Seminar on Industrial Automation

Topic:

Discrete Control using PLCs

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Groover MP (2008). Automation, Production Systems, and Computer-Integrated Manufacturing, Third Edition, Pearson Prentice Hall, Chapter 9.

Outline

1. Discrete Process Control
2. Ladder Logic Diagrams
3. Programmable Logic Controllers
4. Personal Computers Using Soft Logic

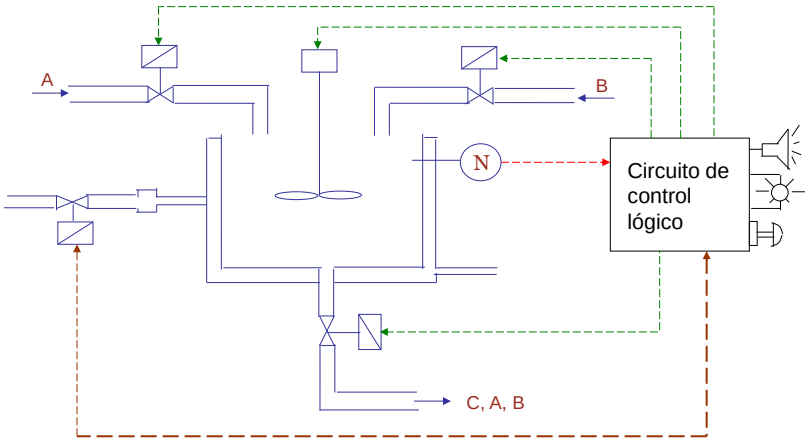
Discrete process control

Control systems that operate on parameters and variables that change at discrete moments in time

- Parameters and variables are also discrete, usually binary (0 or 1, off or on, open or closed, etc.)

Sensors	Limit switch	Contact/no contact
	Photo-detector	On/off
	Timer	On/off
Actuators	Motor	On/off
	Valve	Open/closed
	Clutch	Engaged/not engaged

Discrete control systems



Categories of discrete control

1. Logic control –event-driven changes
2. Sequencing –time-driven changes

Logic control

A switching system whose output at any moment is determined exclusively by the values of inputs

- No memory
- No operating characteristics that depend on time
- Also called combinational logic control

Elements of logic control

Basic elements, called logic gates:

- AND –output = 1 if all inputs = 1, zero otherwise
- OR –output = 1 if any input = 1, zero otherwise
- NOT –output = 1 if (single) input = 0, and vice versa

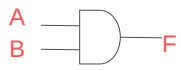
Additional elements:

- NAND –combination of AND and NOT
- NOR –combination of OR and NOT

Elements of logic control

Logic functions

AND A•B

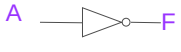


A	B	F
0	0	0
0	1	0
1	0	0
1	1	1

OR A+B

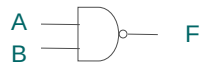
A	B	F
0	0	0
0	1	1
1	0	1
1	1	1

NOT A'



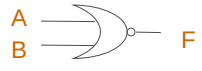
A	F
0	1
1	0

NAND (A•B)'



A	B	F
0	0	1
0	1	1
1	0	1
1	1	0

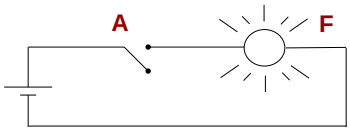
NOR (A+B)'



A	B	F
0	0	1
0	1	0
1	0	0
1	1	0

Logic functions of one variable

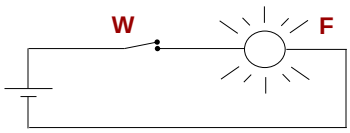
- *Identification function*



A	F
0	0
1	1

F = A

- *Inverter or logic negation function*



W	F
0	1
1	0

F = W ’

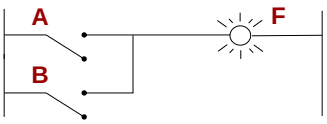
Logic functions of more than one variable

- *And*

A	B	F
0	0	0
0	1	0
1	0	0
1	1	1

F = A · B

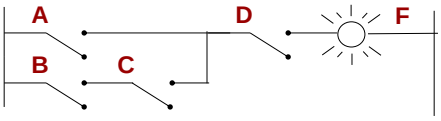
- *Or*



A	B	F
0	0	0
0	1	1
1	0	1
1	1	1

F = A + B

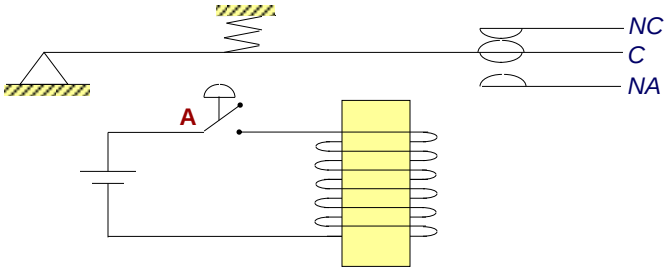
- *Combination of And and Or functions*



F = (A + BC) D

Relays

Offer
- *Contacts that reproduce the behavior of the switch.*
- *Contacts that invert the behavior of the switch.*



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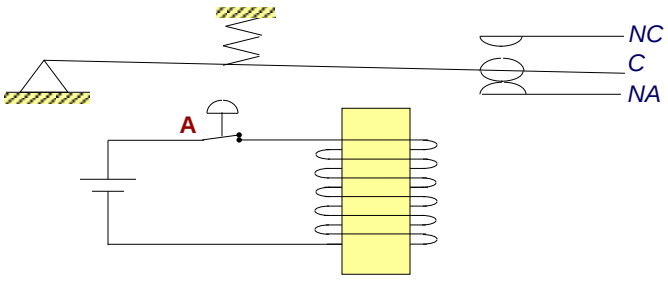
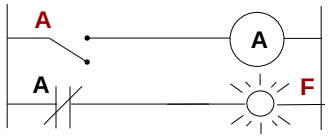


Relays

Representation of relays in an electric ladder diagram

Implementation of **F = A'** where A is a normally open switch



A	F
0	1
1	0

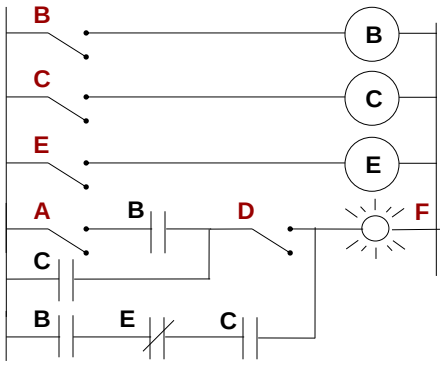
Implementation of **F = W** where W is a normally closed switch

W	F
0	0
1	1

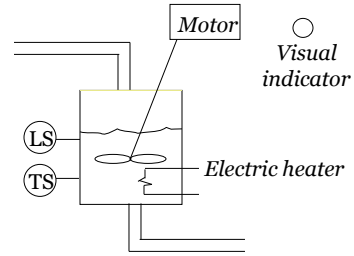
Relays

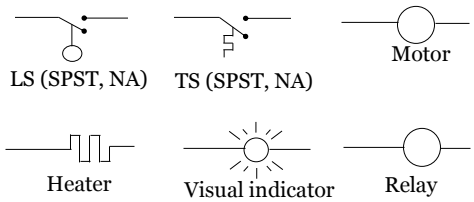
Representation of relays in an electric ladder diagram

Implementation of **F = (AB+C)D+BE'C** with normally open switches



Relays. Exercise 1.

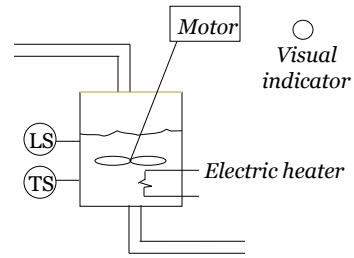




The following functions are required
- *if the level within the tank is high, the mixer is turned on;*
- *if the temperature is low, the heater is turned on, and*
- *if the temperature is high, the visual indicator is turned on.*

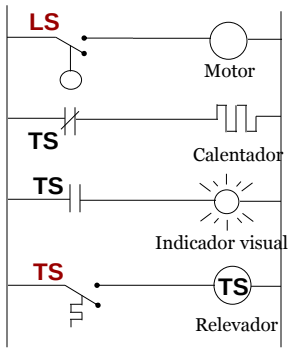
Design the electric ladder diagram that implements the above functions.

Relays. Exercise 1.



Switches are normally open

Requirements:
- *if the level within the tank is high, the mixer is turned on;*
- *if the temperature is low, the heater is turned on, and*
- *if the temperature is high, the visual indicator is turned on.*



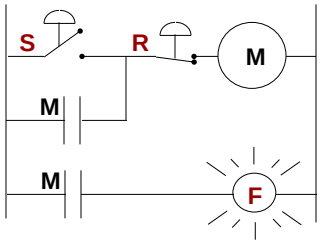
Use of relay for a set-reset function

How is the visual indicator operated with buttons S (set) and R (reset)?

S	R	M	M
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	0
1	1	1	0

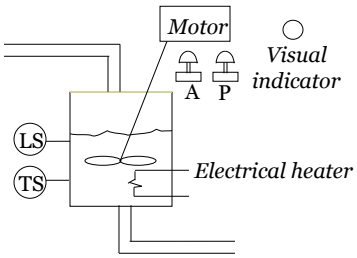
M = SR' + MR'

M = (S + M) R'



24 V

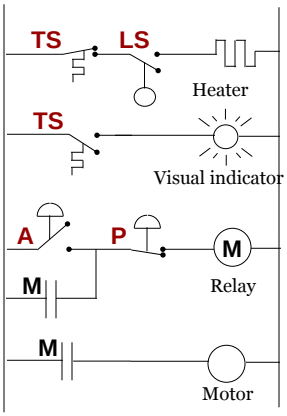
Relays. Exercise 2: how does it work?



Switches LS, TS, A and P have one normally open contact and one normally closed contact

Answer:

- *if temperature is low and level is high, the heater is turned on;*
- *if temperature is high, the visual indicator is turned on and*
- *if A is pushed, the mixer is turned on and until P is pushed.*



Sequencing

A switching system that uses internal timing devices to determine when to initiate changes in output variables

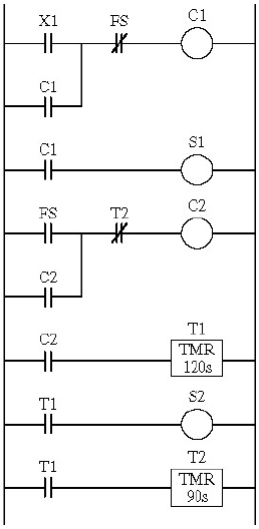
- Outputs are usually generated “open loop”
  - No feedback that control function is executed
- Sequence of output signals is usually cyclical, as in a high production work cycle
  - The signals occur in the same repeated pattern within each regular cycle
- Common sequencing devices:
  - Timer –output switches on/off at preset times
  - Counter –counts electrical pulses and stores them

Ladder logic diagrams

A diagram in which various logic elements and other components are displayed along horizontal rungs connected on either end to two vertical rails

- Types of elements and components:
  1. Contacts -logical inputs (usually), e.g., limit switches, photo-detector
  2. Loads -outputs, e.g., motors, lights, alarms, solenoids
  3. Timers -to specify length of delay
  4. Counters -to count pulses received

Ladder logic diagram



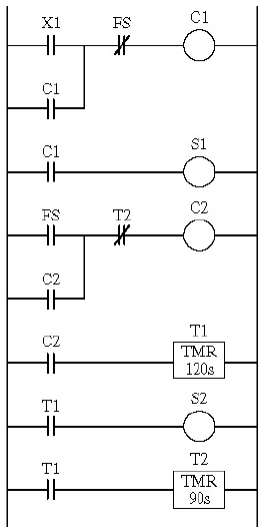
Symbols for common elements of ladder logic diagrams

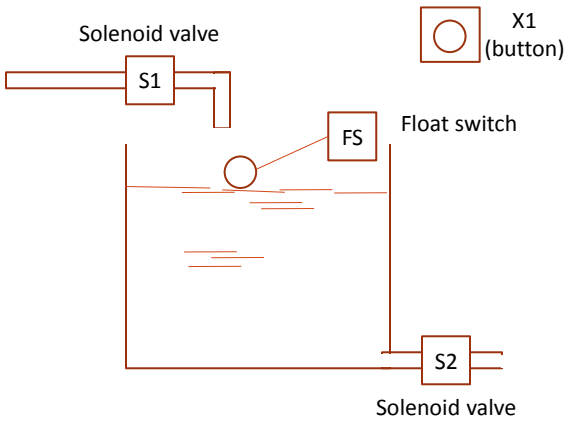
Ladder symbol	Hardware component
(a) —||—	Normally open contacts (switch, relay, other ON/OFF devices)
(b) —|/|—	Normally closed contacts (switch, relay, etc.)
(c) —( )—	Output loads (motor, lamp, solenoid, alarm, etc.)
(d) —[TMR 3s]—	Timer
(e) —[CTR]—	Counter

Advantages of ladder logic diagrams

1. Familiar to shop personnel who must construct, test, maintain, and repair the control system
2. Analogous to the electrical circuits used to accomplish logic and sequence control
3. Principal technique for programming PLCs

Ladder diagram for PLC
Exercise 3: how does it work?





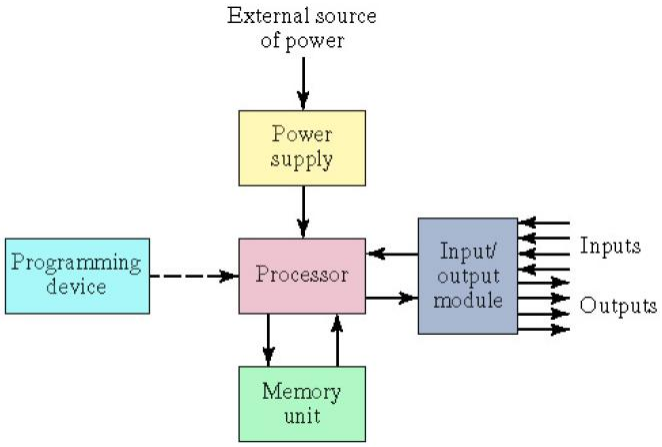
Internal variables: C1, C2
Timers: T1, T2

Programmable logic controllers

A microcomputer-based controller that uses stored instructions in programmable memory to implement logic, sequencing, timing, counting, and arithmetic functions through digital or analog modules, for controlling machines and processes

- Applications in both process industries and discrete manufacturing
- Introduced around 1970
- Replaced hard-wired electromechanical relay panels

Components of a PLC



Advantages of PLCs compared to relays control panels

- Programming a PLC is easier than wiring a relay control panel
- PLC can be reprogrammed
- PLCs take less floor space
- Greater reliability, easier maintenance
- PLC can be connected to computer systems (CIM)
- PLCs can perform a greater variety of control functions

PLC components

1. Processor –executes logic and sequencing functions by operating on the PLC inputs to determine the appropriate output signals
2. Input/output module –connections to process
3. Memory unit –contains the programs of logic, sequencing, and I/O operations
4. Power supply –converts 120 V (ac) to dc voltages of ±5 V compatible with process equipment
5. Programming device

Typical PLC operating cycle

1. Input scan –inputs are read by processor and stored in memory
2. Program scan –control program is executed
3. Input values stored in memory are used in the control logic calculations to determine values of outputs
4. Output scan –output values are updated to agree with calculated values
5. Time to perform the three steps (scan time) varies between 1 and 25 msec

Additional PLC capabilities

- Analog control –PID control available on some PLCs for continuous processes
- Arithmetic functions –permits more complex control algorithms to be implemented than conventional logic and sequencing elements
- Matrix functions –e.g., linear programming for optimal control
- Data processing and reporting –business applications
  - Blurs the distinction between PLCsand PCs

PLC programming

- Graphical languages:
  1. Ladder logic diagrams –most widely used
  2. Function block diagrams –instructions composed of operation blocks that transform input signals
  3. Sequential function charts –series of steps and transitions from one state to the next (Europe)
- Text-based languages:
  1. Instruction list -low-level computer language
  2. Structured text –high-level computer language

Personal computers using soft logic

- Available in sturdy enclosures for plant environment
- Membrane-type keyboards to protect against dirt, moisture, etc.
- Can be ordered with I/O cards and other hardware to connect to machines and processes
- Installed with Windows for implementing control applications
- Can be programmed with soft logic -software that emulates the operations of the built-in control software in PLCs