Chapter 2
Ladder Programming

2.1 Conditional Logic

The PLC scans its inputs and, depending on the program, switches on or off various combinations of outputs. The logic state of the output depends on the input conditions and so the term *conditional logic* is used.

A simple example of conditional logic could be stated as follows:

"A machine switches on if either of two *start* switches are closed and all of three *stop* switches are closed."

The conditions could be realised by a hard wire solution as shown in Fig 2.1.

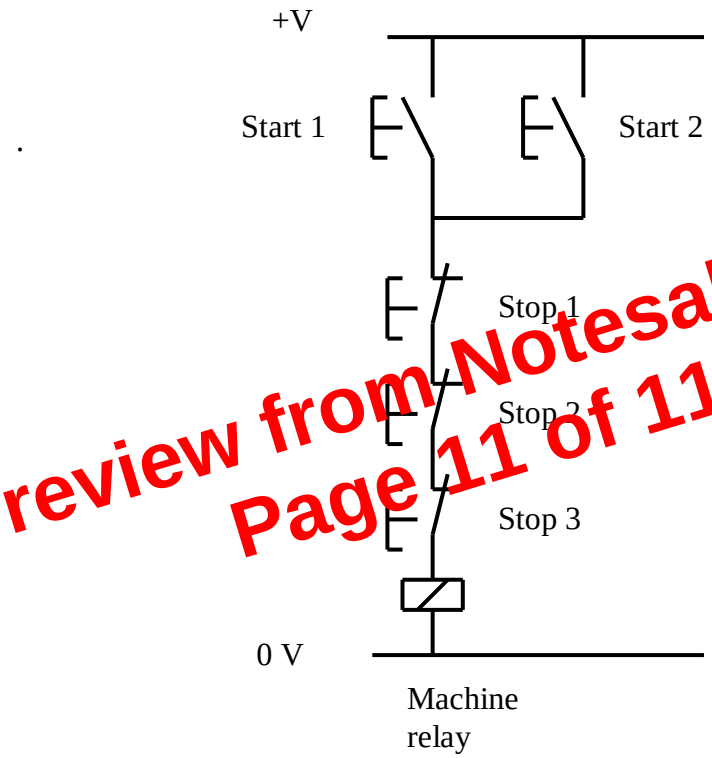
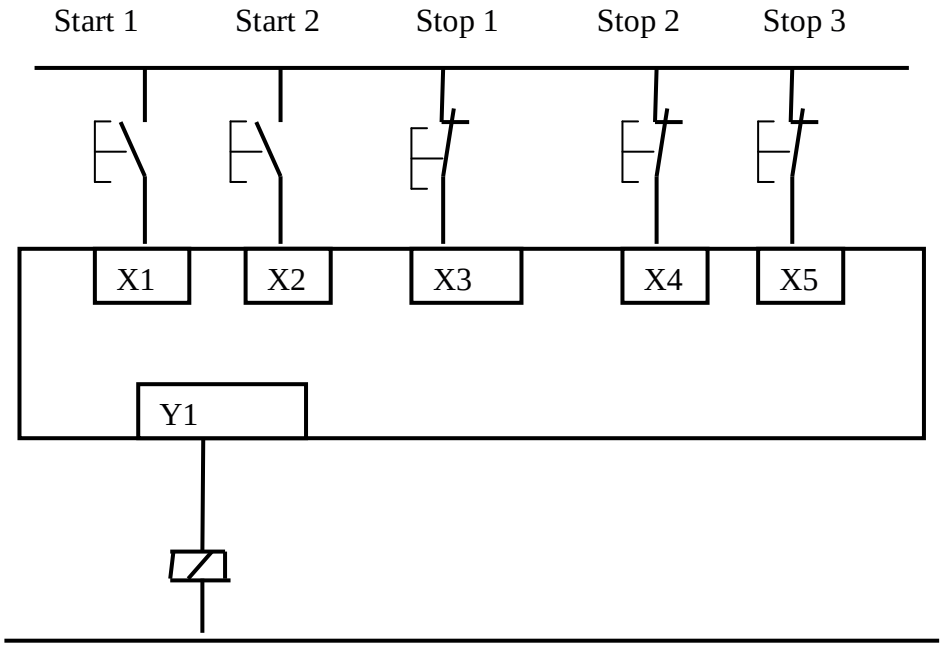


Fig 2.1 Hard-Wire Conditional Logic Example

The two *start* switches are connected in parallel. Current will flow if one *or* the other *or* both are closed. The start switches are normally open. This means that the contacts are apart and no current flows when the switches are in their normal (or *unoperated* or *rest*) state.

The three *stop* switches are connected in series. Current can only flow if the first *and* the second *and* the third are closed. The *stop* switches are normally closed. This means that the contacts are connected and current can flow when the switches are in their normal state.



Machine Relay

Fig 2.13

The latch concept can be extended to any number of start and stop switches. The output Y1 in *Fig 2.13* is to be switched on by X1 or X2 and is to stay on until any of the inputs X3, X4 or X5 is switched off. The required ladder diagram is shown in *Fig 2.14* below.

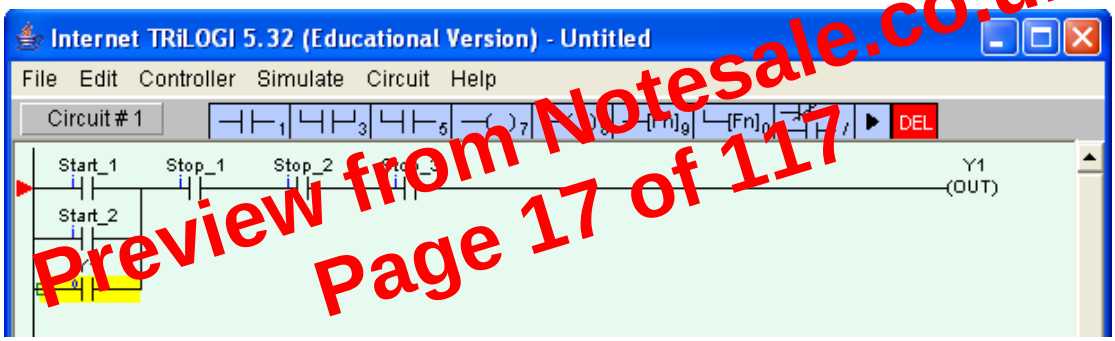


Fig 2.14

2.5 Internal relays

These have the same properties as outputs but they only exist in software. They have many uses. *Fig 2.15* shows an internal relay being used to implement the logic function NAND. This is the inverse of the result of X1 AND X2. We will be making extensive use if internal relays later in the book.

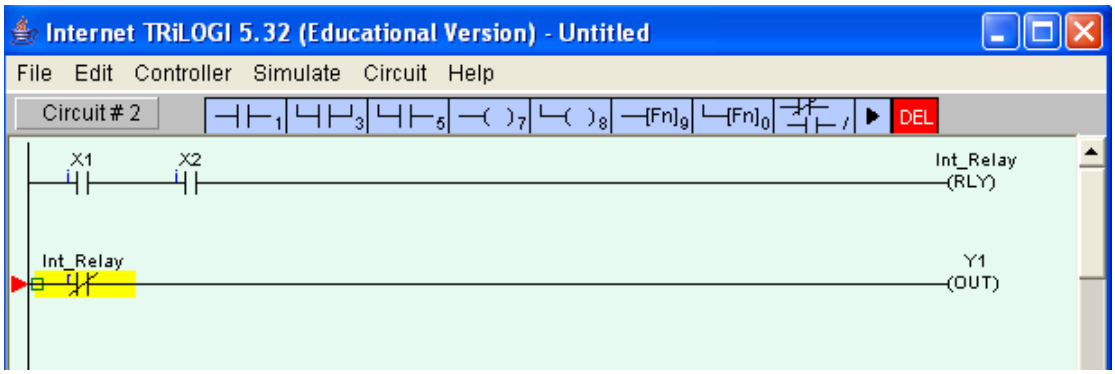


Fig 2.15 Use of internal relay

Note: Most PLCs include a function called a *Set and Reset* or a *flip-flop* which latches and delatches an output or an internal relay. Throughout this book I use the latch as described in section 2.4, because of the visual resemblance of the ladder rung to the equivalent hard-wire circuit, in which a relay coil is latched on by a normally-open contact connected in parallel with the start button.

2.6 Timers

The delay-on timer introduces a delay between the start of one event and the start of another.

For example, when a start push button is pressed, the pneumatic cylinder shown in *Fig 2.16* extends, remains extended for 5 seconds and then returns. Draw the PLC wiring diagram and the appropriate ladder logic.

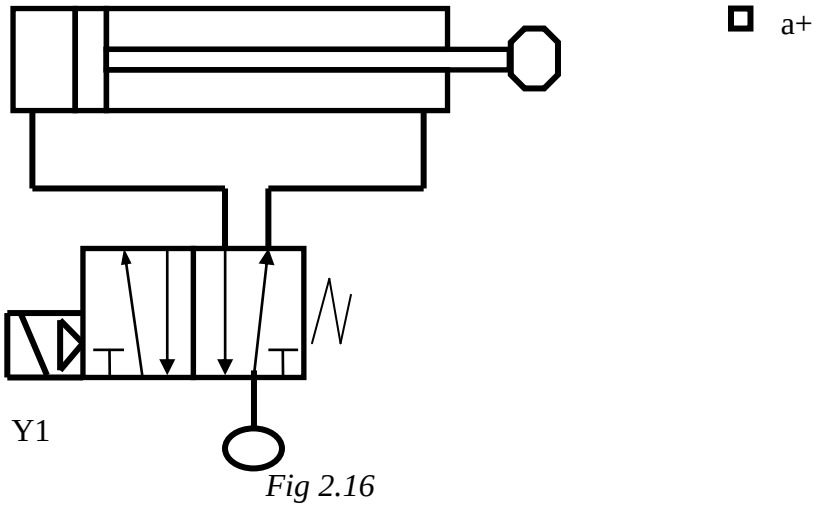


Fig 2.16

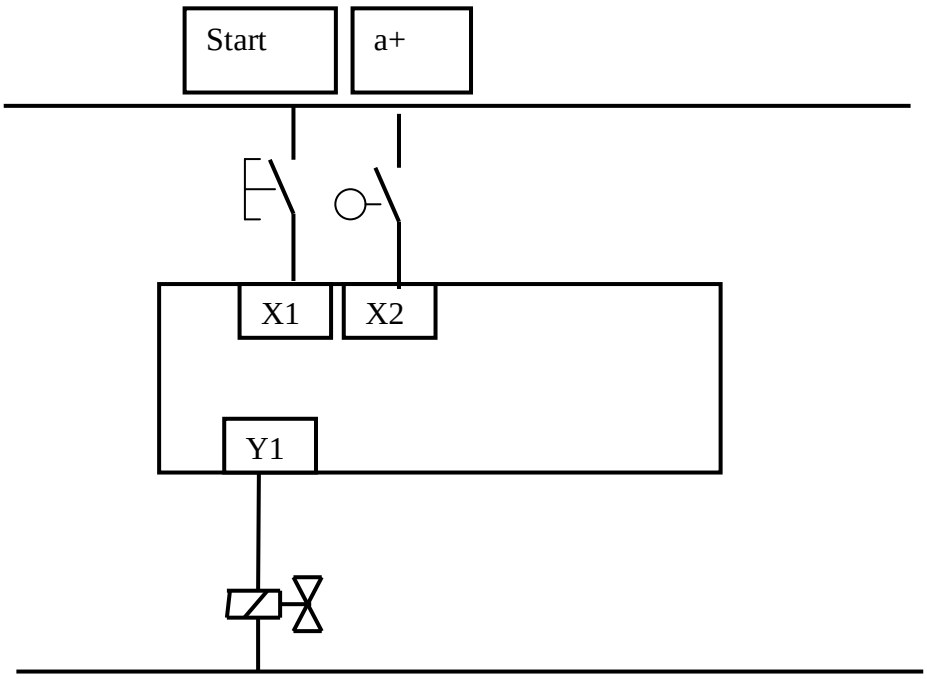


Fig 2.17

The *start* button and the end-of-stroke limit switch *a+* are the PLC inputs and the solenoid Y1 is the output. Any other components needed for the program can be created in software.

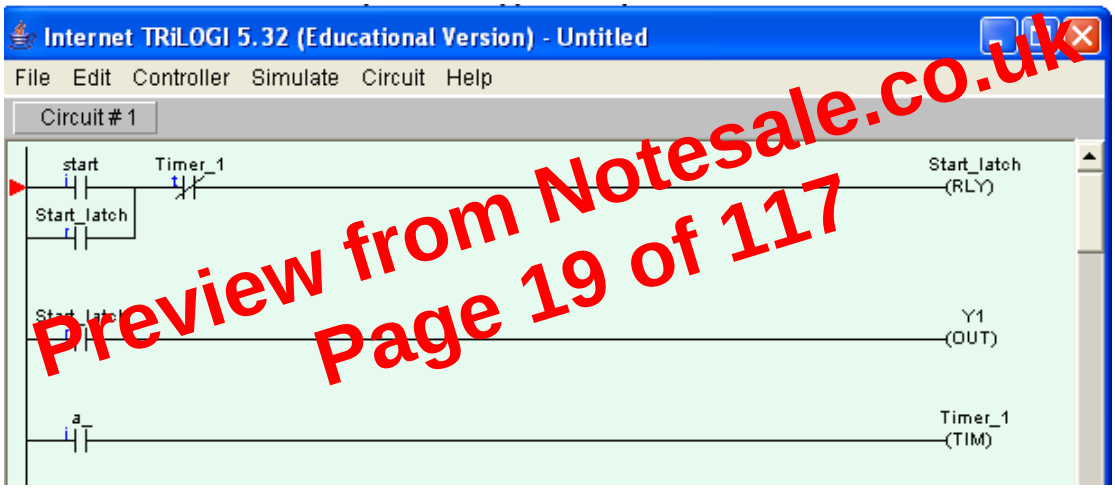


Fig 2.18

Pressing the *start* button latches on an internal relay called *start_latch*. The *start_latch* relay switches on the output Y1 which energises the solenoid, and the cylinder extends. The cylinder rod closes the limit switch a+ which starts the timer in software. When the timer set value time has elapsed the normally-closed contact *Timer_1* in the first line of the program de-energises the *Start_latch* relay and the cylinder returns.

The timer set value in the TRiLOGI software is in units of 0.1 s. For a 5 s delay a value of 50 is entered in the drop-down menu. (More details are given in the appendix)

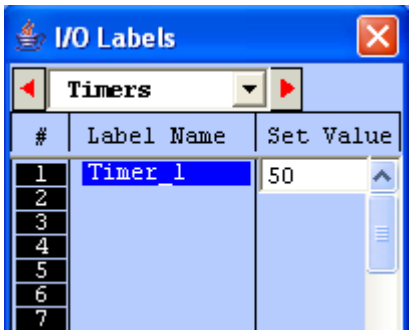


Fig 2.19 Setting Timer preset Value

We can do another example using the same hardware with the addition of an alarm as a second output:

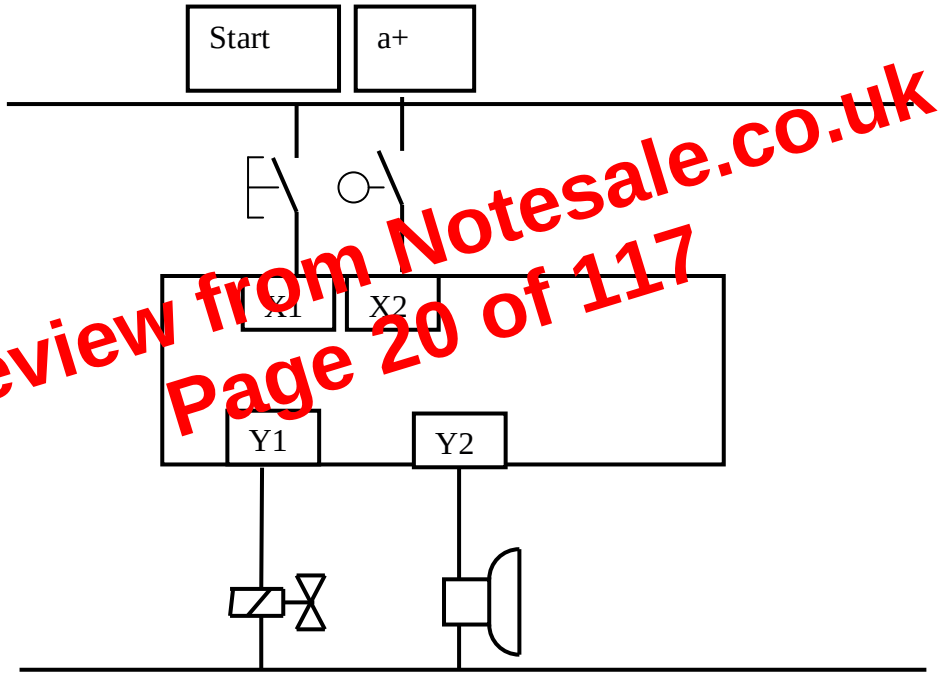


Fig 2.20

Questions and Exercises

1. Pick the correct statement below about the plc ladder

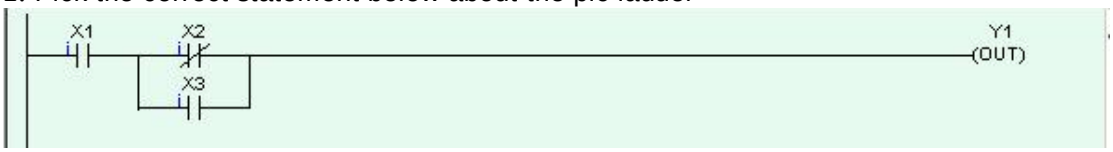


Fig 2.32

Answer:
- a. Y1 switches on if X1 is off OR either X2 is on AND X3 is off
- b. Y1 switches on if X1 is on AND either X2 is off OR X3 is on
- c. Y1 switches on if X1 is on OR either X2 is off AND X3 is on
- d. Y1 switches on if X1 is off AND either X2 is on OR X3 is off

2. Pick the incorrect statement below about the ladder diagram shown

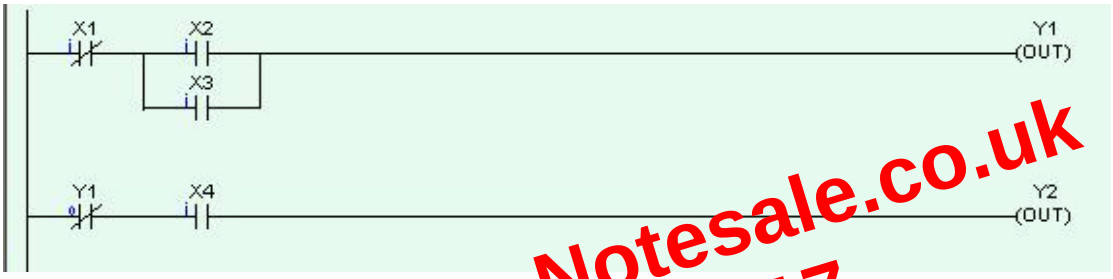


Fig 2.33

Answer:
- a. Y2 switches on if X1 is on AND X2 AND X4 are on.
- b. Y2 switches on if X1 is on AND X3 AND X4 are on
- c. Y2 switches on if X1 is off AND X2 AND X3 are off AND X4 is on.
- d. Y2 switches on if Y1 AND X4 are both on

3. Which form of logic gate system is given by a ladder diagram with a rung having two normally open sets in parallel as shown?

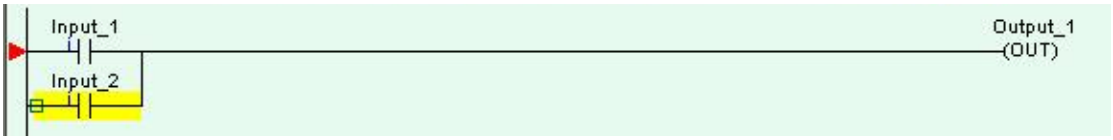


Fig 2.34

Answer:
- a. OR
- b. NOR
- c. AND
- d. NAND

Example 3.2.

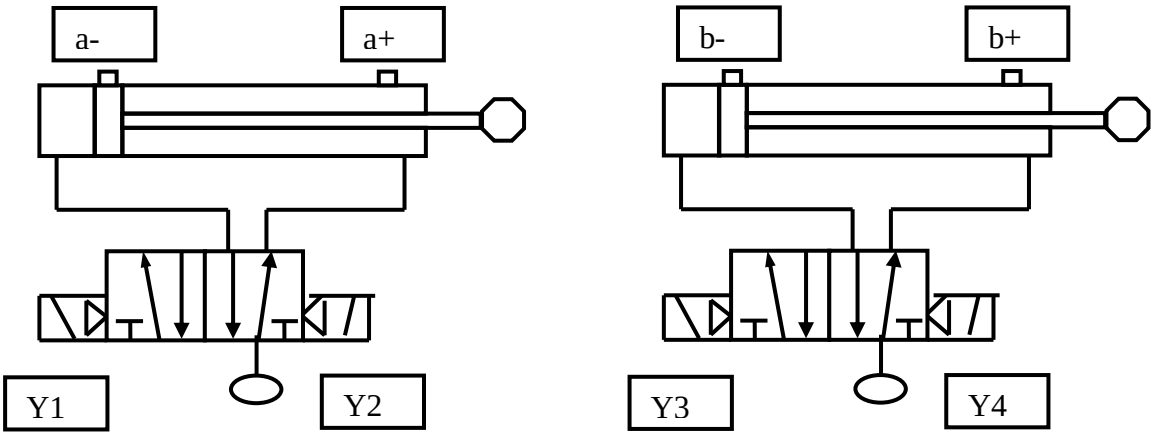


Fig 3.16

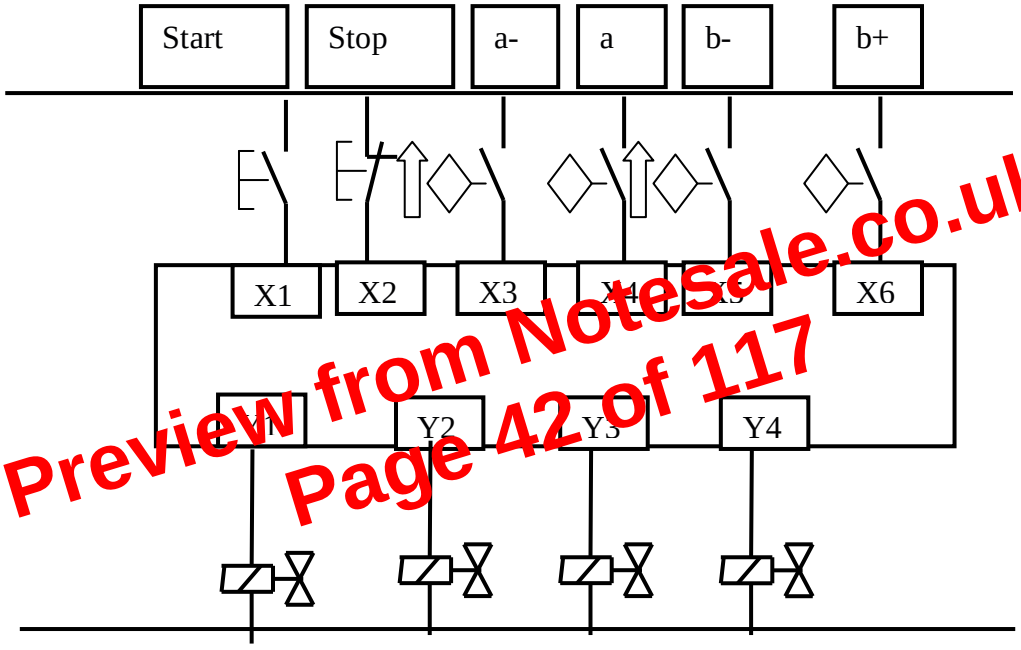


Fig 3.17

We'll use the SFC method to implement the sequence

A+ B+ A- B-

The SF chart is shown in *Fig 3.18* and the assignment list in *Table 3.3*.

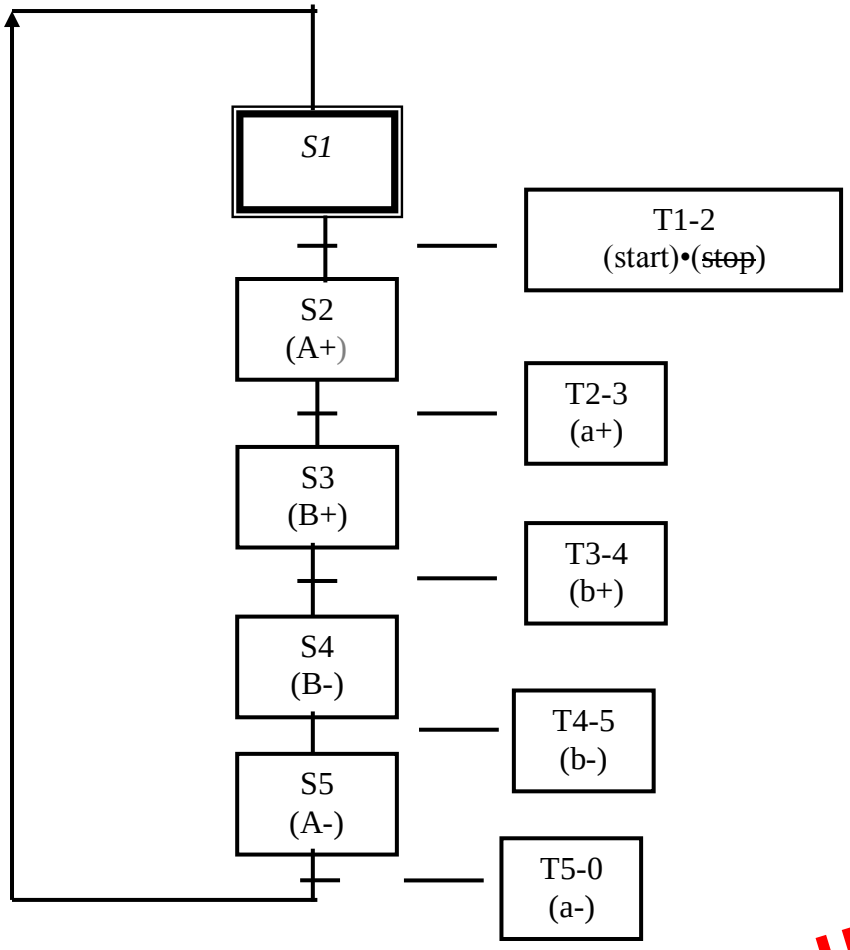


Fig 3.18

S1	R1
S2	R2
S3	R3
S4	R4
S5	R5
T1-2	R6
T2-3	R7
T3-4	R8
T4-5	R9
T5-0	R10

Table 3.3

During State 2 the conveyor drive is energised (*Fig 3.39*) and the closing of the cam switch increments the counter. The counter is reset by the pressing of the *Start* button (*Fig 3.40*).

Questions and Exercises 3

1.

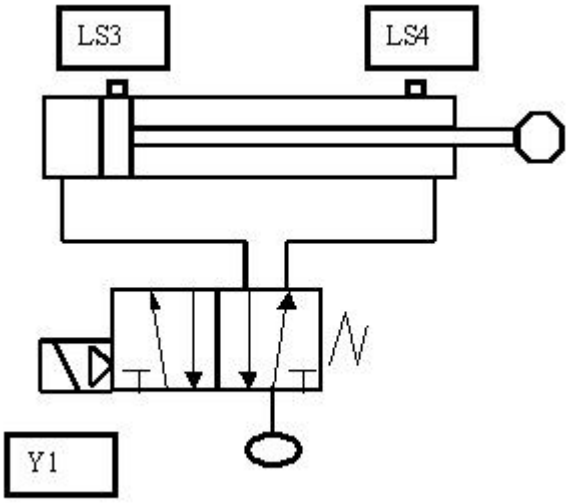


Fig 3.41

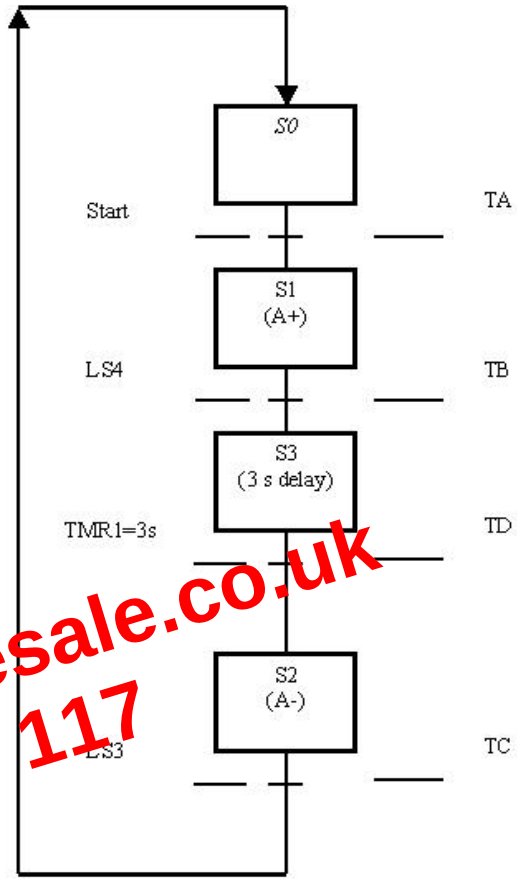


Fig 3.42

The dcv and cylinder in *Fig 3.41* are controlled by a plc with the program shown in *Fig 3.43.* If the 5/2 solenoid/spring dcv was replaced by a 5/2 double solenoid dcv and the second solenoid, Y2, connected to plc output Y2, then which statement below correctly describes during which states the outputs Y1 and Y2 would be energised?

Answer:

- a. Y1 in states 1 and 3, Y2 in state 2
- b. Y1 in states 1 and 3, Y2 in states 0 and 2
- c. Y1 in state 0, Y2 in state 3
- d. Y1 in state 1, Y2 in state 2

9.

It is necessary to automate the drilling of 2 holes in the clamp body shown in *Fig 3.52*. Both holes are at an angle of 45º to the vertical .

For the drilling operation, the clamp is mounted on the rotation jig shown in *Fig 3.53*

Two views of the drill assembly are shown in *Fig 3.54*. Each double acting pneumatic cylinder is operated by a double solenoid 5/2 directional control valve. Limit switches are positioned as shown to detect the advanced and retracted cylinder positions.

When the start button is pressed the sequence is as follows

1. The first hole is drilled.
2. The jig is unclamped by cylinder I.
3. The jig is rotated through 90º by the rack on cylinder R.
4. The jig is clamped (cylinder I).
5. The second hole is drilled.
6. The jig is unclamped (cylinder I)
7. The jig is rotated back through 90º (cylinder R).
8. The jig is clamped (cylinder I).

The drill motor runs continuously throughout the sequence.

(a) Draw the appropriate state/transition diagram.

(b) Draw a suitable plc wiring diagram assigning I/Os as necessary.

(c) Draw the lines of ladder logic to operate the system as designed.

The PLC wiring diagram is shown in *Fig 4.2* and the SF chart in *Fig 4.3*

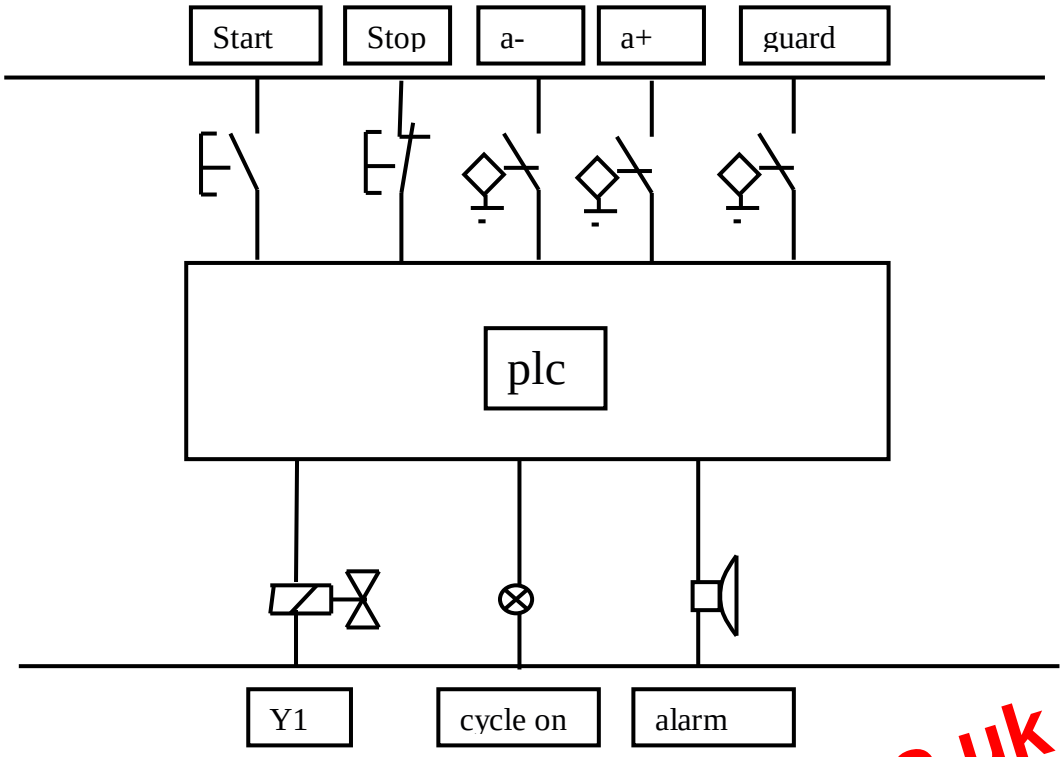


Fig 4.2

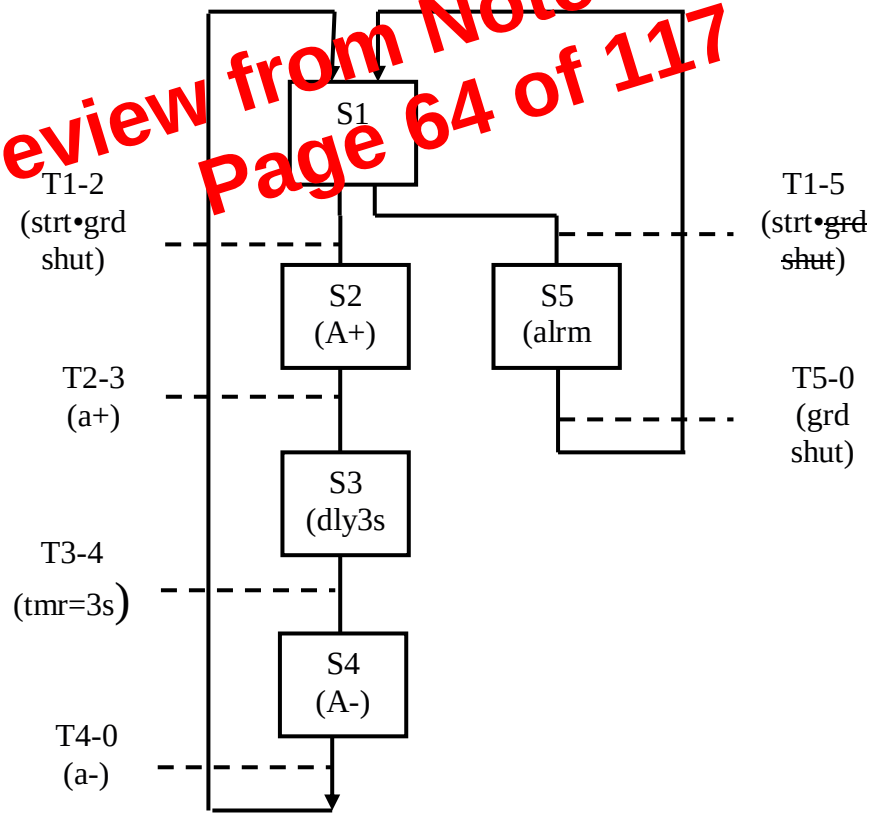


Fig 4.3

Example 4.2

Here is another example that uses the selective branching technique.

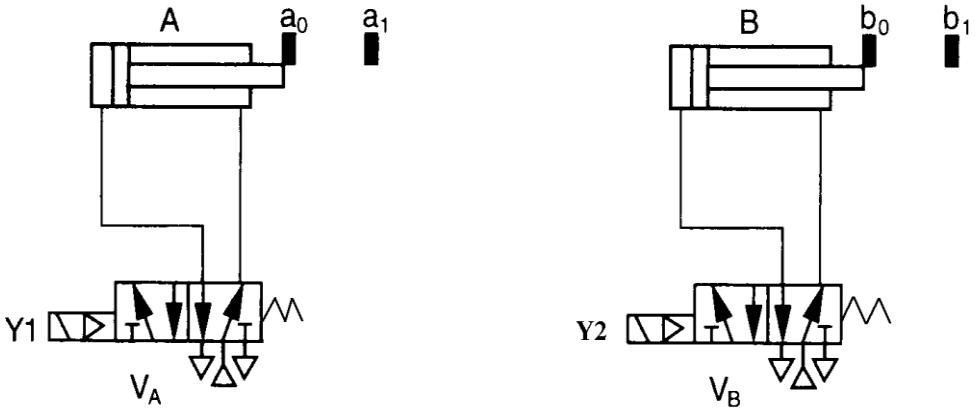


Fig 4.9

The cylinders above are to execute the sequence A+ B+ B- A- continuously until a stop button is pressed when both cylinders will stop at the end of the sequence.

If, however a self-latching switch is turned on the cycle becomes A+, 5s delay, A-, executed continuously as before.

(a) Draw a plc wiring diagram for the system.

(b) Write out an assignment list for the system

(c) Draw a sequential function chart for the system.

(d) Draw the ladder logic to operate the system as designed.

Solution

(a)

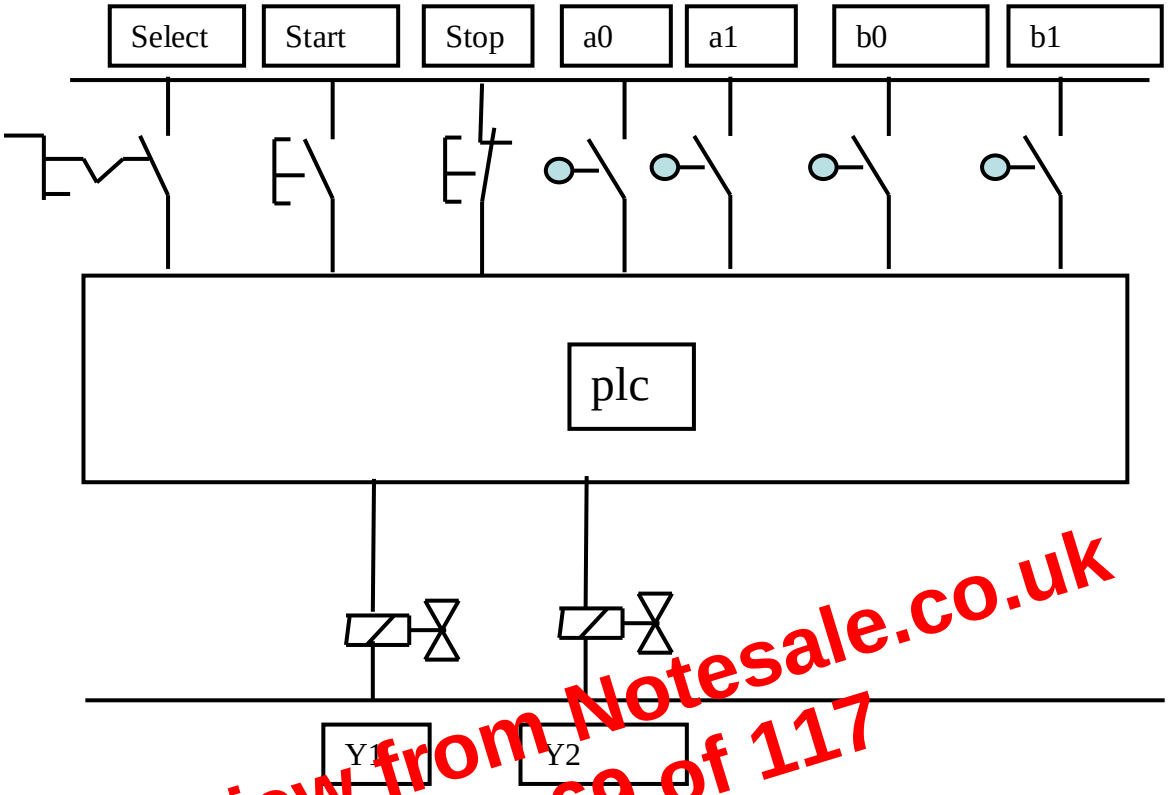


Fig 4.10

(d)

Initial Conditions:

Fig 4.12

Transitions:

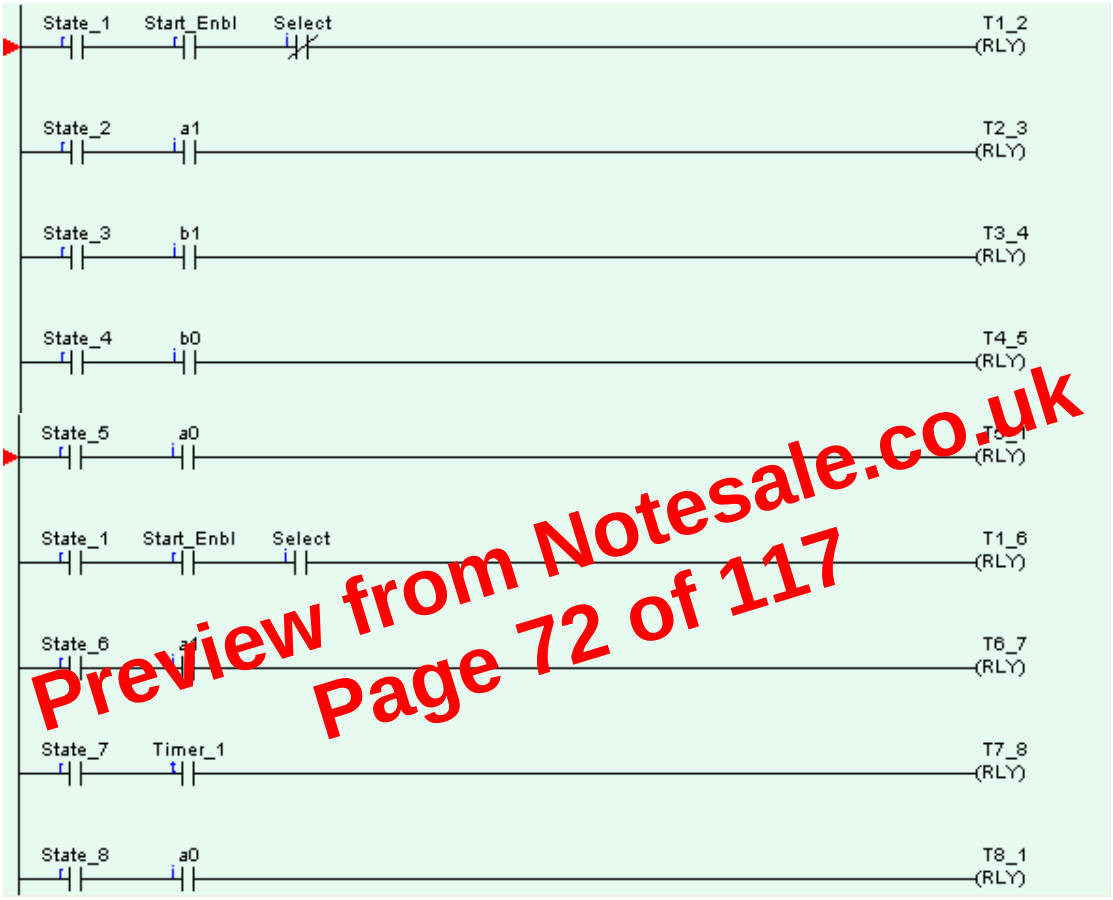


Fig 4.13

8.
The sequence for a set of traffic lights is to be plc controlled.

The sequence is, red, red and amber, green, amber.

Select the only incorrect statement below regarding the program.

Answer:
- a. The transitions from one state to the next will be activated by timers.
- b. Selective branching will be necessary for the red and amber part of the sequence.
- c. The lights will be plc outputs.
- d. Two outputs will be on during the red and amber state.

9.

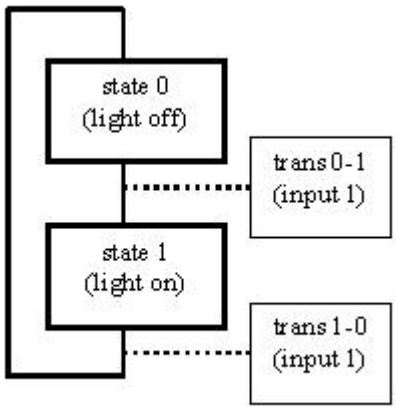


Fig 4.35

Select the only correct statement below regarding the diagram *Fig 4.35.*

Answer:
- a. There can be no default state in such a sequence.
- b. Input 1 only switches the light on.
- c. Input 1 only switches the light off.
- d. Input 1 alternately switches the light on and off.

10.

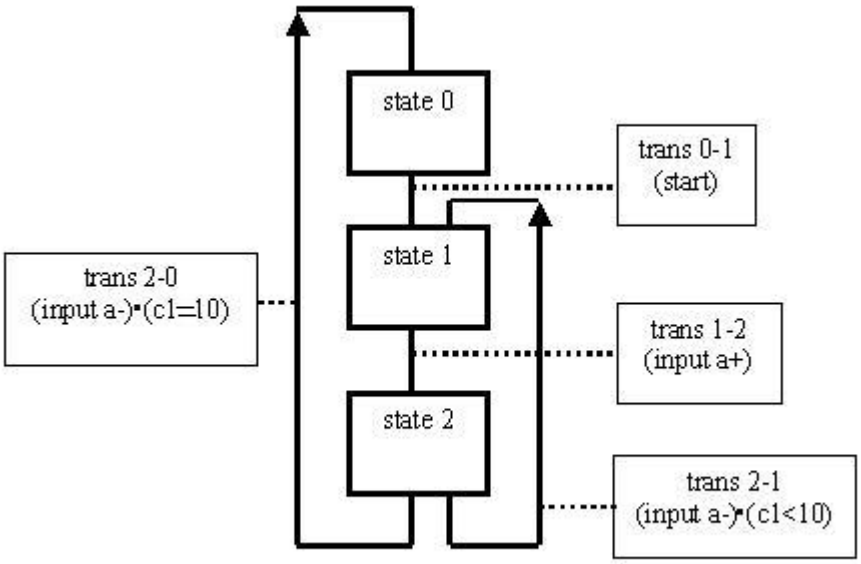


Fig 4.36

Select the only incorrect statement below regarding the diagram *Fig 4.36*. (c1 is a plc counter)

Answer:

- a. If the plc count is less than 10, state 0 will always follow state 2
- b. If the plc count is less than 10, state 1 will always follow state 2
- c. Provision must be made in the system to reset the counter.
- d. The counter's present value is the deciding factor between trans 2-0 and trans 2-1

Solution
(a)

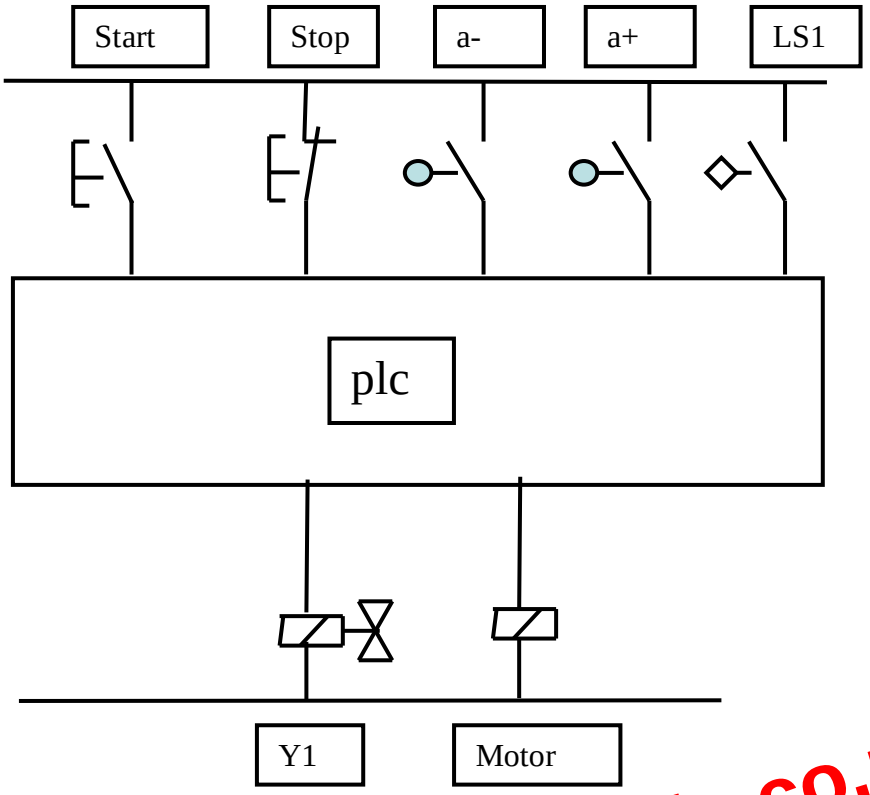


Fig 5.3

Two extra waiting states S10 and S11 have been introduced because it is not possible for a the sequence to simultaneously enter a selective and a parallel branch. Once states 10 and 11 are active the choice of routes for the program depends on whether components are in place under the drill and countersink.

The PLC wiring diagram with the two additional inputs is shown in *Fig 5.18* and the modified assignment list is shown in *Table 5.3.*

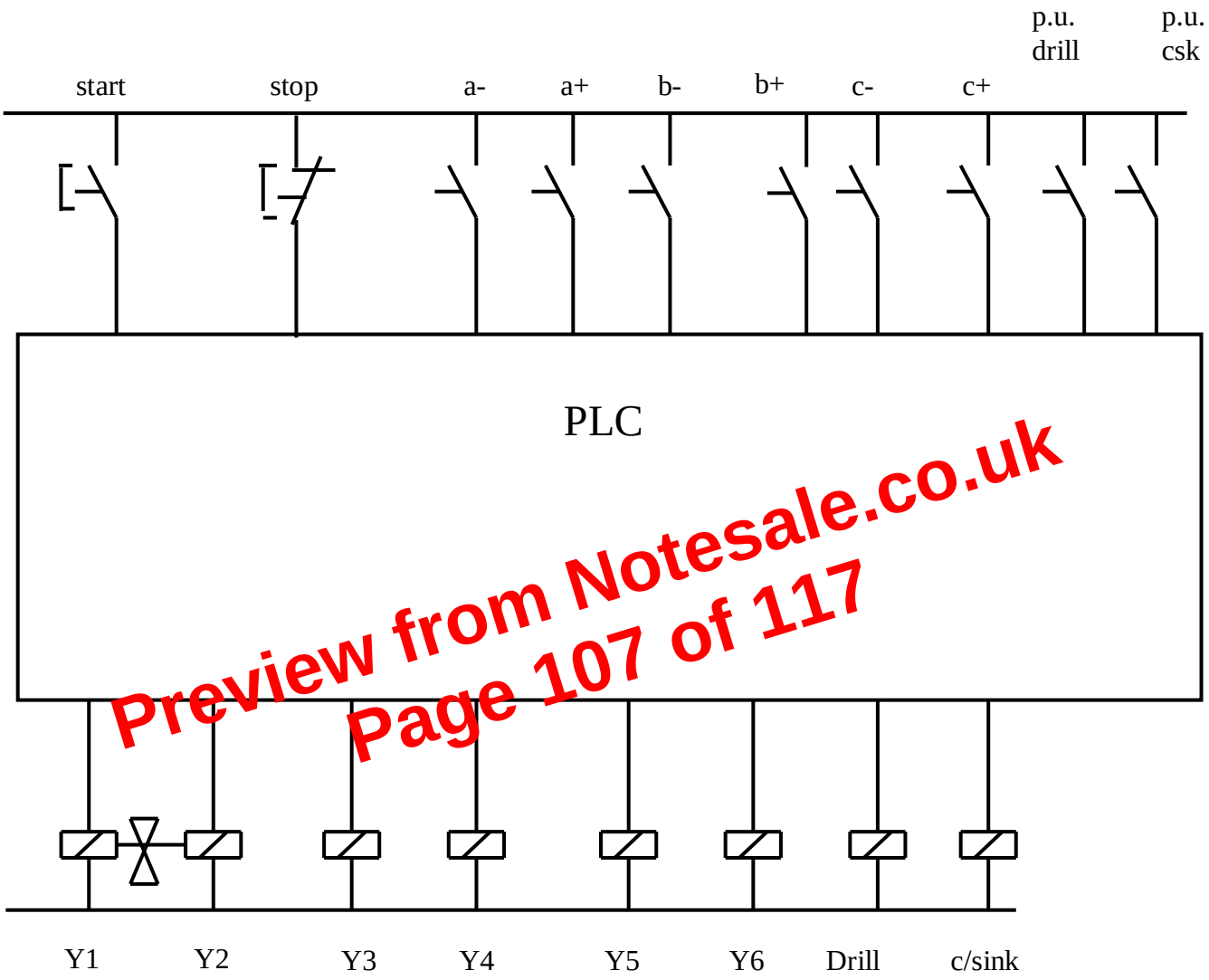
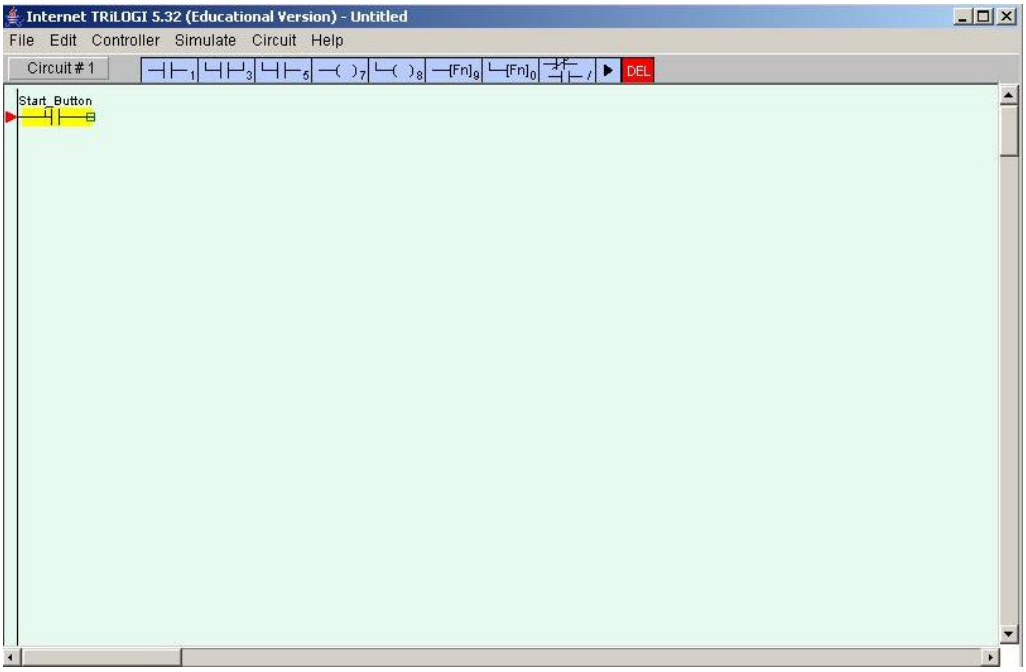


Fig 5.18

- Call the input *Start_Button* or *Start Button* and press return.



Select another n/o contact and call it *Stop Button*