Programmable Logic Controller

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Ch 4

PLC programming

- Design Overview
- Basic Circuits ★
  - Start-hold-stop
  - Motor circuit for forward/reverse rotation
  - Single-pulse generator
  - Continuous-plus generator
- Programming Methods
  - Logical Algebraic Method
  - Time Sequence Diagram Method
  - Sequential Function Chart Method ★

4.0 Design Overview

- **The system design includes hardware circuit design and software program design**

- **Design principles:**
  - ✓ **Safe, reliable, practical and easy to maintain**
  - ✓ **Simple, economical and cost-effective**
  - ✓ **Have a certain margin in hardware configuration**

4.0 Design Overview

4.0.1 Design procedure

- **Conduct an in-depth investigation of the production process and set clear objectives of the tasks of PLC control system**
  - ✓ **ON/OFF switch control or analog control or digital control?**
  - ✓ **System control scale ? How many I/O points are there?**
  - ✓ **Analog control: Channels and bits of the signal?**
  - ✓ **Digital control: Frequency at which PLC receives or outputs high-speed pulses**
  - ✓ **Data acquisition and display monitoring requirements?**
  - ✓ **PID operation, closed loop control and communication network and other higher requirements?**
  - ✓ **Estimate the memory capacity if necessary.**

4.0 Design Overview

4.0.1 Design procedure

- **Understand the mode of operation and the actions to be performed under each mode of operation**
  - ✓ **Operation mode : Manual or automatic**
  - ✓ **Automatic mode : Single cycle (semi-automatic) or continuous (full automatic).**
  - ✓ **Target actions: action sequence, action conditions, necessary protection and interlocking, etc.**

- **Understand the work environment of PLC**
  - ✓ **Environment temperature, moistureproof, dustproof, anticorrosion, shockproof, electromagnetic interference requirements.**

4.0 Design Overview

4.0.1 Hardware circuit design

- **Select PLC model**
  - ✓ **Performance matches tasks**
  - ✓ **Key Indicators: Maximum I/O points, working speed, memory capacity, memory configuration, working power supply, PLC output mode, special function configuration, PLC installation size**
- **Proper structure and unified model**
  - ✓ **Make the models consistent for the same Producer**
- **Reliability**
  - ✓ **The control system must work reliably**
  - ✓ **After-sales service and technical support**
  - ✓ **For important industries (such as power plants and ports), dual-system hot backup or redundancy should be adopted**

4.0 Design Overview

4.0.1 Hardware circuit design

- **Select input element, output element**
  - ✓ **Input components: button, travel switch, proximity switch, photoelectric switch, rotary encoder, level switch, transmitter, etc.**
  - ✓ **Output actuator: contactor, solenoid valve, indicator light, digital tube, etc.**
- **I/O point distribution, and the main circuit design**
  - ✓ **Establish I/O points and input, output components of the corresponding relationship: easy to remember, convenient programming, save wiring.**
  - ✓ **Use some technique or tricks to economize THE PLC I/O points**

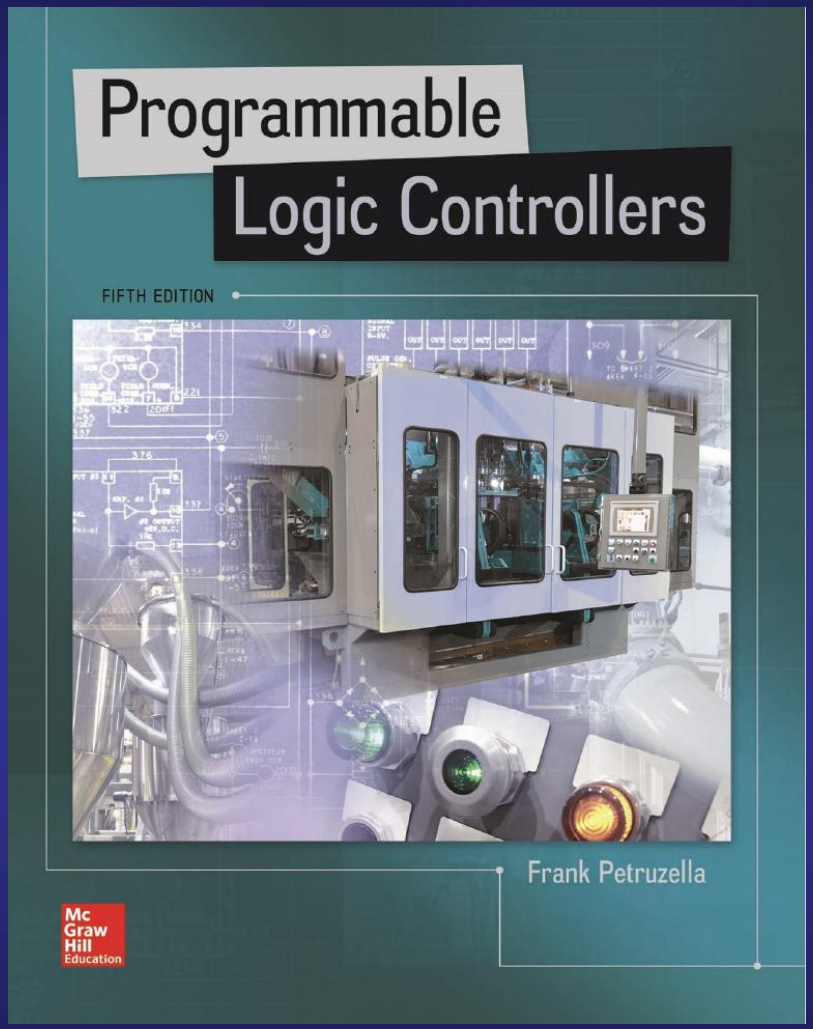
4.0 Design Overview

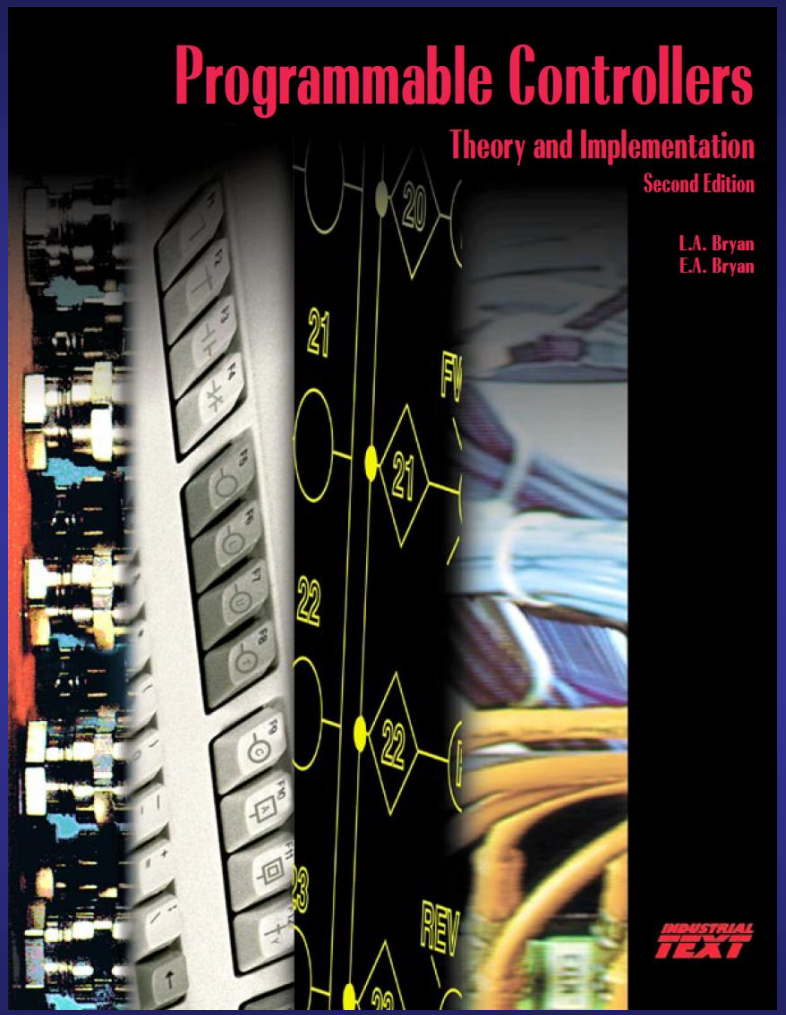
4.0.1 PLC control wiring

- **Input terminal**
  - ✓ **24 V DC power supply**
  - ✓ **Be careful not to exceed its rated capacity**

- **Output terminal**
  - ✓ **Connect the fuse to the common terminal**
  - ✓ **Inductive load: Access the corresponding protection circuit**
    - **AC inductive load: RC absorption circuit**
    - **DC inductive load : RC absorption circuits or continuous-current diodes**
  - ✓ **Install external emergency shutdown circuit**

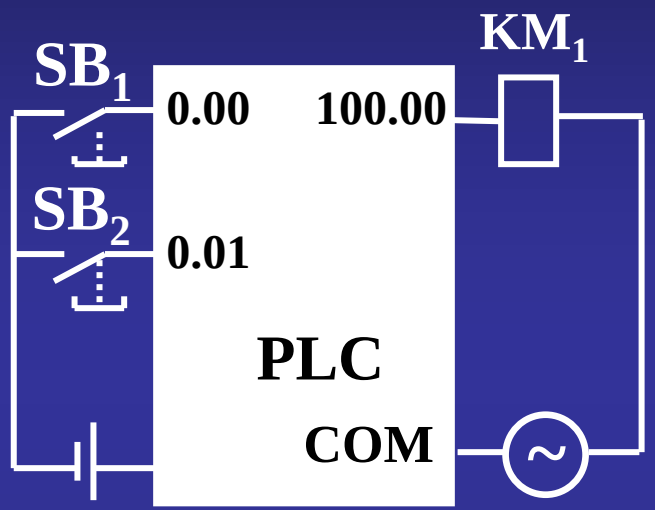
4.0 Design Overview

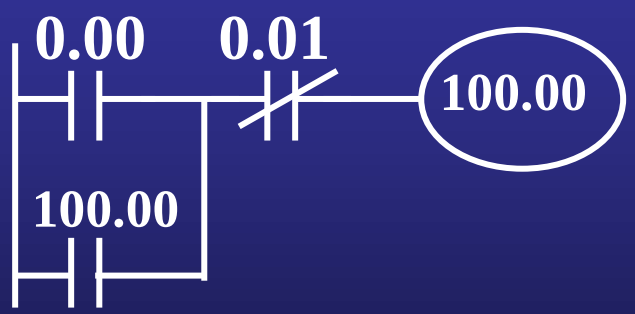


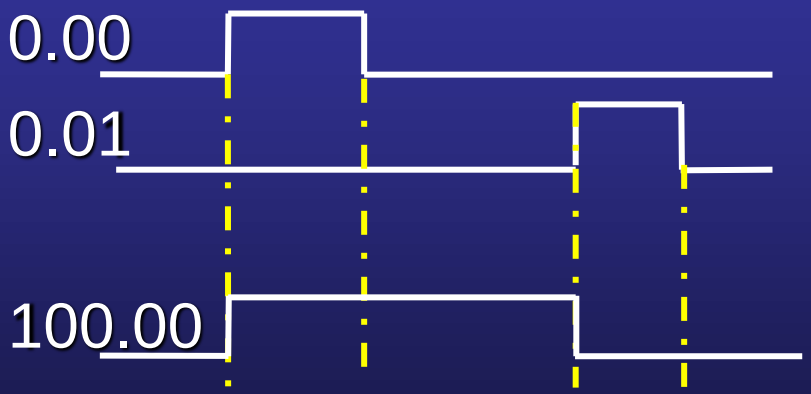


4.1 Basic Circuits

- ✓Start-hold-stop circuit

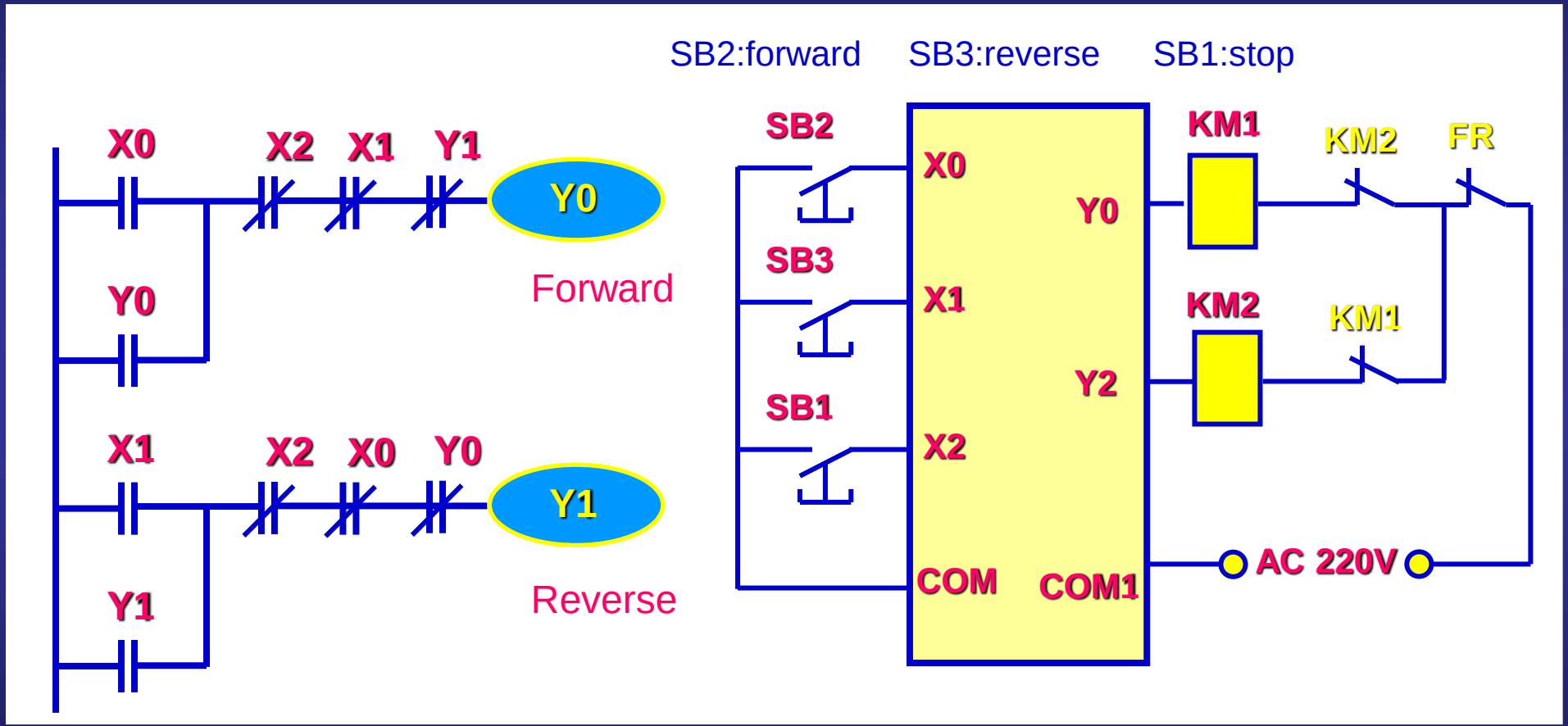






4.1 Basic Circuits

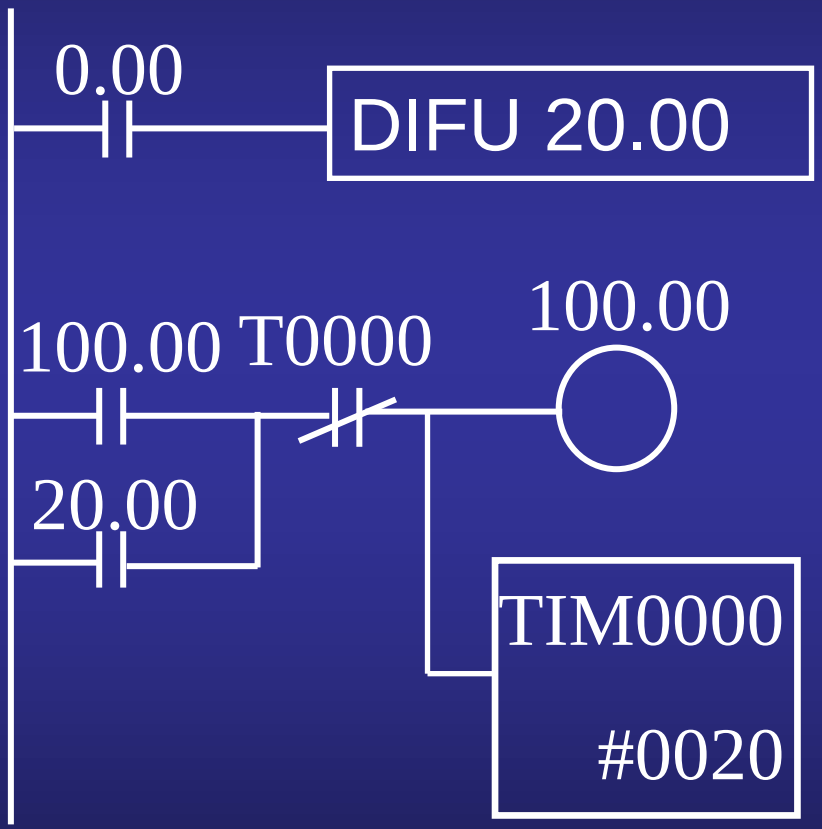
✓Motor circuit for forward/reverse rotation

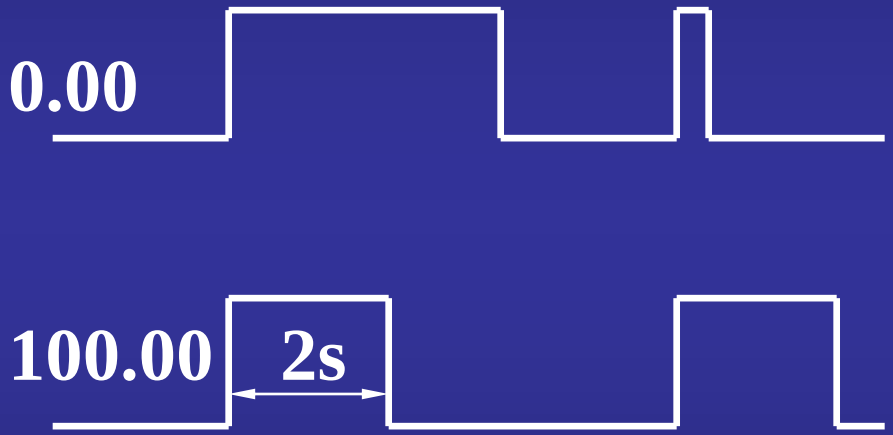


Security measures: output coil interlock, pushbutton interlock

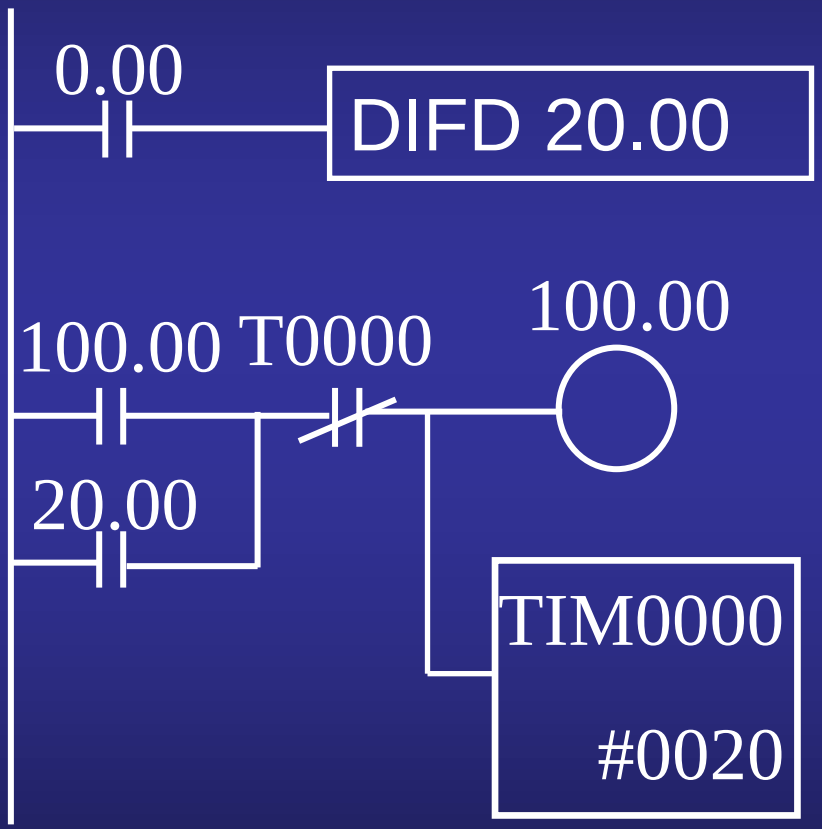
4.1 Basic Circuits

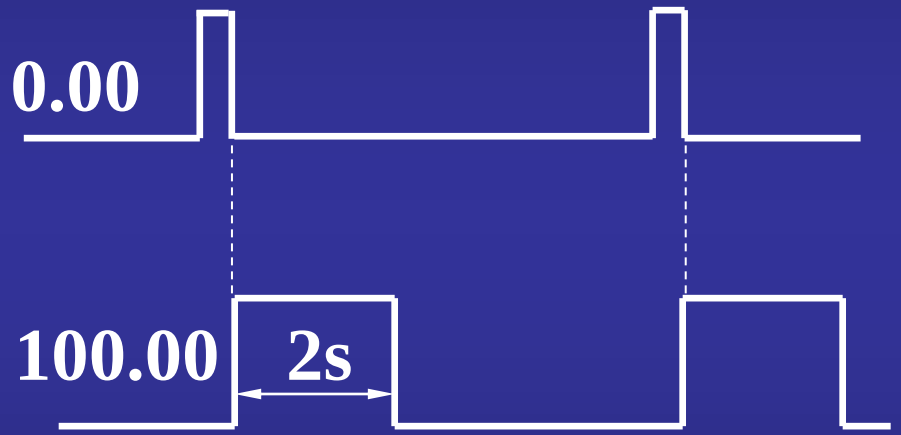
- ✓Single-pulse generator





4.1 Basic Circuits

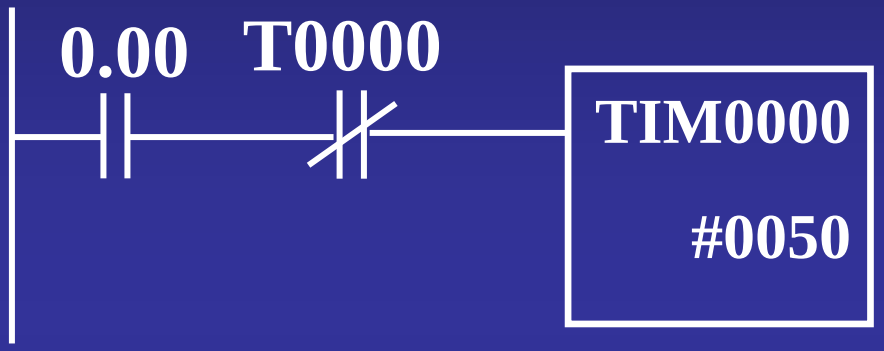




4.1 Basic Circuits

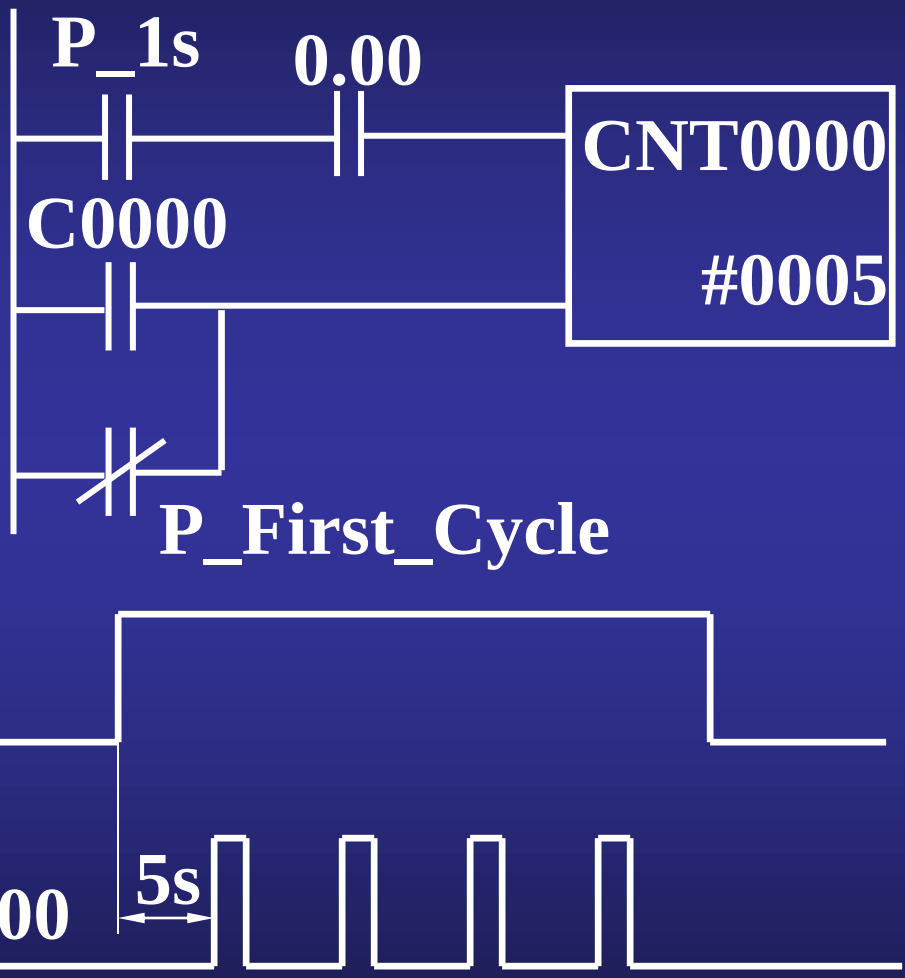
- ✓Pulse generator

Using timer



4.1 Basic Circuits

Using counter



4.2 PLC Programming methods - Overview

- **Logical Algebraic Method**
- **Time Sequence Diagram Method**
- **Sequential Function Chart Method**

4.2 Logical Algebraic Method

- **Step**

  - ✓Establish the logical algebraic function between the input and output (usually using the logic state table);
  - ✓Reduce the logical algebraic function;
  - ✓Create the ladder diagram according to the function;

4.2 Logical Algebraic Method

➢**Example**

Using a light to indicate the states of 3 electrical blowers

1) If 2 or 3 blowers are on, light is ON;
2) If only 1 blower is on, light will flash with frequency of 0.5Hz
3) If none is on, light will flash with frequency of 2Hz.
4) Use a switch to control the system

4.2 Logical Algebraic Method

✓**analysis**

Signals representing the state of blowers are input to PLC

Output of PLC is used to control the on/off of light

✓**I/O assignment**

Input				output
blower1	**blower2**	**blower3**	**control switch**	**light**
0.00	**0.01**	**0.02**	**0.03**	**100.00**

4.2 Logical Algebraic Method

➢**Logical relationship analysis**

Constant ON

0.5 Hz

2 Hz

Input			output		
0.00	0.01	0.02	20.00	20.01	20.02
0	0	0	0	0	1
0	0	1	0	1	0
0	1	0	0	1	0
0	1	1	1	0	0
1	0	0	0	1	0
1	0	1	1	0	0
1	1	0	1	0	0
1	1	1	1	0	0

$$20.01=\overline{20.00}\cdot\overline{20.02}$$

$$20.00=\overline{0.00}\cdot 0.01\cdot 0.02+0.00\cdot\overline{0.01}\cdot 0.02+0.00\cdot 0.01\cdot\overline{0.02}+0.00\cdot 0.01\cdot 0.02$$

$$20.02=\overline{0.00}\cdot\overline{0.01}\cdot\overline{0.02}$$

4.2 Logical Algebraic Method

- **Reduction**

$$20.00 = \overline{0.00} \cdot 0.01 \cdot 0.02 + 0.00 \cdot \overline{0.01} \cdot 0.02 + 0.00 \cdot 0.01 \cdot \overline{0.02} + 0.00 \cdot 0.01 \cdot 0.02$$

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

$$20.00 = 0.00 \cdot 0.01 + 0.00 \cdot 0.02 + 0.01 \cdot 0.02$$

$$20.02 = \overline{0.00} \cdot \overline{0.01} \cdot \overline{0.02}$$

$$20.01 = \overline{20.00} \cdot \overline{20.02}$$

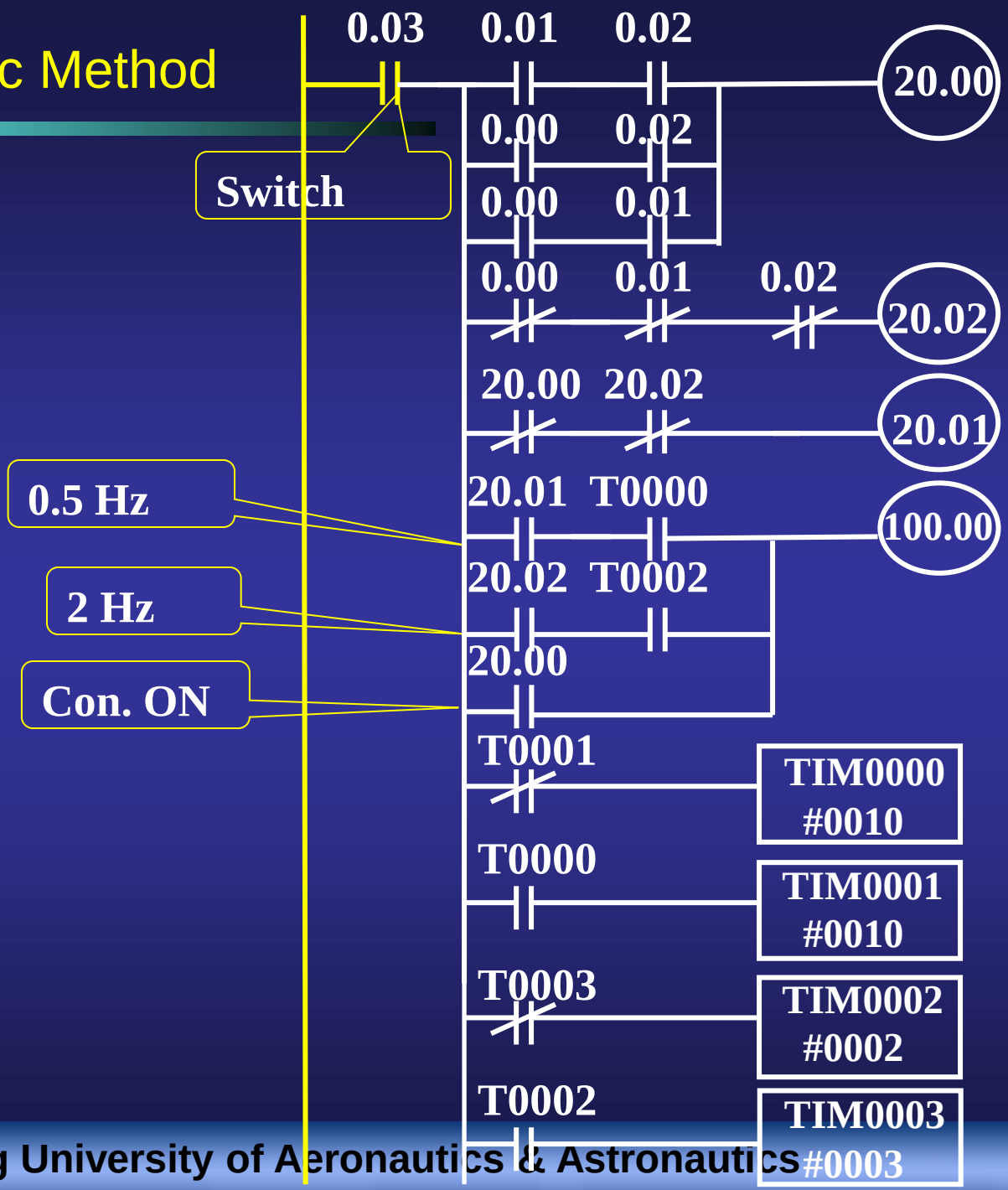
4.2 Logical Algebraic Method

➢Diagram

$$20.00 = 0.00 \cdot 0.01 + 0.00 \cdot 0.02 + 0.01 \cdot 0.02$$

$$20.02 = \overline{0.00 \cdot 0.01 \cdot 0.02}$$

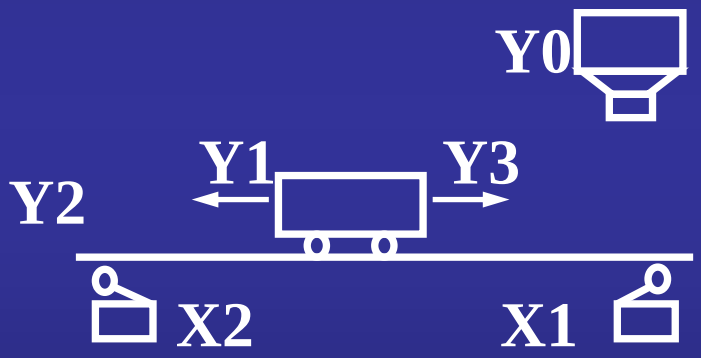
$$20.01 = \overline{20.00} \cdot \overline{20.02}$$

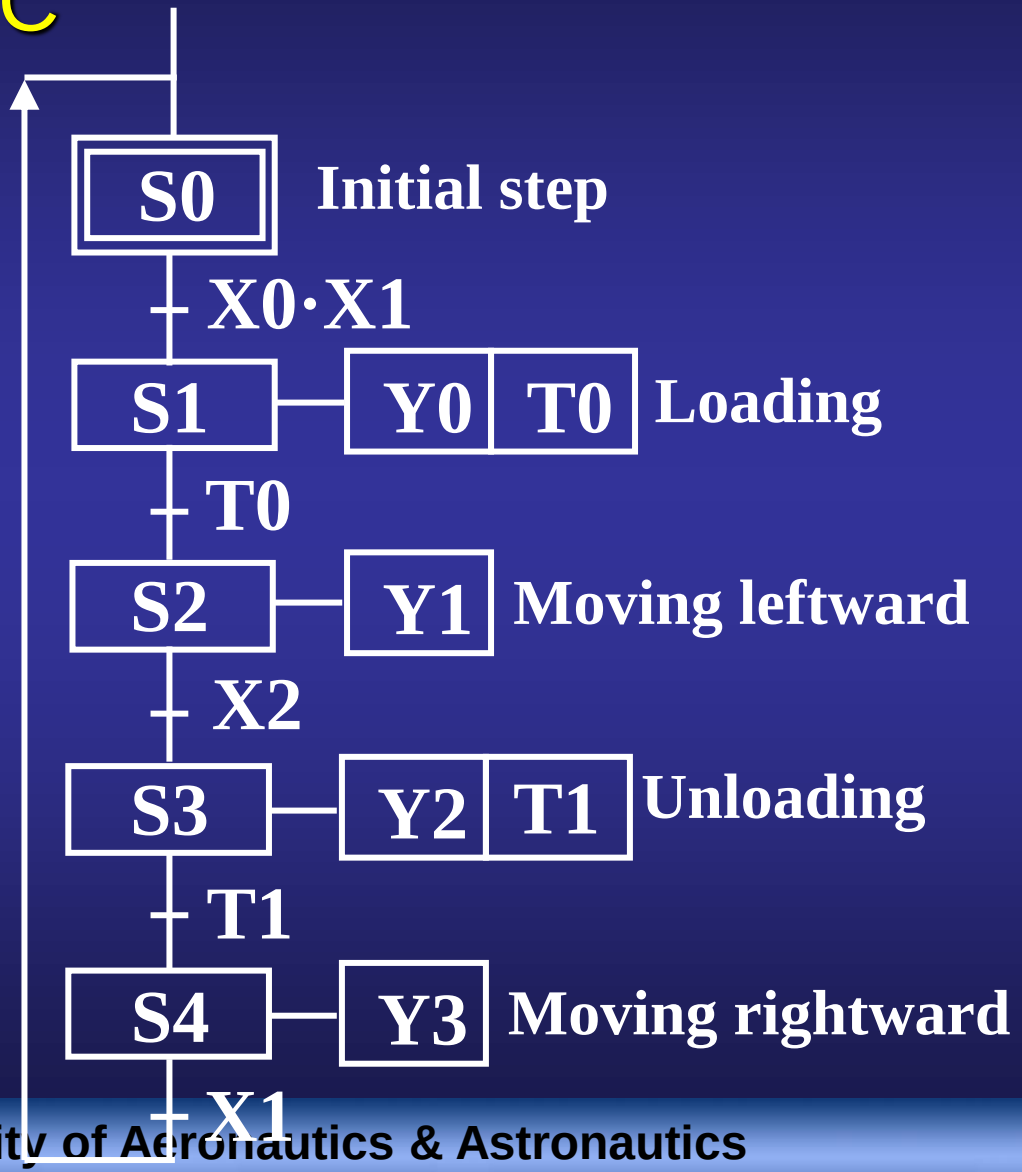


4.4 Sequential Function Chart Method

4.4.1 Basic idea of SFC

Material transport vehicle





4.4 Sequential Function Chart Method

➢ Basic idea

✓Dividing the working cycle of system into sequential stages, i.e., steps

- •Using internal relay to represent each step.
- •Dividing criteria: the state of output.
- •The outputs of neighboring two steps are different.
- •If the step is active, then its associated action is executed. If the step is inactive, then its associated action isn't executed.

4.4 Sequential Function Chart Method

✓The signal used to realize the shift from current step to next step is called transition condition

- •Transition condition can be the input signal from input device, e.g. button, switch;
- •Can be the internal signal of PLC, e.g. timer, counter.
- •Can be the logical combination of signals

✓Sequential control method uses the transition condition to control the ON/OFF status of relays representing the steps, and makes the status of relays change in certain order, then uses the relay to control the output of PLC

4.4 Sequential Function Chart Method

4.4.2 Basic elements of SFC

➢**Step**——stage in the control process

✓Dividing criteria：state of output

✓Represented by rectangular box, initial step is represented by double-line rectangular box

✓Representation in diagram：use internal relay

✓Type：

- **Active step：** step the system is in is called active step and its corresponding action is performed.
- **Inactive step**

4.4 Sequential Function Chart Method

➢**Action——output corresponding to step**

Represented by rectangular box and connected to step

Attention: Timer and counter are also action

➢**Transition condition**：condition causing the shift between steps

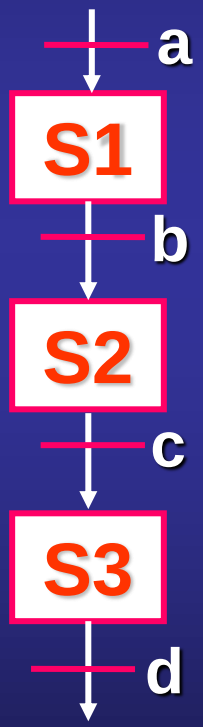
- Transition condition can be the input signal from input device, e.g. button, switch;
- Can be the internal signal of PLC, e.g. timer, counter.
- Can be the logical combination of signals

➢**Flow-line**：connects steps and transitions; indicates the shift direction

4.4 Sequential Function Chart Method

4.4.3 Structure of SFC

- **Single sequence**



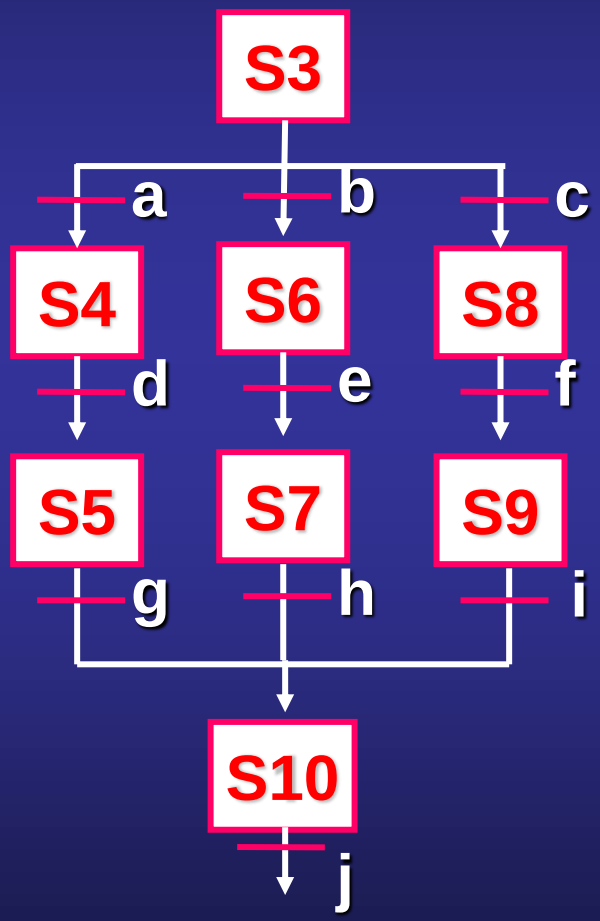
Features：

✓There is only one transition condition after each step

✓There is only one step after each transition condition

4.4 Sequential Function Chart Method

➢ Selective sequence



✓Branching

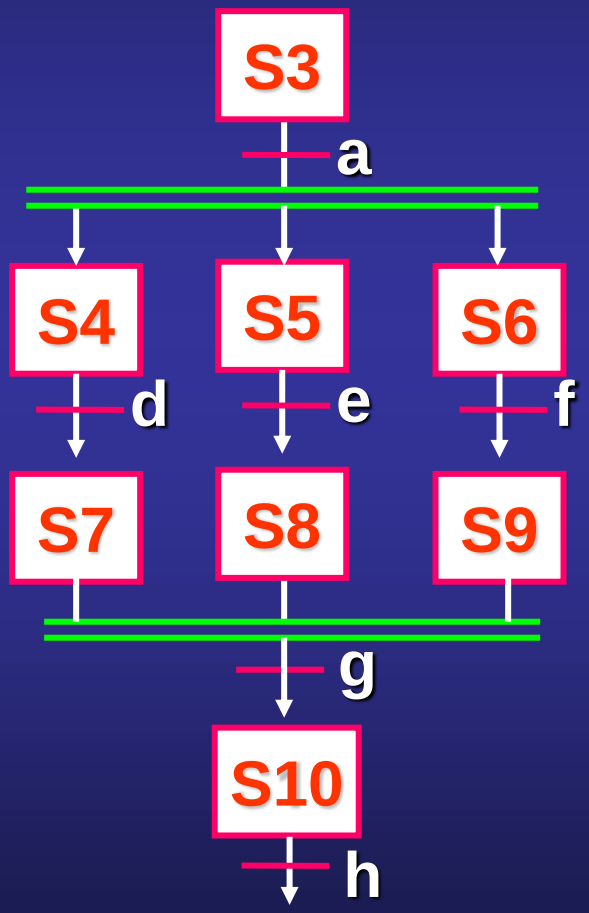
There are several sequences after a step, and only one sequence can be shifted to when a transition condition is met.

✓Convergence

Several sequences converge to one sequence.

4.4 Sequential Function Chart Method

➢ Parallel sequence



✓Branching

If condition is met, the sequences after the step are activated simultaneously.

✓Convergence

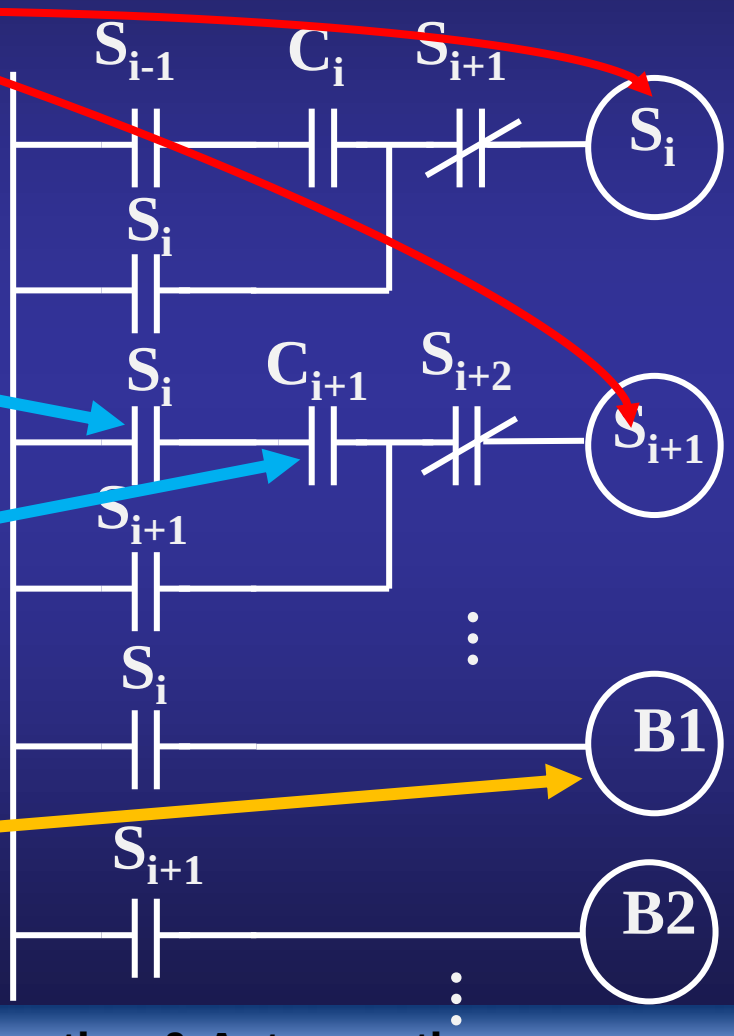
The **final steps** of parallel sequences are **active steps** and transition condition is met, then shift to the next step.

4.4 Sequential Function Chart Method

4.4.4 Transitions of Steps

- **Each step has a control bit. If the control bit is ON, this step turns to active status (Condition 1) and the corresponding programs start.**

- **If the transition condition is ON (Condition 2), the control bit of next step is ON while that of previous step is OFF, and the program of previous step stops.**



4.4 Sequential Function Chart Method

Notes for SFC：Step connections

- ✓ Two steps are not connected directly and always divided by the transition.
- ✓ Two transitions are not connected directly and divided by the step.
- ✓ The initial step corresponds to the initial state of system waiting for start.
- ✓ For automatic control system, the SFC is closed.
- ✓ Only when the upper step is active and transition condition is met, the lower step can be activated.

4.4 Sequential Function Chart Method

Notes for SFC： Transition criteria

- Prerequisites for transition

✓Upper step of transition is active
✓Transition condition is 1

- Results of transition

✓Lower step of transition will be active.
✓Upper step of transition is inactive.

4.4 Sequential Function Chart Method

Notes for SFC： Sequences

- Single sequence

A shift has only one upper step and one lower step.

- Selective sequence

In branching and convergence, a shift has only one upper step and one lower step.

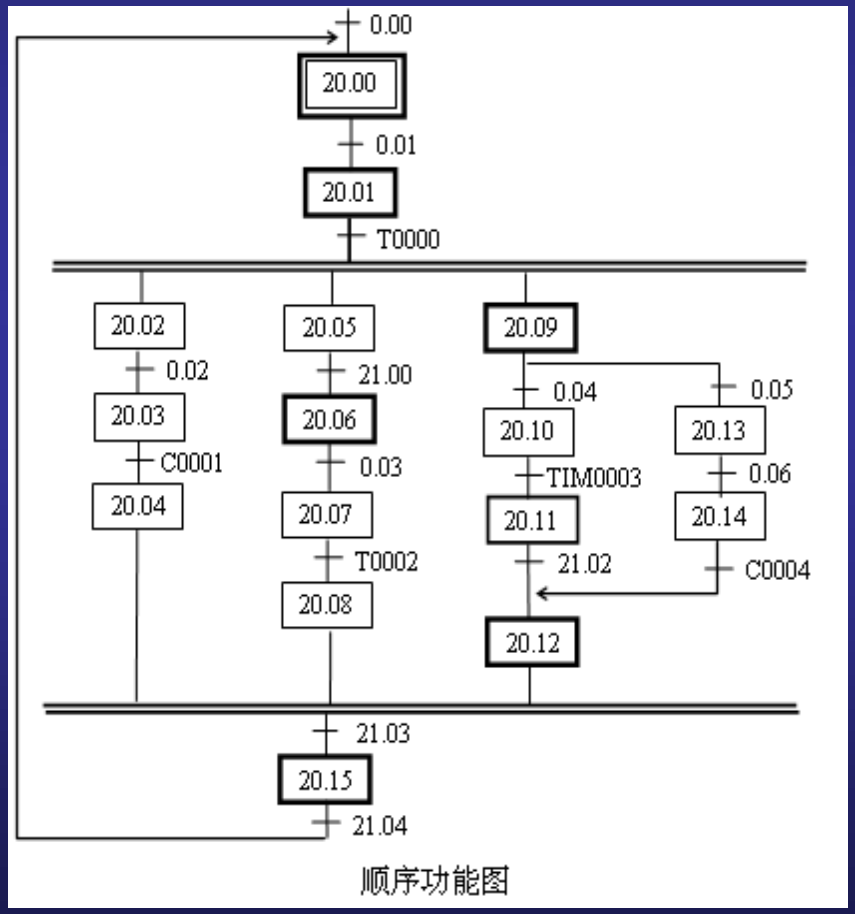
- Parallel sequence

At branching, a shift has several lower steps.
At convergence, a shift has several upper steps.

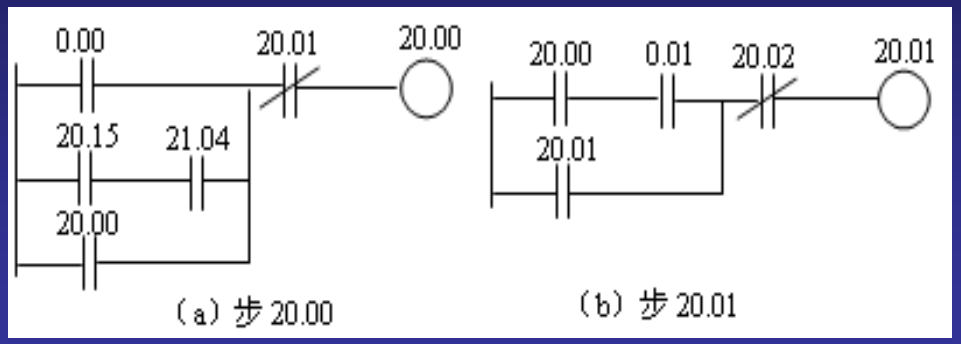
4.4 Sequential Function Chart Method

4.4.5 Ladder Diagram of Typical Steps

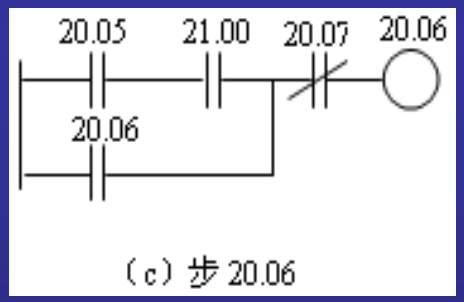
- Auxiliary relay



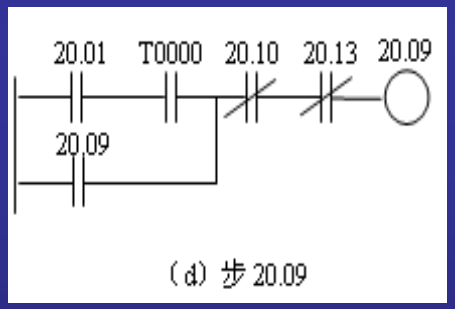
顺序功能图



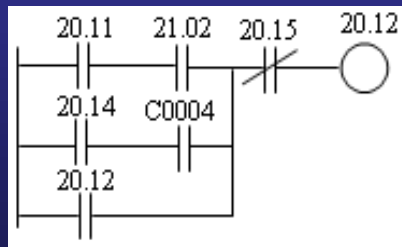
（a）步 20.00　（b）步 20.01



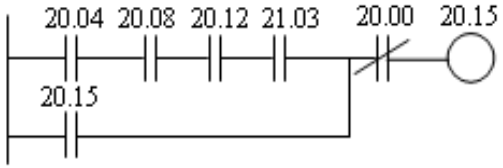
（c）步 20.06



（d）步 20.09



（e）步 20.12



（f）步 20.15

4.4 Sequential Function Chart Method

4.4.5 Typical Steps

- 20.00: Merge Step of two

- Activation Cond. of Step 20.00:

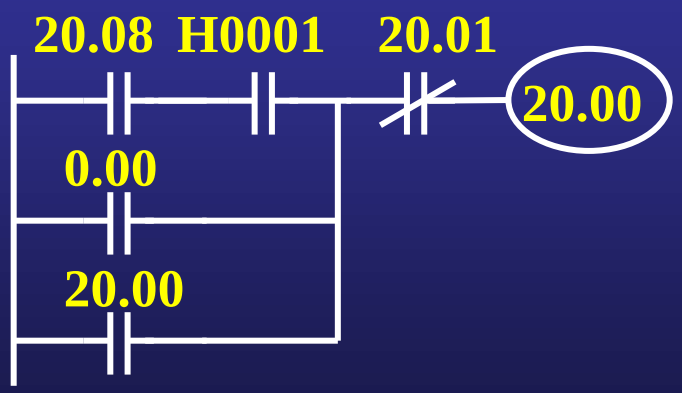
Cond. 0.0 = ON

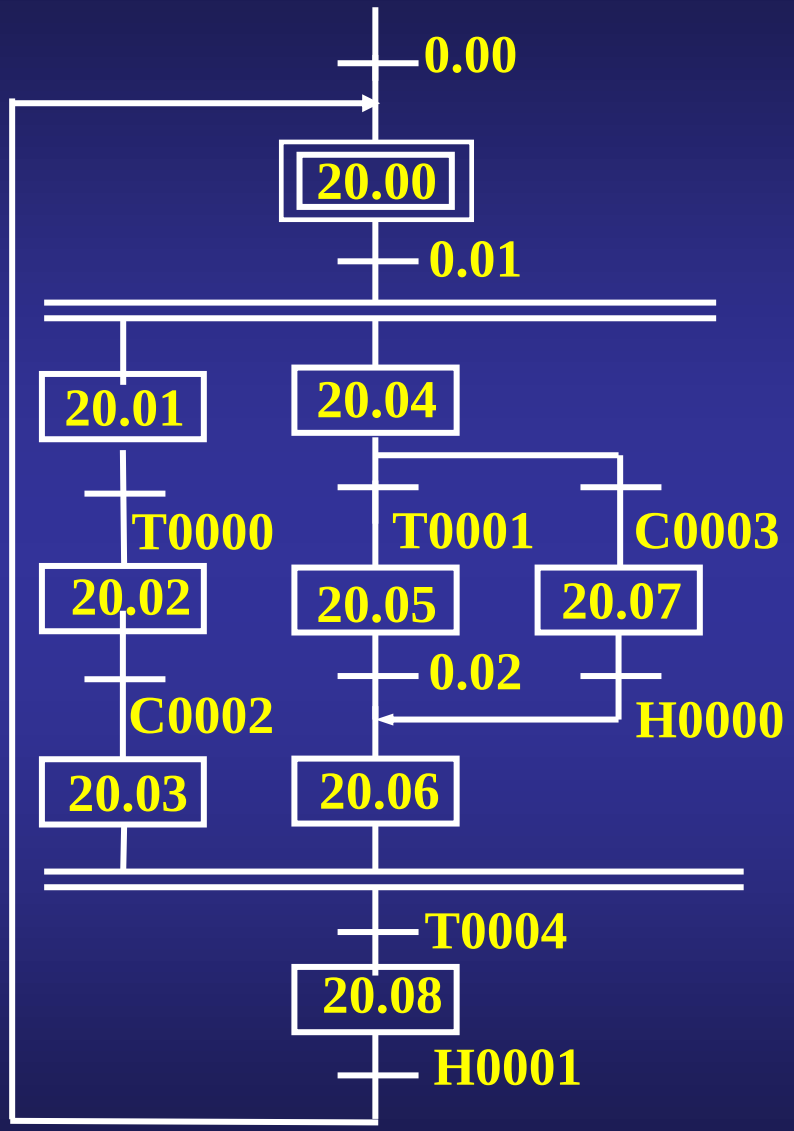
OR Step 20.08 is active and Cond. H0001 = ON.

- Inactivation Cond. of Step 20.00:

Step 20.01 OR 20.04 is active.

Ladder diagram:





4.4 Sequential Function Chart Method

4.4.5 Typical Steps

- 20.01: **First Step** of single sequence

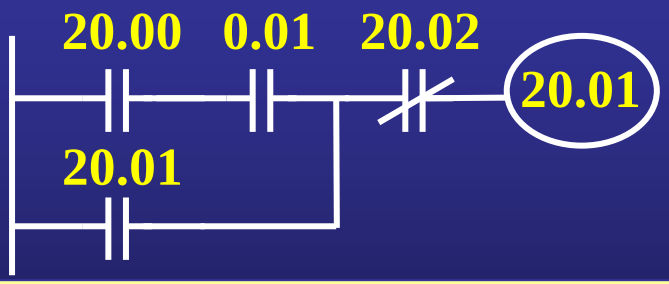
- **Activation Cond. of Step 20.01:**

Step 20.00 is active and Cond. 0.01 = ON.

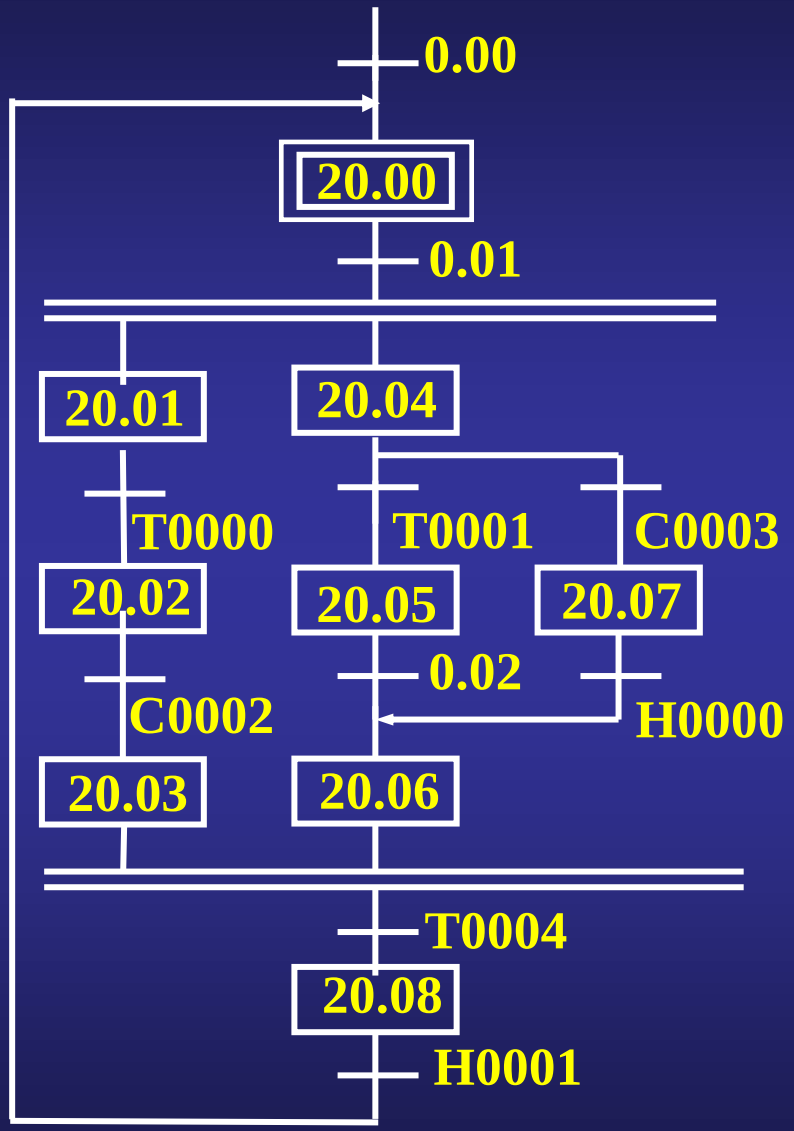
- **Inactivation Cond. of Step 20.01:**

Step 20.02 is active.

Ladder diagram:



Step 20.02/20.03 is similar to Step 20.01.



4.4 Sequential Function Chart Method

4.4.5 Typical Steps

- **20.04: Start Step of optional branch**

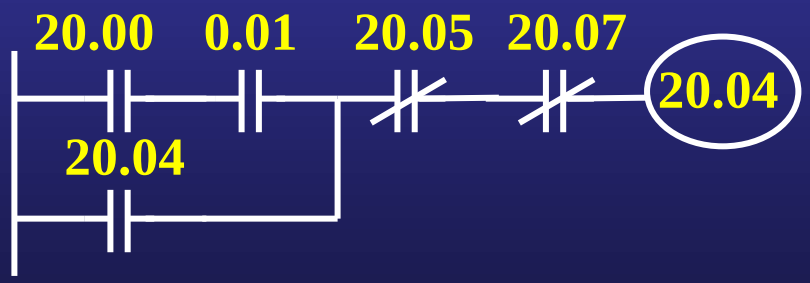
- **Activation Cond. of Step 20.04:**

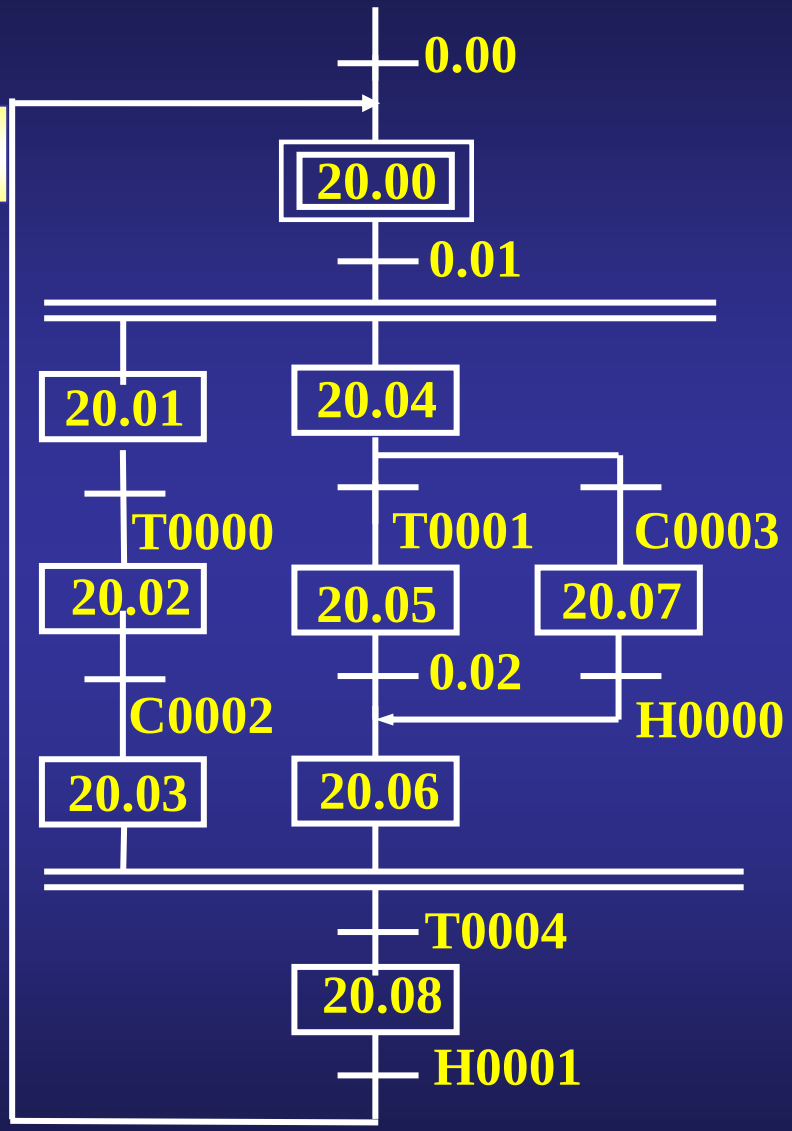
Step 20.00 is active and Cond. 0.01 = ON.

- **Inactivation Cond. of Step 20.04:**

Step 20.05 OR 20.07 is active.

Ladder diagram:





4.4 Sequential Function Chart Method

4.4.5 Typical Steps

- **20.05: Middle Step of a sequence**

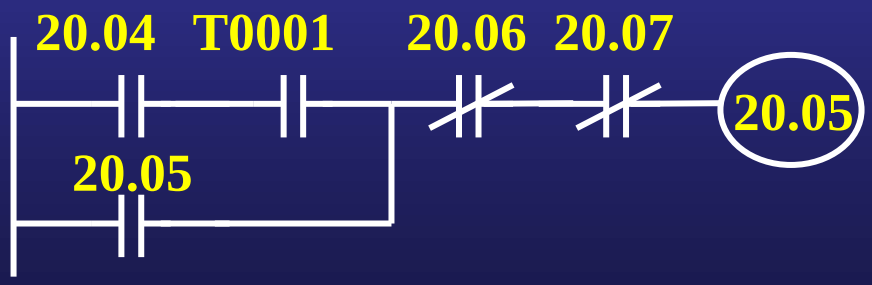
- **Activation Cond. of Step 20.05:**

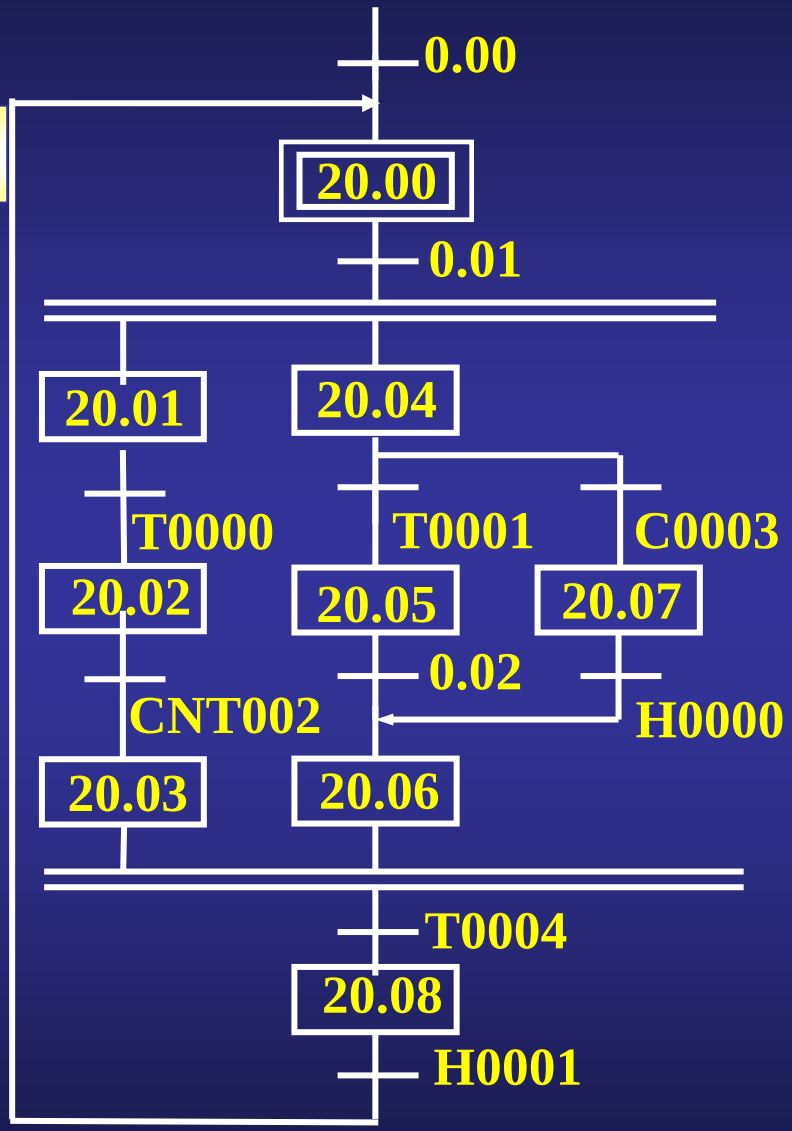
Step 20.04 is active and
Cond. T0001 = ON.

- **Inactivation Cond. of Step 20.05:**

Step 20.06 OR 20.07 is active.

Ladder diagram:





4.4 Sequential Function Chart Method

4.4.5 Typical Steps

- **20.06: Merge Step**

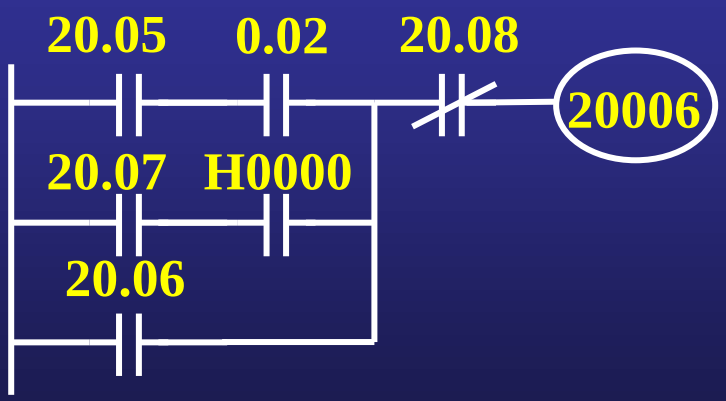
- **Activation Cond. of Step 20.06:**

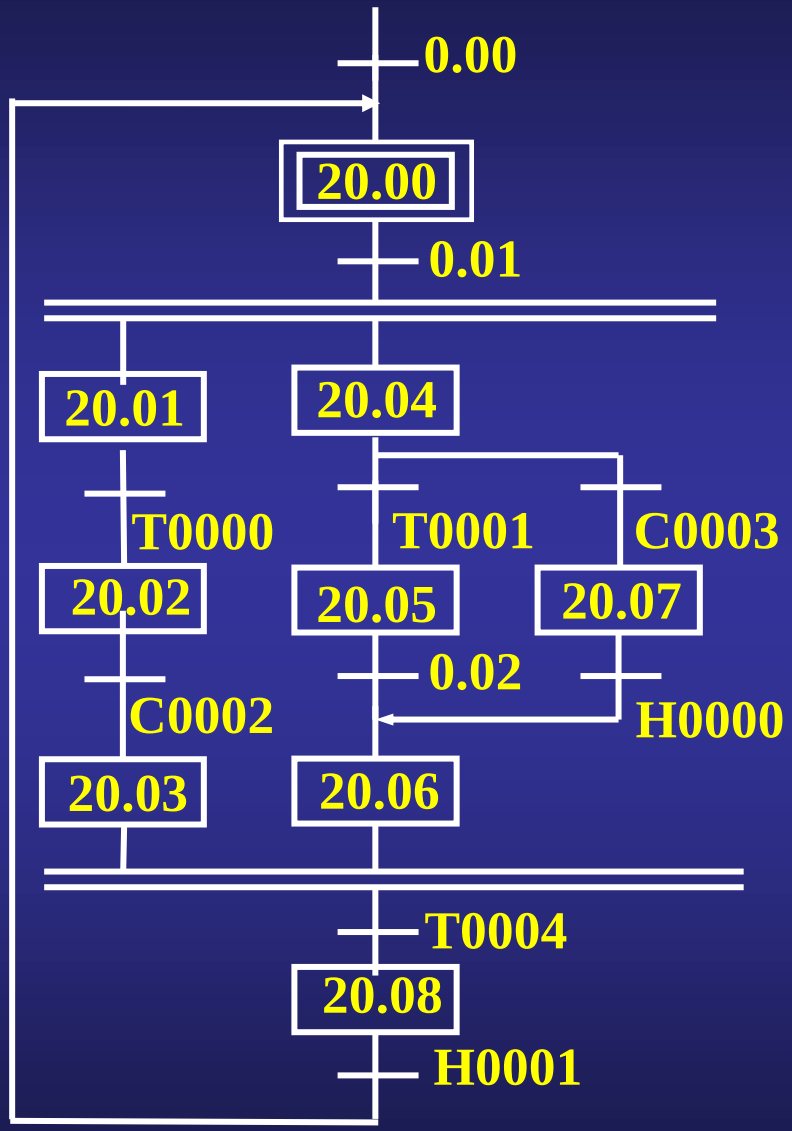
Step 20.05 is active and Cond. 0.02= ON.
OR Step 20.07 is active and Cond. H0000 = ON.

- **Inactivation Cond. of Step 20.06:**

Step 20.08 is active.

Ladder diagram:





4.4 Sequential Function Chart Method

4.4.5 Typical Steps

- **20.08: Merge Step of parallel sequences**

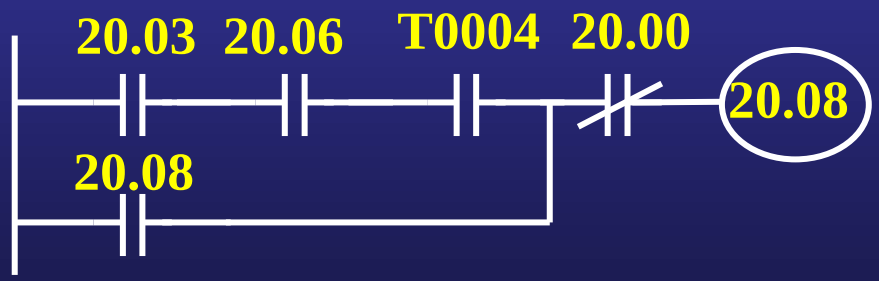
- **Activation Cond. of Step 20.08:**

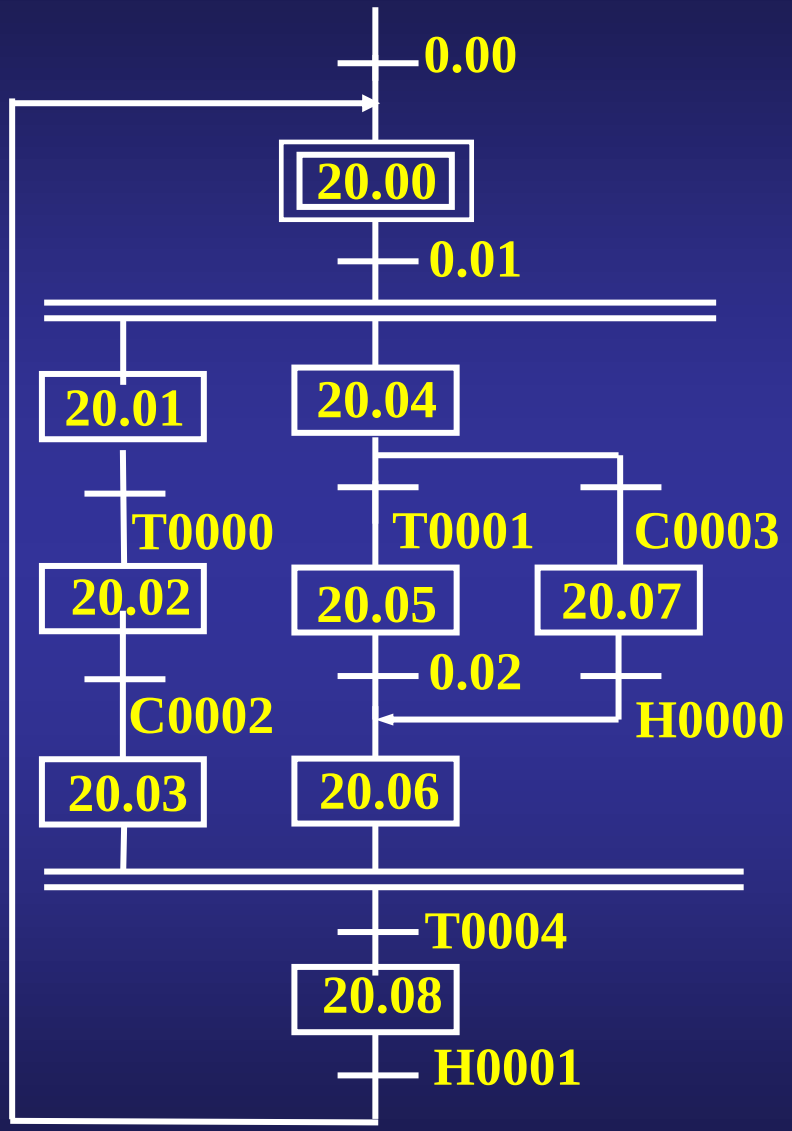
Step 20.03 and Step 20.06 are both active
AND
Cond. T0004 = ON.

- **Inactivation Cond. of Step 20.08:**

Step 20.00 is active.

Ladder diagram:





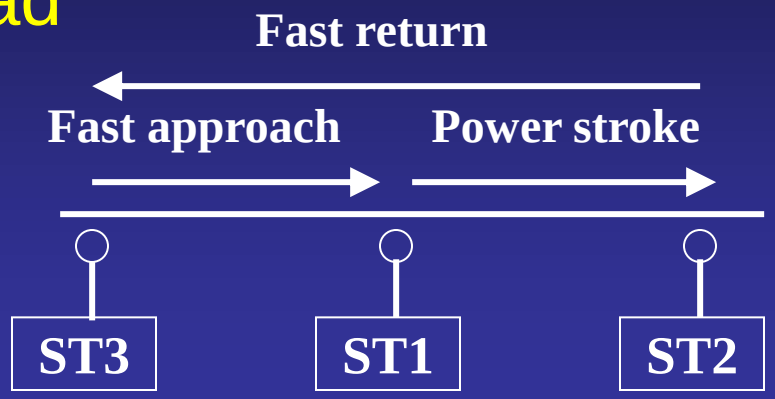
4.4 Sequential Function Chart Method

4.4.6 Overall programming procedures

- ✓Figure out the working process of system
- ✓Determine the PLC type, number of I/O points and I/O assignment.
- ✓Divide the cycle into steps
- ✓Determine the transition condition
- ✓Draw the SFC
- ✓Convert the SFC into Ladder diagram

4.4 Sequential Function Chart Method

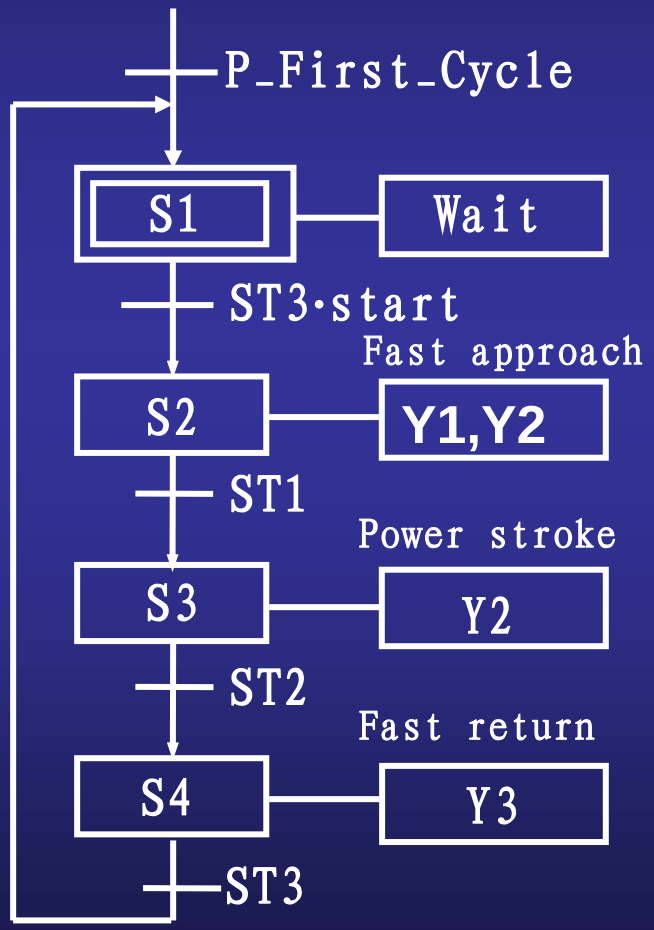
- **Example 1：** power head
  - ✓Working process
  - ✓I/O assignment

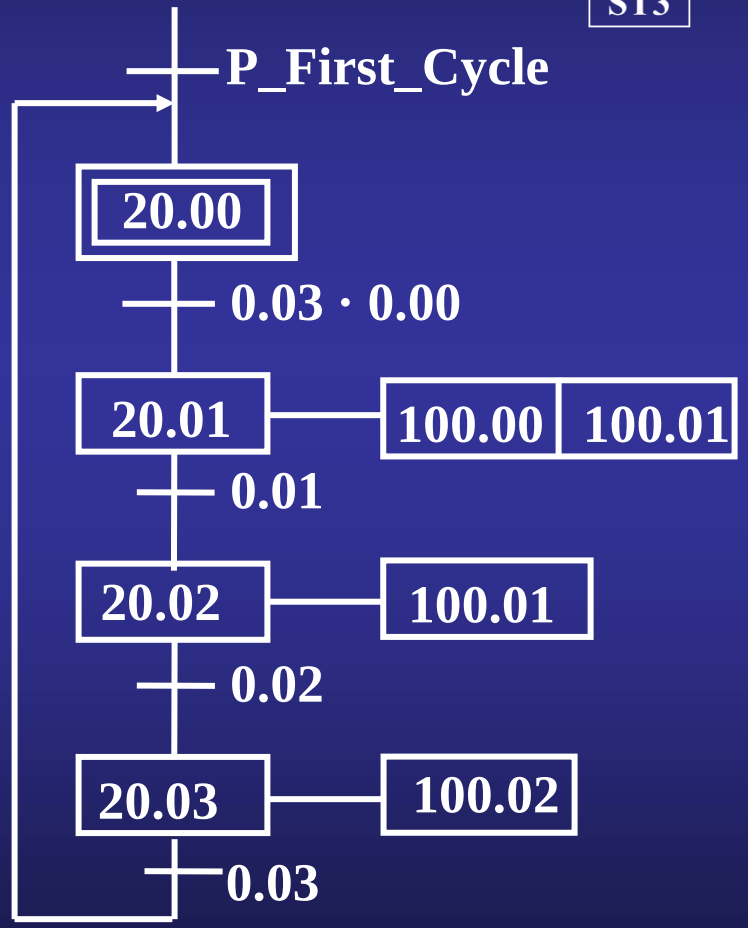


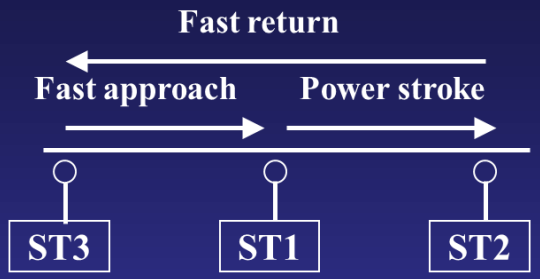
Input		Output	
Start	0.00	Y1	100.00
ST1	0.01	Y2	100.01
ST2	0.02	Y3	100.02
ST3	0.03		

4.4 Sequential Function Chart Method

✓SFC





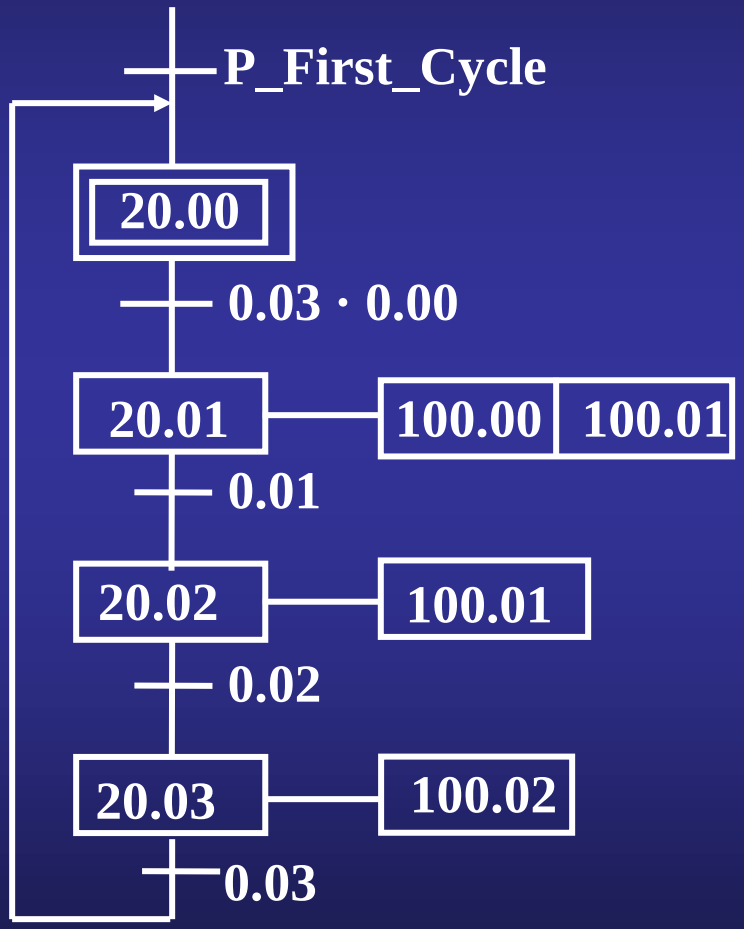


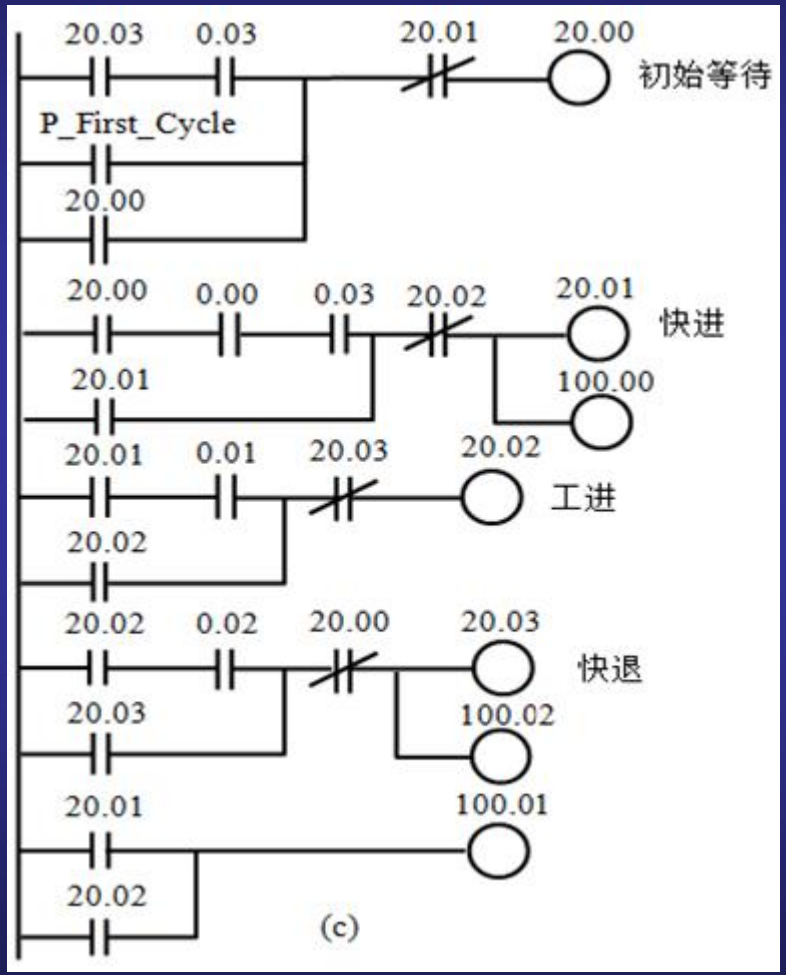
input	
start	0.00
ST1	0.01
ST2	0.02
ST3	0.03

output	
Y1	100.00
Y2	100.01
Y3	100.02

4.4 Sequential Function Chart Method

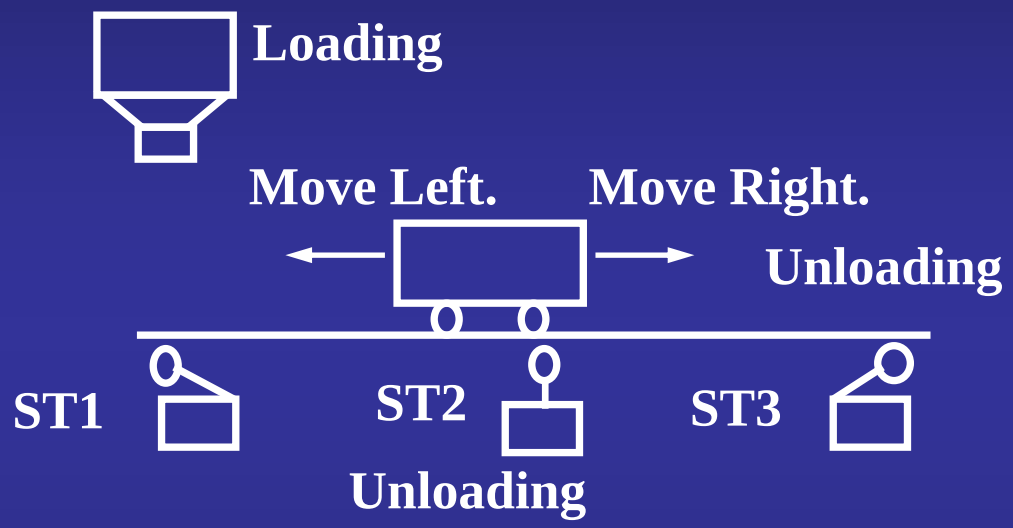
✓**Ladder diagram**





4.4 Sequential Function Chart Method

- Example 2: material transport vehicle
  - ✓Working process



1.At first, vehicle stops at ST1.
2.When start button is pressed, vehicle is loaded for 10s.
3.Vehicle moves rightwards 10 later and pushes down the ST2, then is unloaded for 5s.

4. 5s later, vehicle moves leftwards and pushes down the ST1 and is loaded for 10s.

5.When 10s lapses, vehicle moves rightwards and pushes down the ST3, then is unloaded for 5s.

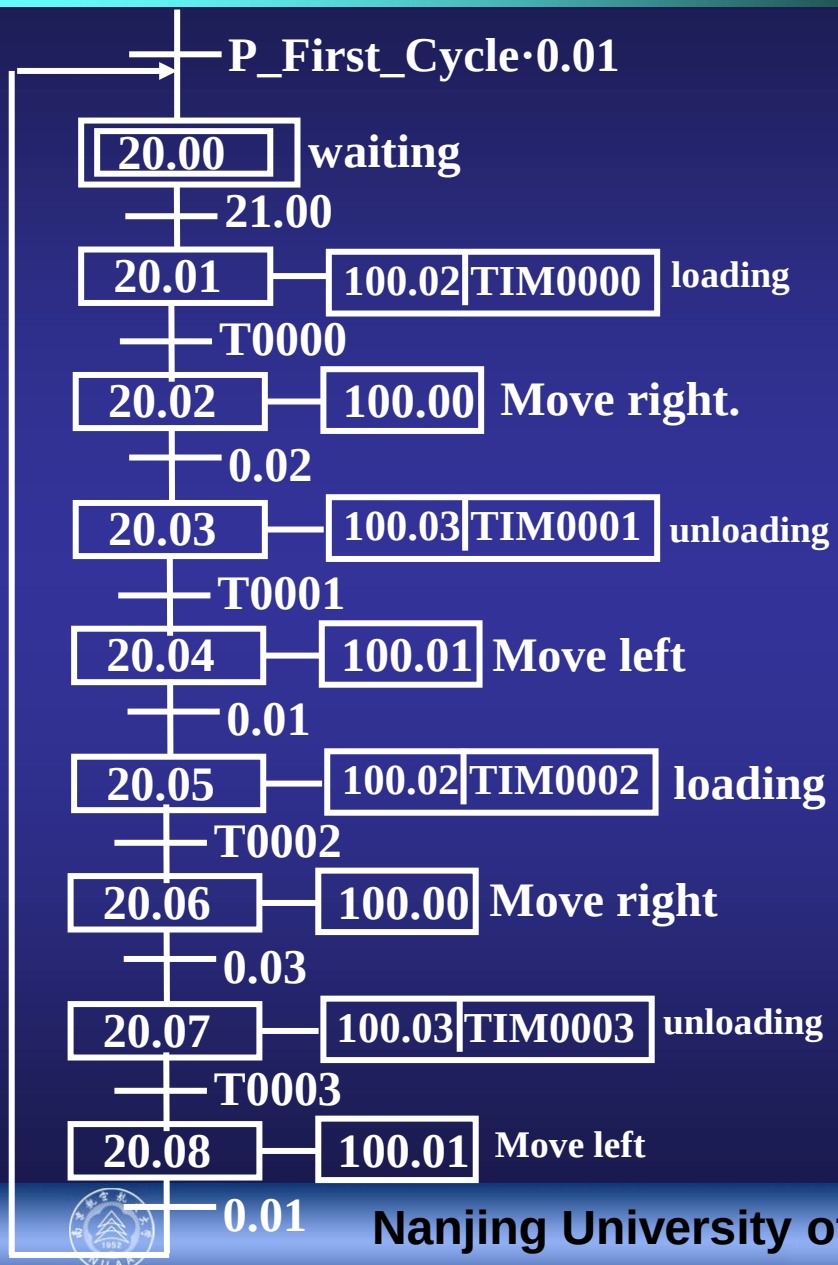
6.When 5s lapses, vehicle moves leftwards until the ST1 is pushed and stops at ST1.

4.4 Sequential Function Chart Method

- ✓I/O assignment

Input		Output	
Start	0.00	M.R.	100.00
ST1	0.01	M.L.	100.01
ST2	0.02	Load	100.02
ST3	0.03	Unload	100.03
Stop	0.04		

4.4 Sequential Function Chart Method



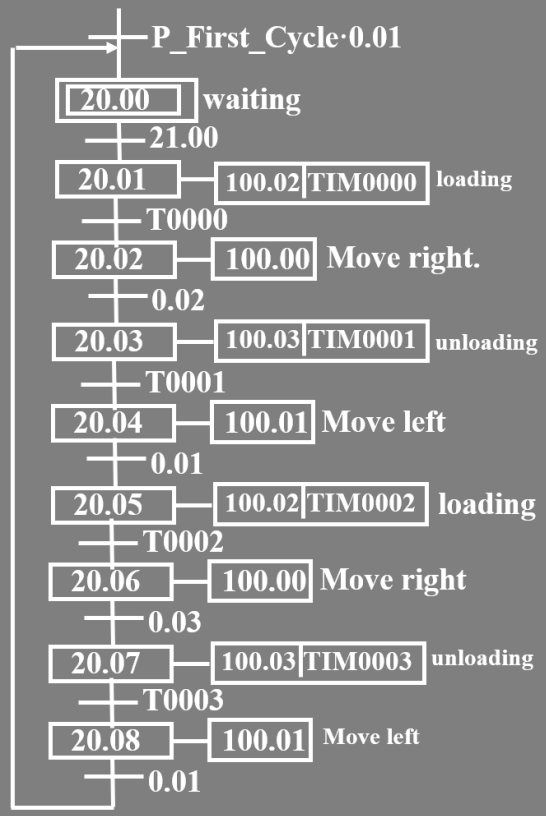
✓SFC

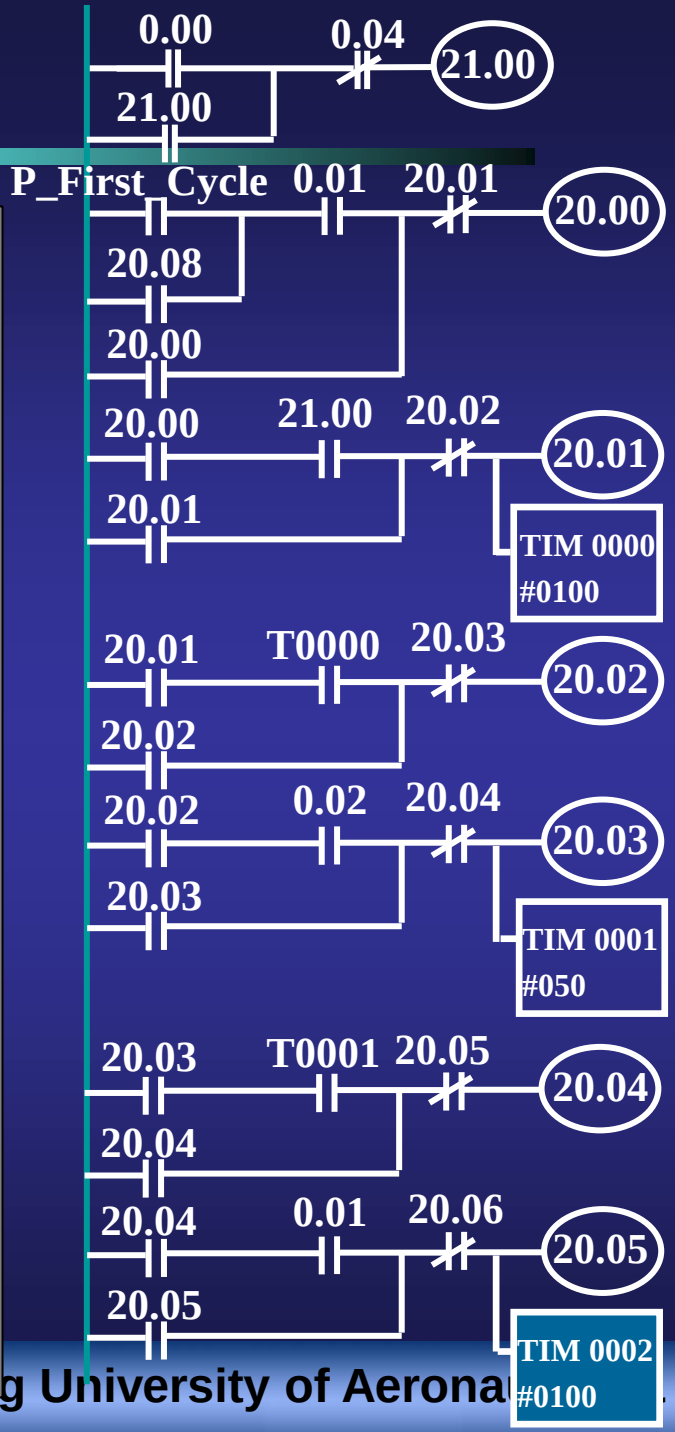
Input	
Start	0.00
ST1	0.01
ST2	0.02
ST3	0.03
Stop	0.04

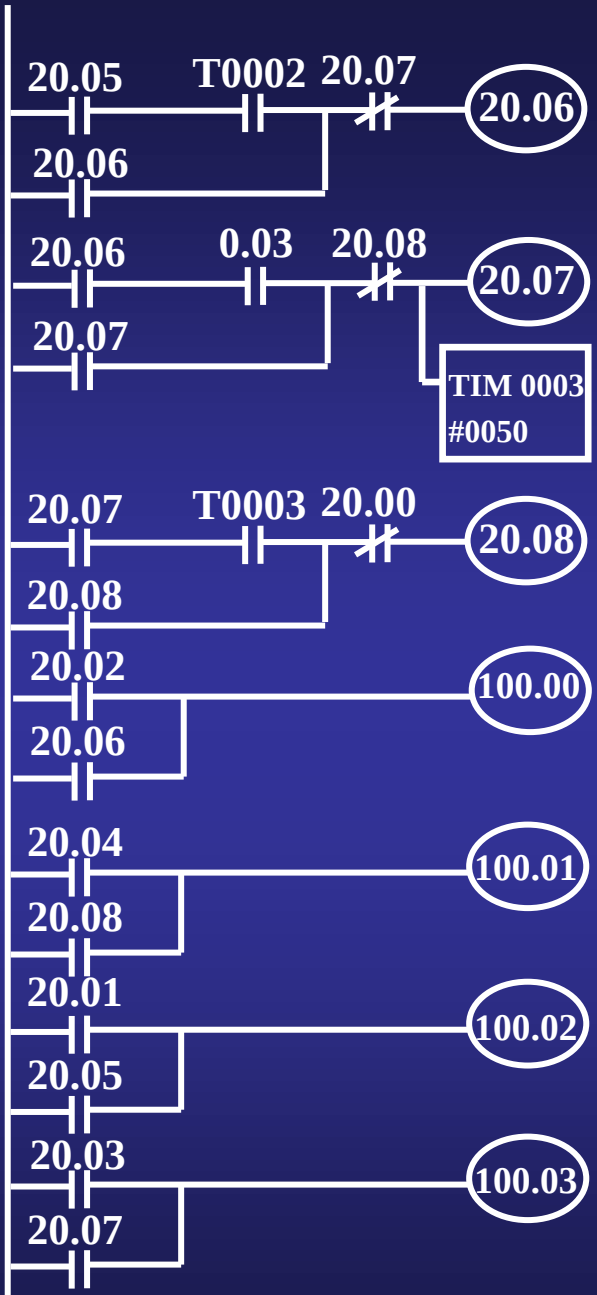
Output	
M.R.	100.00
M.L.	100.01
Load	100.02
Unload	100.03

✓Ladder diagram

Input		Output	
Start	0.00	M.R.	100.00
ST1	0.01	M.L.	100.01
ST2	0.02	Load	100.02
ST3	0.03	Unload	100.03
Stop	0.04		

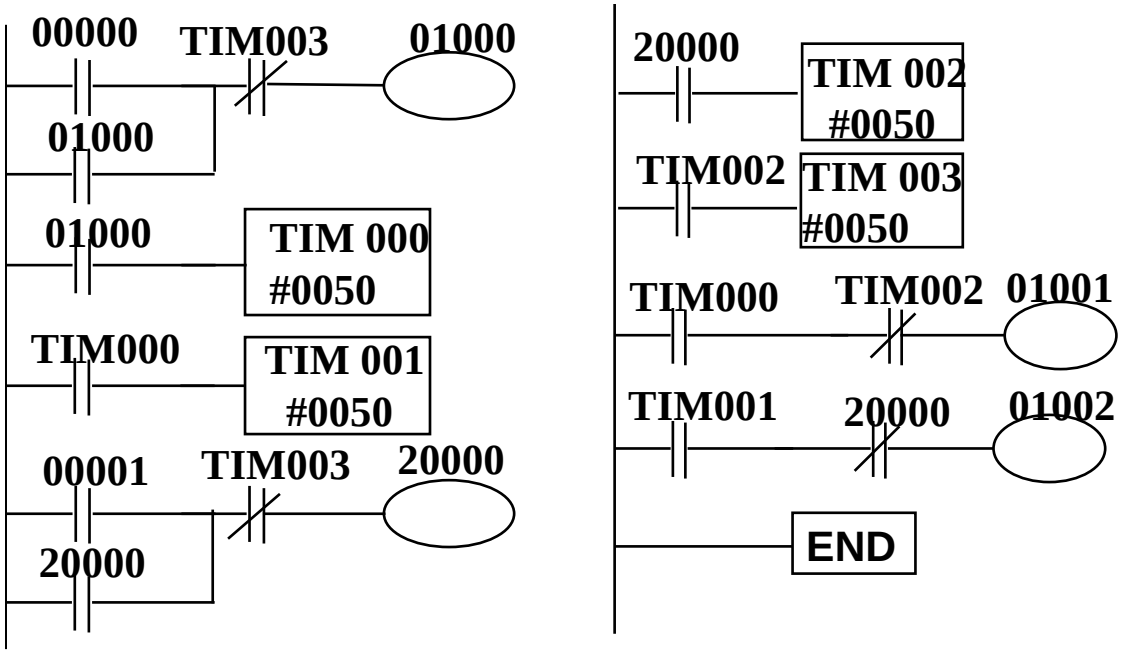






Homework

1. Off delay
2. On delay and off delay
3. Analysis the diagram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01001
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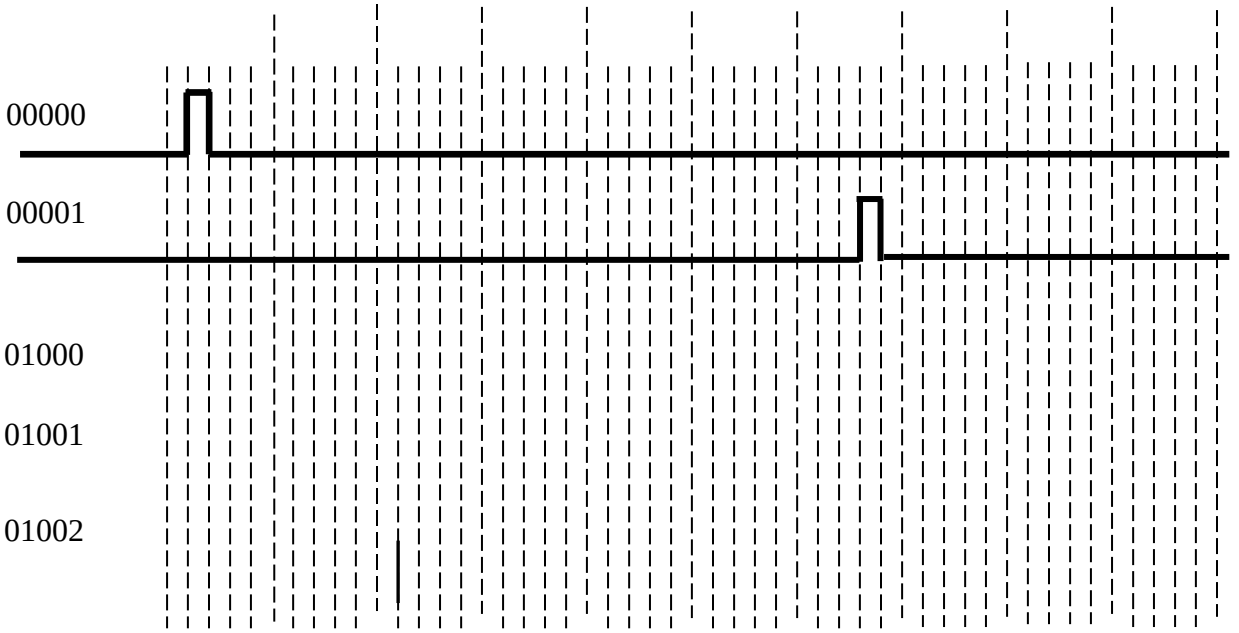
01002
END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