UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 7 Examination in Engineering: November 2019

Module Number: ME7313 **Module Name: Industrial Automation and Control**

[Three Hours]

[Answer **all questions**, each question carries **10** marks]

Clearly state all assumptions that you may make. Refer Annex – A and Annex – B for standard symbols.

Q1. i) Explain four factors that will determine the pace and extent of automation of processes or systems of an organization. Give suitable examples.

(2 Marks)

ii) Compare and contrast four main levels of controlling in the hierarchy of an industrial automation. List examples for controllers used in each level.

(3 Marks)

iii) Describe the measuring principles, operation, types and practical applications of following sensors with suitable sketches.

(a) Strain gauge
(b) Capacitive sensor
(c) Inductive proximity sensor
(d) Linear Variable Differential Transformer (LVDT)
(e) Digital optical encoder

(5 Marks)

Q2. i) List main components of an industrial compressed air preparation and utilization system (related to industrial automation) in the order of their position. Briefly explain function and importance of each component.

(3 Marks)

ii) Explain with suitable pneumatic circuits, how to use pressure-based and time-based control to control operation of a double acting cylinder by detecting its end position.

(2 Marks)

iii) A system designed for automatic drilling of a work piece is shown in Figure Q2(iii). A double acting cylinder is connected to the drill to move it up and down, and single acting cylinder is used to clamp the work piece until the drilling operation is finished. Four limit switches are positioned to detect the cylinders' positions as shown. Work pieces are manually placed on the vice for drilling and when the start pushbutton (PB) is pressed.

(a) Design the complete pneumatic circuit for the above task and explain its operation.

(b) Draw displacement – step diagram for both cylinders.

(c) Design electro-pneumatic circuit for the automatic operation that includes the PB, contacts for forward and reverse operation of the motor for drilling and return.

(5 Marks)

Q3. i) Briefly describe unitary PLCs, modular type and rack-mounted PLCs. Compare their operational characteristics.

(2 Marks)

ii) A lifting device shown in Figure Q3(ii)-1 transfers workpieces from one roller conveyor at the lower position to another at the upper position. There are three pneumatic drives to drive cylinder 1A that lifts the workpieces, to drive cylinder 2A that pushes the workpieces onto the upper roller conveyor, and to drive cylinder 3Athat is used as a stopper, for releasing and interrupting the supply of workpieces. Table Q3(iii) summarizes the moving cycle of three pneumatic drives. Assume that a PLC (24VDC) is used to control the operations of the device with two control modes;

- Single cycle operating mode: Sequence in the Table Q3(ii) is processes precisely once. This will actuate using the pushbutton (Single cycle Start) of the control panel shown in Figure Q3(ii)-2.
- Continues cycle operating mode: With the input from the pushbutton (Continues cycle ON) in the control panel, device will run in a continues cycle operation until stopped by pressing the pushbutton: Continues cycle OFF.

1B1, 1B2, 2B1, 2B2, and 3B1 are limit switches that indicate cylinder positions 1A, 2A and 3A respectively. B5 and B6 are limit switches that are positioned to identify presence of packages on the lifting position and the stopper position respectively.

Table Q(ii): Sequence of operations

Step	Cylinder 1A movement	Cylinder 2A movement	Cylinder 3A movement	End of step, step enabling condition	Comments
1	None	None	Retract	B5 triggered indicating a package is present	Start device
2	Advance	None	Advance	1B2 triggered	Lift package
3	None	Advance	None	2B triggered	Push out package
4	Retract	Retract	None	1B1, 2B1 triggered	Retract drives to initial positions

Control panel inputs executes the following operations;

- Main Switch: A toggle switch that has two positions to connect and disconnect the main power supply (single phase, 230VAC) to the drive system and the controller.
- Emergency Stop: When this is actuated, not only the electrical power supply, also the pneumatic power supply must be shut down.
- Automatic: A pushbutton that will enable the automatic operation and this should be enabled to have single cycle and continues cycle operations.
- Manual: A pushbutton that enable the manual mode
- Reset: A pushbutton that returns the system to the initial position, i.e. the piston rods of cylinders 1A and 2A retract, the piston rod of cylinder 3A extends.

In addition, all the system consists of main power supply indicator lamp, and indicators for each pushbutton operation to indicate specified operations. Single cycle and continues cycle are needed to be started with 1 second delay after certain input enable and number of continues operations to be counted it clears by the reset pushbutton.

(a) Design the PLC wiring diagram showing all inputs and outputs.

Q3 continued to next page

(b) Draw complete electrical wiring diagram.

(c) Design electropneumatic circuits showing three pneumatic drives and assigning pilot control for drive 1A.

(d) Design the PLC ladder logic program for the complete device operation.

(8 Marks)

Q4. (i) The PLC is a sequential control device, which can sequentially and repeatedly activate a series of output devices on the basis of the states of a series of input devices. A PLC and a vision system consisting of a digital camera and a simple image processor (say, with an edge-detection algorithm) are planned to be used for sorting fruits on the basis of quality and size for packaging and pricing. Assume that the vision system (the digital camera and the image processor) above provide six outputs; V1: small size, V2: medium size, V3: large size, V4: ripen, V5: not-ripen, V6: error (cannot recognized/ not a certain fruit)

(a) Design an automated system to process the above operations fully automatically. You may use suitable sketches to describe your design that includes proper loading, unloading, transportation, detection, sorting units (in to small, medium, large, ripen and not-ripen) and display/ monitoring unit.

(b) State all the specifications of the system you designed above.

(c) Draw PLC wiring diagram and design PLC ladder logic program.

(6 Marks)

(ii) It is planned to implement a measurement system to evaluate the sorting of fruits. Describe the meaning and how to practice it related to the sorting system automated above. You may use random samples to observe the performance of the automated system. Compare differences between manual sorting and automated sorting with respect to;

(a) Accuracy
(b) Precision
(c) Uncertainty
(d) Repeatability
(e) Reproducibility

(4 Marks)

Q5. Assume you are an engineer who has been assigned the task of designing and instrumenting a packaging and labeling system for raw eggs (packet size with 6 and 10 eggs). In the project reports, you have to describe the steps of establishing the design/performance specifications for the system, selecting and sizing sensors, actuators, drive systems, controllers, signal conditioning and interface hardware, and software for the fully or semi-automation of such systems. Keeping this in mind, answer following. for both the systems above separately:

i) Describe the system indicating the purpose of the system for high quality packaging and labeling, how the system operates, what are the important inputs, response or output variables to be measured to have open loop or close-loop control appropriate for the system operation. You may use suitable sketches.

(2 Marks)

Q5 continued to next page

ii) Propose suitable controller(s) and indicate the operation of the controller(s) in the system. List five specifications required to select suitable controller modal/ brand.

(2 Marks)

iii) Give any constraints related to cost, size, weight, handling of the system and its operation environment.

(1 Mark)

v) List the sensors required to automate the system, indicate the type and prepare four specifications.

(2 Marks)

vi) List actuators and drive systems present in such systems and indicate the type and which of these actuators have to be controlled. Prepare four specifications for each actuator that you have proposed.

(2 Marks)

vii) Describe how the users or the operators interact with the system, and the user interface requirements.

(1 Mark)

Q6 i) According to BCC Research analyst *Lisa Marshall* in a press release on the technological revolution in material handling, advanced technologies such as robotics, autonomous control, driverless vehicles, and wearable computing will be key drivers of Automated Material Handling (AMH) growth over the next 15–20 years.

(a) Briefly explain four factors to be considered when planning an AHM in general.

(b) Compare and contrast Automated Guided Vehicle (AGV) over Autonomous Mobile Robots (AMR) related industrial material handling.

(3 Marks)

ii) A Supervisory Control and Data Acquisition (SCADA) is a collection of software and hardware systems that allows supervision and control of plants locally and remotely and real-time. You may refer your experience and observations of the field visit to Ceylon Cold Stores to support your answers.

(a) Sketch, indicate and briefly describe main components of a SCADA system.

(b) There is a confusion between SCADA system and Human Machine Interface (HMI) because of their similarity. Explain the difference between SCADA and HMI.

(3 Marks)

iii) Speed Drives are used in any applications in which there is mechanical equipment powered by motors. The drives provide extremely precise electrical motor control so that motor speeds can be ramped up and down, and maintained, at speeds required. By doing so utilizes only the energy required, rather than having a motor run at constant (fixed) speed and utilizing an excess of energy.

(a) Explain the function of a Variable Frequency Drive (VFD) by giving an example on simple control of water pump.

(b) What is a soft starter related to driving of AC motors?

Q6 continued to next page

(c) The VFD is a basically a soft starter with speed control. Give two real-world applications where AC motor controlling is required and, compare and contrast the suitability of the VFD with the suitability the soft starter.

(4 Marks)

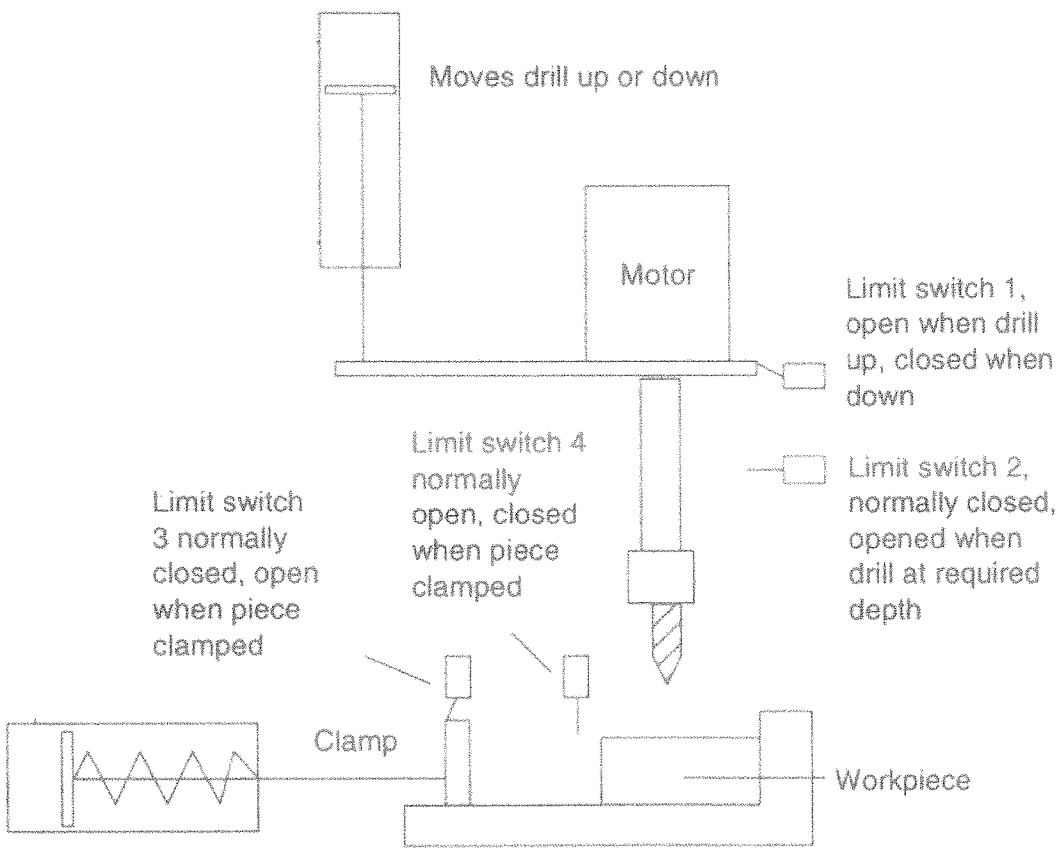


Figure Q2(iii): Automatic drill

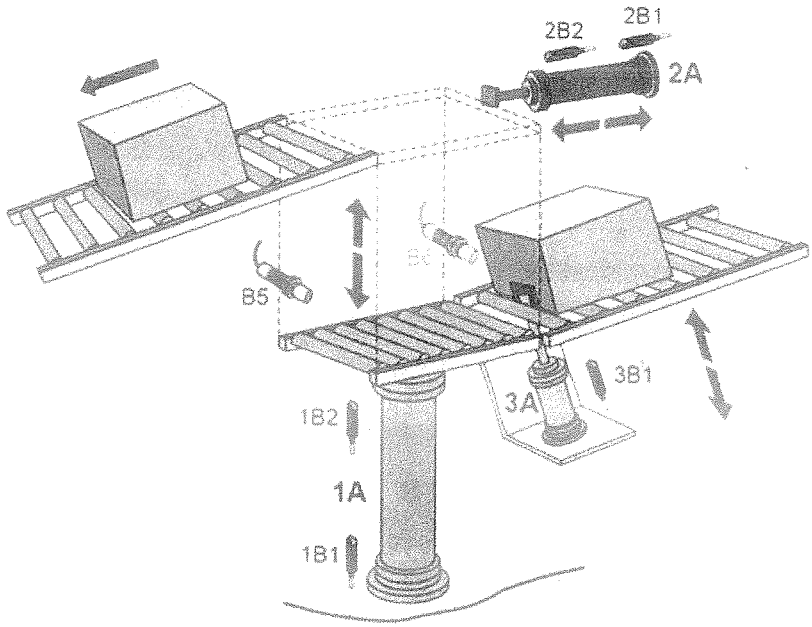


Figure Q3(ii)-1: Lifting device (A: Pneumatic drives, B: Limit switches)

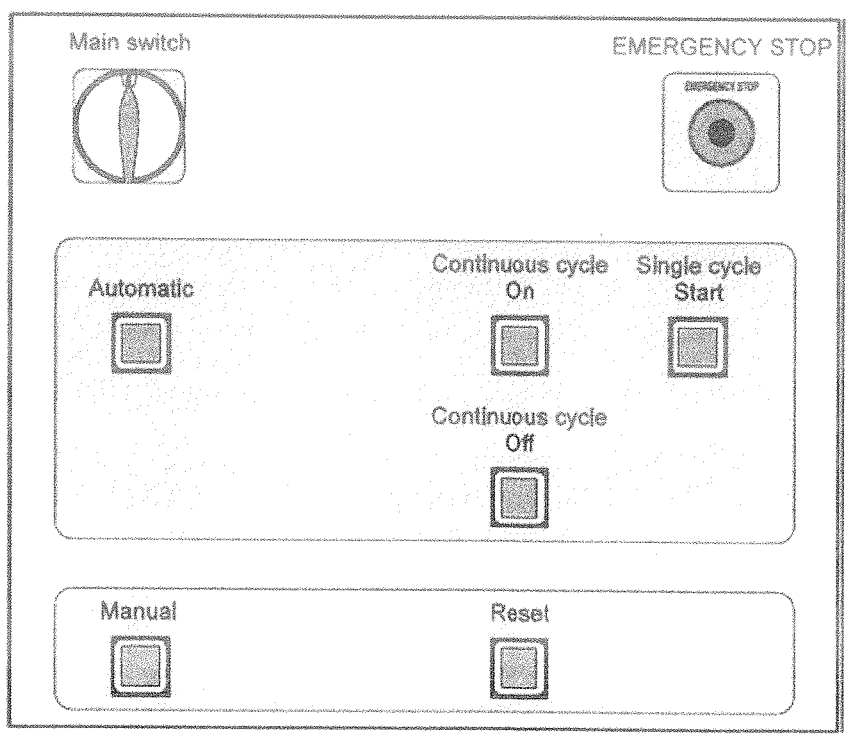
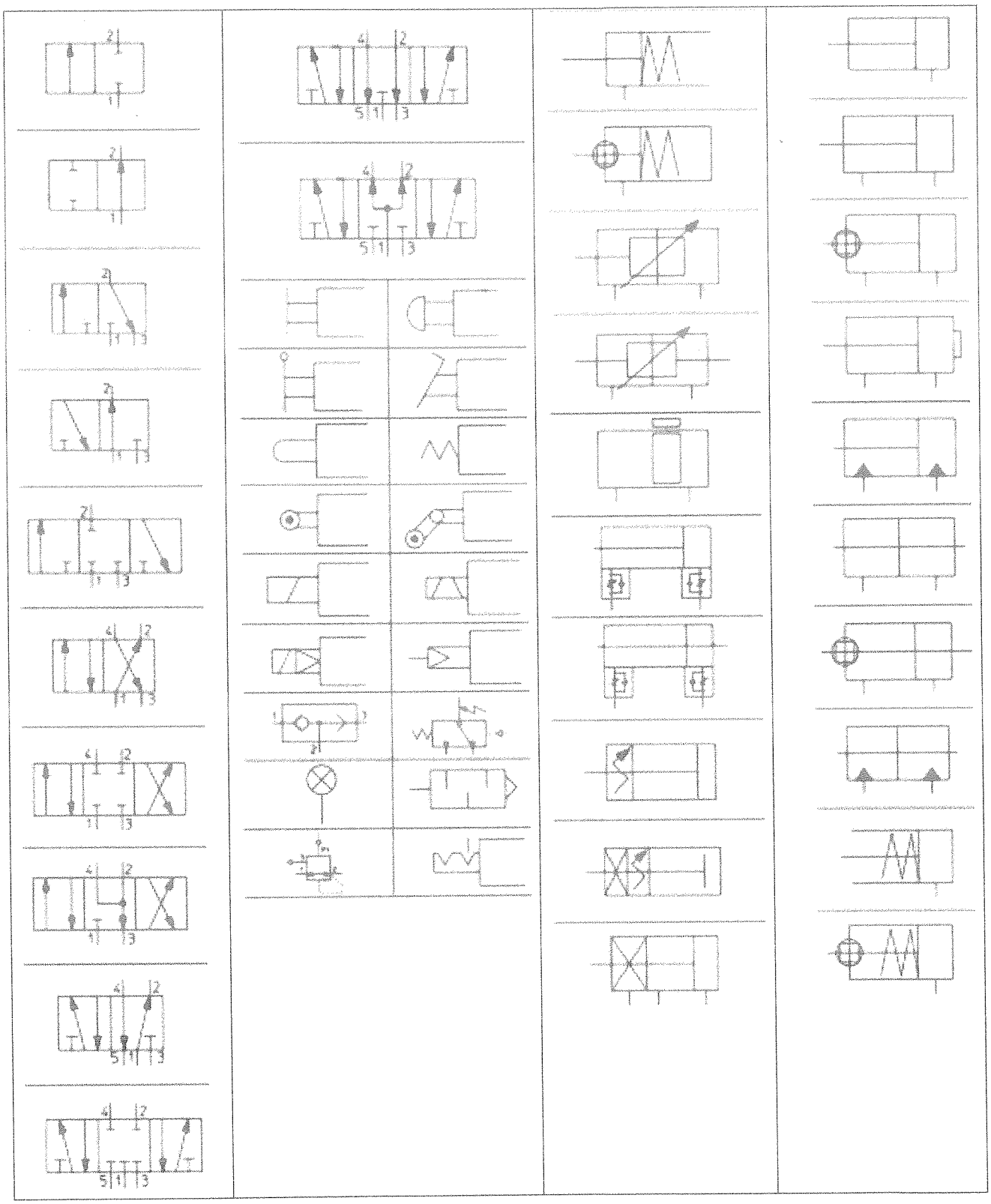


Figure Q3(ii)-2: Control panel of the lifting device

Annex – A: Pneumatic symbols

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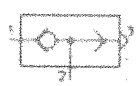
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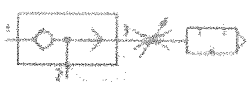
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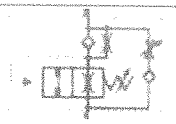
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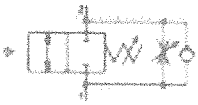
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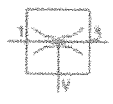
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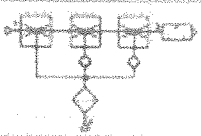
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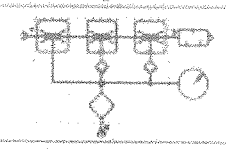
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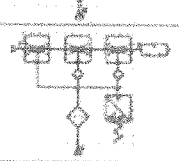
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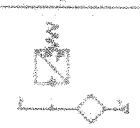
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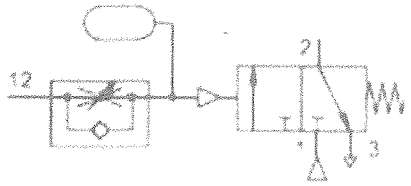
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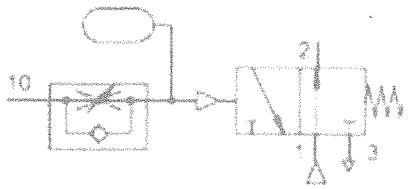
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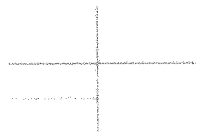
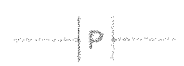
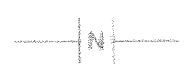
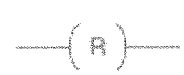
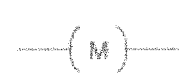
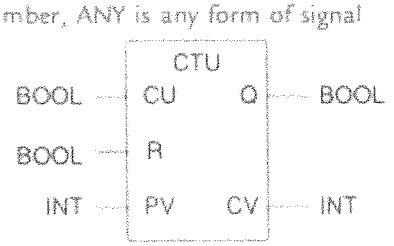
A horizontal link along which power can flow	
Interconnection of horizontal and vertical power flows	
Left-hand power connection of a ladder rung	
Right-hand power connection of a ladder rung	
Normally open contact	
Normally closed contact	
Positive transition-sensing contact, power flow occurs when associated variable changes from 0 to 1.	
Negative tranistion-sensing contact, power flow occurs when assoaciated variable changes from 1 to 0	
Output coil: if the power flow to it is on then the coil state is on	
Set coil	
Reset coil	
Retentive memory coil, the state of the associated variable is retained on PLC power fail	

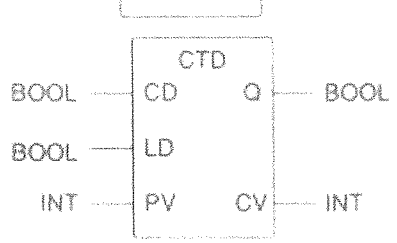
Commonly Encountered Blocks

BOOL is a Boolean signal, INT is an integer, REAL is a floating point number, ANY is any form of signal

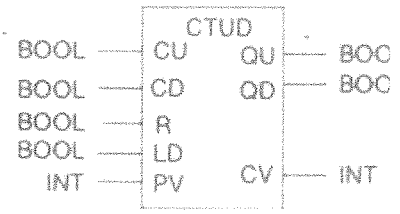
Up-counter counts the number of rising edges at input CU. PV defines the maximum value of the counter. Each new rising edge at CU increments CV by 1. Output Q occurs after set count. R is the reset.



Down-counter counts down the number of rising edges at input CU. PV defines the starting value of the counter. Each new rising edge at CU decrements CV by 1. Output Q occurs when count reaches zero.



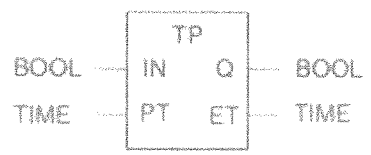
Up-down counter. It can be used to count up on one input and down on the other.



On-delay timer. When input IN goes true, the elapsed time at about ET starts to increase and when it reaches the set time, specified by input PT, the output Q goes true.

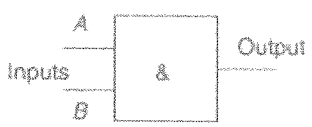
Off-delay timer. When input IN goes true, the output Q follows and remains true for the set time after which the input Q goes false.

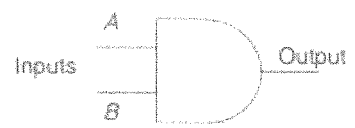
Pulse timer. When input IN goes true, output Q follows and remains true for the pulse duration specified by input PT.



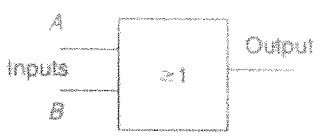
Logic Gates

AND gate

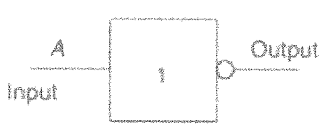


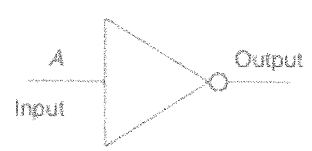


OR gate

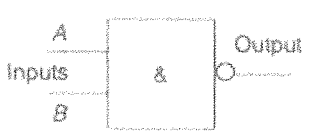


NOT gate





NAND gate



NOR Gate