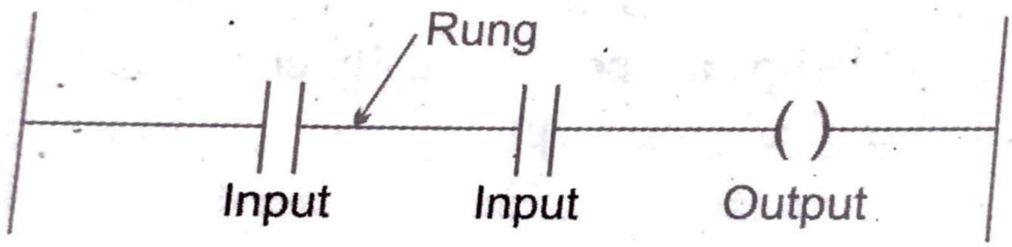
MODULE 2

The operation of an electrical system is achieved by a number of combination and sequential operations. The pre-determined sequence of operations may be called the logic combinational and the system operation. When the operational sequence is carried out with the help of relays, it is called relay-based logic whereas if it is carried out with a PLC, it is called PLC logic

Input and output Contact Program Symbols

A ladder logic diagram consists of one or more horizontal lines. Each horizontal line is called a rung. A rung is one program statement as shown in fig



Power always flows from left bus rail to the right bus rail. Suppose in a DC Circuit the left bus rail represents the positive terminal and the right bus rail represents the negative terminal.

A program statement consists of a condition or condition along with some form of action. Inputs are the conditions and the actions or the output is the result of these conditions.

Each rung of the PLC Ladder can be looked at as a problem the processor have to solve

The program symbol for a PLC input will look like a normal open or normal closed contact used in typical electrical diagrams. These symbols are shown in Table below

Table 2.1(a) Program Symbols of PLC Input

Logic	Switched on	Switched off
Normally Open –| |– (NO)	Power can flow	Power cannot flow
Normally Closed –|/|– (NC)	Power cannot flow	Power can flow

Table 2.1(b) Program Symbols of PLC Output

Logic	Symbol	Switched on	Switched off
OE	-( )-	If the input condition of the logic return a true or on false.	Otherwise

Numbering System of Inputs and Outputs

The real world switches are connected to the input terminals and the output relay and contacts are connected to the output terminals of the PLC.

The input and output terminals are grouped together and placed in modules. Each of the manufacturers produces a variety of input and output modules. Since the programmable controller may have hundreds of input or output modules, it is important to have some kind of numbering system to identify each module and all its input and output terminals.

The generalised identification numbering system of input and output terminals of a PLC consists of the following parameters:

Input/Output – Module number – Rack number – Slot number – Word number – Terminal number

Following this generalised numbering system, manufacturers prepare their own system. The Allen Bradley numbering system is ***Y : e. s / b.*** The meaning of each character has been shown in table

Y	:	e	.	s	/	b
Y = O for output terminal Y = I for input terminal	Element delimiter	Slot number (decimal). Slot 0, adjacent to the power supply in the first chassis, applies to the processor module (CPU). Succeeding slots are I/O slots, numbered from 1 to a maximum of 30.	word delimiter. Required only if a word number is necessary	word number Required if the number of inputs or outputs exceeds 16 for the slot. Range 0-255.	bit delimiter	Terminal number, Inputs 0-15, outputs 0-15.

Program Format

The basic program format for a PLC is very similar to an electrical ladder diagram. This format is used because the ladder diagram has been the working language of electricians for many years. It is also used because the computer scans the program in a sequential manner. Devices in a schematic electrical diagram are described as being open or closed. PLC ladder instructions are typically referred to as either true or false .When a PLC solves the user program, it is said to be solving ladder logic.

Ladder logic programming has some basic rules. They are:

- The power will flow from left hand side bus rail to the right hand side bus rail
- Each rung must start with a contact from the left and end with an output on the right
- Outputs cannot be connected to the left bus rail
- Contacts cannot be connected to right bus rail
- Only one output may be placed on each rung
- Each output can be used once in a program
- Inputs with the same terminal number can be used many times

Introduction to Logic

Equivalent Ladder Diagram of AND Gate

The truth table and the symbol of a two input AND gate are given in Table 2.3 and Fig. 2.3 respectively.

Table 2.3 Truth Table of AND Gate

Control signal C1 (I:0/1)	Control signal C2 (I:0/2)	Output Y (O:0/1)
0	0	0
0	1	0
1	0	0
1	1	1

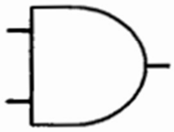


Fig. 2.3 Symbol of AND Gate

The Boolean expression is written as: **Y = A . B**

The output is high only when all the inputs are high. Therefore, the AND gate is equivalent to a series combination of normally open switches in a ladder as shown in Fig. 2.4.

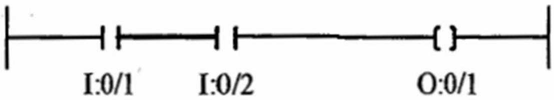


Fig. 2.4 Equivalent Logic Diagram of AND Gate

Equivalent Ladder Diagram of OR gate

The truth table and the symbol of a two input OR gate are given in Table 2.4 and Fig. 2.5 respectively.

The Boolean expression is written as: **Y = A ⊕ B**

Table 2.4 Truth Table of OR Gate

Control signal C1 (I:0/1)	Control signal C2 (I:0/2)	Output Y (O:0/1)
0	0	0
0	1	1
1	0	1
1	1	1

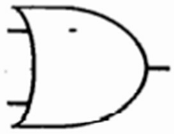


Fig. 2.5 Symbol of OR Gate

In an OR gate the output is high if any one or all of the inputs are high. Therefore, the OR gate is equivalent to a parallel combination of normally open switches in the ladder as shown in Fig. 2.6.

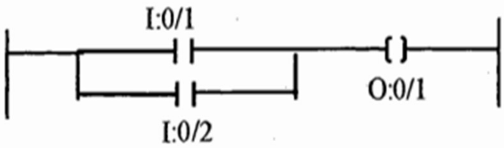


Fig. 2.6 Equivalent Logic Diagram of OR Gate

Equivalent Ladder Diagram of NOT Gate

The truth table and the symbol of a two input NOT gate are given in Table 2.5 and Fig. 2.7 respectively.

Table 2.5 Truth Table of NOT Gate

Control signal C1 I:0/1	Output O:0/1
0	1
1	0

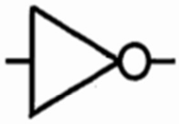


Fig. 2.7 Symbol of NOT Gate

The Boolean expression is written as: $\mathbf{Y = \bar{A}}$

The NOT gate is an inverter, and is equivalent to the XIC contact in the ladder as shown in Fig. 2.8.

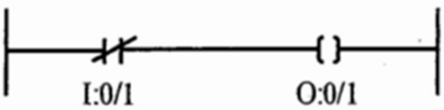


Fig. 2.8 Equivalent Logic Diagram of NOT Gate

Equivalent Ladder Diagram of XOR Gate

The truth table and the symbol of a two input XOR gate are given in Table 2.6 and Fig. 2.9 respectively.

Table 2.6 Truth Table of XOR Gate

Control signal C1 (I:0/1)	Control signal C2 (I:0/2)	Output Y (O:0/1)
0	0	0
0	1	1
1	0	1
1	1	0

Fig.2.9 Symbol of XOR Gate

For an XOR gate, the Boolean expression is: $\mathbf{Y = \bar{A}B + A\bar{B}}$.

Therefore the output of the XOR gate is 1 if one input is 1 and the other input is 0.

The equivalent ladder diagram is shown in Fig. 2.10.

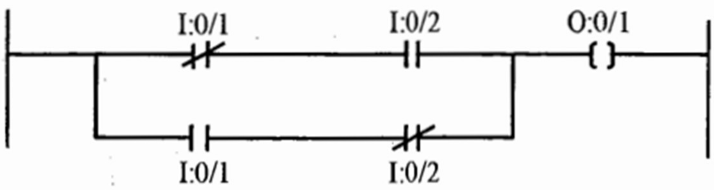


Fig. 2.10 Equivalent Logic Diagram of XOR Gate

Equivalent Ladder Diagram of NAND Gate

The truth table and the symbol of a two input NAND gate are given in Table 2.7 and Fig. 2.11 respectively.

Table 2.7 Truth Table of NAND Gate

Control signal C1 (I:0/1)	Control signal C2 (I:0/2)	Output Y (O:0/1)
0	0	1
0	1	1
1	0	1
1	1	0

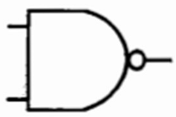


Fig. 2.11 Symbol of NAND Gate

The output of the NAND gate is zero if both the inputs are 1. Thus, a NAND gate is equivalent to a parallel combination of two XIC contacts as shown in Fig. 2.12.

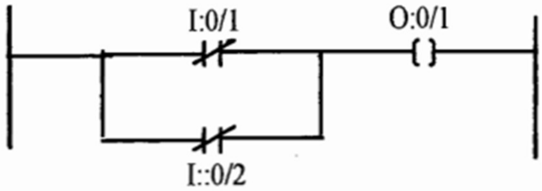


Fig. 2.12 Equivalent Logic Diagram of NAND Gate

Equivalent Ladder Diagram of NOR Gate

The truth table and the symbol of a two input NOR gate are given in Table 2.8 and Fig. 2.13 respectively.

Table 2.8 Truth Table of NOR Gate

Control signal C1 (I:0/1)	Control signal C2 (I:0/2)	Output Y (O:0/1)
0	0	1
0	1	0
1	0	0
1	1	0

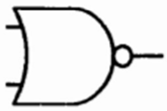


Fig. 2.13 Symbol of NOR Gate

The output of the NOR gate is 1, if and only if both the inputs are zero. Thus, the NOR gate is equivalent to a series combination of two XIC contacts as shown in Fig.2.14.

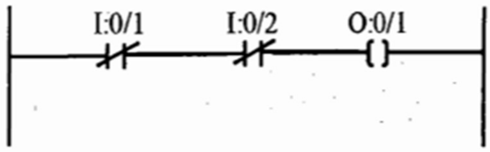


Fig. 2.14 Equivalent Logic Diagram of NOR Gate

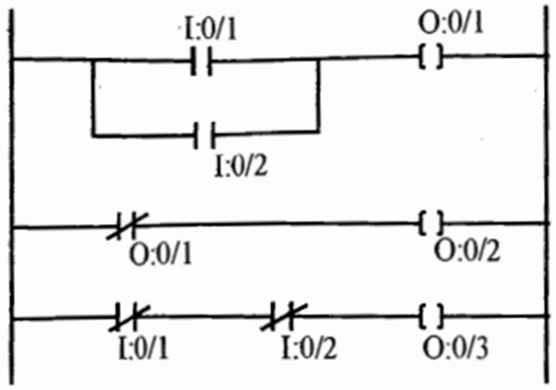
Equivalent Ladder Diagram to Demonstrate De Morgan's Theorem

Assume the inputs are connected to I:0/1 and I:0/2 and the output terminals are O:0/1 and O:0/2

1ST Theorem: Complement of a logical sum is equal to the logical product of the complements

$$\overline{A + B} = \bar{A}.\bar{B}$$

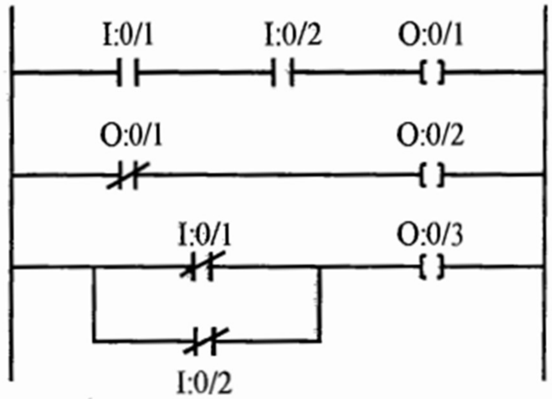
Ladder Diagram-



2nd Theorem: The complement of a logical product is equal to the logical sum of the complement

$$\overline{A.B} = \bar{A} + \bar{B}$$

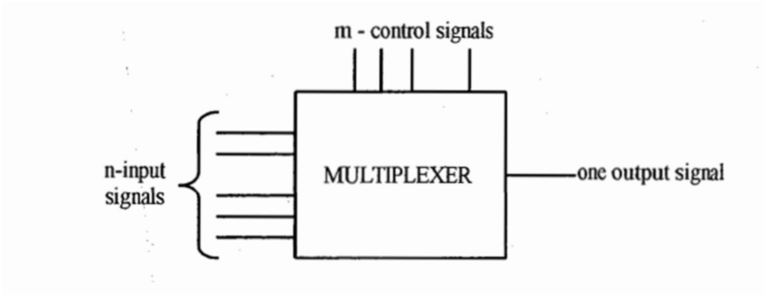
Ladder Diagram-



Problems –

Design a 4:1 multiplexer using ladder logic. Assume the inputs are connected to I:0/1 and I:0/2, I:0/3 and I:0/4; control signals are connected to I:0/5 and I:0/6 and the output terminal is O: 0/1

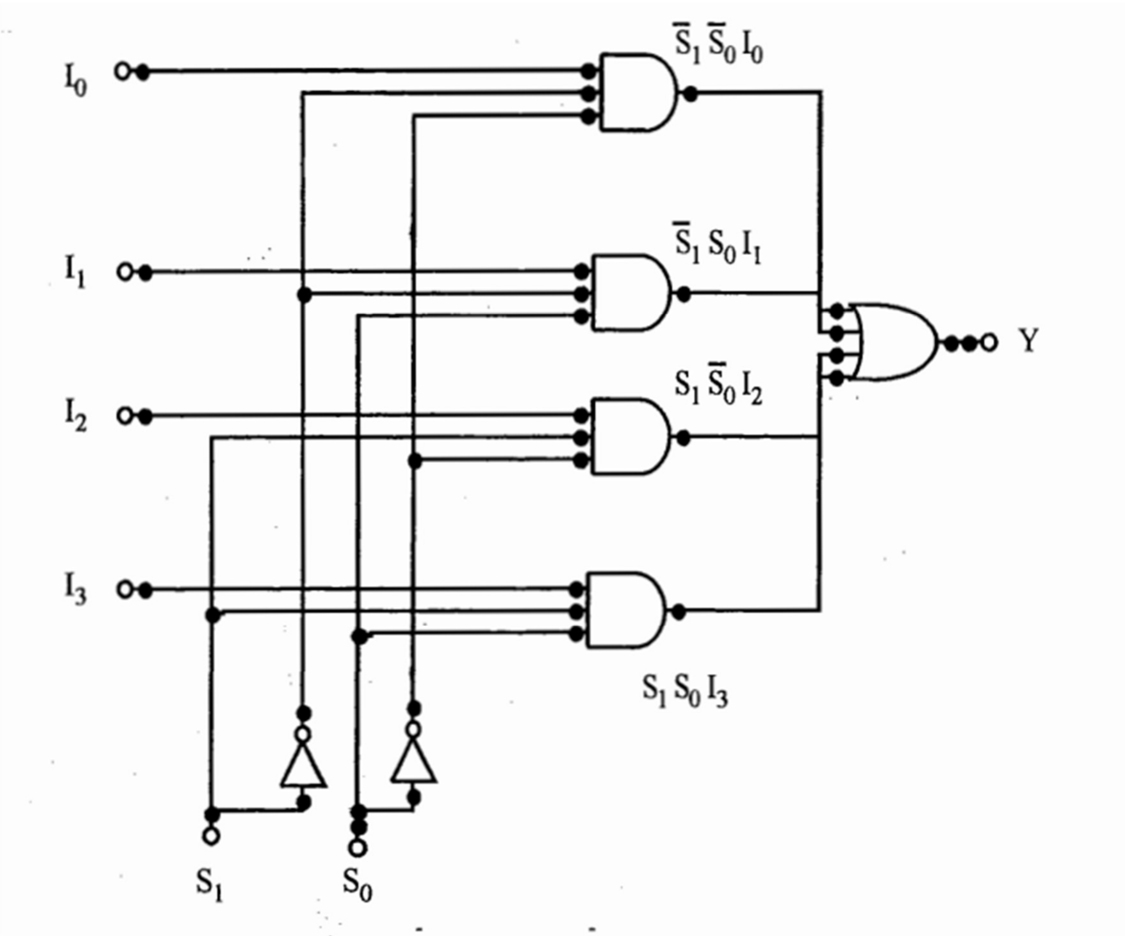
A multiplexer is a circuit with many input nut only one output. By applying a suitable control signal, any input can be steered to the output



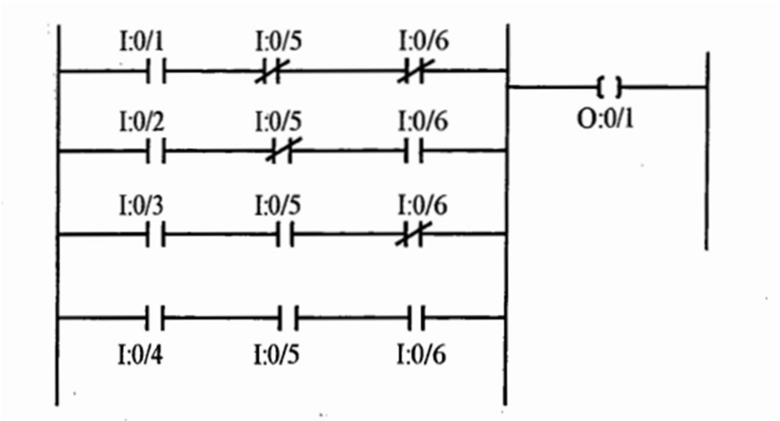
Truth Table:

Control signal S1	Control signal S2	Output Y
0	0	I_0
0	1	I_1
1	0	I_2
1	1	I_3

Circuit Diagram:

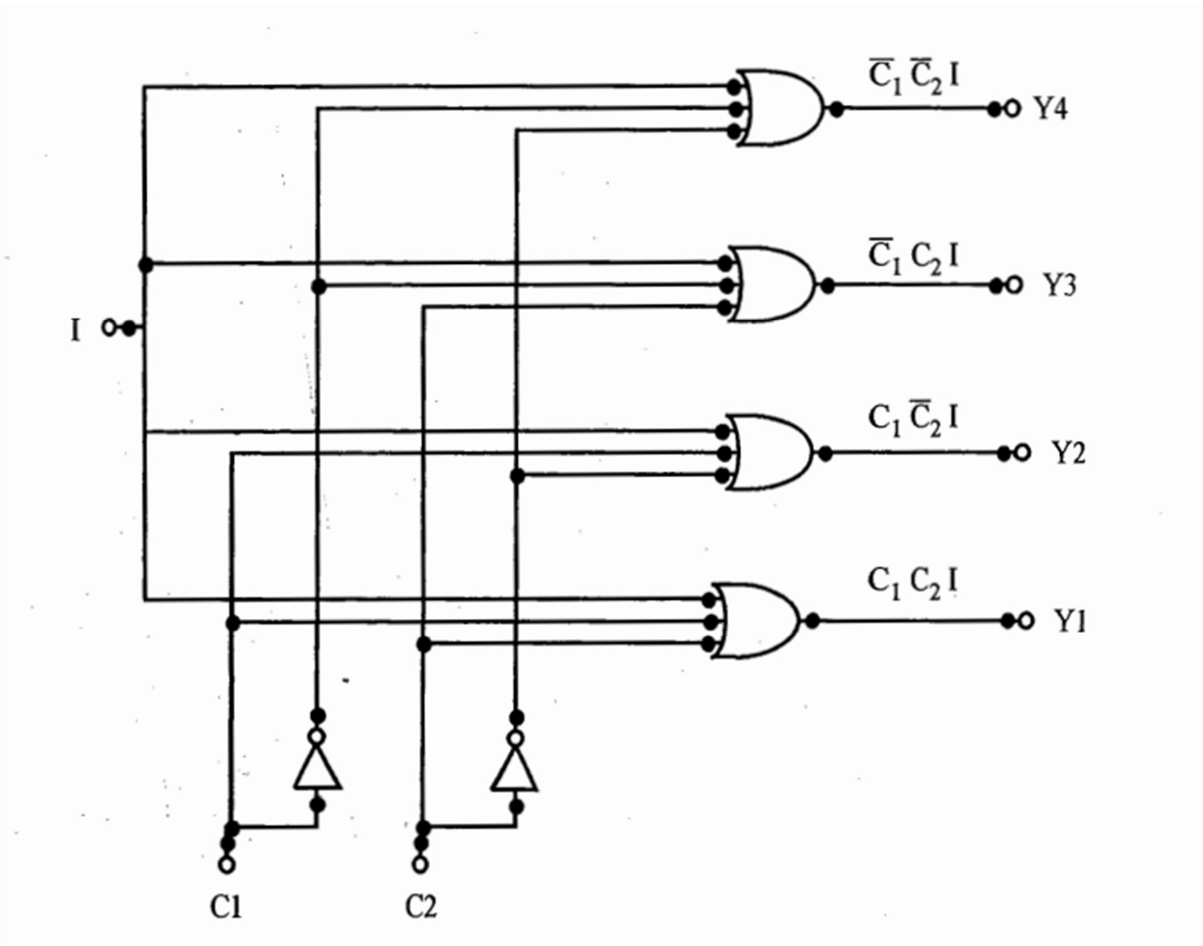


Ladder Diagram:



Problem 2: Design a 1:4 demultiplexer using ladder logic. Assume the inputs are connected to I:0/1, control signals are connected to I:0/2 and I:0/3 and the output terminals are O:0/1, O:0/2, O:0/3 and O:0/4

A demultiplexer is a circuit with one input and many outputs. By applying proper control signal, the input signal can be steered to one of the output lines

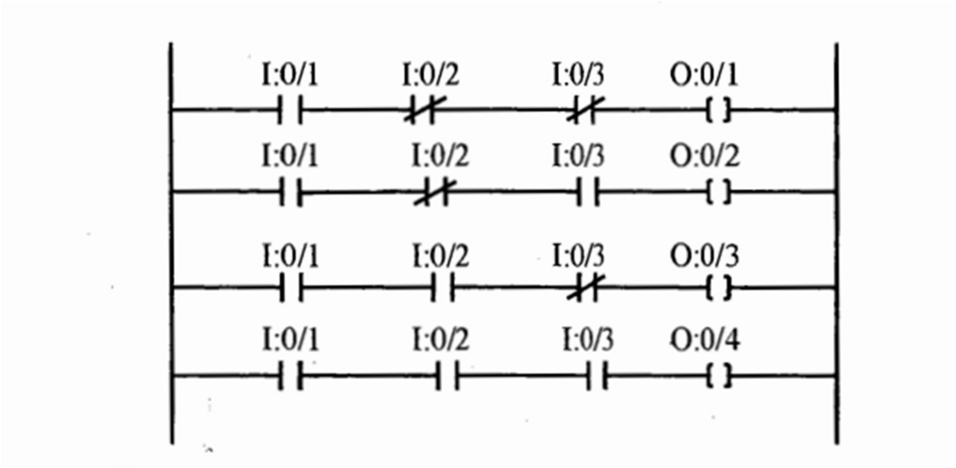


Truth Table

Table 2.10: Truth Table of 1:4 Demultiplexer

Control signal C1	Control signal C2	Output Y1	Output Y2	Output Y3	Output Y4
0	0	D	0	0	0
0	1	0	D	0	0
1	0	0	0	D	0
1	1	0	0	0	D

Ladder Diagram



Problem 3: A selection committee comprises four members including the chairman. In order for a candidate to be selected, he or she has to have the support of at least two members. The chairman, however, can push any candidate through. If each member is provide with a switch, design a logic that will ring a bell when a candidate is selected.

Assume the switch of the chairman is represented by CH, that of the the first member is by A, the second member by B and the third member by C, The inputs and the output are co0nnected to the PLC as follows:

$$CH \Rightarrow I:0/1$$
$$A \Rightarrow I:0/2$$
$$B \Rightarrow I:0/3$$
$$C \Rightarrow I:0/4$$
$$SELECT \Rightarrow O:0/1$$

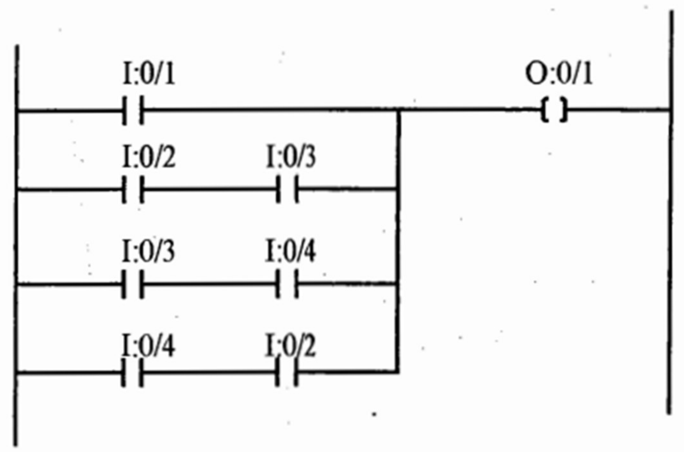
Then the logic for the desired operation can be written as

$$Y = CH$$
$$Y = A.B$$
$$Y = B.C$$
$$Y = C.A$$

Truth Table:

Input from Chairman	Input from Member A	Input from Member B	Input from Member C	OUTPUT Select
1	0	0	0	1
0	1	1	0	1
0	0	1	1	1
0	1	0	1	1

Ladder Diagram:



Problem 4: A railway station has 3 platforms A, B and C. A train is coming into the station. It has to be given entrey to platform A if A is empty. If both A and B are occupied then it has to be given entry to platform C. If all the platform are full then the train has to wait. Design the necessary logic diagram.

The input signals for the conditions described in the problem are as follows:

Ta – Train present at A

Tb – Train present at B

Tc – Train present at C

Pa – Go to platform A

Pb – Go to platform B

Pc – Go to platform C

W – Wait

The logic of the PLC can be written as

I**:0/1** – Train at A

I:0/2 – Train at B

I:0/3 – Train at C

O:0/1 – Platform A

O:0/2 – Platform B

O:0/3 – Platform C

O:0/4 – Wait

Truth Table:

Input Ta	Input Tb	Input Tc	Output Pa	Output Pb	Output Pc	Output W
0	X	X	1	0	0	0
1	0	X	0	1	0	0
1	1	0	0	0	1	0
1	1	1	0	0	0	1

Ladder Diagram: