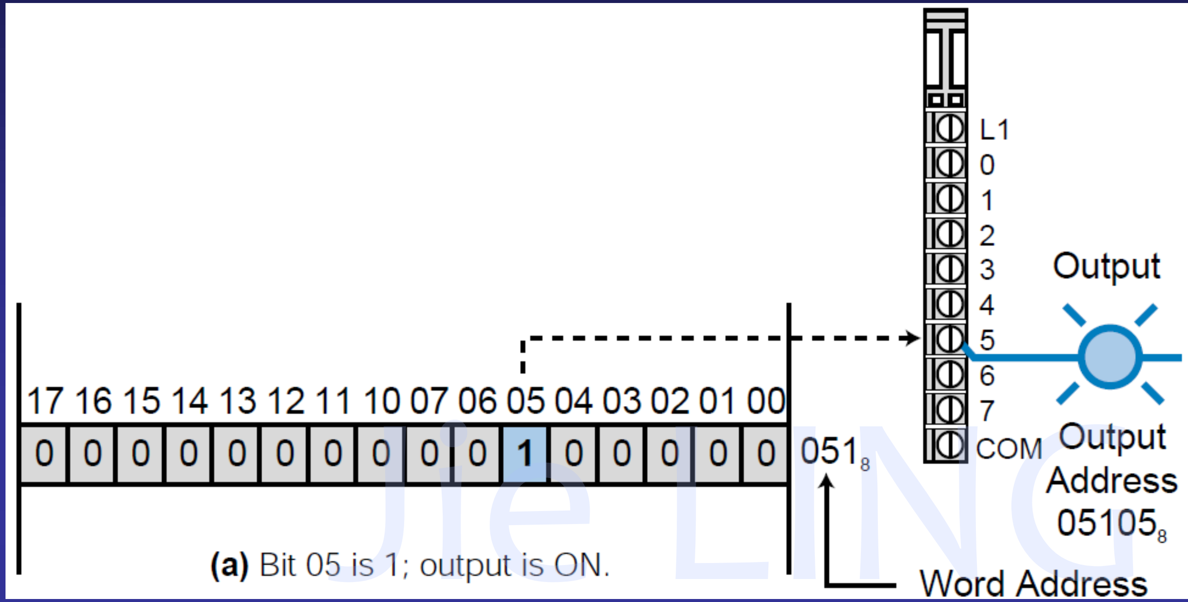


(a) Limit switch is open; bit 07 is 0.

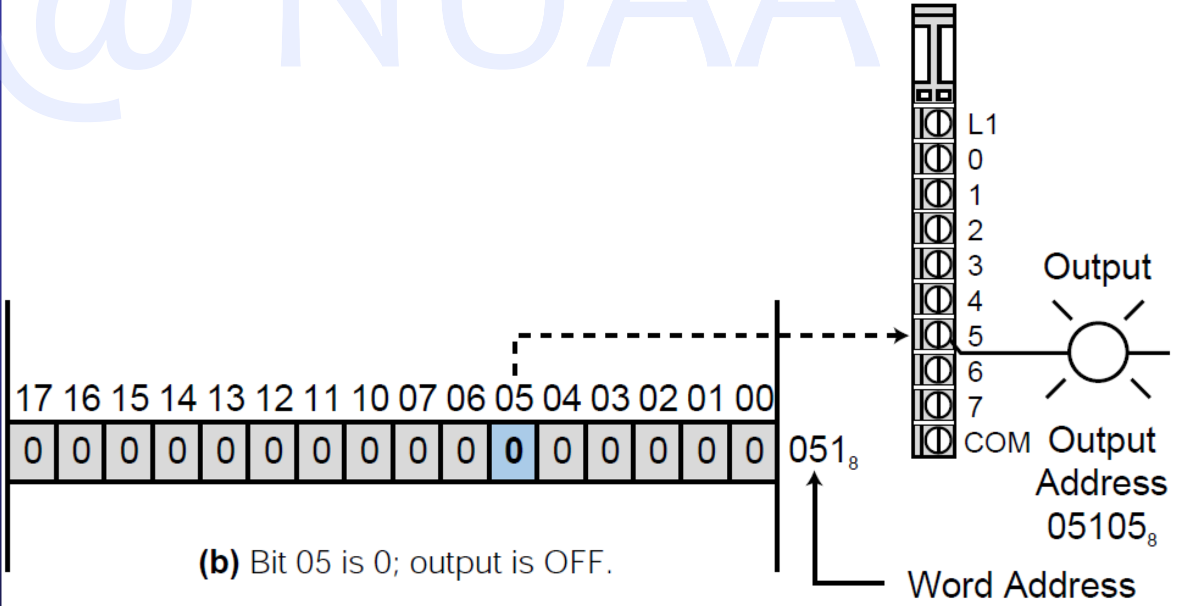


(b) Limit switch is closed; bit 07 is 1.

1.2 Architecture of PLC



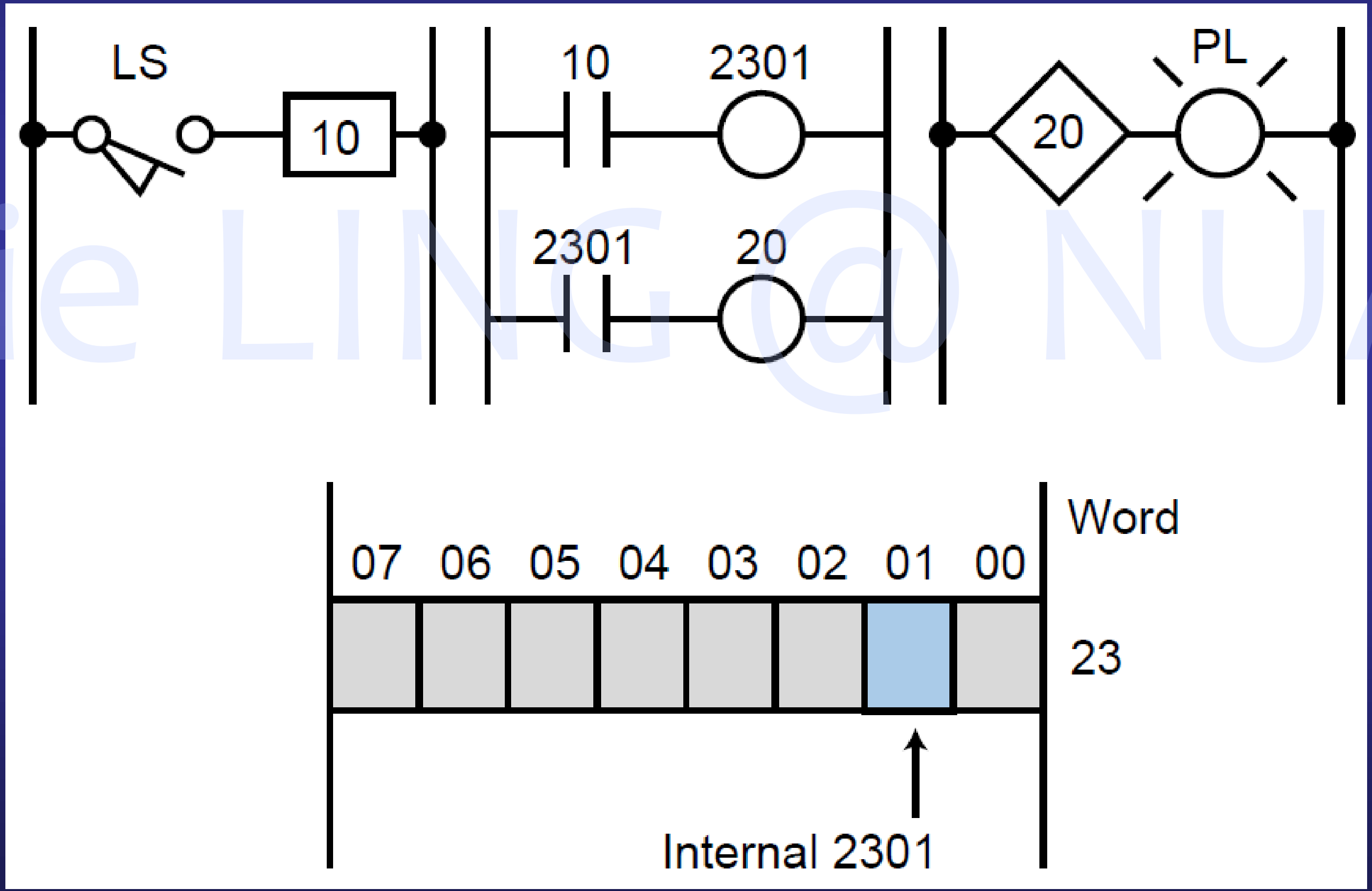
(a) Bit 05 is 1; output is ON.



(b) Bit 05 is 0; output is OFF.

1.2 Architecture of PLC

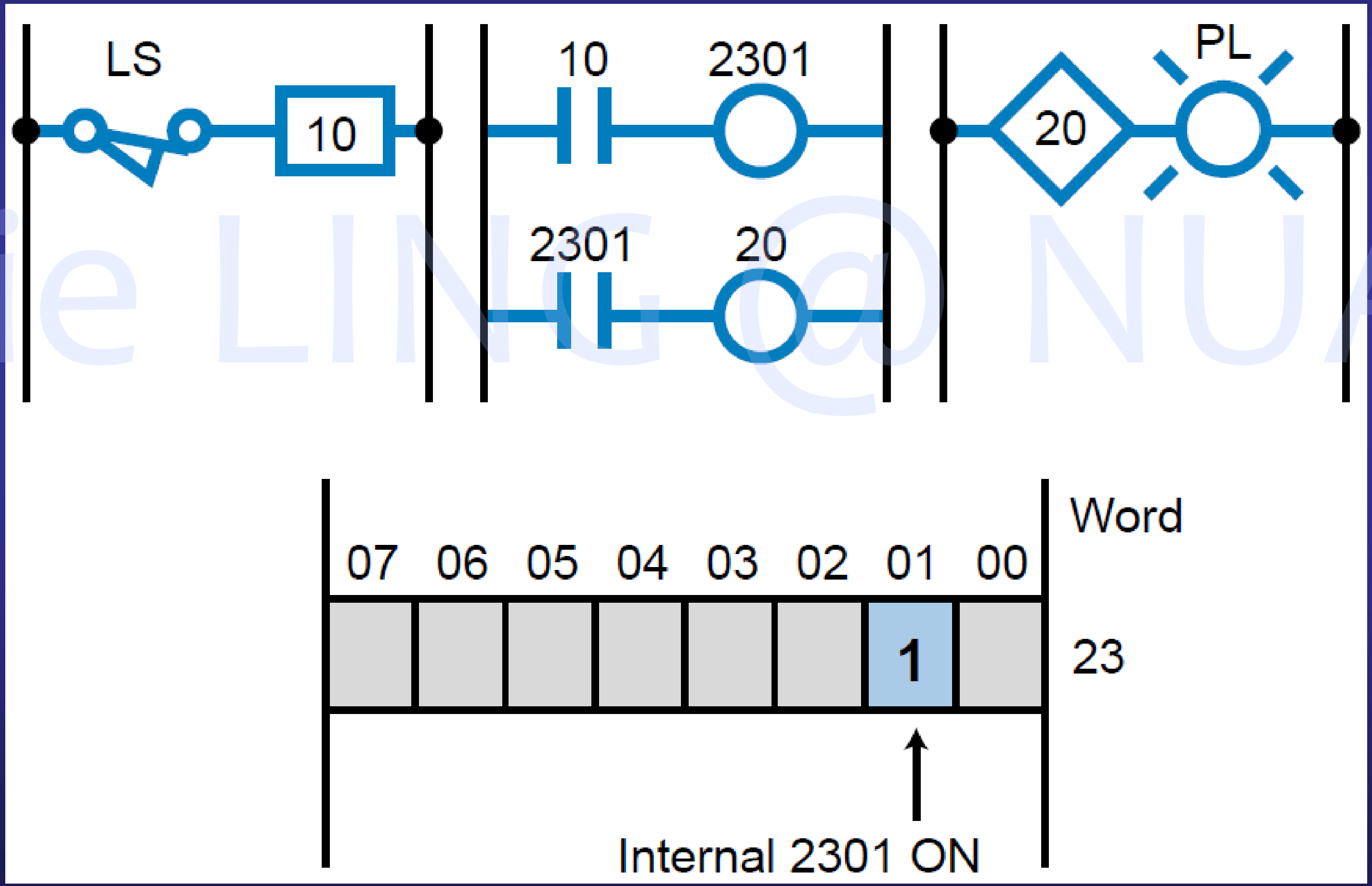
✓e.g What happens to internal 2301 (word 23, bit 01) when the limit switch connected to input terminal 10 closes?



1.2 Architecture of PLC

✓e.g

What happens to internal 2301 (word 23, bit 01) when the limit switch connected to input terminal 10 closes?



1.2 Architecture of PLC

✓Memory types

- Volatile memory

  Loses its programmed contents if all operating power is lost

- Nonvolatile memory

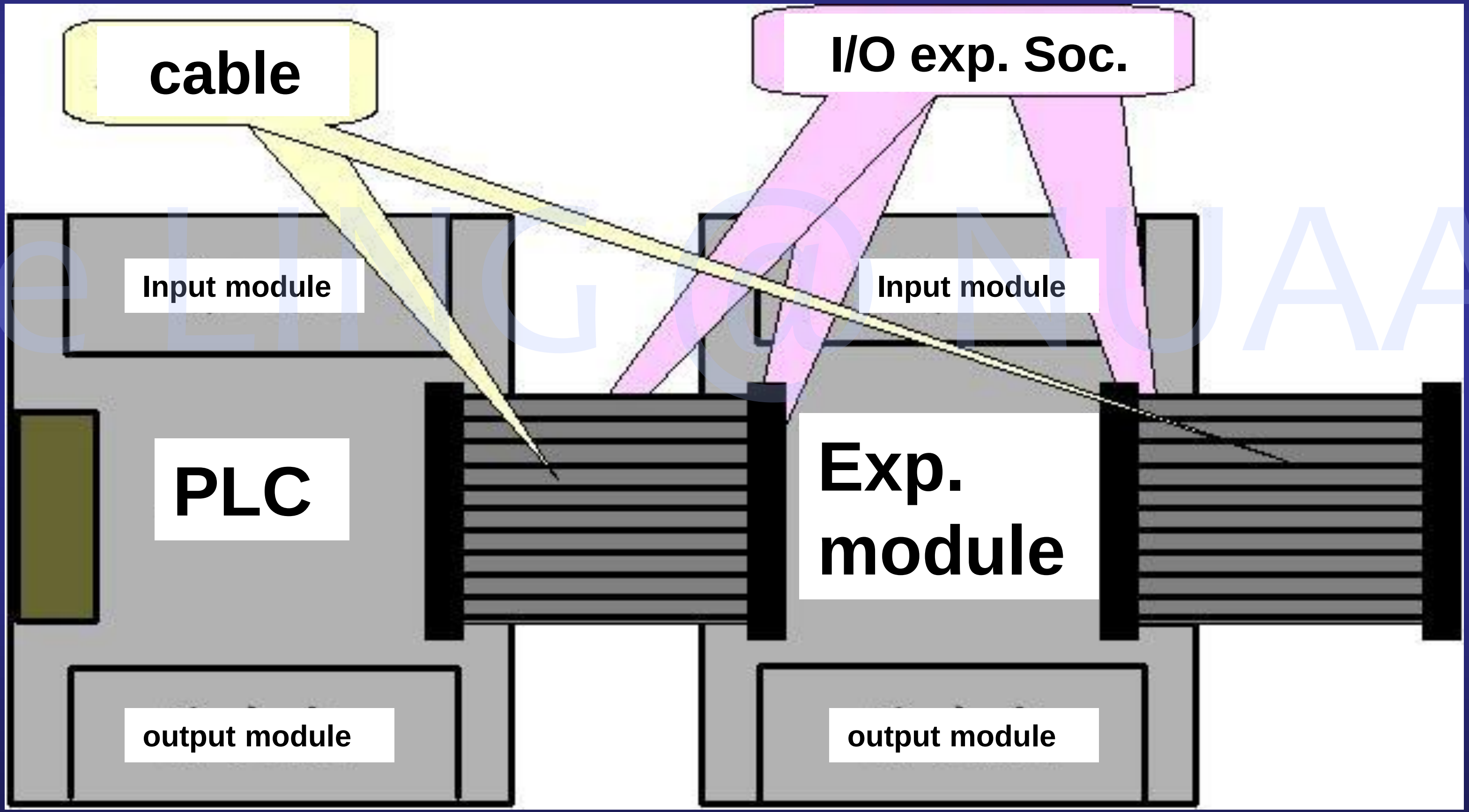
  Retains its programmed contents, even during a complete loss of operating power, without requiring a backup source.

1.2 Architecture of PLC

- Read-only memory (ROM)
- Random-access memory (RAM)
- Programmable read-only memory (PROM)
- Erasable programmable read-only memory (EPROM)
- Electrically alterable read-only memory (EAROM)
- Electrically erasable programmable read-only memory (EEPROM)

1.2 Architecture of PLC

- Expansion socket



1.2.3 Discrete Input/output system

➢Overview

- **Function:** provide physical connection between CPU and field devices (On/Off).
- **Input:** used to wire the external control signal, such as from pushbutton, limit switch, contact of thermal relay etc, and conditions these signals into standard signals, and waits for CPU read in I/O update step.
- **Output：** Transform signals from CPU in I/O update into signals to drive the external load, for example light, coil etc.
- Sensors and actuators can often be directly connected to them.

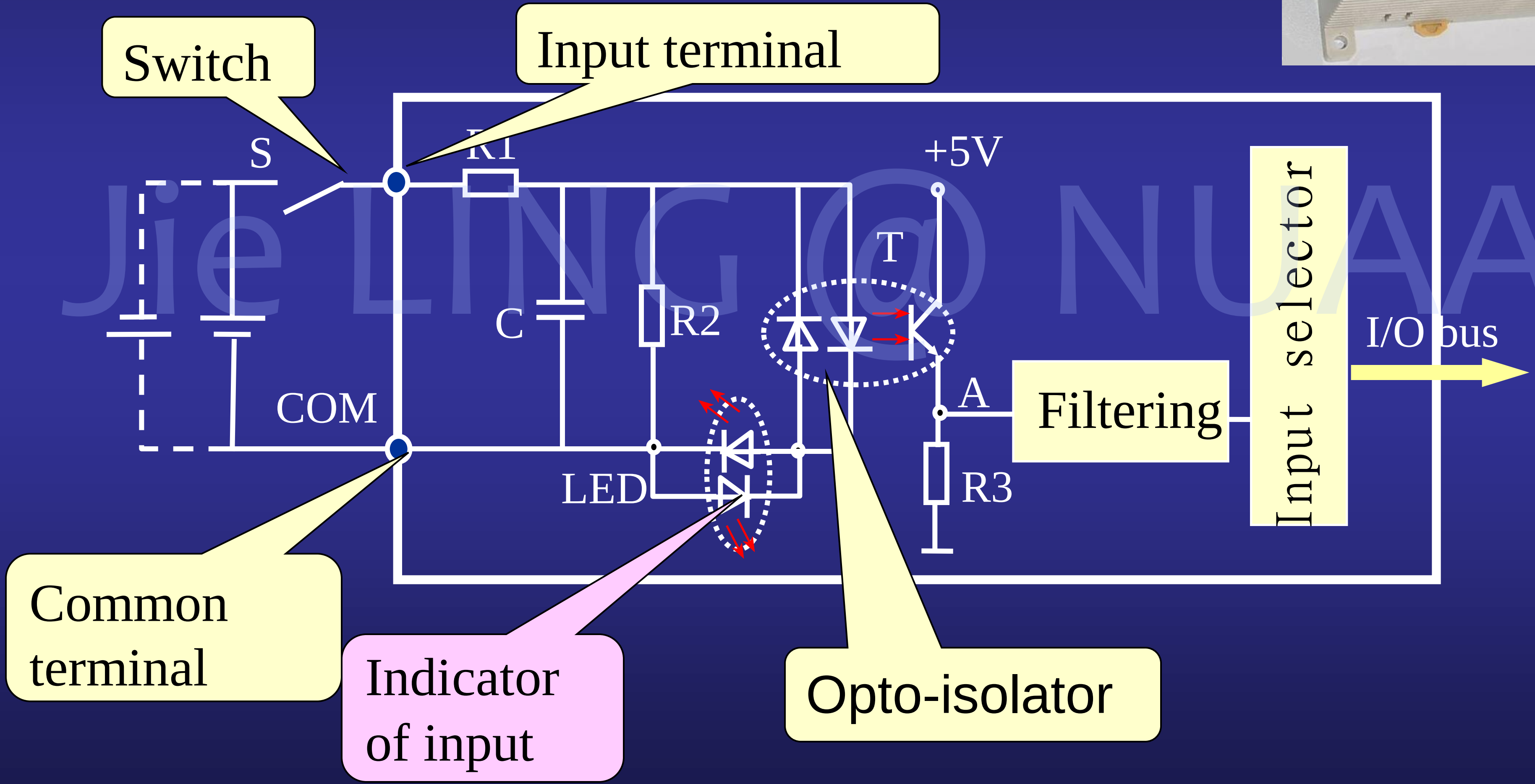
1.2 Architecture of PLC

- **Category of discrete I/O**

- Discrete input
  - DC input
  - AC input
- Discrete output
  - Transistor output
  - Triac output
  - Relay output

1.2 Architecture of PLC

- ➢**Discrete Inputs**
  - ✓**DC Inputs**



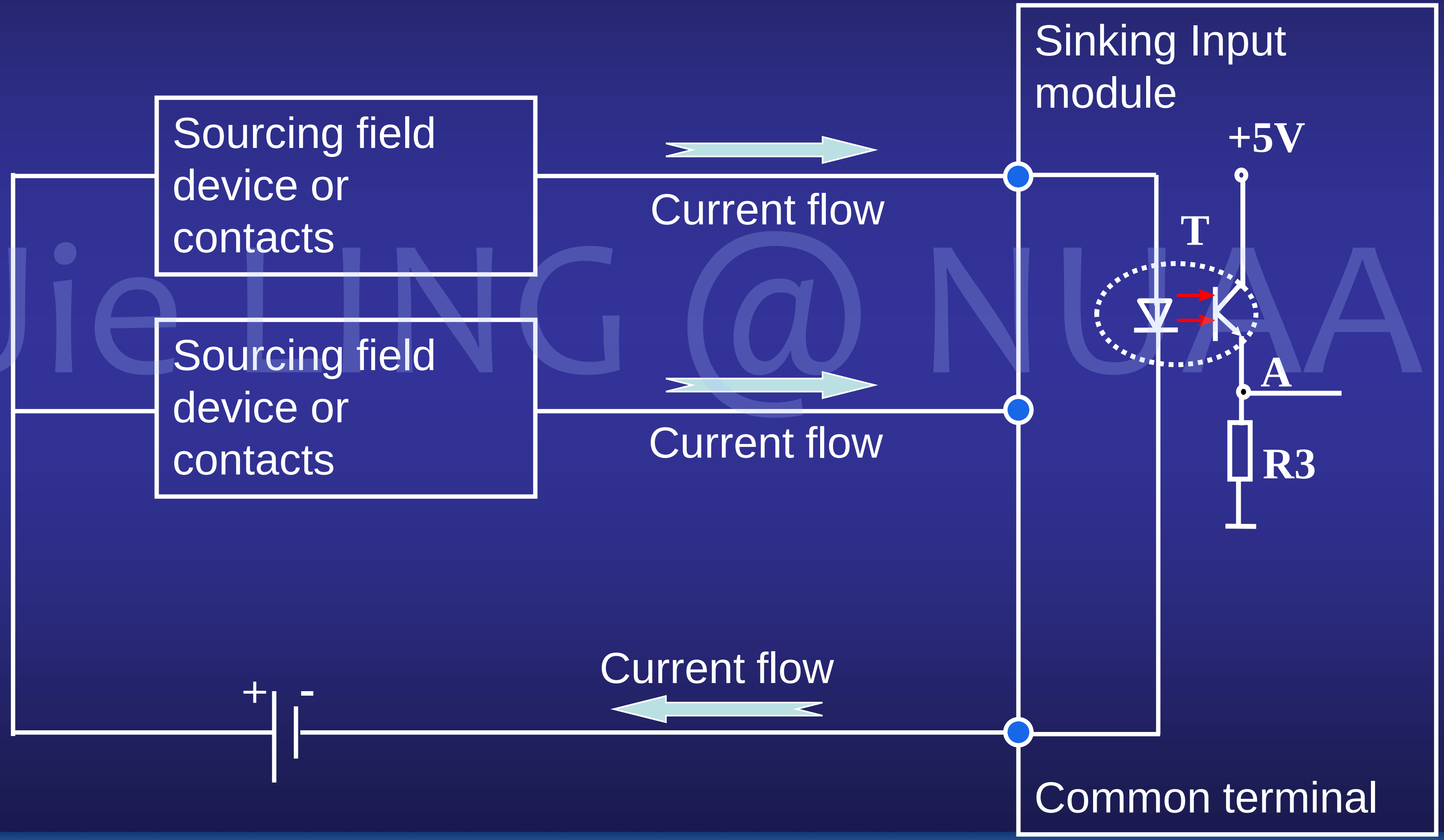
1.2 Architecture of PLC

✓Sourcing and sinking

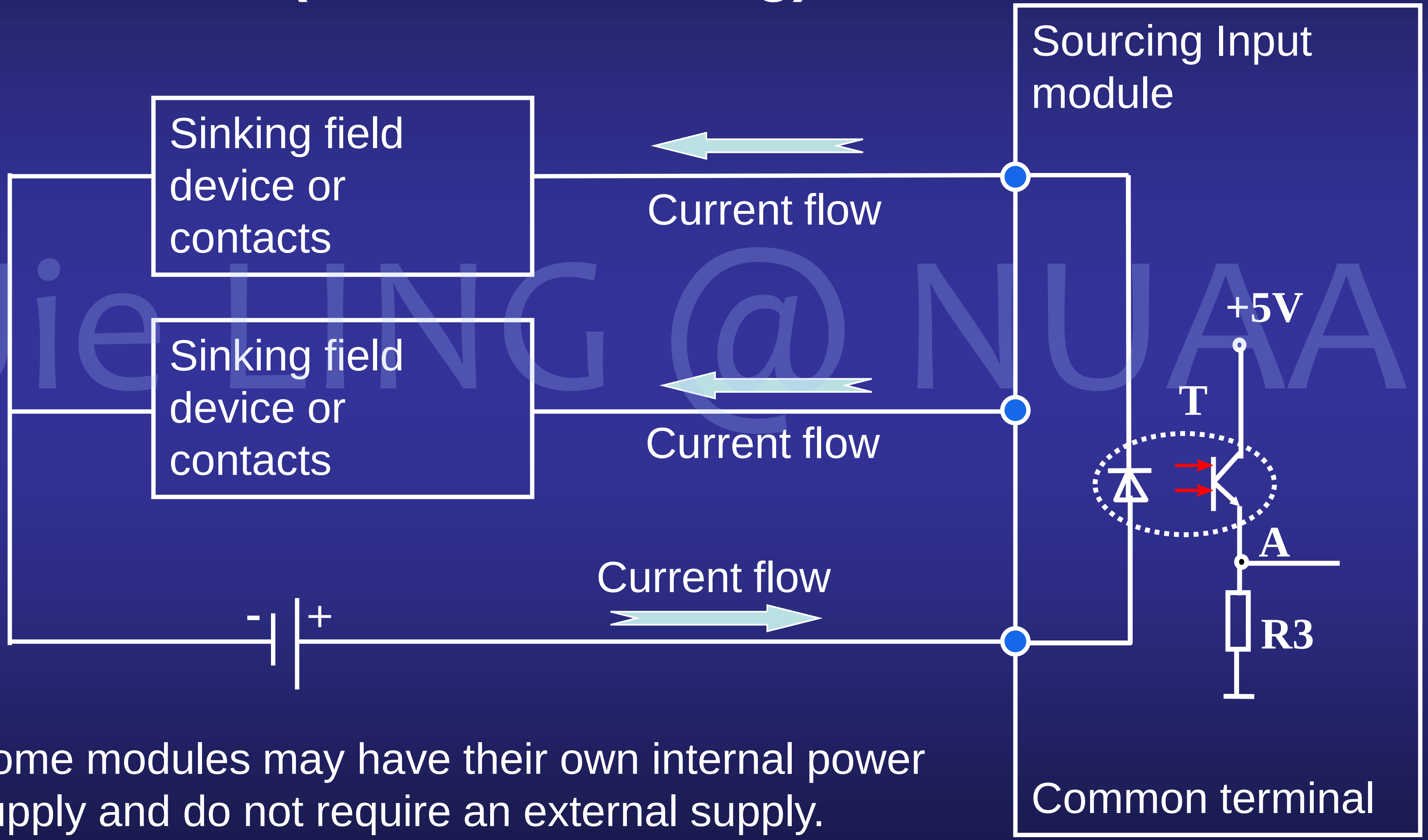
- The terms **sourcing** and **sinking** refer to the manner in which DC devices are interfaced with the PLC
- For a PLC input unit with sourcing, it is the source of the current supply for the input device connected to it
- With sinking, the input device provides the current to the input unit
- Current sinking sensors must be matched to current sourcing PLC inputs
- Current sourcing sensors must be matched with current sinking PLC inputs

1.2 Architecture of PLC

✓**DC input module (current sinking)**



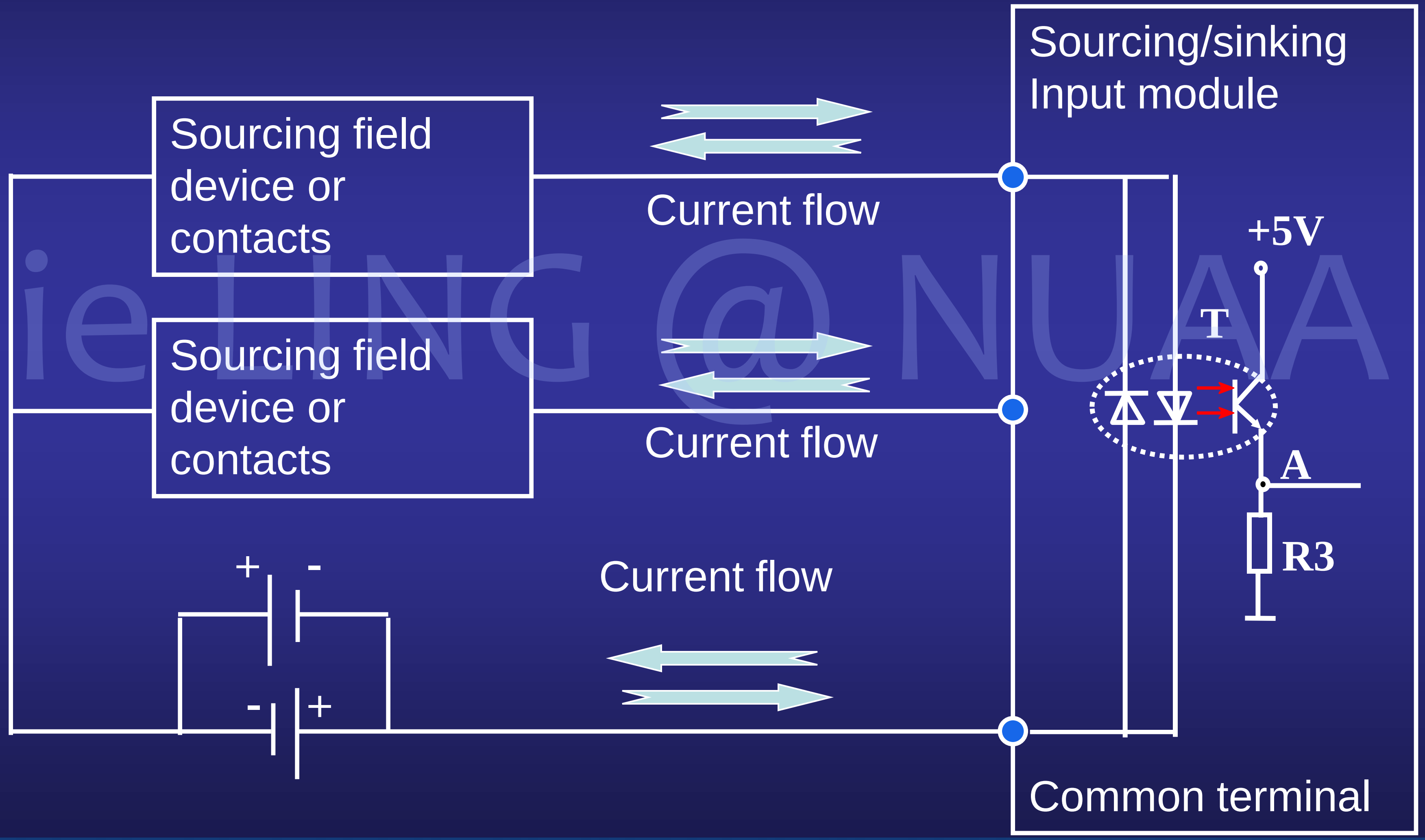
✓DC input module (current sourcing)



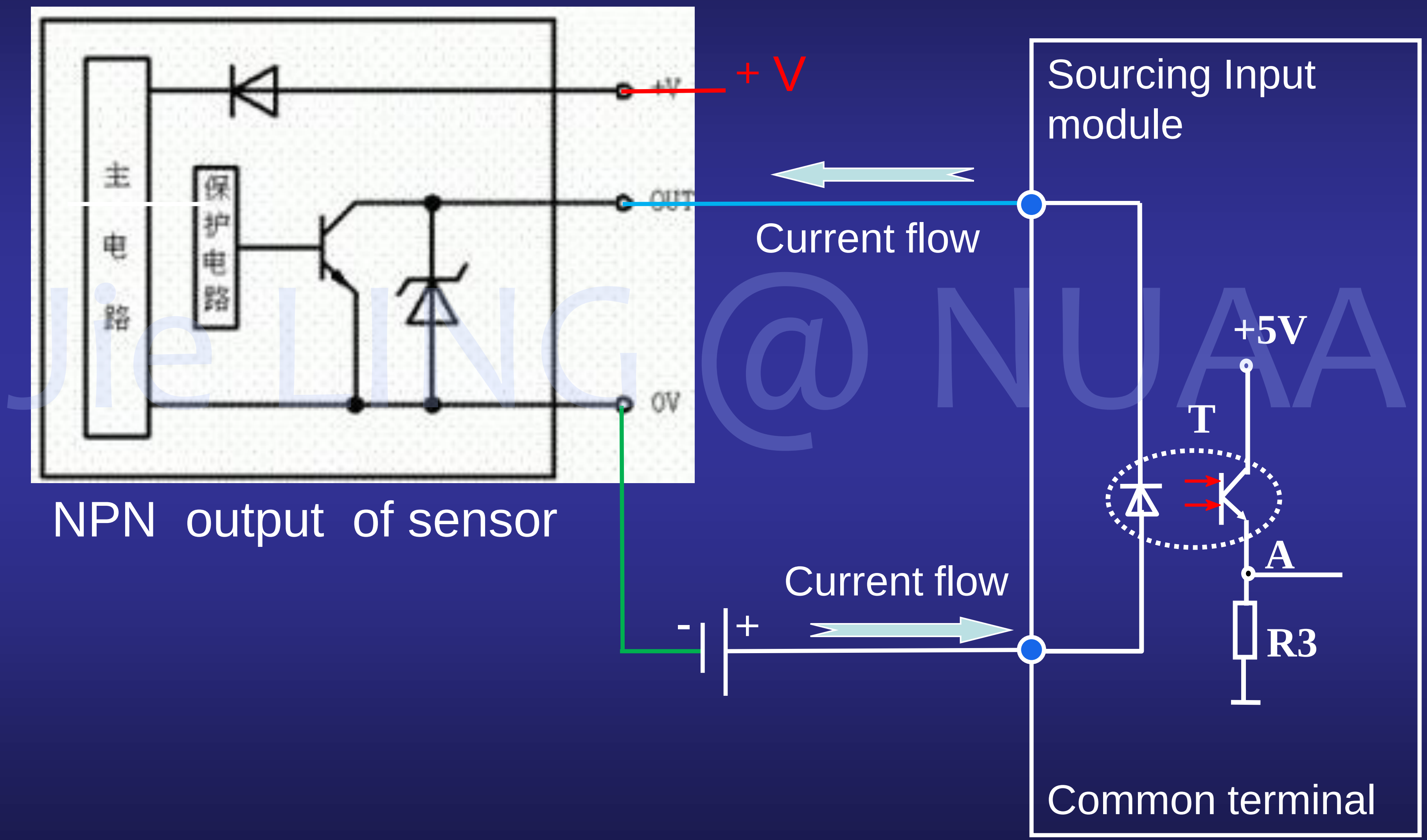
Some modules may have their own internal power supply and do not require an external supply.

1.2 Architecture of PLC

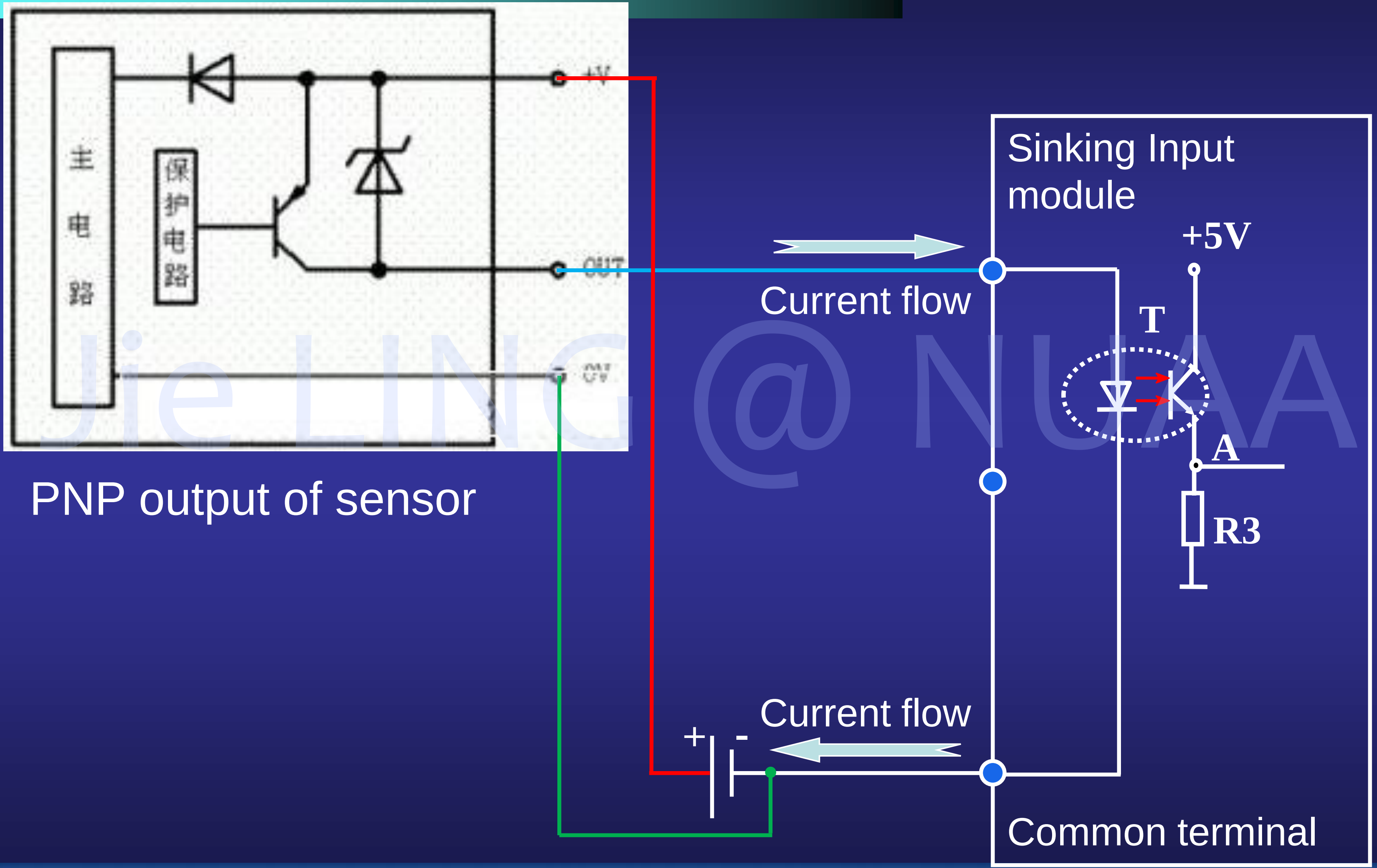
✓DC input module (current sinking/sourcing)



1.3 Input devices and output actuators



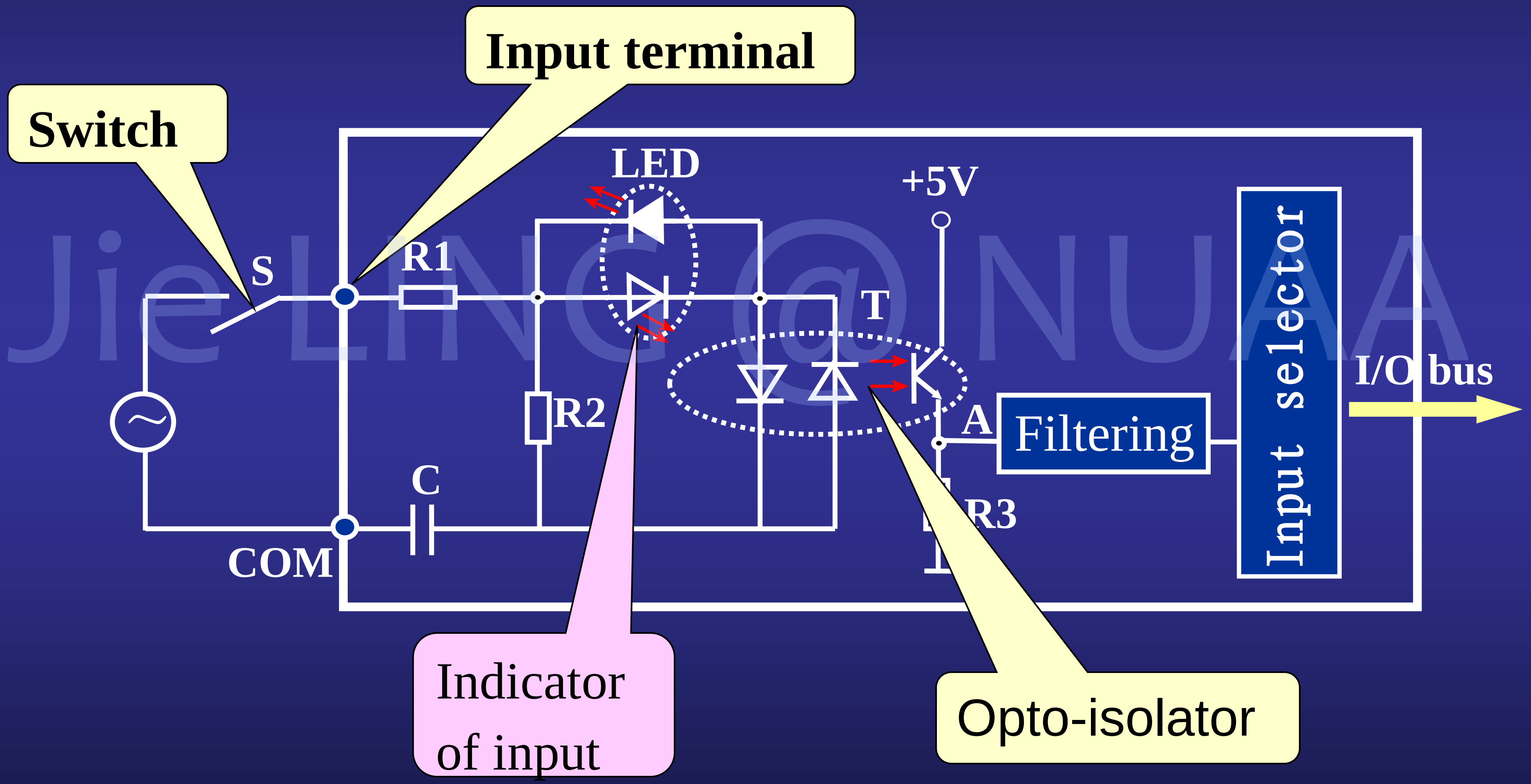
1.3 Input devices and output actuators



PNP output of sensor

1.2 Architecture of PLC

- AC inputs



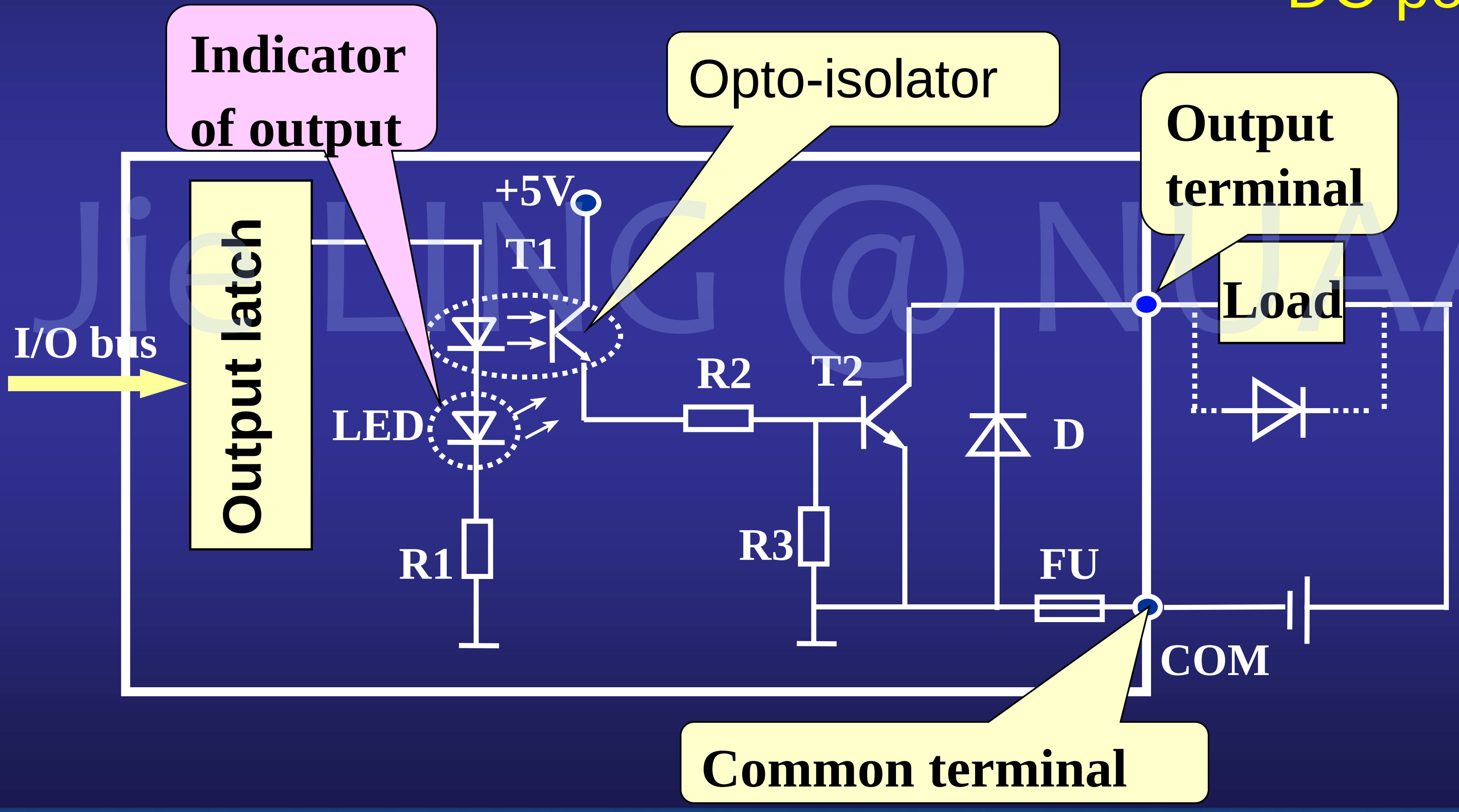
1.2 Architecture of PLC

- **Discrete outputs**
  - ✓**Transistor output circuit**

High freq., low power

>10kHz

DC power supply



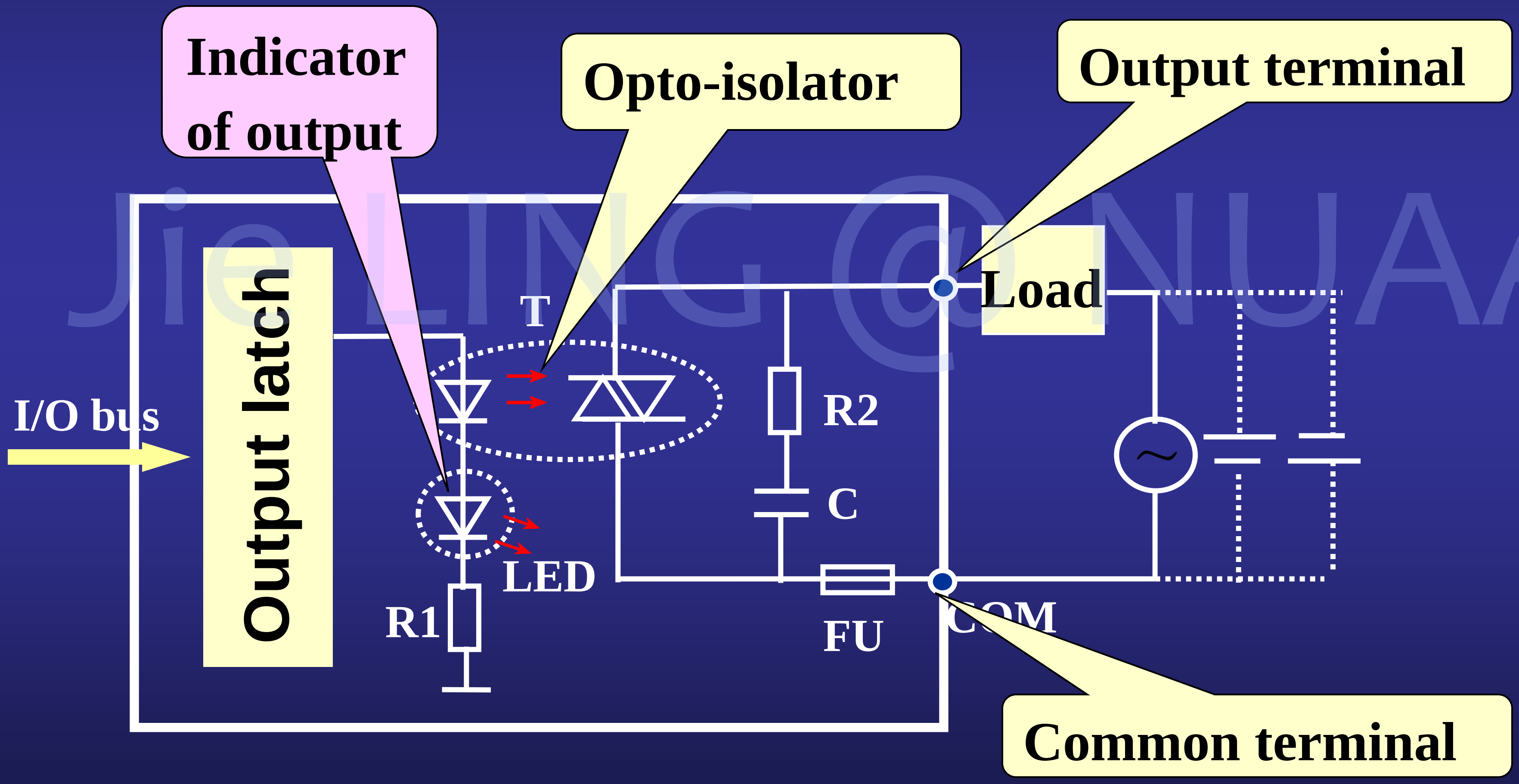
1.2 Architecture of PLC

High freq. and power

>1kHz

AC power supply

✓**Triac output circuit**



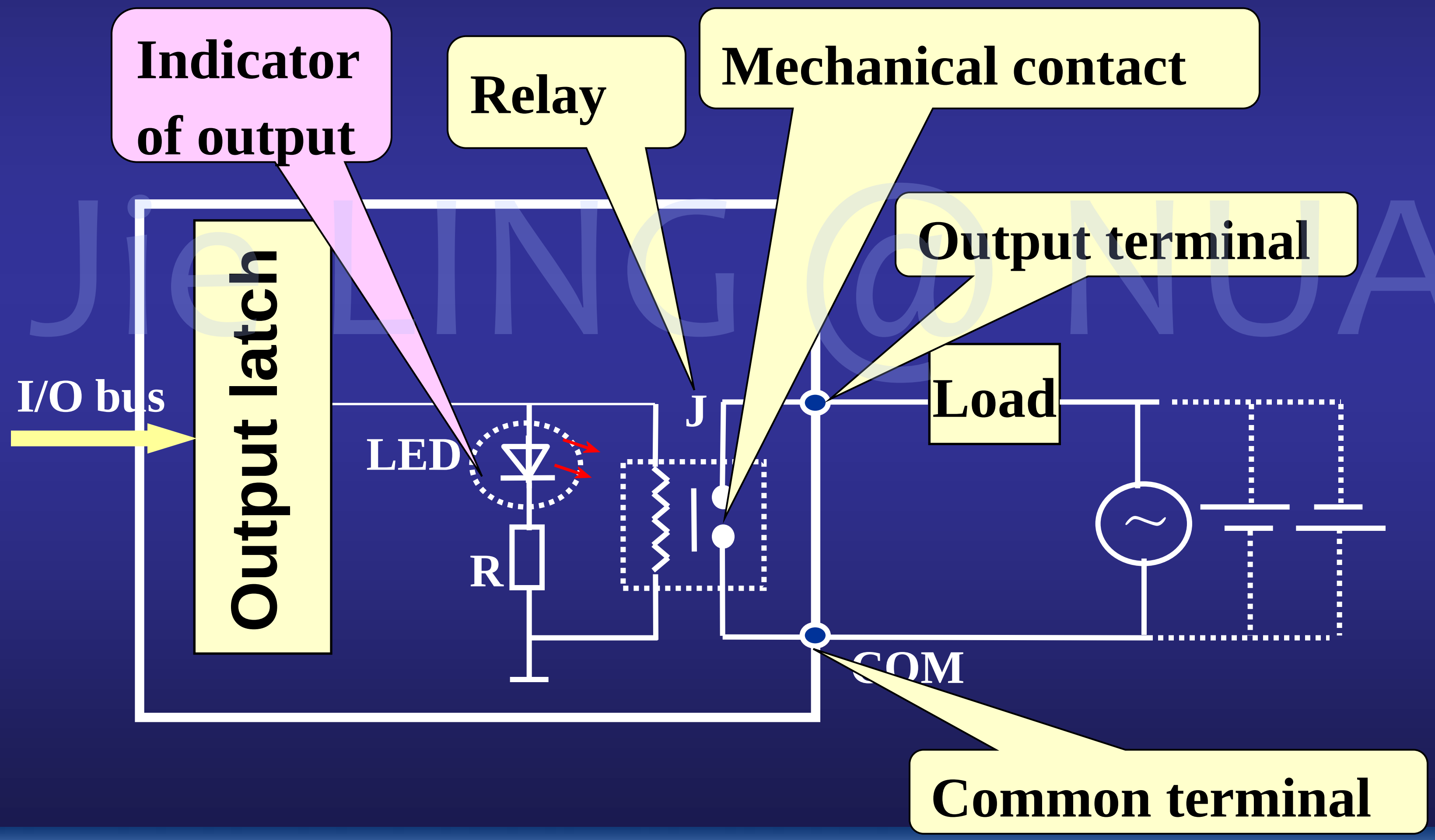
1.2 Architecture of PLC

Low freq. high power

DC or AC power supply

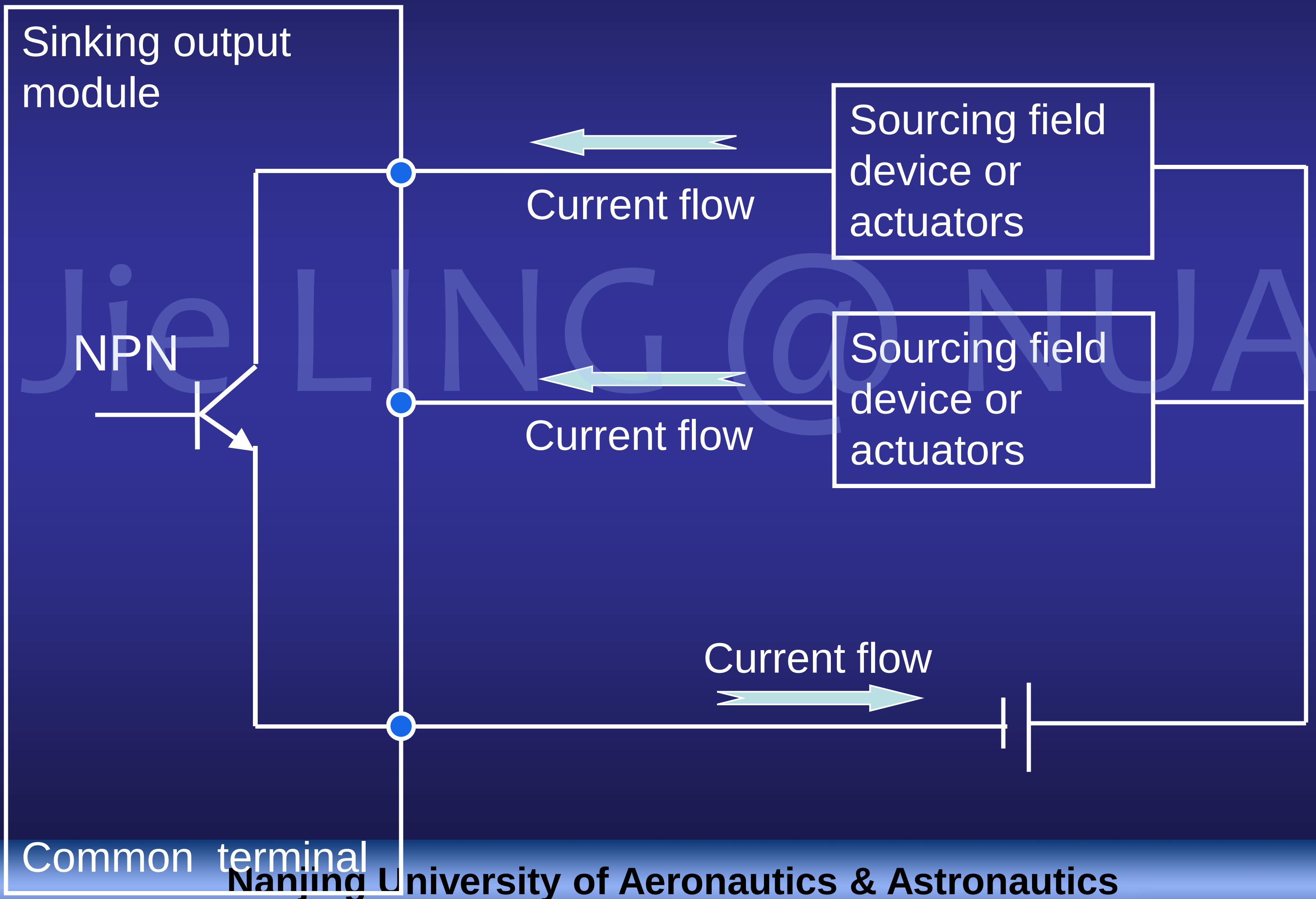
Response time 10ms

✓**Relay output circuit**



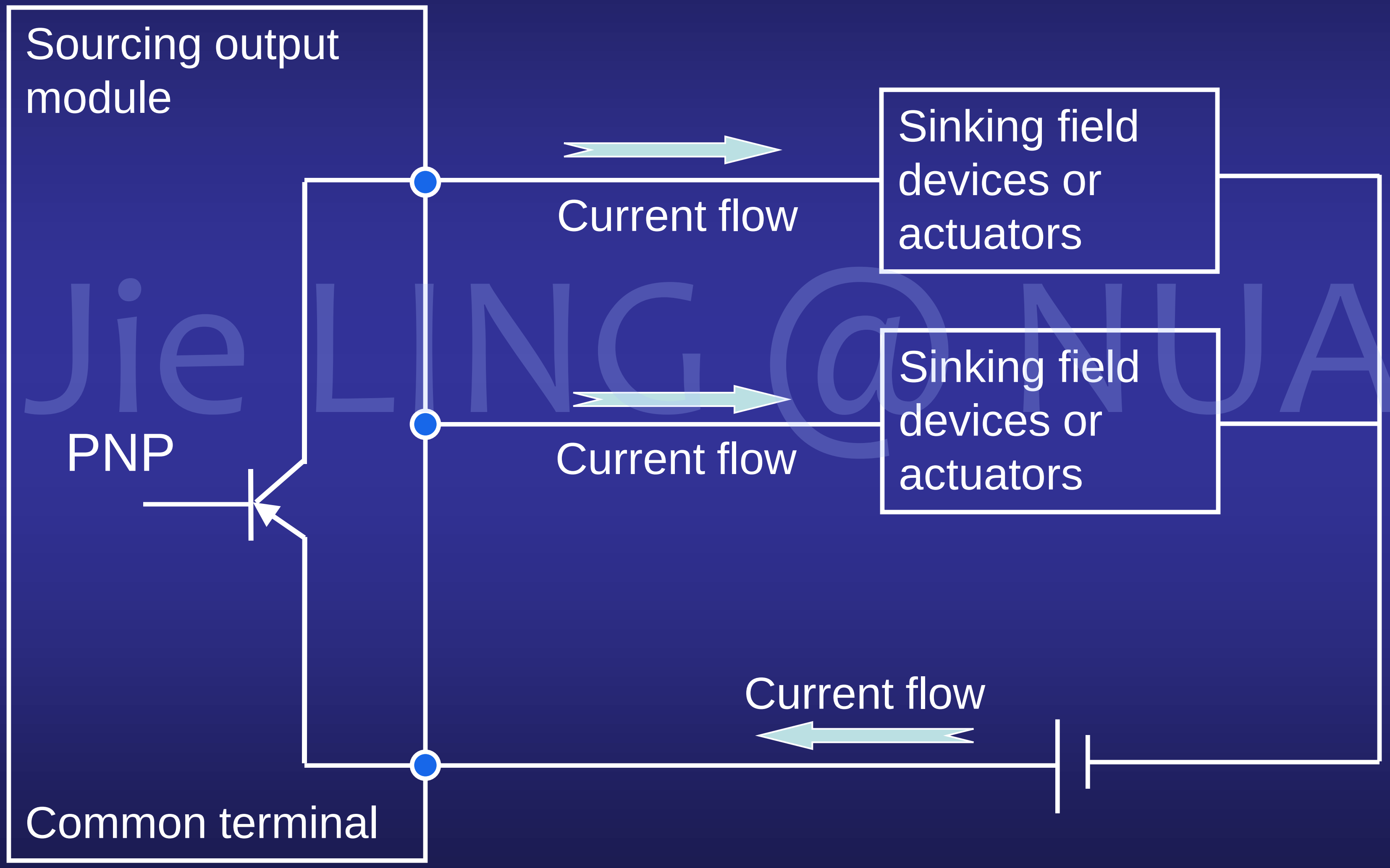
1.2 Architecture of PLC

✓DC output module (current sinking)



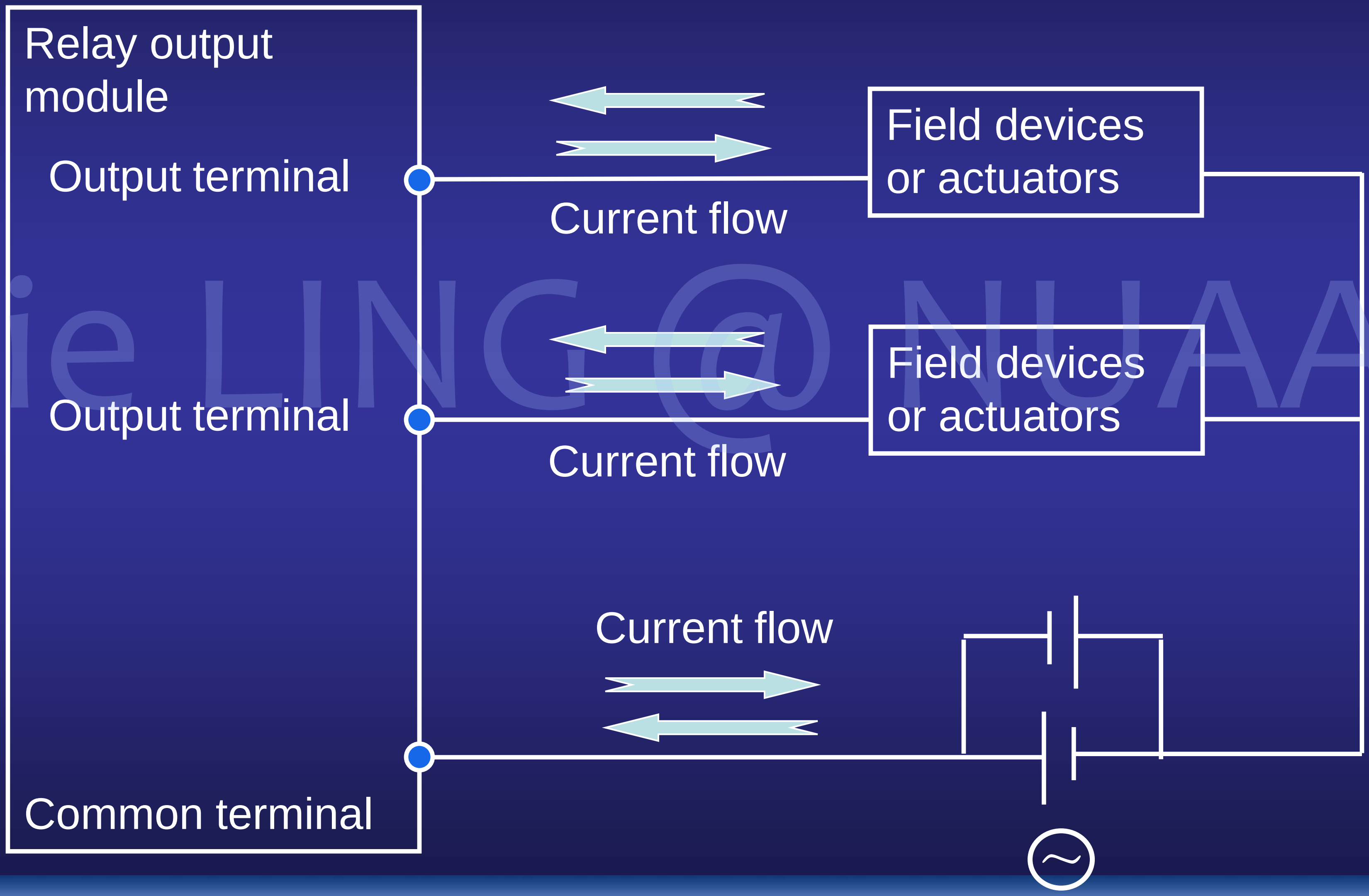
1.2 Architecture of PLC

✓**DC output module (current sourcing)**



1.2 Architecture of PLC

✓Relay output module



1.2 Architecture of PLC

✓Discrete I/O Addressing(CP1)

Method: Word address + bit address

Represented by 4 numbers, each word has 16 bits

Represented by 2 numbers, i.e. 00-15

e.g: address of a relay is 000**1.06**

Word address

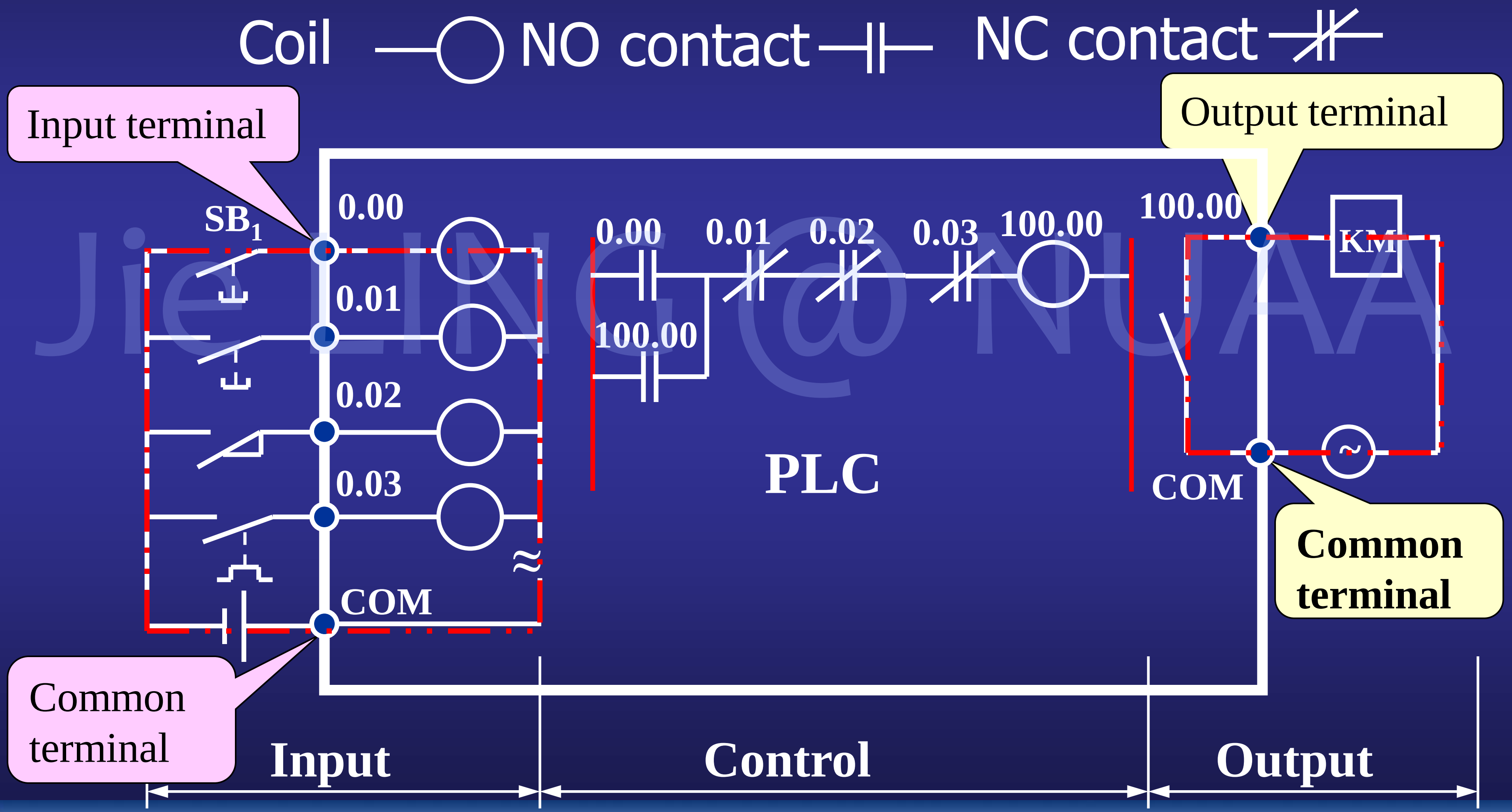
Bit address

1.2 Architecture of PLC

- Input relay (word 0~16)
  - 0、1 for CPU unit input
  - 2~16 for exp. module input
- Output relay (word 100~116)
  - 100、101 for CPU unit output
  - 102~116 for exp. Module output

1.2 Architecture of PLC

✓**PLC equivalent circuit**



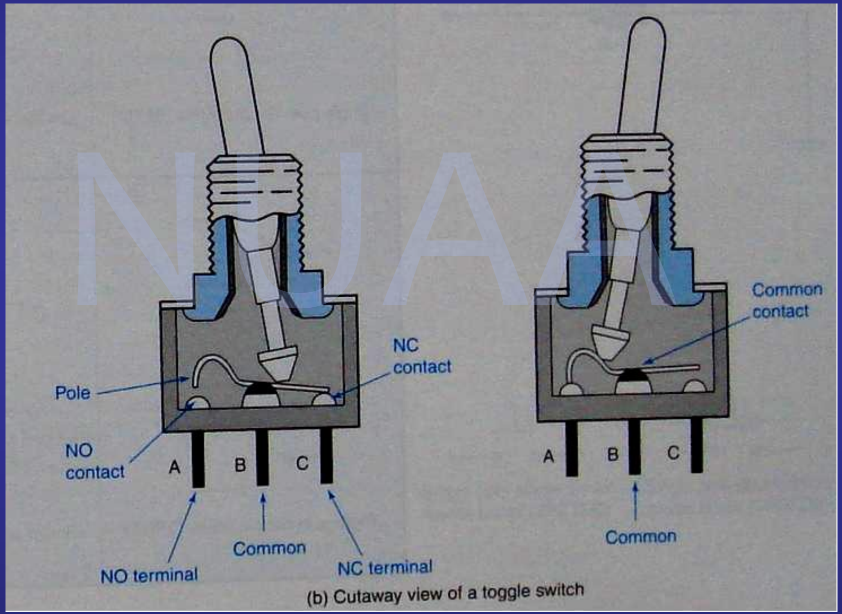
1.3 Input devices and output actuators

- Manually operated industrial switches
- Mechanically operated industrial switches
- Industrial sensors
- Interfacing input field devices
- Electromagnet output actuators
- Interfacing output field devices

1.3 Input devices and output actuators

1.3.1Manually operated industrial switches

✓Toggle switches



To prevent inadvertent switch activation, two-step operation sometime is used: Pull out the lever handle and move it to the desired position.

1.3 Input devices and output actuators

Source: Electrical Simulation@Youtube

✓Pushbutton switches

1.3 Input devices and output actuators

Source: Electrical Simulation@Youtube

✓Selector switches

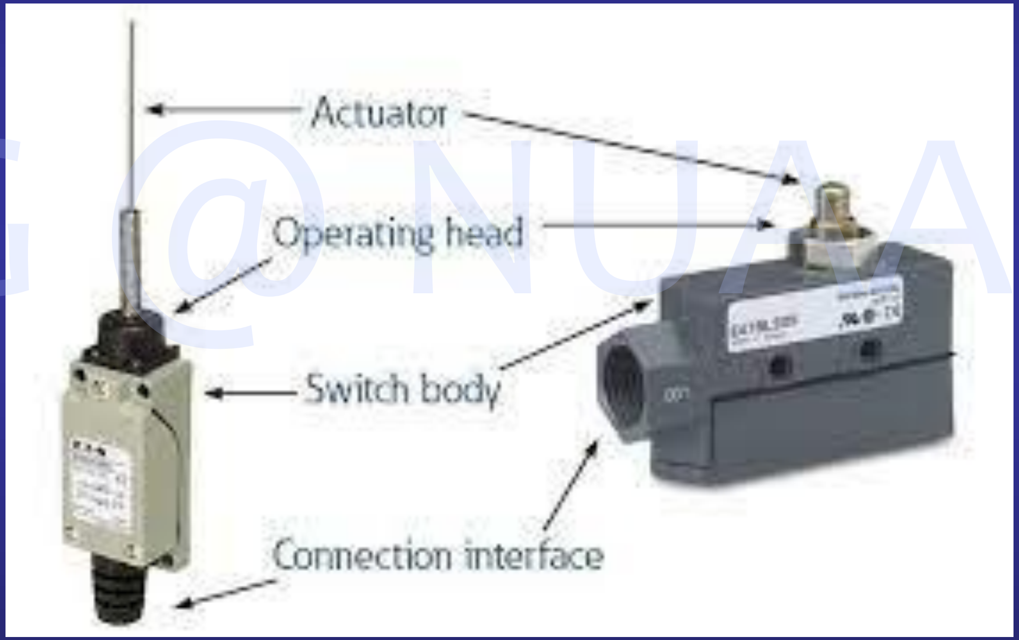
1.3 Input devices and output actuators

1.3.2 Mechanically operated industrial switches

Automatically opened or closed by a process parameter such as position, pressure or temperature.

1.3 Input devices and output actuators

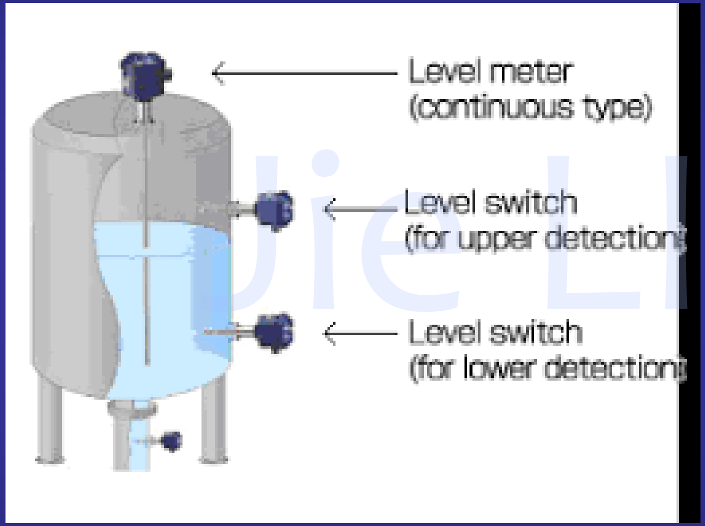
✓Limit switches



1.3 Input devices and output actuators

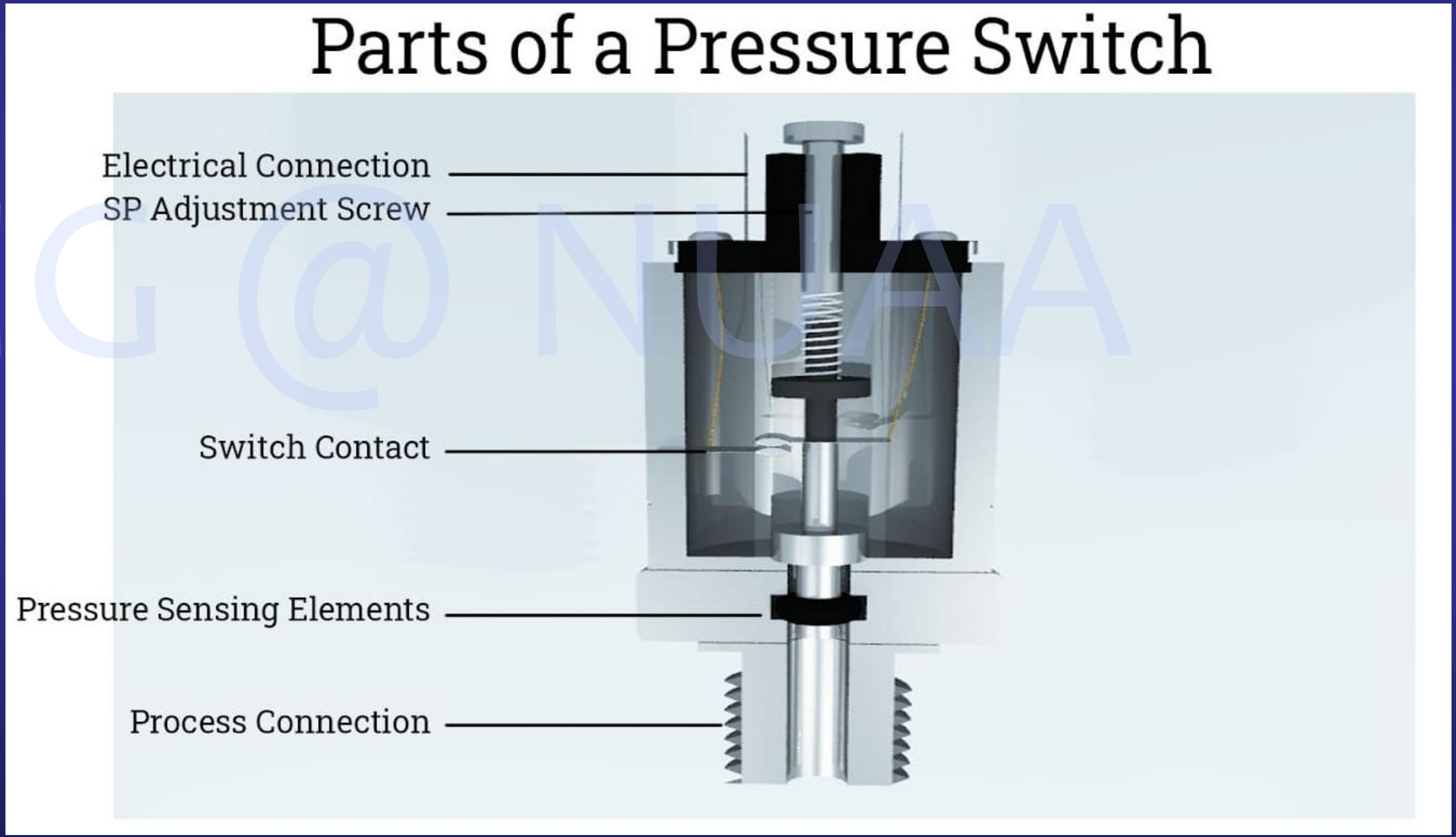
✓Level switches

Source: Tech Learning@Youtube



1.3 Input devices and output actuators

✓Pressure switches

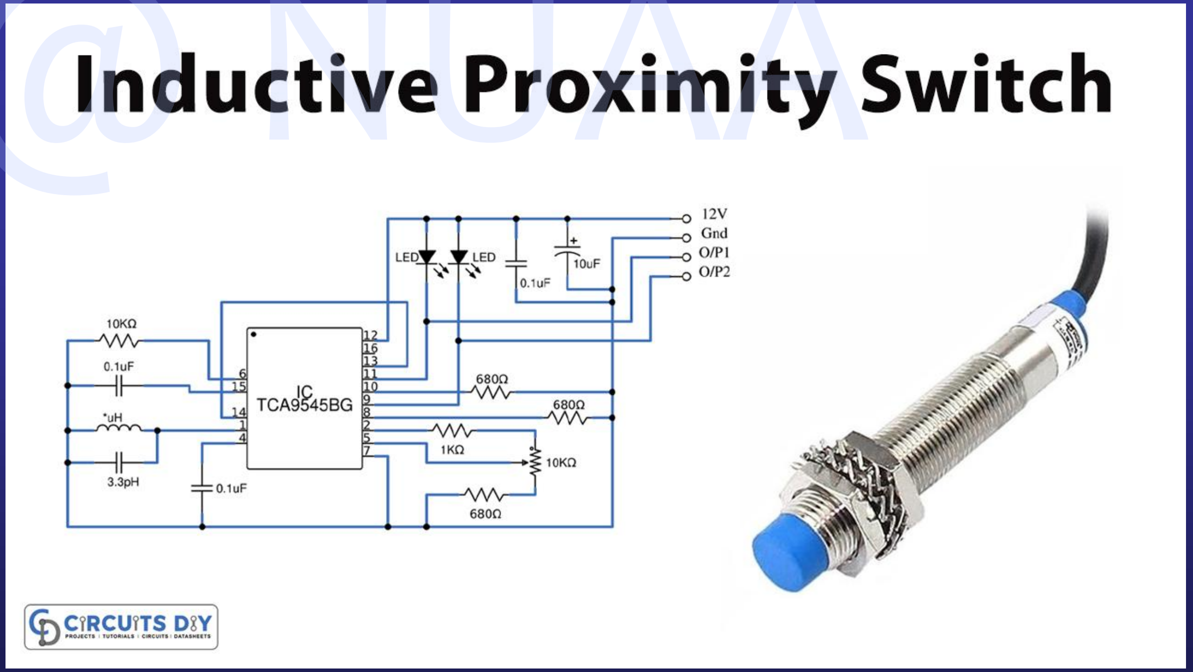


1.3 Input devices and output actuators

13.3 Industrial sensors

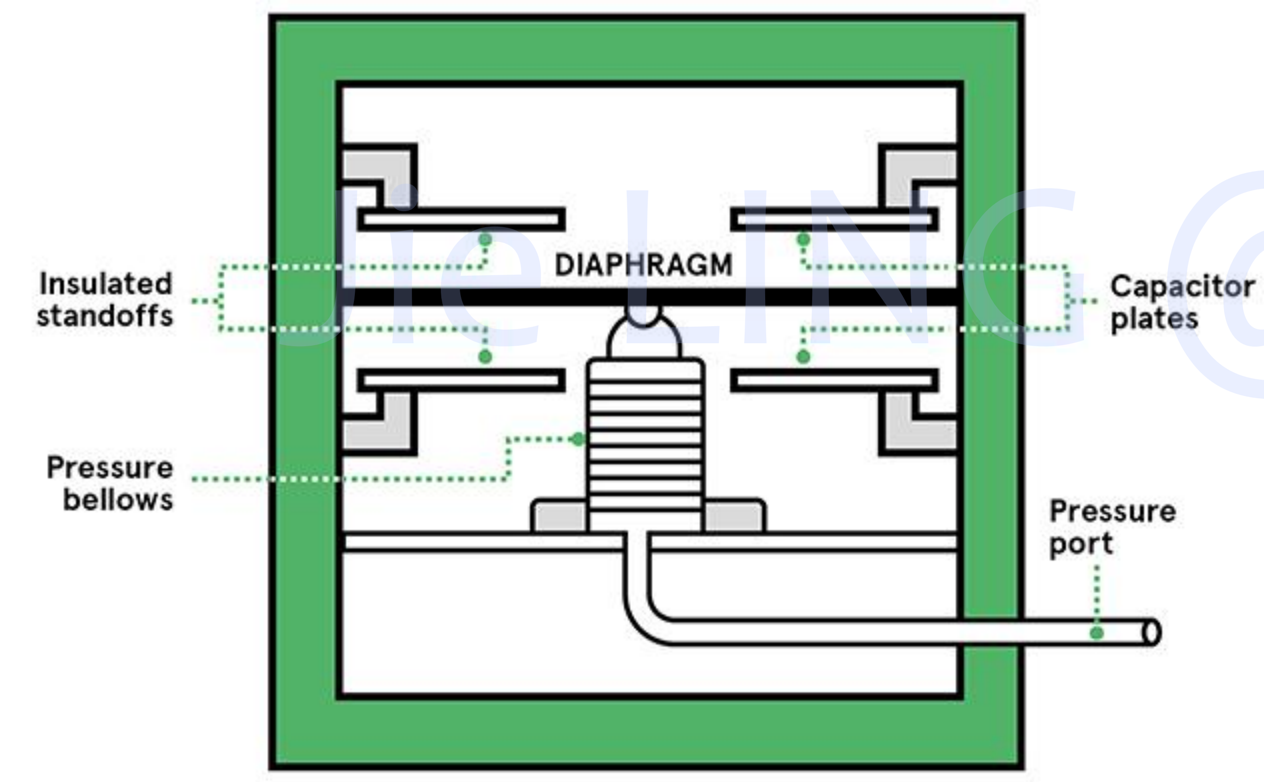
- ➢Proximity sensors
  - ✓Inductive sensors

The part must be conductive



1.3 Input devices and output actuators

✓Capacitive sensors



- Capacitive sensors sense both metallic and nonmetallic objects.
- Target acts as the second plate of capacitor. As an approaching target interacts with the electrostatic field created by the sensor, the capacitance is change.

1.3 Input devices and output actuators

➢Photoelectric sensors

✓Function: Provide detection of objects without physical contact.

✓Two main components: light source and receiver to detect the presence of light source

•light source: typically a light emitting diode (LED)

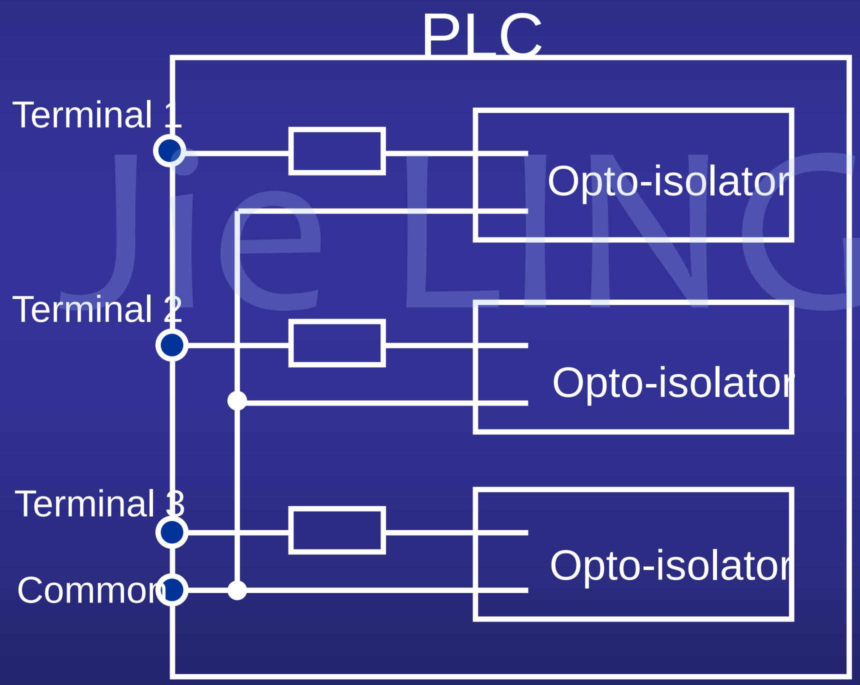
•Light detector: produce a change in current directly proportional to the amount of light falling on the detector. Photodiodes or phototransistors.

•Output device: signals a PLC that a change has occurred.

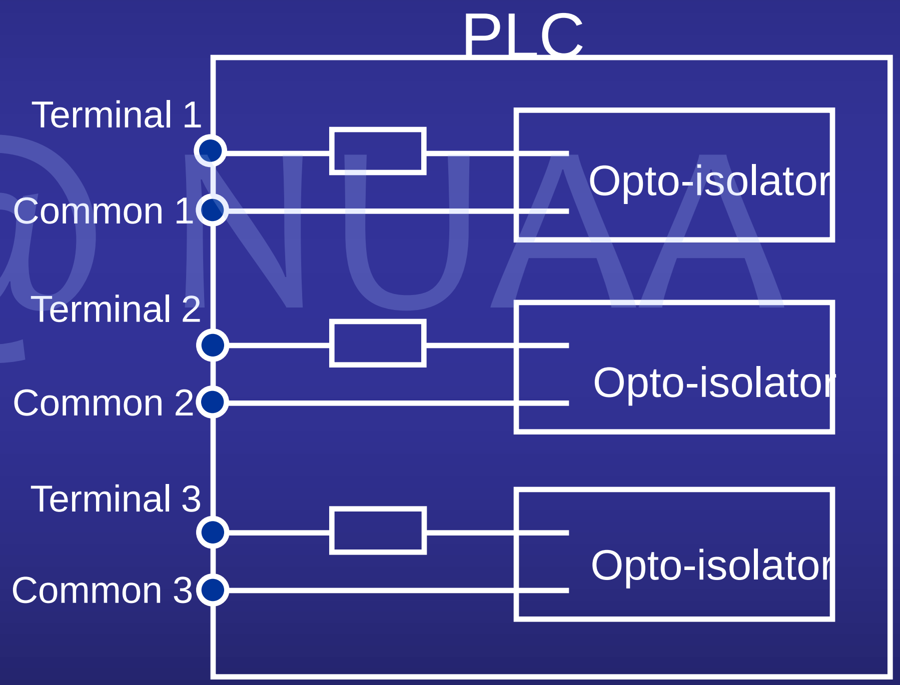
1.3 Input devices and output actuators

1.3.4 Interfacing input field device

✓Input wiring



PLC inputs with one common terminal

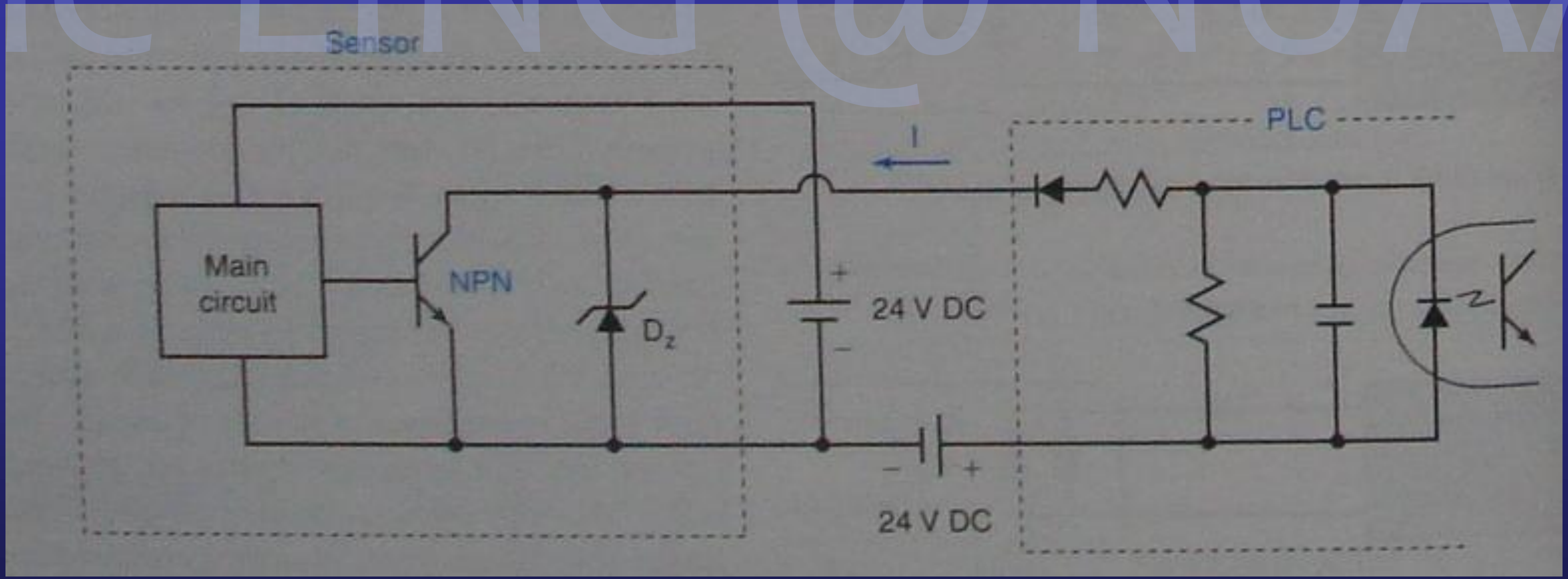


PLC inputs with individual common terminals

1.3 Input devices and output actuators

✓Current sinking and sourcing devices

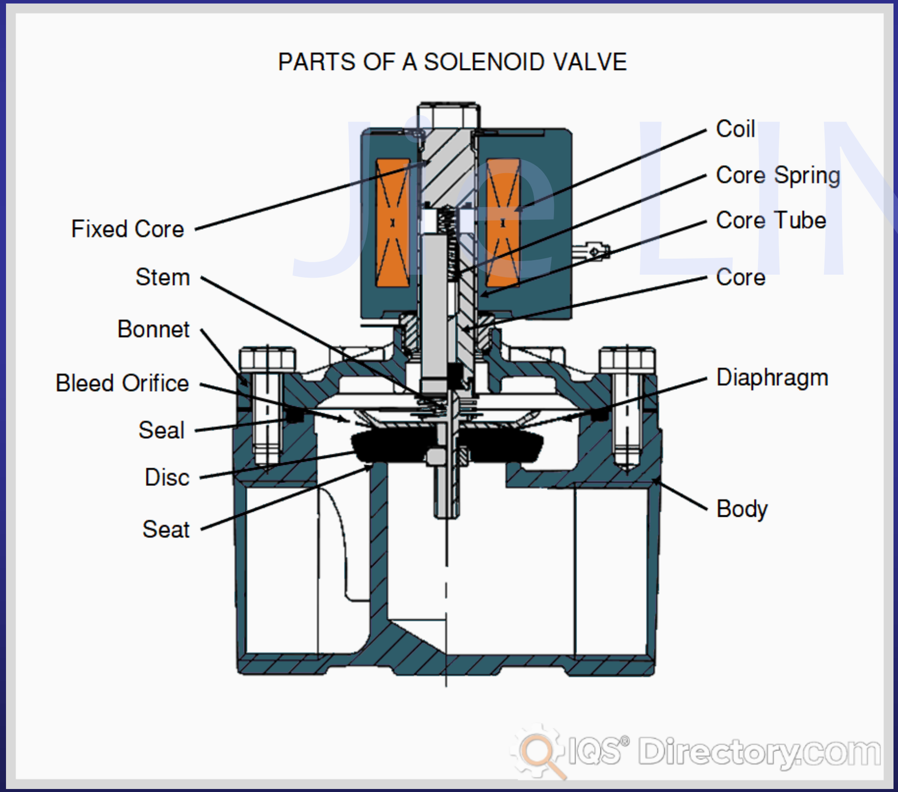
- Current sinking sensors must be matched to current sourcing PLC inputs
- Current sourcing sensors must be matched with current sinking PLC inputs



1.3.5 Output field devices

✓Solenoid controlled devices

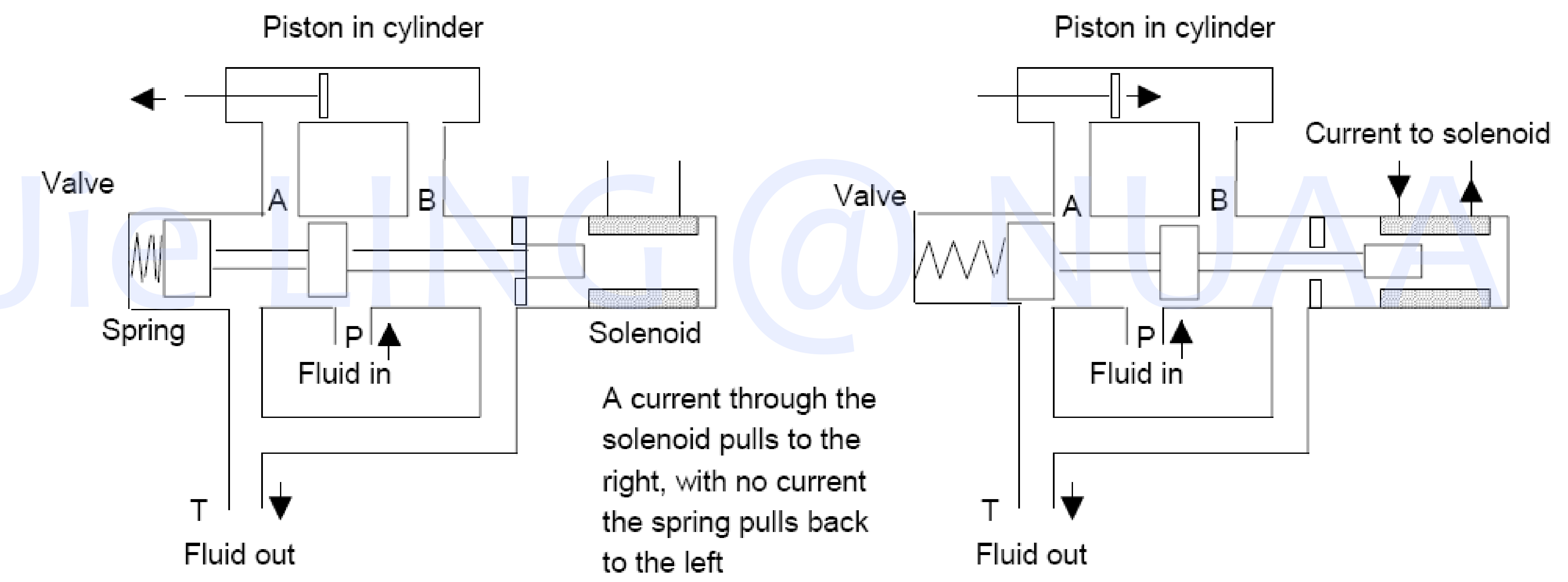
A very common solenoid-controlled device is the valve. A solenoid valve is an electromechanical device that is used to control the flow of air or fluids such as water, oil or refrigerant.



Source: The Engineering Mindset@Youtube

1.3 Input devices and output actuators

An example of a solenoid operated valve



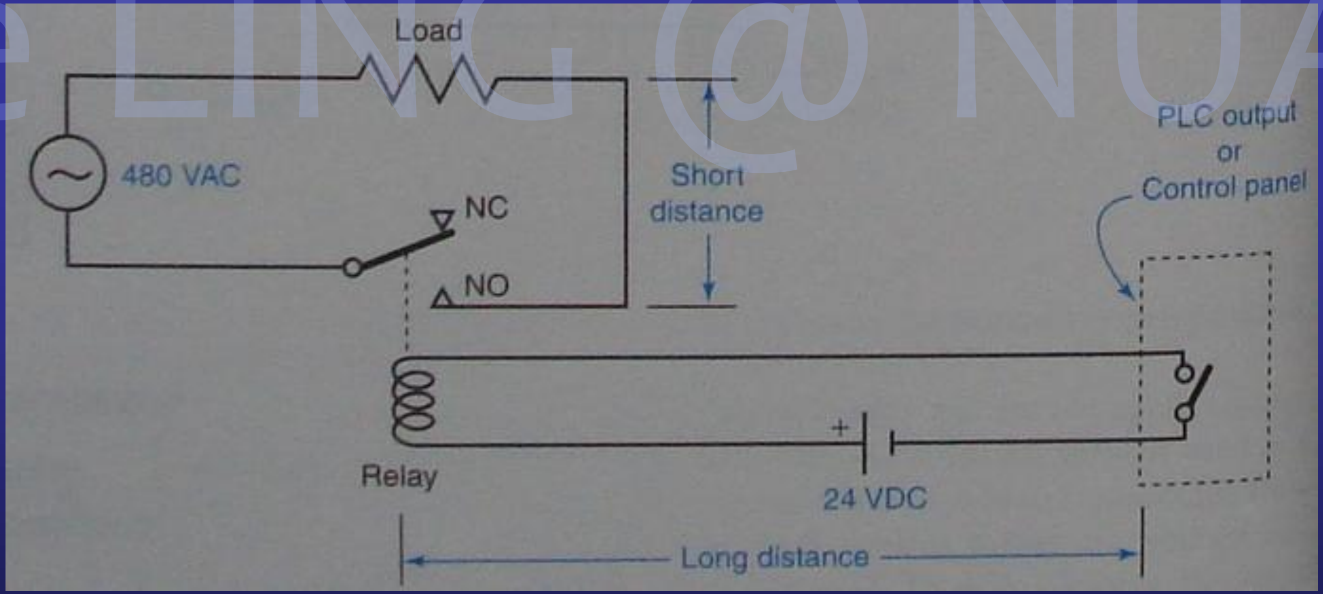
(a) Position with no current

(b) Position with current

1.3 Input devices and output actuators

✓Control relays

Two functions: control of a large current and/or voltage with a small electrical signal; isolation of the power used to control the action from the power that must be switched to cause some action.



1.3.6 Interfacing output field devices

✓Powering output field device

- Typically, the power for output devices is not supplied by the PLC but provided separately.
- Device specifications detail the power requirements for the field devices.
- The user must ensure that the current requirements of the devices are compatible with the PLC output capability.

1.3 Input devices and output actuators

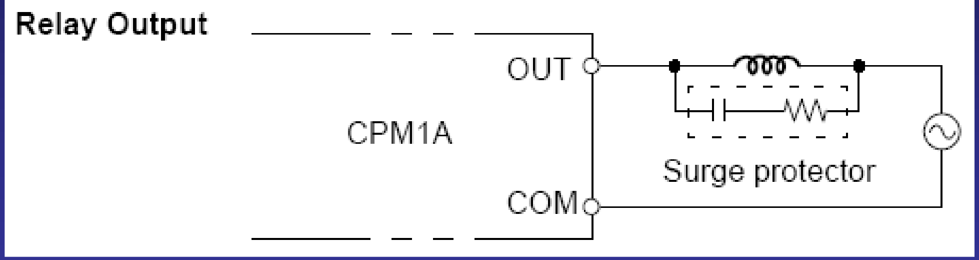
✓Output wiring

Share a common terminal or totally isolated.

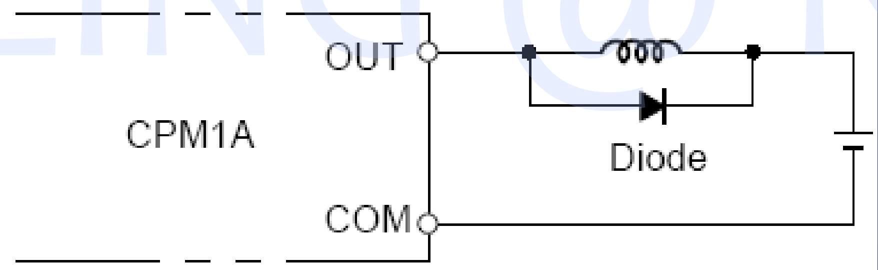
1.3 Input devices and output actuators

✓Suppression of Inductive Loads(CPM1A)

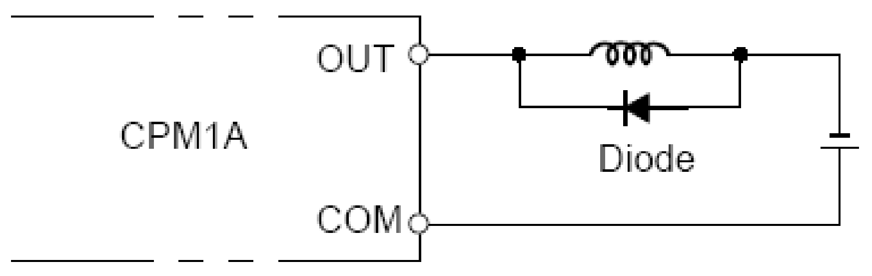
- Relay output



- Transistor output (sink type)



- Transistor output (source type)



1.4 Language of PLC

1.4.1 Types of languages used in PLCs

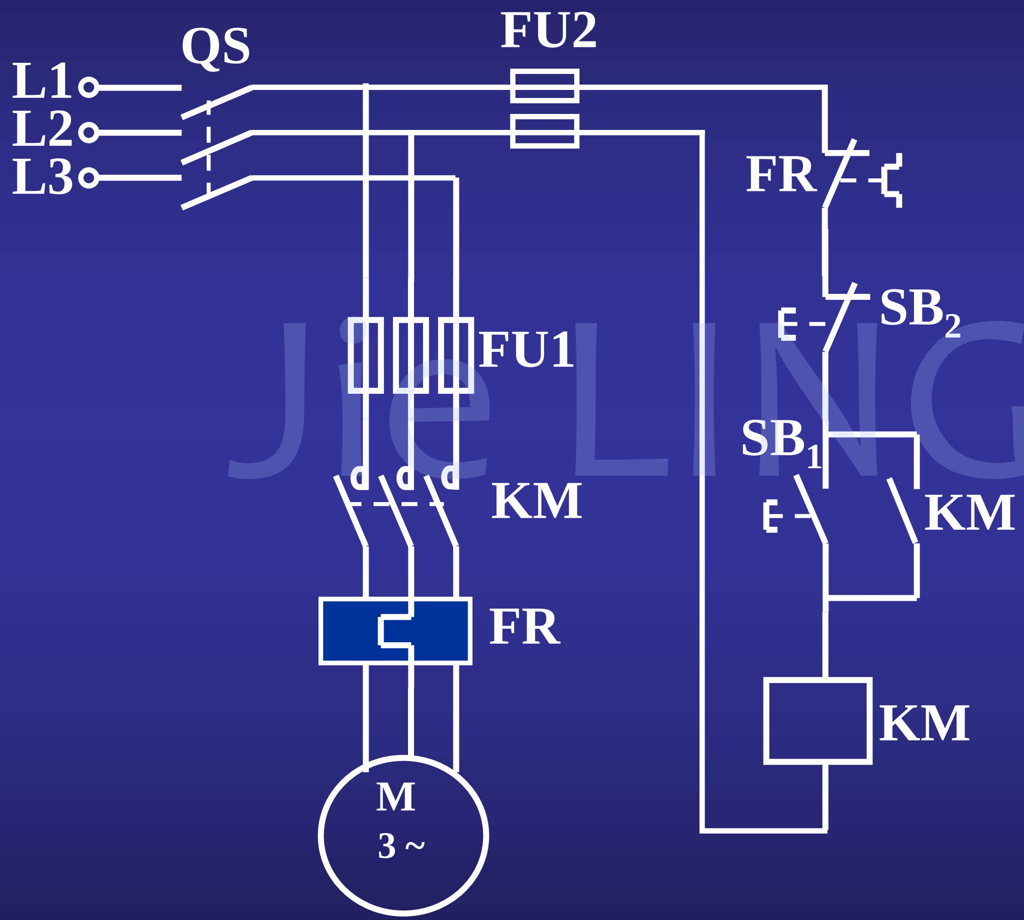
- Ladder diagram

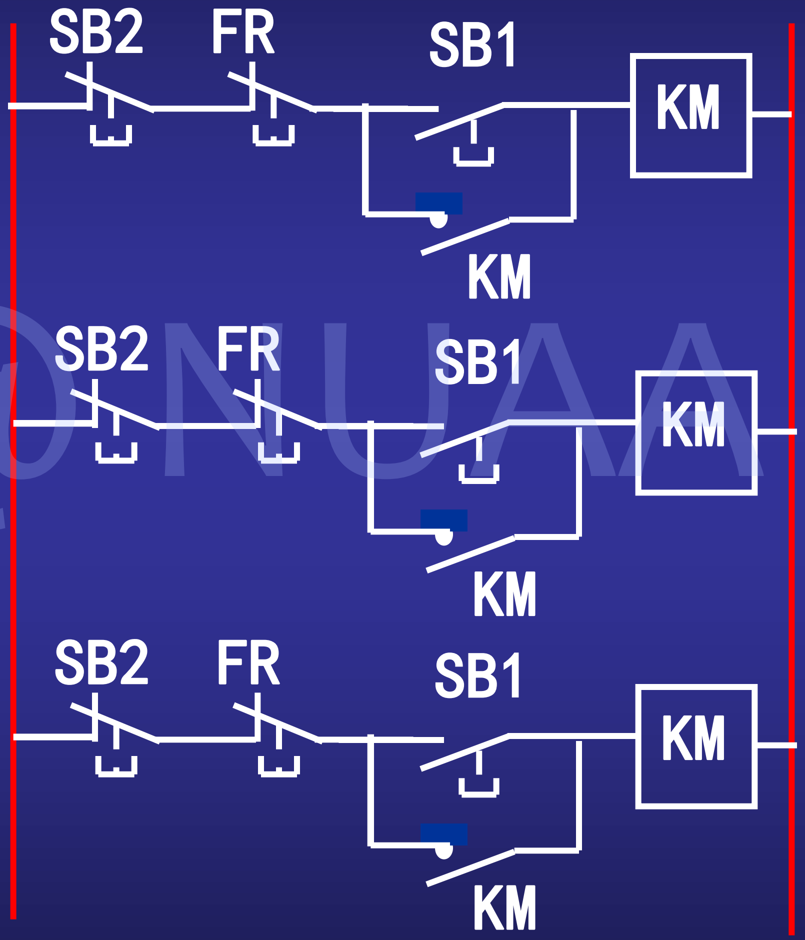
  Commonly used method of programming PLCs based on the use of ladder diagrams. Come from ladder diagram of relay logic control

- Mnemonic instruction

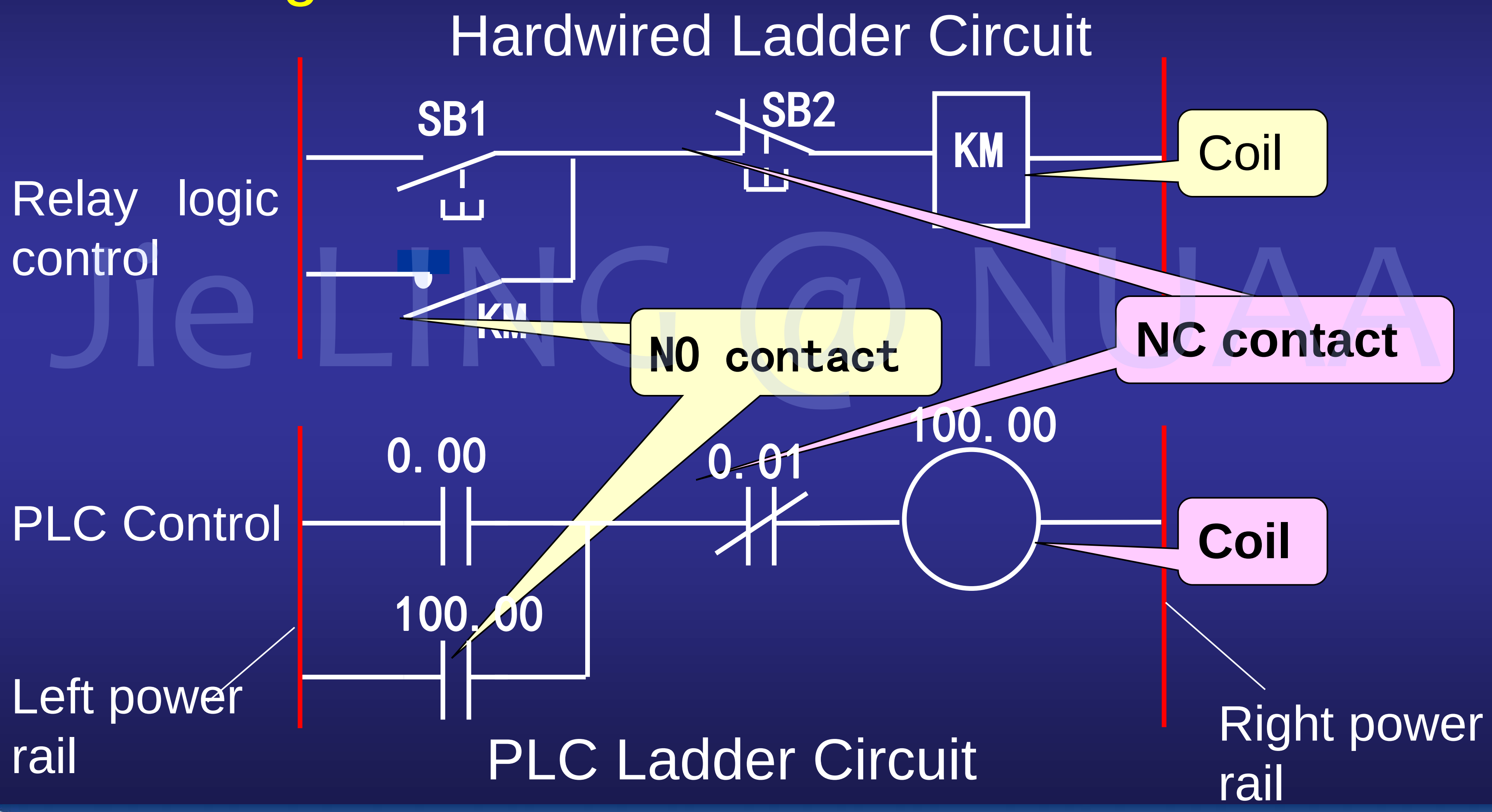
  These instructions can be derived directly from the ladder logic diagrams and entered into the PLC through a simple programming terminal.. mnemonic program is equivalent to the ladder diagram

1.4 Language of PLC





1.4.2 Ladder diagram

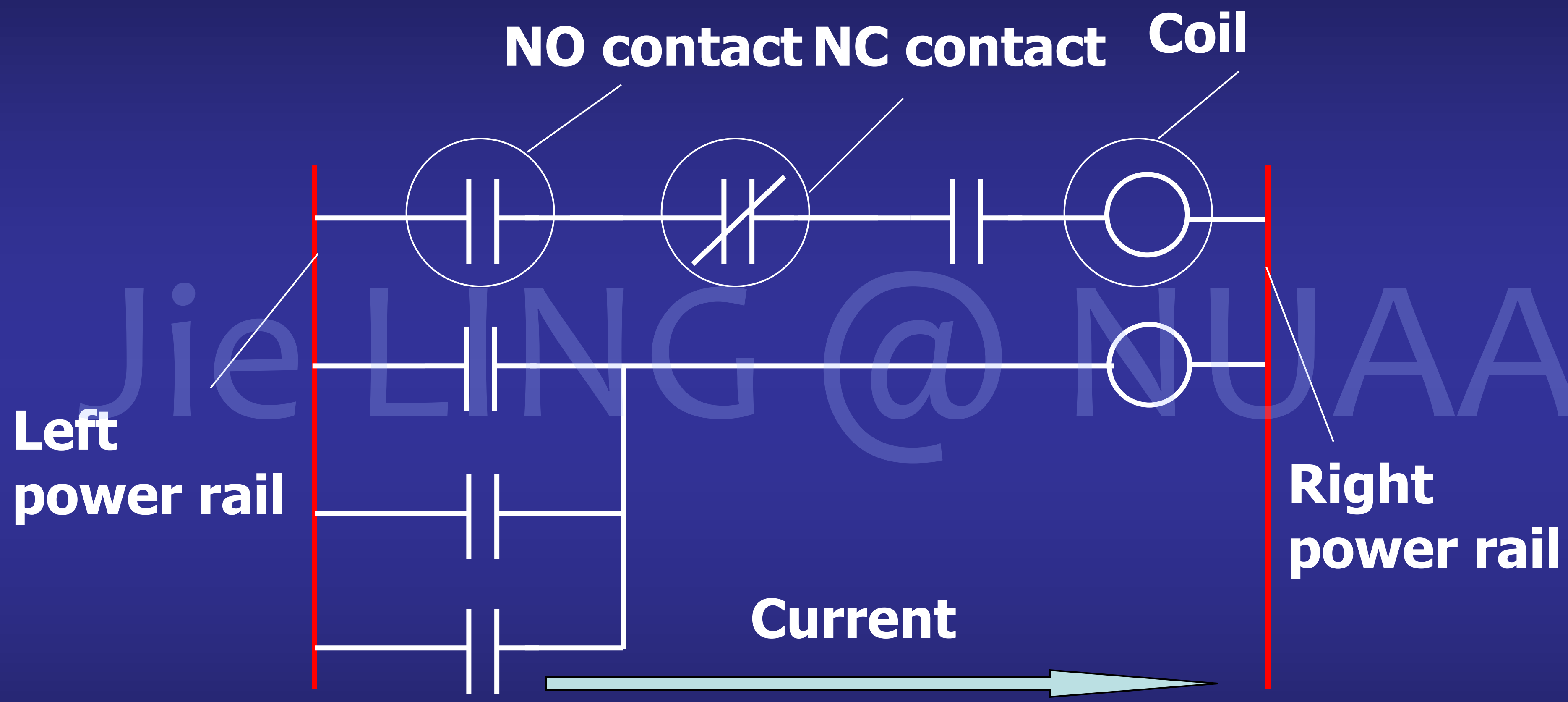


1.4 Language of PLC

An important concept—— Relay

- ✓Derived from “Relay” in the relay logic control
- ✓Relay is not physical and corresponding to one bit in data table area
- ✓Relay has its coil, NO contacts and NC contacts
- ✓No limit in the use of contacts of relay in Ladder diagram
- ✓For input relay, only contacts but coil can appear in ladder diagram

1.4 Language of PLC

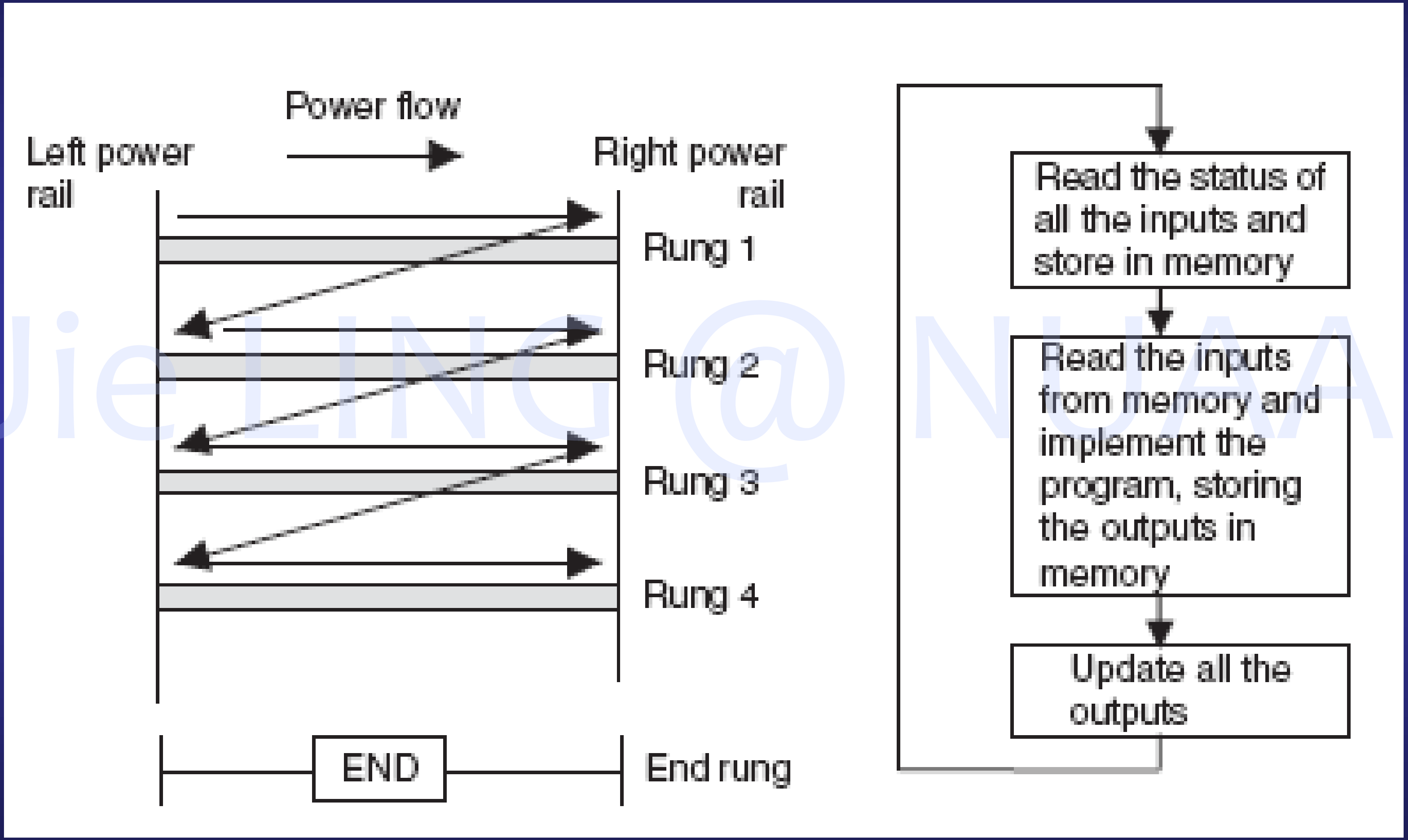


1.4 Language of PLC

➢Features of ladder diagram

- ✓Relay is not physical and corresponding to one bit in data table area.
- ✓Relay has its coil, NO contacts and NC contacts
- ✓No limit in the use of contacts of relay；
- ✓For input relay, Only contacts but coil can appear in ladder diagram.
- ✓No physical current in diagram, but imaginary current
- ✓From top to bottom, and from left to right;
- ✓cyclic program execution

1.4 Language of PLC



1.4 Language of PLC

✓When executing, the state of contact of input relay is read from input datatable, not the field state.

✓The state of output relay is stored in output table, not send to the output terminal immediately, but at the time of I/O updating.

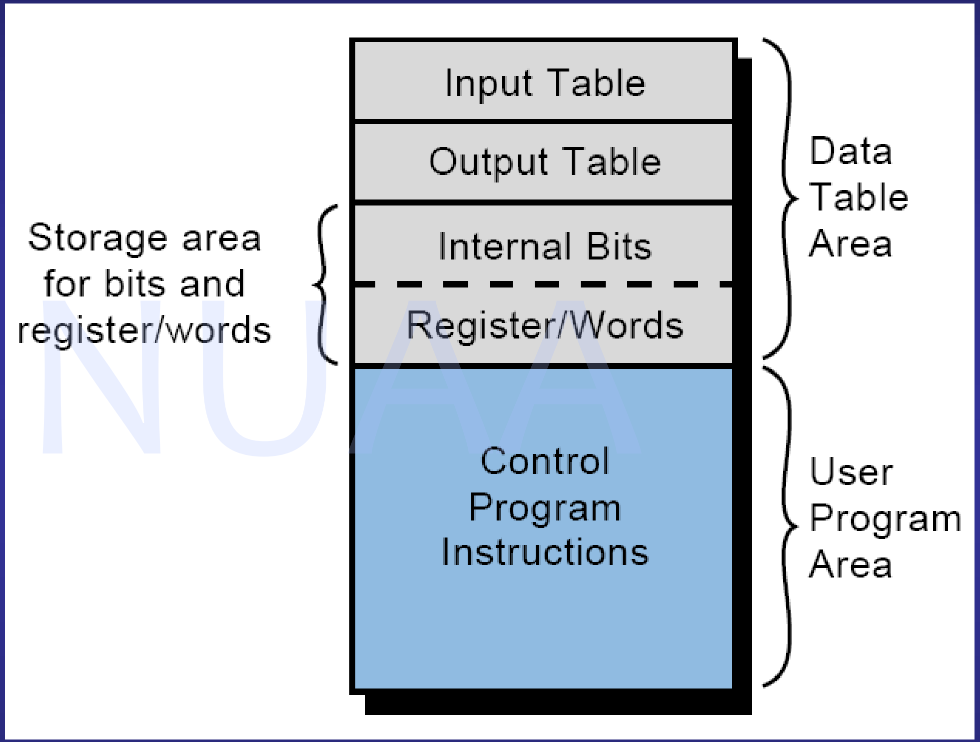
✓Each rung must start with an input or inputs and must end with at least one output or function block.

✓The inputs and outputs are all identified by their addresses.

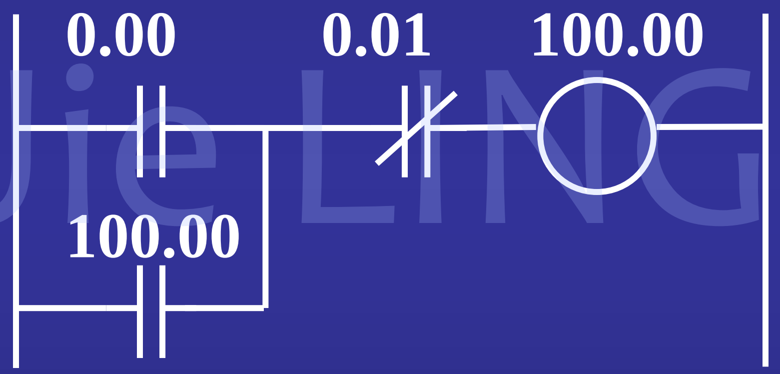
1.4 Language of PLC

➢PLC relay

- ✓Input/output relay
- ✓Internal relay
- ✓Special relay (SR)
- ✓Timer/counter (TIM/CNT)
- ✓Holding relay (HR)
- ✓Temporary Relay (TR)
- ✓Auxiliary Relay (AR)



1.4.3 Mnemonic instruction



LD	0.00
OR	100.00
AND NOT	0.01
OUT	100.00

Ladder diagram

mnemonic program

1.5 Principle of operation

1.5.1 Operation of PLC: cyclic scan operation

- **Initialization**
- **Self test**
- **Program execution**

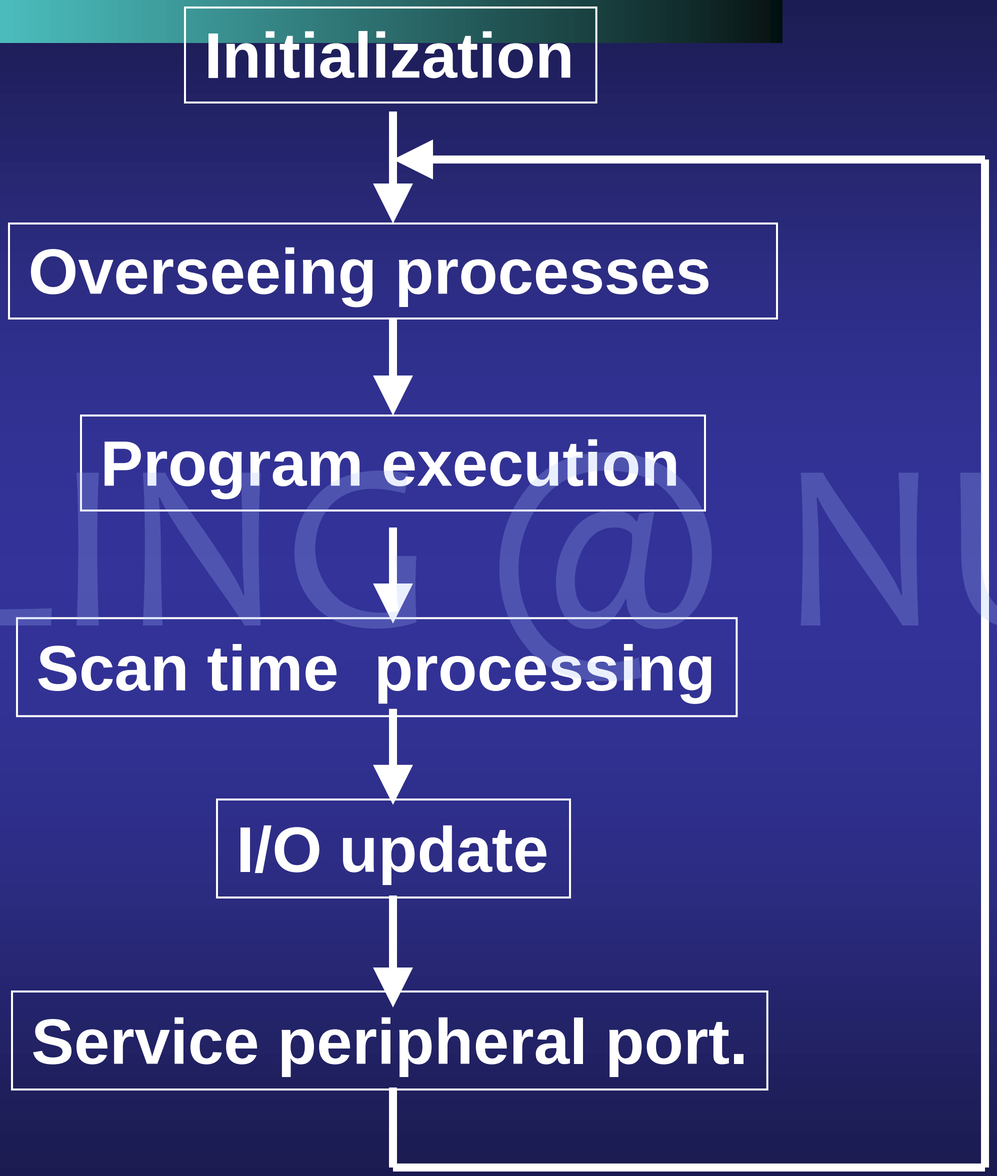
Input relay
Output relay
Other relay
} Logic operation → Output relay

- **Scan time computation**
- **I/O update**

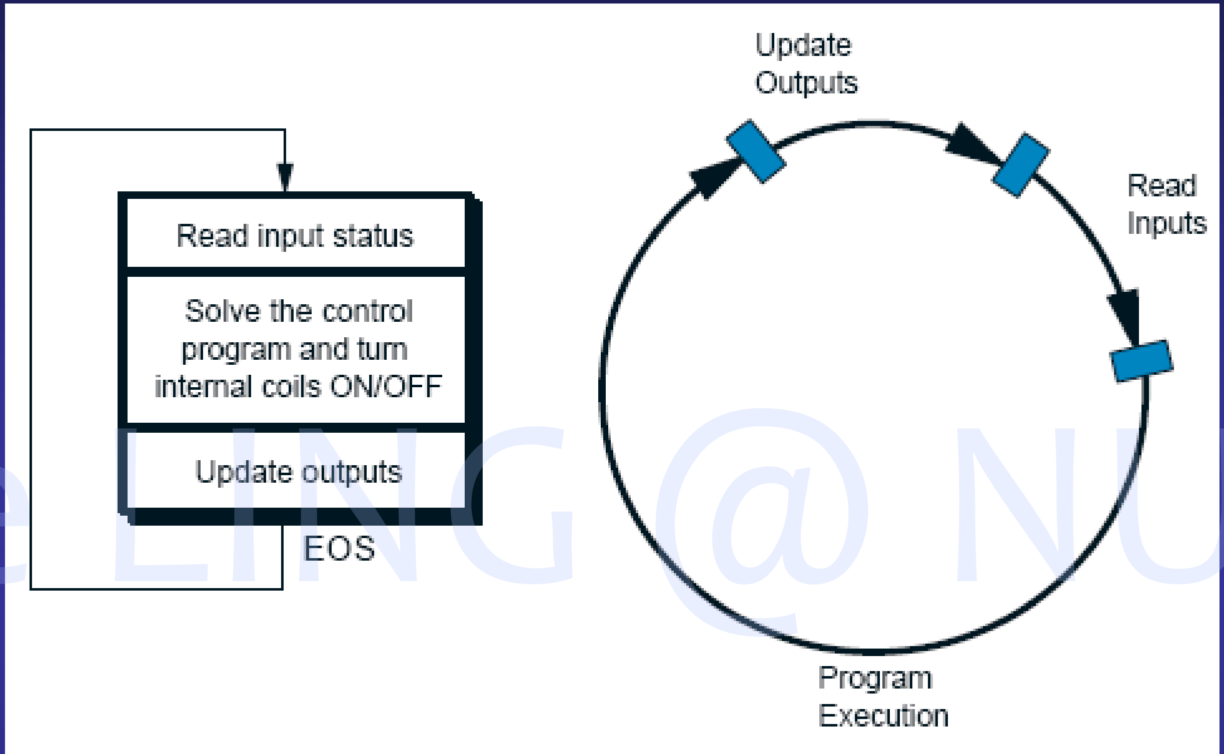
Input state → Input relay
Output relay → Output latch → activate load

- **External Communications**

1.5 Principle of operation



1.5 Principle of operation



✓Read the status of inputs and store in memory

✓Read the inputs from the memory and implement the program, storing the outputs in memory

✓Update all the outputs

1.5 Principle of operation

When the ladder logic is scanned it uses the values in memory, not the actual input or output values.

Advantage

- ✓This makes the PLC operation faster
- ✓avoids cases where an input changes from the start to the end of the program if a program uses an input value in multiple places

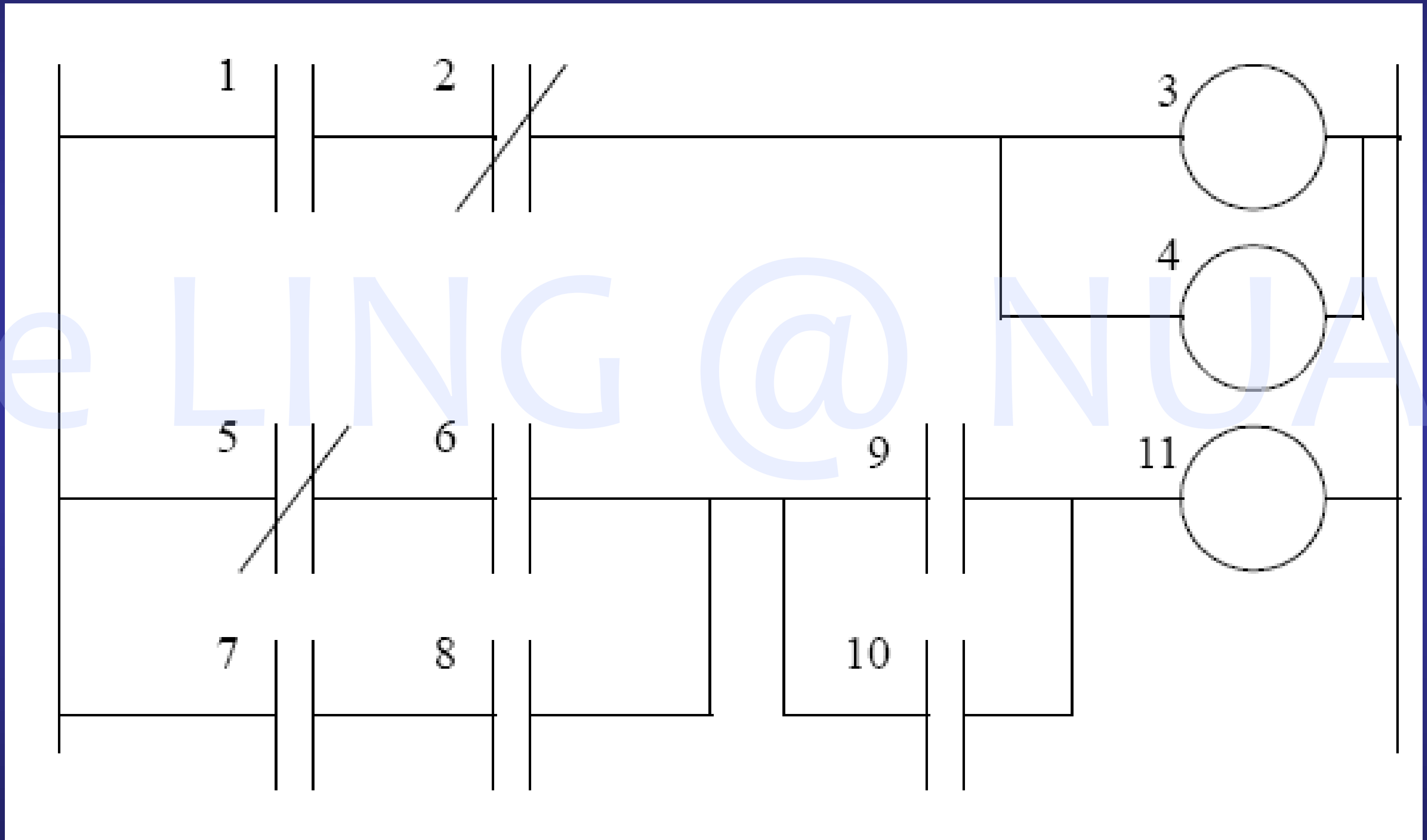
Disadvantage

- ✓Miss short signal

Solution: There are special PLC functions that read the inputs directly.

1.5 Principle of operation

Ladder Logic Execution Sequence

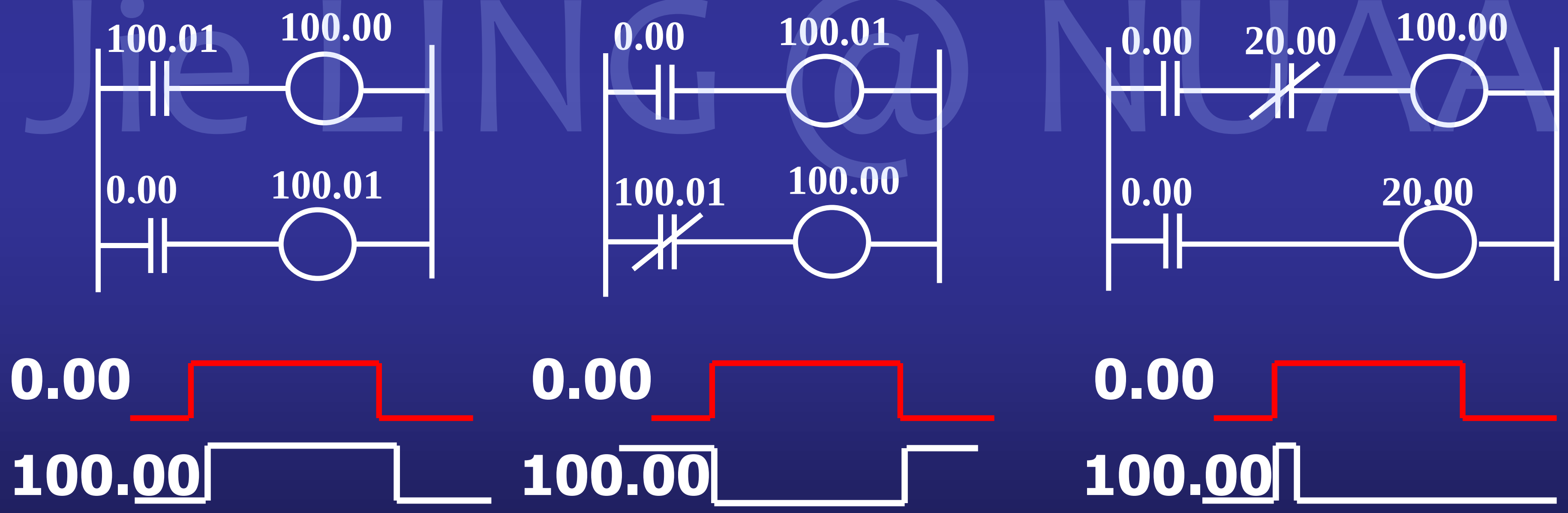


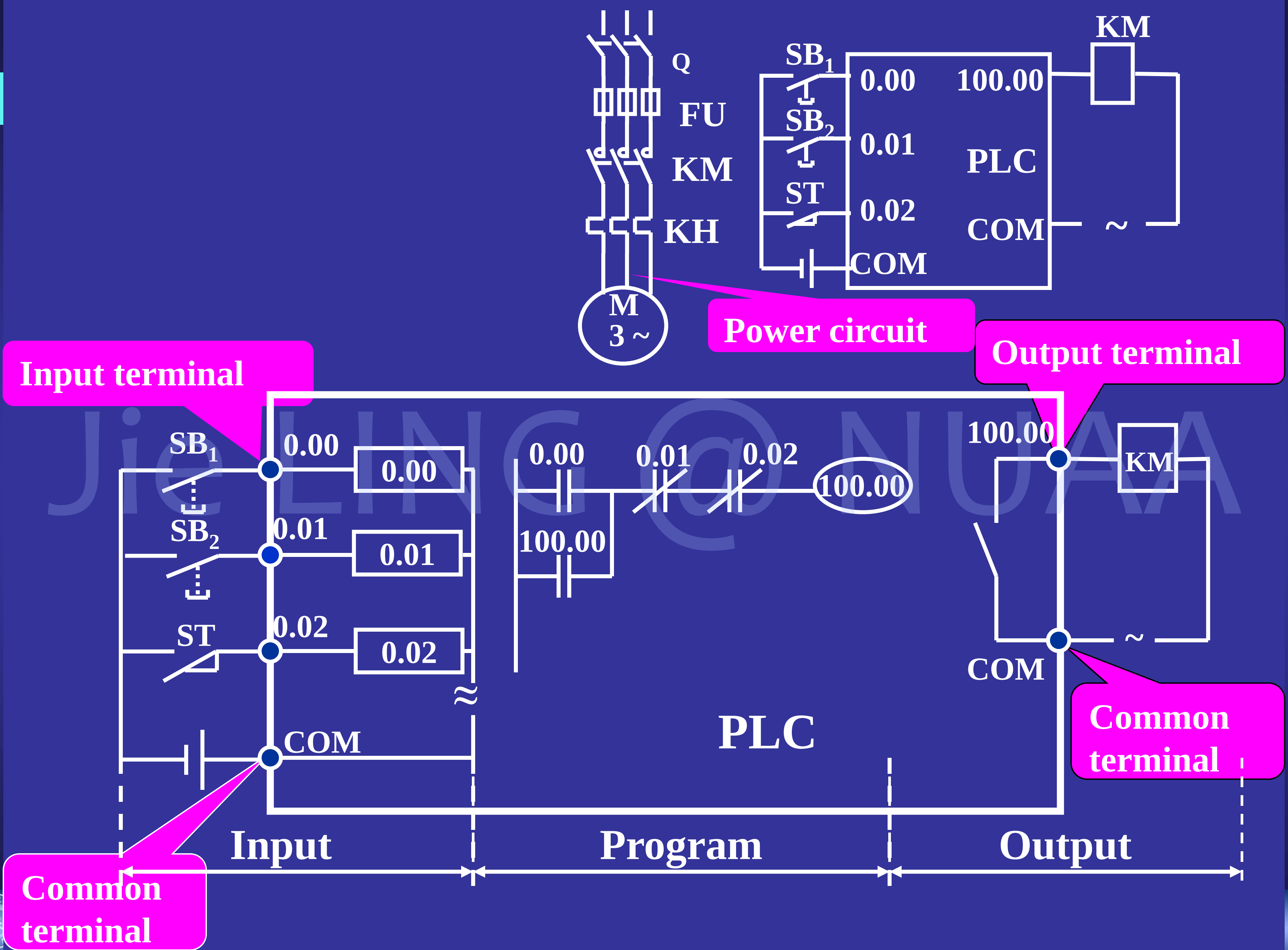
1.5 Principle of operation

0.00: input

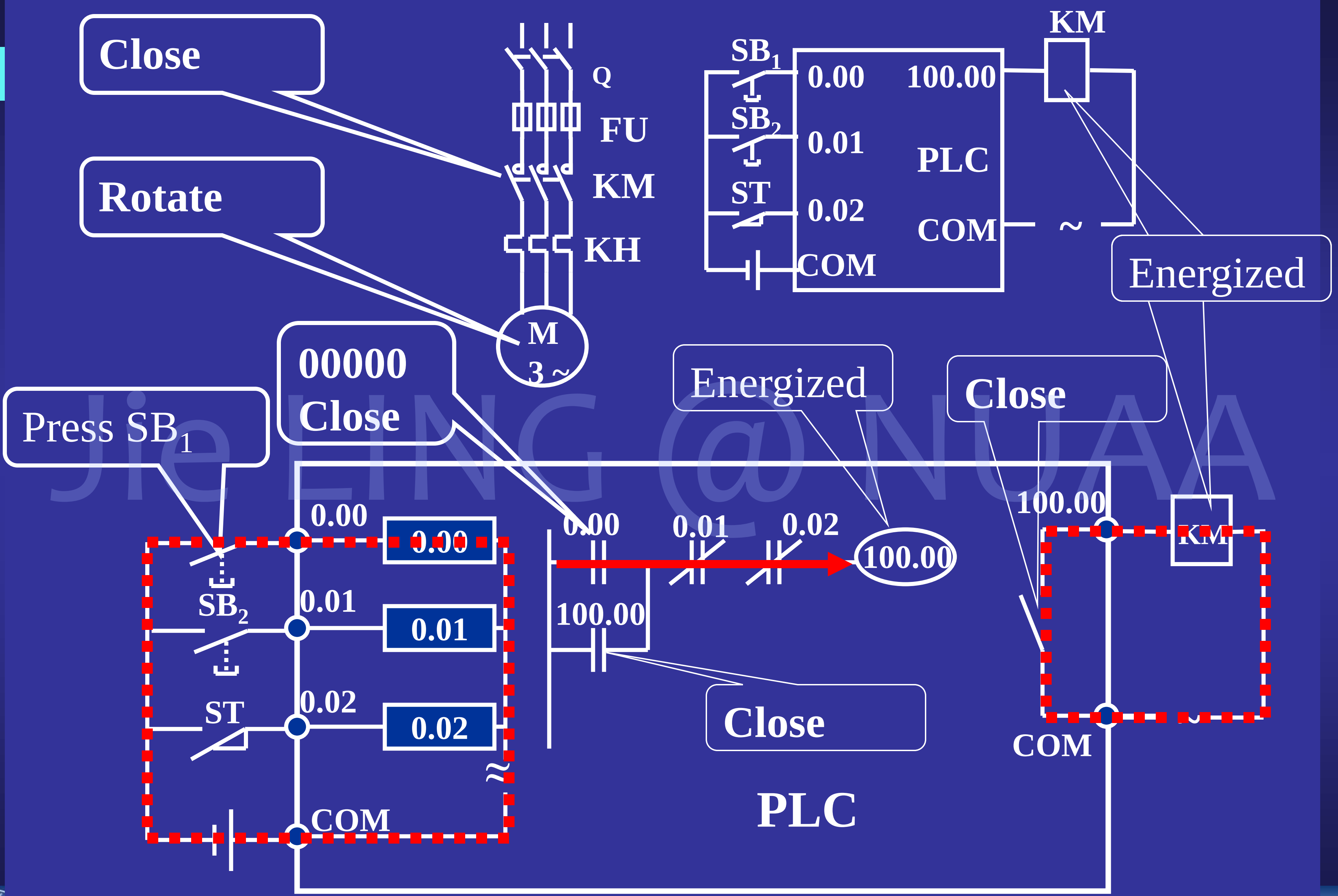
100.00, 100.01: output

20.00: auxiliary relay

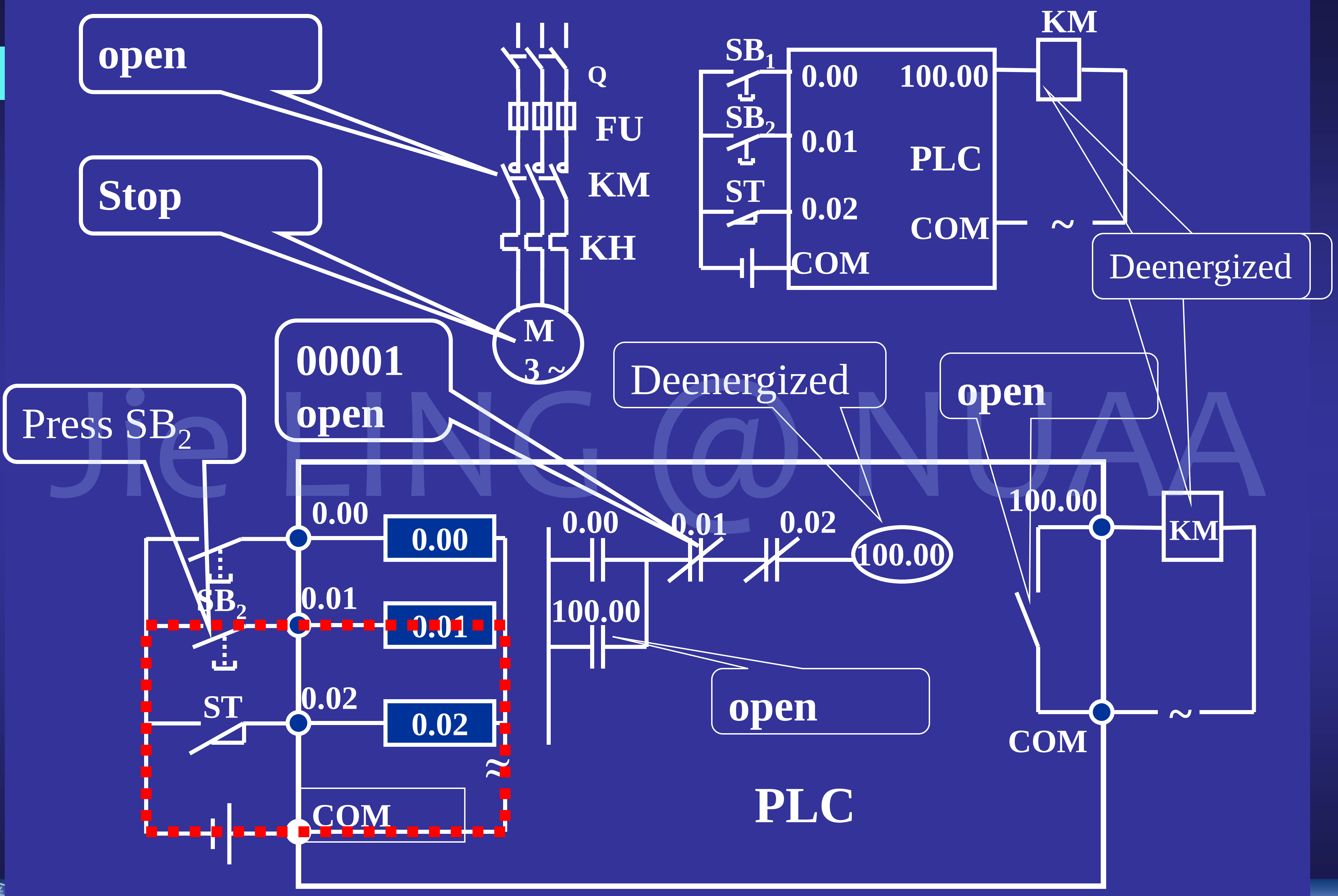




Q
FU
KM
KH
M
3 ~
SB1
SB2
ST
0.00
0.01
0.02
COM
100.00
PLC
COM
KM
~
Power circuit
Input terminal
Output terminal
SB1
SB2
ST
0.00
0.01
0.02
COM
0.00
0.01
0.02
0.00
0.01
0.02
100.00
100.00
100.00
KM
~
COM
PLC
Common terminal
Common terminal
Input
Program
Output



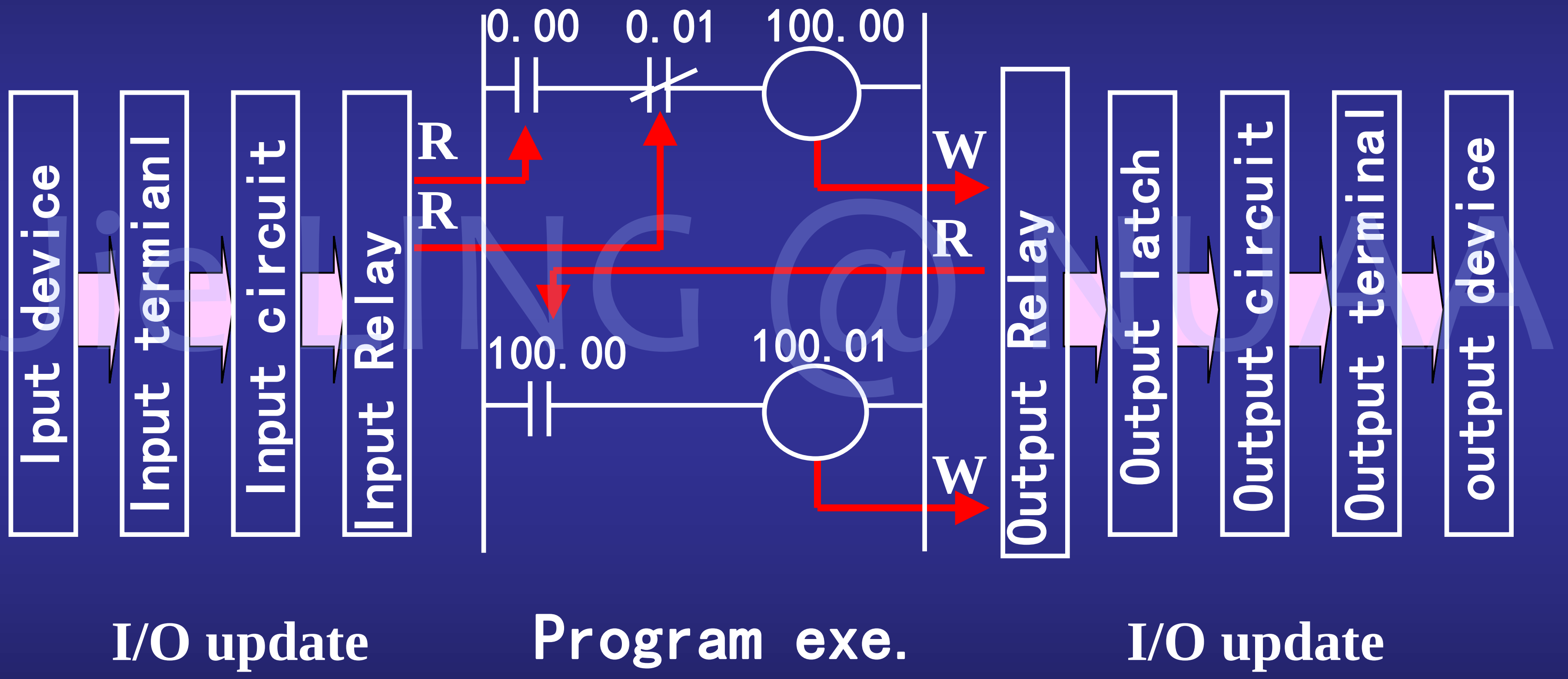
Close
Rotate
Q
FU
KM
KH
M
3 ~
SB1
SB2
ST
0.00
0.01
0.02
COM
100.00
PLC
COM
KM
~
Energized
00000
Close
Press SB1
Energized
Close
0.00
0.01
0.02
COM
0.00
0.01
0.02
0.00
0.01
0.02
100.00
100.00
Close
100.00
KM
COM
PLC



open
Stop
Q
FU
KM
KH
M
3 ~
SB1
SB2
ST
0.00
0.01
0.02
COM
100.00
PLC
COM
KM
~
Deenergized
00001
open
Press SB2
Deenergized
open
0.00
0.00
SB2
0.01
0.01
ST
0.02
0.02
COM
0.00
0.01
0.02
100.00
100.00
open
100.00
KM
COM
~
PLC

1.5 Principle of operation

1.5.2 Signal transmission of PLC



1.5 Principle of operation

➢ **State of Input and output**

✓The state of input relay depends on the state of input device in the last I/O update.

✓Result of program execution depends on the program, input/output relay, and other internal relay.

✓The state of output relay depends on the result of program execution.

✓Data in output latch depends on the state of output relay in last I/O update.

✓The state of output module depends on the output latch.

1.5 Principle of operation

1.5.3 Characteristics of program execution

- From top to bottom, from left to right
- Data in program execution are from：
  - ✓Input, output relay
  - ✓Internal relay
- State of input relay and output relay
  - ✓Input relay: remain unchanged in a scan cycle.
  - ✓Output relay, internal relay: can be read and written in a scan cycle.
- Read input and write output in I/O update
- Scan serially

1.5 Principle of operation

1.5.4 I/O delay

- Response time

——time from a input signal changing to its corresponding output signal changing.

- Scan time

  - ✓The time needed for one scan cycle
  - ✓Average value 1-100ms
  - ✓Depends on the length of user program, speed of CPU, and instructions used.

1.5 Principle of operation

➢Reasons for I/O delay

✓Cyclic scan operation mode of PLC

PLC only read input and write output in I/O update, and cause the lag.

✓RC filter

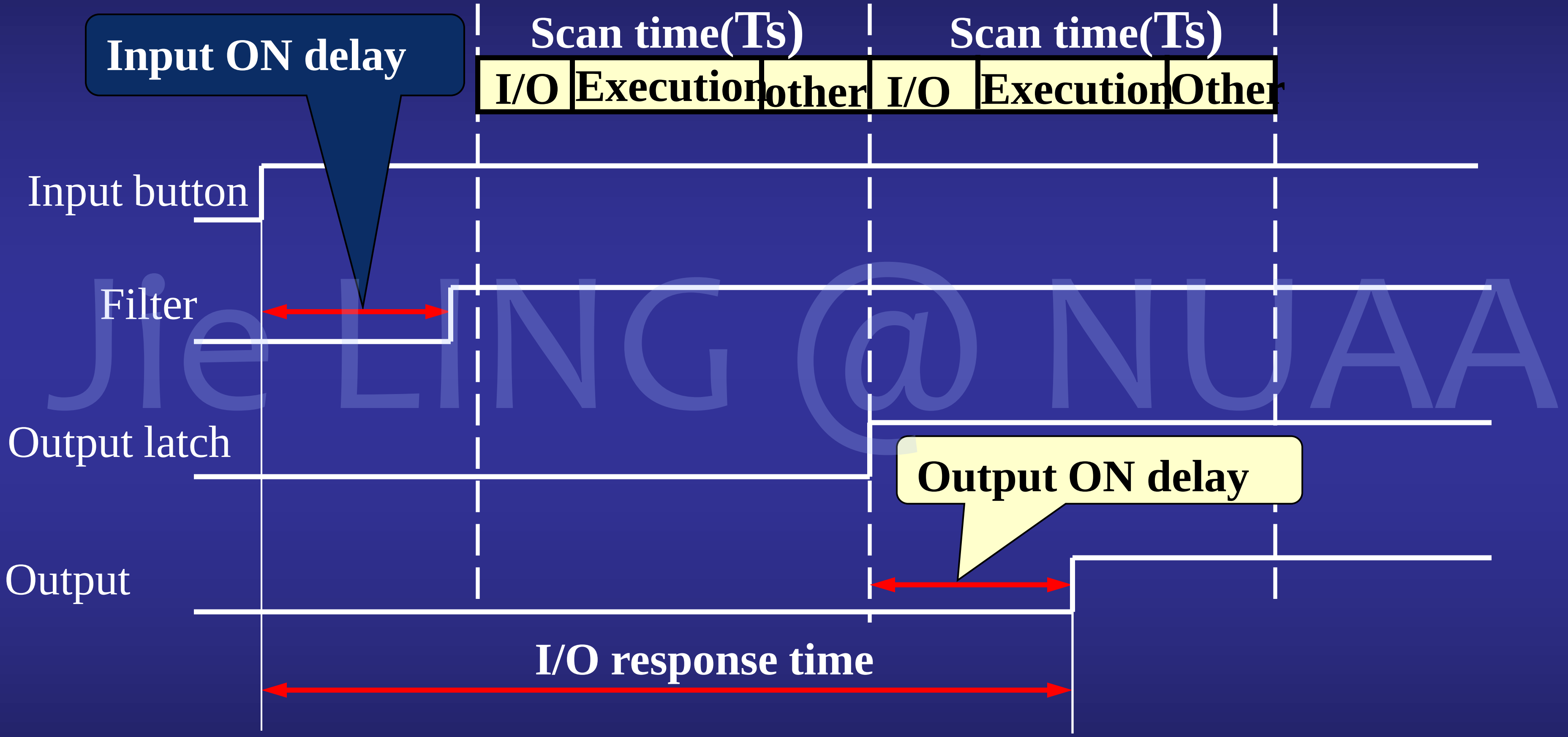
The larger RC constant, the large lag time

✓Relay output module

✓Length and arrangement of user program

1.5 Principle of operation

➢Minimum I/O response time

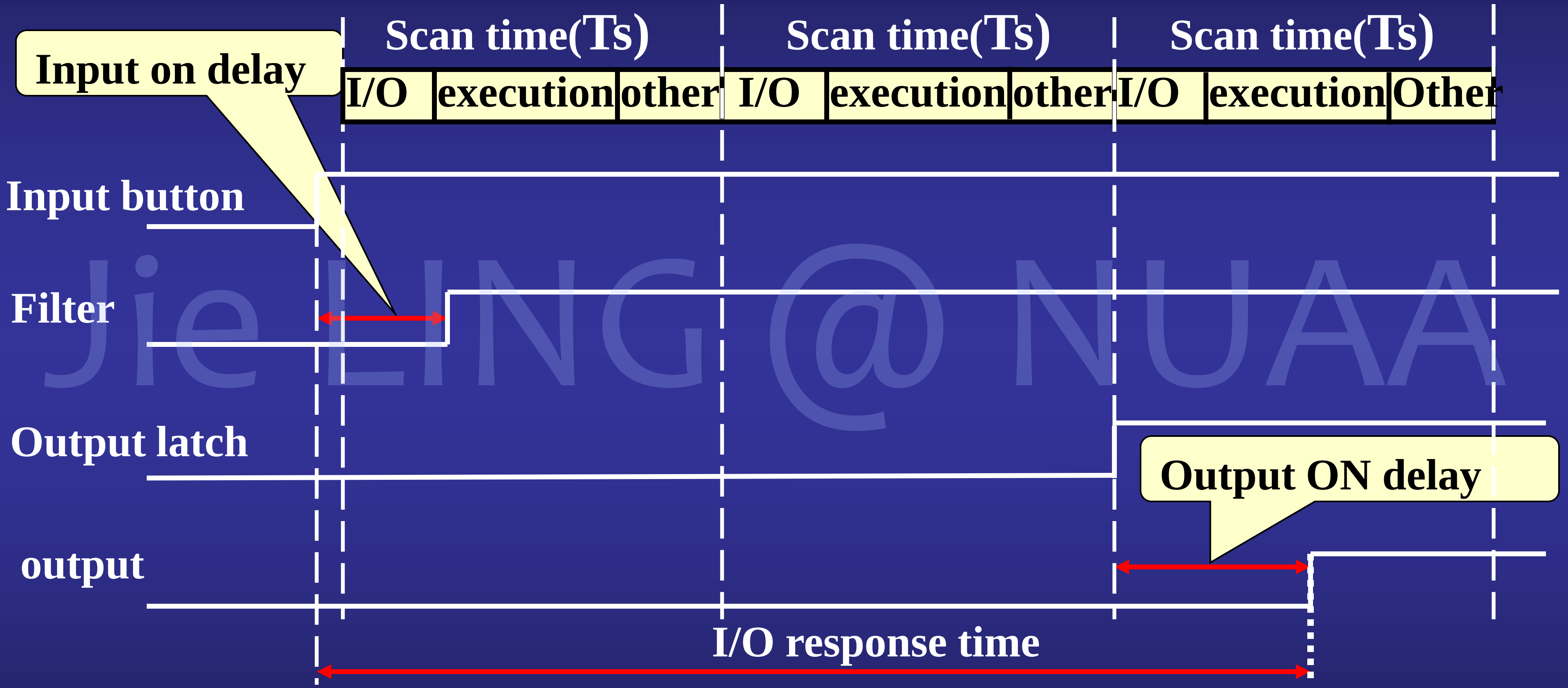


Minimum I/O response time

= input ON delay + scan time + output ON delay

1.5 Principle of operation

➢ **Maximum I/O response time**

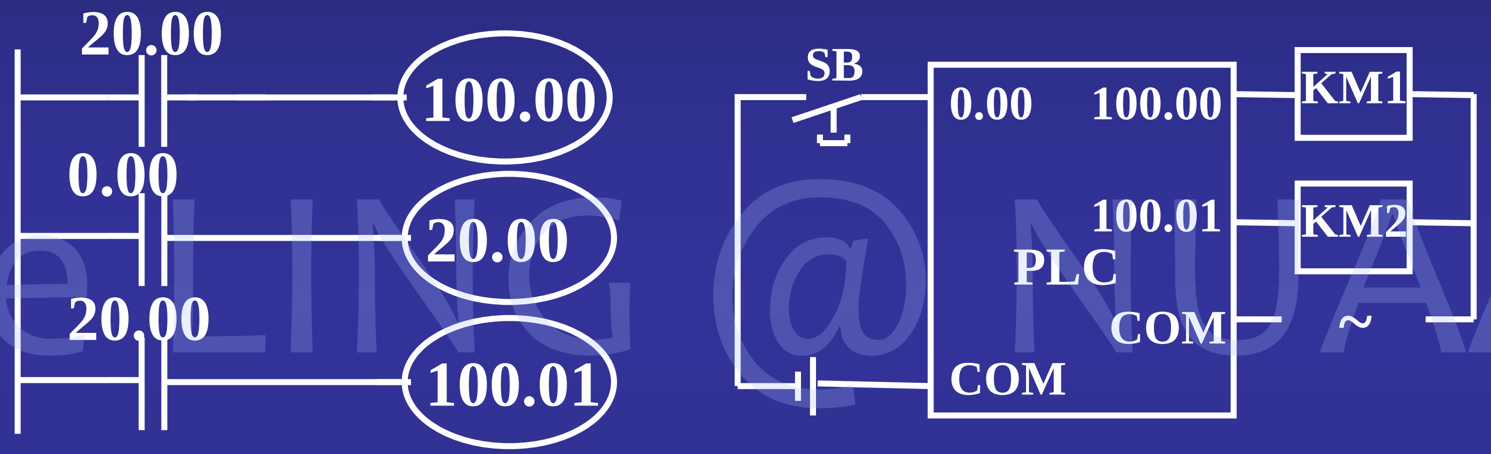


Maximum I/O response time

= input ON delay + scan time × 2 + output on delay

1.5 Principle of operation

The influence of arrangement of program on I/O response time

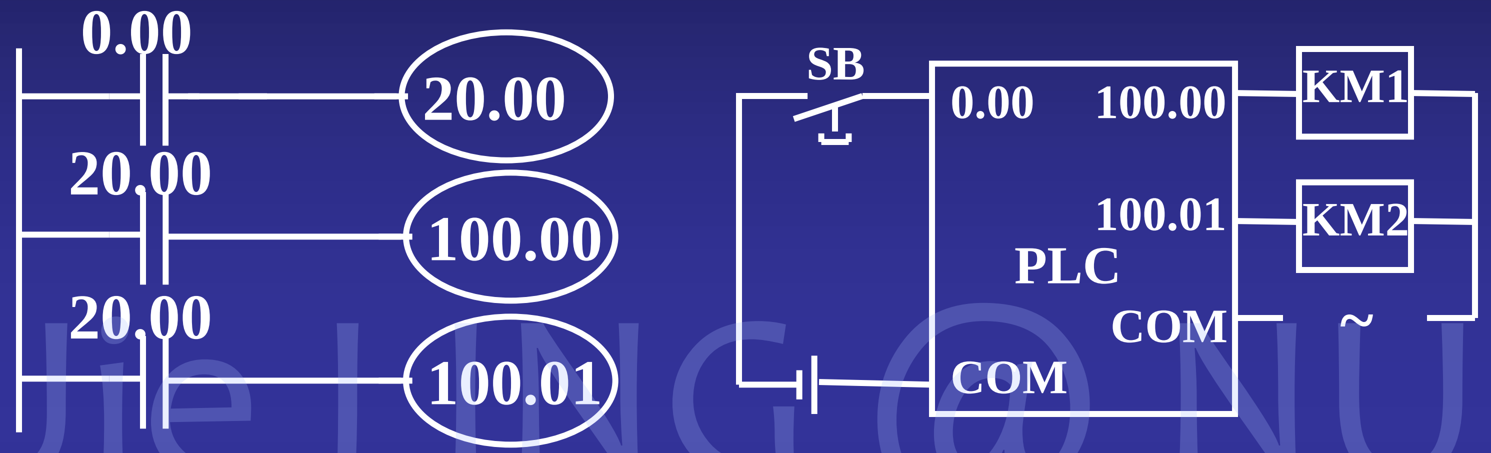


✓SB close， after I/O update 0.00 is ON

✓At the end of this scan cycle， 100.00 is OFF

✓100.00 is ON after next scan cycle

1.5 Principle of operation



SB closes, after I/O updates, 0.00 is ON

100.00, 100.01 are ON after the scan cycle.

1.6 Features and application

1.6.1 Features of PLC

- Reliable, high anti-interference capability
  - ✓No or few mechanical contacts
  - ✓Hardware measures (shielding, filter, opto-isolation, redundant etc);
  - ✓Software measures (supervisory program, watchdog timer, backup battery, scan operation)
- Flexible
  - ✓Program control, modularization, Serialization
- Easy use
- Compact, low consumption

1.6.2 Application of PLC

- Digital logic control

  Automatic product line, puncher, molding machine, conveyer, packing machine etc.

- Motion control

  Cutting machine, assembly robot, etc.

- Analog close-loop control

  Temperature, pressure, etc.

- Data processing

  Arithmetic operation, data transmitting etc.

- Communication, network and distributive control

1.7.1 History of PLC

✓Before 1960s, relay logic control based on electromechanical relays, timers, counters, and sequencers were the standard.

✓Many control panels contained hundreds of these devices and a mile or more of wires.

Disadvantages**:**

Reliability low, maintenance costs high

Inflexibility: cost high to modify or upgrade control panels.

Advantages **of computer system:** Flexible

1.7 Development of PLC

•In 1968 the GM Hydramatic division(the automatic transmission division of General Motors) specified a device that would become what we know today as the programmable logic controller to replace relay logic control.

✓In 1969， DEC developed the first PLC, model PDP-14
✓In 1971， Japan developed first PLC of Japan
✓1973， Western Europe first PLC.

1.7 Development of PLC

Some of the initial specifications included :

- The new control system had to be price competitive with the use of relay systems.
- The system had to be capable of sustaining an industrial environment.
- The input and output interfaces had to be easily replaceable.
- The controller had to be designed in modular form, so that subassemblies could be removed easily for replacement or repair.
- The control system needed the capability to pass data collection to a central system.
- The system had to be reusable.
- The method used to program the controller had to be simple, so that it could be easily understood by plant personnel.

1.7 Development of PLC

➢Early PLCs

- Only relay replacers
- Have no timers or counters
- No math instructions
- No data manipulation instructions

1.7 Development of PLC

- Present PLCs
  - ✓Logic control
  - ✓Motion control
  - ✓Close-loop control of analog signal
  - ✓Data processing
  - ✓Communication, industrial network and distributive control

1.7.2 Development of PLC

- First generation： From first PLC to the beginning of 70s

CPU: medium, small-scale IC, Memory: ferrite-core memory

- Second： from the beginning of 70s to the end of 70s

CPU: microprocessor, Memory: EPROM

- Third： from the end of 70s to the middle of 80s

CPU: 8, 16-bit or multi-microprocessor ,EPROM

- Fourth： from the middle of 80s to the middle of 90s

8, 16-bit slice microprcessor， up to 1us/step

- Fifth： from the middle of 90s to now

16, 32-bit microprocessor, EEPROM or flash

1.7 Development of PLC

1.7.3 Main manufacturer of PLC

USA： GE：SERIES、GE…；

TI：TI、PM；

Rockwell: Allen-Bradley ；

Japan： Mitsubishi：F、FX、A、K…；

OMRON : CPM1A, CP1…

Germany： Siemens：SIMATIC S5, S7…

France： Schneider

1.7.4 Single-Chip Microcomputer ,IPC and PLC

- Single Chip Microcomputer
  - ✓Integrating CPU, I/O, timer/counter, memory on a chip, powerful, respond fast, cheap.
  - ✓Need other chips and electronic parts, design hardware schematics and make printed circuit board
  - ✓Program using assemble language or C, need to be familiar with its hardware
  - ✓Used in industrial control, the personnel’s design ability of hardware and software
  - ✓Need the many anti-interference Measures include hardware, software to guarantee the reliability.

1.7 Development of PLC

✓PLCs are used mainly in logic control, although they have other functions.

✓The reliability of PLC is incomparable, the hold-up time is the least.

✓PLCs are designed aiming at the control of industrial control, their reliability is very high.

✓PLCs are easy to use.

Software: language is ladder diagram. Easy to learn.

Hardware: just to wire devices to PLC

✓IPC is powerful, and usually used as host computer in industrial control and communicates with PLC.