

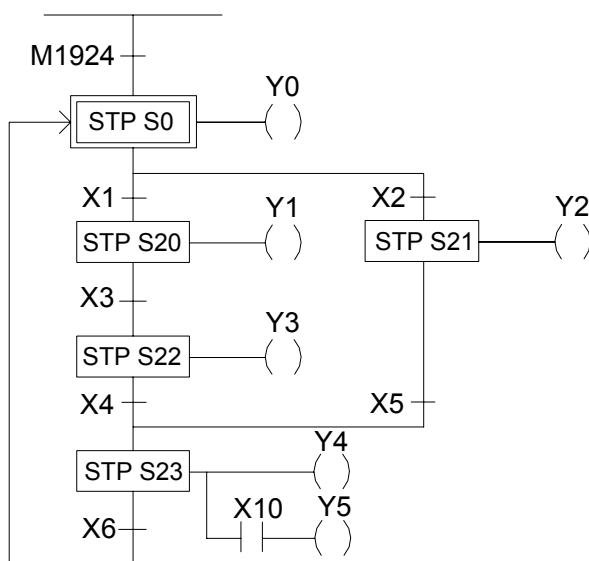
Chapter 8 Step Instruction Description

Structured programming design is a major trend in software design. The benefits are high readability, easy maintenance, convenient updating and high quality and reliability. For the control applications, consisted of many sequential tasks, designed by conventional ladder program design methodology usually makes others hard to maintain. Therefore, it is necessary to combine the current widely used ladder diagrams with the sequential controls made especially for machine working flow. With help from step instructions, the design work will become more efficient, time saving and controlled. This kind of design method that combines process control and ladder diagram together is called the step ladder language.

The basic unit of step ladder diagram is a step. A step is equivalent to a movement (stop) in the machine operation where each movement has an output. The complete machine or the overall sequential control process is the combination of steps in serial or parallel. Its step-by-step sequential execution procedure allows others to be able to understand the machine operations thoroughly, so that design, operation, and maintenance will become more effective and simpler.

8.1 The Operation Principle of Step Ladder Diagram

【Example】



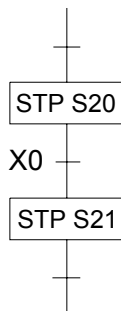
【Description】

1. **STP Sxxx** is the symbol representing a step Sxxx that can be one of S0 ~ S999. When executing the step (status ON), the ladder diagram on the right will be executed and the previous step and output will become OFF.
2. M1924 is on for a scan time after program start. Hence, as soon as ON, the stop of the initial step S0 is entered (S0 ON) while the other steps are kept inactive, i.e. Y1~Y5 are all OFF. This means M1924 ON→S0 ON→Y0 ON and Y0 will remain ON until one of the contacts X1 or X2 is ON.
3. Assume that X2 is ON first; the path to S21 will then be executed.

$$X2 \text{ ON} \Rightarrow \begin{cases} S21 \text{ ON} \\ S0 \text{ OFF} \end{cases} \Rightarrow \begin{cases} Y2 \text{ ON} \\ Y0 \text{ OFF} \end{cases}$$
 Y2 will remain ON until X5 is ON.
4. Assume that X5 is ON, the process will move forward to step S23.
 i.e. $X5 \text{ ON} \Rightarrow \begin{cases} S23 \text{ ON} \\ S21 \text{ OFF} \end{cases} \Rightarrow \begin{cases} Y4 \text{ ON} \\ Y2 \text{ OFF} \end{cases}$
 Y4 and Y5 will remain ON until X6 is ON.
 ※If X10 is ON, then Y5 will be ON.
5. Assume that X6 is ON, the process will move forward to S0.
 i.e. $X6 \text{ ON} \Rightarrow \begin{cases} S0 \text{ ON} \\ S23 \text{ OFF} \end{cases} \Rightarrow \begin{cases} Y0 \text{ ON} \\ Y4, Y5 \text{ OFF} \end{cases}$
 Then, a control process cycle is completed and the next control process cycle is entered.

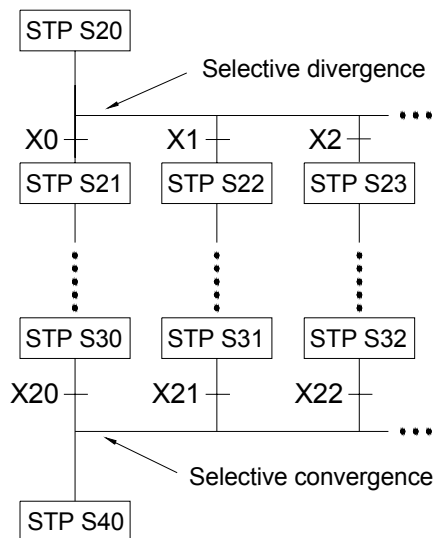
8.2 Basic Formation of Step Ladder Diagram

① Single path



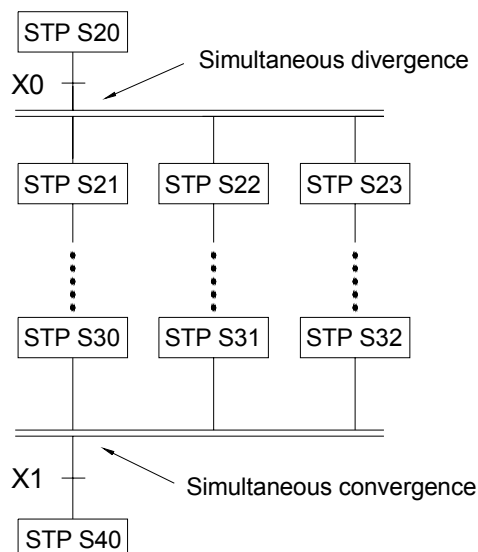
- Step S20 alone moves to step S21 through X0.
- X0 can be changed to other serial or parallel combination of contacts.

② Selective divergence/convergence



- Step S20 selects an only one path which divergent condition first met. E.g. X2 is ON first, then only the path of step S23 will be executed.
- A divergence may have up to 8 paths maximum.
- X1, X2,, X22 can all be replaced by the serial or parallel combination of other contacts.

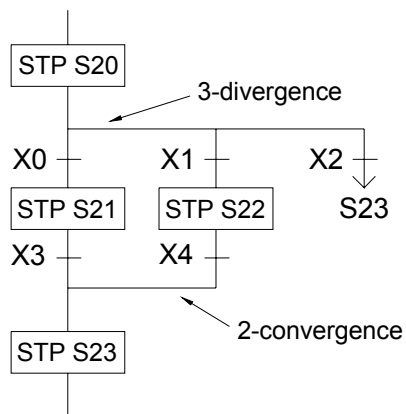
③ Simultaneous divergence/convergence



- After X0 is ON, step S20 will simultaneously execute all paths below it, i.e. all S21, S22, S23, and so on, are in action.
- All divergent paths at a convergent point will be executed to the last step (e.g. S30, S31 and S32). When X1 is ON, they can then transfer to S40 for execution.
- The number of divergent paths must be the same as the number of convergent paths. The maximum number of divergence/convergence path is 8.

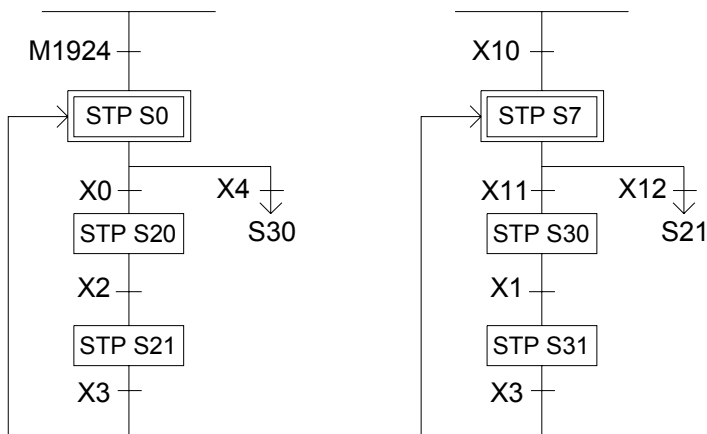
④ Jump

a. The same step loop



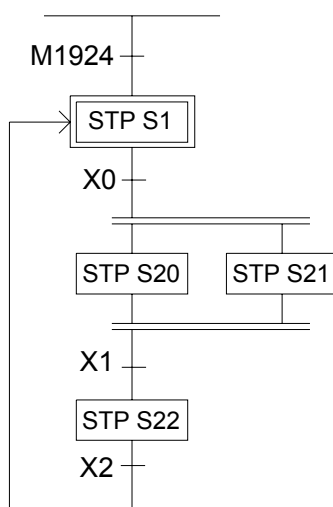
- There are 3 paths below step S20 as shown on the left. Assume that X2 is ON, then the process can jump directly to step S23 to execute without going through the process of selective convergence.
- The execution of simultaneous divergent paths can not be skipped.

b. Different step loop

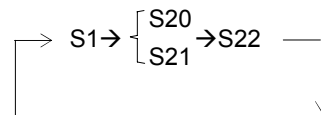


⑤ Closed Loop and Single Cycle

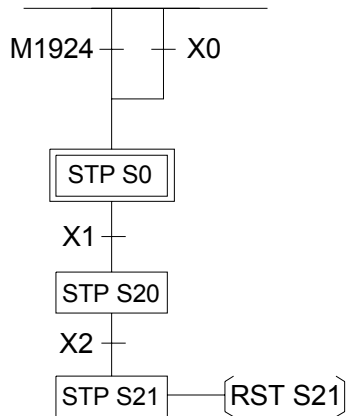
a. Closed Loop



- The initial step S1 is ON, endless cycle will be continued afterwards.

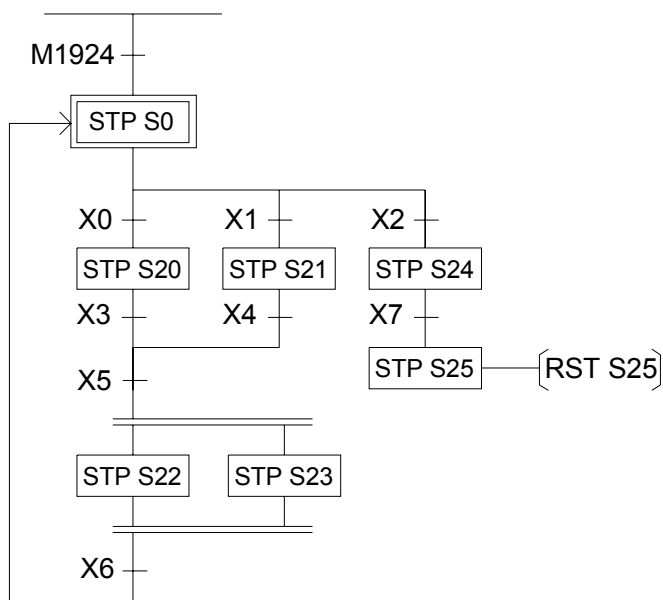


b. Single Cycle

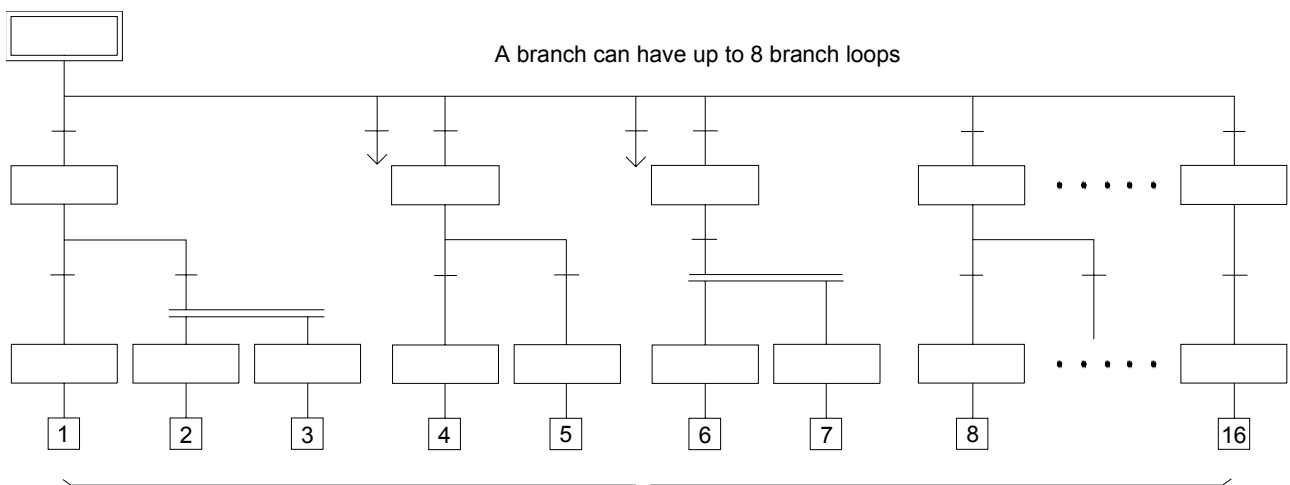


- When step S20 is ON, if X2 is also ON, then “RST S21” instruction will let S21 OFF which will stop the whole step process.

c. Mixed Process



⑥ Combined Application



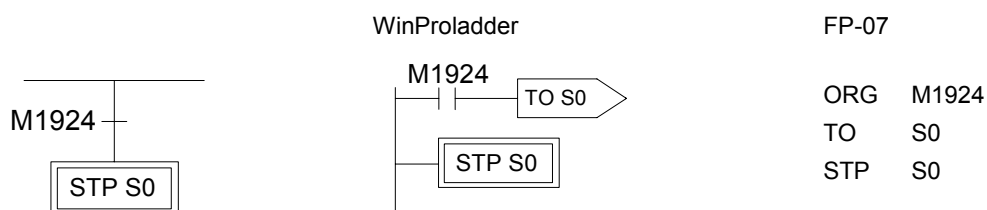
The maximum number of downward horizontal branch loops of an initial step is 16

8.3 Introduction of Step Instructions: STP, FROM, TO and STPEND

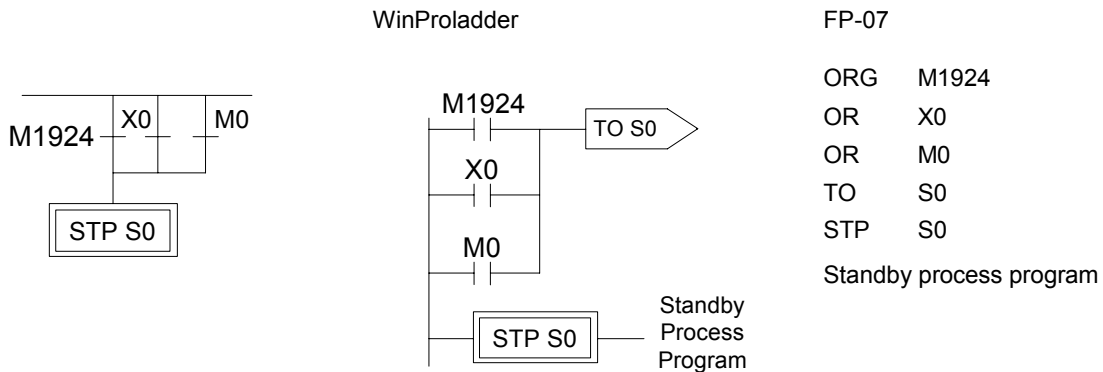
- **STP Sx** : $S0 \leq Sx \leq S7$ (Displayed in WinProladder)
or
STP Sx : $S0 \leq Sx \leq S7$ (Displayed in FP-07)

This instruction is the initial step instruction from where the step control of each machine process can be derived. Up to 8 initial steps can be used in the FBs series, i.e. a PLC can make up to 8 process controls simultaneously. Each step process can operate independently or generate results for the reference of other processes.

【Example 1】 Go to the initial step S0 after each start (ON)



【Example 2】 Each time the device is start to run or the manual button is pressed or the device is malfunction, then the device automatically enters the initial step S0 to standby.



【Description】 X0: Manual Button, M0: Abnormal Contact.

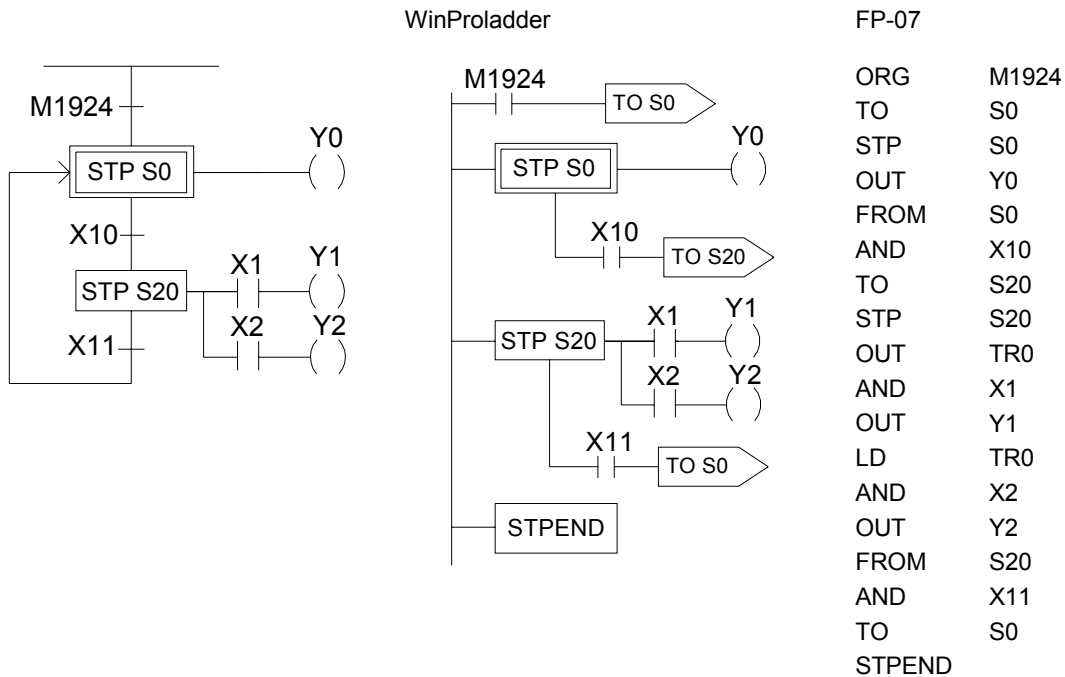
● **STP Sxxx** : $S20 \leq Sxxx \leq S999$ (Displayed in WinProLadder)

or

STP Sxxx : $S20 \leq Sxxx \leq S999$ (Displayed in FP-07)

This instruction is a step instruction, each step in a process represents a step of sequence. If the status of step is ON then the step is active and will execute the ladder program associate to the step.

【Example】



【Description】 1. When ON, the initial step S0 is ON and Y0 is ON.

2. When transfer condition X10 is ON (in actual application, the transferring condition may be formed by the serial or parallel combination of the contacts X, Y, M, T and C), the step S20 is activated. The system will automatically turn S0 OFF in the current scan cycle and Y0 will be reset automatically to OFF.

$$\text{i.e. } X10 \text{ ON} \Rightarrow \begin{cases} S20 \text{ ON} \\ S0 \text{ OFF} \end{cases} \Rightarrow \begin{cases} X1 \text{ ON} \rightarrow Y1 \text{ ON} \\ X2 \text{ ON} \rightarrow Y2 \text{ ON} \\ Y0 \text{ OFF} \end{cases}$$

3. When the transfer condition X11 is ON, the step S0 is ON, Y0 is ON and S20, Y1 and Y2 will turn OFF at the same time.

$$\text{i.e. } X11 \text{ ON} \Rightarrow \begin{cases} S0 \text{ ON} \\ S20 \text{ OFF} \end{cases} \Rightarrow \begin{cases} Y0 \text{ ON} \\ Y1 \text{ OFF} \\ Y2 \text{ OFF} \end{cases}$$

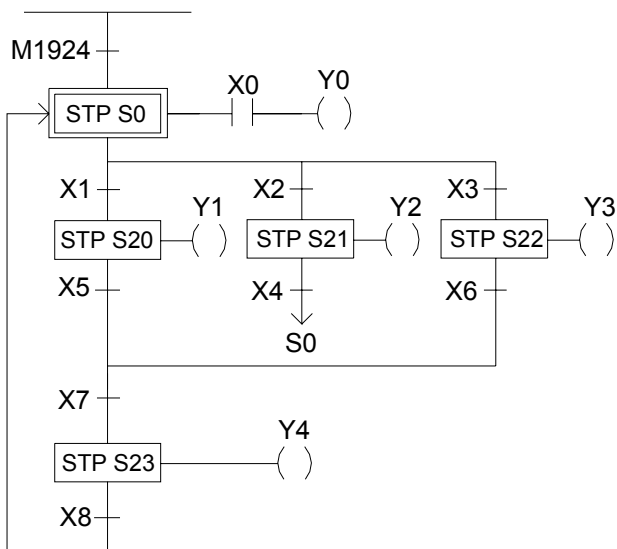
● FROM Sxxx : $S0 \leq Sxxx \leq S999$ (Displayed in WinProladder)

or

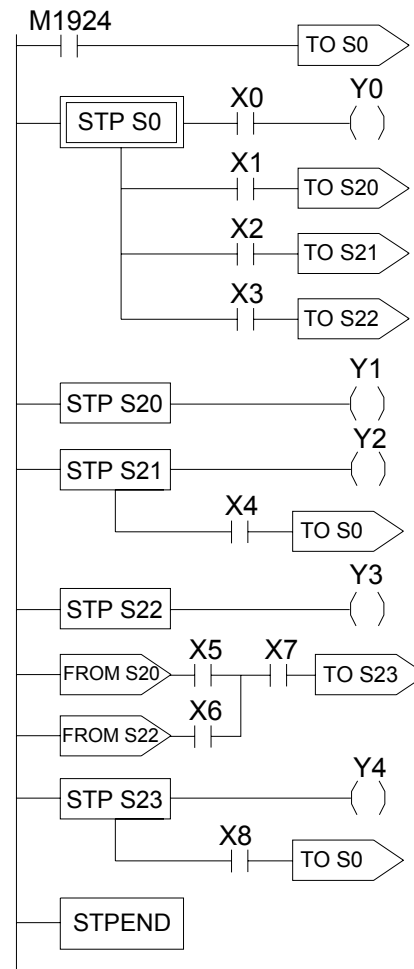
FROM Sxxx : $S0 \leq Sxxx \leq S999$ (Displayed in FP-07)

The instruction describes the source step of the transfer, i.e. moving from step Sxxx to the next step in coordination with transfer condition.

【Example】



WinProladder



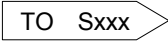
FP-07

```

ORG      M1924
TO        S0
STP       S0
AND       X0
OUT       Y0
FROM      S0
OUT TR    0
AND       X1
TO        S20
LD TR     0
AND       X2
TO        S21
LD TR     0
AND       X3
TO        S22
STP       S20
OUT       Y1
STP       S21
OUT       Y2
FROM      S21
AND       X4
TO        S0
STP       S22
OUT       Y3
FROM      S20
AND       X5
FROM      S22
AND       X6
ORLD
AND       X7
TO        S23
STP       S23
OUT       Y4
FROM      S23
AND       X8
TO        S0
STPEND

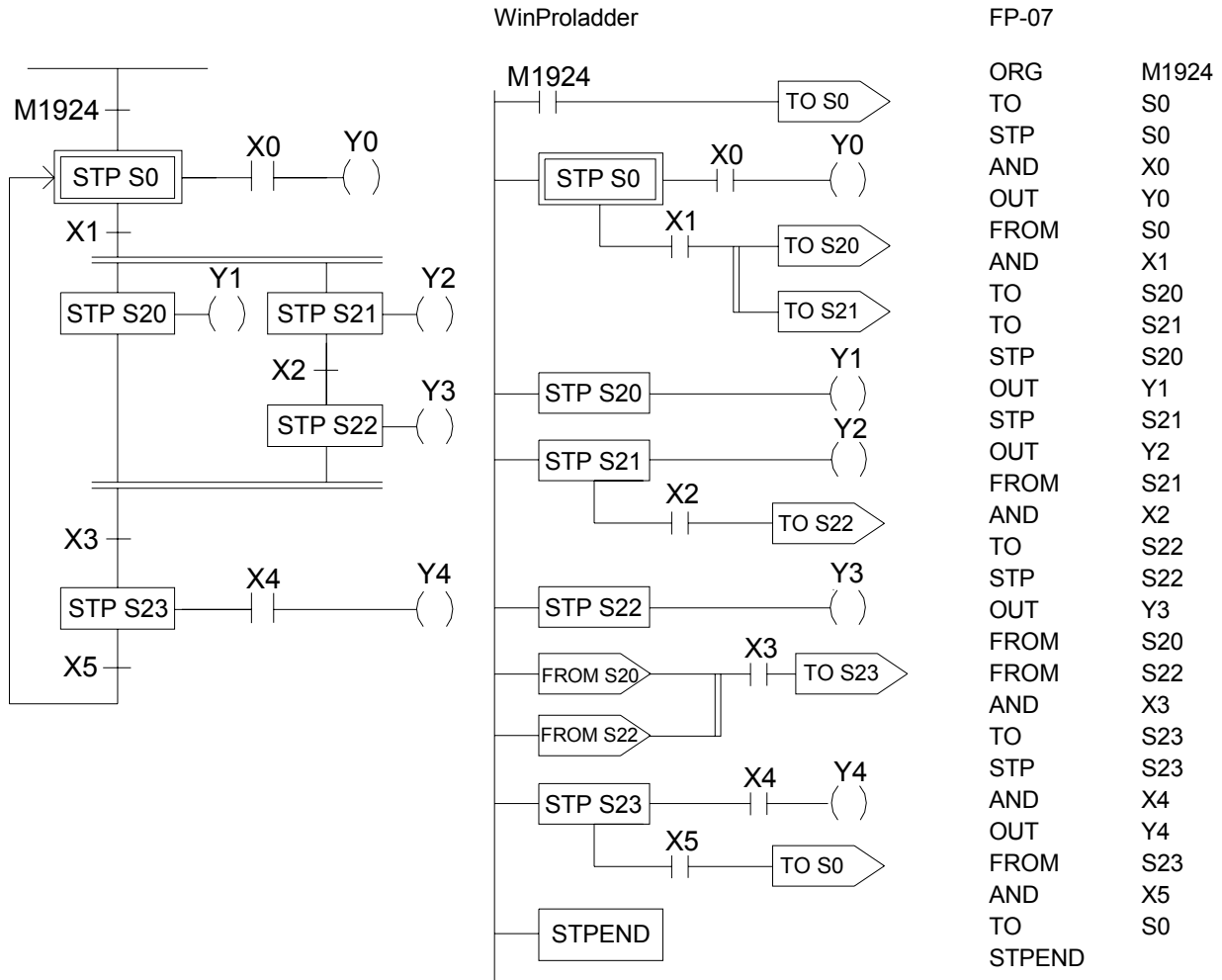
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- 【Description】** : 1. When ON, the initial step S0 is ON. If X0 is ON, then Y0 will be ON.
2. When S0 is ON: a. if X1 is ON, then step S20 will be ON and Y1 will be ON.
b. if X2 is ON, then step S21 will be ON and Y2 will be ON.
c. if X3 is ON, then step S22 will be ON and Y3 will be ON.
d. if X1, X2 and X3 are all ON simultaneous, then step S20 will have the priority to be ON first and either S21 or S22 will not be ON.
e. if X2 and X3 are ON at the same time, then step S21 will have the priority to be ON first and S22 will not be ON.
3. When S20 is ON, if X5 and X7 are ON at the same time, then step S23 will be ON, Y4 will be ON and S20 and Y1 will be OFF.
4. When S21 is ON, if X4 is ON, then step S0 will be ON and S21 and Y2 will be OFF.
5. When S22 is ON, if X6 and X7 are ON at the same time, then step S23 will be ON, Y4 will be ON and S22 and Y3 will be OFF.
6. When S23 is ON, if X8 is ON, then step S0 will be ON and S23 and Y4 will be OFF.

-  : $S0 \leq Sxxx \leq S999$ (Displayed in WinProladder)
or
TO Sxxx : $S0 \leq Sxxx \leq S999$ (Displayed in FP-07)

This instruction describes the step to be transferred to.

【Example】



【Description】 : 1. When ON, the initial step S0 is ON. If X0 is ON, then Y0 will be ON.

2. When S0 is ON: if X1 is ON, then steps S20 and S21 will be ON simultaneously and Y1 and Y2 will also be ON.
3. When S21 is ON: if X2 is ON, then step S22 will be ON, Y3 will be ON and S21 and Y2 will be OFF.
4. When S20 and S22 are ON at the same time and the transferring condition X3 is ON, then step S23 will be ON (if X4 is ON, then Y4 will be ON) and S20 and S22 will automatically turn OFF and Y1 and Y3 will also turn OFF.
5. When S23 is ON: if X5 is ON, then the process will transfer back to the initial step, i.e. S0 will be ON and S23 and Y4 will be OFF.

● **STPEND** : (Displayed in WinProladder)

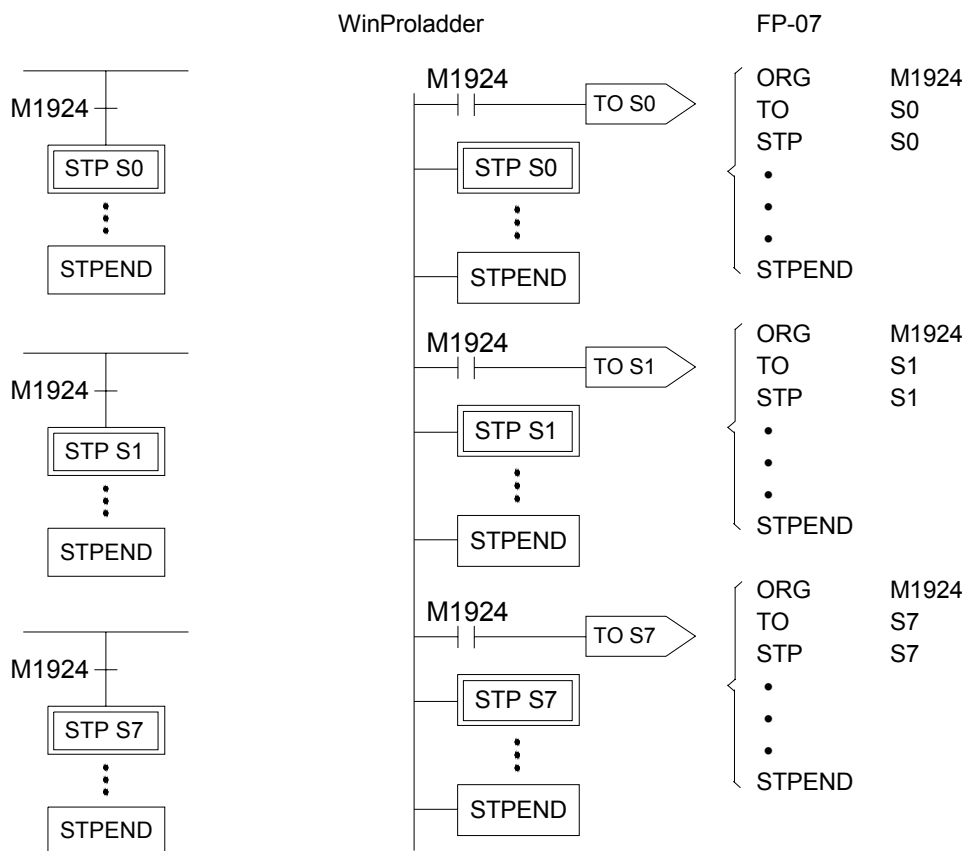
or

STPEND : (Displayed in FP-07)

This instruction represents the end of a process. It is necessary to include this instruction so all processes can be operated correctly.

A PLC can have up to 8 step processes (S0~S7) and is able to control them simultaneously. Therefore, up to 8 **STPEND** instructions can be obtained.

【Example】

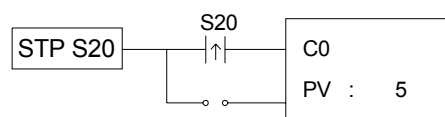


【Description】 When ON, the 8 step processes will be active simultaneously.

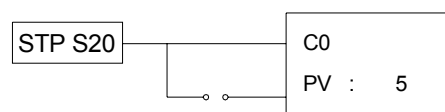
8.4 Notes for Writing a Step Ladder Diagram

【Notes】

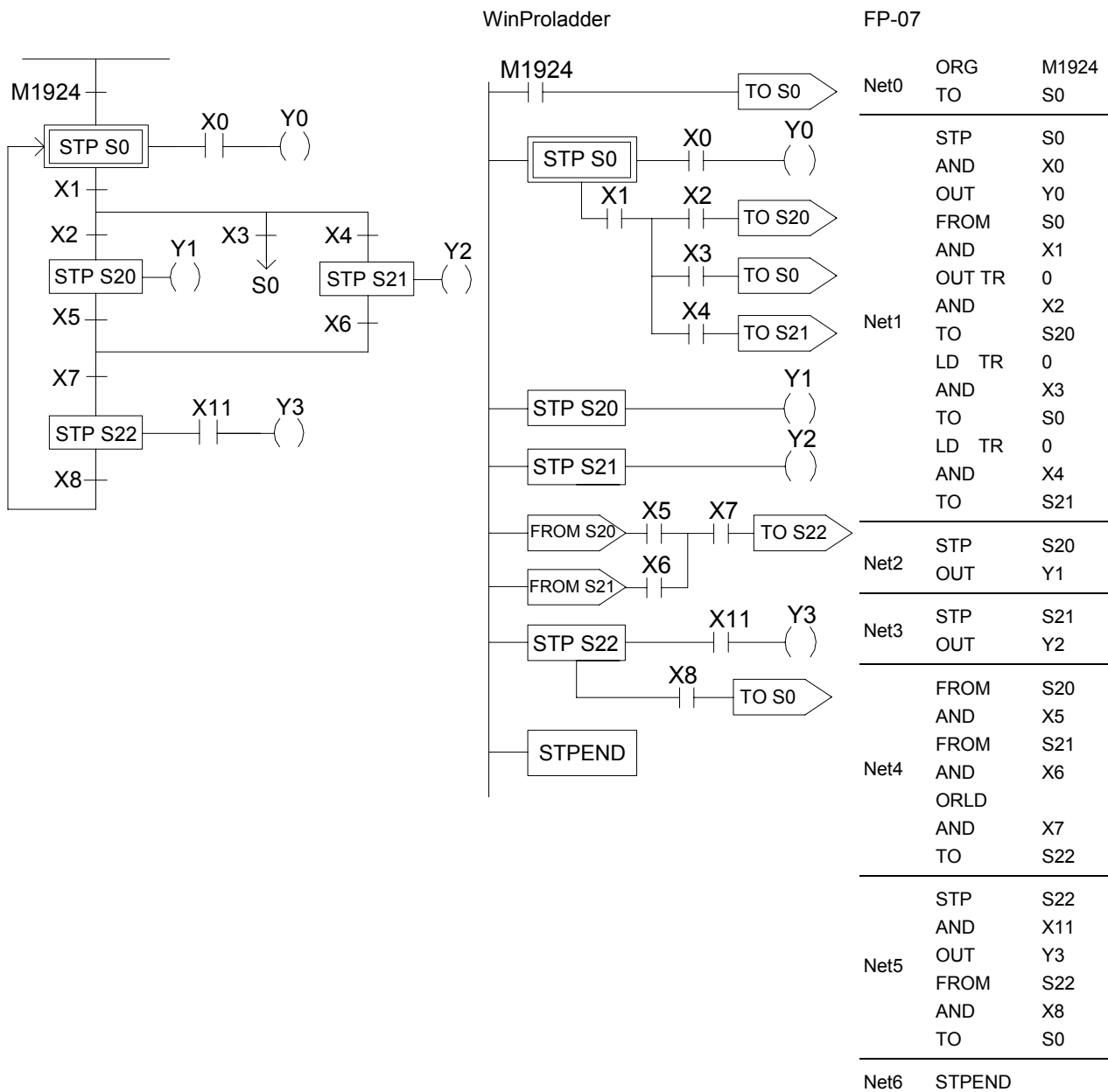
- In actual applications, the ladder diagram can be used together with the step ladder.
- There are 8 steps, S0~S7, that can be used as the starting point and are called the “initial steps”.
- When PLC starts operating, it is necessary to activate the initial step. The M1924 (the first scan ON signal) provided by the system may be used to activate the initial step.
- Except the initial step, the start of any other steps must be driven by other step.
- It is necessary to have an initial step and the final STPEND instruction in a step ladder diagram to complete a step process program.
- There are 980 steps, S20~S999, available that can be used freely. However, used numbers cannot be repeated. S500~S999 are retentive(The range can be modified by users), can be used if it is required to continue the machine process after power is off.
- Basically a step must consists of three parts which are control output, transition conditions and transition targets.
- MC and SKP instructions cannot be used in a step program and the sub-programs. It's recommended that JMP instruction should be avoided as much as possible.
- If the output point is required to stay ON after the step is divergent to other step, it is necessary to use the SET instruction to control the output point and use RST instruction to clear the output point to OFF.
- Looking down from an initial step, the maximum number of horizontal paths is 16. However, a step is only allowed to have up to 8 branch paths.
- When M1918=0 (default) , if a PULSE type function instruction is used in master control loop (FUN 0) or a step program, it is necessary to connect a TU instruction before the function instruction. For example,



When M1918=1, the TU instruction is not required, e.g.:



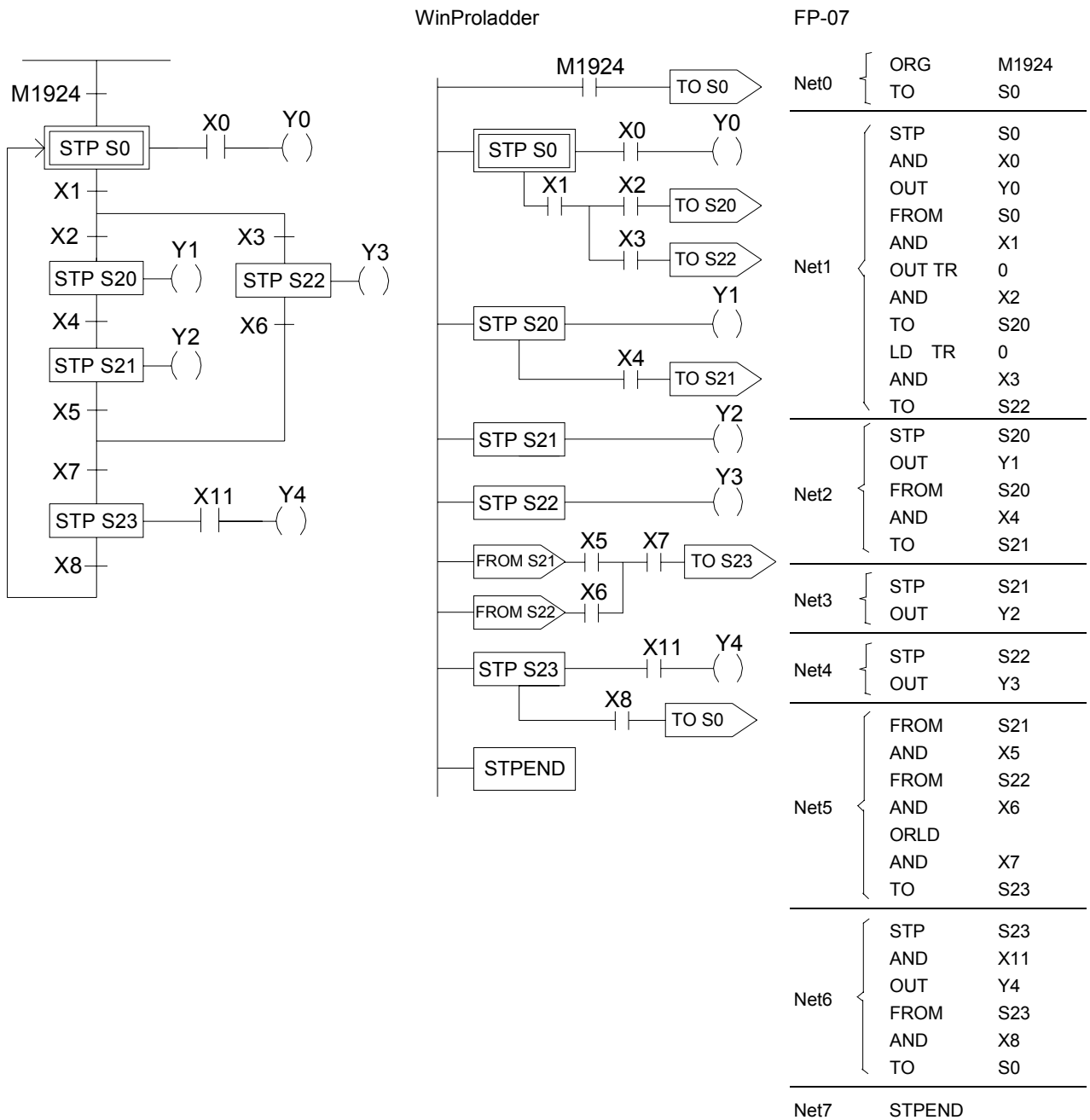
Example 1



Description

1. Input the condition to initial step S0
2. Input the S0 and the divergent conditions of S20, S0 and S21
3. Input the S20
4. Input the S21
5. Input the convergence of S20 and S21
6. Input the S22

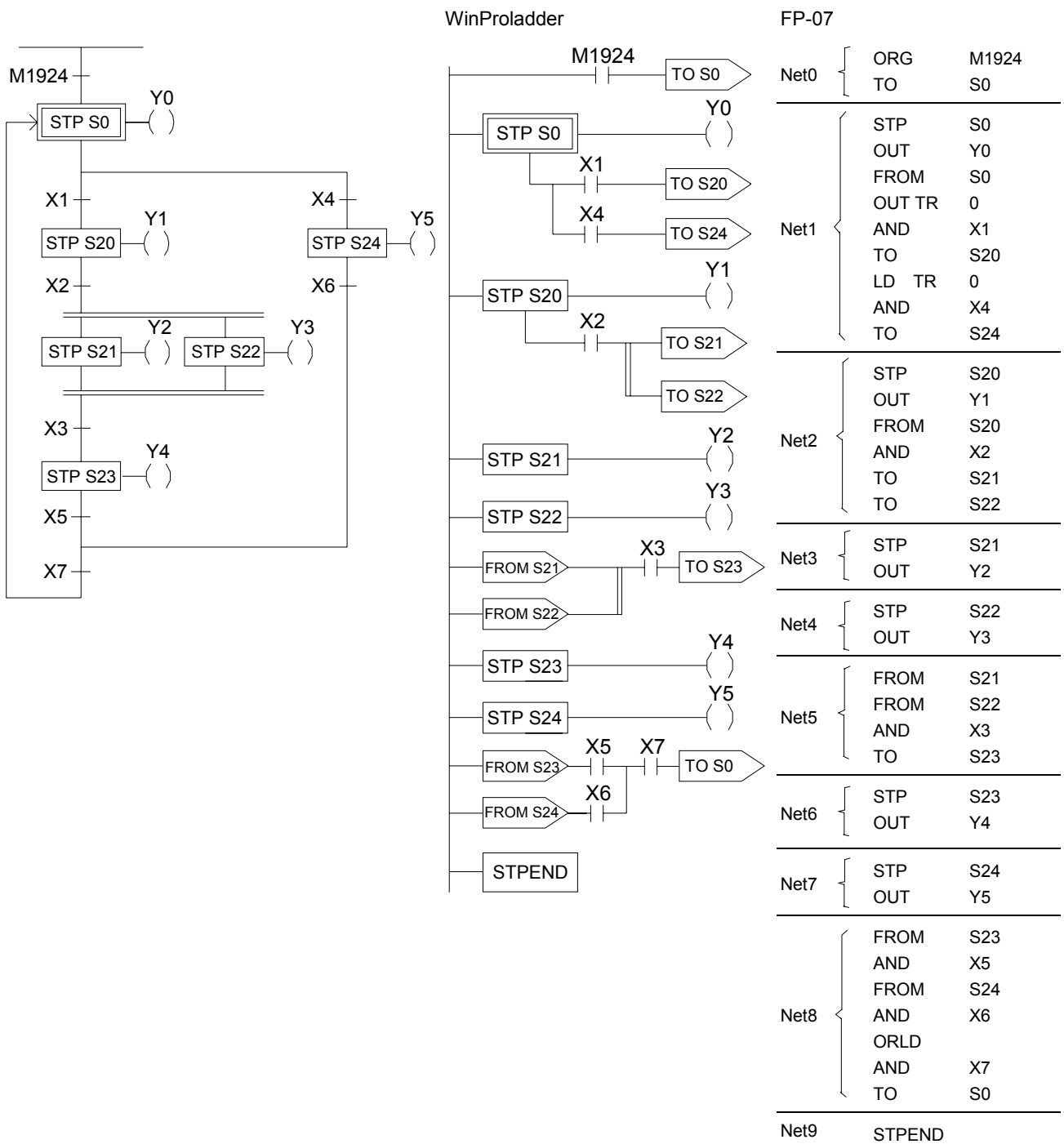
Example 2



Description

1. Input the condition to initial step S0
2. Input the S0 and the divergent condition of S20 and S22
3. Input the S20
4. Input the S21
5. Input the S22
6. Input the convergence of S21 and S22
7. Input the S23

Example 3

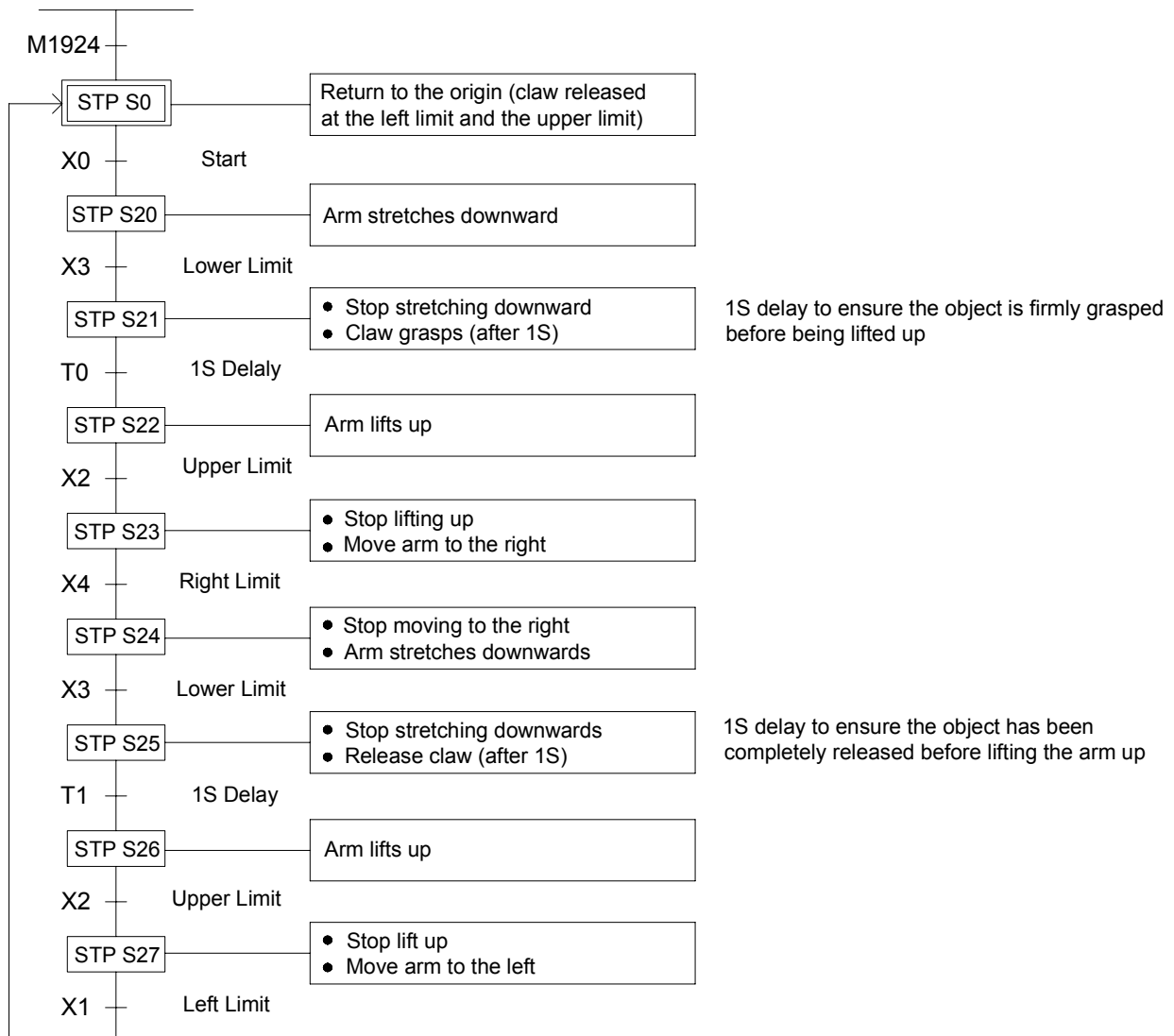
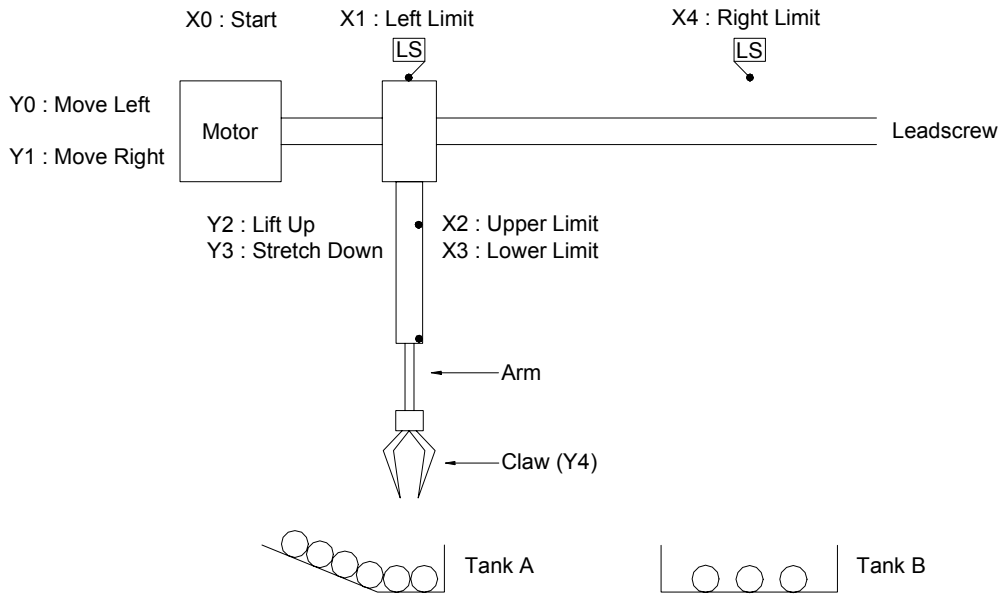


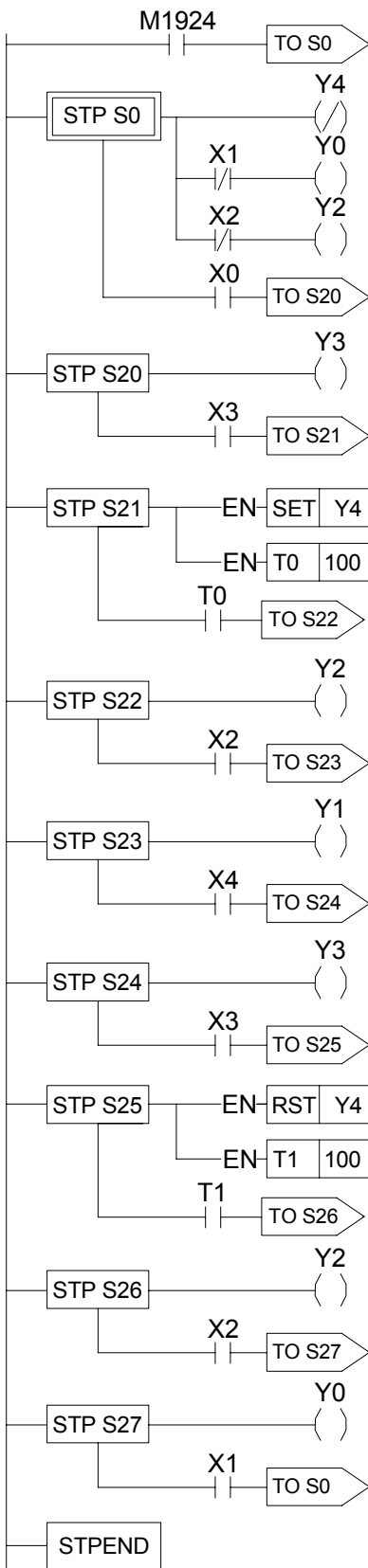
Description

1. Input the condition to initial step S0
2. Input the S0 and the divergences of S20 and S24
3. Input the S20
4. Input the S20 and the divergences of S21 and S22
5. Input the S21
6. Input the S22
7. Input the convergences of S21 and S22
8. Input the S23
9. Input the S24
10. Input the convergences of S23 and S24

8.5 Application Examples

Example 1 Grasp an object from tank A and put it in Tank B





Release claw

Return to the left limit

Return to the upper limit

Turn the switch ON before moving to S20

Stretch arm downward

Move to S21 after stretching to the lower limit

Claw grasps (since the SET instruction is used, Y4 should remain ON after departing from STP S21)

Divergent into S22 after 1S

Lift the arm up

Divergent into S23 after reaching the upper limit

Move arm to the right

Divergent into S24 after moving to the right limit

Stretch the arm downward

Divergent into S25 after stretching to the lower limit

Release claw

Delay for 1S

Transfer into S26 after 1S

Lift the arm up

Divergent into S27 after reaching the upper limit

Move the arm to the left

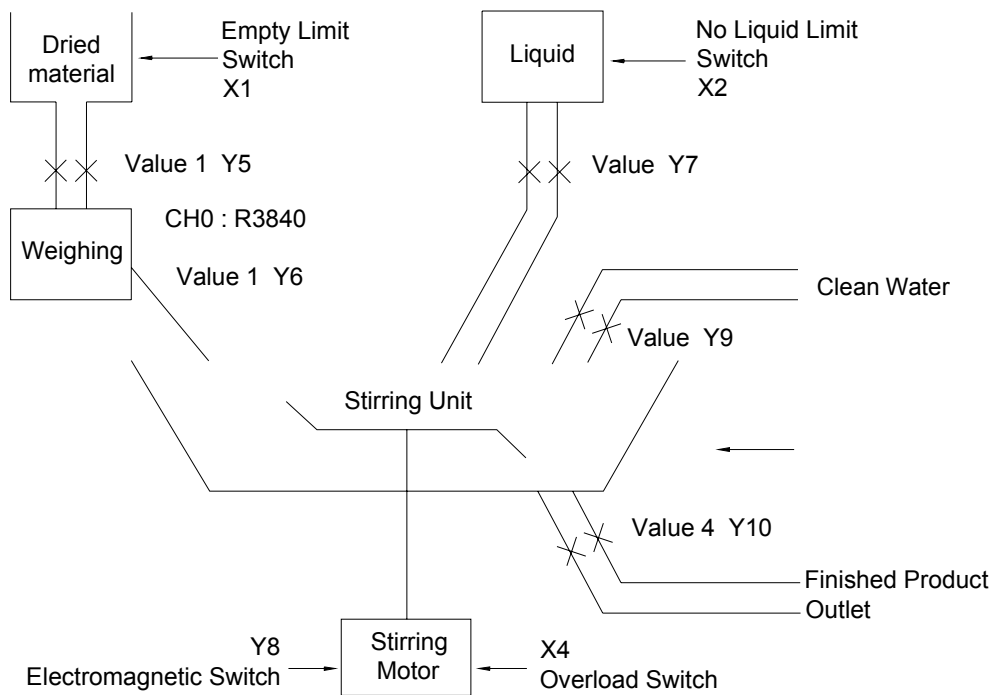
Divergent into S0 after moving to the left limit (a complete cycle)

```

ORG      M1924
TO       S0
STP      S0
OUT TR   0
OUT NOT  Y4
AND NOT  X1
OUT      Y0
LD TR    0
AND NOT  X2
OUT      Y2
FROM     S0
AND      X0
TO       S20
STP      S20
OUT      Y3
FROM     S20
AND      X3
TO       S21
STP      S21
SET      Y4
T0 PV:   100
FROM     S21
AND      T0
TO       S22
STP      S22
OUT      Y2
FROM     S22
AND      X2
TO       S23
STP      S23
OUT      Y1
FROM     S23
AND      X4
TO       S24
STP      S24
OUT      Y3
FROM     S24
AND      X3
TO       S25
STP      S25
RST      Y4
T1 PV:   100
FROM     S25
AND      T1
TO       S26
STP      S26
OUT      Y2
FROM     S26
AND      X2
TO       S27
STP      S27
OUT      Y0
FROM     S27
AND      X1
TO       S0
STPEND

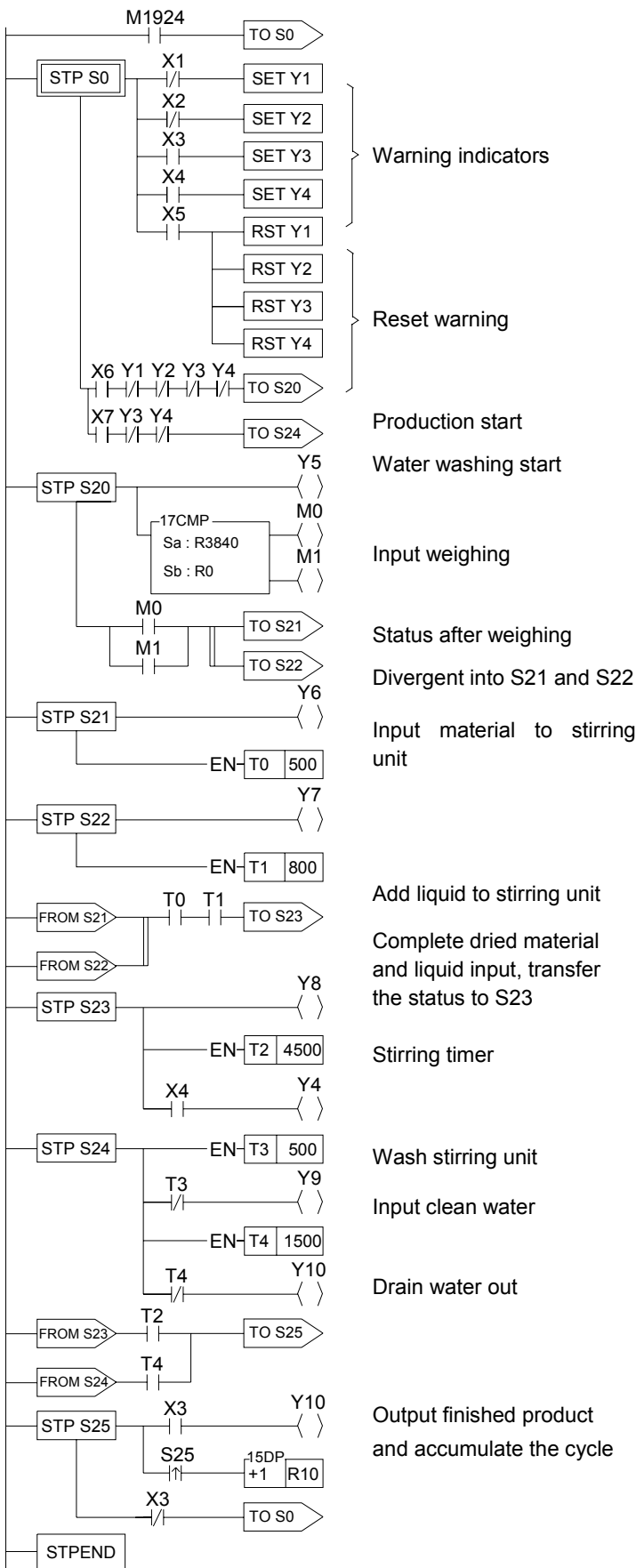
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Example 2 Liquid Stirring Process



- Input Points: Empty limit switch X1
No liquid limit switch X2
Empty limit switch X3
Over-load switch X4
Warning clear button X5
Start button X6
Water washing button X7
- Warning Indicators: Empty dried material Y1
Insufficient liquid Y2
Empty stirring unit Y3
Motor over-load Y4
- Output Points: Dried material inlet valve Y5
Dried material inlet valve Y6
Liquid inlet valve Y7
Motor start electromagnetic valve Y8
Clean water inlet valve Y9
Finished product outlet valve Y10
- Weighing Output: CH0 (R3840)
- M1918=0

WinProladder

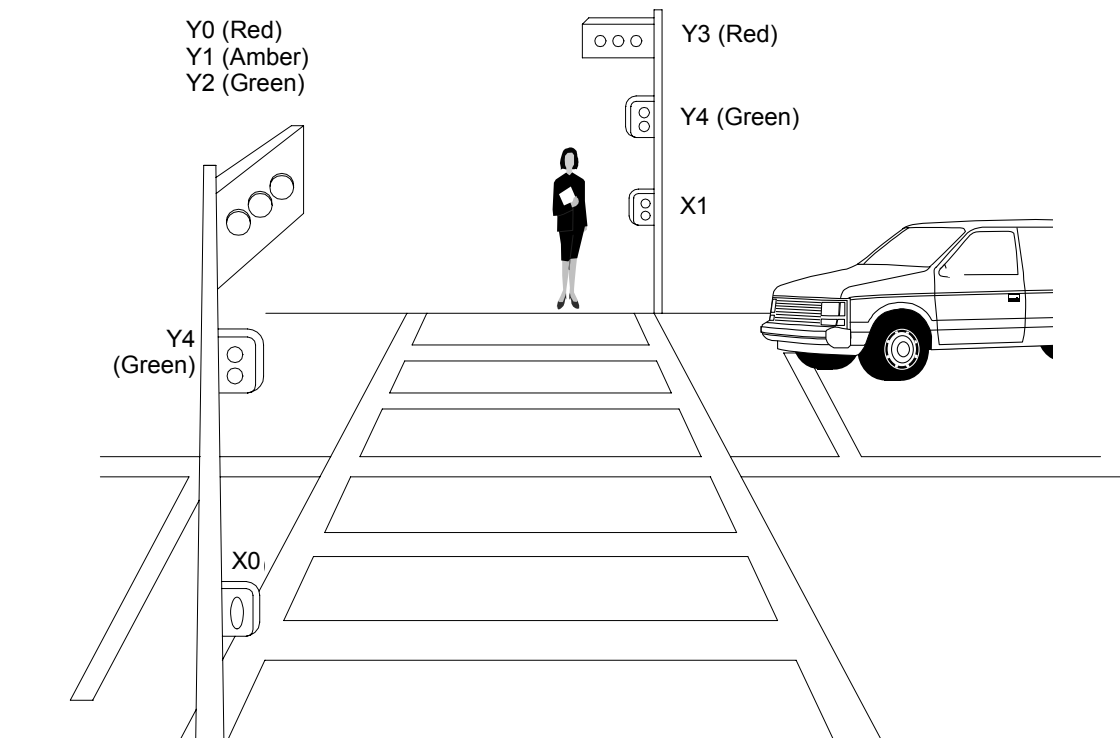


FP-07

ORG	M1924	STP	S22
TO	S0	OUT	Y7
STP	S0	T1 PV: 800	
OUT TR	0	FROM	S21
AND NOT	X1	FROM	S22
SET	Y1	AND	T0
LD TR	0	AND	T1
AND NOT	X2	TO	S23
SET	Y2	STP	S23
LD TR	0	OUT TR	0
AND	X3	OUT	Y8
SET	Y3	LD TR	0
LD TR	0	T2 PV: 4500	
AND	X4	LD TR	0
SET	Y4	AND	X4
LD TR	0	OUT	Y4
AND	X5	STP	S24
RST	Y1	OUT TR	0
RST	Y2	T3 PV: 500	
RST	Y3	LD TR	0
RST	Y4	AND NOT	T3
FROM	S0	OUT	Y9
OUT TR	1	LD TR	0
AND	X6	T4 PV: 1500	
AND NOT	Y1	LD TR	0
AND NOT	Y2	AND NOT	T4
AND NOT	Y3	OUT	Y10
AND NOT	Y4	FROM	S23
TO	S20	AND	T2
LD TR	1	FROM	S24
AND	X7	AND	T4
AND NOT	Y3	ORLD	
AND NOT	Y4	TO	S25
TO	S24	STP	S25
STP	S20	OUT TR	0
OUT	Y5	AND	X3
FUN	17	OUT	Y10
Sa:R3840 Sb:R0		LD TR	0
FO	0	AND TU	S25
OUT	M0	FUN	15DP
FO	1	D:R10	
OUT	M1	FROM	S25
FROM	S20	AND NOT	X3
LD	M0	TO	S0
OR	M1	STPEND	
ANDLD			
TO	S21		
TO	S22		
STP	S21		
OUT	Y6		
T0 PV: 500			

Example 3

Pedestrian Crossing Lights

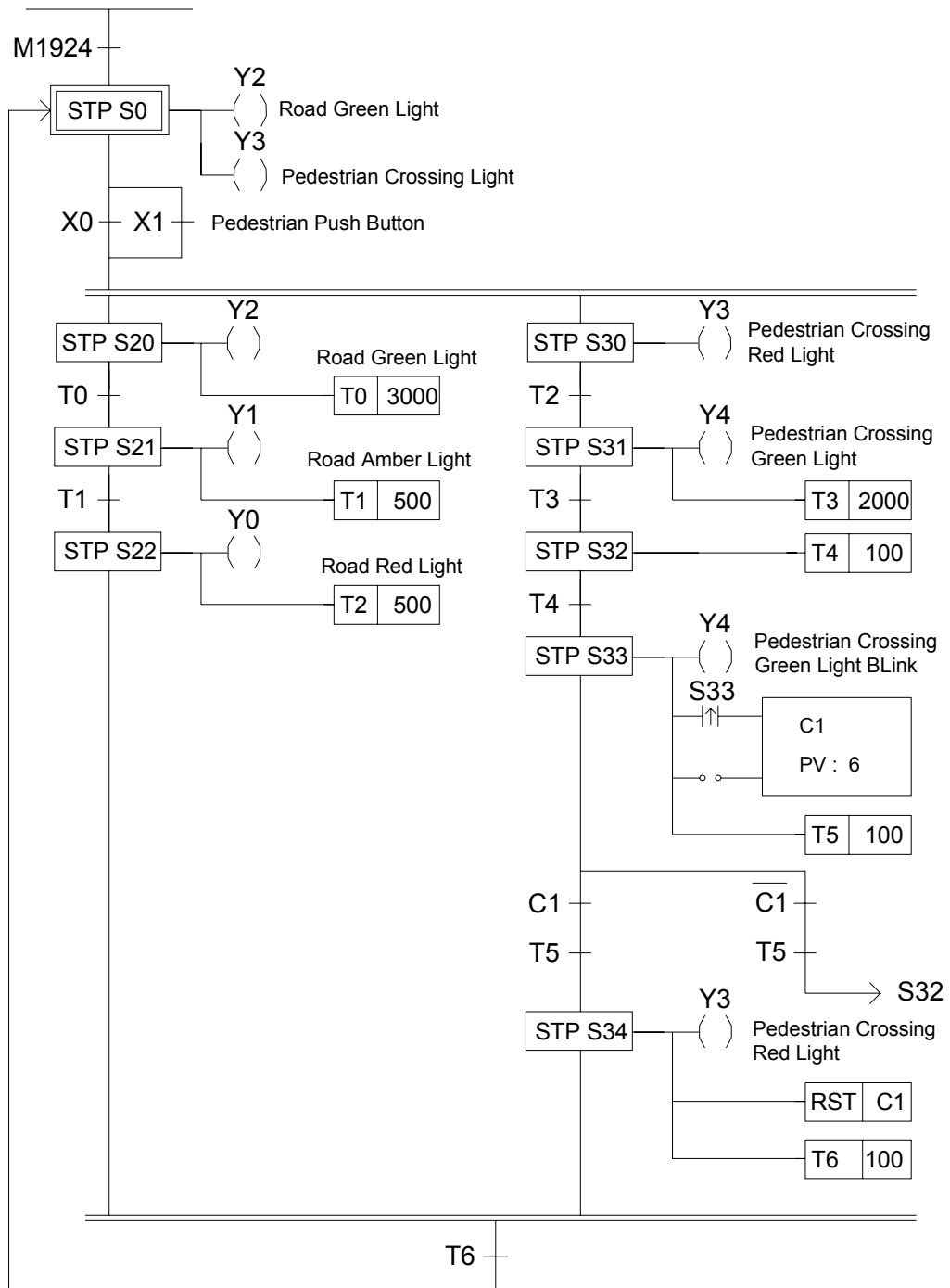


- ♦ Input Points: Pedestrian Push Button X0
Pedestrian Push Button X1

- ♦ Output Points: Road Red Light Y0
Road Amber light Y1
Road Green Light Y2
Pedestrian Crossing Red Light Y3
Pedestrian Crossing Green Light Y4

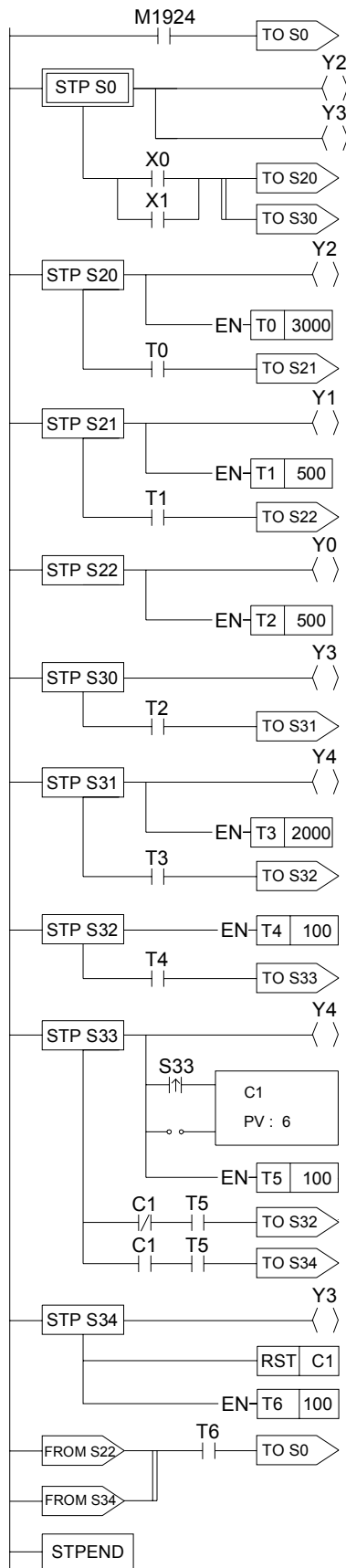
- ♦ M1918=0

● Pedestrian Crossing Lights Control Process Diagram



● Pedestrian Crossing Lights Control Program

WinProladder



FP-07

ORG	M1924	STP	S32
TO	S0	T4 PV:	100
STP	S0	FROM	S32
OUT	Y2	AND	T4
OUT	Y3	TO	S33
FROM	S0	STP	S33
LD	X0	OUT TR	0
OR	X1	OUT	Y4
ANDLD		LD TR	0
TO	S20	AND TU	S33
TO	S30	LD	OPEN
STP	S20	C1 PV:	6
OUT	Y2	LD TR	0
T0 PV:	3000	T5 PV:	100
FROM	S20	FROM	S33
AND	T0	OUT TR	1
TO	S21	AND NOT	C1
STP	S21	AND	T5
OUT	Y1	TO	S32
T1 PV:	500	LD TR	1
FROM	S21	AND	C1
AND	T1	AND	T5
TO	S22	TO	S34
STP	S22	STP	S34
OUT	Y0	OUT	Y3
T2 PV:	500	RST	C1
STP	S30	T6 PV:	100
OUT	Y3	FROM	S22
FROM	S30	FROM	S34
AND	T2	AND	T6
TO	S31	TO	S0
STP	S31	STPEND	
OUT	Y4		
T3 PV:	2000		
FROM	S31		
AND	T3		
TO	S32		

8.6 Syntax Check Error Codes for Step Instruction

The error codes for the usage of step instruction are as follows:

- E51 : TO(S0-S7) must begin with ORG instruction.
- E52 : TO(S20-S999) can't begin with ORG instruction.
- E53 : TO instruction without matched FROM instruction.
- E54 : To instruction must comes after TO, AND, OR, ANDLD or ORLD instruction.
- E56 : The instructions before FROM must be AND, OR, ANDLD or ORLD
- E57 : The instruction after FROM can't be a coil or a function
- E58 : Coil or function must before FROM while in STEP network.
- E59 : More than 8 TO# at same network.
- E60 : More than 8 FROM# at same network.
- E61 : TO(S0-S7) must locate at first row of the network.
- E62 : A contact occupies the location for TO instruction.
- E72 : Duplicated TO Sxx instruction.
- E73 : Duplicated STP sxx instruction.
- E74 : Duplicated FROM sxx instruction.
- E76 : STP(S0~S7) without a matched STPEND or STPEND without a matched STP(S0~S7).
- E78 : TO(S20~S999), STP (S20~S999) or FROM instructions comes before or without STP(S0~S19).
- E79 : STP Sxx or FROM Sxx instructions comes before or without TO Sxx.
- E80 : FROM Sxx instruction comes before or without STP Sxx.
- E81 : The max. level of branches must ≤ 16 .
- E82 : The max. no. of branches with same level must ≤ 16 .
- E83 : Not place the step instruction with TO->STP->FROM sequence.
- E84 : The definition of STP# sequence not follow the TO# sequence.
- E85 : Convergence do not match the corresponding divergence.
- E86 : Illegal usage of STP or FROM before convergent with TO instruction.
- E87 : STP# or FROM# comes before corresponding TO#.
- E88 : During this branch, STP# or FROM# comes before the corresponding TO#.
- E89 : FROM# comes before corresponding TO# or STP#.
- E90 : Invalid To# usage in the simultaneous branch.
- E91 : Flow control function can not be used in the step ladder region.