SNS COLLEGE OF ENGINEERING

Kurumbapalayam (Po), Coimbatore – 641 107

An Autonomous Institution

Accredited by NBA – AICTE and Accredited by NAAC – UGC with 'A' Grade
Approved by AICTE, New Delhi & Affiliated to Anna University, Chennai

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

19EE602 INDUSTRIAL AUTOMATION

III YEAR / 06 SEMESTER EEE

Unit 2 – **PLC INSTRUCTIONS & I/O DEVICES**

TIMERS

Mechanical Timing Relays

- There are very few industrial control systems that do not need at least one or two timed functions.
- **Mechanical timing relays** are used to delay the opening or closing of contacts for circuit control.
- The operation of a mechanical timing relay is similar to that of a control relay, except that certain of its contacts are designed to operate at a preset time interval, after the coil is energized or de-energized.
- Typical types of mechanical and electronic timing relays are shown in Figure 7-1.
- Timers allow a multitude of operations in a control circuit to be automatically started and stopped at different time intervals.

Solid-state timing relay

Pneumatic timing relay

Plug-in timing relay

Figure 7-1 Timing relays.

- PLC timers are instructions that provide the same functions as on-delay and off-delay mechanical and electronic timing relays.
- All PLC timers are **output instructions**.
- PLC timers offer several advantages over their mechanical and electronic counterparts.
    - The entire timing function occurs inside the controller.
    - Time settings can be easily changed.
    - The number of timers used in a circuit can be increased or decreased through the use of programming changes rather than wiring changes.
    - Timer accuracy and repeatability are extremely high because time delays are generated in the PLC processor.

There are three different PLC timer types:

- *on-delay timer (**TON**)*,
- *off-delay timer (**TOF**)*, and
- *retentive timer on (**RTO**)*

The most common is the on-delay timer, which is the basic function.

These timer commands can be summarized as follows:

TON (Timer On Delay)—Counts time-based intervals when the instruction is true.

TOF (Timer Off Delay)—Counts time-based intervals when the instruction transitions from a true to false condition.

RTO (Retentive Timer On)—Counts time-based intervals when the instruction is true and retains the accumulated value when the instruction goes false or when power cycle occurs.

RES (Reset)—Resets a retentive timer's accumulated value to zero.

Several quantities are associated with the timer instruction:

Time Base

- It is the unit of time used by a timer to time an event.
- A timer instruction times an event by counting the number of times the time base has occurred. Depending on the manufacturer and type of PLC, time base values can be in 1 ms (0.001 s), 10 ms (0.01 s), 100 ms (0.1 s), or 1 second intervals.
- For example, if a timer has a time base of 1 second and it is timing something that is 5 seconds long, the PLC will wait until the time base has occurred 5 times before the timer times out.
- Conversely, if the PLC’s time base setting is 0.01 seconds, it will wait until the time base has occurred 500 times before timing out.
- The smaller the time base, the better the accuracy of the timer.

Preset Value

- The preset value of a timer represents the time duration for the timing circuit.
- Total timing interval = the preset value x time base.
- For example, for a timer with a preset value of 100 and a time base of 0.1s the time duration for the timer is: Total timing interval = 100 × 0.1 s = 10 seconds

Accumulated Value

- The accumulated value of the timer represents the amount of time that has elapsed from the moment the timing started.
- It keeps track of how many times the time base has occurred since the timer instruction was initiated.

Figure 7-9 shows a **coil- formatted timer** instruction.

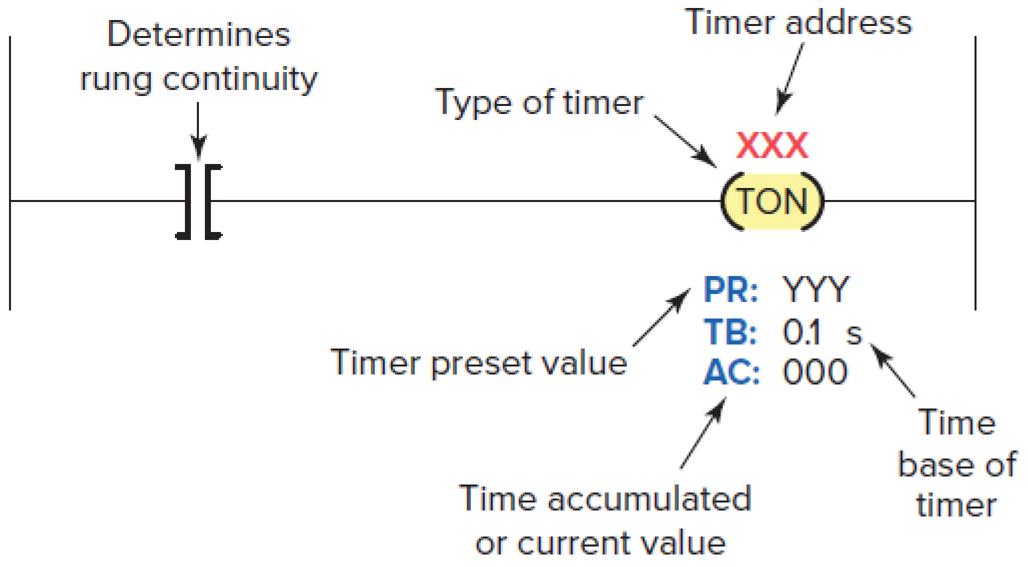

Figure 7-9 Coil-formatted timer instruction.

Timers are most often represented by boxes in ladder logic.
Figure 7-10 illustrates a generic **block format** for a retentive timer that requires two input lines.

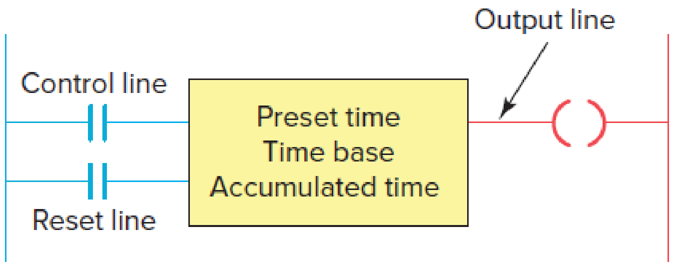

Figure 7-10 Block-formatted timer instruction.

Its operation can be summarized as follows:
• The timer block has two input conditions associated with it, namely, the *control* and *reset*.
• The control line controls the actual timing operation of the timer. Whenever this line is true or power is supplied to this input, the timer will time. Removal of power from the control line input halts the further timing of the timer.
• The reset line resets the timer's accumulated value to zero.

Some manufacturers require that *both* the control and reset lines be true for the timer to time; removal of power from the reset input resets the timer to zero.

• Other manufacturers' PLCs require power flow for the control input only and no power flow on the reset input for the timer to operate.

- For this type of timer operation, the timer is reset whenever the reset input is true.

The timer instruction block contains information pertaining to the operation of the timer, including the preset time, the time base of the timer, and the current or accumulated time.

All block-formatted timers provide at least one output signal from the timer. The timer continuously compares its current time with its preset time, and its output is false (logic 0) as long as the current time is less than the preset time. When the current time equals the preset time, the output changes to true (logic 1).

On-Delay Timer Instruction

- Most timers are output instructions that are conditioned by input instructions.
- An ***on-delay timer*** is used when you want to program a time delay before an instruction becomes true.
- Figure 7-11 illustrates the principle of operation of an on-delay timer. Its operation can be summarized as follows:
- The on-delay timer operates such that when the rung containing the timer is true, the timer time-out period commences.
- The timed output becomes true sometime after the timer rung becomes true; hence, the timer is said to have an on-delay.
- The length of the time delay can be adjusted by changing the preset value.

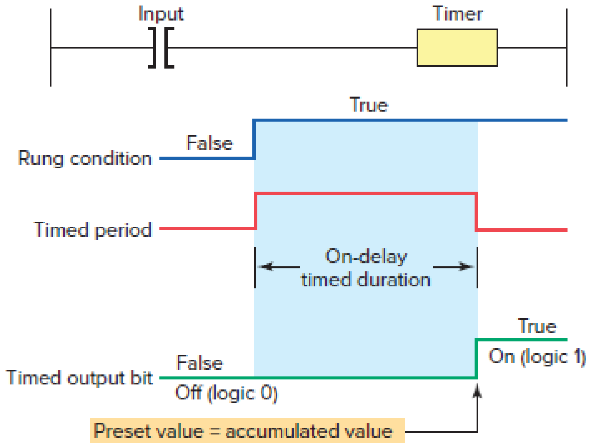

Figure 7-11 Principle of operation of an on-delay timer.

- In addition, some PLCs allow the option of changing the time base, or resolution, of the timer. As the time base you select becomes smaller, the accuracy of the timer increases.

- The Allen-Bradley SLC 500 timer file is file 4 (Figure 7-12). Each timer is composed of three 16-bit words, collectively called a timer element. There can be up to 256 timer elements.

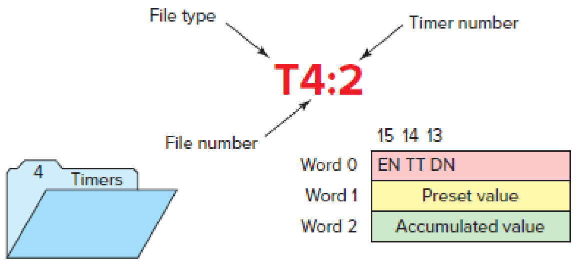

Figure 7-12 SLC 500 timer file.

Addresses for timer file 4, timer element number 2 (T4:2), are listed below.
T4 = timer file 4:2 = timer element number 2 (0–255 timer elements per file)
T4:2/DN is the address for the done bit of the timer.
T4:2/TT is the address for the timer-timing bit of the timer.
T4:2/EN is the address for the enable bit of the timer.

The *control word* uses the following three control bits:

Enable (EN) bit—The enable bit is true (has a status of 1) whenever the timer instruction is true. When the timer instruction is false, the enable bit is false (has a status of 0).

Timer-timing (TT) bit—The timer-timing bit is true whenever the accumulated value of the timer is changing, which means the timer is timing. When the timer is not timing, the accumulated value is not changing, so the timer-timing bit is false.

Done (DN) bit—The done bit changes state whenever the accumulated value reaches the preset value. Its state depends on the type of timer being used.

The *preset value (PRE) word* is the set point of the timer, that is, the value up to which the timer will time. The preset word has a range of 0 through 32,767 and is stored in binary form. The preset will not store a negative number.

The *accumulated value (ACC) word* is the value that increments as the timer is timing. The accumulated value will stop incrementing when its value reaches the preset value. The timer instruction also requires that you enter a *time base*, which is either 1.0 or 0.01 s. The actual preset time interval is the time base multiplied by the value stored in the timer's preset word. The actual accumulated time interval is the time base multiplied by the value stored in the timer's accumulated word.

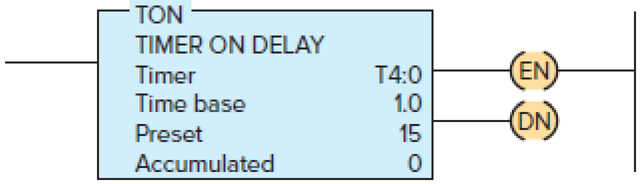

Figure 7-13 On-delay timer instruction.

Figure 7-13 shows an example of the on-delay timer instruction used as part of the Allen-Bradley SLC 500 controller instruction sets. The information to be entered includes:

Timer number—This number must come from the timer file. In the example shown, the timer number is T4:0, which represents timer file 4, timer 0 in that file. The timer address must be unique for this timer and may not be used for any other timer.

Time base—The time base (which is always expressed in seconds) may be either 1.0 or 0.01 s. In the example shown, the time base is 1.0 s.

Preset value—In the example shown, the preset value is 15. The timer preset value can range from 0 through 32,767.

Accumulated value—In the example shown, the accumulated value is 0. The timer's accumulated value normally is entered as 0, although it is possible to enter a value from 0 through 32,767. Regardless of the value that is preloaded, the timer value will become 0 whenever the timer is reset.

The on-delay timer (TON) is the most commonly used timer. Figure 7-15 shows a PLC program that uses an on delay timer. The operation of the program can be summarized as follows:

- The timer is activated by input switch A.

Timer ON DELAY (TON)		
TON Instruction OFF	Enable Bit (EN)	0
	Timer Timing Bit (TT)	0
	Done Bit (DN)	0
	Accumulating	NO
TON Instruction ON	Enable Bit (EN)	1
	Timer Timing Bit (TT)	1
	Done Bit (DN)	0
	Accumulating	YES
Timed Out Accum = Preset	Enable Bit (EN)	1
	Timer Timing Bit (TT)	0
	Done Bit (DN)	1
	Accumulating	NO
Instruction OFF after timed out	Enable Bit (EN)	0
	Timer Timing Bit (TT)	0
	Done Bit (DN)	0
	Accumulating	Reset

Table showing how each bit is effected during the program operation.

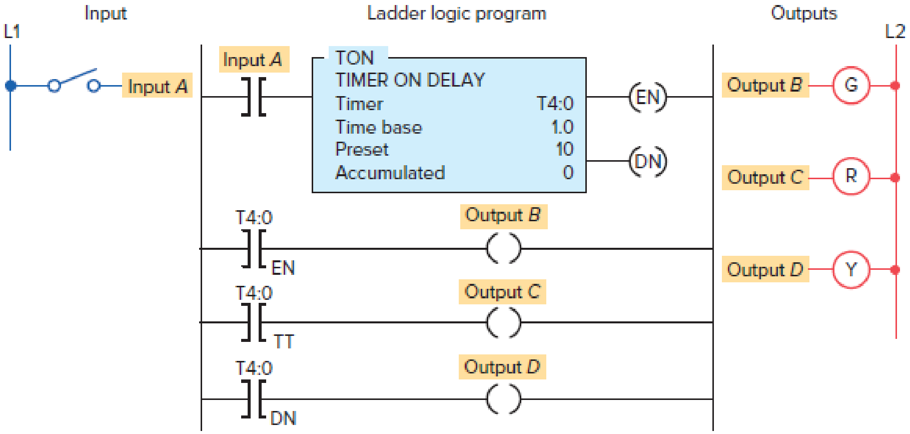

Figure 7-15 PLC on-delay timer program.

- When input switch A is closed (true or set to 1), the processor starts timer T4:0 timing and sets the EN and TT bits to true or 1.
- This turns ON outputs B and C
- The accumulated value increases in one-second time base intervals.
- When the accumulated time equals the preset time (10 s), the DN bit is set to 1, output D is turned ON, the TT bit is reset to 0 and output C is turned OFF.
- As long as input switch A remains closed the EN bit is set to 1 and output B will be ON.

- If input switch A is opened at any time before or after the timer has timed out, the accumulated time is automatically reset to 0 and output B is turned OFF.
- This timer configuration is termed *nonretentive* because any loss of continuity to the timer causes the timer instruction to reset.
- This timing operation is that of an on-delay timer because output D is switched on 10 s after the switch has been actuated from the off to the on position.

- Figure 7-16 shows the timing diagram for the on delay timer's control bits. The sequence of operation is as follows:
- The first true period of the timer rung shows the timer timing to 4 s and then going false.
- The timer resets, and both the timer-timing bit and the enable bit go false. The accumulated value also resets to 0.
- For the second true period input *A* remains true in excess of 10 s.

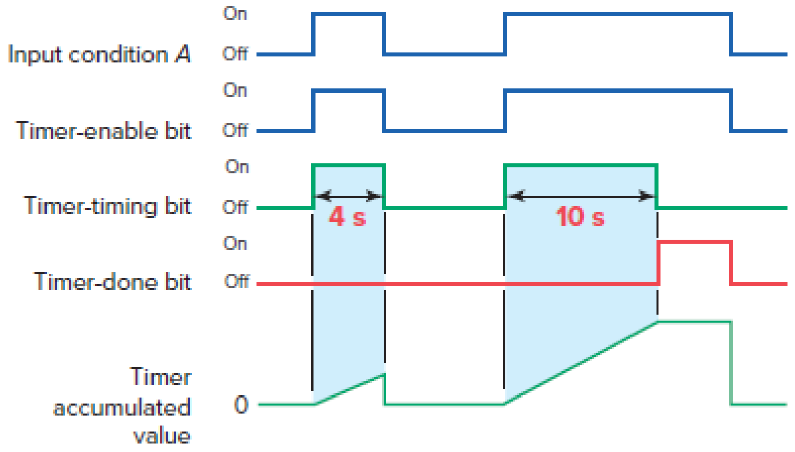

Figure 7-16 Timing diagram for an on-delay timer.

- When the accumulated value reaches 10 s, the done bit (DN) goes from false to true and the timertiming bit (TT) goes from true to false.
- When input *A* goes false, the timer instruction goes false and also resets, at which time the control bits are all reset and the accumulated value resets to 0.

Off-Delay Timer Instruction

- The ***off-delay timer (TOF)*** operation will keep the output energized for a time period after the rung containing the timer has gone false.
- Figure 7-21 illustrates the programming of an off-delay timer that uses the SLC 500 TOF timer instruction.
- TOF starts timing when the instruction goes from ON to OFF or from true to false.
- The operation of the circuit can be summarized as follows:

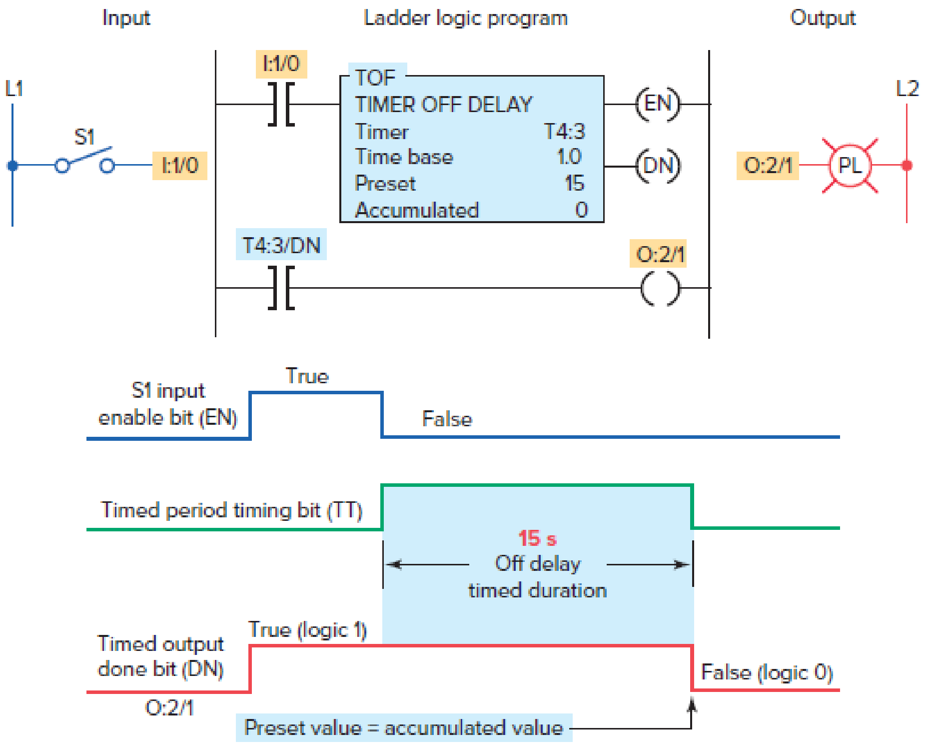

Figure 7-21 Off-delay programmed timer.

- When the switch connected to input I:1/0 is first closed, timed output O:2/1 is set to 1 immediately and the lamp is switched on.
- If this switch is now opened, logic continuity is lost and the timer begins counting.
- After 15 s, when the accumulated time equals the preset time, the output is reset to 0 and the lamp switches off.
- If logic continuity is gained before the timer is timed out, the accumulated time is reset to 0. For this reason, this timer is also classified as nonretentive.

Timer OFF DELAY (TOF)		
TOF Instruction ON	Enable Bit (EN)	1
	Timer Timing Bit (TT)	0
	Done Bit (DN)	1
	Accumulating	NO
TOF Instruction OFF	Enable Bit (EN)	0
	Timer Timing Bit (TT)	1
	Done Bit (DN)	1
	Accumulating	YES
Timed Out Accum = Preset	Enable Bit (EN)	0
	Timer Timing Bit (TT)	0
	Done Bit (DN)	0
	Accumulating	NO
Instruction OFF after timed out	Enable Bit (EN)	1
	Timer Timing Bit (TT)	0
	Done Bit (DN)	1
	Accumulating	Reset

Table showing how each bit is effected during the program operation.

Retentive Timer

- A ***retentive timer*** accumulates time whenever the device receives power, and it maintains the current time should power be removed from the device.
- When the timer accumulates time equal to its preset value, the contacts of the device change state.
- Loss of power to the timer after reaching its preset value does not affect the state of the contacts.
- The retentive timer must be intentionally reset with a separate signal for the accumulated time to be reset and for the contacts of the device to return to its nonenergized state.
- Figure 7-26 illustrates the action of a motor-driven, electromechanical retentive timer used in some appliances.
- The shaft-mounted cam is driven by a motor.
- Once power is applied, the motor starts turning the shaft and cam.
- The positioning of the lobes of the cam and the gear reduction of the motor determine the time it takes for the motor to turn the cam far enough to activate the contacts.
- If power is removed from the motor, the shaft stops but *does not reset.*
- A PLC retentive timer is used when you want to retain accumulated time values through power loss or the change in the rung state from true to false.
- The PLC-programmed retentive on-delay timer (RTO) is programmed in a manner similar to the nonretentive on-delay timer (TON), with one major exception—a retentive timer reset (RES) instruction.

- Unlike the TON, the RTO will hold its accumulated value when the timer rung goes false and will continue timing where it left off when the timer rung goes true again.
- This timer must be accompanied by a timer reset instruction to reset the accumulated value of the timer to 0.
- The RES instruction is the only automatic means of resetting the accumulated value of a retentive timer.
- The RES instruction has the same address as the timer it is to reset.
- Whenever the RES instruction is true, both the timer accumulated value and the timer done bit (DN) are reset to 0.
- Figure 7-27 shows a PLC program for a retentive on-delay timer.

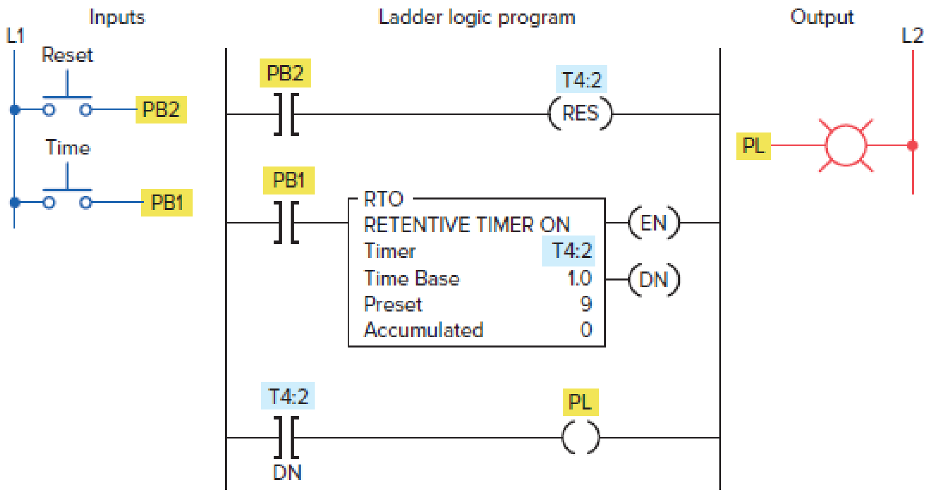

Figure 7-27 Retentive on-delay timer program.

The operation of the program can be summarized as follows:

- The timer will start to time when time pushbutton PB1 is closed.
- If the pushbutton is closed for 3 s and then opened for 3 s, the timer accumulated value will remain
- at 3 s.
- When the time pushbutton is closed again, the timer picks up the time at 3 s and continues timing.
- When the accumulated value (9) equals the preset value (9), the timer done bit T4:2/DN is set to 1 and the pilot light output PL is switched on.
- Whenever the momentary reset pushbutton is closed, the timer accumulated value is reset to 0.

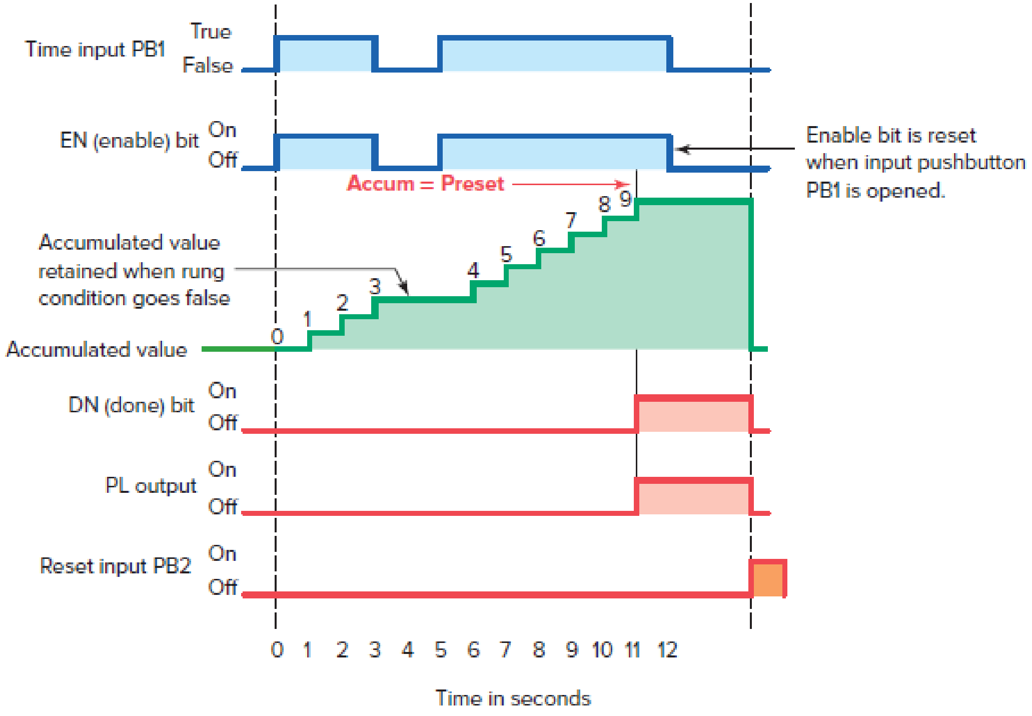

Figure 7-28 Retentive on-delay timer timing chart.

Figure 7-28 shows a timing chart for the retentive on delay timer program. The timing operation can be summarized as follows:

- When the timing rung is true (PB1 closed), the timer will commence timing.
- If the timing rung goes false, the timer will stop timing but will recommence timing for the stored accumulated value each time the rung goes true.
- When the reset PB2 is closed, the T4:2/DN bit is reset to 0 and turns the pilot light output off.
- The accumulated value is also reset and held at zero until the reset pushbutton is opened.

- The program drawn in Figure 7-29 illustrates a practical application for an RTO.
- The purpose of the RTO timer is to detect whenever a piping system has sustained a *cumulative* overpressure condition for 60 s.
- At that point, a horn is sounded automatically to call attention to the malfunction.
- When they are alerted, maintenance personnel can silence the alarm by switching the key switch S1 to the reset (contact closed) position.
- After the problem has been corrected, the alarm system can be reactivated by switching the key switch to open contact position.

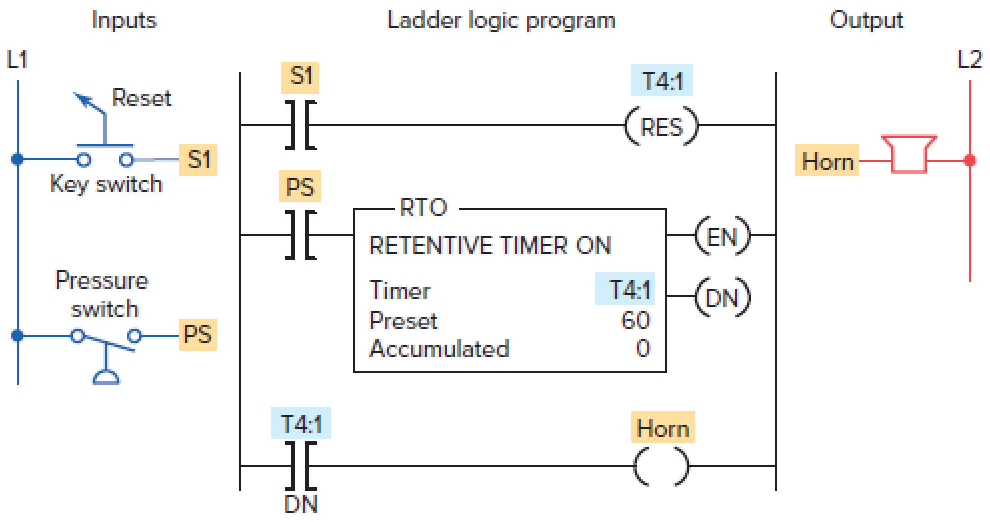

Figure 7-29 Retentive on-delay timer alarm program.

Cascading Timers

When one timer’s output triggers another timer’s input, those timers are referred to as **cascaded**. Timers can be interconnected, or cascaded, to satisfy a number of logic control functions.

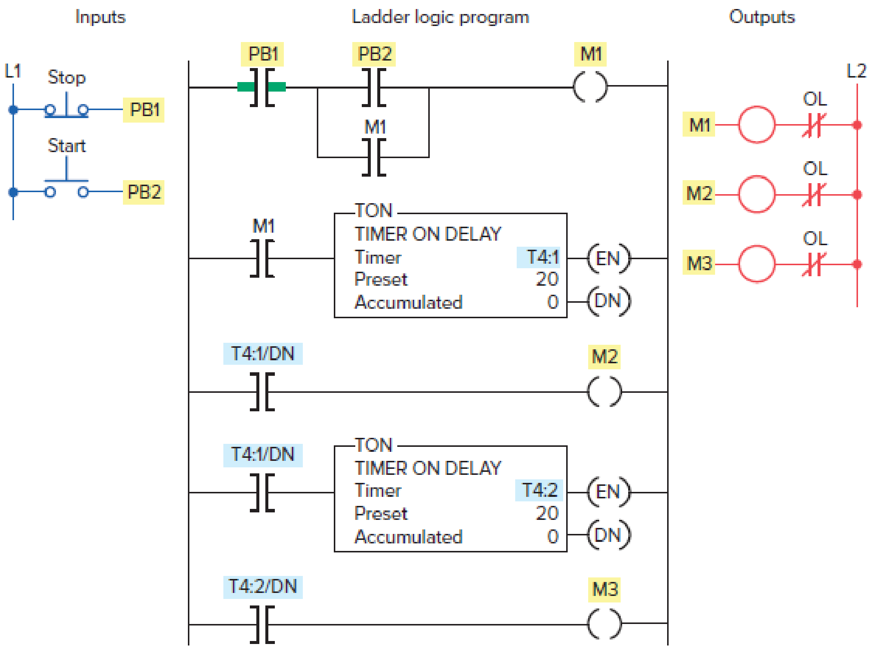

Figure 7-32 Equivalent PLC program of the sequential time-delayed motor-starting circuit.

- Two programmed on-delay timers are cascaded together to obtain the same logic as the original hardwired timer relay circuit.
- Note that the output of timer T4:1 is used to control the input logic to timer T4:2.
- **Reciprocating** timers are defined as timing functions where the output of one timer is used to reset the input of a second timer, each resetting the other.
- These types of timers are used in situations where a constant cycling of an output is required.
- For example, if a flashing light is required in the event of a control system failure, a program with reciprocating timers could be used to create the flashing output function.
- Two timers can be interconnected to form an oscillator or reciprocating circuit. The oscillator logic is basically a timing circuit programmed to generate periodic output pulses of any duration.

Counter Instructions

- Programmed counters can serve the same function as mechanical counters.
- Figure 8-1 shows the construction of a simple **mechanical counter.**
- Every time the actuating lever is moved over, the counter adds one number; the actuating lever then returns automatically to its original position.
- Resetting to zero is done with a pushbutton located on the side of the unit.

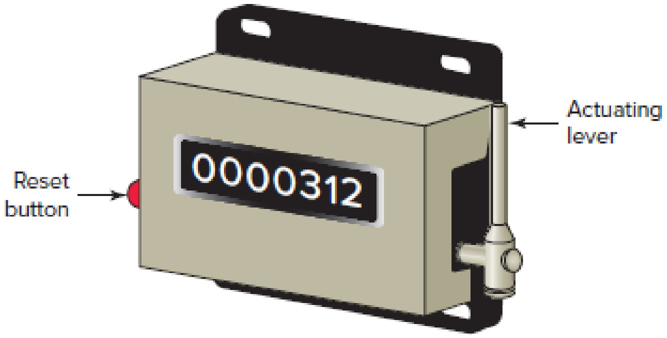

Figure 8-1 Mechanical counter.

- **Electronic counters,** such as those shown in Figure 8-2, can count up, count down, or be combined to count up and down.
- Although the majority of counters used in industry are up-counters, numerous applications require the implementation of down-counters or of combination up/down-counters.
- All PLC manufacturers offer some form of counter instruction as part of their instruction set.

Figure 8-2 Electronic counters.
Source: Photo courtesy Omron Industrial Automation, www.ia.omron.com.

- One common counter application is keeping track of the number of items moving past a given point as illustrated in Figure 8-3.
- Counters are similar to timers except that they do not operate on an internal clock but are dependent on external or program sources for counting.
- The two methods used to represent a counter within a PLC’s ladder logic program are the coil **format and the block format.**
- Figure 8-4 shows a typical coil-formatted upcounter instruction.
- The up-counter increments its accumulated value by 1 each time the counter rung makes a false-to-true transition. When the accumulated count equals the preset count the counter output is energized or set to 1.

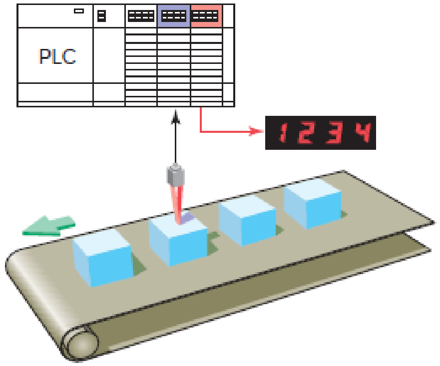

Figure 8-3 Counter application.

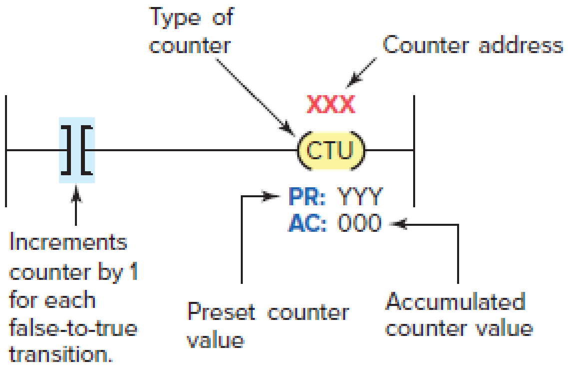

Figure 8-4 Coil-formatted up-counter instruction.

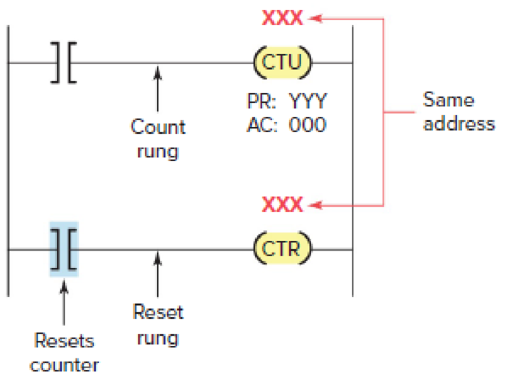

Figure 8-5 Coil-formatted counter and reset instructions.

Shown as part of the instruction are the:
Counter type
Counter address
Counter preset value
Accumulated count

- The counter reset instruction must be used in conjunction with the counter instruction.
- Up-counters are always reset to zero.
- Down-counters may be reset to zero or to some preset value.
- Some manufacturers include the reset function as a part of the general counter instruction, whereas others dedicate a separate instruction for resetting the counter.
- Figure 8-5 shows a **coil-formatted** counter instruction with a separate instruction for resetting the counter.
- When programmed, the counter reset coil (CTR) is given the same reference address as the counter (CTU) that it is to reset.
- In this example the reset instruction is activated whenever the CTR rung condition is true.

Activity

Find the Ten Difference

ASSESSMENT

1. **The Field coils of the DC generator are made up of ----?**

(A) Steel

(B) Copper

(C) Aluminum

(D) Iron

2. **The insulating material used between the commutator segments is normally**

(A) Graphite
(B) Paper
(C) Mica
(D) Insulating varnish

REFERENCES

TEXT BOOKS

- Frank D Petruzella, “Programmable Logic Controllers”, Tata McGraw Hill Publications, 6th Edition, 2016.
- Jon Stenerson, “Industrial Automation and Control”, Prentice Hall of India, 4th Edition, 2015.

REFERENCES

- Sharma, K. L.S., “Overview of Industrial Process Automation”, Elsevier, 2011
- Webb, John W, “Programmable Logic Controllers - Principles and applications”, PHI Publication, 5th Edition, 2016.
- Stuart A Boyer, “SCADA-supervisory control and data acquisition”, International Society of automation, 4th Edition, 2014.

WEB RESOURCES

- www.progea.com
- www.rockwellautomation.com
- https://nptel.ac.in/courses/industrial