# 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】
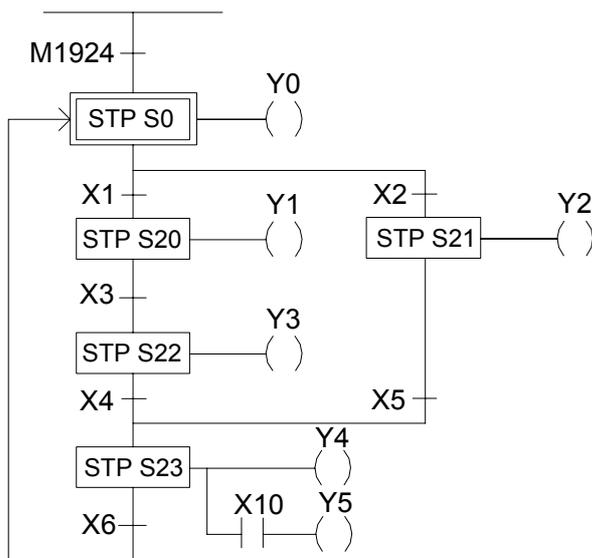
【Description】

1. $\boxed{\text{STP Sxxx}}$ 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.
   $$\text{X2 ON} \Rightarrow \begin{cases} \text{S21 ON} \\ \text{S0 OFF} \end{cases} \Rightarrow \begin{cases} \text{Y2 ON} \\ \text{Y0 OFF} \end{cases}$$
   Y2 will remain ON until X5 is ON.

4. Assume that X5 is ON, the process will move forward to step S23.
   i.e. $\text{X5 ON} \Rightarrow \begin{cases} \text{S23 ON} \\ \text{S21 OFF} \end{cases} \Rightarrow \begin{cases} \text{Y4 ON} \\ \text{Y2 OFF} \end{cases}$
   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. $\text{X6 ON} \Rightarrow \begin{cases} \text{S0 ON} \\ \text{S23 OFF} \end{cases} \Rightarrow \begin{cases} \text{Y0 ON} \\ \text{Y4、Y5 OFF} \end{cases}$
   Then, a control process cycle is completed and the next control process cycle is entered.
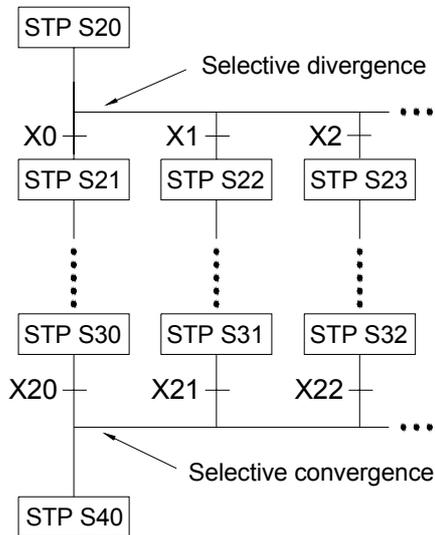
## 8.2   Basic Formation of Step Ladder Diagram

① Single path
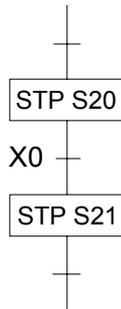
● Step S20 alone moves to step S21 through X0.

● 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.
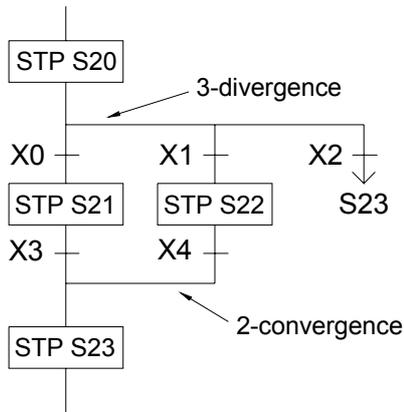
③ Simultaneous divergence/convergence
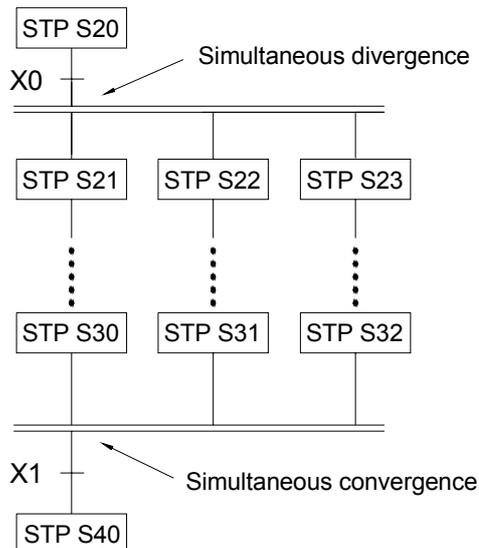
● After X0 is ON, step S20 will simultaneously execute all paths below it, i.e. all S21, S22, S23, and so on, are in action.

● 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.
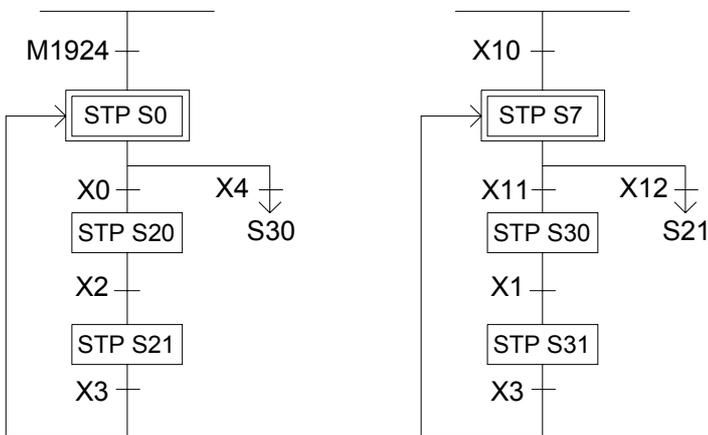
④ Jump

a. The same step loop

STP S20

3-divergence

X0   X1   X2

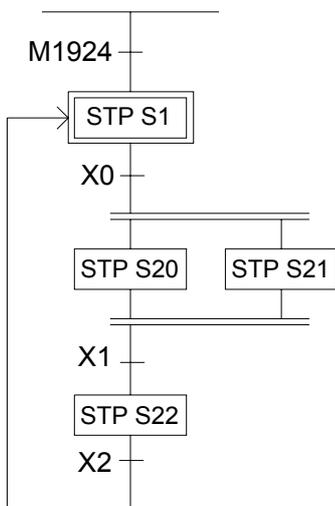STP S21   STP S22   S23

X3   X4

2-convergence

STP S23

- 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

M1924

STP S0

X0   X4

STP S20   S30

X2

STP S21

X3

X10

STP S7

X11   X12

STP S30   S21

X1

STP S31

X3

⑤ Closed Loop and Single Cycle

a. Closed Loop

M1924

STP S1

X0

STP S20   STP S21

X1

STP S22

X2

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

$$S1 \rightarrow \begin{cases} S20 \\ S21 \end{cases} \rightarrow S22$$

b. Single Cycle

```
          ┌──────┬────────┐
M1924 ──┤      ├──┤ X0
          │      └────────┘
          │
       ┌──┴───┐
       │ STP S0 │
       └──┬───┘
   X1 ────┤
       ┌──┴────┐
       │ STP S20 │
       └──┬────┘
   X2 ────┤
       ┌──┴────┐         ⌐────────┐
       │ STP S21 ├─────────┤ RST S21 │
       └───────┘         └────────┘
```
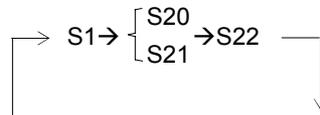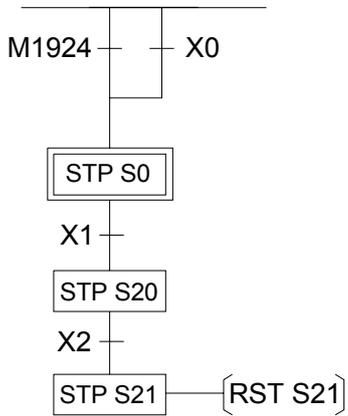
● When step S20 is ON, if X2 is also ON, then "RST S21" instruction will let S21 OFF which will stop the whole step process.

c. Mixed Process

```
          ┌──────────────────┐
M1924 ──┤
          │
      →┌──┴───┐
      │ │ STP S0 │
      │ └──┬───┘
      │     ├──────────┬──────────┐
      │ X0 ─┤      X1 ─┤      X2 ─┤
      │ ┌──┴────┐ ┌──┴────┐ ┌──┴────┐
      │ │ STP S20 │ │ STP S21 │ │ STP S24 │
      │ └──┬────┘ └──┬────┘ └──┬────┘
      │ X3 ─┤      X4 ─┤      X7 ─┤
      │     │          │      ┌──┴────┐      ⌐────────┐
      │ X5 ─┤          │      │ STP S25 ├──────┤ RST S25 │
      │     │          │      └───────┘      └────────┘
      │     ├══════════┤
      │ ┌──┴────┐ ┌──┴────┐
      │ │ STP S22 │ │ STP S23 │
      │ └──┬────┘ └──┬────┘
      │     ├══════════┤
      │ X6 ─┤
      └─────┘
```
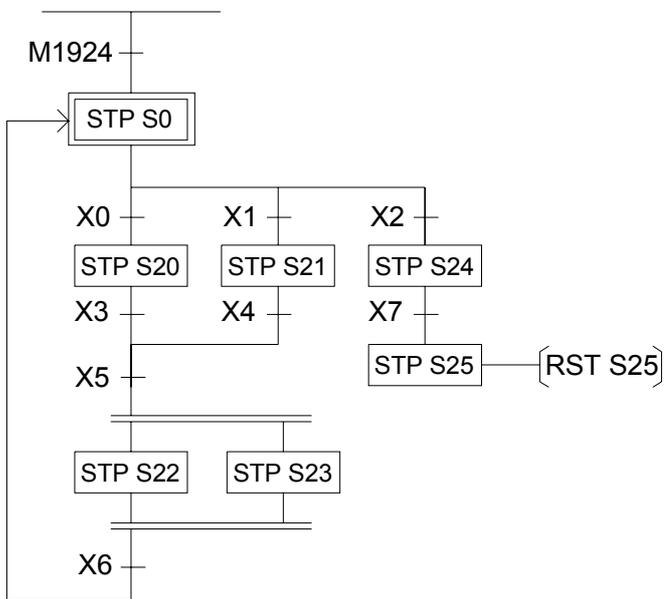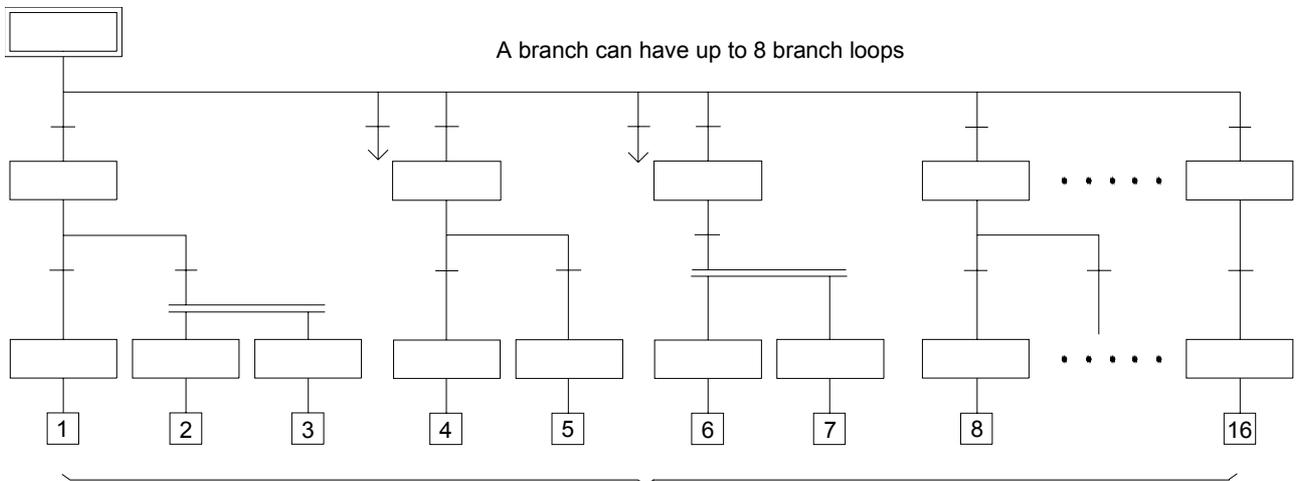
⑥ Combined Application

A branch can have up to 8 branch loops

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 16 |

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

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