Chapter 7

RLL Design and Sequencing System

7.1 **Commonly used industrial machine sequence**

Sequencing control system can be considered as single path or multi-path systems. Multi-path or parallel path sequencing control system cover controlling multi-tasks in one time, while single task is considered for single-path sequencing system

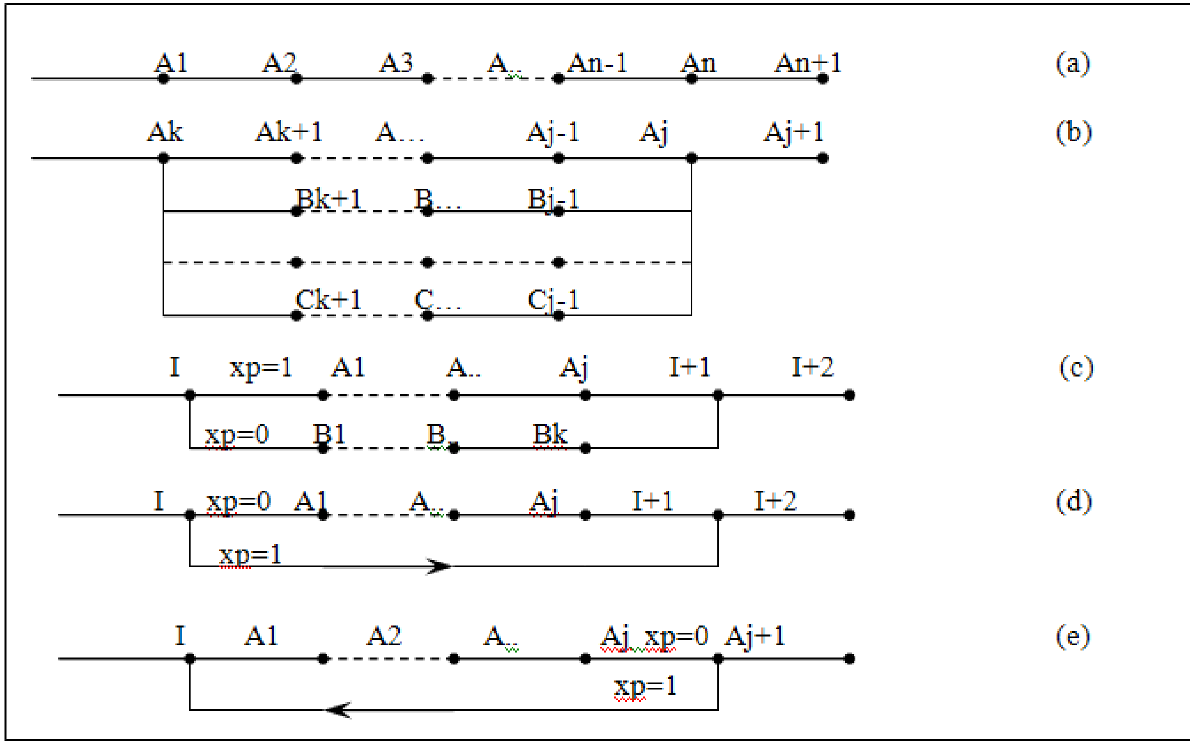


Fig. 7.1 Common machine sequence used by industry.

a) Single path machine sequence.
b) Parallel path machine sequence.
c) Parallel path machine sequence with two or more alternative path selection.
d) Single path machine sequence with option bypass machine sequence.
e) Single path machine sequence with optional repeat certain steps.

7.2 **Design Using Sequencing Chart**

Sequence charts (also called time-motion diagrams, state diagram, or bar charts) are useful for visualizing the operation of switching systems.
They can be used to describe the step-by-step operation of relay systems, pneumatic systems, or any other type of switching systems and sometime helpful in design RLL

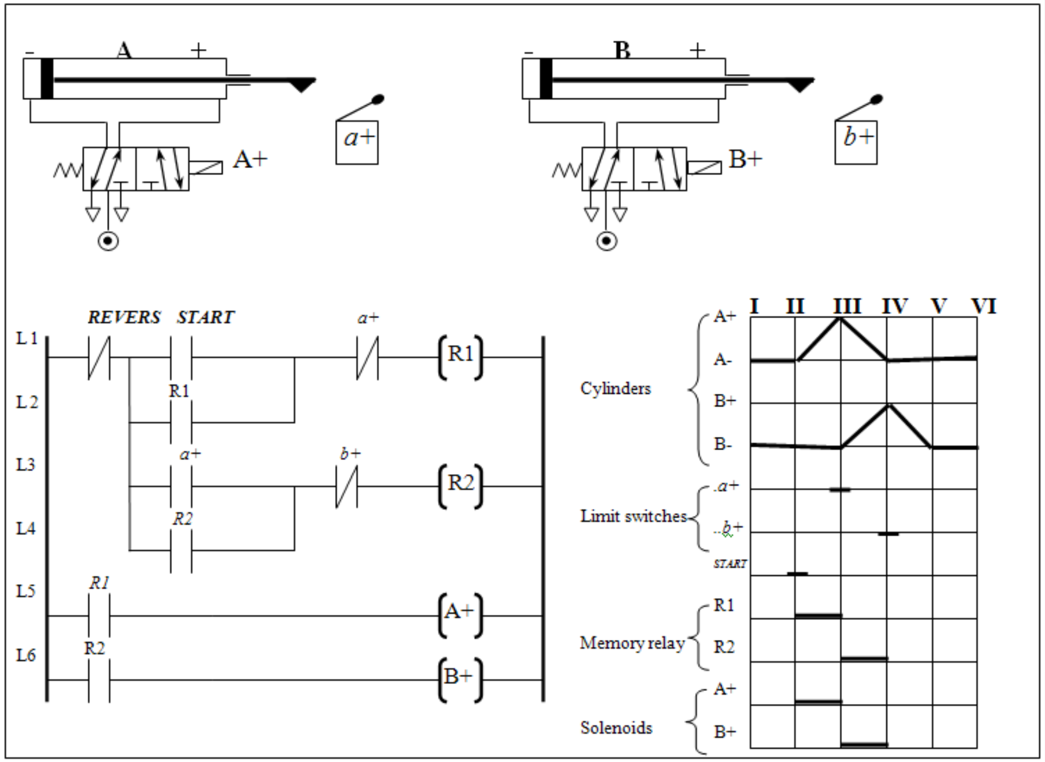


Fig. 7.2 Relay ladder logic (RLL) developed using sequencing chart to control two double acting cylinders using 5/2 solenoid valve with return spring and two limit switches. Machine sequence *START, A+,A-,B+,B-*

7.2 Design Using Sequencing Chart

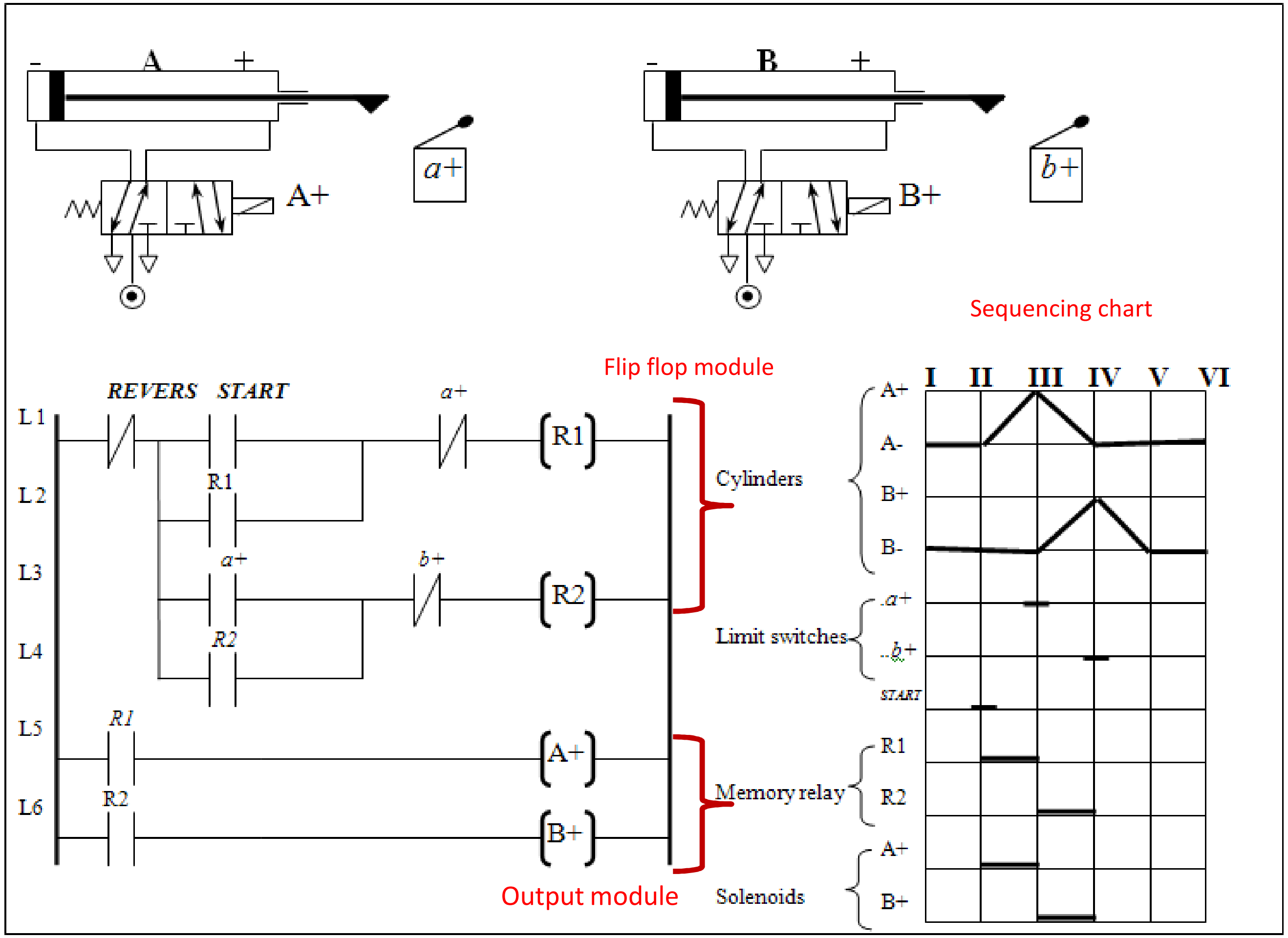


Fig. 7.2 Relay ladder logic (RLL) developed using sequencing chart to control two double acting cylinders using 5/2 solenoid valve with return spring and two limit switches. Machine sequence *START, A+,A-,B+,B-*

7.2 **Design Using Sequencing Chart**

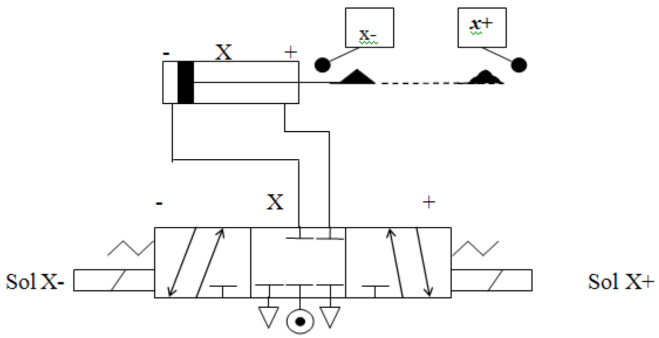
Exercise: Modify the above example to carry out the following control sequence ;

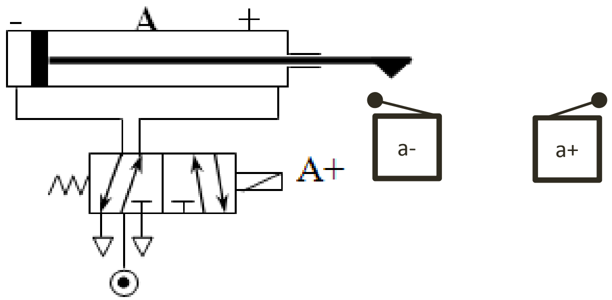
1. *START* push button.
2. Cylinder *(A)* forward and keep it in the forward position.
3. Cylinder *(B)* forward.
4. All cylinders *(A) & (B)* backward.

   Machine cycle will be ; *START, A+, B+,A-,B-*.

One of the efficient methods to design sequencing control problems is the CASCADE method [7.1]. This technique can be used to control the sequence of operations of machine sequence having non-sustain control signals or sustain control signals.

What we mean by non-sustain and sustain control signals ?





Non-sustain control signal:
Have mechanical memory.

Sustain control signal:
No mechanical memory.

Design RLL for Single-Path Machine Sequence using CASCADE method Non-Sustain Control Signals:

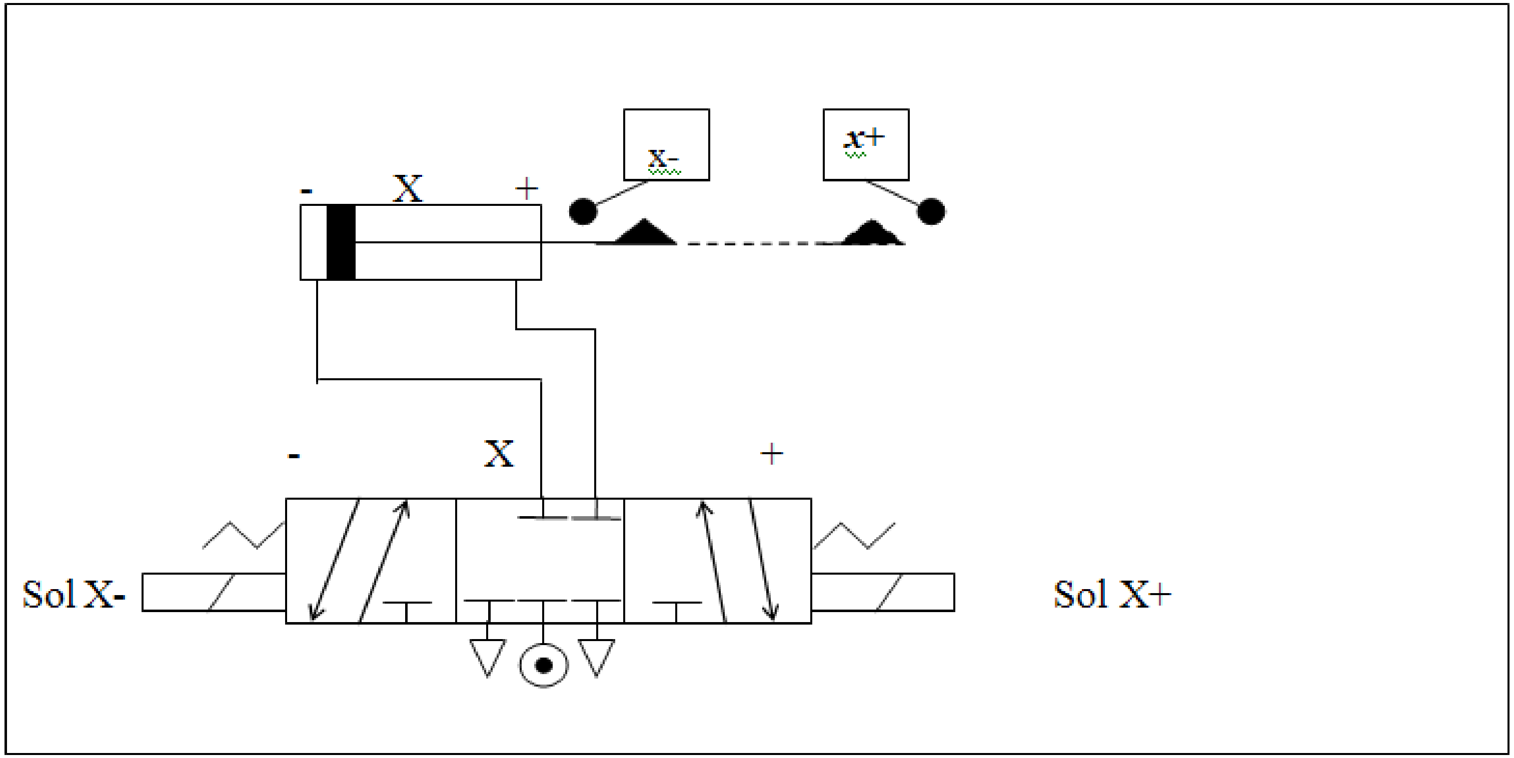


Fig. 7.3, Cylinder X operation having two electric limit switches $x+$ and $x-$ showing two- solenoid valve 5/3 symbol with two-spring return.

requirement, the given machine sequence can be divided into three groups such that no letter is repeated in any group and given as follows;

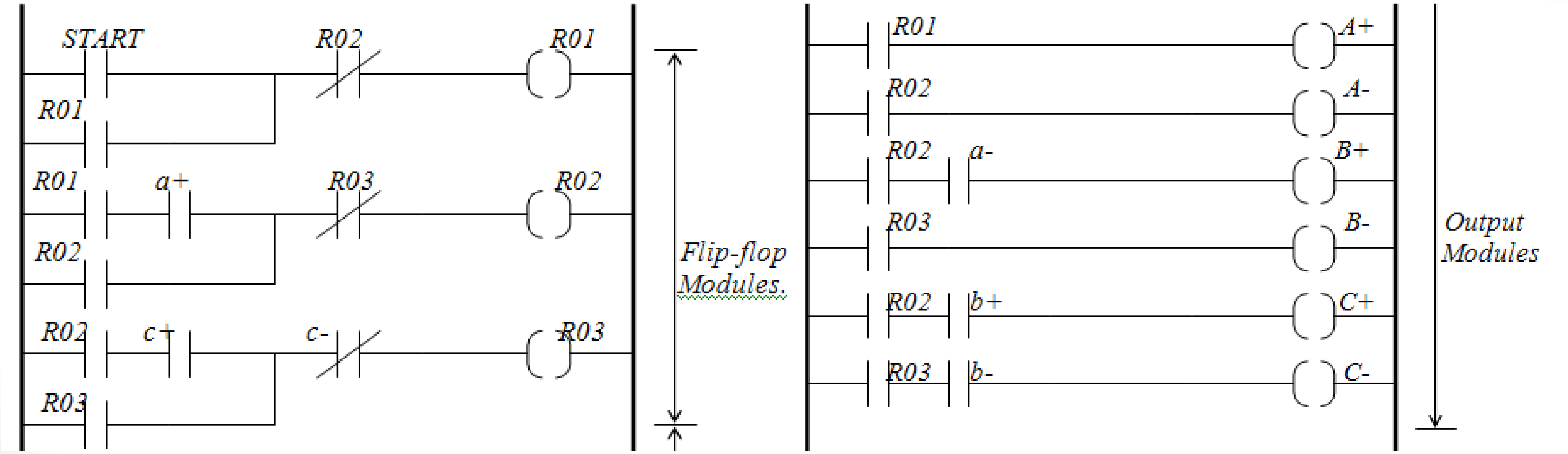
Machine control sequence : **START, A+, A-, B+, C+, B-, C-.**

Group I | Group II | Group III

7.3 RLL Design for Sequencing System Using CASCADE Methods

Design RLL for Single-Path Machine Sequence using CASCADE method Non-Sustain Control Signals:

Machine control sequence : **START, A+, A-, B+, C+, B-, C-.**
Group I | Group II | Group III

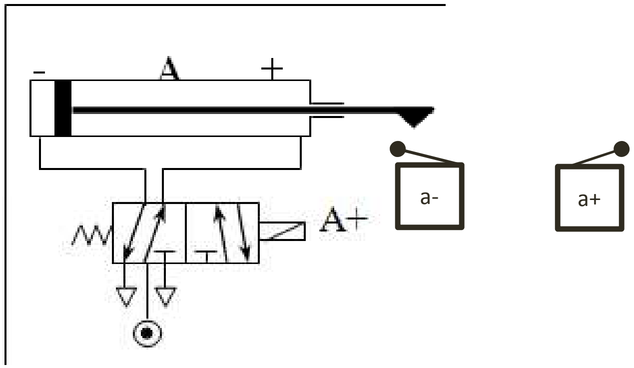


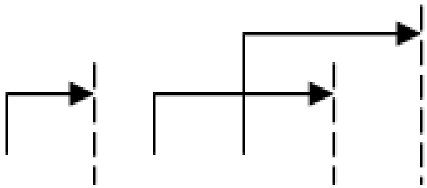
(a) Relay ladder logic without sustain outputs

7.3 RLL Design for Sequencing System Using CASCADE Methods

Design RLL for Single-Path Machine Sequence using CASCADE method

Sustain Control Signals:





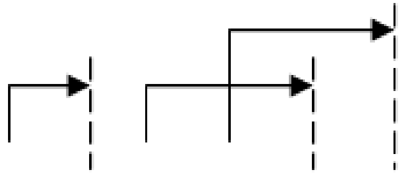
Machine control sequence : **START, A+, A-, B+, C+, B-, C-.**

Group I | Group II | Group III

7.3 RLL Design for Sequencing System Using CASCADE Methods

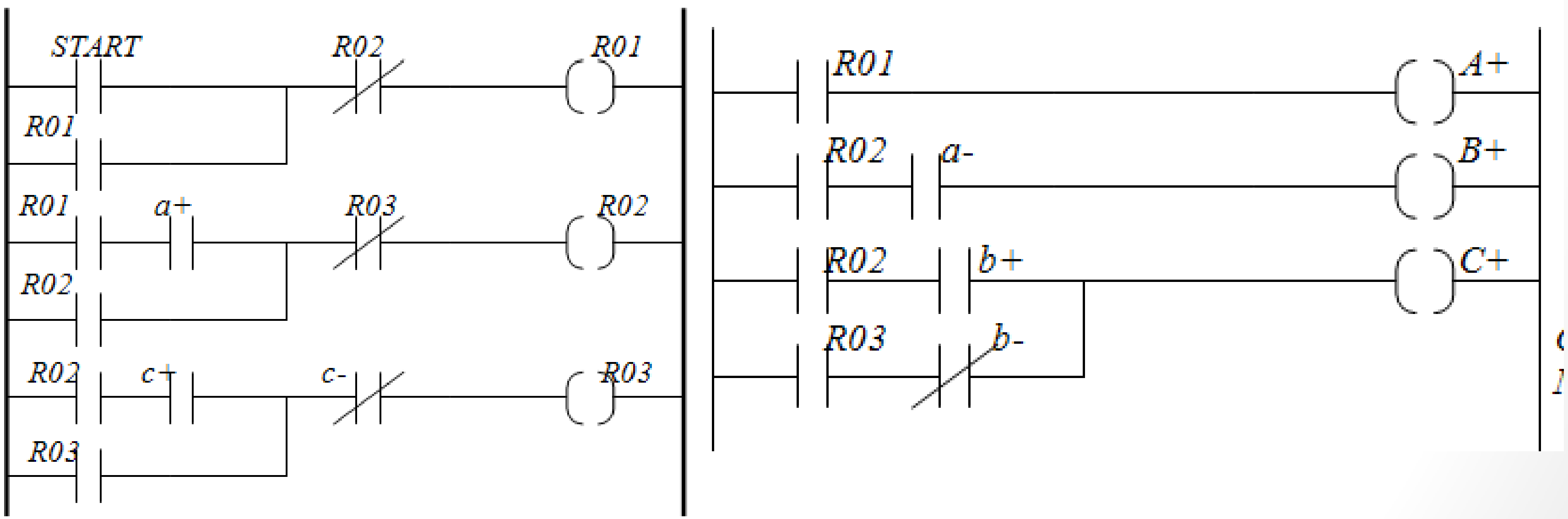
Design RLL for Single-Path Machine Sequence using CASCADE method Sustain Control Signals:

Example 7.0

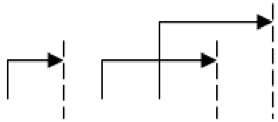


Machine control sequence : **START, A+, A-, B+, C+, B-, C-.**

Group I | Group II | Group III



7.3 RLL Design for Sequencing System Using CASCADE Methods



Machine control sequence : **START, A+, A-, B+, C+, B-, C-.**

Group I | Group II | Group III

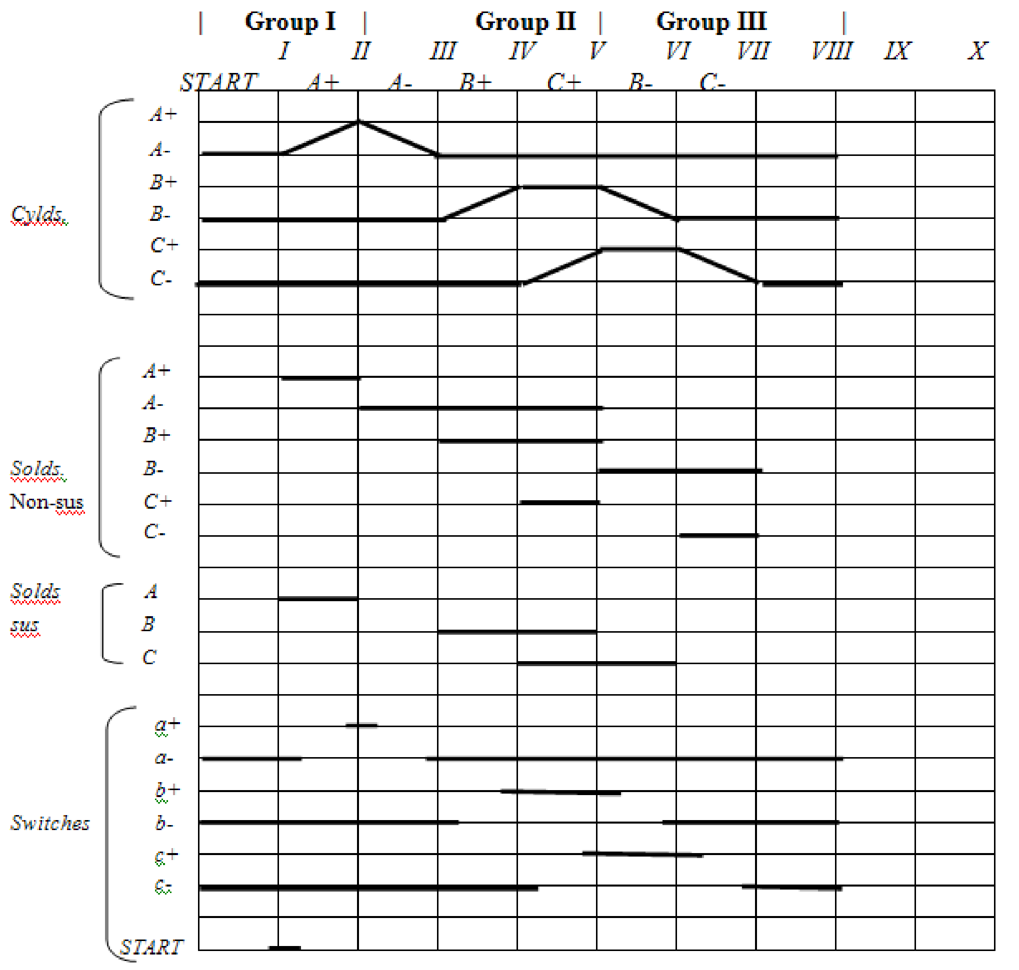
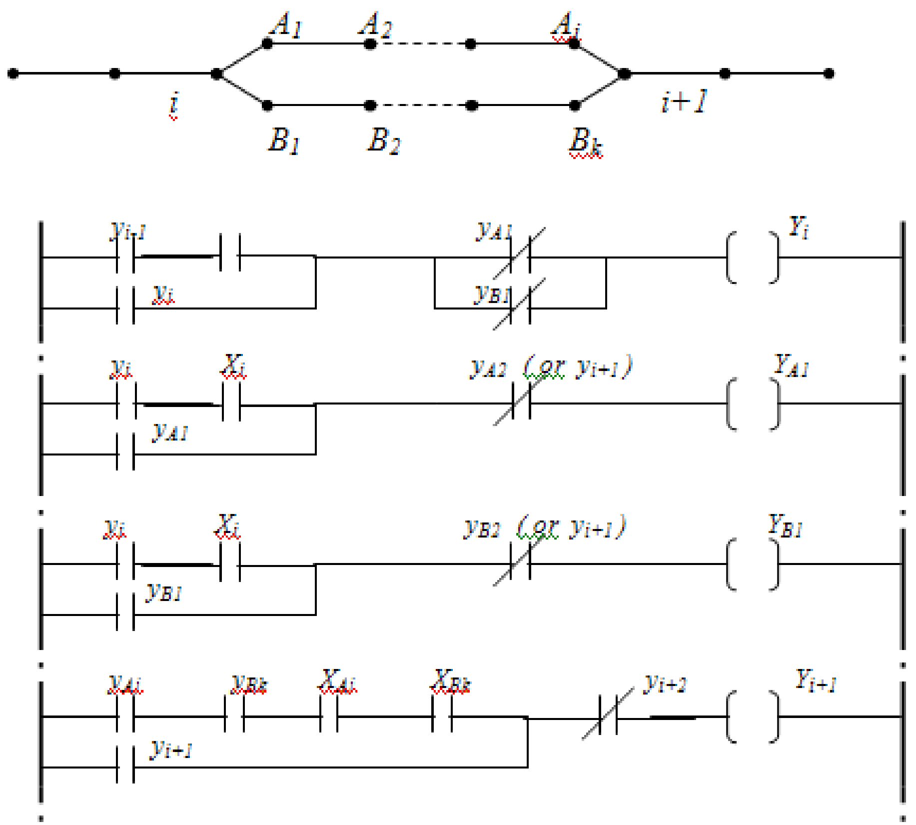


Fig. 7.5 Sequencing chart for machine cycle *START,A+,A-,B+,C+,B-,C-.*

Design RLL for Multi-Path Machine Sequence using CASCADE method (Sustain/Non-Sustain Outputs)

Cascade method also can be applied to multi-path machine control sequence.

Here program proceeds as regular single path up to the completion of *step(i).* At this point, two parallel paths *A* and *B* are carried out simultaneously. Path *A* has *j* steps, and path *B* has *k* steps; the *j* and *k* are not necessarily equal. Only after both paths have been completed AND function, the program continue with the next single-path *step(i+1)*.

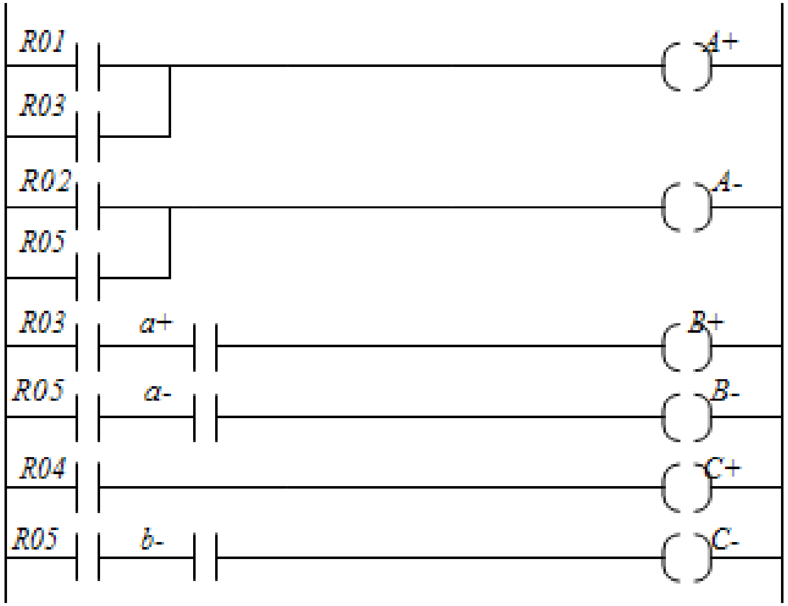


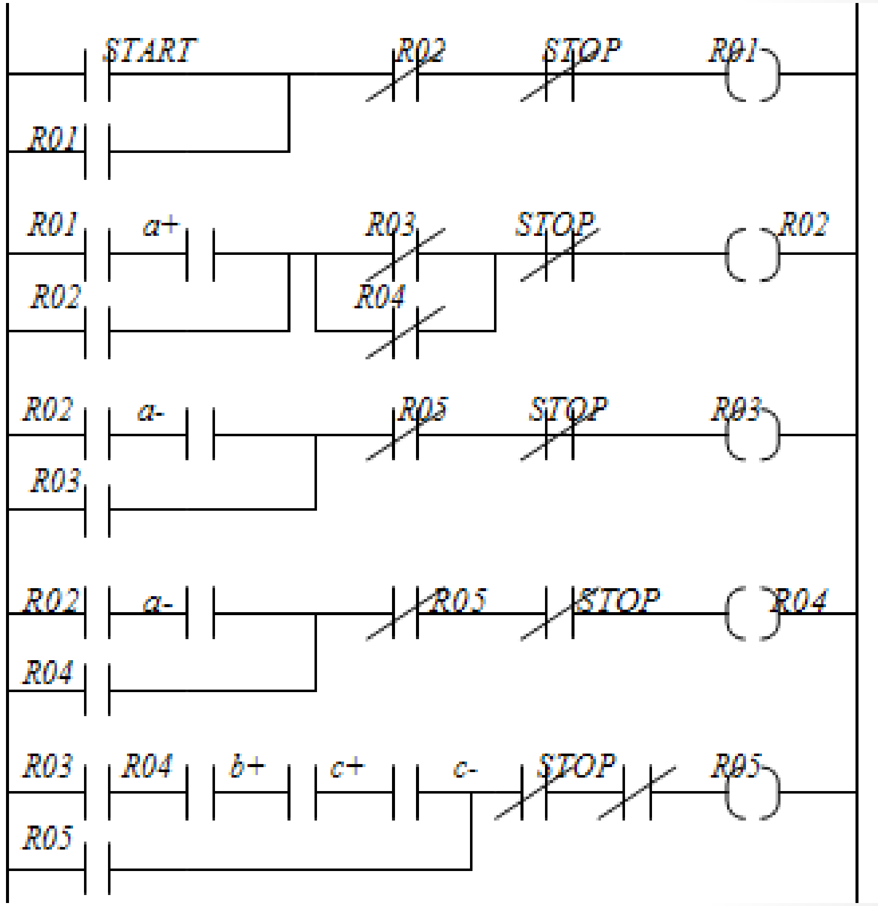
Design RLL for Multi-Path Machine Sequence using CASCADE method (Sustain/Non-Sustain Outputs)

Example 7.1

$$START\ , A^{+}, A^{-}, \begin{pmatrix} A^{+}, B^{+} \\ C^{+} \end{pmatrix}, A^{-}, B^{-}, C^{-}.$$

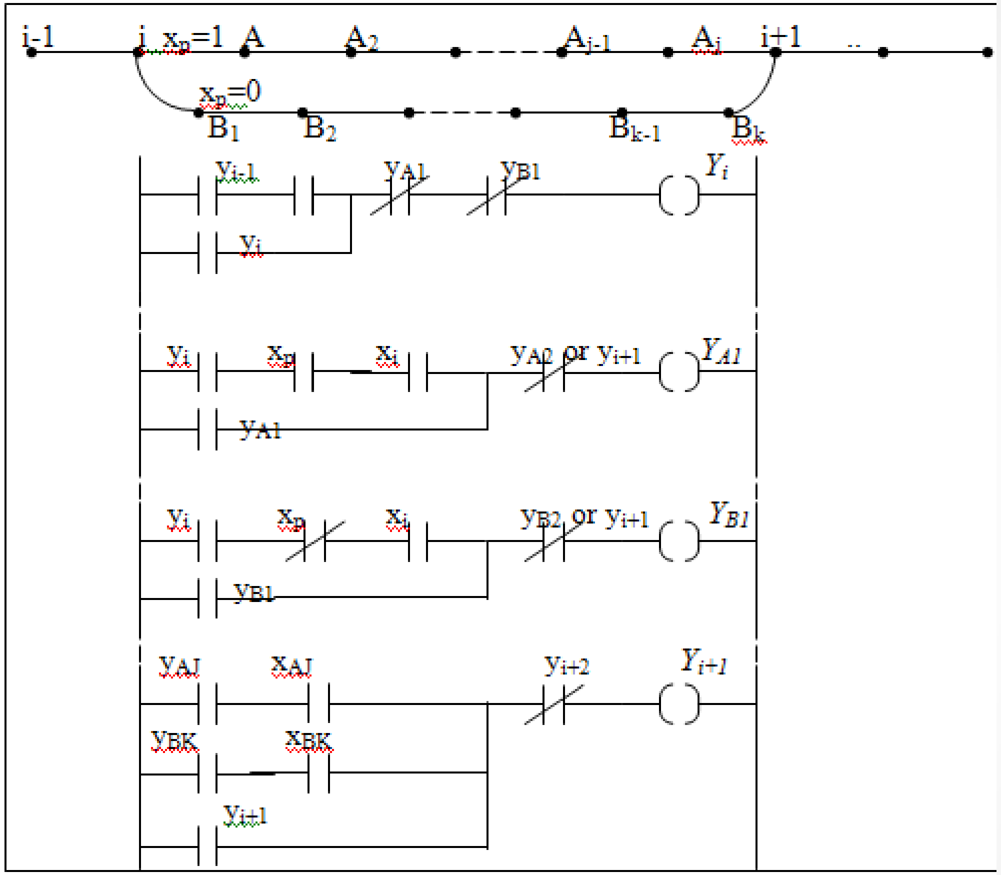
$$START\ , G1,\ G2\ \begin{pmatrix} G3 \\ G4 \end{pmatrix}, \quad G5.$$





Design RLL for Multi-Path Machine Sequence with two or more alternative parallel paths

Some of machine control sequence require two or more alternative parallel sequence. Hence, this required to use multiple RLL sequence for each path.
Any parallel machine sequence can be enabled using selector switch/switches, or any other external switch.
After step *i* is completed and after switch x_l is set logic 1, either flip-flop Y_{A1} or Y_{B1} is set, depending on whether x_p = 1 or 0, respectively.
Compellation of either step A_j or B_k sets flip-flop Y_{i+1} .

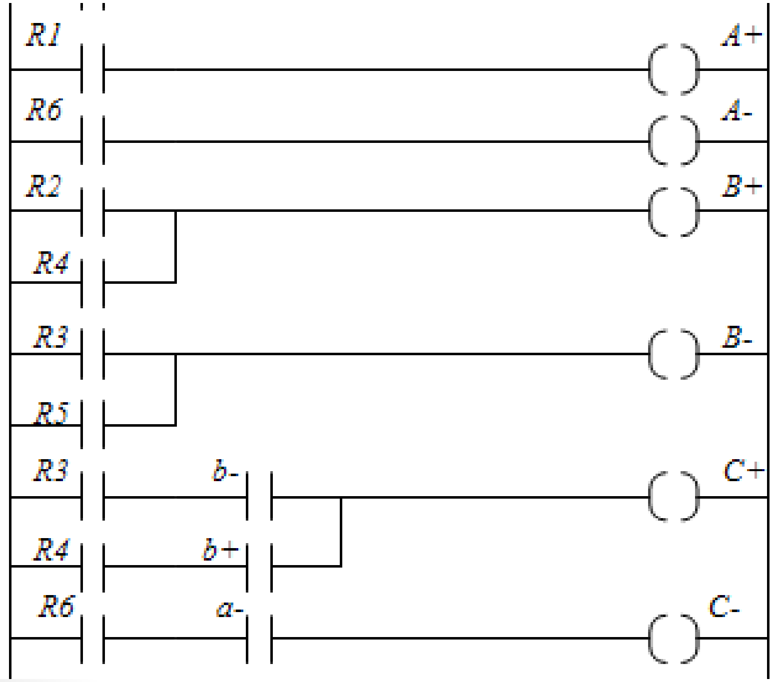


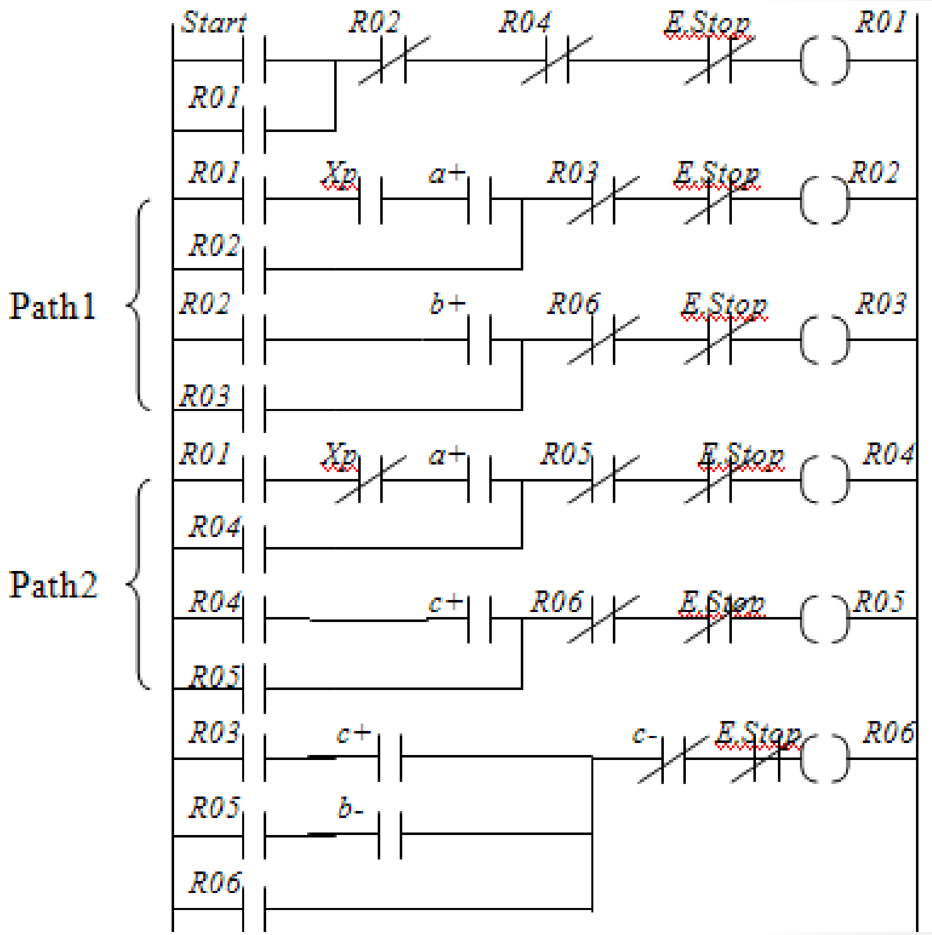
Design RLL for Multi-Path Machine Sequence with two or more alternative parallel paths

Example 7-2

$$START, A^{+}, \begin{pmatrix} x_p = 1; (B^{+}, B^{-}, C^{+}) \\ x_p = 0; (B^{+}, C^{+}, B^{-}) \end{pmatrix}, A^{-}, C^{-}.$$

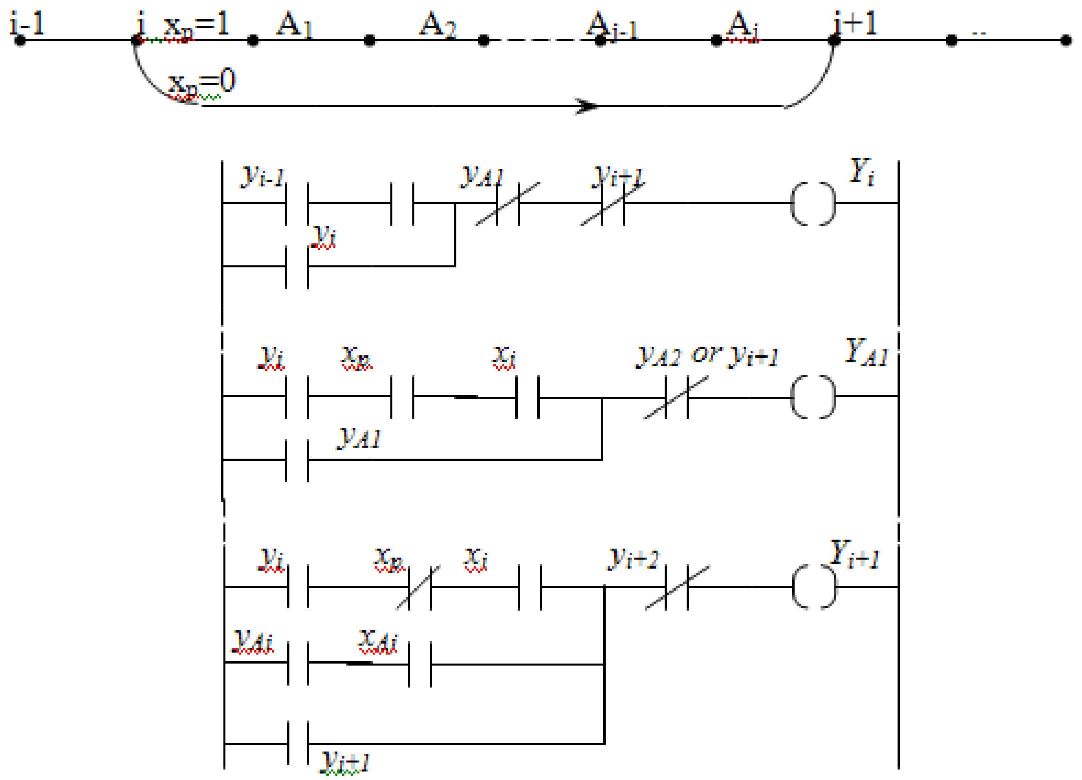
$$START, G1, \begin{pmatrix} x_p = 1; G2, G3 \\ x_p = 0; G4 \quad , G5 \end{pmatrix}, G6$$





Design RLL for Machine Sequence with option of bypassing certain steps

Here there are a machine sequence with the option of bypassing certain machine sequence steps.
At the completion of step *i*, if input control signal x_p =1, then the system goes through program steps from A_1 to A_j, and continue with step *I+1*. If, on the other hand, x_p = 0, then the system jumps directly from step *I* to *I+1*.

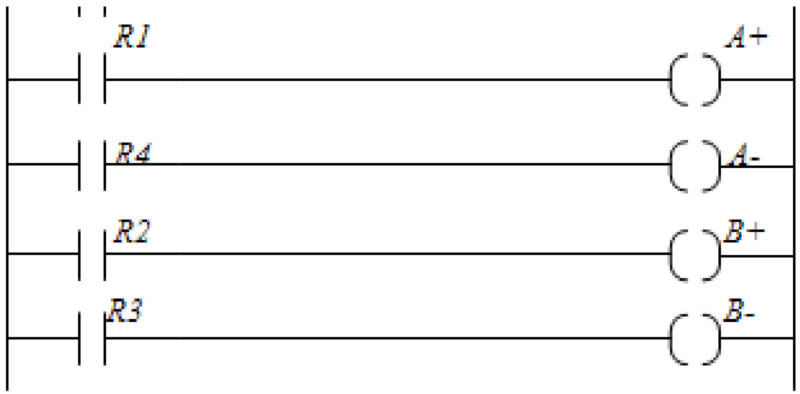


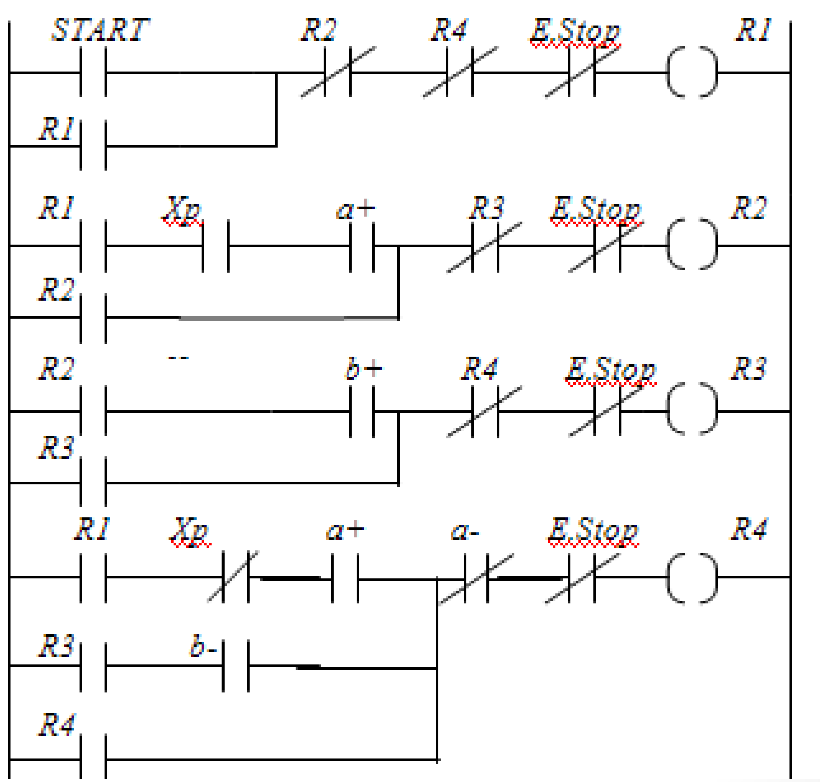
Design RLL for Machine Sequence with option of bypassing certain steps

Example 7.3

START, *A+* , ⎧ X_p=1; (B+, B-) **G2 | G3** ; X_p=0; by pass ⎫ , *A-* .

G1 — **G2 | G3** — **G4**





7.3 RLL Design for Sequencing System Using CASCADE Methods

Design RLL for Machine Sequence with option of repeating certain steps

Here a multi-path machine sequence with the option of repeating certain steps.
At the completion of step A_j, the system will continue with step $i+1$, provided $x_p = 1$. If, however, $x_p = 0$, then steps A_1 to A_j are repeated indefinitely until x_p becomes 1. This circuit is suitable for machine sequence to be repeated until the desired effect is achieved.

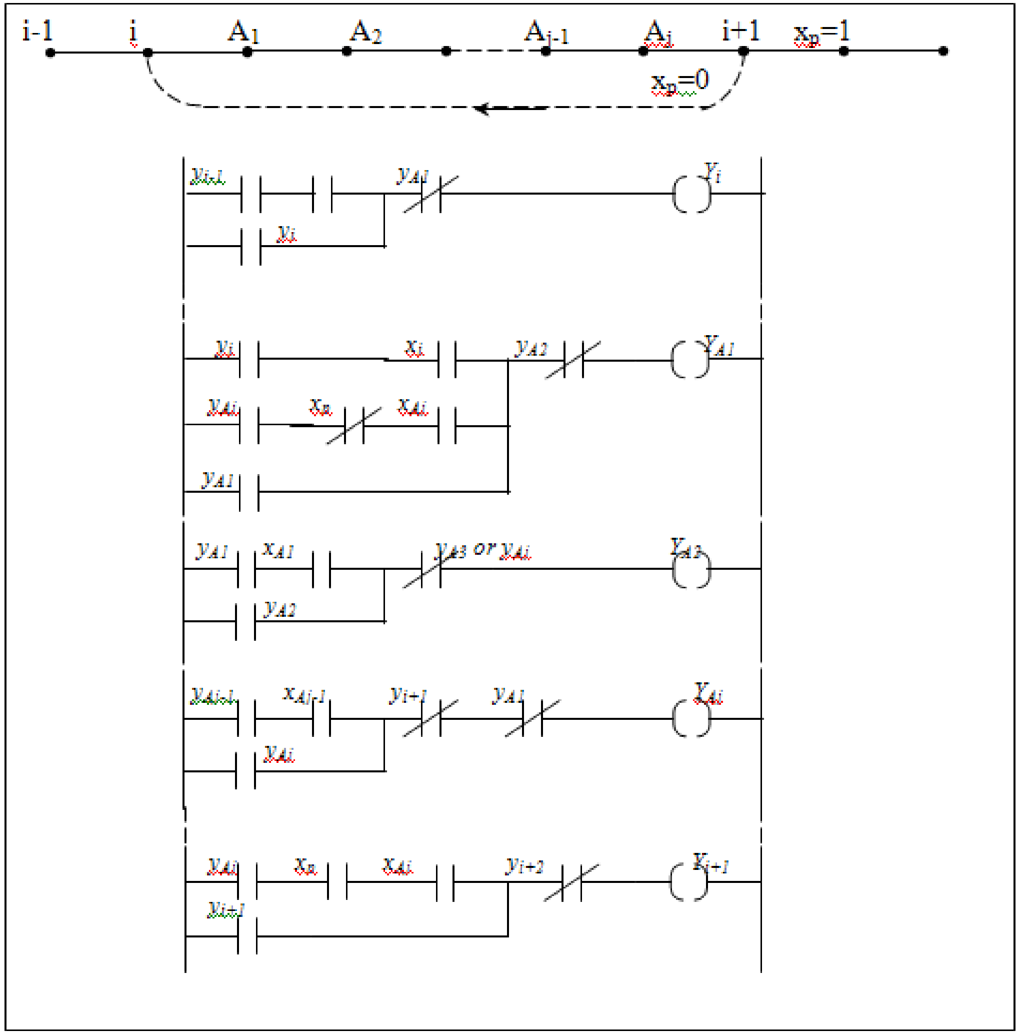
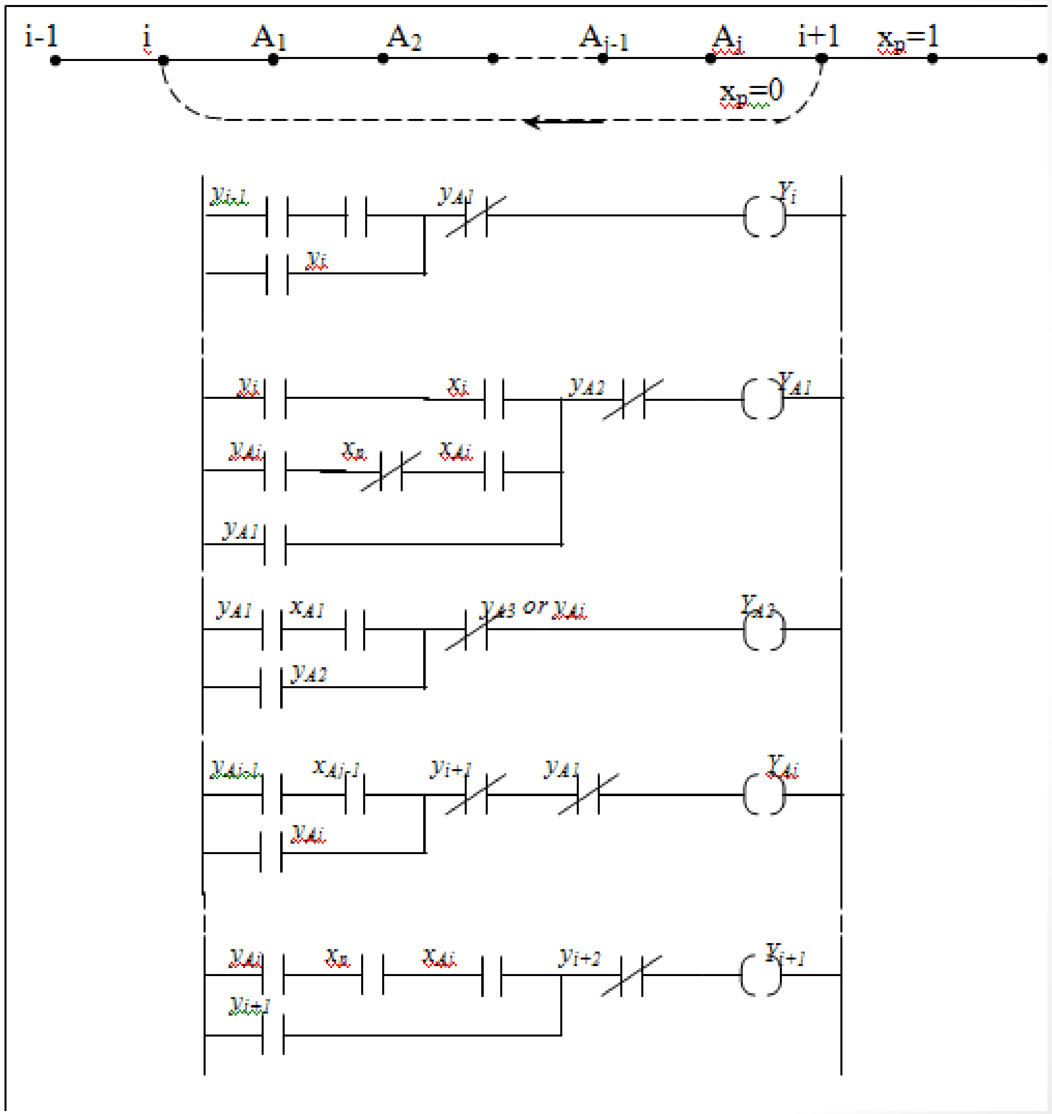


Fig. 7.12 Keyed RLL for machine sequence with option of repeat machine sequence steps.

Design RLL for Machine Sequence with option of repeating certain steps

Note; at least <u>three</u> flip-flops must be allocated for repeated machine steps. If only one or two flip-flops were assigned for the repeated machine steps, they will set and reset simultaneously and multifunction would occur. Even the rule to divide the machine sequence into groups calls for only two groups to cover the repeated steps, a third 'dummy' group must be added.

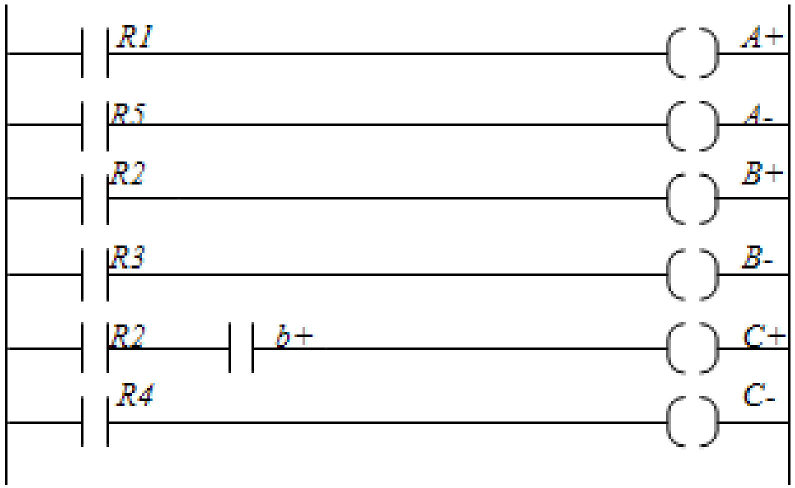


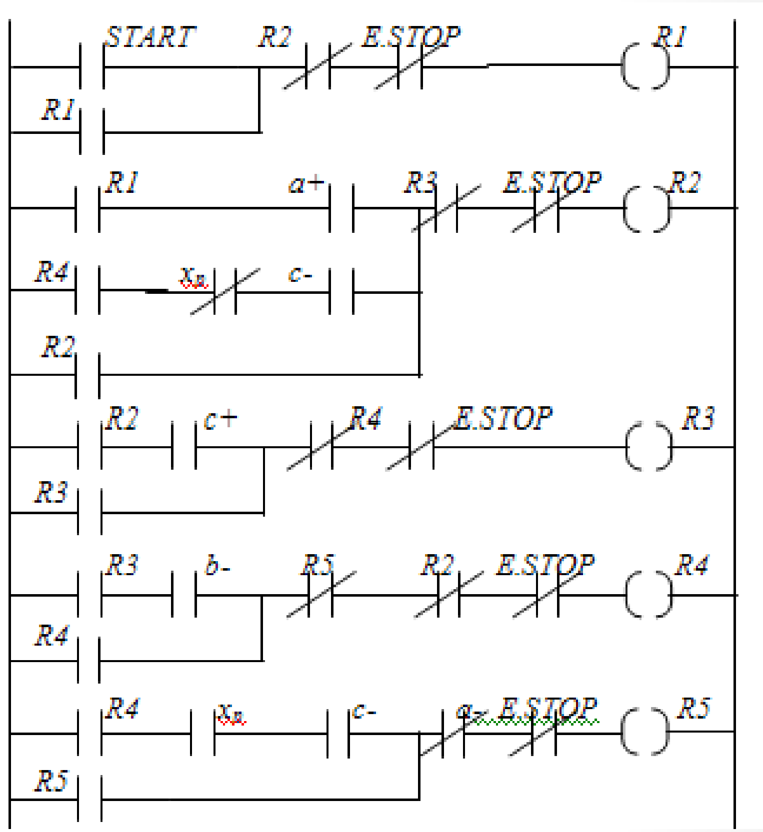
Design RLL for Machine Sequence with option of repeating certain steps

Example 7.4

$$START, A^{+}, \left(x_{p} = 0; repeat\,(B^{+}, C^{+}, B^{-}, C^{-})\right), A^{-}.$$

$$START, G1, (\qquad G2 \qquad , G3, G4 \;) \; G5$$





PROPLEMS:

7.1) Develop the sequencing chart for the following machine cycles using double acting cylinder having two limit switches, at the two extreme positions. Solve the problem assuming non-sustain control signals (5/3 double solenoids and two spring for valve center);

a) START, A+, A-, A+, A-, B+, B-.

b) START, A+, B+, B-, B+, B-, A-.

c) START, A+, A-, B+, C+, B-, C-.

d) START, A+, B+, A-, A+, B-, A-.

e) START, A+, B+, A-, B-, A+, A-.

7.2) Group the machine cycles given in Prob. 7.1 using Cascade method then develop the *RLL?*

7.3) Resolve Problem 7.1 using sustain control signals (5/2 solenoid valve with return spring)?

7.4) Resolve Problem 7.2 using sustain control signals (5/2 solenoid valve with return spring)?

PROPLEMS:

7.5) Group the following parallel path machine cycles using Cascade method, develop the sequencing chart, and *RLL* using non-sustain control signals;

a) $START, A^+, A^-, \begin{pmatrix} A^+ \\ B^+ \end{pmatrix}, A^-, B^-.$

b) $START, A^+, A^-, \begin{pmatrix} A^+ \\ B^+ \\ C^+ \end{pmatrix}, C^-, B^-, A^-.$

7.6) Group the following machine cycles using Cascade method and develop the *RLL* for the given machine sequence having three alternative paths and using two selector switches X_{p1} and X_{p2}. The machine sequence given as follows (assume non-sustain control signal for cylinders *B*,*C* and *D*, while sustain control signal for cylinder *A*):

$$START, A^+, \begin{pmatrix} x_{p1} = 1, x_{p2} = 1; (B^+, B^-) \\ or \\ x_{p1} = 1, x_{p2} = 0; (C^+, C^-) \\ or \\ x_{p1} = 0, x_{p2} = 1; (D^+, D^-) \end{pmatrix}, \quad A^-.$$

PROPLEMS:

7.7) Group the following machine cycle using Cascade method and develop the RLL for the given machine sequence having two alternative paths and bypass machine cycle path. The selection of machine paths and bypass path is achieved using two selector switches X_{p1} and X_{p2}. The machine sequence given as follows(assuming non-sustain control signals for all cylinders):

$$START, A^+, \begin{pmatrix} x_{p1}=1, x_{p2}=1; (B^+, B^-) \\ or \\ x_{p1}=1, x_{p2}=0; (C^+, C^-) \\ or \\ x_{p1}=0, x_{p2}=1; bypass \end{pmatrix}, \quad A^-.$$

7.8) Develop RLL for machine sequence with optional repeat machine steps. The selection of repeated machine path is achieved using two selector switches x_{p1} and x_{p2} for the machine sequence given as follows (assuming non-sustain control signal for all cylinders):

$$START, A^+, \left(x_{p1}=1 \,\&\, x_{p2}=1;\ repeat\ (until\ x_{p1}=1 \,\&\, x_{p2}=0;\ B^+, B^-) \right), A^-.$$

7.9) Resolve Prob. 7.8 by adding alternative path of machine sequence as illustrated below:

$$START, A^+, \begin{pmatrix} x_{p1}=1 \,\&\, x_{p2}=1;\ repeat\ (until\ x_{p1}=1 \,\&\, x_{p2}=0;\ B^+, B^-) \\ or \\ x_{p1}=0 \,\&\, x_{p2}=1;\ (C^+, C^-) \end{pmatrix}, A^-.$$