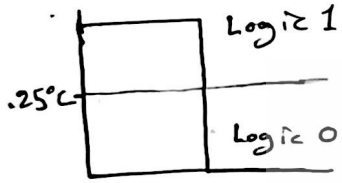
Chapter 9-1 (CH.9 - Lect.1)

Discrete Control

1. switching elements (actuators) ON/OFF
2. Discrete variables, ex:



Logic control (independant of time)

* في حال كانت الحرارة فوق 25c تُغلق المروحة
وفي حال كانت أقل من 25c تُغلق المروحة
* لا تعتمد على زمن معين

---

sequencing: time-driven changes
Logic control: events-driven changes
} for automation

Example (المثال) / Slide 6

Inputs:

A [1 = A, 0 = $\bar{A}$]

B [1 = B, 0 = $\bar{B}$]

C [1 = C, 0 = $\bar{C}$]

logic statements → connects between input and output

Output:

D [1 = D, 0 = $\bar{D}$]

conditions / statements

1. $\bar{A} . B$
2. $A . C$
3. $A . \bar{C} . B$

$\Rightarrow D = \bar{A} . B + A . C + A . \bar{C} . B$
(and, or)

[Boolean expression]

Truth tables

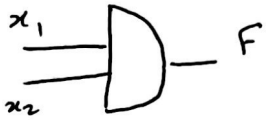
OR

x_1	x_2	F
0	0	0
1	0	1
0	1	1
1	1	1

Digital/logic gates
[multiple inputs ⇒ single output]

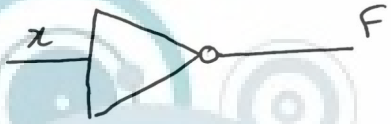
AND

x_1	x_2	F
0	0	0
0	1	0
1	0	0
1	1	1

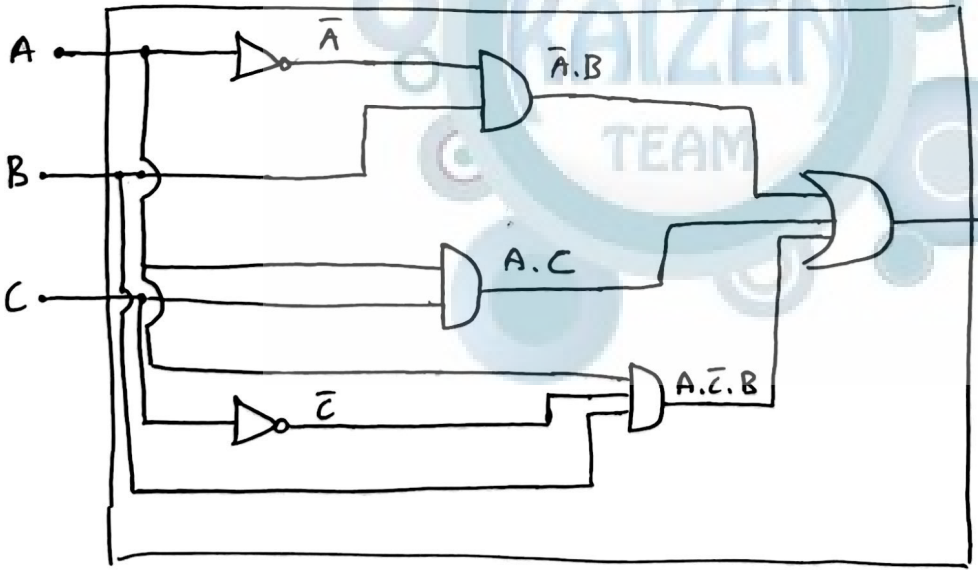


Inverter

x	F
0	1
1	0



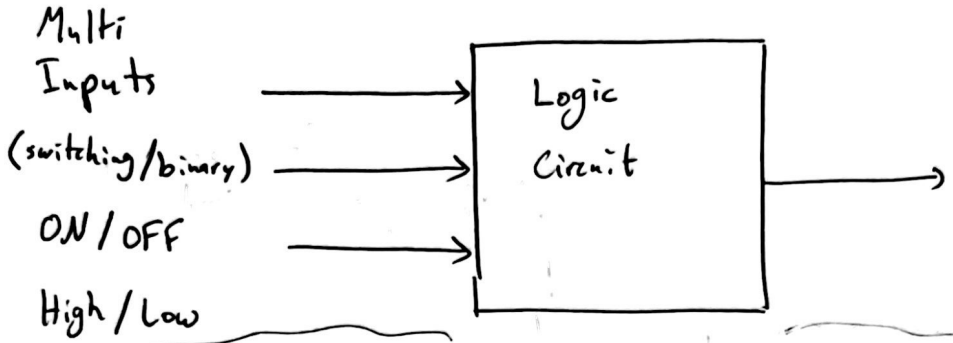
"Combination logic gates"



$D = \bar{A}.B + A.C + A.\bar{C}.B$

⇒ for the same example

CH.9 - lect.2



steps to build logic controlers

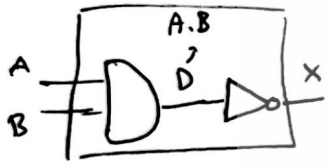
① Logic statements (given in question)

↓

② Boolean expression (built using logic gates)

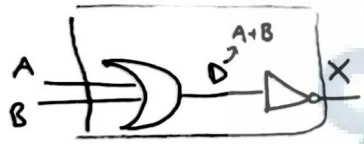
③ simplification based on Boolean algebra rules

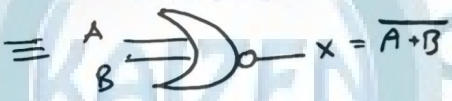
④ Implementation by using combinational logic gates



NAND gate

A	B	D	X
0	0	0	1
0	1	0	1
1	0	0	1
1	1	1	0

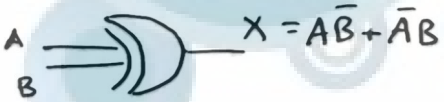




NOR

A	B	D	X
0	0	0	1
1	0	1	0
0	1	1	0
1	1	1	0

A	B	X
0	0	0
1	0	1
0	1	1
1	1	0

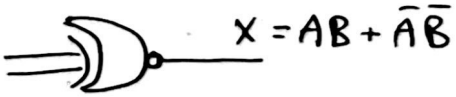


XOR

عند الاختلاف ⇐ 1

عند التشابه ⇐ 0

A	B	D	X
0	0	0	1
1	0	1	0
0	1	1	0
1	1	0	1

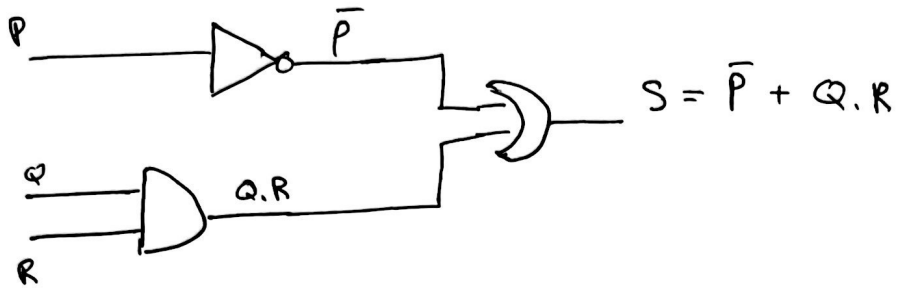


XNOR

عند الاختلاف ⇐ 0

عند التشابه ⇐ 1

Copy machine example (Slide 13)



Fundamentals of logic (some proofs)

* Absorption law:

$$A(A+B) = A.A + A.B$$
$$= A + A.B$$
$$= A(1+B)$$
$$= A(1)$$
$$= A$$

يمكن الإثبات بهذه الطريقة أو من خلال Truth table

---

* De morgan's : $\overline{AB} = \bar{A} + \bar{B}$

A	$\bar{A}$	B	$\bar{B}$	A.B	$\overline{A.B}$	$\bar{A}+\bar{B}$
0	1	0	1	0	1	1
1	0	0	1	0	1	1
0	1	1	0	0	1	1
1	0	1	0	1	0	0

equal ✓

Example

A, B, C inputs

D output

* D is high when two of the 3 inputs is at least high

⇒ Drive Boolean expression for D

1. no. of states = $2^{n \rightarrow \text{no. of inputs}} = 2^3 = 8$
2. Truth table:

A	B	C	D
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	1
1	0	0	0
1	0	1	1
1	1	0	1
1	1	1	1

$$D = \bar{A}BC + A\bar{B}C + AB\bar{C} + ABC$$

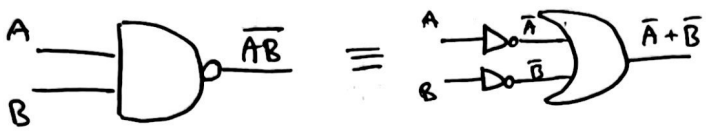
Boolean expression for D

CH.9 - lect.3

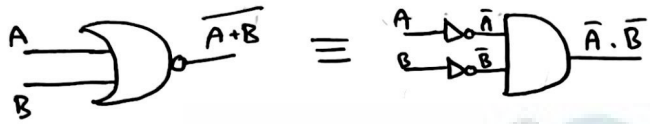
De Morgan's Law

* فكرة القانون:
إذا نقلنا الـ inverter من الـ input للـ output أو العكس، تنقلب الـ gate
AND ⇒ OR
OR ⇒ AND

① $\overline{AB} = \bar{A} + \bar{B}$ (أثبتناها سابقًا)



② $\overline{A+B} = \bar{A}.\bar{B}$



---

* Extra laws:

① $A + \bar{A}B = A + B$

② $\bar{A} + AB = \bar{A} + B$

A	B	$\bar{A}$	$\bar{A}B$	$A+\bar{A}B$ ①	$A+B$ ①	AB	$\bar{A}+AB$ ②	$\bar{A}+B$ ②
0	0	1	0	0	0	0	1	1
1	0	0	0	1	1	0	0	0
0	1	1	1	1	1	0	1	1
1	1	0	0	1	1	1	1	1

① equal ② equal

Example

[1] $A\bar{B}\,(\overline{\bar{A}\bar{C}})$

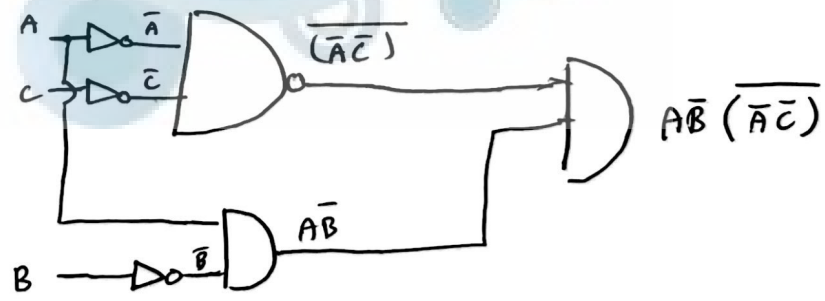
$= A\bar{B}\,(\bar{\bar{A}} + \bar{\bar{C}})$

$= A\bar{B}\,(A + C)$

$= A\bar{B} + A\bar{B}C$

$= A\bar{B}\,(1 + C)$

$= A\bar{B}$



≡

Copy machine example (using truth table)

P	Q	R	S
0	0	0	1
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	1

$\Rightarrow$

$$S = \bar{P}\bar{Q}\bar{R} + \bar{P}\bar{Q}R + \bar{P}Q\bar{R} + \bar{P}QR + PQR + \bar{P}QR$$

$$= \bar{P}\bar{Q}(\bar{R}+R) + \bar{P}Q\bar{R} + QR(\bar{P}+P) + \bar{P}QR$$

$A + A = A$, $AB + A\bar{B} = A$

$$= \bar{P}\bar{Q} + \bar{P}Q\bar{R} + QR + \bar{P}QR$$

$$= \bar{P}\bar{Q} + \bar{P}Q(\bar{R}+R)' + QR$$

$$= \bar{P}\bar{Q} + \bar{P}Q + QR$$

$$= \bar{P}(\bar{Q}+Q)' + QR$$

$$= \bar{P} + QR$$

CH.9 - lect. 4

Examples

1 $Z = A\bar{B}\bar{C} + A\bar{B}C + ABC$ (sum of multiplications) (SOM)

$= A\bar{B}(\bar{C} + C) + ABC$

$= A\bar{B} + ABC$

$= A(\bar{B} + BC)$ $[\bar{B} + BC = \bar{B} + C]$

$= A(\bar{B} + C)$

OR

$Z = A\bar{B}\bar{C} + A\bar{B}C + ABC + A\bar{B}C$ $[A + A = A]$

$= A\bar{B}(\bar{C} + C) + AC(\bar{B} + B)$

$= A\bar{B} + AC$

* إذا عندنا 3 terms ، ممكن نضيف حد رابع يكون الحد اللي فيه عوامل مشتركة من الحدّين الباقيين (بحالتنا $A\bar{B}C$)

---

2 $Z = \bar{A}C\overline{(\bar{A}BD)} + \bar{A}B\bar{C}\bar{D} + A\bar{B}C$ * Hint: start with brackets

$= \bar{A}C(\bar{\bar{A}} + \bar{B} + \bar{D}) + \bar{A}B\bar{C}\bar{D} + A\bar{B}C$

$= 0 + \bar{A}\bar{B}C + \bar{A}C\bar{D} + \bar{A}B\bar{C}\bar{D} + A\bar{B}C$

$= \bar{B}C(\bar{A} + A) + \bar{A}\bar{D}(C + B\bar{C})$

$= \bar{B}C + \bar{A}C\bar{D} + \bar{A}B\bar{D}$

---

3 $X = (\bar{A} + B)(A + B + D)\bar{D}$ (multiplication of sum) (MOS)

$=$

$= (B + \bar{A}D)\bar{D}$

~~$B\bar{D} + \bar{A}$~~

$= B\bar{D}$

$A + B + D$

$\bar{A} + B$

$0 + \bar{A}B + \bar{A}D + AB + B + BD$

$= B(\bar{A} + A) + B(1 + D) + \bar{A}D$

$= B + \bar{A}D$

Exercises:

1. $X = A\bar{B}C + \bar{A}BD + \bar{C}\bar{D}$
2. $X = RS\bar{T} + \bar{R}S\bar{T} + \bar{T}$
3. $X = A\overline{CD} + \bar{A}CD$
4. $X = MN\bar{P} + (M + \bar{N})P$
5. $X = AB + \bar{A}B\bar{C} + A\bar{B}\bar{C}D$

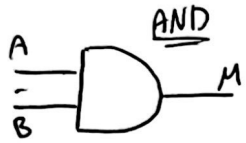
CH.9 - lect. 5

ladder diagram

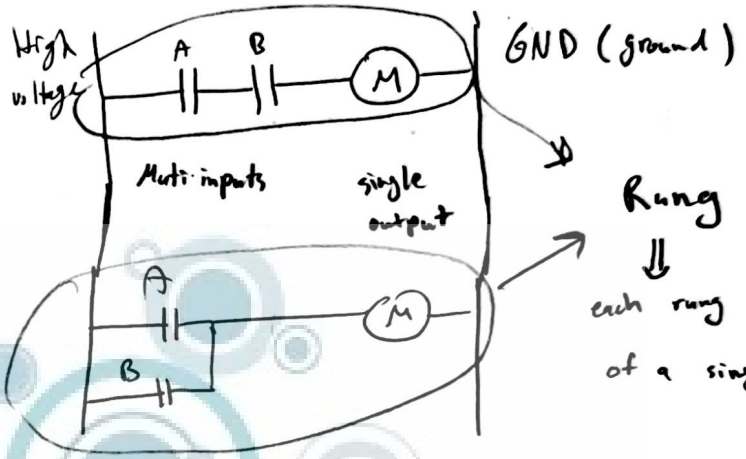
A	High	ON	⊣⊢	logic 1	Active	Start
$\bar{A}$	Low	OFF	⊣/⊢	logic 0	Inactive	Stop

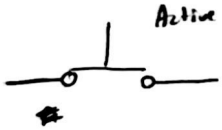
↳ shattered switches

logic gate

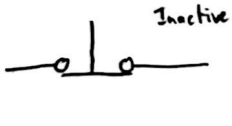


ladder diagram





≡ ⊣⊢ ⇒ Normally Open (NO) / Starts

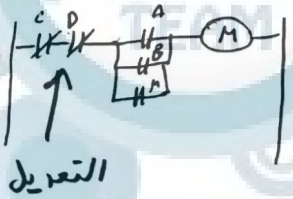


≡ ⊣/⊢ ⇒ Normally closed (NC) / Stops

[هاي كأنّ الـ logic هو إنها مش شغالة]

---

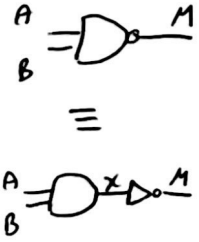
* Example 4-9 ⇒ تعديل



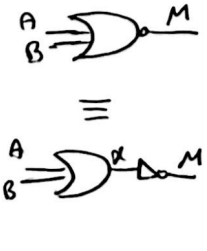
(slide 24)

التعديل هُنا

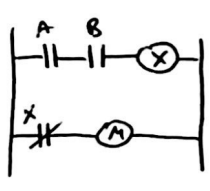
NAND

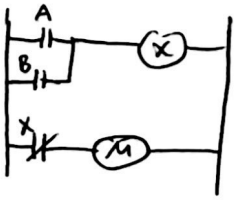


NOR



↳





ladder diagrams

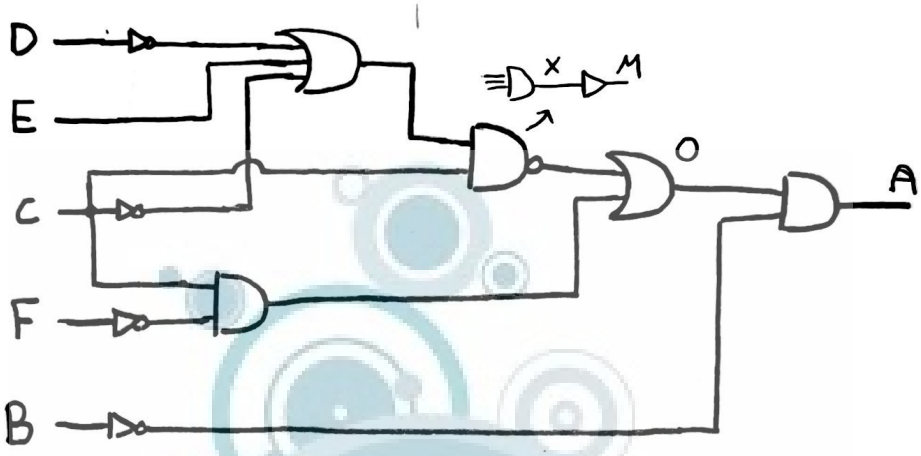
Example $A = \overline{B}.\left(\overline{C.(\overline{D}+E+\overline{C})} + \overline{F}.C\right)$

* Before simplification:
  1. Draw logic combination circuit for A
  2. Draw the ladder diagram for A
* After simplification:
  3. Draw logic combinational circuit for A
  4. Draw ladder diagram for A

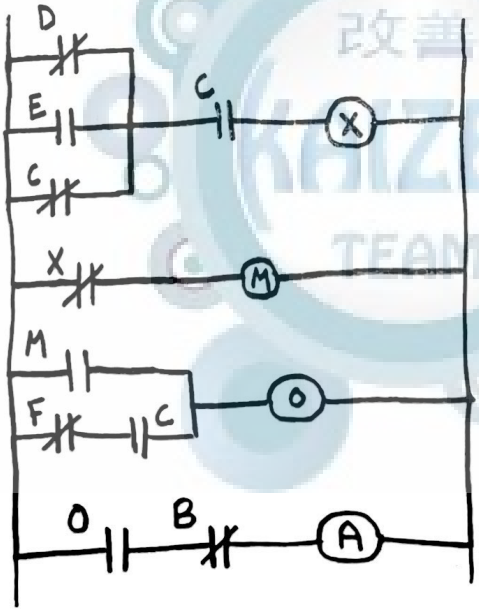
Answer

* Before: Simplification

1.



2.



Contd.

* Simplification:

$$A = \overline{\overline{B}.\left(\overline{C.(\overline{D}+E+\overline{C})} + \overline{\overline{F}.C}\right)}$$

AND

OR

$\overline{C.(\overline{D}+E+\overline{C})}$

$\overline{C} + \overline{(\overline{D}+E+\overline{C})}$ $\Rightarrow$ De Morgan's

$\overline{C} + (\overline{\overline{D}}.\overline{E}.\overline{\overline{C}})$

$\overline{C} + \underline{DE}C$ $\Rightarrow$ $\bar{A} + BA = \bar{A} + B$

$\boxed{\overline{C} + D\overline{E}}$

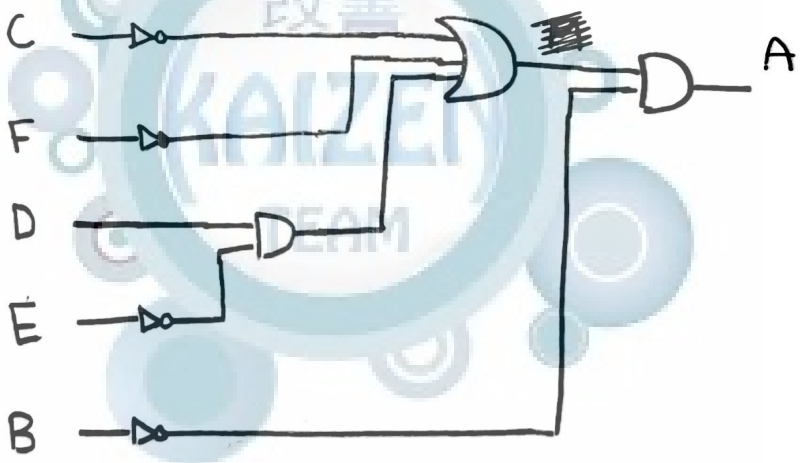
$A = \overline{B}.(\underline{\overline{C}} + D\overline{E} + \underline{\overline{F}C})$ $\Rightarrow$ $\overline{C} + \overline{F}C = \overline{C} + \overline{F}$

$A = \overline{B}.(\overline{C} + \overline{F} + D\overline{E})$

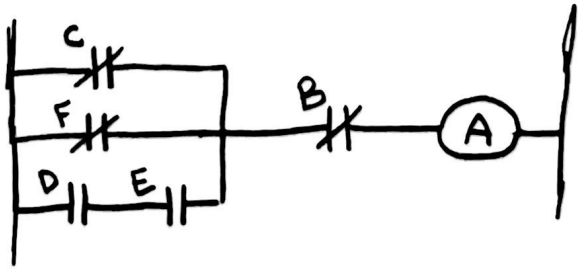
$\boxed{A = \overline{B}\overline{C} + \overline{B}\overline{F} + \overline{B}D\overline{E}}$

* After simplification

3

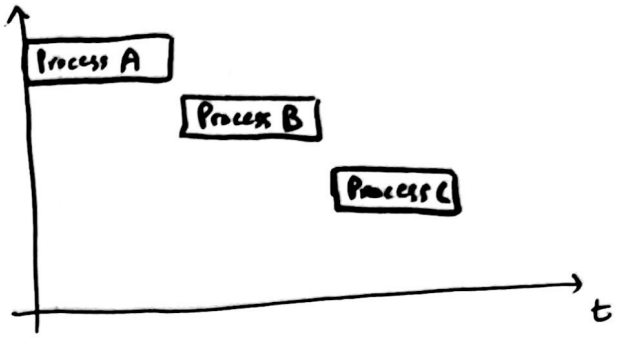


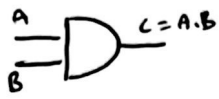
4

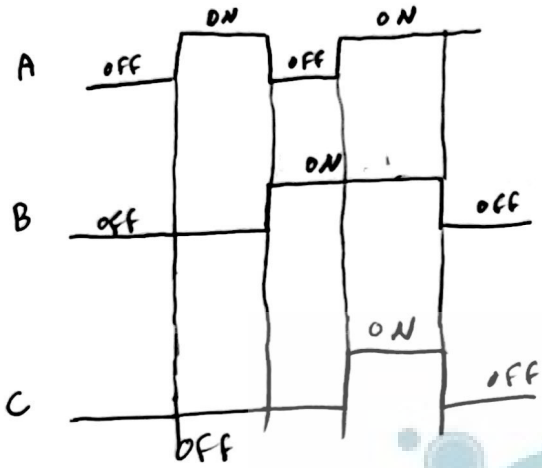


Ch. 9 - lect. 6

Sequencing

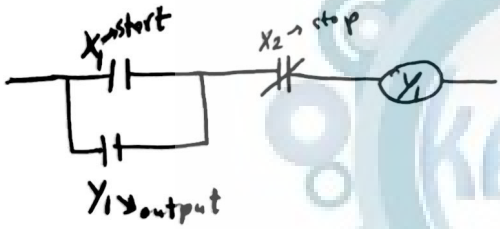






Time - dependant

Push Button Switch / Start - Stop switch



* latching: output parallel with start switch

⇒ in our case, Y_1 is latched with start switch X_1

ladder diagram (components)

* Inputs
- switches: START STOP
- Sensors

* Outputs
- Actuators
- Indicators (lights)
- Valves
- Motors

* [Timers / counters]

⇓

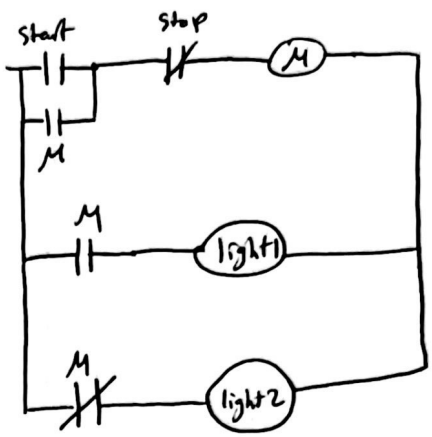
Dependencies

Example 8

Slide 43

~~ladder diagram~~

ladder diagram



Q2) Automatic doors example (PLC questions file)

Y_0

Opening process

X_0 high

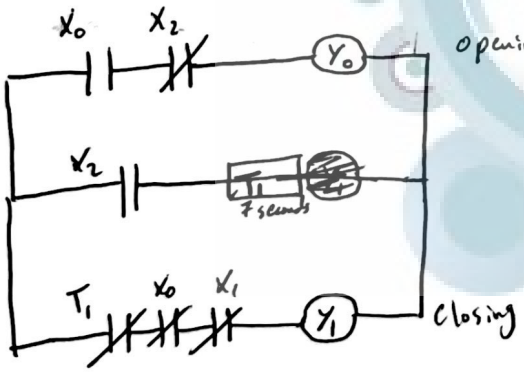
Closing process

X_2 high
T high

T low
X_0 low

X_1 high
X_0 high

ladder diagram

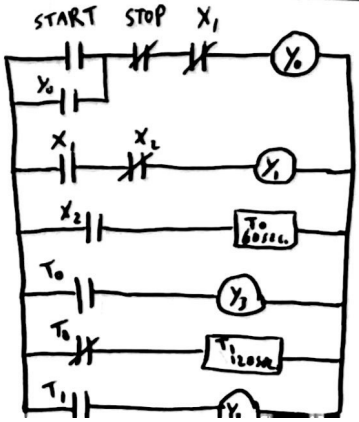


Q4) Infusing container system example

Process 1 : inlet

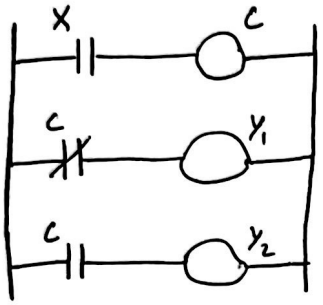
Process 2 : Mixing , T_0 = 60 sec.

Process 3 : Draining , T_1 = 120 sec.



CH. 9 - lect. 7

* Control Relay: an actuator that manages multiple (NO, NC) applicants (circuits) using one control signal

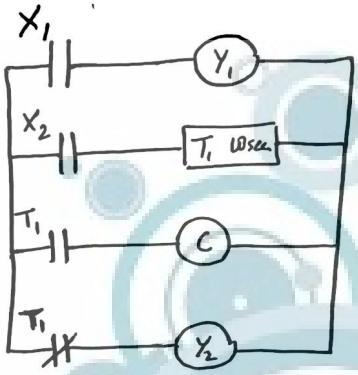


Y_1 : Normally Closed (NC), opens when the relay is energized

Y_2 : Normally Open (NO), closes when the relay is energized

PLC questions file

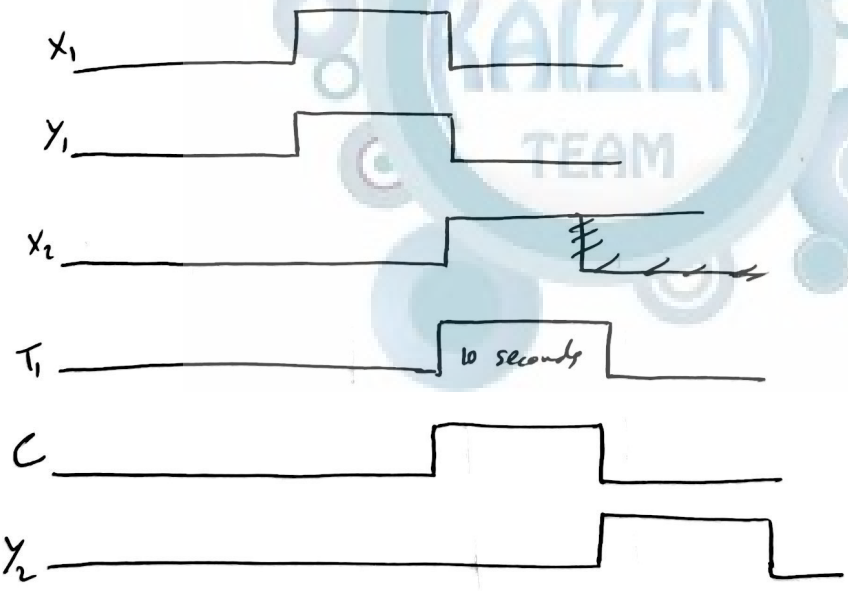
Q1) Industrial Robot



Process 1 : nest → heating coil

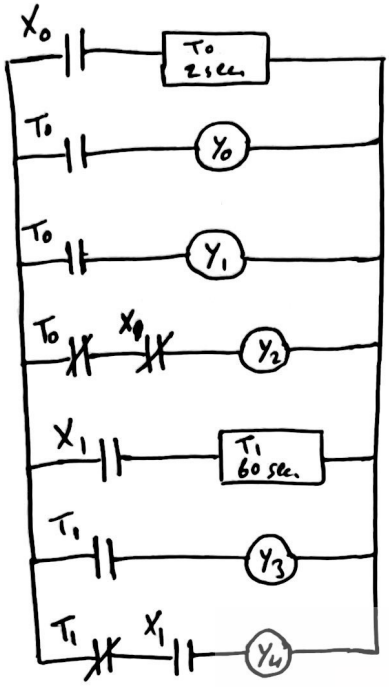
Process 2 : Heating

Process 3 : heating coil → conveyer



Timing diagram (signals)

Coffee machine example (Q3)



→ A coin is inserted

→ A paper cup is sent out

→ certain amount of coffee will be poured into the container

→ Hot water poured into the container

→ Agitator mixing

→ Made coffee pouring out from Y_4 outlet into the paper cup