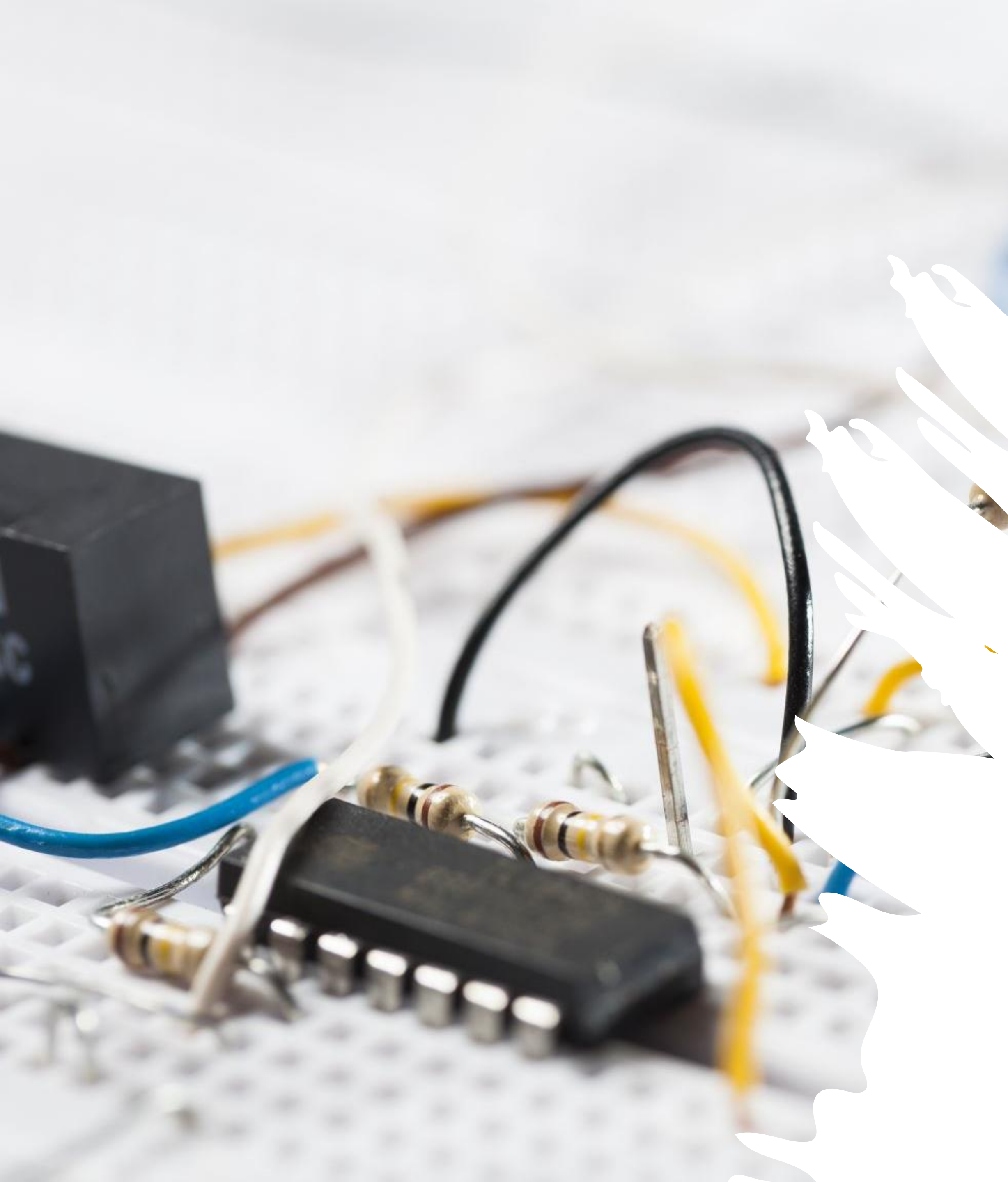


PLC Main Logic Function

LEX 4

PLC Logic Function – Internal Relays

- A variety of other terms are often used to describe these elements, such as auxiliary relays, markers, flags, coils, and bit storage.
- These are one of the elements included among the special built-in functions with PLCs and are very widely used in programming.
- A small PLC might have a hundred or more internal relays, some of them battery backed so that they can be used in situations where it is necessary to ensure safe shutdown of a plant in the event of power failure.
- In PLCs there are elements that are used to hold data, that is, bits, and behave like relays, being able to be switched on or off and to switch other devices on or off. **Hence the term internal relay**.
- *Such internal relays do not exist as real-world switching devices but are merely bits in the storage memory that behave in the same way as relays.*
- For programming, they can be treated in the same way as an external relay output and input. Thus inputs to external switches can be used to give an output from an internal relay.
- This then results in the internal relay contacts being used, in conjunction with other external input switches, to give an output, such as activating a motor.

PLC Logic Function – Internal Relays

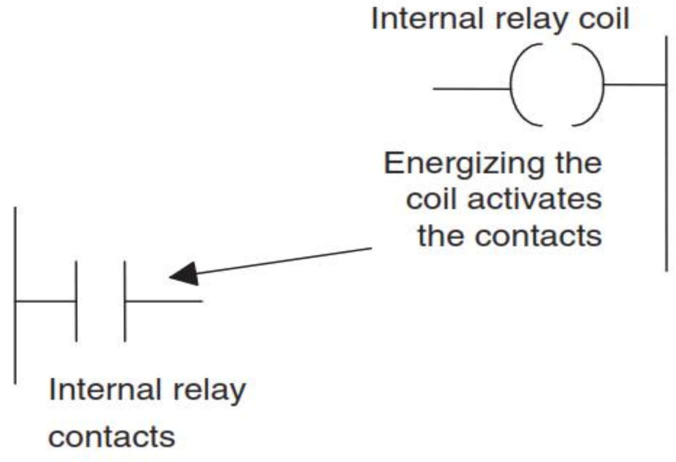
On one rung of the program:

Inputs to external inputs activate the internal relay output. On a later rung of the program.

As a consequence of the internal relay output, internal relay contacts are activated and so control some output.

In using an internal relay, it has to be activated on one rung of a program and then its output used to operate switching contacts on another rung, or rungs, of the program. Internal relays can be programmed with as many sets of associated contacts as desired.

To distinguish internal relay outputs from external relay outputs, they are given different types of addresses. Different manufacturers tend to use different terms for internal relays and have different ways of expressing their addresses. For example, Mitsubishi uses the term auxiliary relay or marker and the notation M100, M101, and so on. Siemens uses the term flag and the notation F0.0, F0.1, and so on.



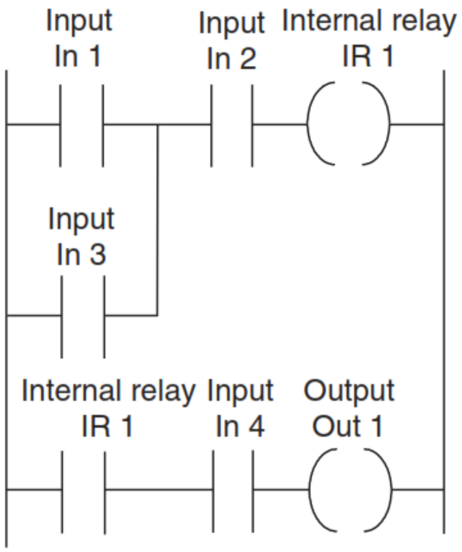
PLC Logic Function – Internal Relays

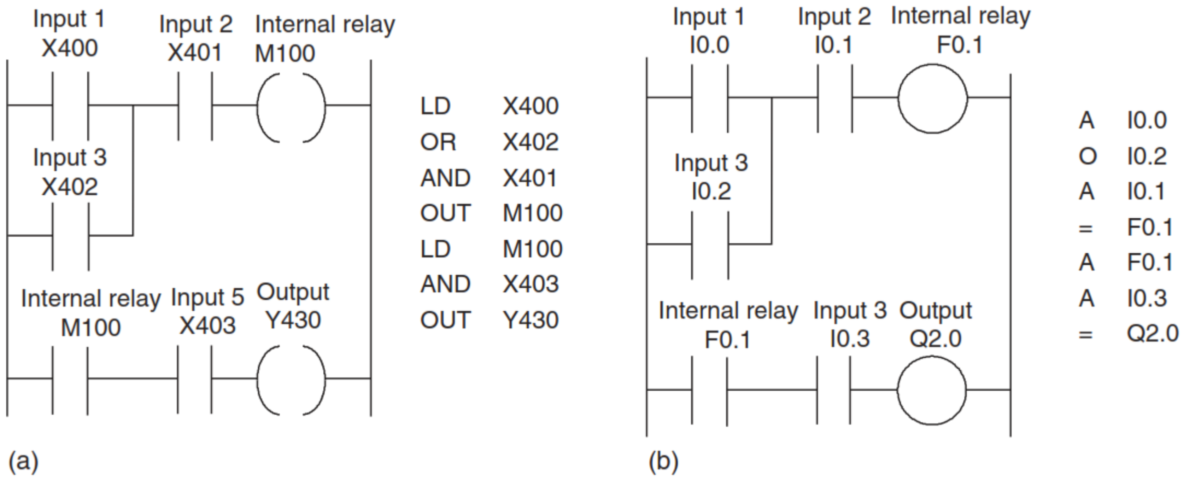
- Programs with Multiple Input Conditions

Figures shows a ladder program for such a task. For the first rung, when input In 1 or input In 3 is closed and input In 2 closed, internal relay IR 1 is activated. This results in the contacts for IR 1 closing.

If input In 4 is then activated, there is an output from output Out 1. Such a task might be involved in the automatic lifting of a barrier when someone approaches from either side.

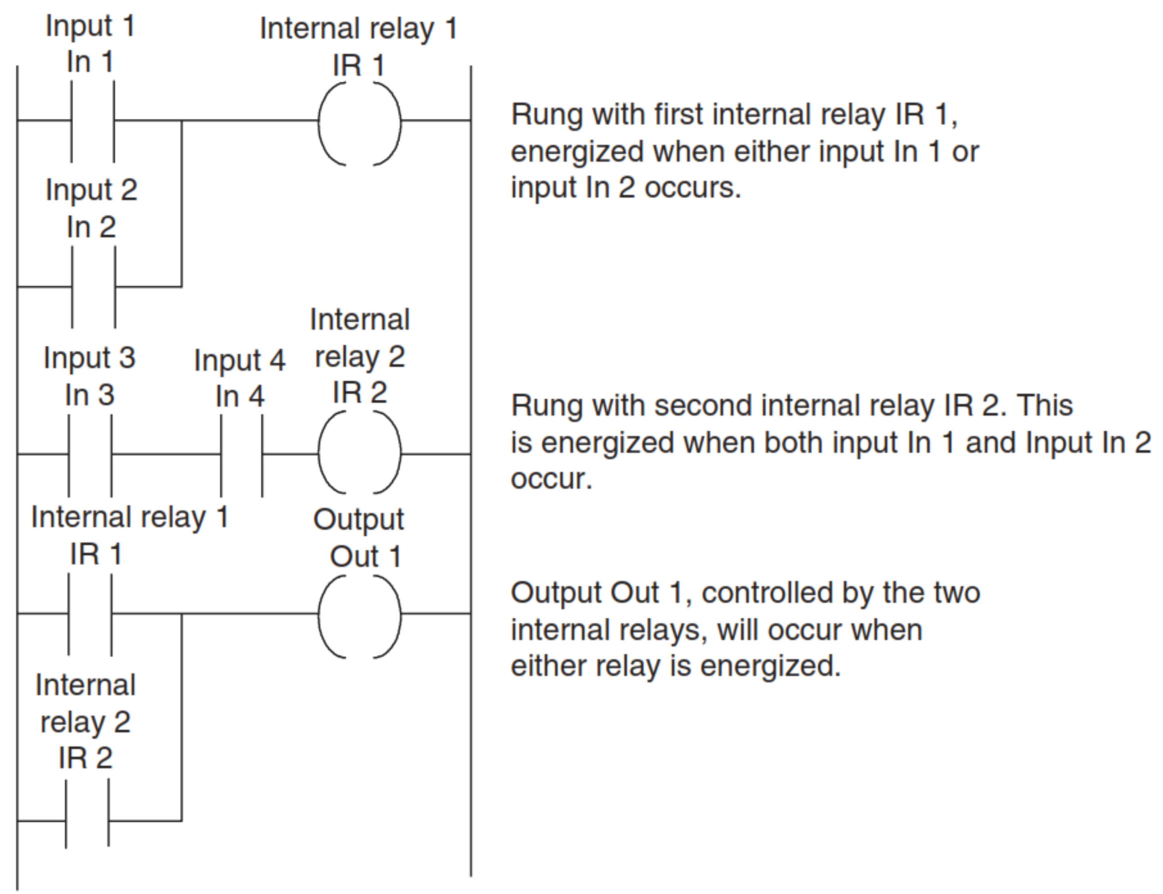
Input In 1 and input In 3 are inputs from photoelectric sensors that detect the presence of a person approaching or leaving from either side of the barrier, input In 1 being activated from one side of it and input In 3 from the other. Input In 2 is an enabling switch to enable the system to be closed down.





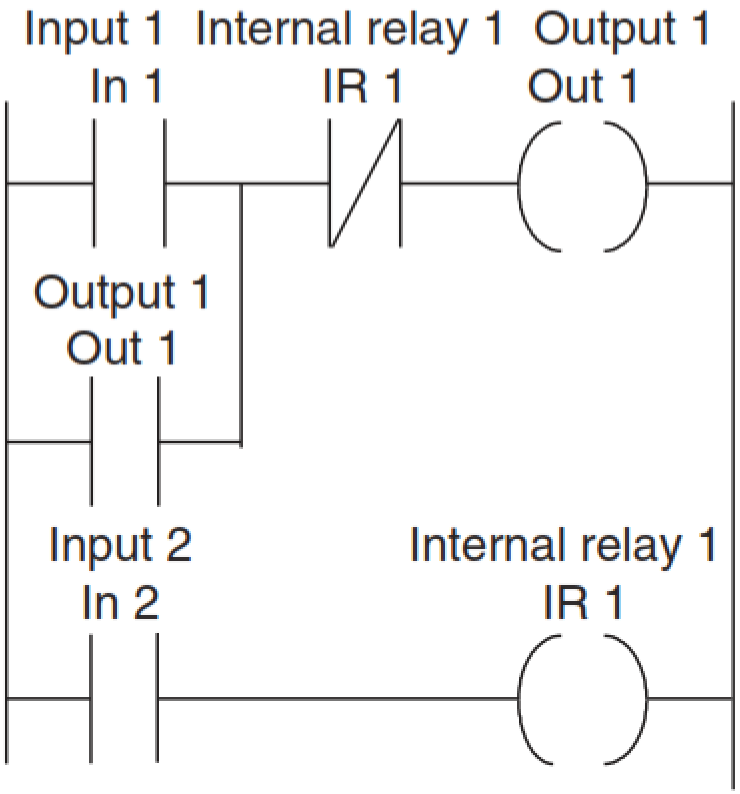
PLC Logic Function – Internal Relays

- Figure is another example of a ladder program involving internal relays.
- Output 1is controlled by two input arrangements. The first rung shows the internal relay IR 1, which is energized if input In 1 or In 2 is activated and closed.
- The second rung shows internal relay IR 2, which is energized if inputs In 3 and In 4 are both energized. The third rung shows that output Out 1 is energized if internal relay IR 1 or IR 2 is activated.
- Thus there is an output from the system if either of two sets of input conditions is realized.



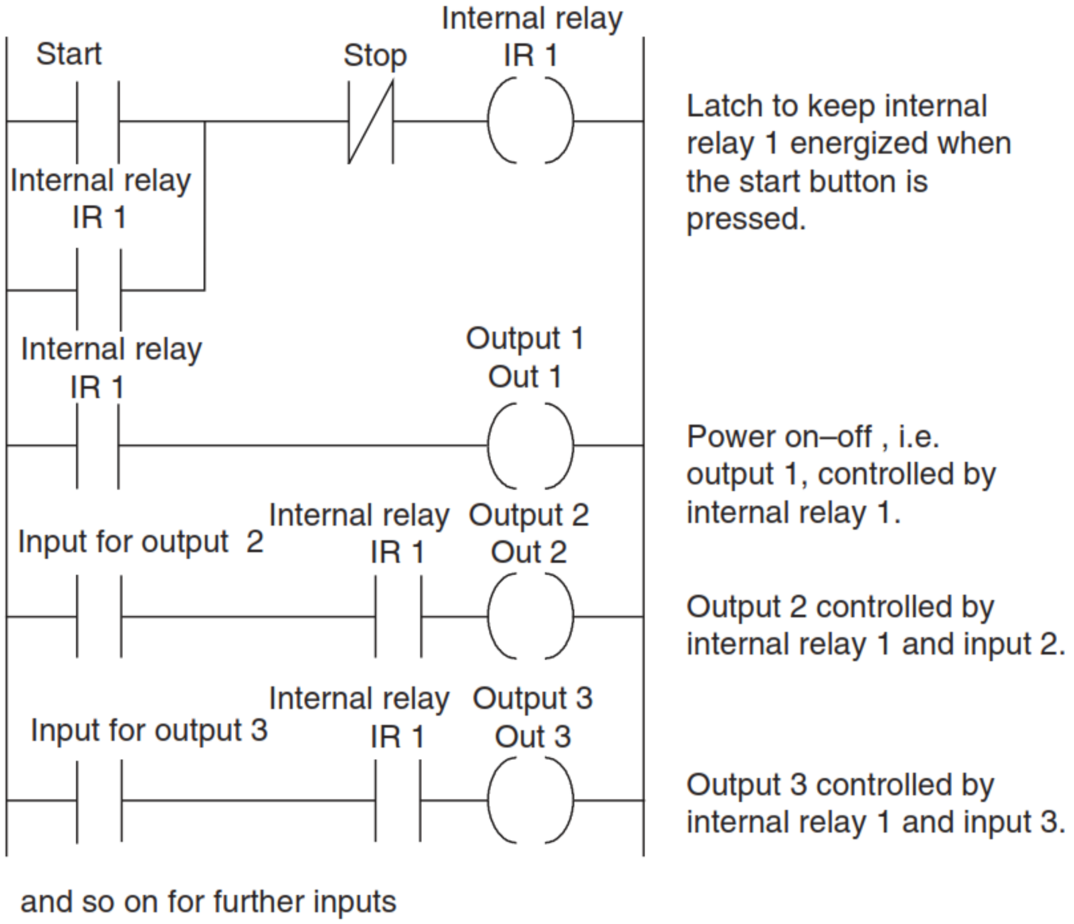
PLC Logic Function – Internal Relays

- Latching Programs:
- Another use of internal relays is for resetting a latch circuit.
- Figure shows an example of such a ladder program.
- When the input In 1 contacts are momentarily closed, there is an output at Out 1.
- This closes the contacts for Out 1 and so maintains the output, even when input In 1 opens.
- When input In 2 is closed, the internal relay IR 1 is energized and so opens the IR 1 contacts, which are normally closed.
- Thus the output Out 1 is switched off and so the output is unlatched.



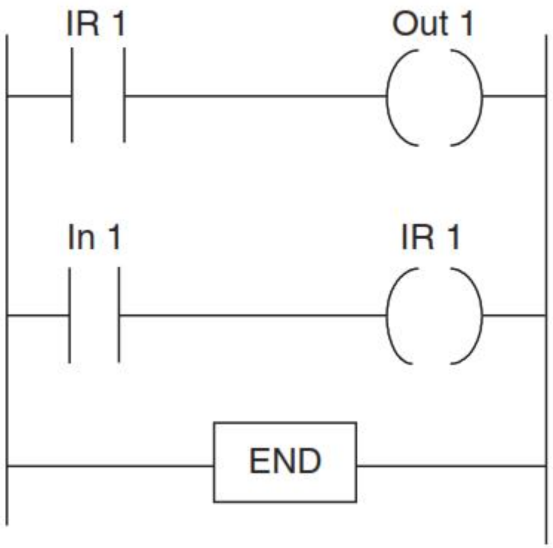
PLC Logic Function – Internal Relays

- Consider a situation requiring latch circuits where there is an automatic machine that can be started or stopped using push-button switches.
- A latch circuit is used to start and stop the power being applied to the machine. The machine has several outputs that can be turned on if the power has been turned on and are off if the power is off. It would be possible to devise a ladder diagram that has individually latched controls for each such output.
- However, a simpler method is to use an internal relay.
- Figure shows such a ladder diagram. The first rung has the latch for keeping the internal relay IR 1 on when the start switch gives a momentary input.



PLC Logic Function – Internal Relays

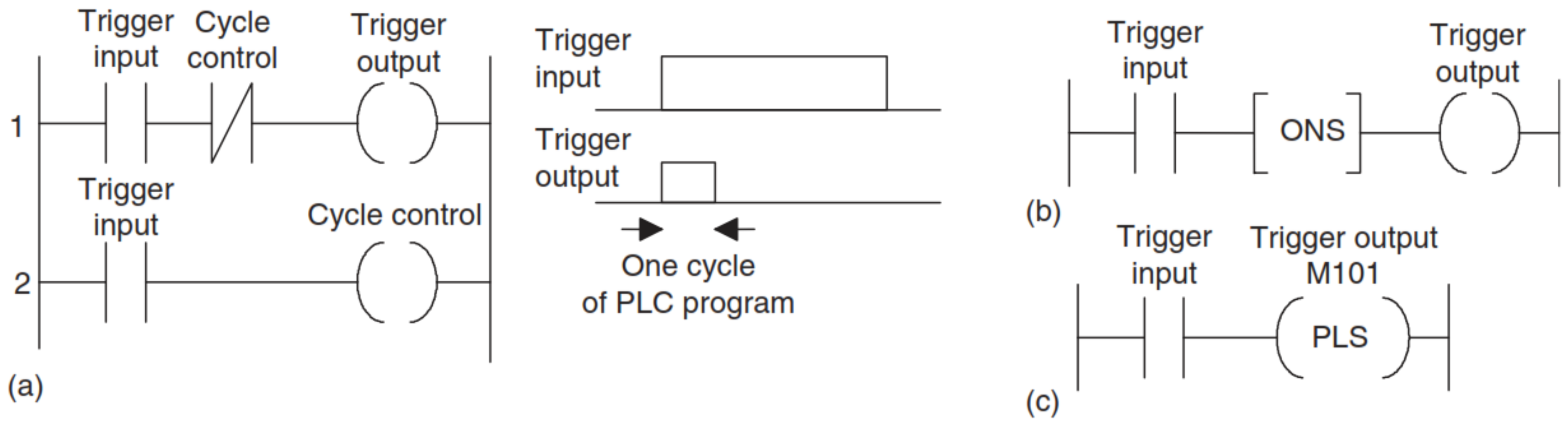
- **Response Time**
- The time taken between an input occurring and an output changing depends on such factors as the electrical response time of the input circuit, the mechanical response of the output device, and the scan time of the program.
- A ladder program is read from left to right and from top to bottom.
- Thus if an output device, such as an internal relay, is set in one scan cycle and the output has to be fed back to earlier in the program, it will require a second scan of the program before it can be activated.
- Figure illustrates this concept.



IR 1 not energized as a result of input to In 1 in the first scan until the second scan of the program.

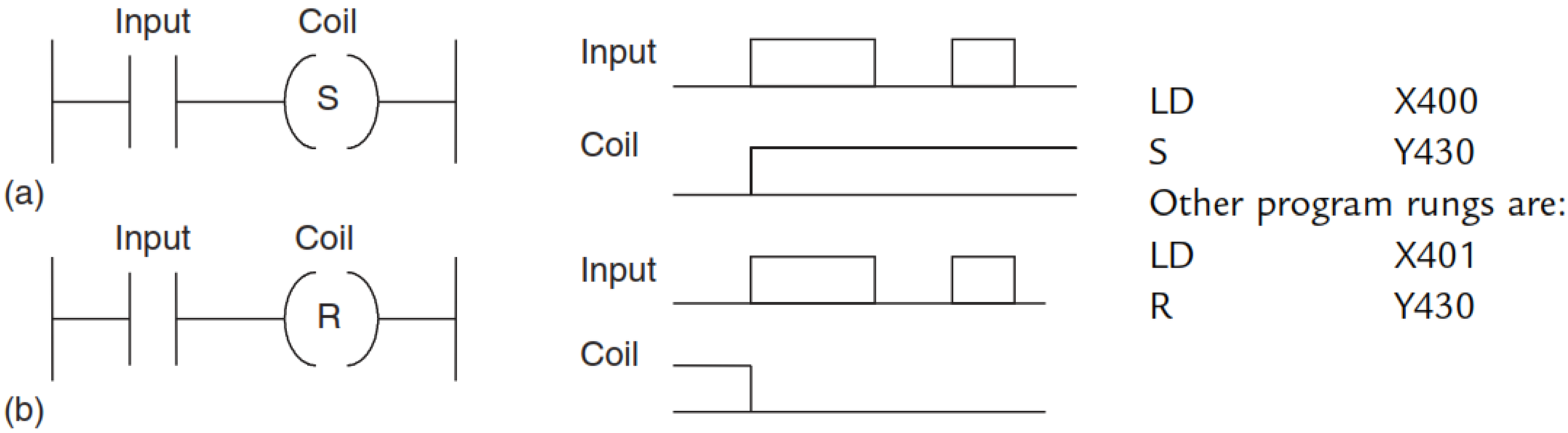
PLC Logic Function – Internal Relays

- **One-Shot Operation**
- One of the functions provided by some PLC manufacturers is the ability to program an internal relay so that its contacts are activated for just one cycle, that is, one scan through the ladder program.
- Hence when operated, the internal relay provides a fixed duration pulse at its contacts. This function is often termed one-shot.
- Though some PLCs have such a function as part of their programs, such a function can also easily be developed with just two rungs of a ladder program.
- Figure shows such a pair of rungs.



PLC Logic Function – Internal Relays

- **Set and Reset**
- Another function that is often available is the ability to set and reset an internal relay. The set instruction causes the relay to self-hold, that is, latch. It then remains in that condition until the reset instruction is received.
- The term flip-flop is often used. Figure shows the IEC 1131-3 standards for such coils. The SET coil is switched on when power is supplied to it and remains set until it is RESET. The RESET coil is reset to the off state when power is supplied to it and remains off until it is SET.



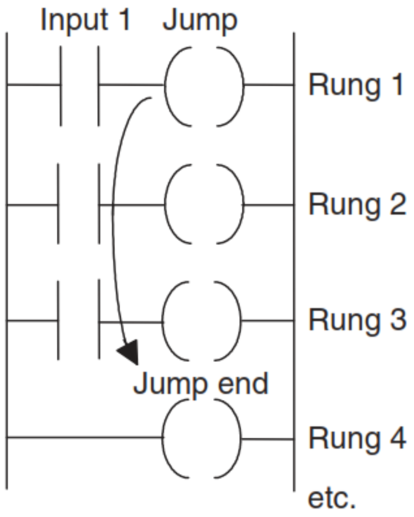
PLC Logic Function – Jump and Call

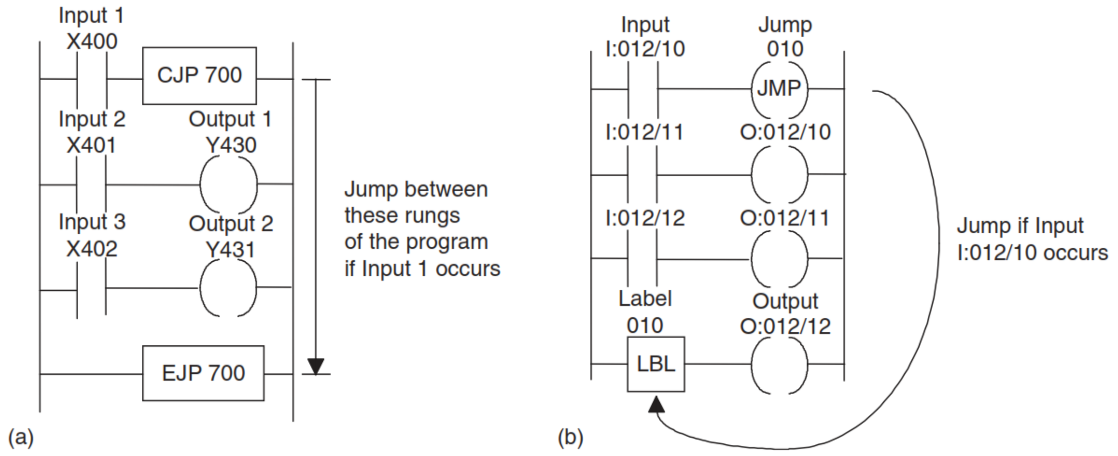
- **Jump** A function often provided with PLCs is the conditional jump. We can describe this as:

IF (some condition occurs) THEN *perform some instructions*

ELSE *perform some other instructions*

Such a facility enables programs to be designed such that if certain conditions are met, certain events occur, and if they are not met, other events occur. Thus, for example, we might need to design a system so that if the temperature is above 60 C a fan is switched on, and if below that temperature no action occurs. Thus, if the appropriate conditions are met, this function enables part of a ladder program to be jumped over.



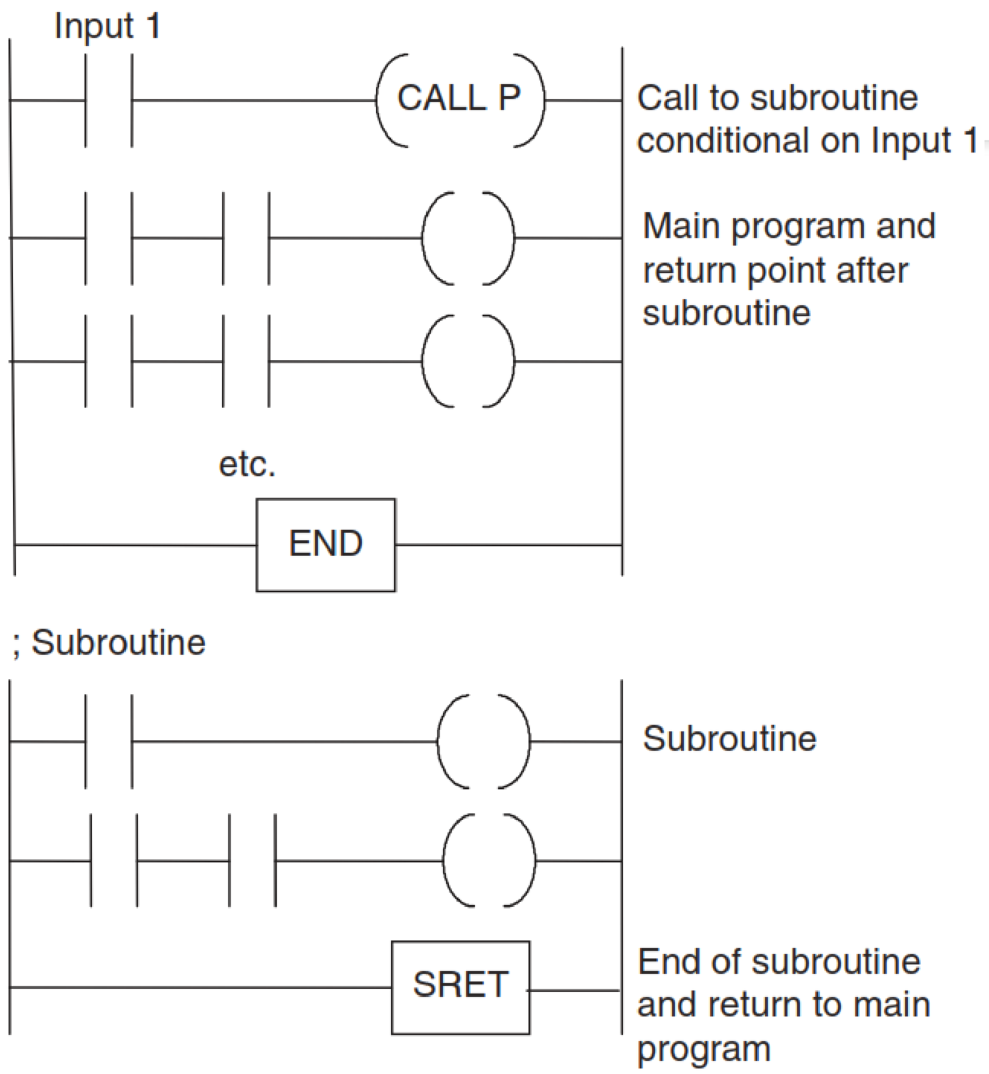


PLC Logic Function – Jump and Call

- **Subroutines** are small programs to perform specific tasks that can be called for use in larger programs.

The advantage of using subroutines is that they can be called repetitively to perform specific tasks without having to be written out in full in the larger program.

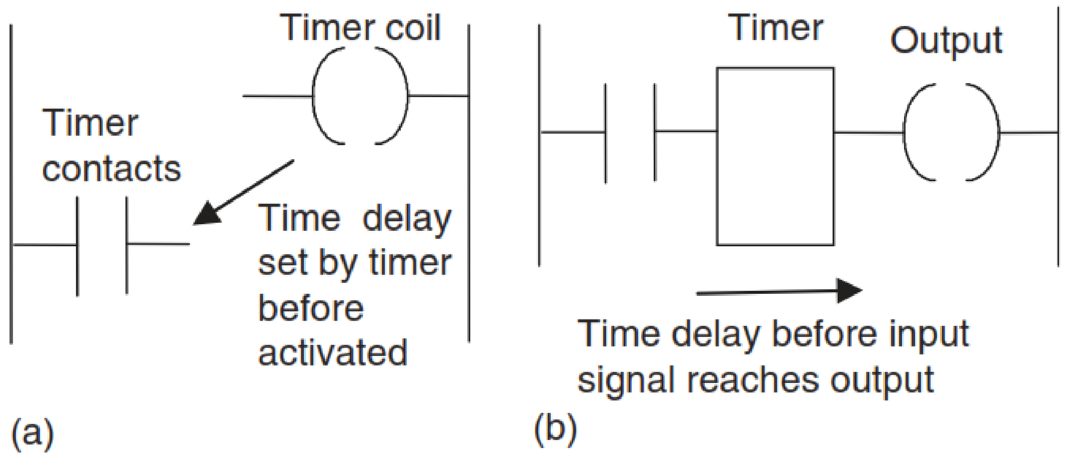
Thus with a Mitsubishi program we might have the situation shown in Figure. When input1 occurs, the subroutine P is called. This is then executed, the instruction SRET indicating its end and the point at which the program returns to the main program.



PLC Logic Function – Timers

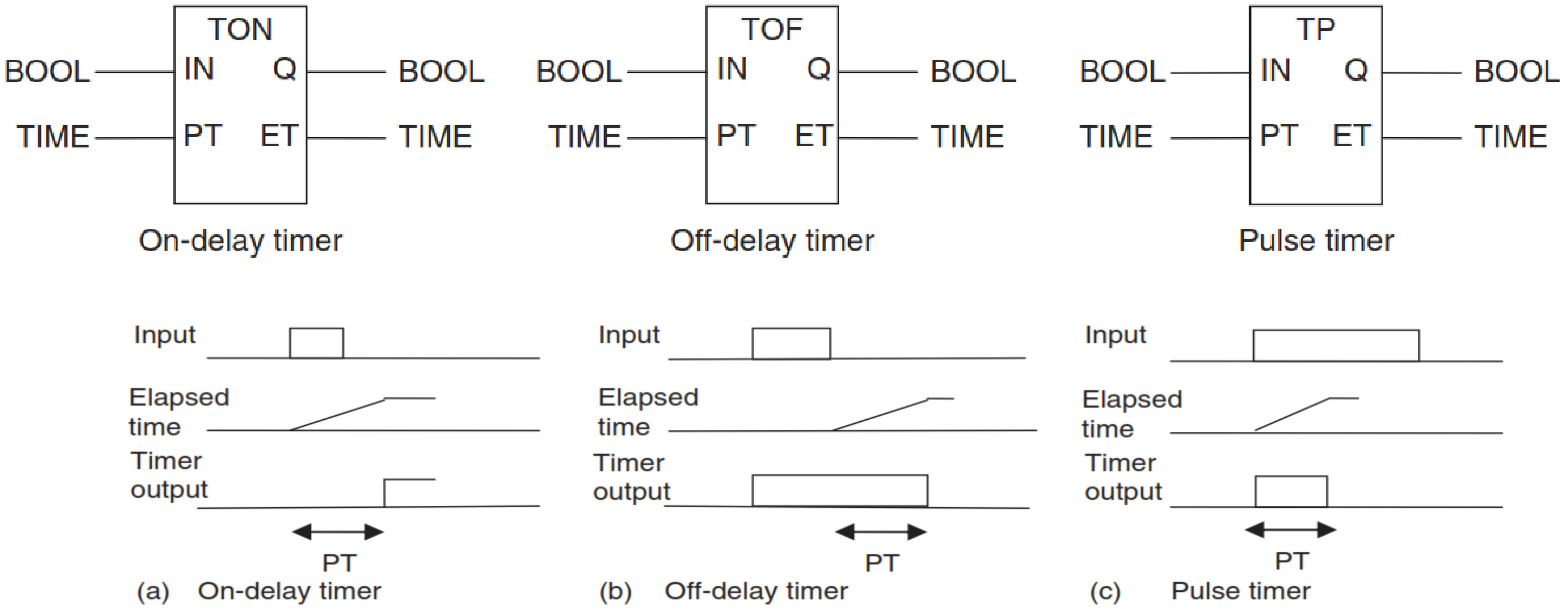
- In many control tasks there is a need to control time. For example, a motor or a pump might need to be controlled to operate for a particular interval of time or perhaps be switched on after some time interval. PLCs thus have timers as built-in devices. Timers count seconds or fractions of seconds using the internal CPU clock.

PLC manufacturers differ on how timers should be programmed and hence how they can be considered. A common approach is to consider timers to behave like relays with coils that when energized, result in the closure or opening of contacts after some preset time. The timer is thus treated as an output for a rung, with control being exercised over pairs of contacts elsewhere (Figure a). Some treat a timer as a delay block that when inserted in a rung, delays signals in that rung from reaching the output (Figure b).



PLC Logic Function – Timers

- There are a number of different forms of timers that can be found with PLCs: on-delay, off- delay, and pulse.
- With small PLCs there is likely to be just one form, the on-delay timers.
- Figure shows the IEC symbols. TON is used to denote on-delay, TOF off-delay, and TP pulse timers. On-delay is also represented by T 0 and off-delay by 0 T.

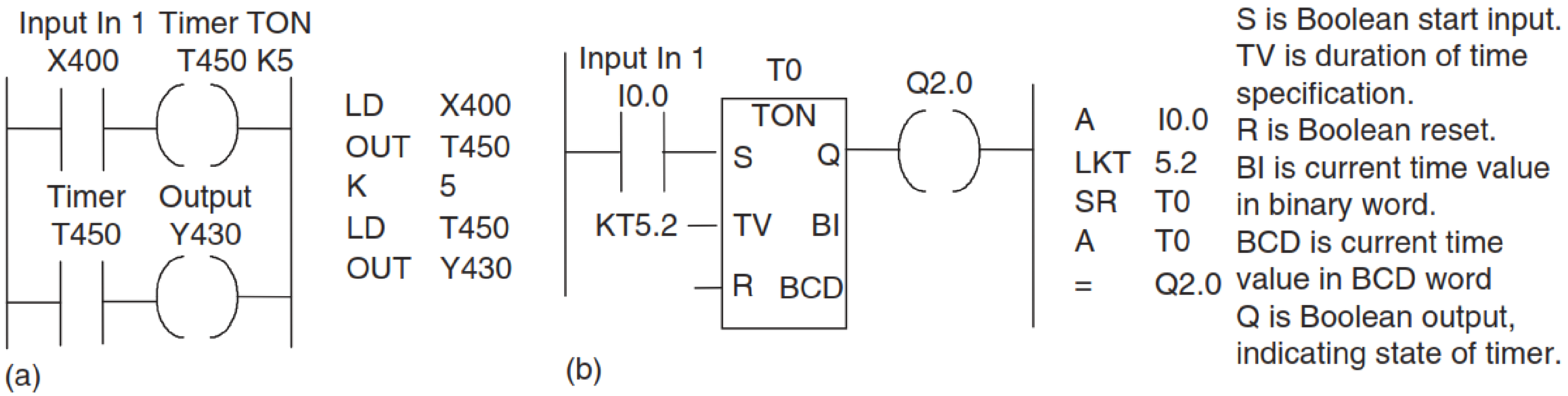


PLC Logic Function – Timers

On-Delay Timers - All PLCs generally have on-delay timers; small PLCs possibly have only this type of timer.

The timer is like a relay with a coil that is energized when input In 1 occurs (rung 1). It then closes, after some preset time delay, its contacts on rung 2. Thus the output occurs some preset time after input In 1 occurs. When the signal at the timer's start input changes from 0 to 1, the timer starts and runs for the programmed duration, giving its output then to the output coil. The time value (TV) output can be used to ascertain the amount of time remaining at any instant. A signal input of 1 at the reset input resets the timer whether it is running or not.

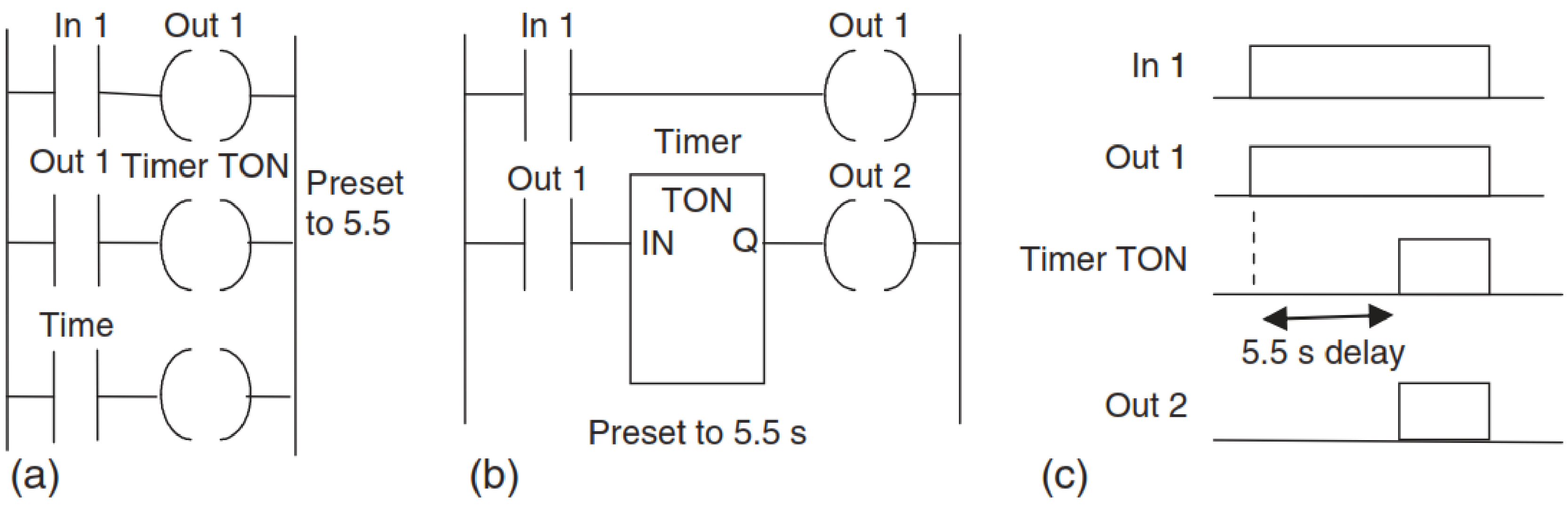
The preset value (PRE) is the number of time increments that the timer must accumulate to reach the required time delay, and the accumulator (ACC) indicates the number of increments that the timer has accumulated while the timer is active and is reset to zero when the timer is reset



PLC Logic Function – Timers

TON Sequencing

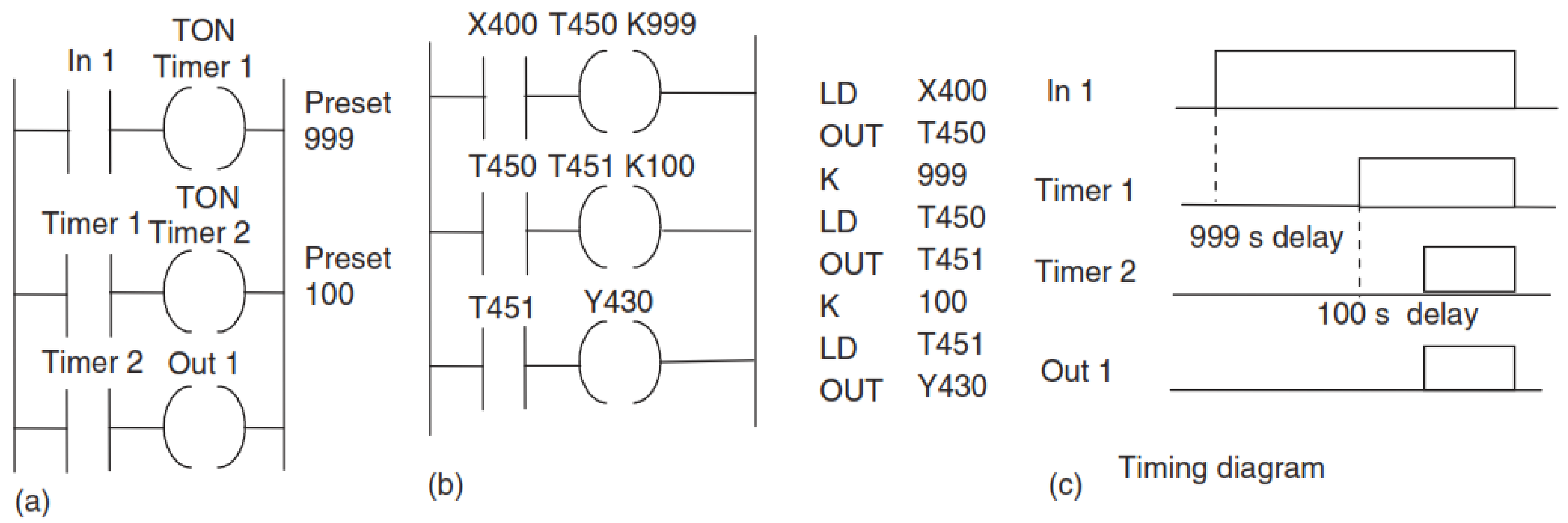
As an illustration of the use of a TON timer, consider the ladder diagram shown in Figure a. When the input In 1 is on, the output Out 1 is switched on. The contacts associated with this output then start the timer. The contacts of the timer will close after the preset time delay, in this case 5.5 s. When this happens, output Out 2 is switched on. Thus, following the input In 1, Out 1 is switched on and followed 5.5 s later by Out 2. This illustrates how a timed sequence of outputs can be achieved.



PLC Logic Function – Timers

TON Cascaded Timers

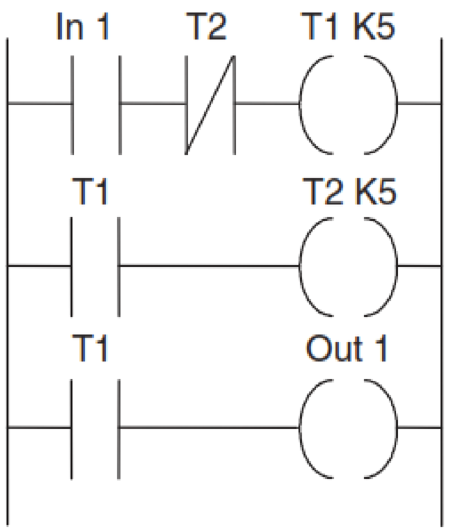
Timers can be linked together (the term cascaded is used) to give longer delay times than are possible with just one timer. Figure a shows the ladder diagram for such an arrangement. Thus we might have timer 1 with a delay time of 999 s. This timer is started when there is an input to In 1. When the 999 s is up, the contacts for timer 1 close. This then starts timer 2. This has a delay of 100 s. When this time is up, the timer 2 contacts close and there is an output from Out 1. Thus the output occurs 1099 s after the input to In 1 started.

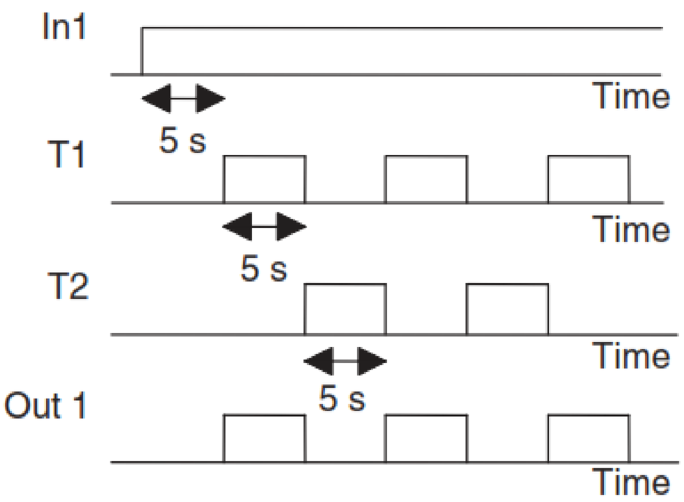


PLC Logic Function – Timers

TON On/Off Cycle Timer

Figure shows how on-delay timers can be used to produce an on/off cycle timer. The timer is designed to switch on an output for 5 s, then off for 5 s, then on for 5 s, then off for 5 s, and so on. When there is an input to In 1 and its contacts close, timer 1 starts. Timer 1 is set for a delay of 5 s. After 5 s, it switches on timer 2 and the output Out 1. Timer 2 has a delay of 5 s. After 5 s, the contacts for timer 2, which are normally closed, open. This results in timer 1 in the first rung being switched off. This then causes its contacts in the second rung to open and switch off timer 2. This results in the timer 2 contacts resuming their normally closed state, and so the input to In 1 causes the cycle to start all over again.

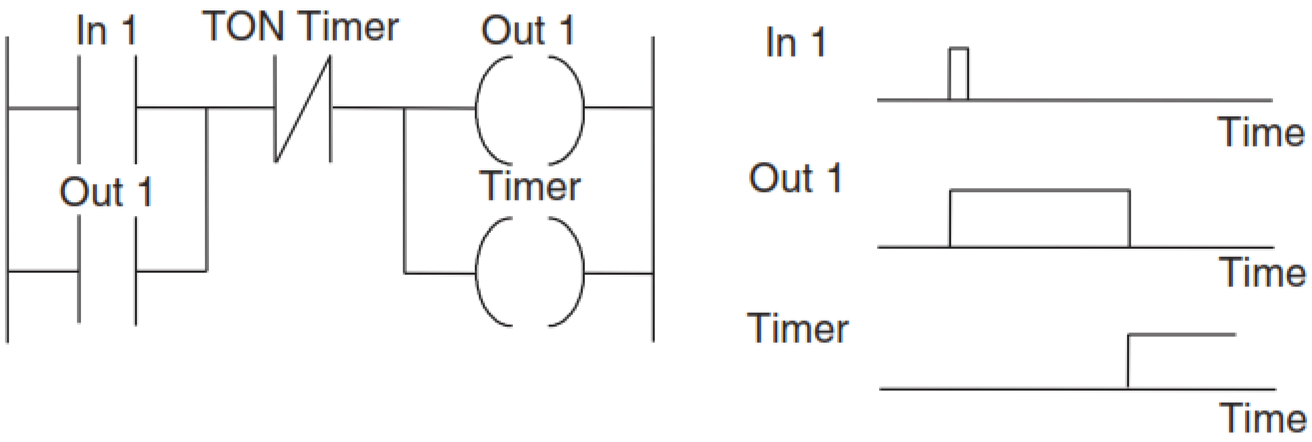




PLC Logic Function – Timers

Off-Delay Timers TOF

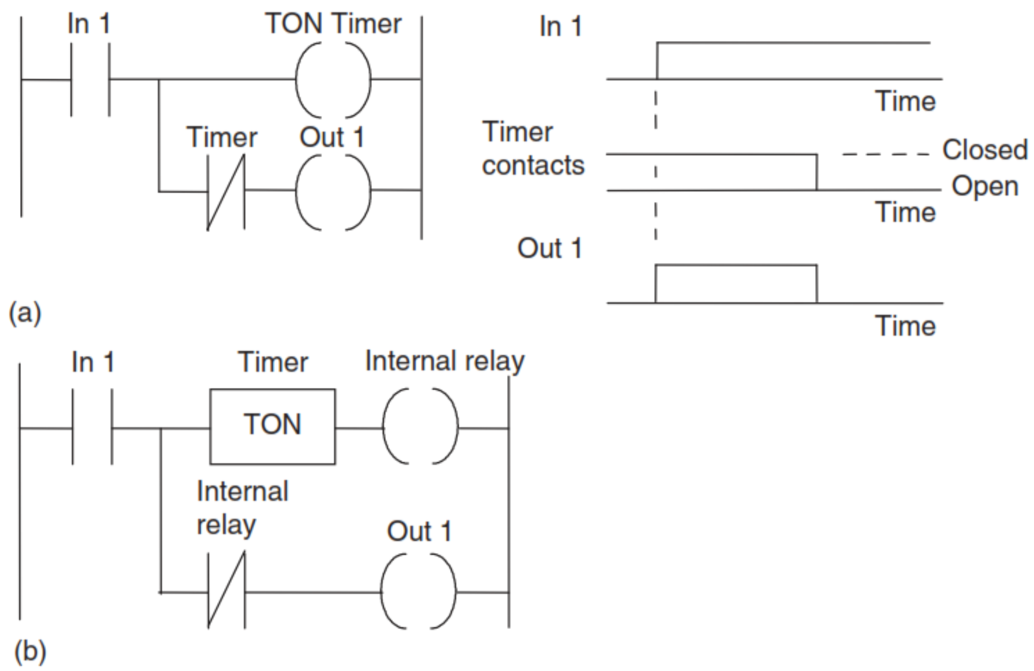
Figure shows how a on-delay timer can be used to produce an off-delay timer. With such an arrangement, when there is a momentary input to In 1, both the output Out 1 and the timer are switched on. Because the input is latched by the Out 1 contacts, the output remains on. After the preset timer delay, the timer contacts, which are normally closed, open and switch off the output. Thus the output starts as on and remains on until the time delay has elapsed.



PLC Logic Function – Timers

Pulse Timers

are used to produce a fixed-duration output from some initiating input. Figure a shows a ladder diagram for a system that will give an output from Out 1 for a predetermined fixed length of time when there is an input to In 1, the timer being one involving a coil. There are two outputs for the input In 1. When there is an input to In 1, there is an output from Out 1 and the timer starts. When the predetermined time has elapsed, the timer contacts open. This switches off the output. Thus the output remains on for only the time specified by the timer.

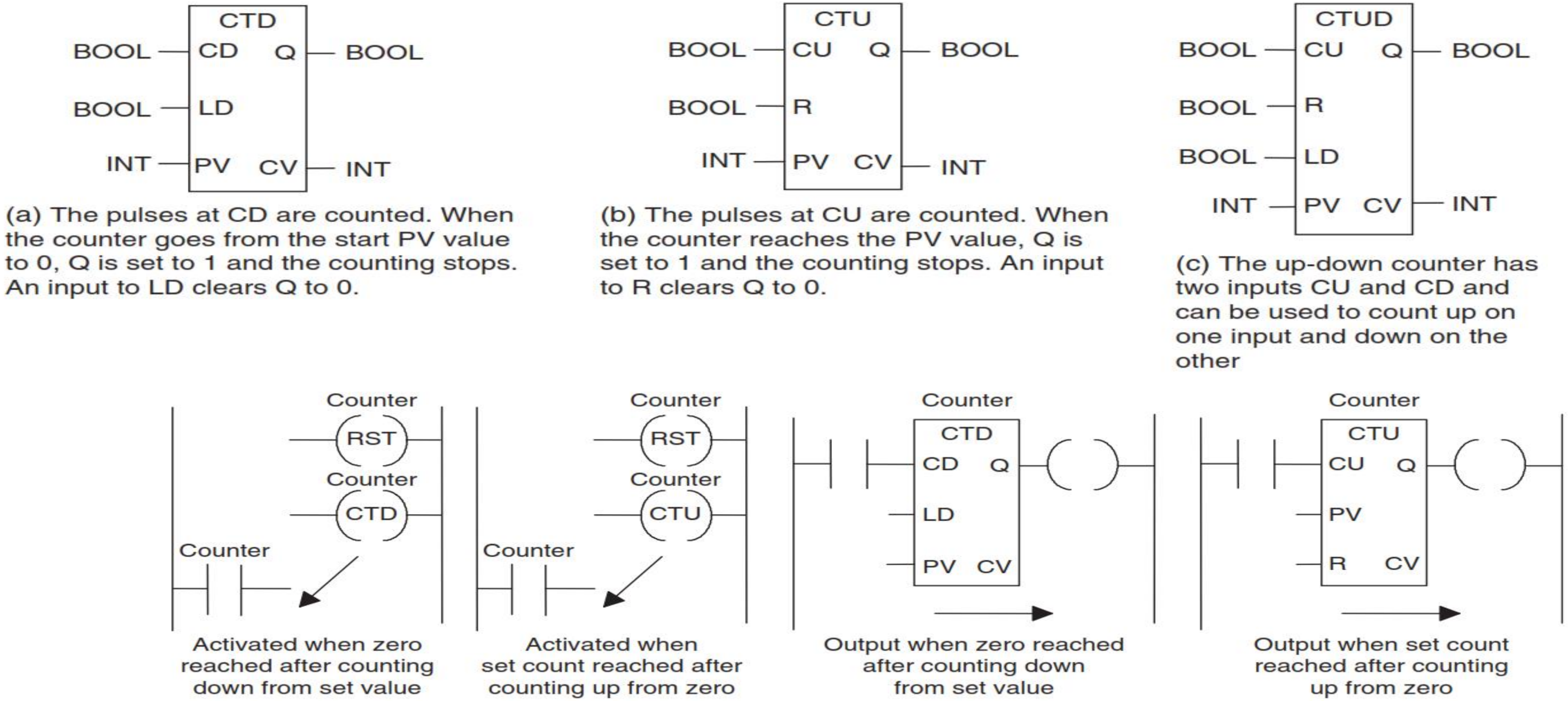


PLC Logic Function – Counters

- Counters are provided as built-in elements in PLCs and allow the number of occurrences of input signals to be counted.
- Some uses might include where items have to be counted as they pass along a conveyor belt, the number of revolutions of a shaft, or perhaps the number of people passing through a door.
- A counter is set to some preset number value and, when this value of input pulses has been received, it will operate its contacts. Normally open contacts would be closed, normally closed contacts opened.
- There are two basic types of counter**: down-counters and up-counters**.
- **Down-counters** count down from the preset value to zero, that is, events are subtracted from the set value. When the counter reaches the zero value, its contacts change state. Most PLCs offer down-counting.
- **Up-counters count** from zero up to the preset value, that is, events are added until the number reaches the preset value. When the counter reaches the set value, its contacts change state.
- Some PLCs offer the facility for both **down- and up-counting**.

PLC Logic Function – Counters

- Different PLC manufacturers deal with counters in slightly different ways.
- Some count down (CTD) or up (CTU) and reset and treat the counter as though it is a relay coil and so a rung output. In this way, counters can be considered to consist of two basic elements: one relay coil to count input pulses and one to reset the counter, the associated contacts of the counter being used in other rungs.



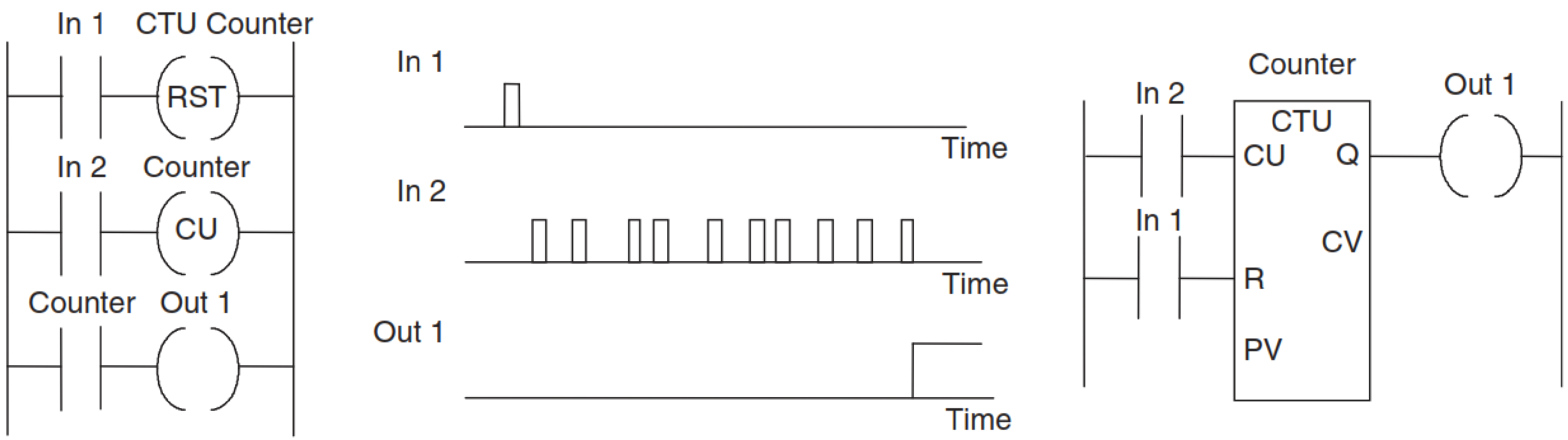
(a) The pulses at CD are counted. When the counter goes from the start PV value to 0, Q is set to 1 and the counting stops. An input to LD clears Q to 0.

(b) The pulses at CU are counted. When the counter reaches the PV value, Q is set to 1 and the counting stops. An input to R clears Q to 0.

(c) The up-down counter has two inputs CU and CD and can be used to count up on one input and down on the other

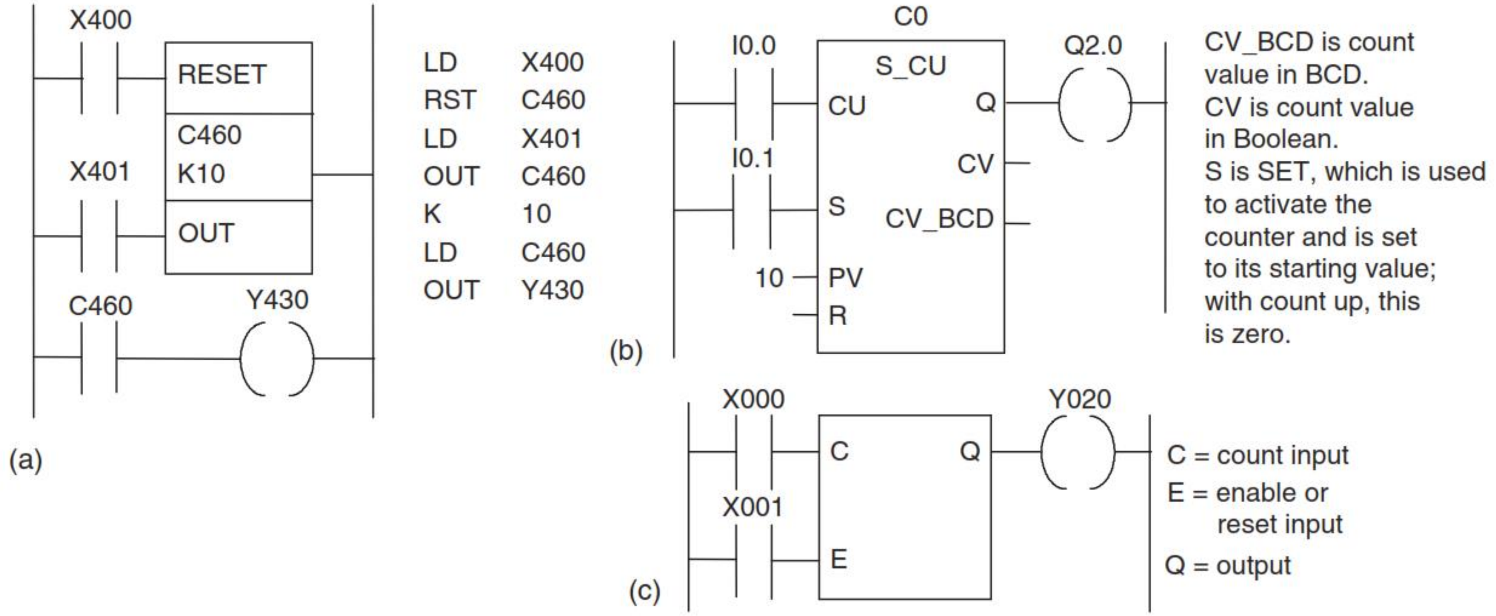
PLC Logic Function – Counters

- **Programming CU CD -** Figure shows a basic counting circuit. Each time there is a transition from 0 to 1 at input In 1, the counter is reset. When there is an input to In 2 and a transition from 0 to 1, the counter starts counting.
- If the counter is set for, say, 10 pulses, then when 10 pulse inputs, that is, 10 transitions from 0 to 1, have been received at In 2, the counter's contacts will close and there will be an output from Out 1.
- If at any time during the counting there is an input to In 1, the counter will be reset, start all over again, and count for 10 pulses.



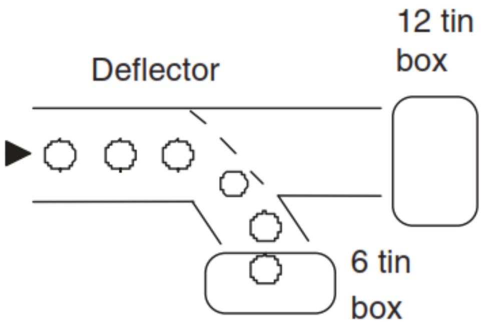
PLC Logic Function – Counters

- **Programming CU CD –** Figure a shows how the preceding program and its program instruction list would appear with a Mitsubishi PLC and a CTU counter. The reset and counting elements are combined in a single box spanning the two rungs. The count value is set by a K program instruction.
- Figure b shows the same program with a Siemens PLC. With this ladder program, the counter is considered a delay element in the output line. The counter is reset by an input to I0.1 and counts the pulses into input I0.0. The CU indicates that it is a up-count counter; a CD indicates a down-count counter. The counter set value is indicated by the LKC number. Figure c illustrates the program for a Toshiba PLC.

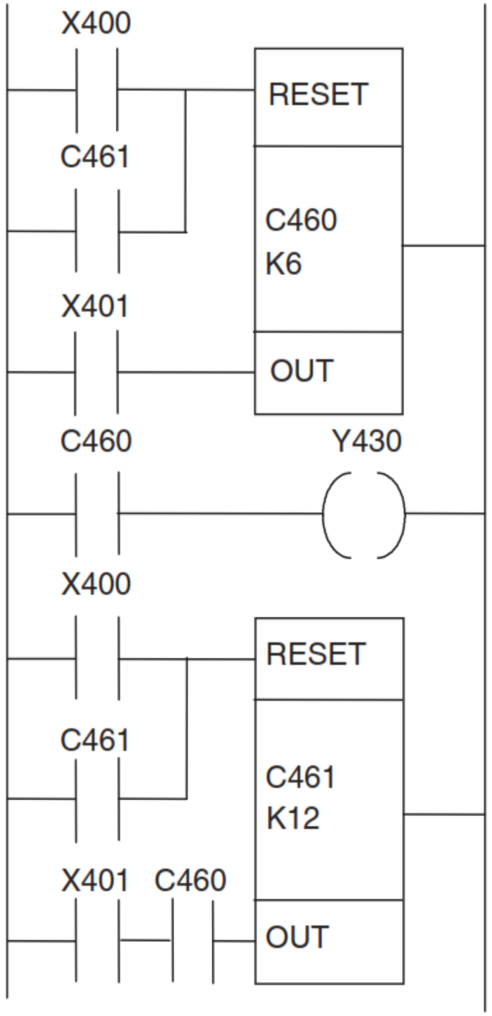


PLC Logic Function – Counters

Application CU CD – As a further illustration of the use of a counter, consider the problem of the control of a machine that is required to direct six tins along one path for packaging in a box and then12 tins along another path for packaging in another box (Figure a). A deflector plate might be controlled by a photocell sensor that gives an output every time a tin passes it. Thus the number of pulses from the sensor has to be counted and used to control the deflector. Figure 10.8b shows the ladder program that could be used, with Mitsubishi notation.



(a)



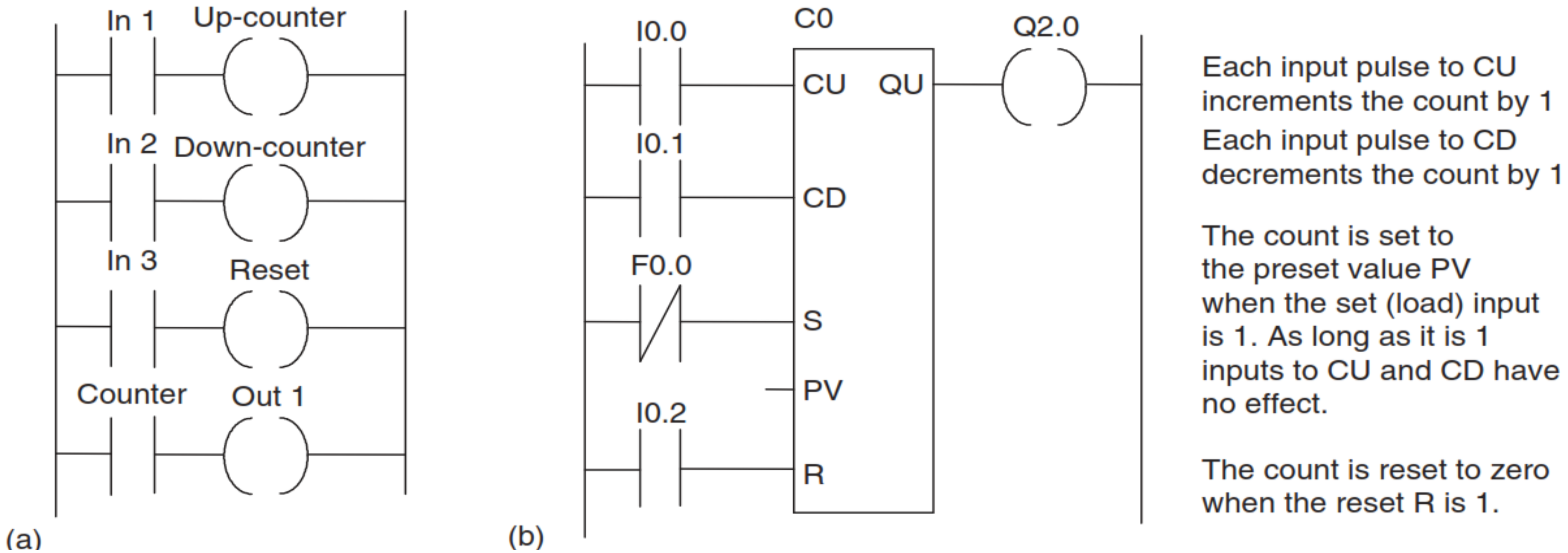
(b)

```
LD    X400
OR    C461
RST   C460
K     6
LD    X401
OUT   C460
LD    C460
OUT   Y430
LD    X400
OR    C461
RST   C461
K     12
LD    X401
AND   C460
OUT   C461
```

PLC Logic Function – Counters

- **Up- and Down-Counting**

It is possible to program up- and down-counters together. Up-down counters are available as single entities. Consider the task of perhaps cars as they enter a multistorage parking lot and as they leave it. An output is to be triggered if the number of cars entering is some number greater than the number leaving, that is, the number in the parking lot has reached a “saturation” value. The output might be to illuminate a “No empty spaces” sign. Suppose we use the up-counter for items entering and the down-counter for items leaving. Figure a shows the basic form a ladder program for such an application can take. CU is the count up input and CD the count down. R is the reset. The set accumulator value is loaded via F0.0, this being an internal relay.



PLC Logic Function – Shift Registers

The term **register** is used for an electronic device in which data can be stored. An internal relay is such a device.

The shift register is a number of internal relays grouped together that allow stored bits to be shifted from one relay to another.

A register is a number of internal relays grouped together, normally 8, 16, or 32. Each internal relay is either effectively open or closed, these states being designated 0 and 1. The term bit is used for each such binary digit.

Therefore, if we have eight internal relays in the register, we can store eight 0/1 states. Thus we might have, for internal relays: each relay might store an on/off signal such that the state of the register at some instant is:

1	2	3	4	5	6	7	8

1	0	1	1	0	0	1	0

that is, relay 1 is on, relay 2 is off, relay 3 is on, relay 4 is on, relay 5 is off, and so on. Such an arrangement is termed an 8-bit register. Registers can be used for storing data that originate from input sources other than just simple, single on/off devices such as switches.

With the shift register it is possible to shift stored bits. Shift registers require three inputs: one to load data into the first location of the register, one as the command to shift data along by one location, and one to reset or clear the register of data.

PLC Logic Function – Shift Registers

To illustrate this idea, consider the following situation where we start with an 8-bit register in the following state:

1	0	1	1	0	0	1	0

Suppose we now receive the input signal 0. This is an input signal to the first internal relay.

Input 0

→	1	0	1	1	0	0	1	0

If we also receive the shift signal, the input signal enters the first location in the register, and all the bits shift along one location. The last bit overflows and is lost.

0	1	0	1	1	0	0	1	→

Overflow 0

The grouping together of internal relays to form a shift register is done automatically by a PLC when the shift register function is selected. With the Mitsubishi PLC, this is done using the programming code SFT (shift) against the internal relay number that is to be the first in the register array. This then causes a block of relays, starting from that initial number, to be reserved for the shift register.

PLC Logic Function – Shift Registers

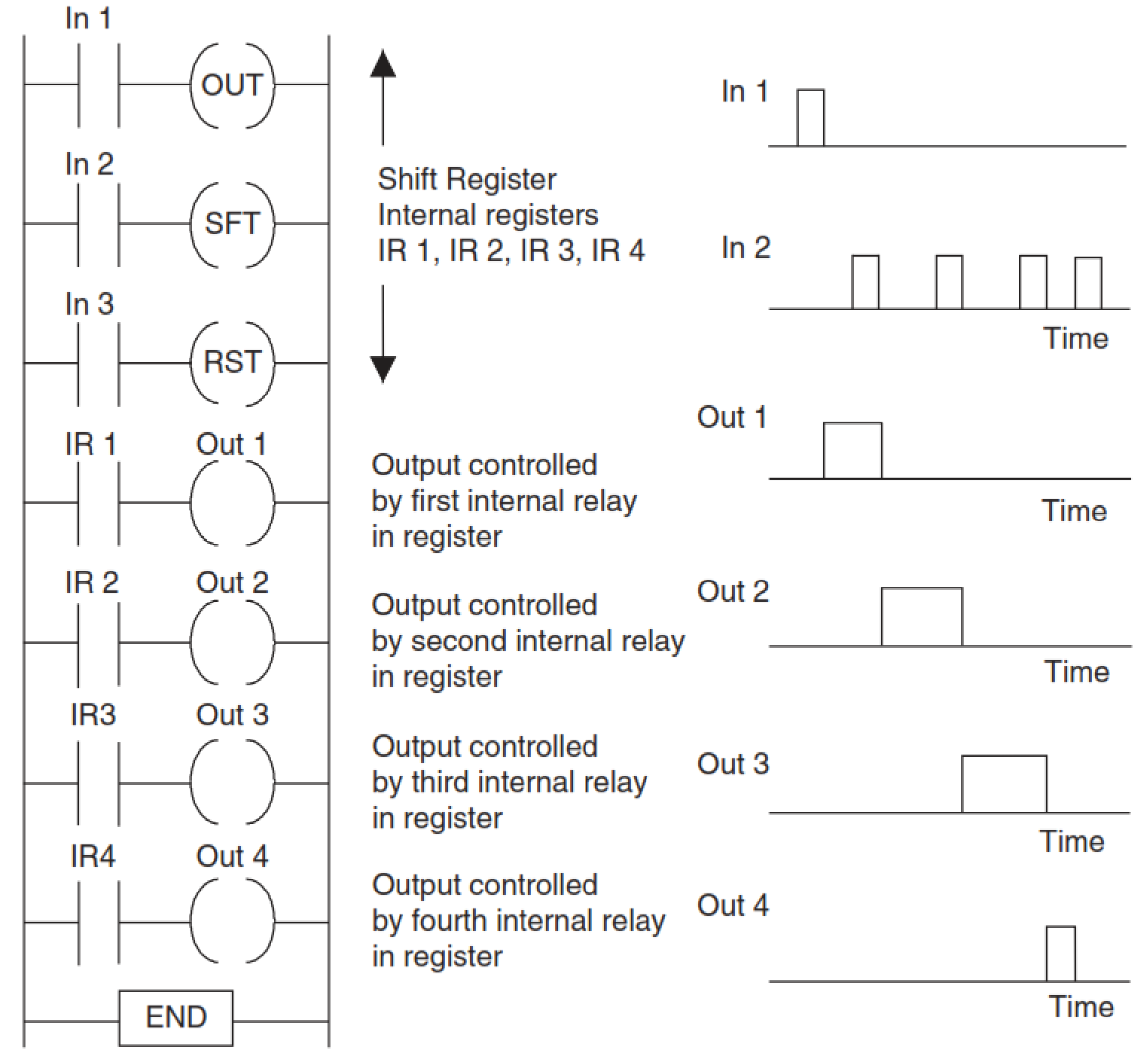
LAD - Consider a 4-bit shift register and how it can be represented in a ladder program (Figure a).

The input In 3 is used to reset the shift register, that is, put all the values at 0.

The input In 1 is used to input to the first internal relay in the register.

The input In 2 is used to shift the states of the internal relays along by one.

Each of the internal relays in the register, that is, IR 1, IR 2, IR 3, and IR 4, is connected to an output, these being Out 1, Out 2, Out 3, and Out 4.



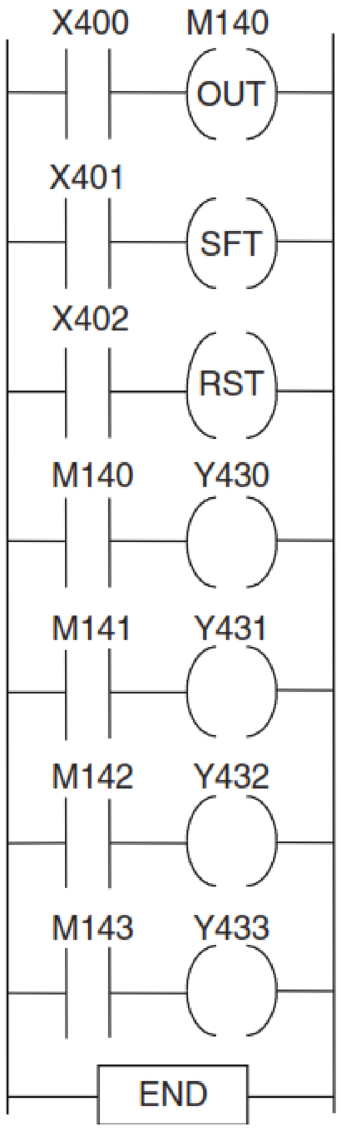
(a) (b)

PLC Logic Function – Shift Registers

LAD - Mitsubishi version of the preceding ladder program and the associated instruction list.

Instead of the three separate outputs for reset, output, and shift, the Mitsubishi shift register might appear in a program as a single function box, as shown in the figure.

With the Mitsubishi shift register, the M140 is the address of the first relay in the register.



Representation of the three shift register elements in a single box

LD	X400
OUT	M140
LD	X401
SFT	M140
LD	X402
RST	M140
LD	M140
OUT	Y430
LD	M141
OUT	Y431
LD	M142
OUT	Y432
LD	M143
OUT	Y433
END	

THANK YOU