7 Programming Timers

After completing this chapter, you will be able to:

- Describe the operation of pneumatic on-delay and off-delay timers
- Describe PLC timer instruction and differentiate between a nonretentive and retentive timer
- Convert fundamental timer relay schematic diagrams to PLC ladder logic programs
- Analyze and interpret typical PLC timer ladder logic programs
- Program the control of outputs using the timer instruction control bits

The most commonly used PLC instruction, after coils and contacts, is the timer. This chapter deals with how timers time intervals and the way in which they can control outputs. The basic PLC on-delay timer function, as well as other timing functions derived from it, will be discussed. Typical industrial timing tasks are also discussed.

Programmed timing operation.
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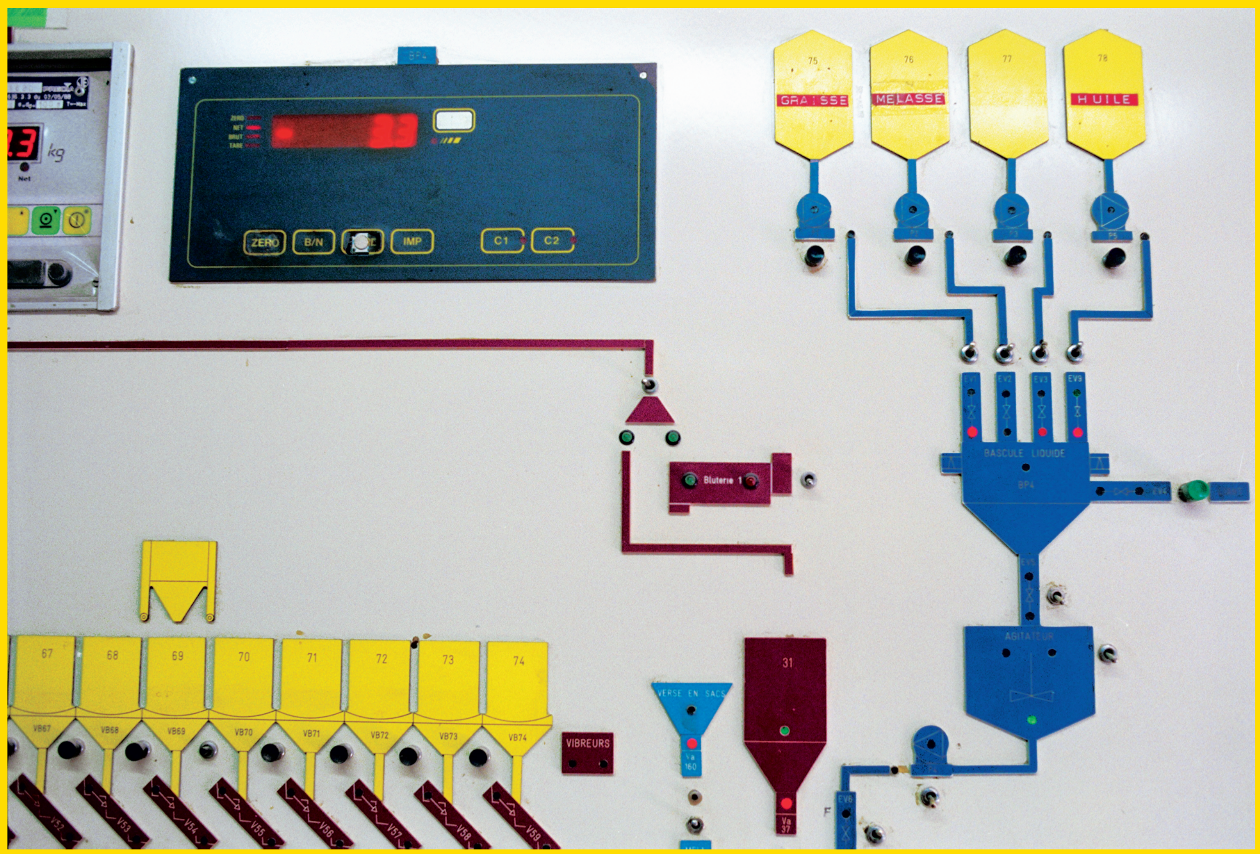


7.1 MECHANICAL TIMING RELAY

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.

Figure 7-1 shows the construction of an on-delay pneumatic (air) timer. The time-delay function depends on the transfer of air through a restricted orifice. The time-delay period is adjusted by positioning the needle valve to vary the amount of orifice restriction. When the coil is energized, the timed contacts are prevented from opening or closing. However, when the coil is de-energized, the timed contacts return instantaneously to their normal state. This particular pneumatic timer has nontimed contacts in addition to timed contacts. These nontimed contacts are controlled directly by the timer coil, as in a general-purpose control relay.

Mechanical timing relays provide time delay through two arrangements. The first arrangement, *on delay* (see Fig. 7-1), provides time delay when the relay is *energized.* The second arrangement, *off delay,* provides time delay when the relay is *de-energized.* Figure 7-2 illustrates the standard relay diagram symbols used for timed contacts.

The circuits of Figures 7-3, 7-4, 7-5, and 7-6 (on pages 173, 174, and 175) are designed to illustrate the basic timed-contact functions. In each circuit, the time-delay setting of the timing relay is assumed to be 10 s.

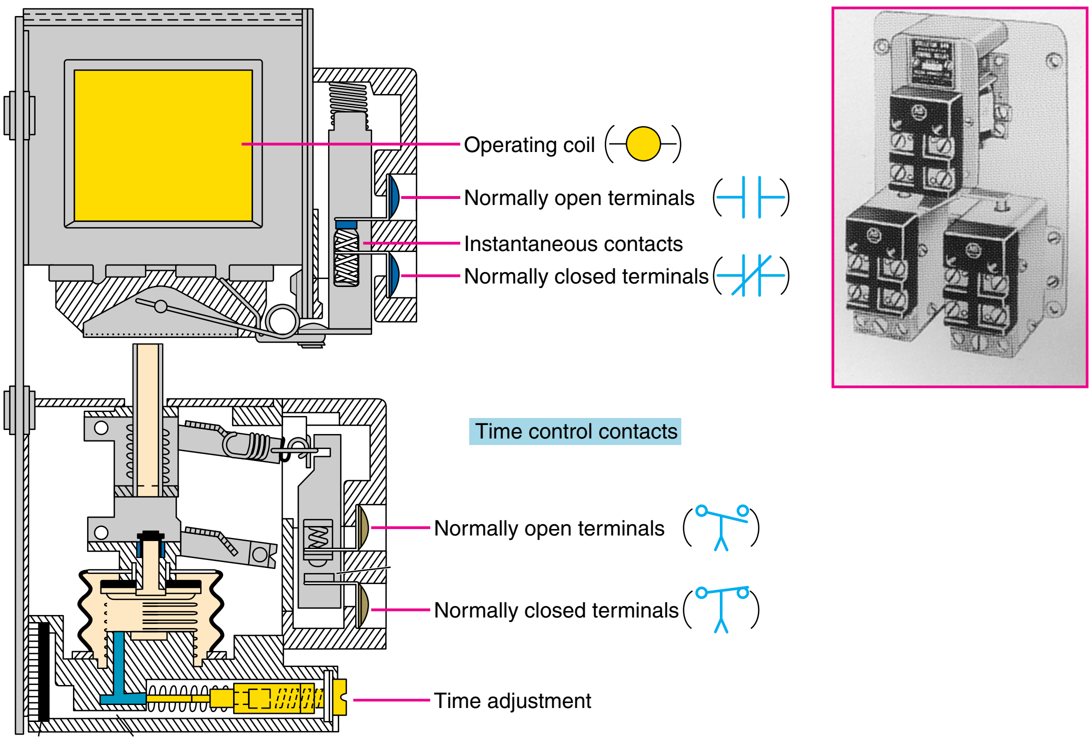


FIGURE 7-1 Pneumatic on-delay timer. (*Courtesy of Allen-Bradley Company, Inc.*)

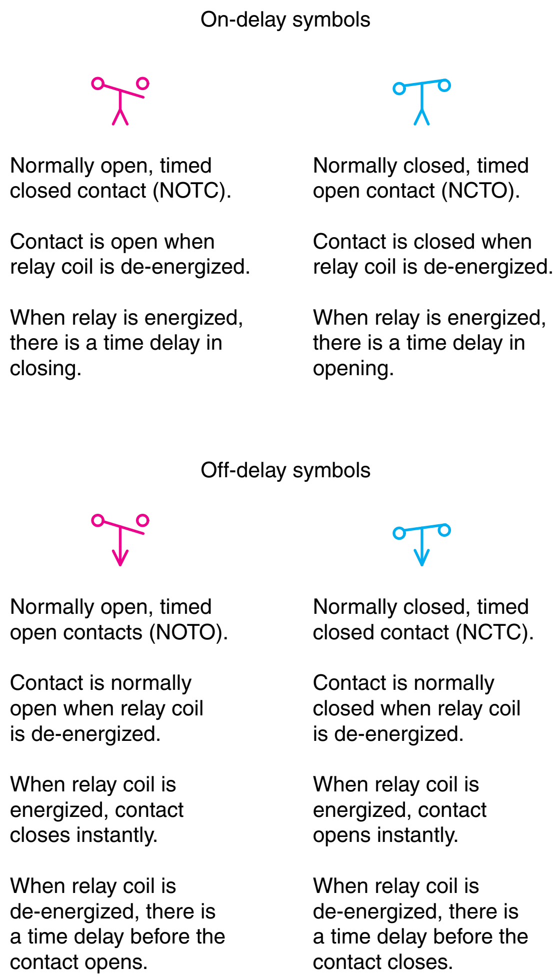


FIGURE 7-2 Timed contact symbols.

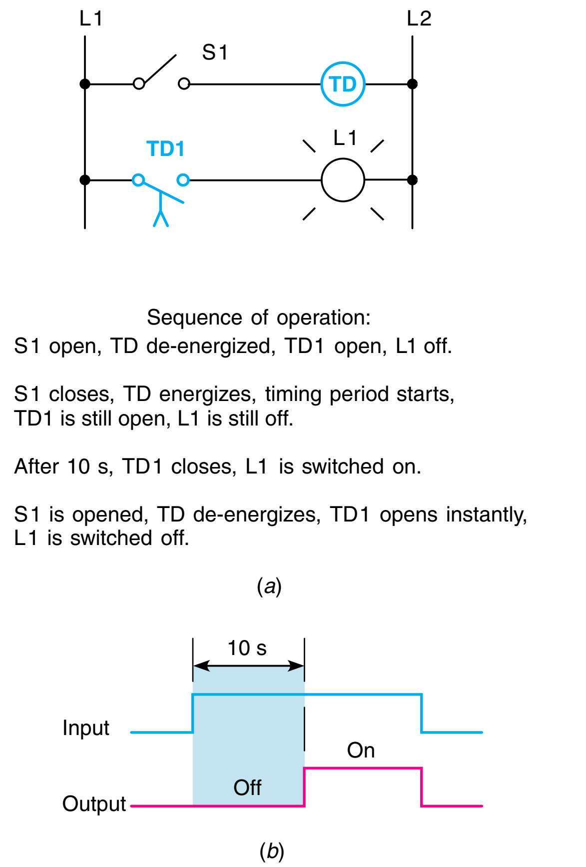


FIGURE 7-3 On-delay timer circuit (NOTC contact). *(a)* Operation. *(b)* Timing diagram.

7.2 TIMER INSTRUCTIONS

PLC timers are output instructions that provide the same functions as mechanical timing relays. They are used to activate or deactivate a device after a preset interval of time. The timer and counter instructions are the second oldest pair of PLC instructions, after the standard relay instruction discussed in Chapter 6. Although first-generation PLC systems did not include these instructions, they are found on all PLCs manufactured today. The number of timers that can be programmed depends on the model of PLC you are using. However, the availability usually far exceeds the requirement.

The advantage of PLC timers is that their settings can be altered easily, or the number of them used in a circuit can be increased or decreased, through the use of programming changes rather than wiring changes. Timer addresses are usually specified by the programmable controller manufacturer and are located in a specific area of the data organization table. Another advantage of the PLC timer is that its timer accuracy and repeatability are extremely high since it is based on solid-state technology.

In general, there are three different timers: the *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. There are also many other timing configurations, all of which can be derived from one or more of the basic time-delay

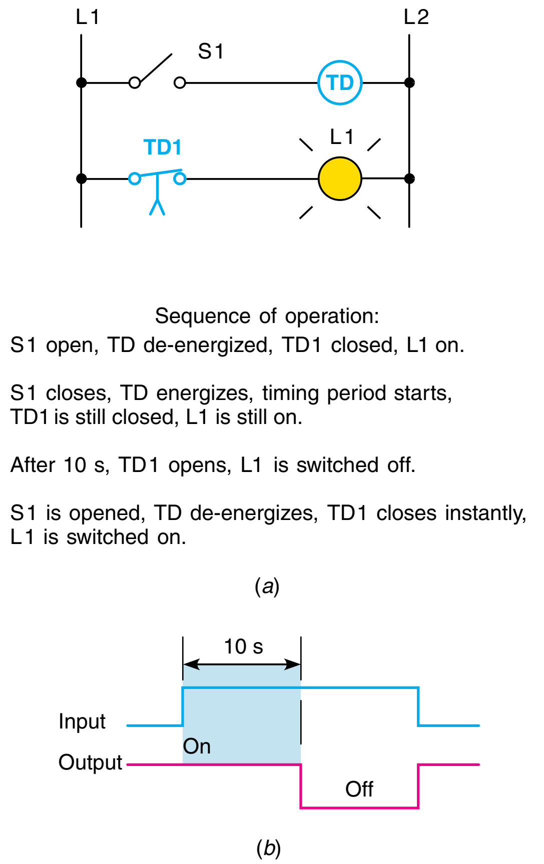


FIGURE 7-4 On-delay timer circuit (NCTO contact). *(a)* Operation. *(b)* Timing diagram.

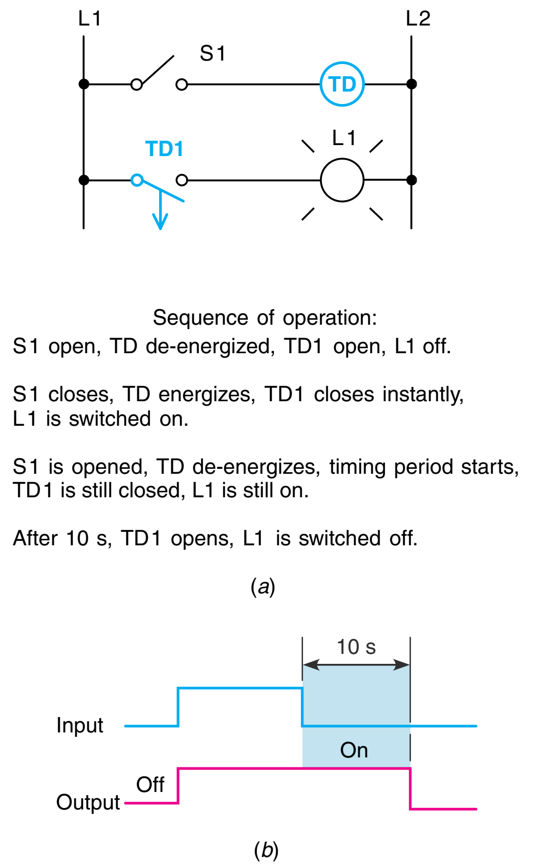


FIGURE 7-5 Off-delay timer circuit (NOTO contact). *(a)* Operation. *(b)* Timing diagram.

functions. Figure 7-7 shows the typical programmed timer commands based on the Allen-Bradley SLC-500 PLC and its associated RSLogix software.

Several quantities are associated with the timer instruction:

- The *preset time* represents the time duration for the timing circuit. For example, if a time delay of 10 s is required, the timer will have a preset of 10 s.
- The *accumulated time* represents the amount of time that has elapsed from the moment the timing coil became energized.
- Once the timing rung has continuity, the timer counts in time-based intervals and times until the preset value and accumulated value are equal or, depending on the type of controller, up to the maximum time interval of the timer. The intervals that the timers time out at are generally referred to as the *time bases* of the timer. Each timer will have a time base. Timers can be programmed with several different time bases: 1 s, 0.1 s, and 0.01 s are typical time bases. If a programmer entered 0.1 for the time base and 50 for the number of delay increments, the timer would have a 5-s delay (50×0.1 s $= 5$ s).

The timers in a programmable controller are operated by an internally generated clock that originates in the processor module. The 0.01 s (10-ms) timer is valuable when the PLC is controlling high-speed events or when it is necessary to generate short-duration pulses. The 10-ms timer may cause problems when it operates in conjunction with extremely long user programs and scan times. To overcome this

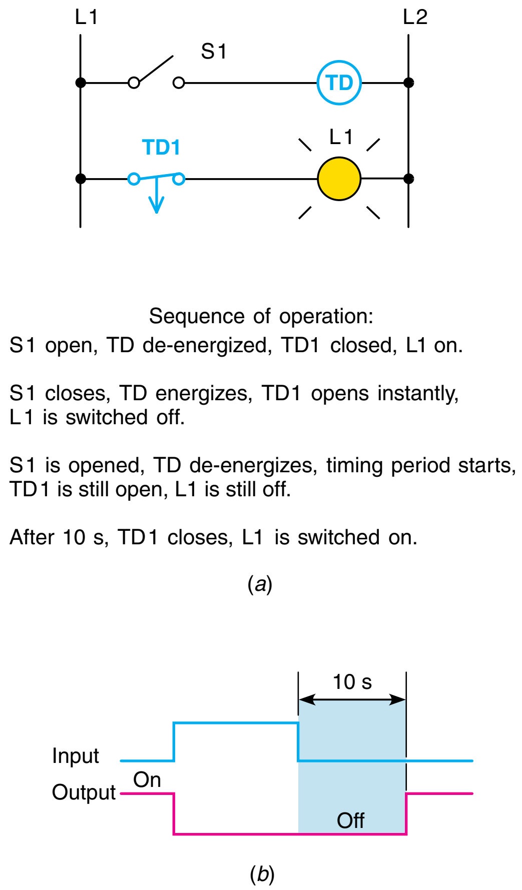
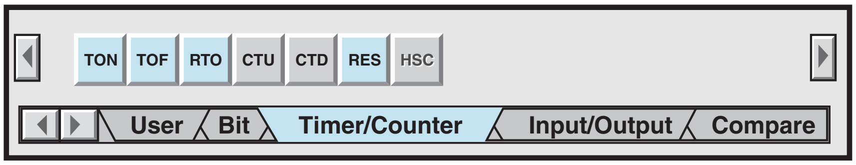


FIGURE 7-6 Off-delay timer circuit (NCTC contact). *(a)* Operation. *(b)* Timing diagram.

problem, the 10-ms timers or other devices that could be affected by a long scan time can be inserted more than once in the program. The additional rungs will ensure that devices are scanned by the processor in a time less than the increment time of the device.

Although each manufacturer may represent timers differently on the ladder logic program, most timers operate in a similar manner. One of the first methods used depicts the timer instruction as a relay coil similar to that of a mechanical timing relay (Fig. 7-8 on page 176). The timer is assigned an address and is identified as a timer. Also included as part of the timer instruction is the time base of the timer, the timer's preset value or time-delay period, and the accumulated value or current time-delay period for the timer. When the timer rung has logic continuity, the timer begins counting time-based intervals and times until the accumulated value equals the preset value. When the accumulated time equals the preset time, the output is energized and the timed output contact associated with the output is closed. The timed contact can be used as many times as you wish throughout the program as an NO or NC contact.



Command	Name	Description
TON	Timer On Delay	Counts time-based intervals when the instruction is TRUE
TOF	Timer Off Delay	Counts time-based intervals when the instruction is FALSE
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

FIGURE 7-7 Timer commands based on the Allen-Bradley SLC-500 PLC and its associated RSLogix software.

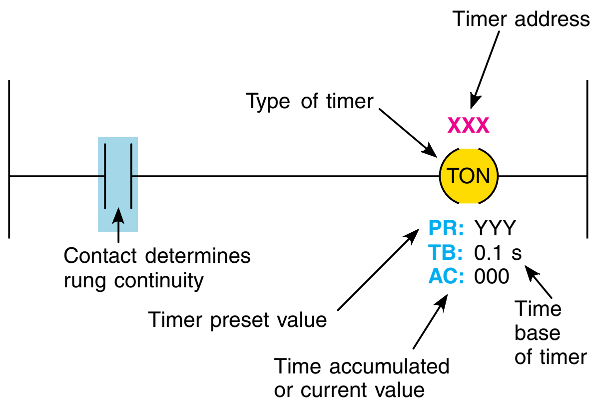


FIGURE 7-8 Coil-formatted timer instruction.

Timers are most often represented by boxes in ladder logic. Figure 7-9 illustrates a generic block format for a retentive timer that requires two input lines. 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.

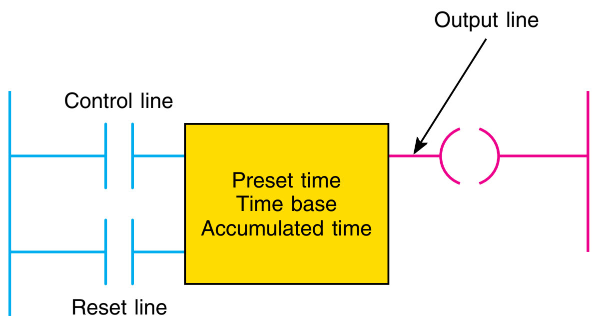


FIGURE 7-9 Block-formatted timer instruction.

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 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 logic 1.

7.3 ON-DELAY TIMER INSTRUCTION

Timers are output instructions that you can condition with input instructions such as *examine if closed* and *examine if open*. They time intervals as determined by your application program logic. The *on-delay timer* operates such that when the rung containing the timer is true, the timer time-out period commences. At the end of the timer time-out period, an output is made active, as shown in Figure 7-10. 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. In addition, most PLCs allow the option of changing the

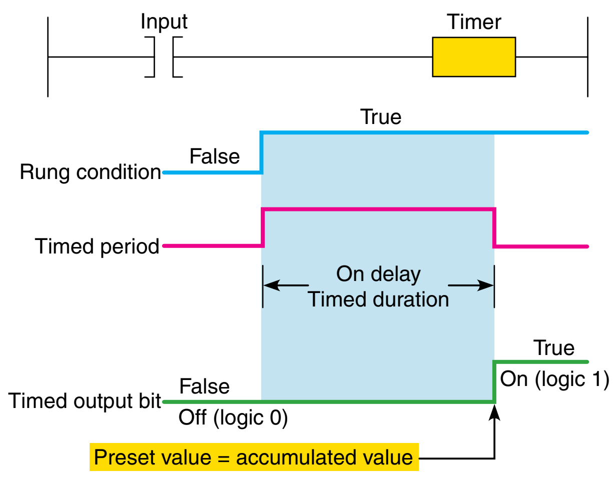


FIGURE 7-10 On-delay timer sequence.

time base, or resolution, of the timer. As the time base you select becomes smaller, the accuracy of the timer increases.

Allen-Bradley PLC-5 and SLC-500 controller timer elements each take three data table words: the control word, preset word, and accumulated word. The *control word* uses 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 s 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 7-11 shows an example of the on-delay timer instruction used as part of the Allen-Bradley PLC-5 and SLC-500 controller instruction sets. The information to be entered includes:

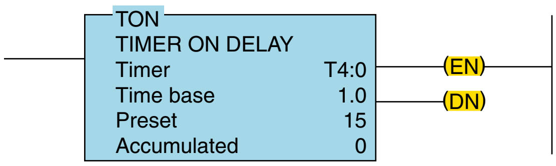
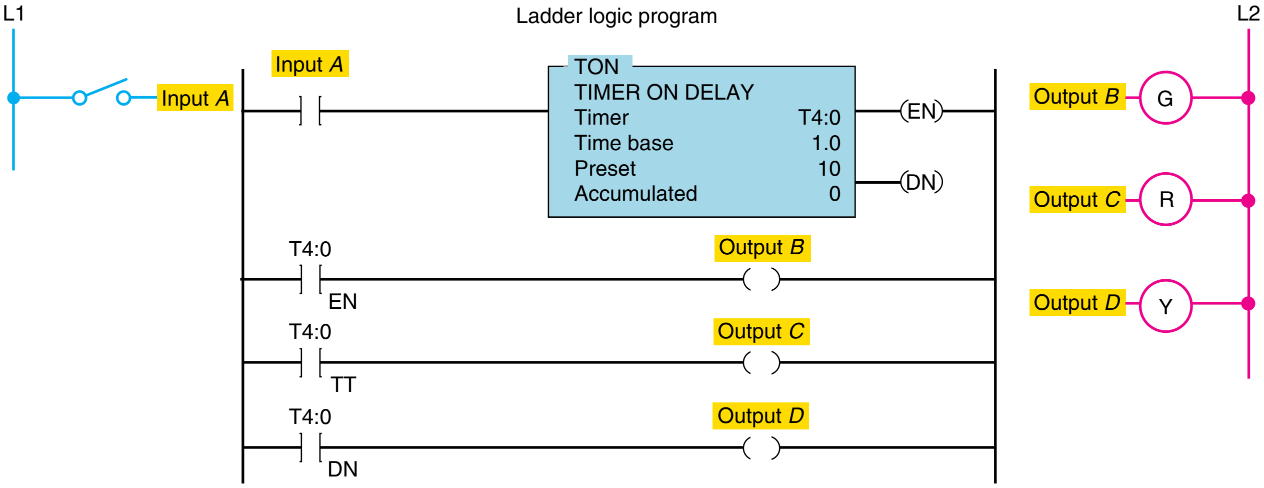


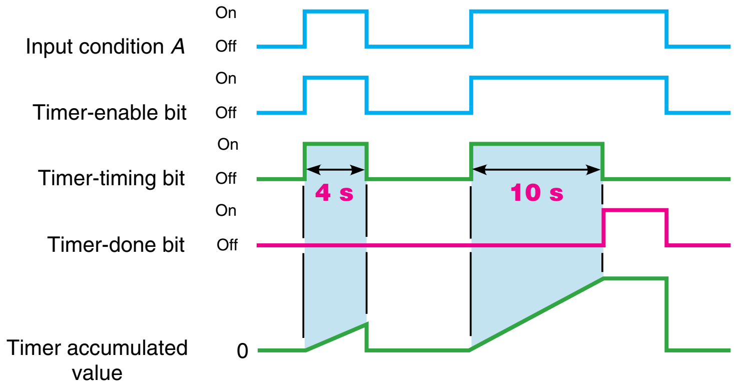
FIGURE 7-11 On-delay timer instruction.

- **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. There may be up to 1000 timers in each timer file, numbered from 0 through 999. 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 s 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.

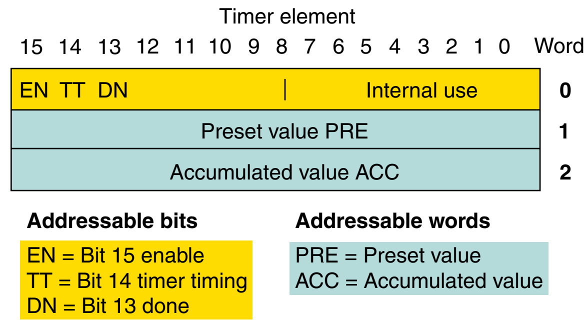
The on-delay timer (TON) is the most commonly used timer. Figure 7-12 on page 178 shows a PLC program that uses an on-delay timer. The timer is activated by closing the switch. The preset time for this timer is 10 s, at which time output *D* will be energized. When the switch is closed, the timer begins counting and counts until the accumulated time equals the preset value; the output is



(*a*) Ladder diagram



(*b*) Timing diagram



(*c*) Timers are 3-word elements. Word 0 is the control word, word 1 stores the preset value, and word 2 stores the accumulated value (Allen-Bradley PLC-5 and SLC-500 format).

FIGURE 7-12 On-delay timer.

then energized. If the switch is opened before the timer is timed out, the accumulated time is automatically reset to 0. This timer configuration is termed *nonretentive* because loss of power flow 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.

In Figure 7-12*b,* the timing diagram first 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. Input *A* then goes true again and remains true in excess of 10 s. When the accumulated value reaches 10 s, the done bit (DN) goes from false to true and the timer-timing 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.

Timer addressing in the Allen-Bradley PLC-5 and SLC-500 is done at three different levels:

the element level, the word level, and the bit level. The timer uses three words per element. Each element consists of a control word, a preset word, and an accumulated word, as shown in Figure 7-12*c*. Each individual word in an element address is referred to as a subelement. Integer elements have one word per element. Each word has 16 bits, which are numbered from 0 to 15. When addressing to the bit level, the address always refers to the bit within the word, or subelement.

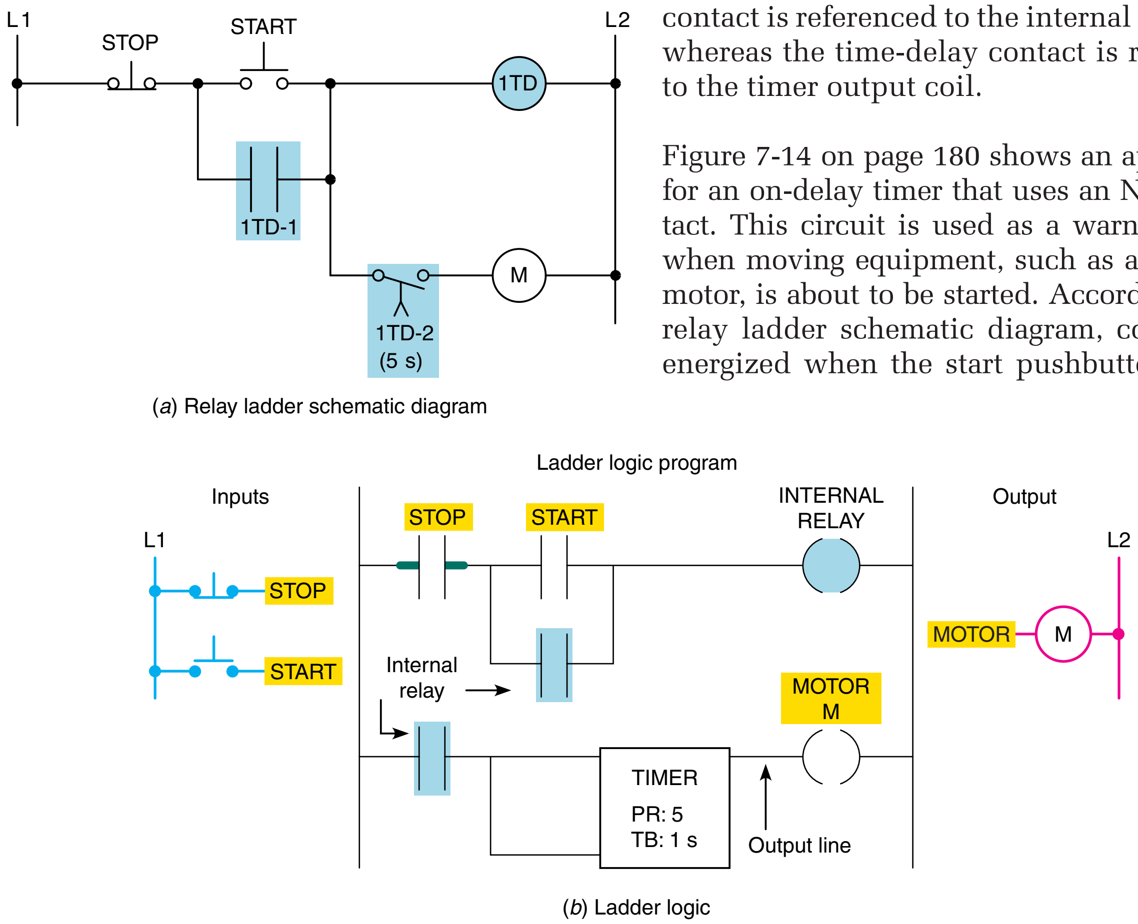
Allen-Bradley ControlLogix controller timers function in the same manner as PLC-5 and SLC-500 controllers. The differences occur in the time base, timer address, and the maximum values of the preset and accumulated values. For the ControlLogix controller:

- the time base is fixed at 1 ms (0.001 s).
- the address is a predefined structure of the TIMER data type.
- the maximum value for the preset and accumulated values is 2,147,483,647.

Timers may or may not have an instantaneous output (also known as the enable bit) signal associated with them. If an instantaneous output signal is required from a timer and it is not provided as part of the timer instruction, an equivalent instantaneous contact instruction can be programmed using an internally referenced relay coil.

Figure 7-13 shows an application of this technique. According to the relay ladder schematic diagram, coil M is to be energized 5 s after the start pushbutton is pressed. Contact 1TD-1 is the instantaneous contact, and contact 1TD-2 is the timed contact. The ladder logic program shows that a contact instruction referenced to an internal relay is now used to operate the timer. The instantaneous contact is referenced to the internal relay coil, whereas the time-delay contact is referenced to the timer output coil.

Figure 7-14 on page 180 shows an application for an on-delay timer that uses an NCTO contact. This circuit is used as a warning signal when moving equipment, such as a conveyor motor, is about to be started. According to the relay ladder schematic diagram, coil CR1 is energized when the start pushbutton PB1 is



(*a*) Relay ladder schematic diagram

(*b*) Ladder logic

FIGURE 7-13 On-delay timer with instantaneous output programming.

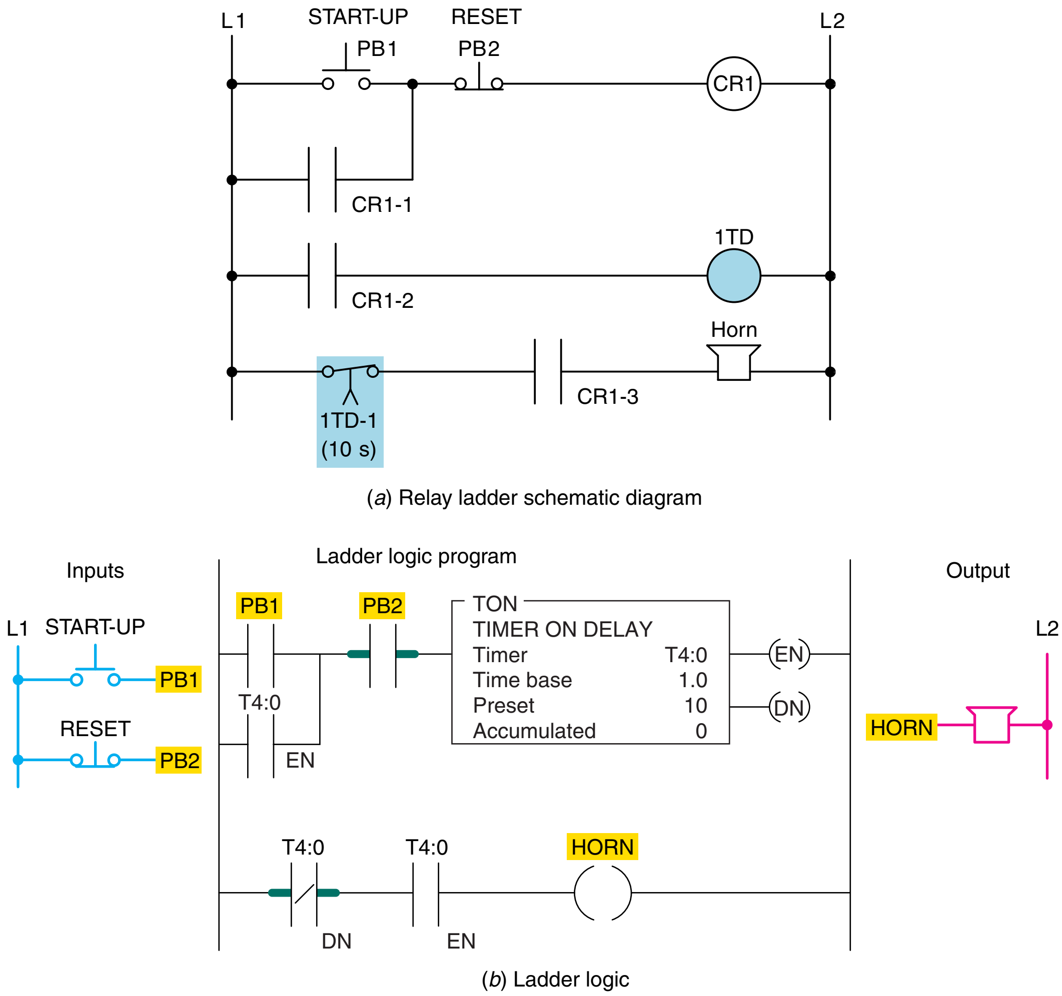


FIGURE 7-14 Starting-up warning signal circuit.

momentarily actuated. As a result, contact CR1-1 closes to seal in CR1, contact CR1-2 closes to energize timer coil 1TD, and contact CR1-3 closes to sound the horn. After a 10-s time-delay period, timer contact 1TD-1 opens to automatically switch the horn off. The ladder logic program shows how the circuit could be programmed using a PLC.

Figure 7-15 shows an application for an on-delay timer that uses a ControlLogix TON timer instruction. This program calls for the

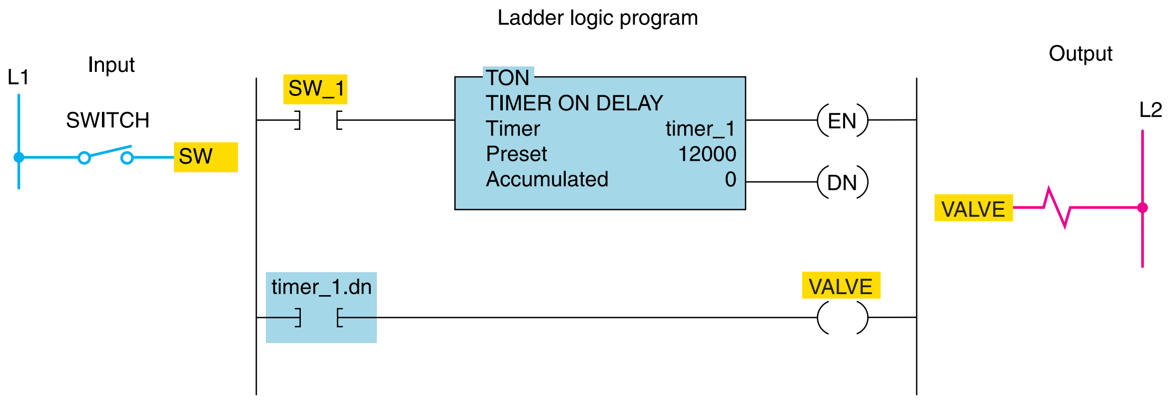
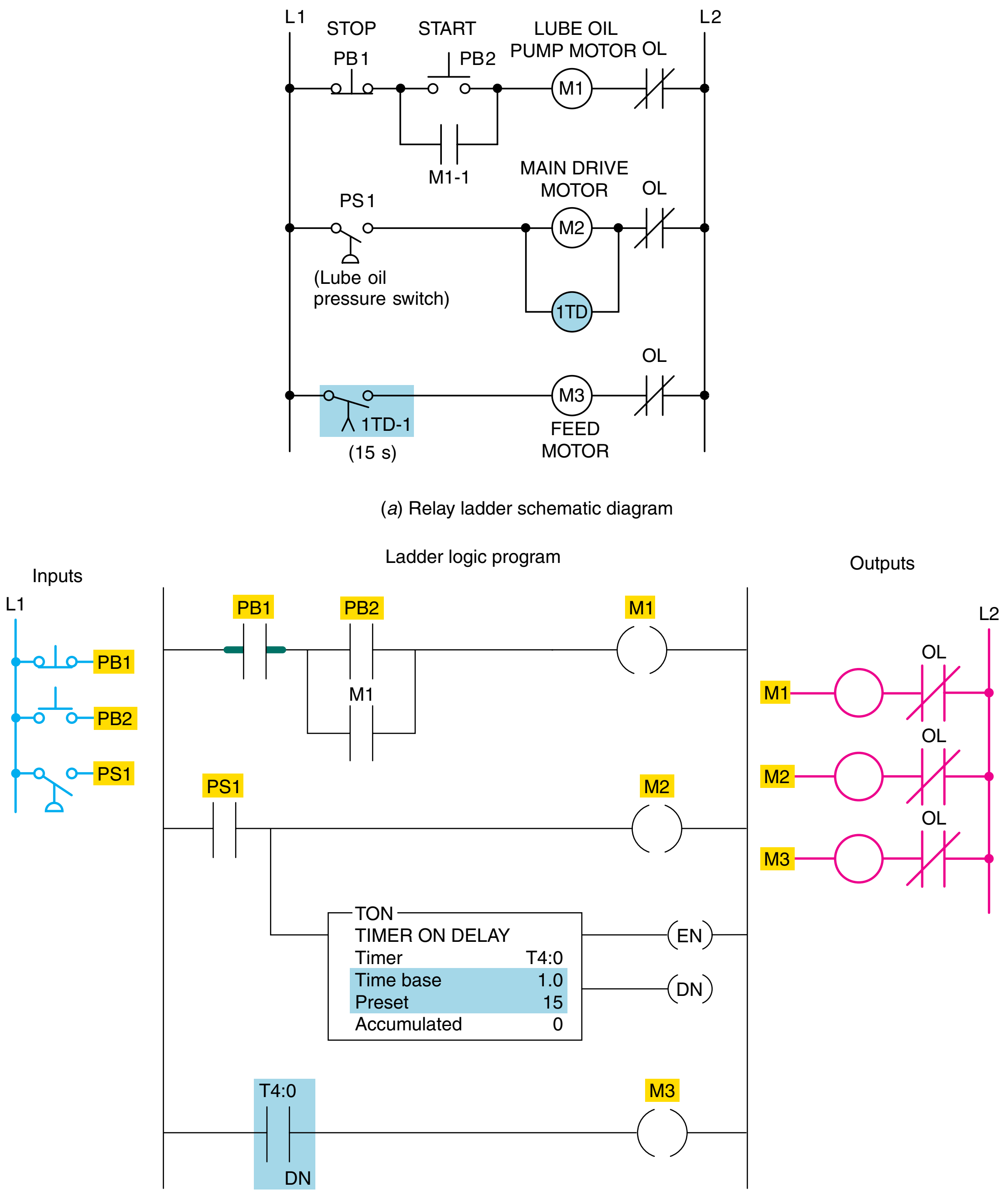


FIGURE 7-15 Program for a solenoid valve to be time-closed using the ControlLogix TON timer.

solenoid valve to be energized if the switch is closed for 12 s.

Timers are often used as part of automatic sequential control systems. Figure 7-16 shows how a series of motors can be started automatically with only one start/stop control station. According to the relay ladder schematic, lube-oil pump motor starter coil M1 is energized when the start pushbutton PB2 is momentarily actuated. As a result, M1-1 control contact closes to seal in M1, and the lube-oil pump motor starts. When the lube-oil pump builds up sufficient oil



(*a*) Relay ladder schematic diagram

(*b*) Ladder logic

FIGURE 7-16 Automatic sequential control system.

pressure, the lube-oil pressure switch PS1 closes. This in turn energizes coil M2 to start the main drive motor and energizes coil 1TD to begin the time-delay period. After the preset time-delay period of 15 s, 1TD-1 contact closes to energize coil M3 and start the feed motor. The ladder logic program shows how the circuit could be programmed using a PLC.

7.4 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 7-17 illustrates the generic programming of an off-delay timer that uses the SLC-500 TOF timer instruction. If logic continuity is *lost,* the timer begins counting time-based intervals until the accumulated time equals the programmed preset value. When the switch connected to input I:1.0/0 is first closed, timed output O:2.0/1 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.

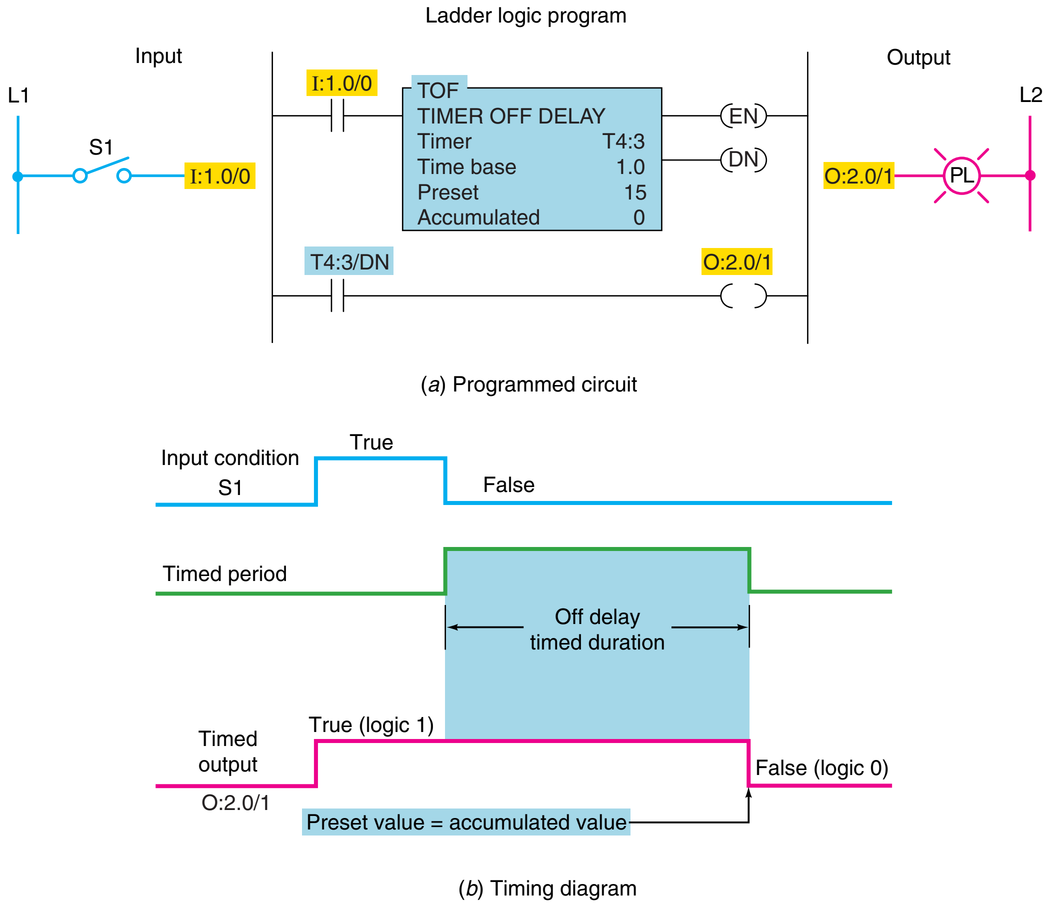


FIGURE 7-17 Off-delay programmed timer.

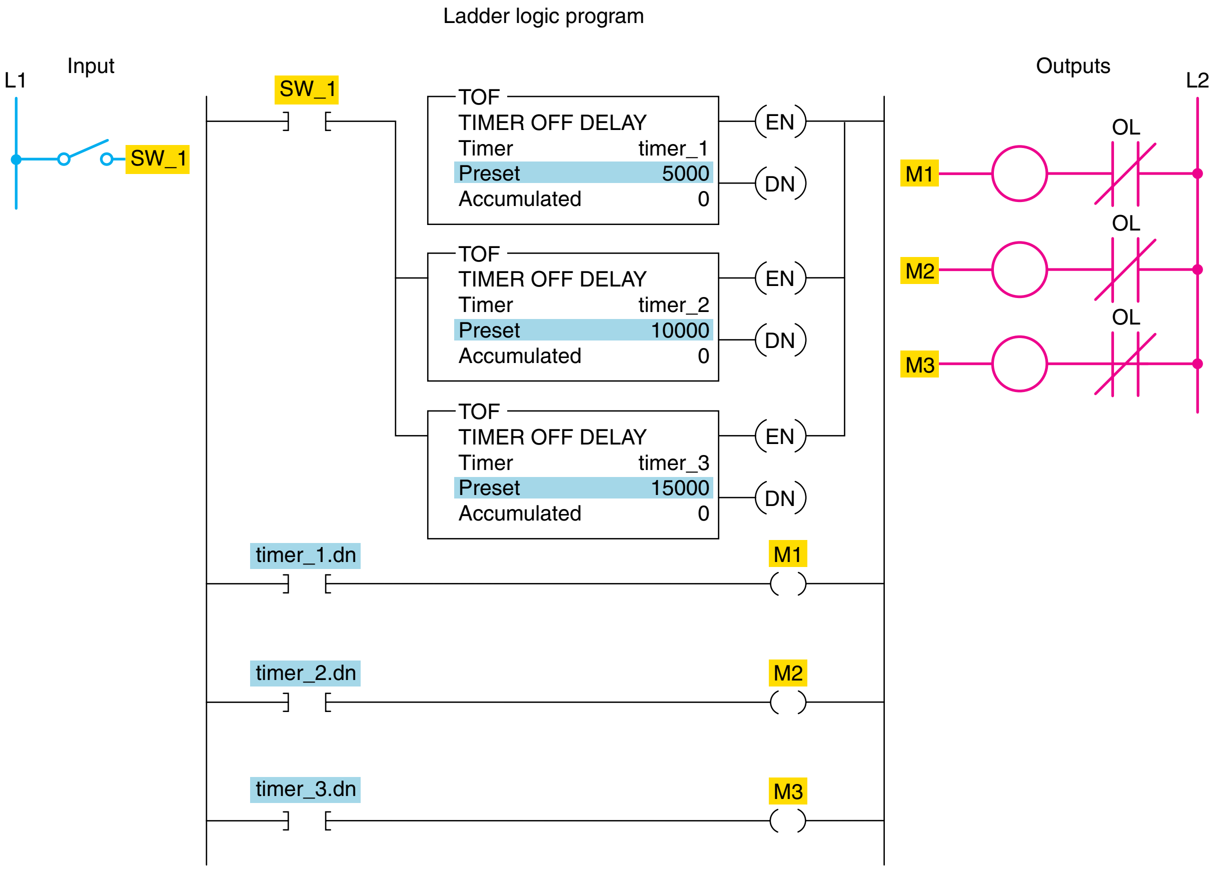
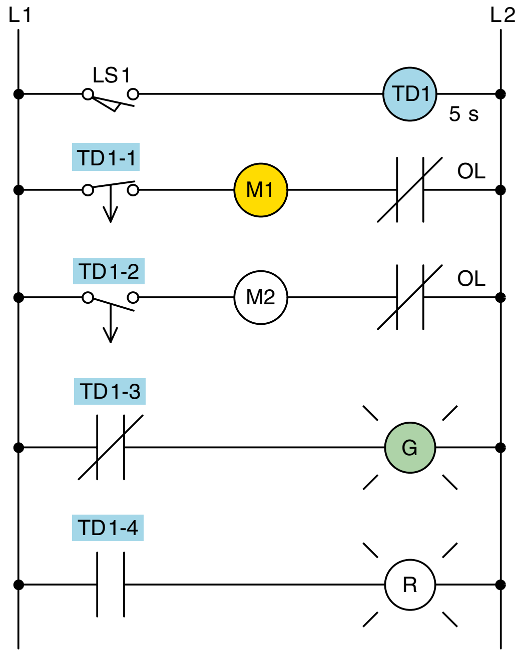


FIGURE 7-18 Off-delay timer instructions programmed to switch motors off at 5-s intervals.

Figure 7-18 illustrates the use of the Control-Logix off-delay timer instruction. In this application, closing the switch immediately turns on motors M1, M2, and M3. When the switch is opened, motors M1, M2, and M3 turn off at 5-s intervals.

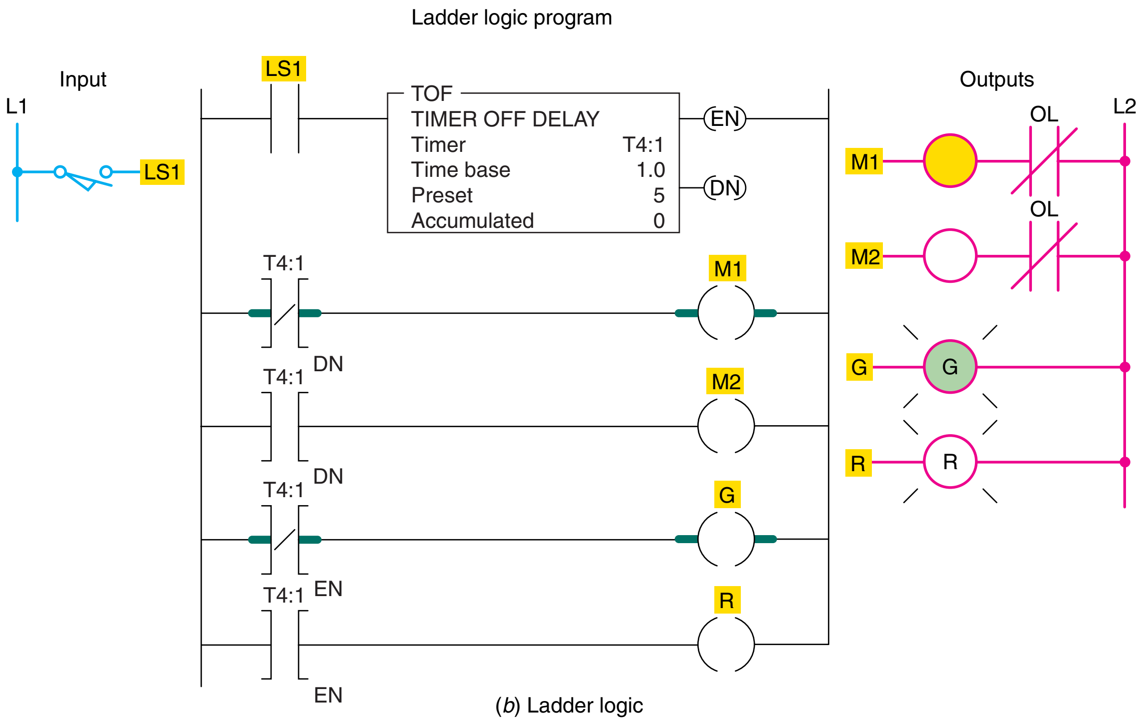
Figure 7-19 shows how a relay circuit with a pneumatic off-delay timer could be programmed using a PLC. According to the relay schematic diagram, when power is first applied (limit switch LS1 open), motor starter coil M1 is energized and the green pilot light is on. At the same time, motor starter coil M2 is de-energized, and the red pilot light is off.

When limit switch LS1 closes, off-delay timer coil TD1 energizes. As a result, timed contact TD1-1 opens to de-energize motor starter coil M1, timed contact TD1-2 closes to



(*a*) Relay schematic diagram

FIGURE 7-19 Programming a pneumatic off-delay timer circuit.



(b) Ladder logic

FIGURE 7-19 (continued) Programming a pneumatic off-delay timer circuit.

energize motor starter coil M2, instantaneous contact TD1-3 opens to switch the green light off, and instantaneous contact TD1-4 closes to switch the red light on. The circuit remains in this state as long as limit switch LS1 is closed.

When limit switch LS1 is opened, the off-delay timer coil TD1 de-energizes. As a result, the time-delay period is started, instantaneous contact TD1-3 closes to switch the green light on, and instantaneous contact TD1-4 opens to switch the red light off. After a 5-s time-delay period, timed contact TD1-1 closes to energize motor starter M1, and timed contact TD1-2 opens to de-energize motor starter M2. Figure 7-19*b* shows how the circuit is programmed using the SLC-500 TOF timer.

Figure 7-20 shows a program that uses both the on-delay and the off-delay timer instruction. The process involves pumping fluid from tank A to tank B. The operation of the process can be described as follows:

- Before starting, PS1 must be closed.
- When the start button is pushed, the pump starts. The button can then be released and the pump continues to operate.
- When the stop button is pushed, the pump stops.
- PS2 and PS3 must be closed 5 s after the pump starts. If either PS2 or PS3 opens, the pump will shut off and will not be able to start again for another 14 s.

7.5 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. Once the device accumulates time equal to its preset value, the contacts of the device change state. Loss of power

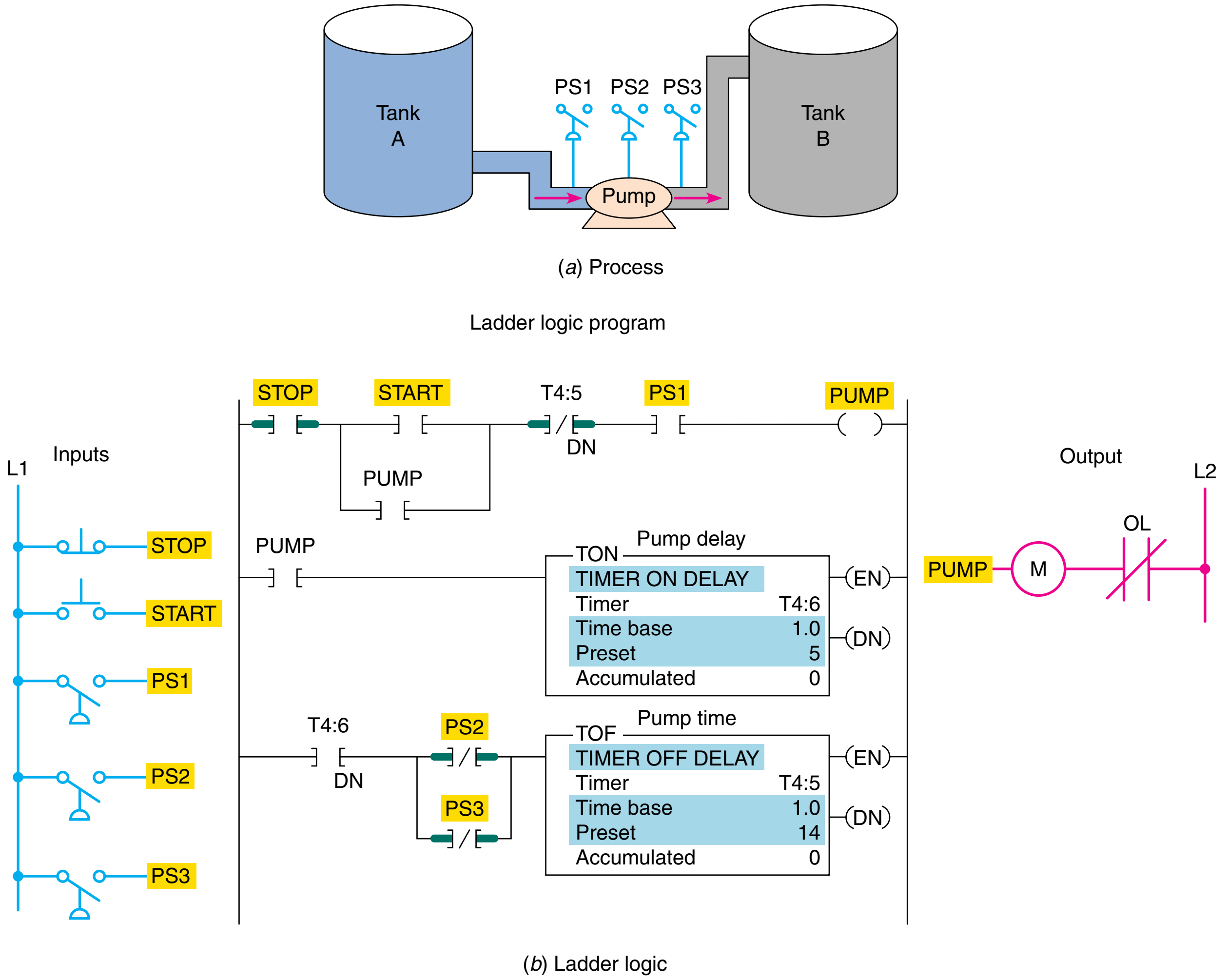


FIGURE 7-20 Fluid pumping process.

to the device 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 their shelf state.

Figure 7-21 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.*

The PLC-programmed RETENTIVE ON-DELAY timer (RTO) operates in the same way as the nonretentive on-delay timer (TON), with

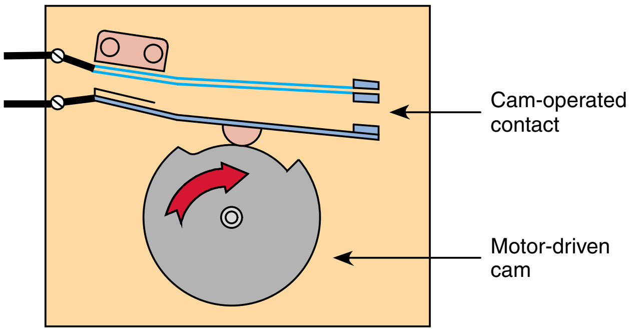


FIGURE 7-21 Electromechanical retentive timer.

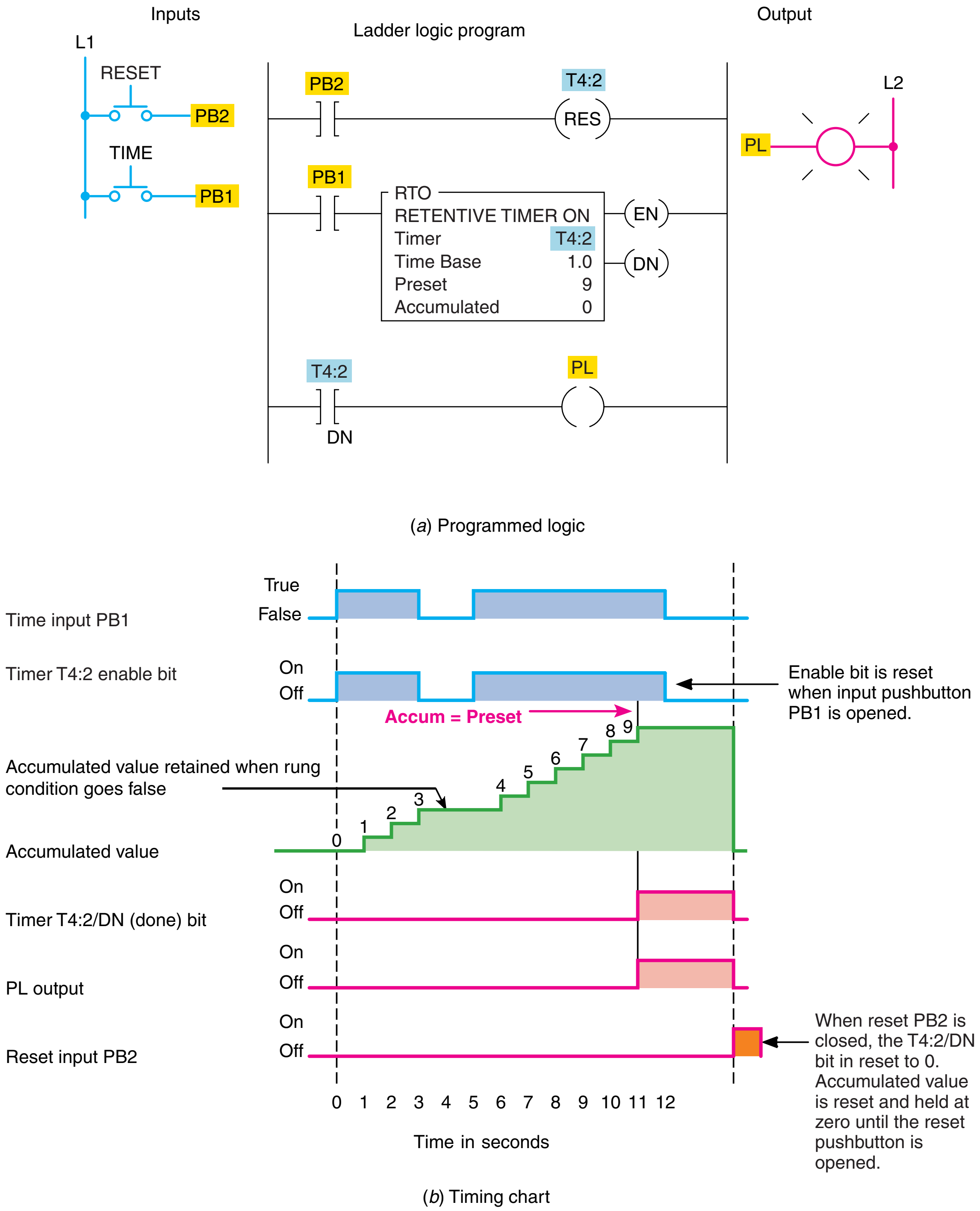


FIGURE 7-22 Retentive on-delay timer program and timing chart.

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,

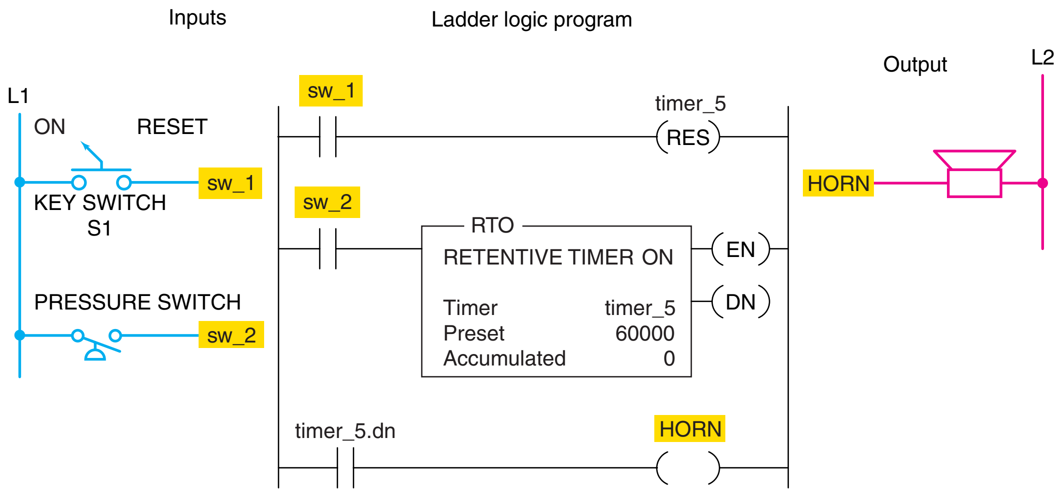


FIGURE 7-23 Retentive on-delay alarm program.

both the timer accumulated value and the timer done bit (DN) are rest to 0).

Figure 7-22 shows a PLC program for a retentive on-delay time along with a timing chart for the circuit. The timer will start to time when time pushbutton PB1 is closed. If the pushbutton is opened 3 s, the timer accumulated value stays 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 equals the preset value, the timer done bit T4:2/DN is set to 1 and the pilot light output PL is switched on.

Because the retentive timer does not reset to 0 when the timer is de-energized, the reset instruction RES must be used to reset the timer. The RES instruction given the same address (T4:2) as the RTO. When reset pushbutton PB2 closes, RES resets the accumulated time to 0 and the DN bit to 0, turning pilot light PL off.

The program drawn in Figure 7-23 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 of 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 the on (contact open) position. The timer shown represents a ControlLogix display, but the PLC-5 and SLC-500 timers function in the same way.

Figure 7-24 on page 188 shows a practical application that uses the on-delay, off-delay, and retentive on-delay instructions in the same program. In this industrial application, there is a machine with a large steel shaft supported by babbitted bearings. This shaft is coupled to a large electric motor. The bearings need lubrication, which is supplied by an oil pump driven by a small electric motor. The sequence of operation is as follows:

- To start the machine, the operator turns SW on.
- Before the *motor* shaft starts to turn, the bearings are supplied with oil by the *pump* for 10 s.
- The bearings also receive oil when the machine is running.
- When the operator turns SW off to stop the machine, the oil pump continues to supply oil for 15 s.

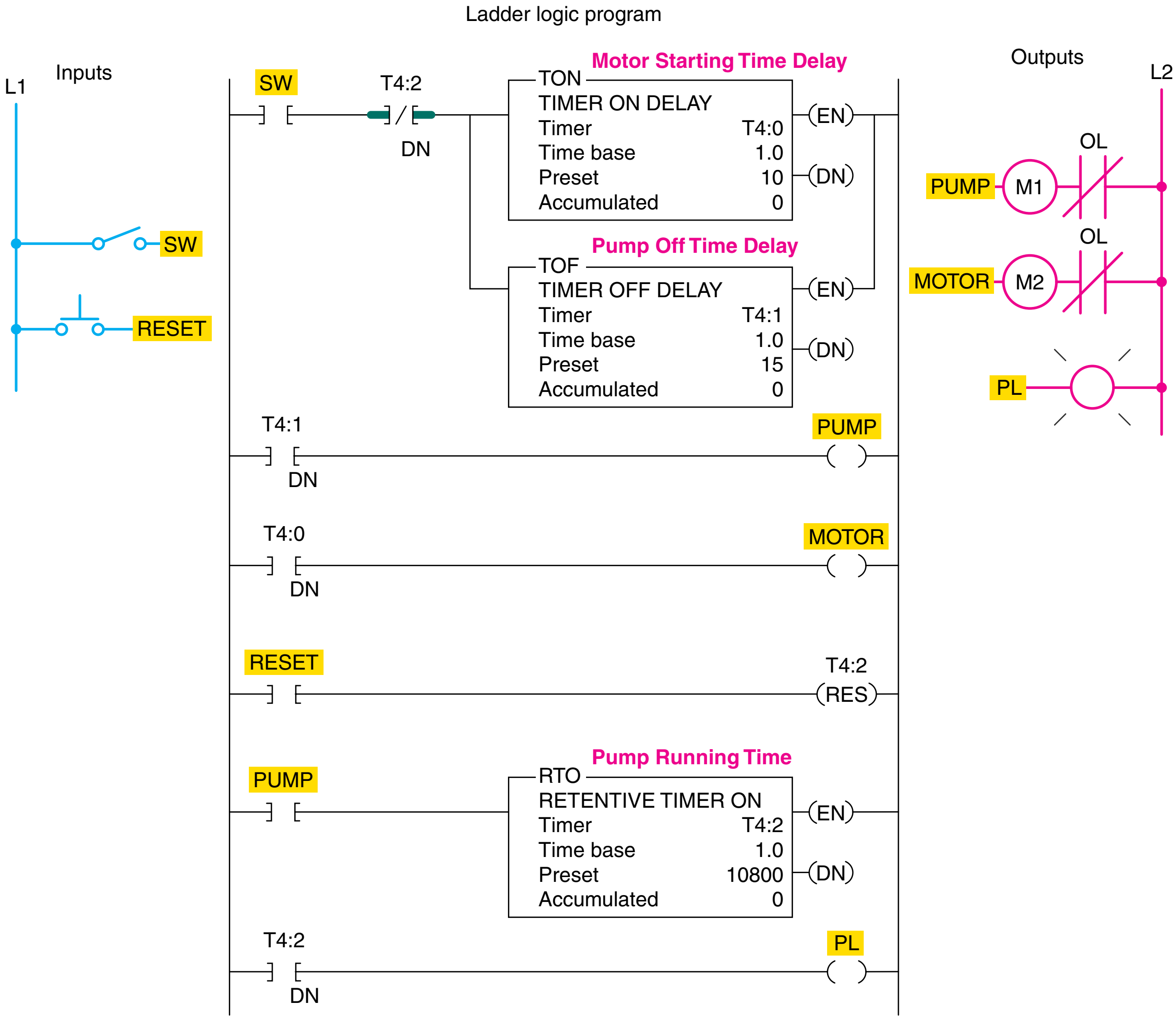


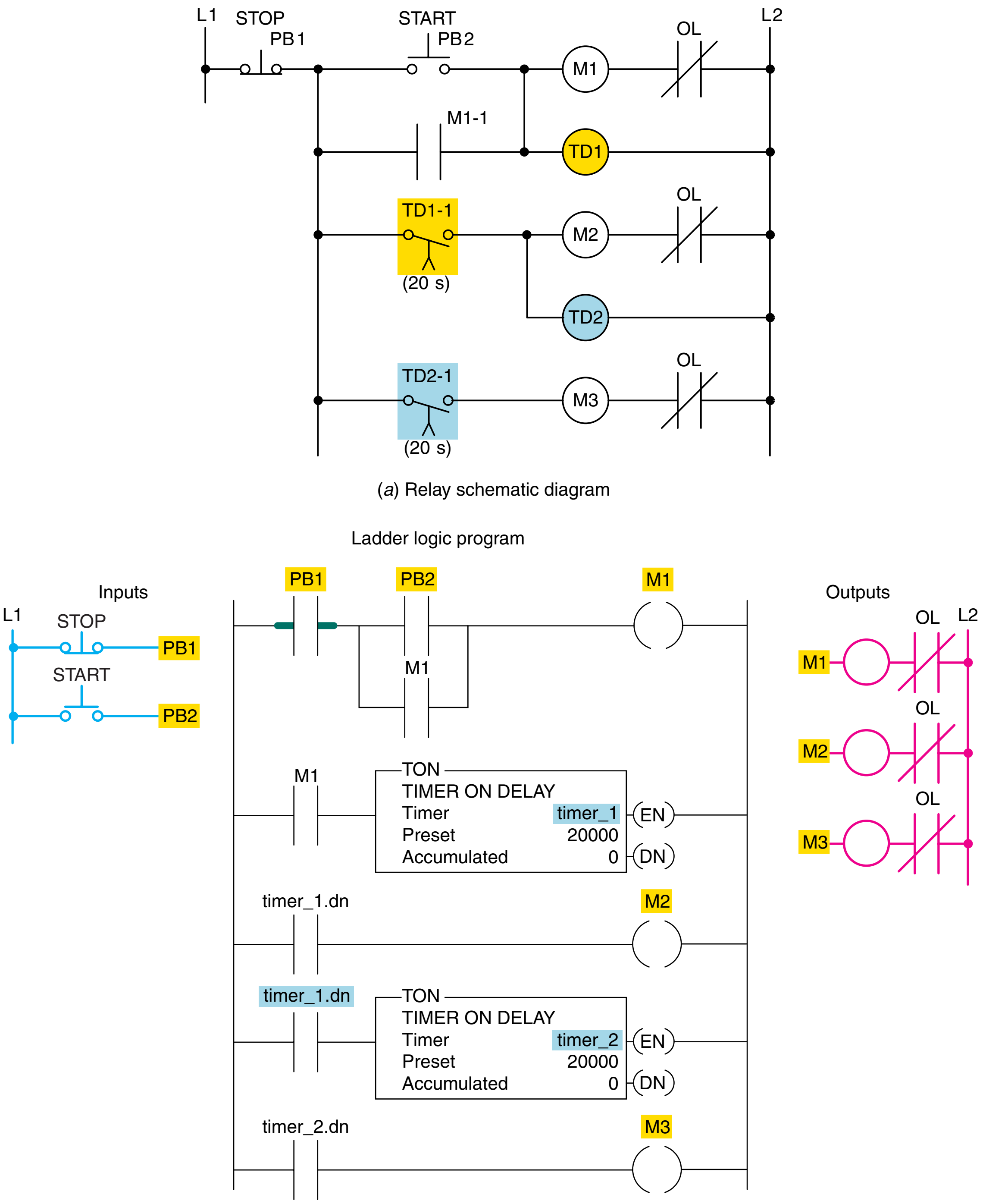
FIGURE 7-24 Bearing lubrication program.

- A retentive timer is used to track the total running time of the pump. When the total running time is 3 h, the motor is shut down and a pilot light is turned on to indicate that the filter and oil need to be changed.
- A reset button is provided to reset the process after the filter and oil have been changed.

A retentive off-delay timer is programmed in the same manner as an RTO. Both maintain their accumulated time value even if logic continuity is lost before the timer is timed out or if power is lost. These retentive timers do *not* have to be timed out completely to be reset. Rather, such a timer can be reset at any time during its operation. Note that the reset input to the timer will override the control input of the timer even though the control input to the timer has logic continuity.

7.6 CASCADING TIMERS

The programming of two or more timers together is called *cascading*. Timers can be interconnected, or cascaded, to satisfy any required control logic. Figure 7-25 shows



(*a*) Relay schematic diagram

(*b*) Ladder logic

FIGURE 7-25 Sequential time-delayed motor-starting circuit.

how three motors can be started automatically in sequence with a 20-s time delay between each motor start-up. According to the relay schematic diagram, motor starter coil M1 is energized when the start pushbutton PB2 is momentarily actuated. As a result, motor 1 starts, contact M1-1 closes to seal in M1, and timer coil TD1 is energized to begin the first time-delay period. After the preset time period of 20 s, TD1-1 contact closes to energize motor starter coil M2. As a result, motor 2 starts and timer coil TD2 is

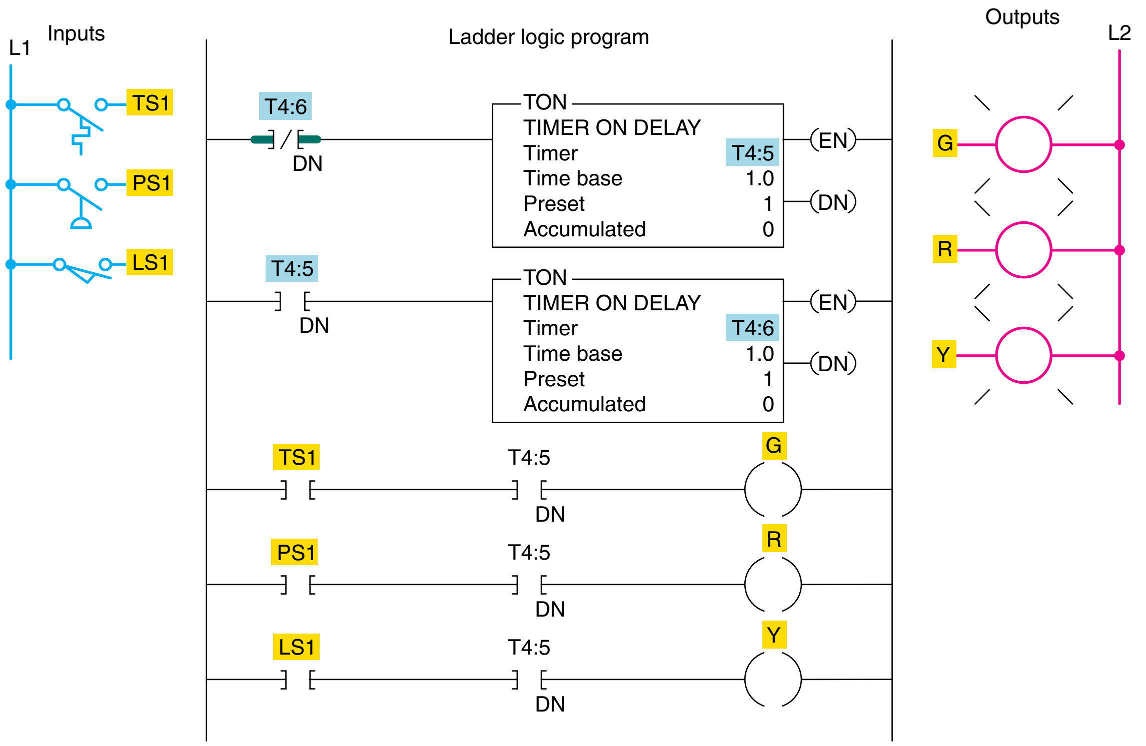


FIGURE 7-26 Annunciator flasher program.

energized to begin the second time-delay period. After the preset time period of 20 s, TD2-1 contact closes to energize motor starter coil M3, and so motor 3 starts. The ladder logic program shows how the circuit could be programmed using a PLC. Note that two ControlLogix timers are used and the output of the first timer is used to control the input logic to the second timer.

Two timers can be interconnected to form an oscillator circuit. The oscillator logic is basically a timing circuit programmed to generate periodic output pulses of any duration. Figure 7-26 shows the program for an annunciator flasher circuit. Two internal timers form the oscillator circuit, which generates a timed, pulsed output. The oscillator circuit output is programmed in series with the alarm condition. If the alarm condition (temperature, pressure, or limit switch) is true, the appropriate output indicating light will flash. Note that any number of alarm conditions could be programmed using the same flasher circuit.

At times you may require a time-delay period longer than the maximum preset time allowed for the single timer instruction of the PLC being used. When this is the case, the

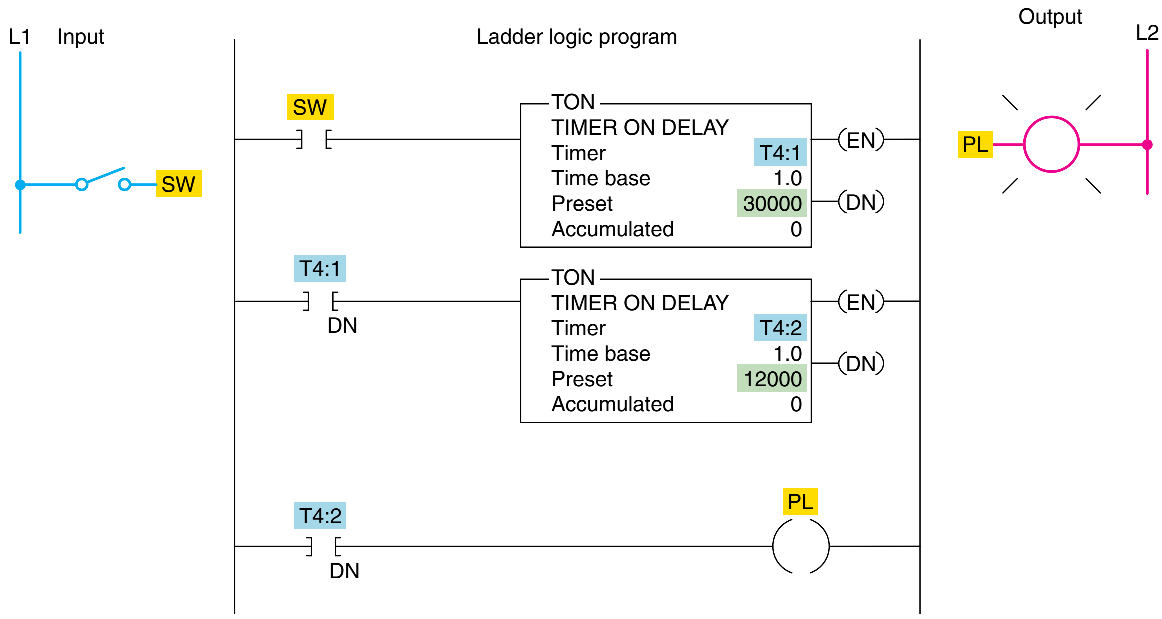


FIGURE 7-27 Cascading of timers for longer time delays.

problem can be solved by simply cascading timers, as illustrated in Figure 7-27. The type of timer programmed for this example is a TON, and the total time delay period required is 42,000 s. The first timer, T4:1, is programmed for a preset time of 30,000 s and begins timing when input SW is closed. When it completes its time-delay period 30,000 s later, the T4:1/DN bit will be set to 1. This in turn activates the second timer, T4:2, which is preset for the remaining 12,000 s of the total 42,000-s time delay. Once T4:2 reaches its preset time, the T4:2/DN bit will be set to 1, which switches on the output PL, the pilot light, to indicate the completion of the full 42,000-s time delay. Opening input SW at any time will reset both timers and switch output PL off.

A typical application for PLC timers is the control of traffic lights. The ladder logic circuit of Figure 7-28 (on page 192) illustrates a simulated control of a set of traffic lights in one direction only. Transition from red to green to amber is accomplished by a cascading timer circuit. The sequence of operation is:

Red	30 s on
Green	25 s on
Amber	5 s on

The sequence then repeats itself. Figure 7-29 shows the original traffic light program modified to include three more lights that control traffic flow in the other direction.

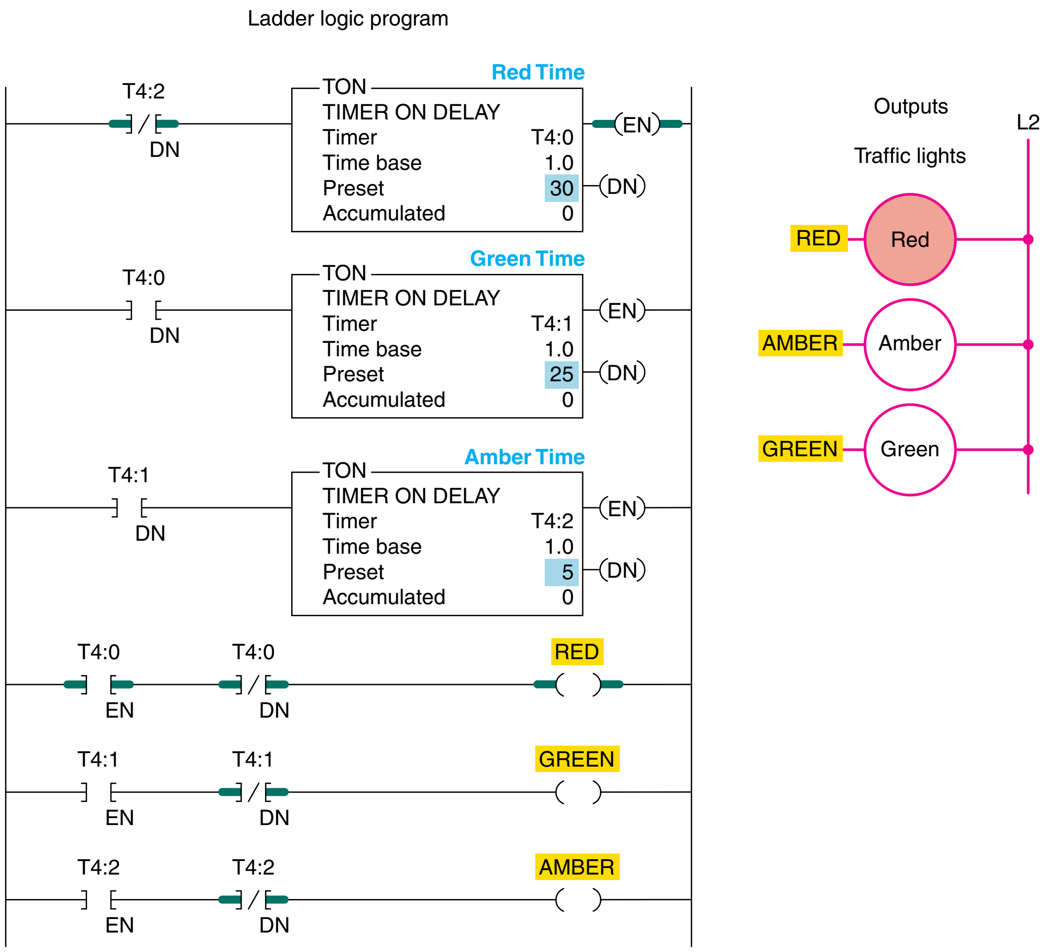
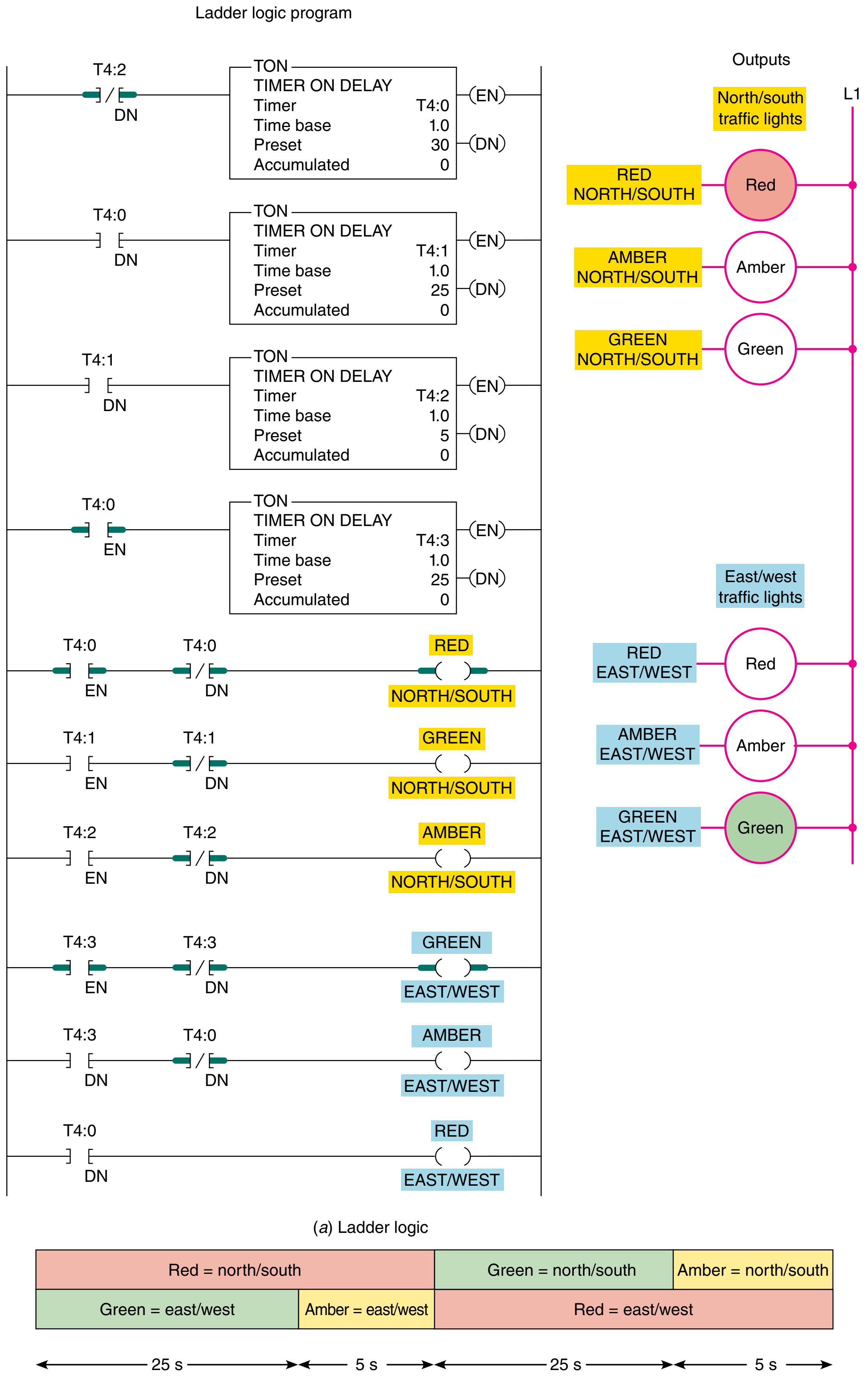


FIGURE 7-28 Control of traffic lights in one direction.



(*b*) Timing chart

FIGURE 7-29 Control of traffic lights in two directions.

Chapter 7 Review

Questions

1. Explain the difference between the timed and instantaneous contacts of a pneumatic timer.

2. Draw the symbol and explain the operation of each of the following timed contacts of a pneumatic timer:
   - **a.** On-delay timer—NOTC contact
   - **b.** On-delay timer—NCTO contact
   - **c.** Off-delay timer—NOTO contact
   - **d.** Off-delay timer—NCTC contact

3. State five pieces of information usually associated with a PLC timer instruction.

4. When is the output of a programmed timer energized?

5. What are the two methods commonly used to represent a timer within a PLC's ladder logic program?

6. **a.** Explain the difference between the operation of a nonretentive timer and that of a retentive timer.
   b. Explain how the accumulated count of programmed retentive and nonretentive timers is reset to zero.

7. State three advantages of using programmed PLC timers.

8. **a.** Name three different types of PLC timers.
   b. Which of the three is most commonly used?

9. Explain what each of the following quantities associated with a PLC timer instruction represents:
   a. Preset time **b.** Accumulated time **c.** Time base

10. **a.** When is the enable bit of a timer instruction true?
    b. When is the timer-timing bit of a timer instruction true?
    c. When does the done bit of a timer change state?

11. State the method used to reset the accumulated time of each of the following:
    a. TON timer **b.** TOF timer **c.** RTO timer

12. Compare the way a timer is addressed in the Allen-Bradley PLC-5 and SLC-500 controllers with the method used in a ControlLogix controller.

Problems

1. A. With reference to the relay schematic diagram in Figure 7-30, state the status of each light (on or off) after each of the following sequential events:

(1) Power is first applied and switch S1 is open.

(2) Switch S1 has just closed.

(3) Switch S1 has been closed for 5 s.

(4) Switch S1 has just opened.

(5) Switch S1 has been opened for 5 s.

B. Design a PLC program and prepare a typical I/O connection diagram and ladder logic program that will execute this hardwired control circuit correctly.

2. Design a PLC program and prepare a typical I/O connection diagram and ladder logic program that will correctly execute the hardwired control circuit shown in Figure 7-31.

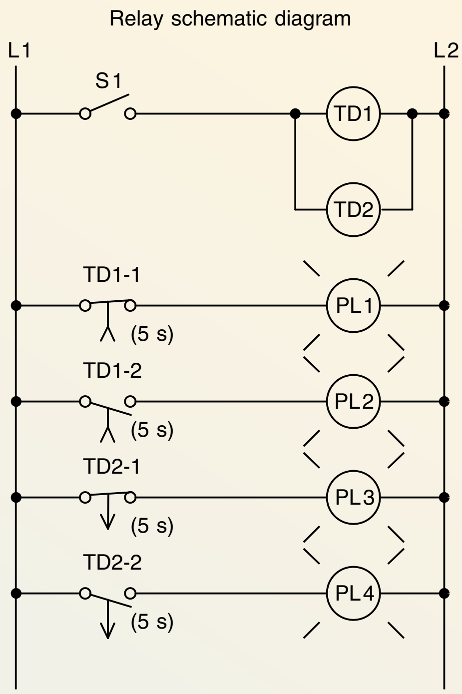


FIGURE 7-30

3. Study the ladder logic program in Figure 7-32 on page 196, and answer the questions that follow:

a. What type of timer has been programmed?

b. What is the length of the time-delay period?

c. What is the value of the accumulated time when power is first applied?

d. When does the timer start timing?

e. When does the timer stop timing and reset itself?

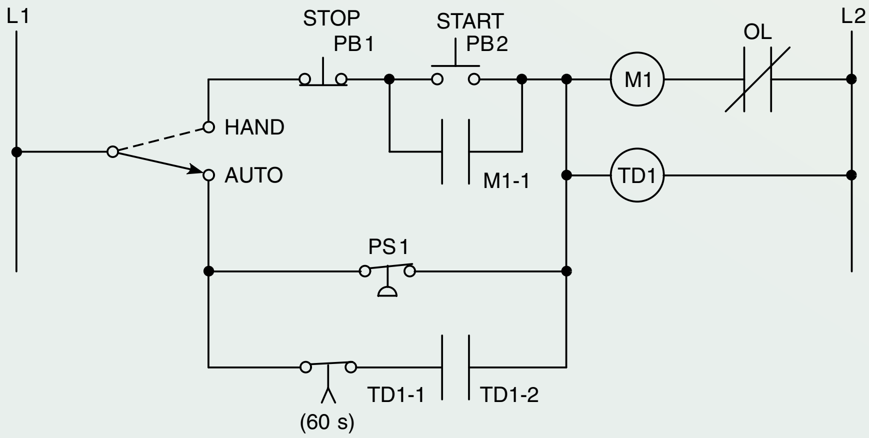


FIGURE 7-31

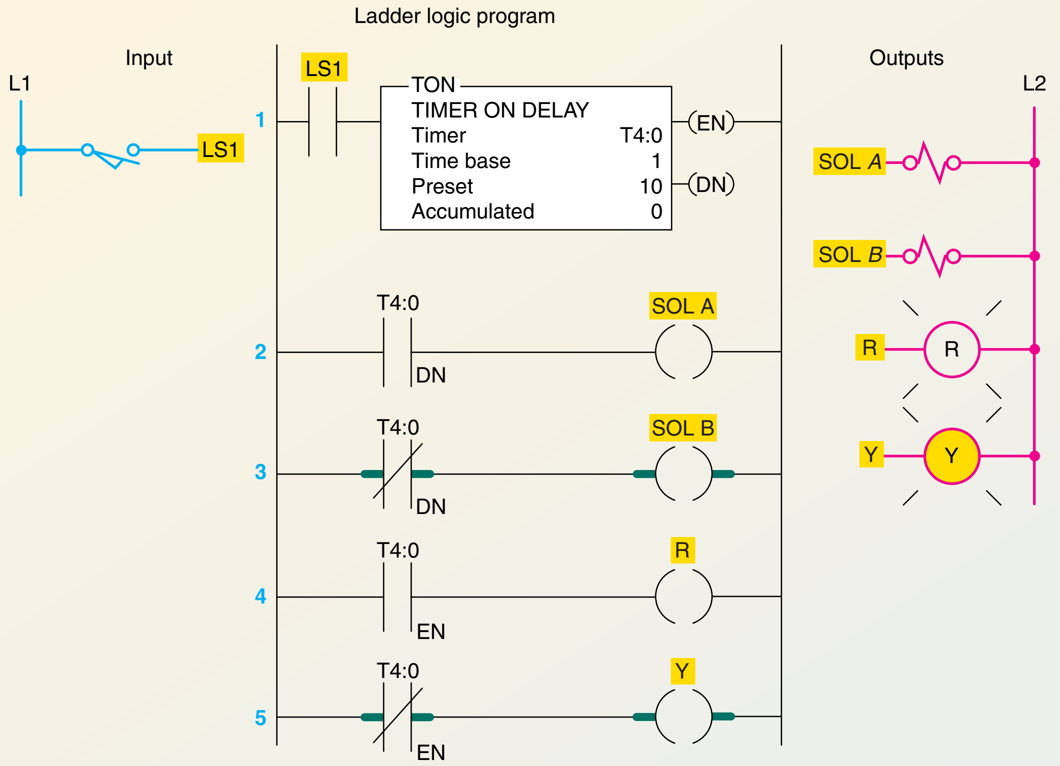


FIGURE 7-32

- **f.** When input LS1 is first closed, which rungs are true and which are false?
- **g.** When input LS1 is first closed, state the status (on or off) of each output.
- **h.** When the timer's accumulated value equals the preset value, which rungs are true and which are false?
- **i.** When the timer's accumulated value equals the preset value, state the status (on or off) of each output.
- **j.** Suppose that rung 1 is true for 5 s and then power is lost. What will the accumulated value of the counter be when power is restored?

4. Study the ladder logic program in Figure 7-33, and answer the questions that follow:

- **a.** What type of timer has been programmed?
- **b.** What is the length of the time-delay period?
- **c.** When does the timer start timing?
- **d.** When is the timer reset?
- **e.** When will rung 3 be true?
- **f.** When will rung 5 be true?
- **g.** When will output PL4 be energized?
- **h.** Assume that your accumulated time value is up to 020 and power to your system is lost. What will your accumulated time value be when power is restored?
- **i.** What happens if inputs PB1 and PB2 are both true at the same time?

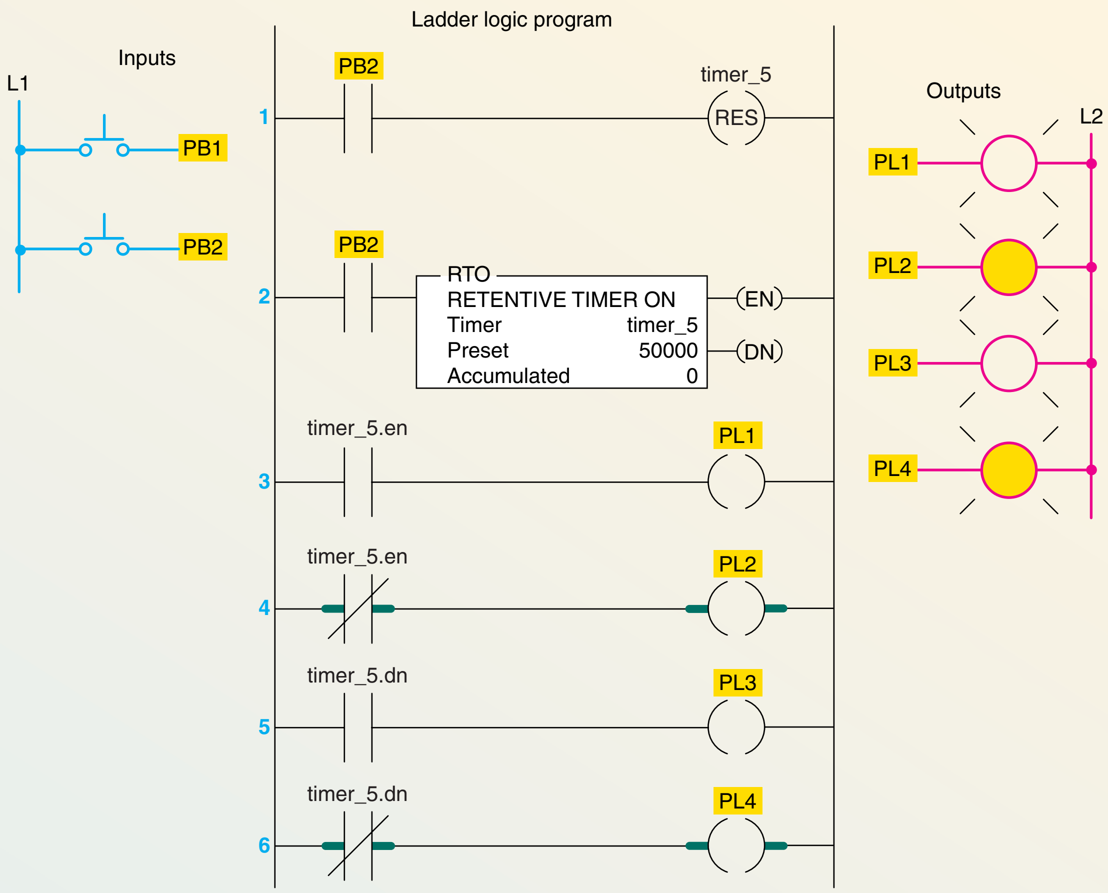


FIGURE 7-33

5. Study the ladder logic program in Figure 7-34 on page 198, and answer the questions that follow:

a. What is the purpose of interconnecting the two timers?

b. How much time must elapse before output PL is energized?

c. What two conditions must be satisfied for timer T4:2 to start timing?

d. Assume that output PL is on and power to the system is lost. When power is restored, what will the status of this output be?

e. When input PB2 is on, what will happen?

f. When input PB1 is on, how much accumulated time must elapse before rung 3 will be true?

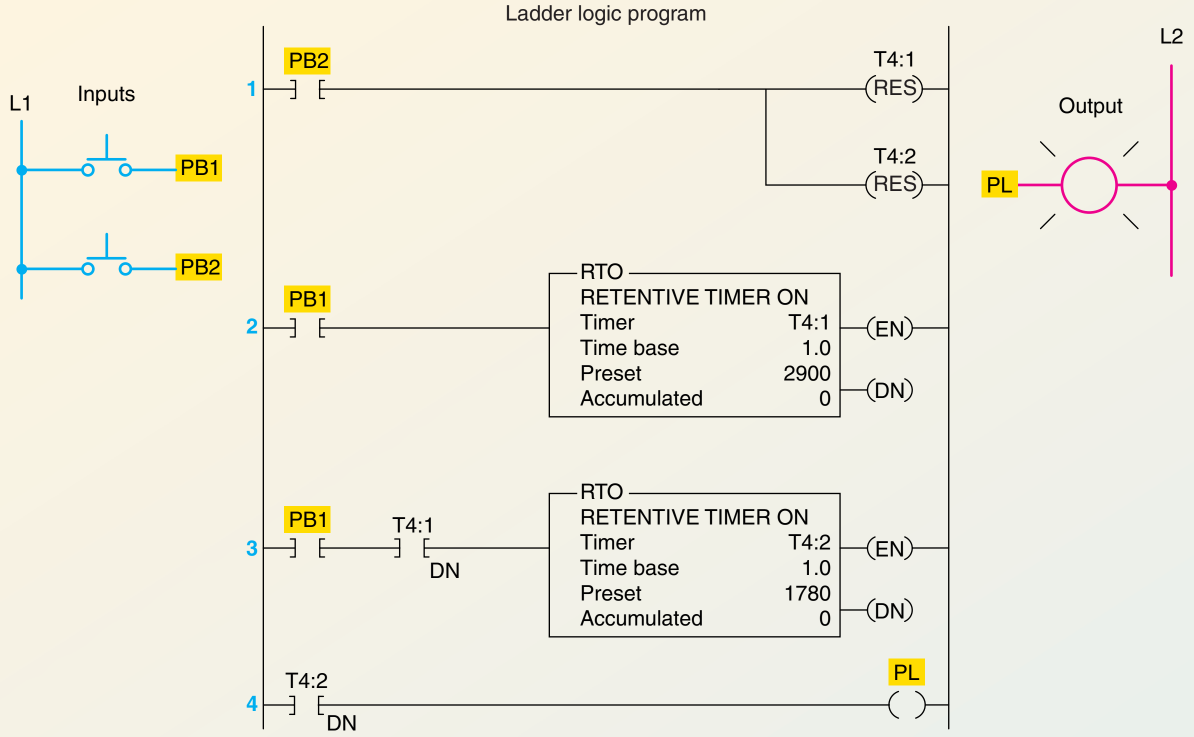


FIGURE 7-34

6. You have a machine that cycles on and off during its operation. You need to keep a record of its total run time for maintenance purposes. Which timer would accomplish this?

7. Write a ladder logic program that will turn on a light, PL, 15 s after switch S1 has been turned on.

8. Study the on-delay timer ladder logic program in Figure 7-35, and from each of the conditions stated, determine whether the timer is reset, timing, or timed out or if the conditions stated are not possible.

- **a.** The input is true, and EN is 1, TT is 1, and DN is 0.
- **b.** The input is true, and EN is 1, TT is 1, and DN is 1.
- **c.** The input is false, and EN is 0, TT is 0, and DN is 0.
- **d.** The input is true, and EN is 1, TT is 0, and DN is 1.

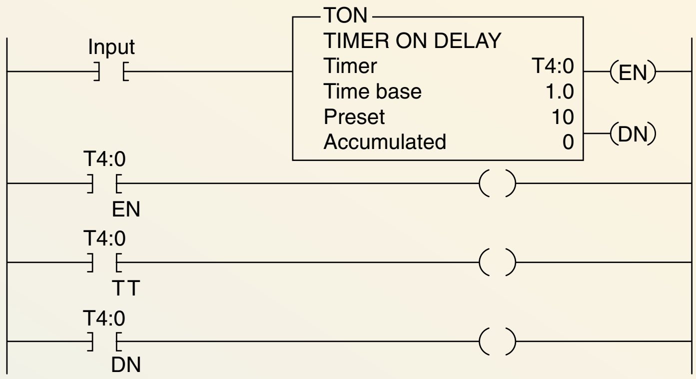


FIGURE 7-35

9. Study the off-delay timer ladder logic program in Figure 7-36, and from each of the conditions stated, determine whether the timer is reset, timing, or timed out or if the conditions stated are not possible.

a. The input is true, and EN is 0, TT is 0, and DN is 1.

b. The input is true, and EN is 1, TT is 1, and DN is 1.

c. The input is true, and EN is 1, TT is 0, and DN is 1.

d. The input is false, and EN is 0, TT is 1, and DN is 1.

e. The input is false, and EN is 0, TT is 0, and DN is 0.

10. Write a program for an "anti–tie down circuit" that will disallow a punch press solenoid from operating unless both hands are on the two palm start buttons. Both buttons must be pressed at the same time within 0.5 s. The circuit also will not allow the operator to tie down one of the buttons and operate the press with just one button. (Hint: Once either of the buttons is pressed, begin timing 0.5 s. Then, if both buttons are not pressed, prevent the press solenoid from operating.)

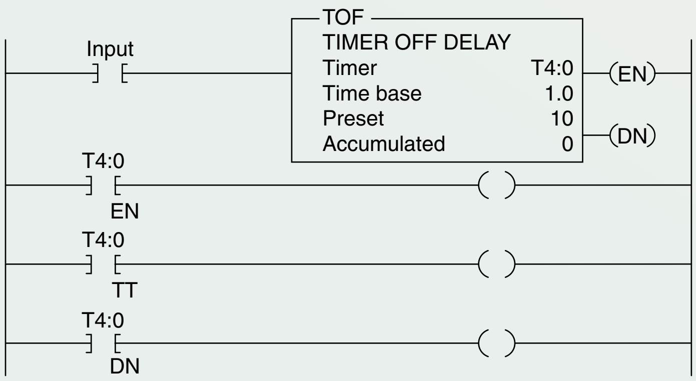


FIGURE 7-36

11. Modify the traffic control program of Figure 7-29 (on page 193) so that there is a 3-s period when both directions will have their red lights illuminated.

12. Write a program to implement the process illustrated in Figure 7-37. The sequence of operation is to be as follows:

- Normally open start and normally closed stop pushbuttons are used to start and stop the process.
- When the start button is pressed, solenoid A energizes to start filling the tank.
- As the tank fills, the empty level sensor switch closes.
- When the tank is full, the full level sensor switch closes.
- Solenoid *A* is de-energized.
- The agitate motor starts automatically and runs for 3 min to mix the liquid.
- When the agitate motor stops, solenoid B is energized to empty the tank.
- When the tank is completely empty, the empty sensor switch opens to de-energize solenoid *B*.
- The start button is pressed to repeat the sequence.

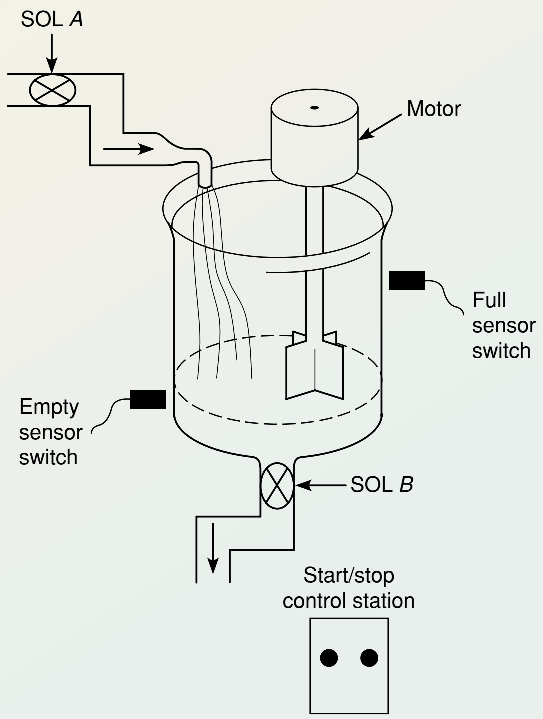


FIGURE 7-37

13. When the lights are turned off in a building, an exit door light is to remain on for an additional 2 min, and the parking lot lights are to remain on for an additional 3 min after the door light goes out. Write a program to implement this process.

14. Write a program to simulate the operation of a sequential taillight system. The light system consists of three separate lights on each side of the car. Each set of lights will be activated separately, by either the left or right turn signal switch. There is to be a 1-s delay between the activation of each light, and a 1-s period when all the lights are off. Ensure that when both switches are on, the system will not operate. Use the least number of timers possible. The sequence of operation should be as follows:

- The switch is operated.
- Light 1 is illuminated.
- Light 2 is illuminated 1 s later.
- Light 3 is illuminated 1 s later.
- Light 3 is illuminated for 1 s.
- All lights are off for 1 s.
- The system repeats while the switch is on.