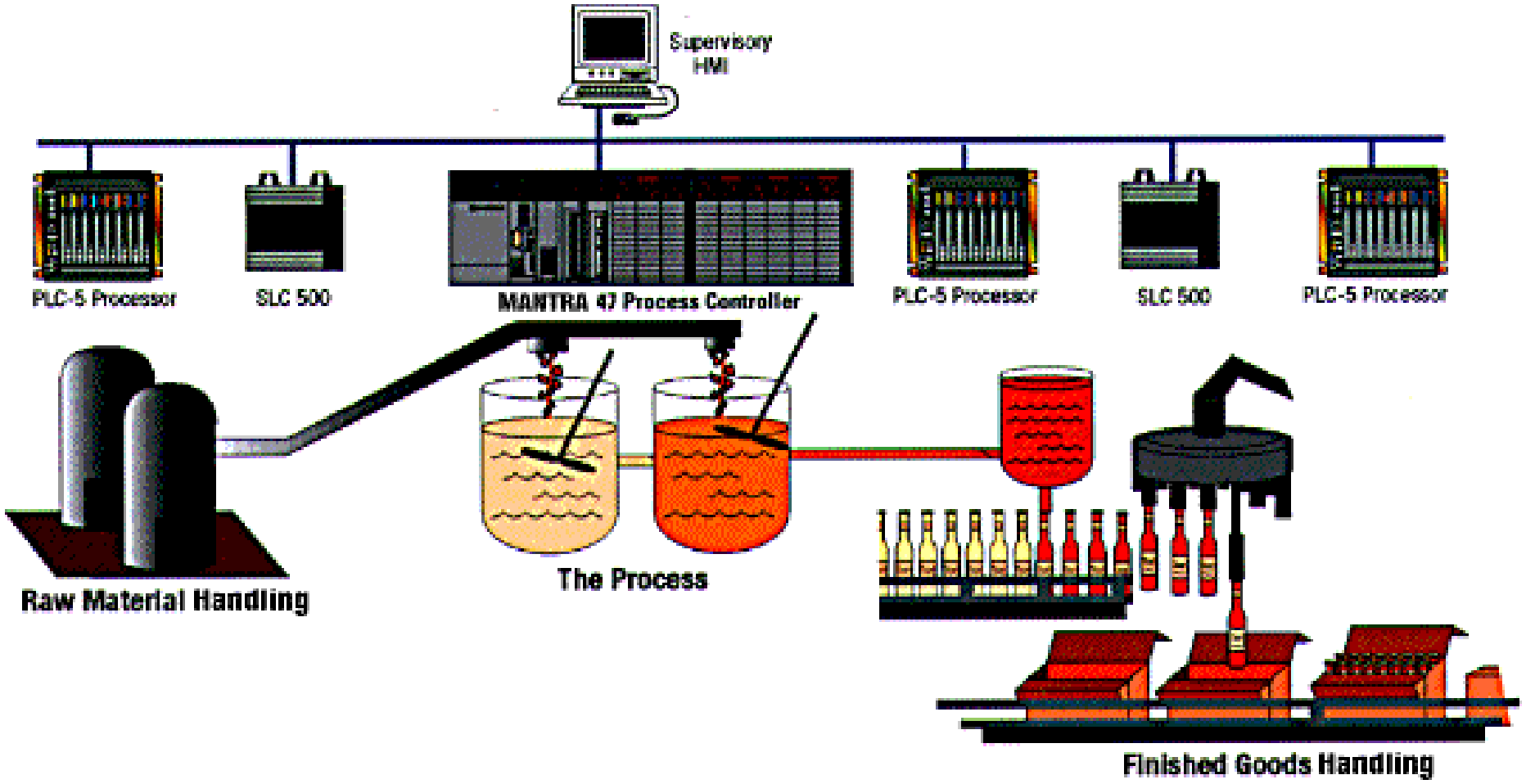
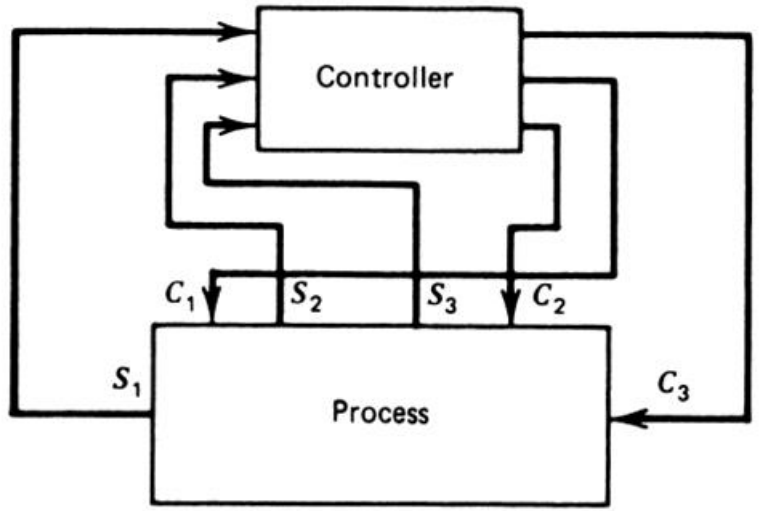
# Discrete State Process Control using Programmable Logic Controllers

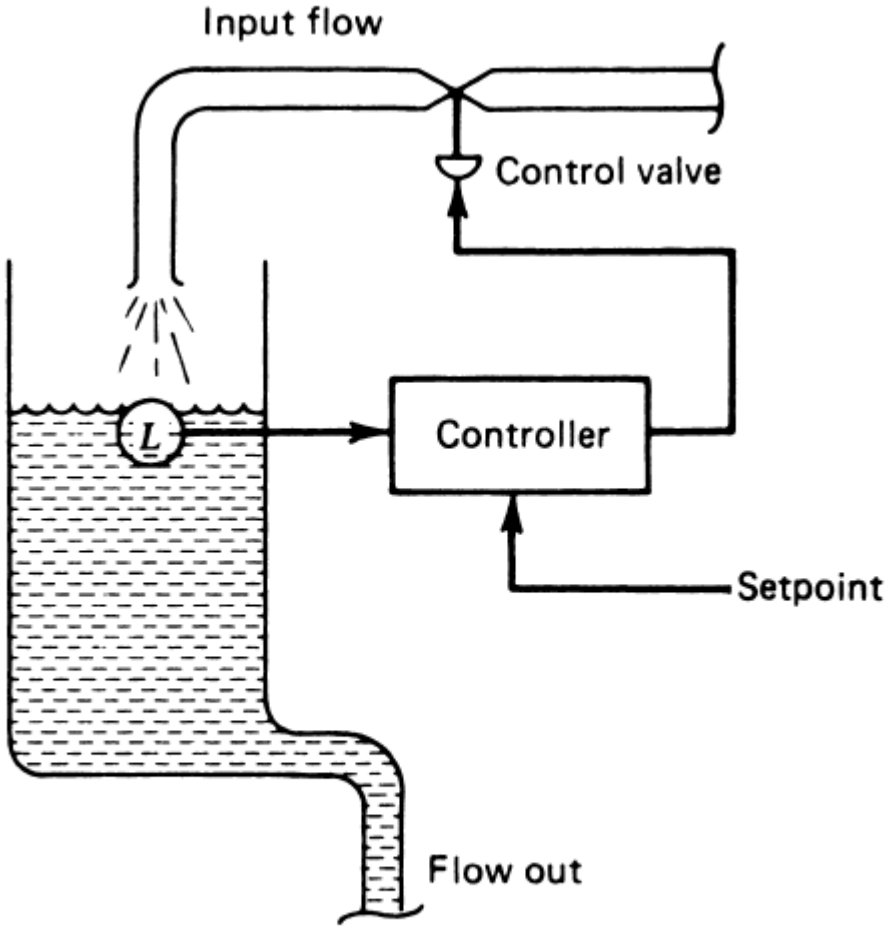


# Discrete State Process Control

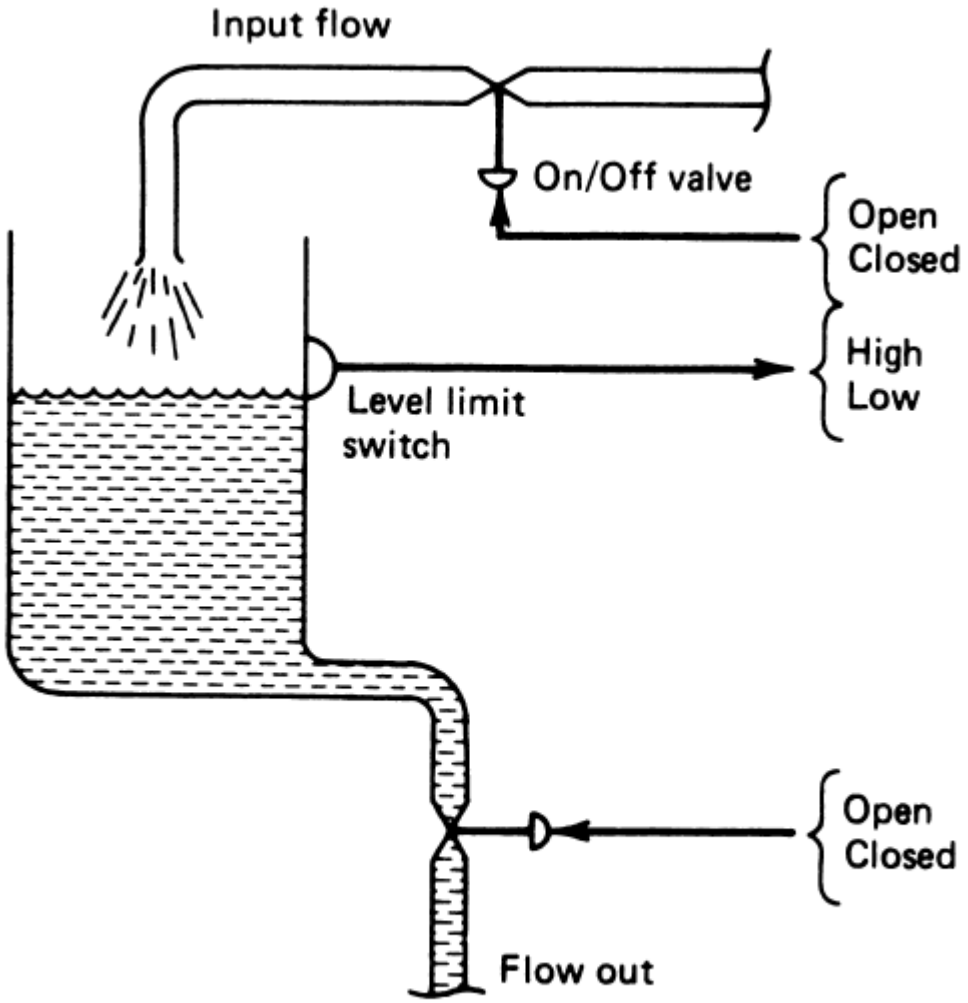
- Suppose that all measurement input variables and all control output variables of the process can take on or be assigned only two values. For example, valves are open/closed, motors are on/off, temperature is high/low, limit switches are closed/open, and so on.
- We define a discrete state of the process at any moment to be the set of all input and output values. Each state is discrete in the sense that there is only a discrete number of possible states.
- As per Figure, there are three input variables (out of process) and three output variables (input of process) , then a state consists of specification of all six values. Because each variable can take on two values, there is a total of 64 possible states.
- An event in the system is defined by a particular state of the system that is, particular assignment of all output values and a particular set of the input variables. The event lasts for as long as the input variables remain in the same state and the output variables are left in the assigned state.
- Example: for a simple oven, we can have the temperature low and the heater on. This state is an event that will last until the temperature rises.



# Discrete State Process Control



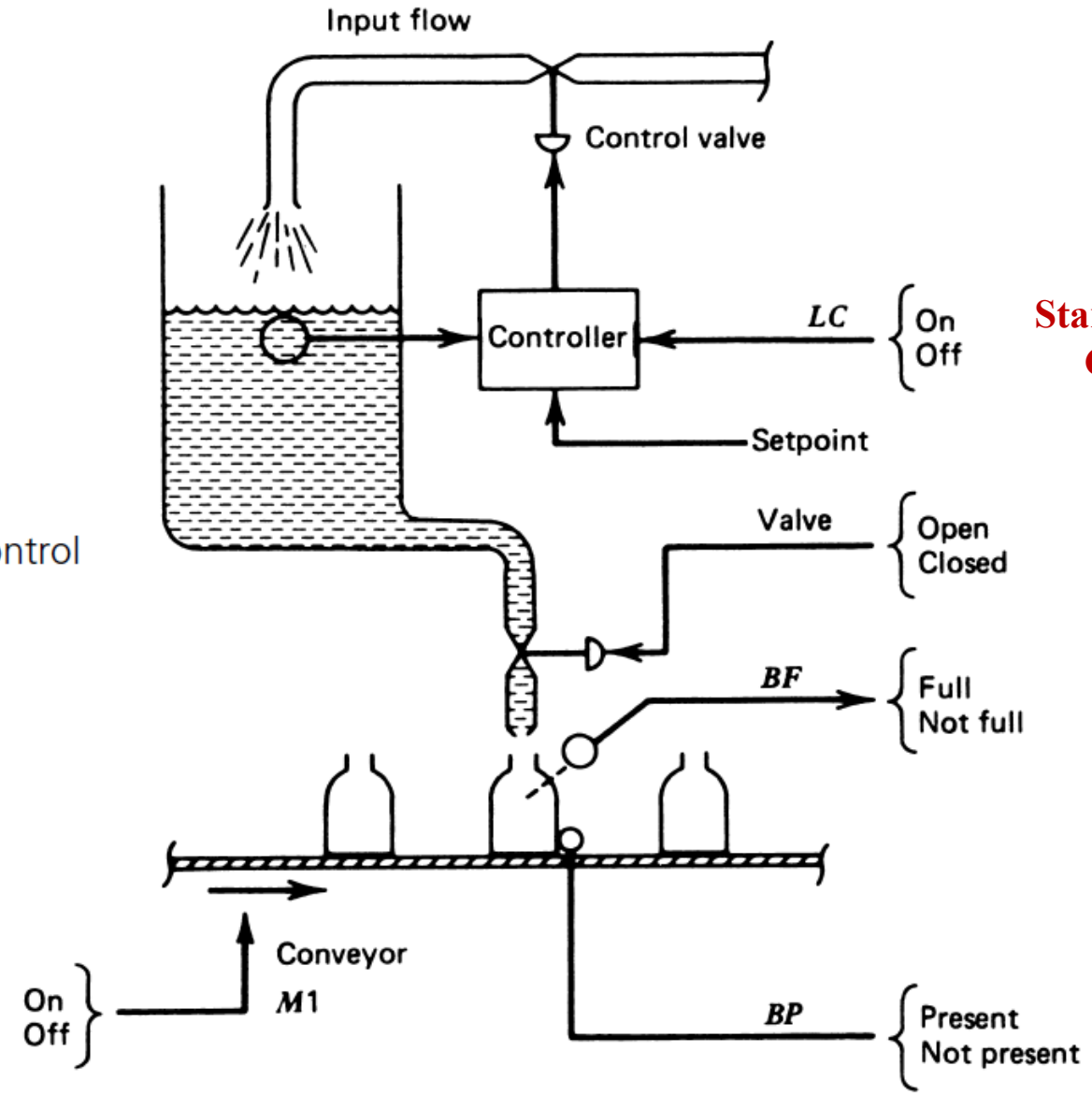

Continuous control of level




Discrete control of level

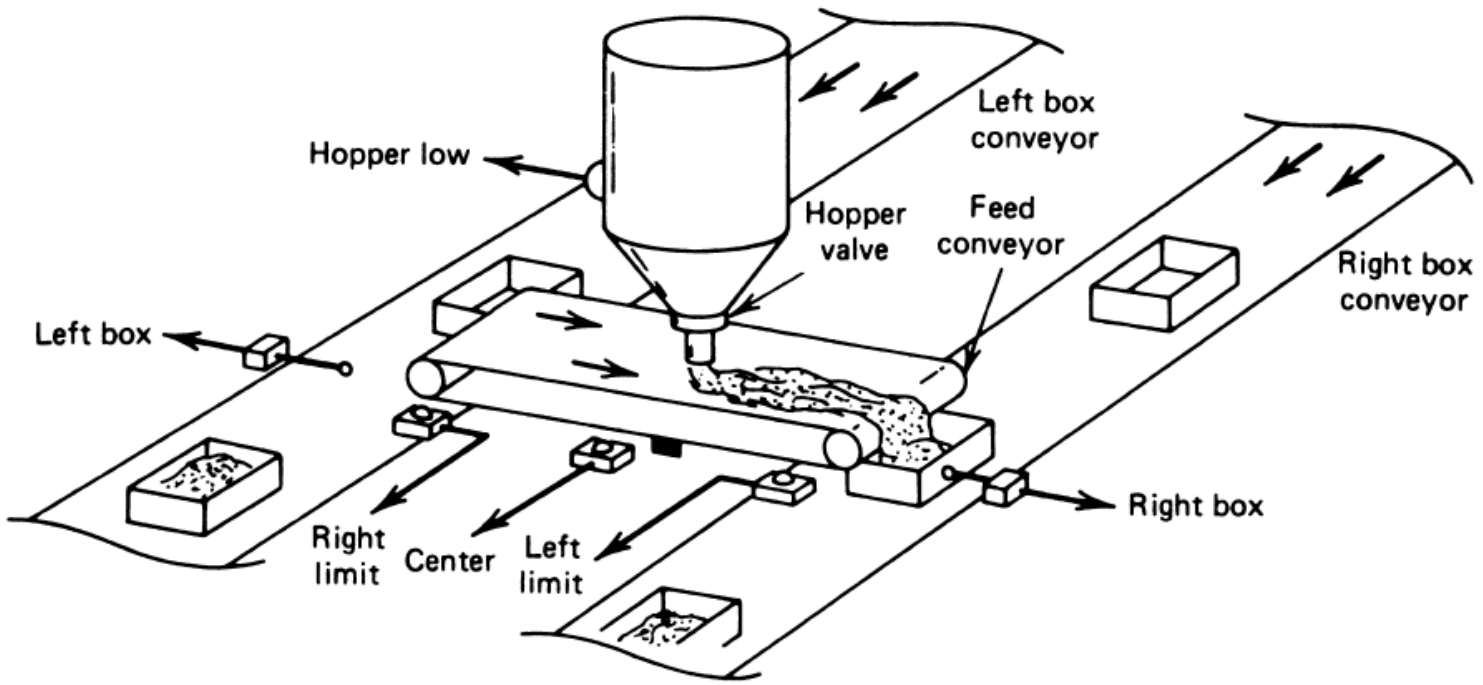
# Composite Process Control

Composite continuous and discrete control




**Start/Stop level Controller**

# Discrete State Process Control: Process Hardware




**"Figure above shows a pictorial representation of process hardware for a conveyor system. The objective is to fill boxes moving on two conveyors from a common feed hopper and material-conveyor system"**

*Input Devices (All Switches)*

- Right box present
- Left box present
- Feed conveyor right travel limit
- Feed conveyor left travel limit
- Hopper low
- Feed conveyor center

*Output Devices*

- Hopper valve solenoid
- Feed stock conveyor motor off
- Feed stock conveyor motor right
- Feed stock conveyor motor left
- Right box conveyor motor
- Left box conveyor motor

# Discrete State Process Control: Event Sequence by Narrative Statements

**"After the objectives of a process and the necessary hardware have been defined, the job remains to describe how this hardware will be manipulated to accomplish the objective"**

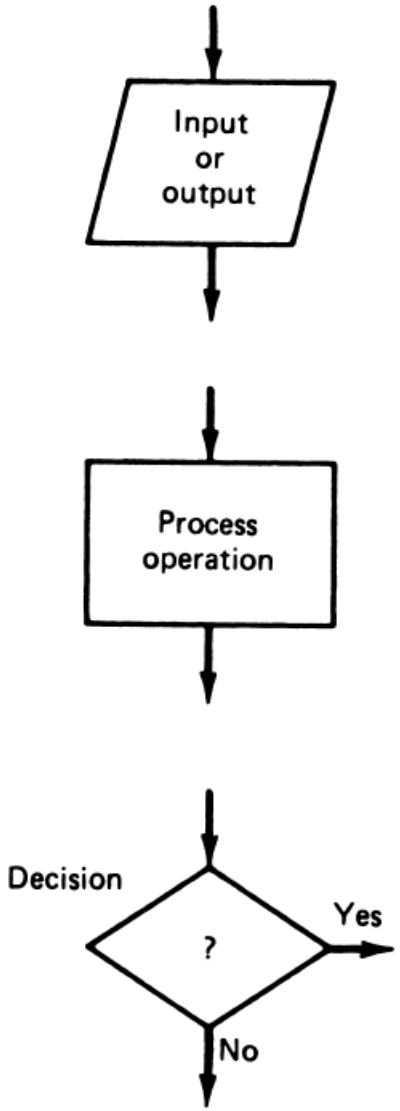
**I.** Initialization Phase
- **A.** All motors off, feed valve solenoid off
- **B.** Test for right limit switch
  - **1.** If engaged, go to C
  - **2.** If not, set feed motor for right motion
  - **3.** Start feed-conveyor motor
  - **4.** Test for right limit switch
    - **a.** If engaged, go to C
    - **b.** If not, go to 4
- **C.** Set feed motor for left motion and start
- **D.** Test for center switch
  - **1.** If engaged, go to E
  - **2.** If not, go to D
- **E.** Open hopper-feed valve
- **F.** Test for left limit switch
  - **1.** If engaged, go to G
  - **2.** If not, go to F
- **G.** All motors off, hopper-feed valve closed
- **H.** Go to running phase

**I.** Running
- **A.** Start right box conveyor
- **B.** Test right box present switch
  - **1.** If set, go to C
  - **2.** If not, go to B
- **C.** Start feed-conveyor motor, right motion
- **D.** Test center switch
  - **1.** If engaged, go to E
  - **2.** If not, go to D
- **E.** Open hopper-feed valve
- **F.** Test right limit switch
  - **1.** If engaged, go to G
  - **2.** If not, go to F
- **G.** Close hopper-feed valve, stop feed conveyor
- **H.** Start left box conveyor
- **I.** Test left box present switch
  - **1.** If set, go to J
  - **2.** If not, go to I
- **J.** Start feed conveyor, left motion
- **K.** Test center switch
  - **1.** If engaged, go to L
  - **2.** If not, go to K
- **L.** Open hopper-feed valve
- **M.** Test left limit switch
  - **1.** If engaged, go to II.A
  - **2.** If not, go to M

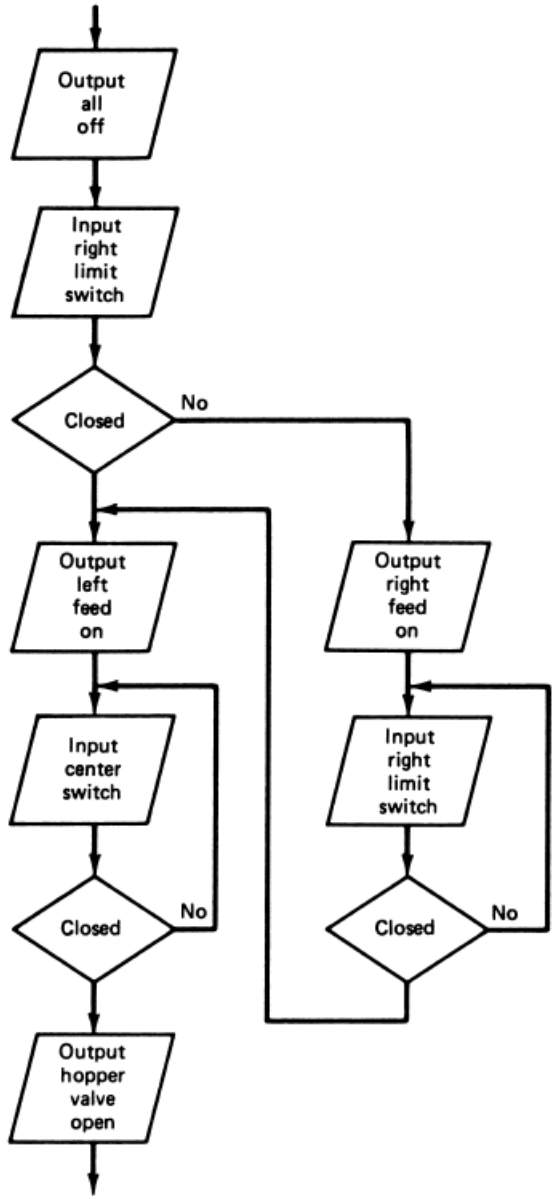
**"Narrative Statements: Specification of the sequence of events starts with narrative descriptions of what events must occur to achieve the objective"**

# Discrete State Process Control:
## Event Sequence by Flowcharts

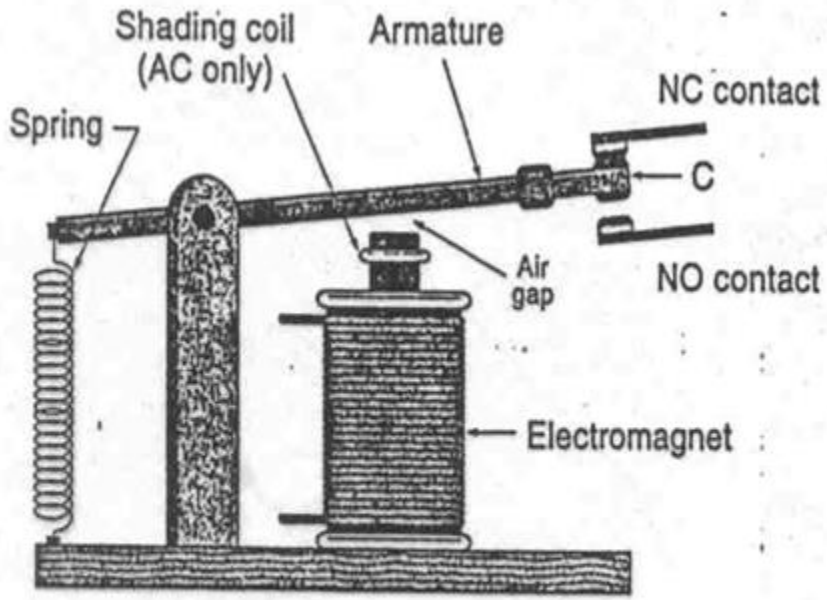
Basic flowchart symbols



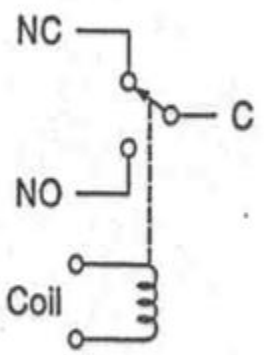

initialization flowchart



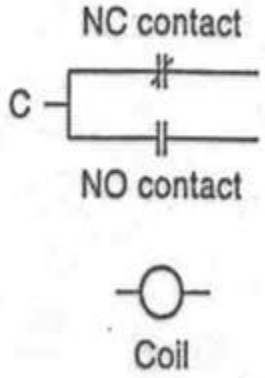
# Relay Based Controllers: Relay




(a) Parts of the relay

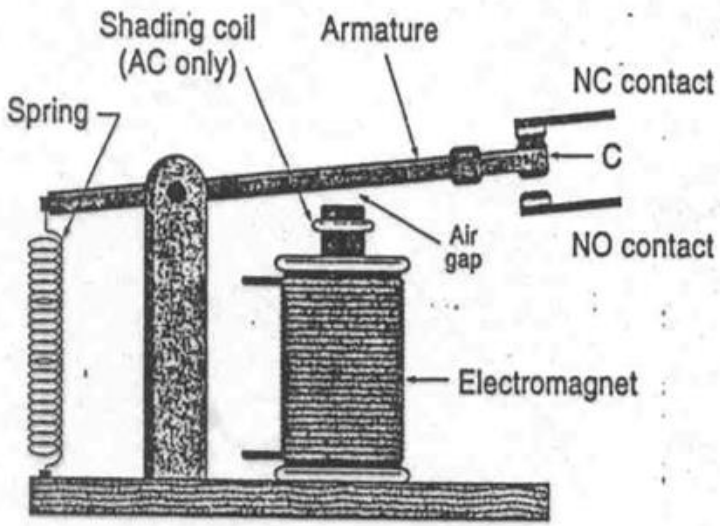



(b) A common schematic symbol

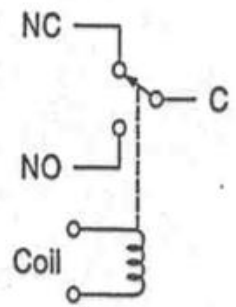



(c) Schematic symbol for a ladder diagram

# Relay Based Controllers: Relay




(a) Parts of the relay

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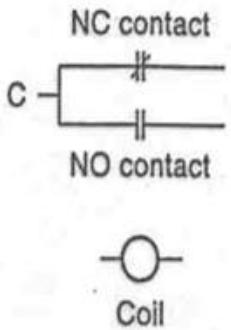
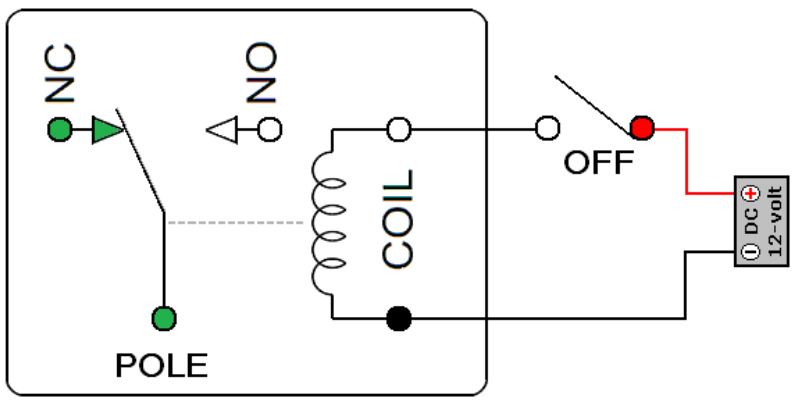



(c) Schematic symbol for a ladder diagram

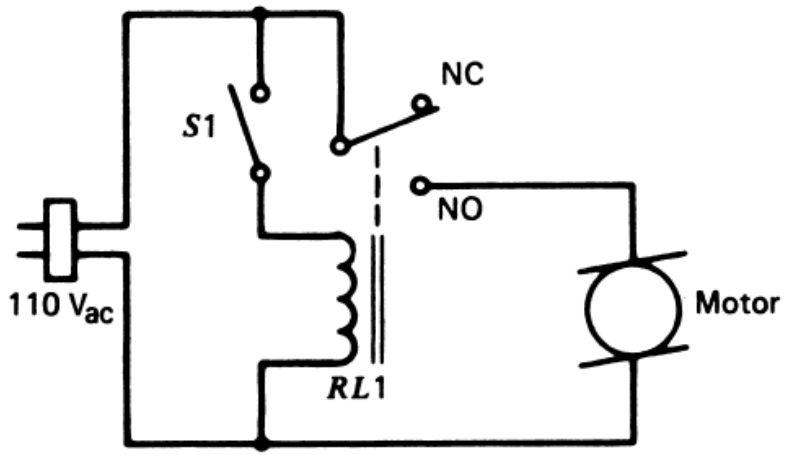


# Relay Based Controllers: Schematic and Ladder Diagrams

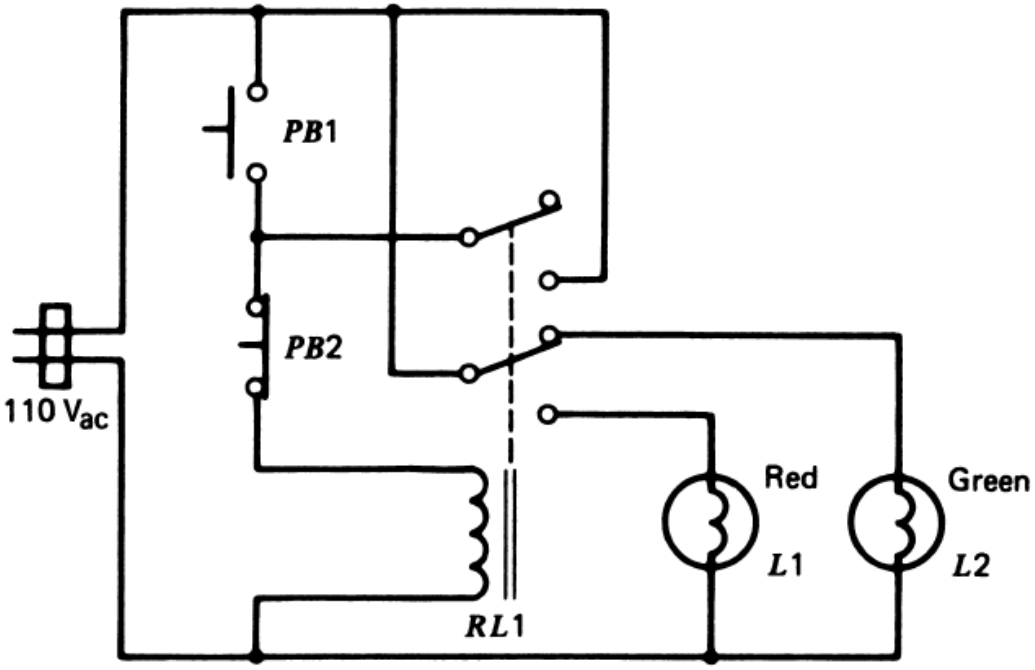
- Schematic Diagrams: The wiring of a relay control system can be described by traditional schematic diagrams. Such diagrams are cumbersome, however, when many relays, each with many contacts, are used in a system. Simplified diagrams called Ladder diagrams have been adopted by the industry.

- Ladder Diagrams: The ladder diagram is a symbolic and schematic way of representing both the system hardware and the process controller. It is called a ladder diagram because the various circuit devices connected in parallel across the ac line form something that looks like a ladder, with each parallel connection a “rung” on the ladder.
- In the construction of a ladder diagram, it is understood that each rung of the ladder is composed of a number of conditions or input states and a single command output. The nature of the input states determines whether the output is to be energized or not energized. Special symbols are used to represent the various circuit elements in a ladder diagram.

# Relay Based Controllers: Schematic and Ladder Diagrams




Use of a relay and switch to start a motor

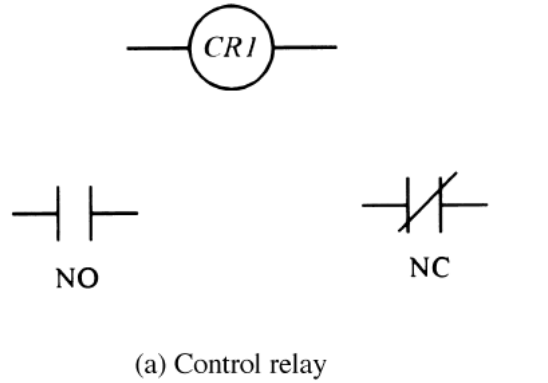



Use of momentary push-button switches and a relay to implement a latch

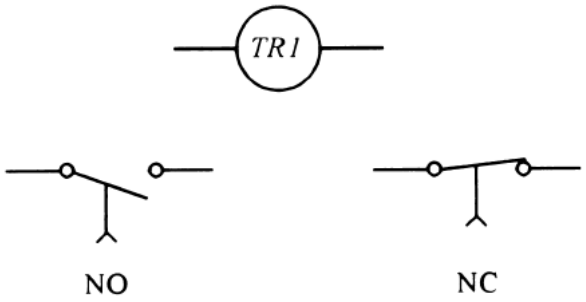
## Schematic Diagrams

# Relay Based Controllers: Schematic and Ladder Diagrams

Symbols of input devices used in ladder diagrams




(a) Control relay




(b) Timer relay


(a) Motor

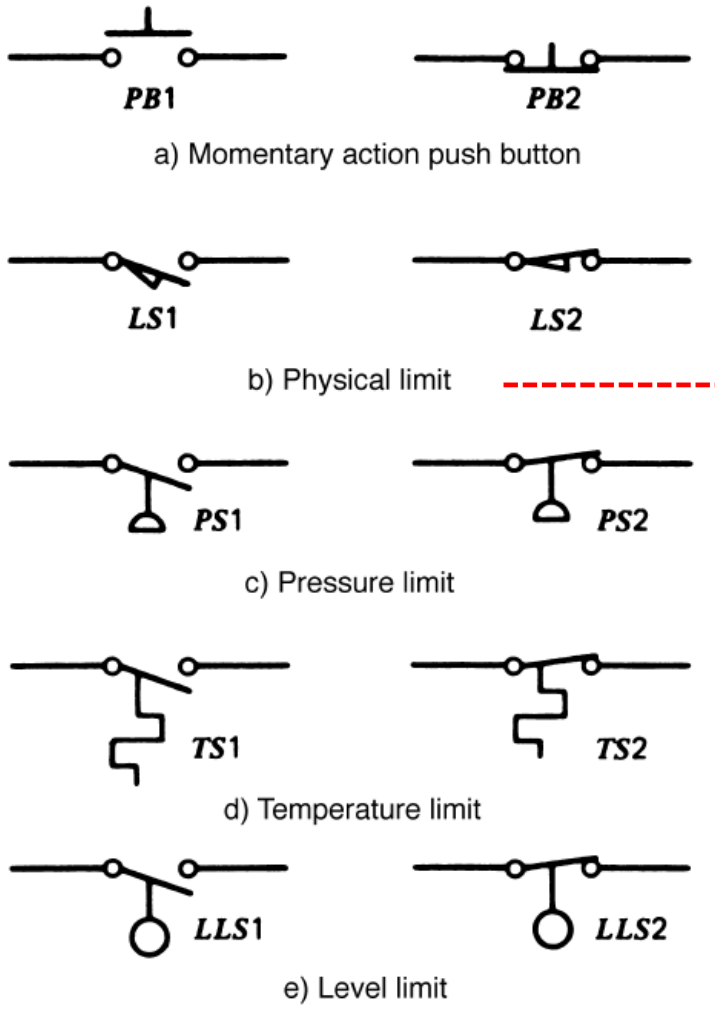

(b) Solenoid

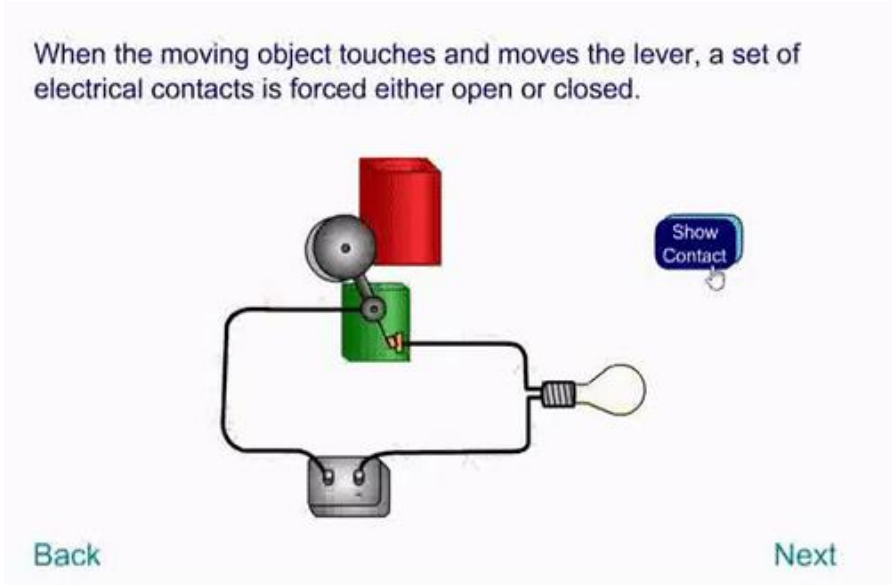

(c) Light (red)

Symbols of output devices used in ladder diagrams

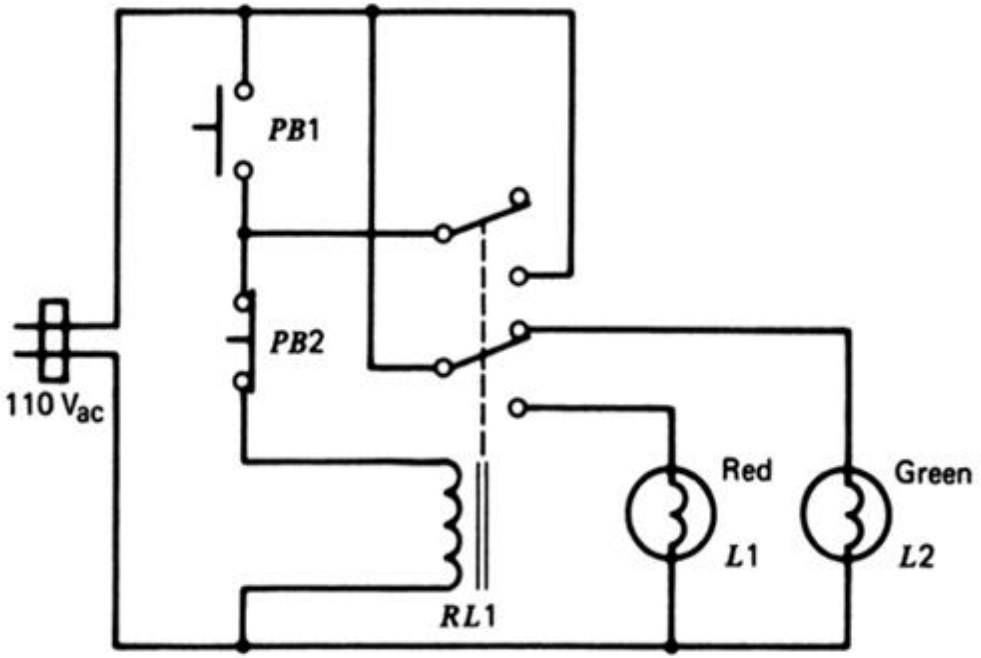
# Relay Based Controllers: Schematic and Ladder Diagrams

Symbols for switches used in ladder diagrams

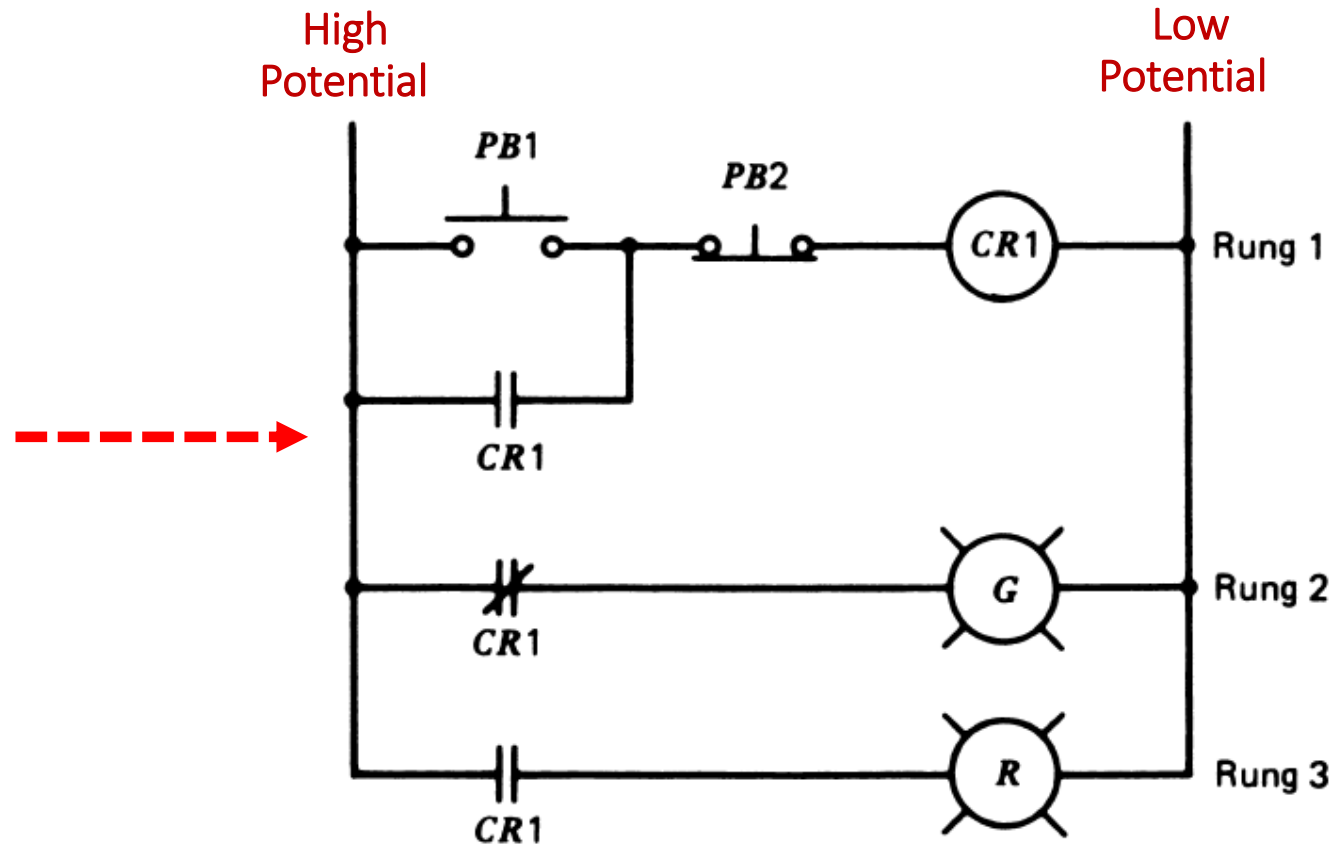


# Relay Based Controllers: Schematic and Ladder Diagrams

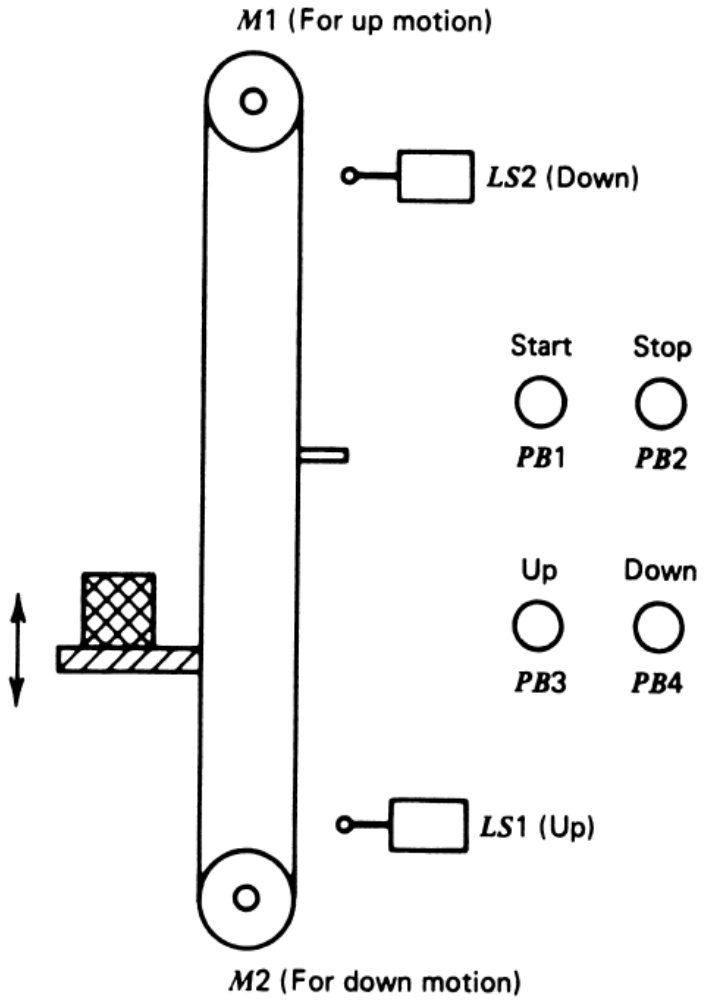



Schematic Diagram for Control of two Lights




Ladder diagram to control two lights

# Relay Based Controllers: Ladder Diagram for Elevator System

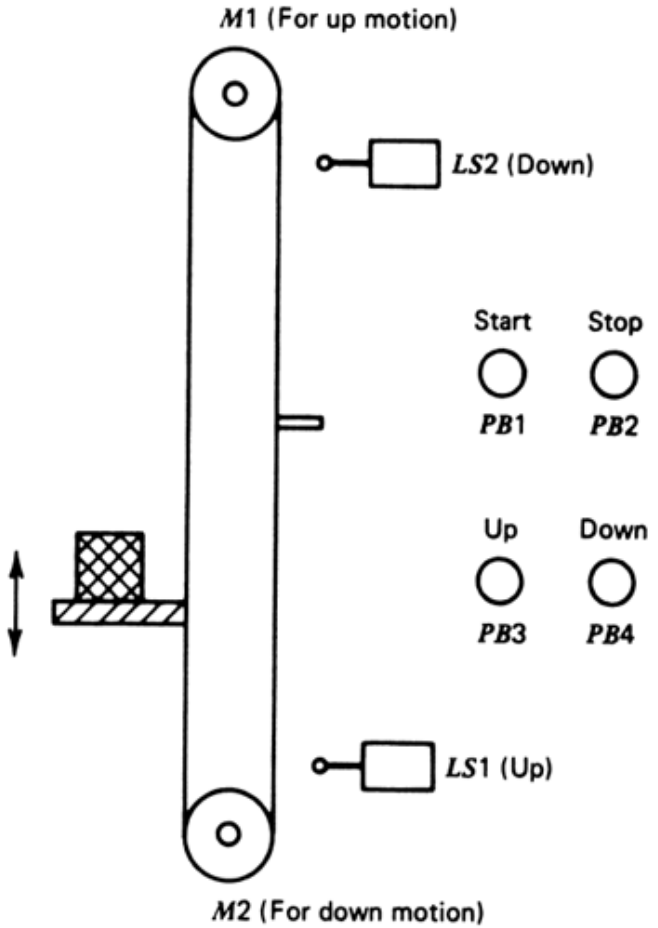



Elevator system

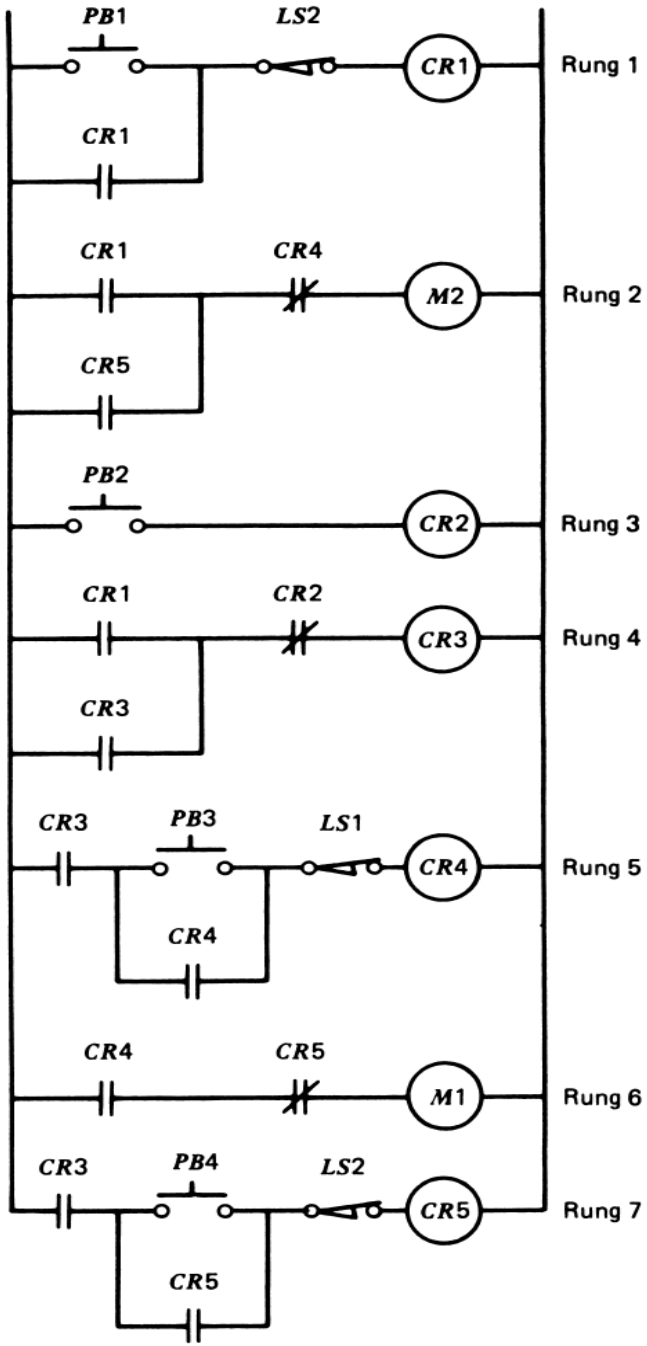
The following narrative description indicates the required sequence of events for the elevator system.

1. When the START button is pushed, the platform is driven to the down position.
2. When the STOP button is pushed, the platform is halted at whatever position it occupies at that time.
3. When the UP button is pushed, the platform, if it is not in downward motion, is driven to the up position.
4. When the DOWN button is pushed, the platform, if it is not in upward motion, is driven to the down position.

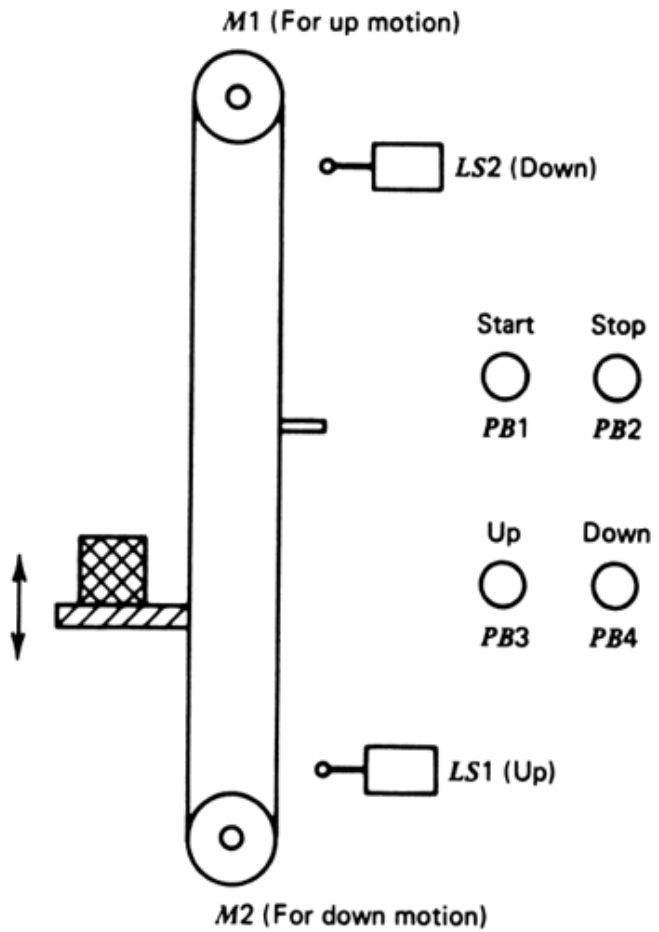
**Ladder Diagram for Elevator System**



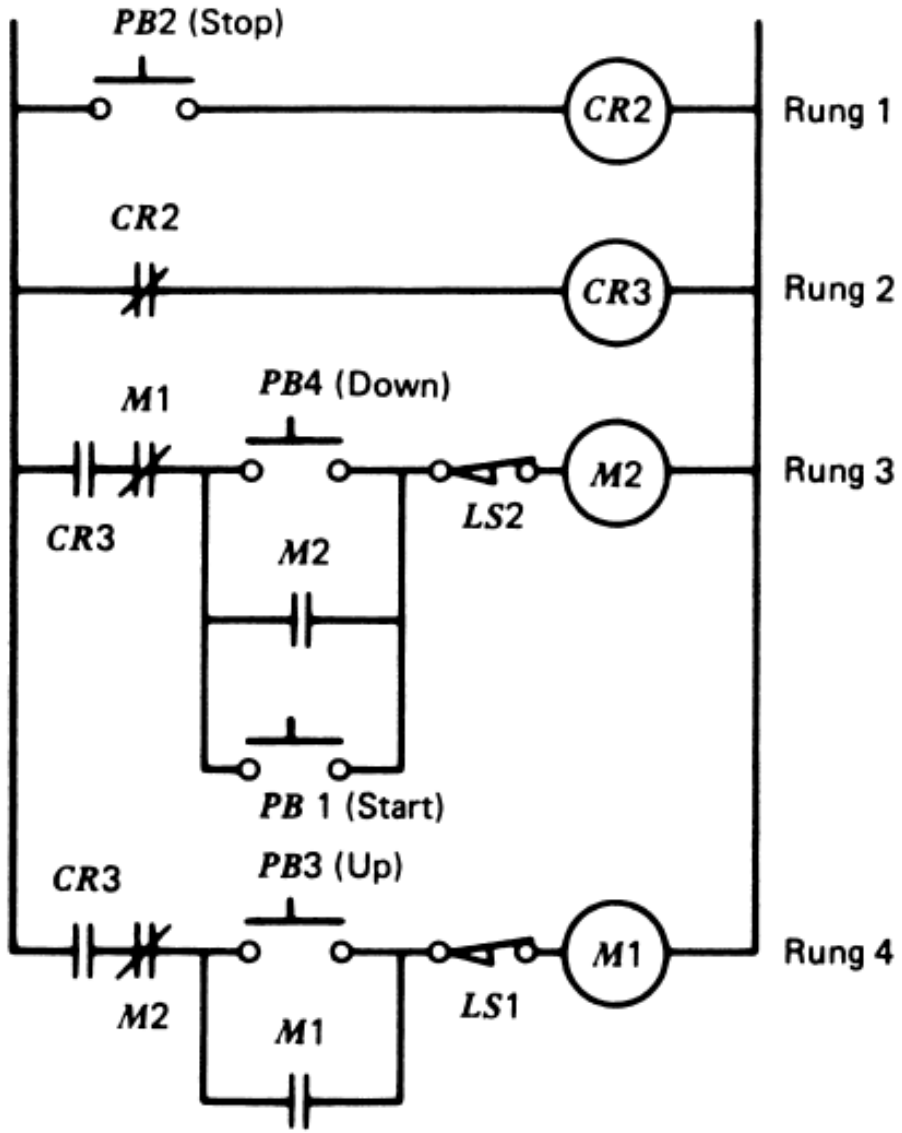

Elevator system



**Simplified Ladder Diagram for Elevator System**




Elevator system



# THANK YOU