7 Internal relays

This chapter continues on from the previous chapters on programming and introduces *internal relays*. A variety of other terms are often used to describe these elements, e.g. *auxiliary relays*, *markers*, *flags*, *coils*, *bit storage*. These are one of the elements giving 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 being battery backed so that they can be used in situations where it is necessary to ensure safe shutdown of plant in the event of power failure. Later chapters consider other common built-in elements.

7.1 Internal relays

In PLCs there are elements that are used to hold data, i.e. bits, and behave like relays, being able to be switched on or off and 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, e.g. activate a motor. Thus we might have (Figure 7.1):

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.

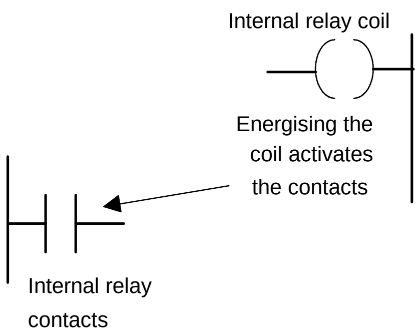


Figure 7.1 *Internal relay*

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 different ways of expressing their addresses. For example, Mitsubishi uses the term *auxiliary relay* or *marker* and the notation M100, M101, etc. Siemens uses the term *flag* and notation F0.0, F0.1, etc. Telemecanique uses the term *bit* and notation B0, B1, etc. Toshiba uses the term *internal relay* and notation R000, R001, etc. Allen-Bradley uses the term *bit storage* and notation in the PLC-5 of the form B3/001, B3/002, etc.

7.2 Ladder programs

With ladder programs, an internal relay output is represented using the symbol for an output device, namely ( ), with an address which indicates that it is an internal relay rather than an external relay. Thus, with a Mitsubishi PLC, we might have the address M100, the M indicating that it is an internal relay or marker rather than an external device. The internal relay switching contacts are designated with the symbol for an input device, namely | |, and given the same address as the internal relay output, e.g. M100.

7.2.1 Programs with multiple input conditions

As an illustration of the use that can be made of internal relays, consider the following situation. A system is to be activated when two different sets of input conditions are realised. We might just program this as an AND logic gate system; however, if a number of inputs have to be checked in order that each of the input conditions can be realised, it may be simpler to use an internal relay. The first input conditions then are used to give an output to an internal relay. This has associated contacts which then become part of the input conditions with the second input.

Figure 7.2 shows a ladder program for such a task. For the first rung: when input 1 or input 3 is closed and input 2 closed, then internal relay IR 1 is activated. This results in the contacts IR 1 closing. If input 4 is then activated, there is an output from output 1. Such a task might be involved in the automatic lifting of a barrier when someone approaches from either side. Input 1 and input 3 are inputs from photoelectric sensors that detect the presence of a person, approaching or leaving from either side of the barrier, input 1 being activated from one side of it and input 3 from the other. Input 2 is an enabling switch to enable the system to be closed down. Thus when input 1 or input 3, and input 2, are activated, there is an output from the internal relay 1. This will close the internal relay contacts. If input 4, perhaps a limit switch, detects that the barrier is closed then it is activated and closes. The result is then an output from Out 1, a motor which lifts the barrier. If the limit switch detects that the barrier is already open, the person having passed through it, then it opens and so output 1 is no longer energised and a counterweight might then close the barrier. The internal relay has enabled two parts of the program to be linked, one part being the detection of the presence of a person and the second part the detection of whether the barrier is already up or down.

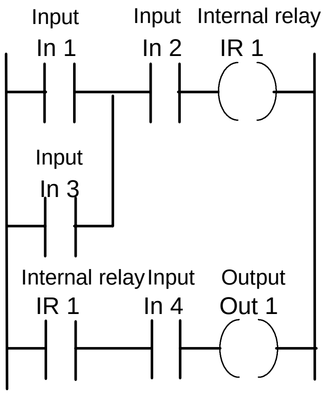


Figure 7.2 *Internal relay*

Figure 7.3(a) shows how Figure 7.2 would appear in Mitsubishi notation and Figure 7.3(b) in Siemens notation.

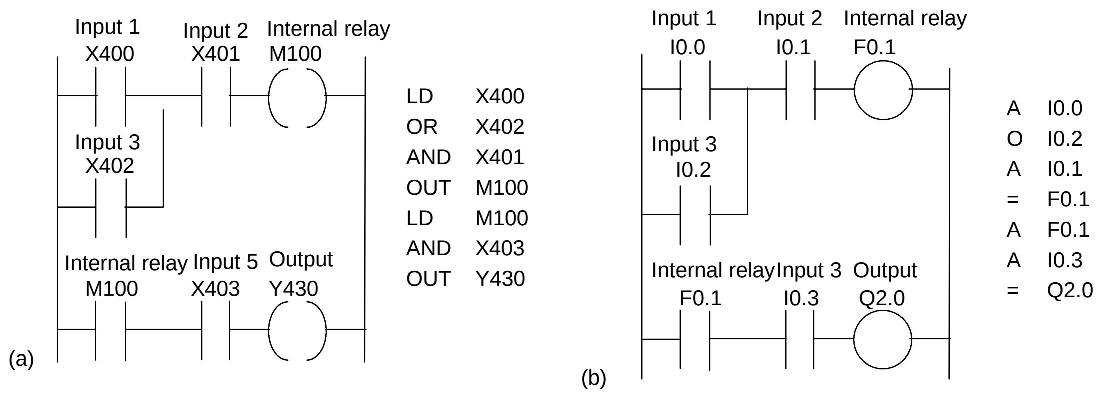


Figure 7.3 *Figure 7.2 in: (a) Mitsubishi notation, (b) Siemens notation*

Figure 7.4 is another example of this type of ladder program. The output 1 is controlled by two input arrangements. The first rung shows the internal relay IR 1 which is energised if the input In 1 or In 2 is activated and closed. The second rung shows the internal relay IR 2 which is energised if the inputs In 3 and In 4 are both energised. The third rung shows that the output Out 1 is energised if the 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 realised.

7.2.2 Latching programs

Another use of internal relays is for resetting a latch circuit. Figure 7.5 shows an example of such a ladder program.

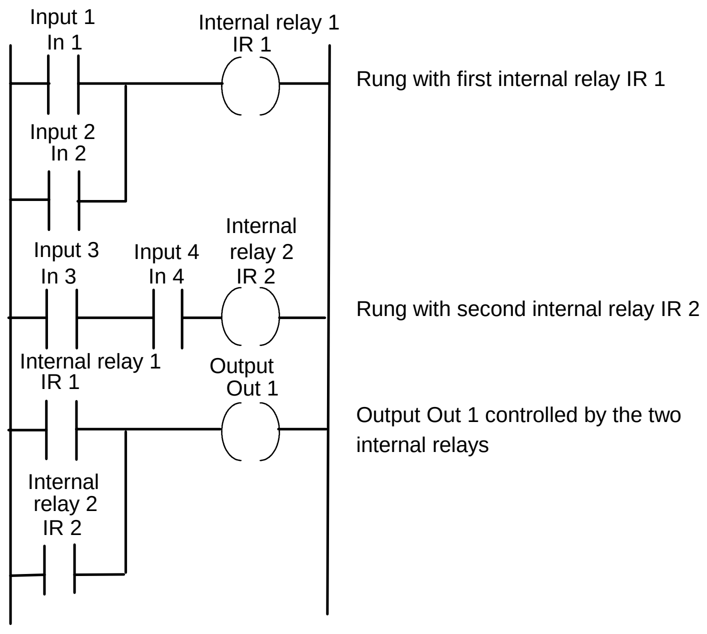


Figure 7.4 *Use of two internal relays*

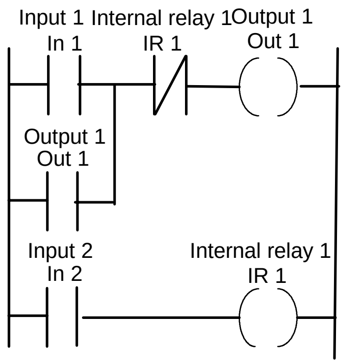


Figure 7.5 *Resetting latch*

When the input 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 1 opens. When input 2 is closed, the internal relay IR 1 is energised 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.

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 which 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 which has individually latched controls for each such output. However, a simpler method is to use an internal relay. Figure 7.6 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. The second rung will then switch the power on. The third rung will also switch on and give output Out 2 if input 2 contacts are closed. The third rung will also switch on and give output Out 3 if input 3 contacts are closed. Thus all the outputs can be switched on when the start push button is activated. All the outputs will be switched off if the stop switch is opened. Thus all the outputs are latched by IR 1.

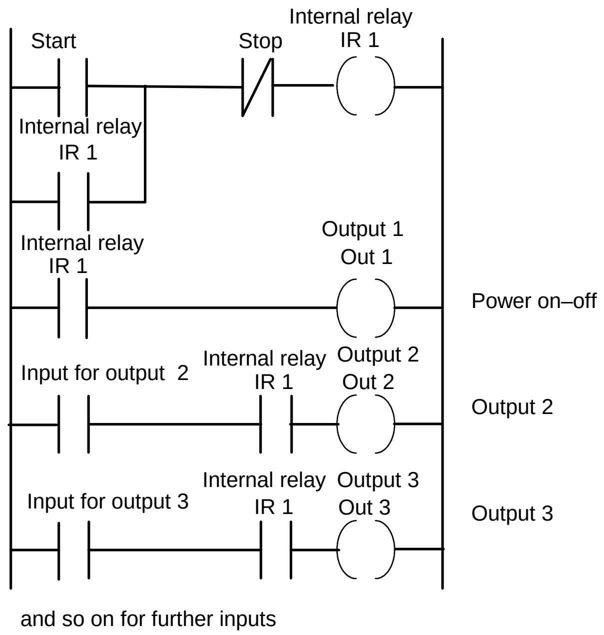


Figure 7.6 *Starting of multiple outputs*

7.3 Battery-backed relays

If the power supply is cut off from a PLC while it is being used, all the output relays and internal relays will be turned off. Thus when the power is restored, all the contacts associated with those relays will be set differently from when the power was on. Thus, if the PLC was in the middle of some sequence of control actions, it would resume at a different point in the sequence. To overcome this problem, some internal relays have battery back-up so that they can be used in circuits to ensure a safe shutdown of plant in the event of a power failure and so enable it to restart in an appropriate manner. Such battery-backed relays retain their state of activation, even when the power supply is off. The relay is said to have been made *retentive*.

The term *retentive memory coil* is frequently used for such elements. Figure 7.7 shows the IEC 1131-3 standard symbol for such elements. With Mitsubishi PLCs, battery-backed internal relay circuits use M300 to M377 as addresses for such relays. Other manufacturers use different addresses and methods of achieving retentive memory. The Allen-Bradley PLC-5 uses latch and unlatch rungs. If the relay is latched, it remains latched if

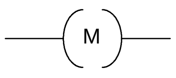


Figure 7.7 *Retentive memory coil*

power is lost and is unlatched when the unlatch relay is activated. See Section 7.5 for a discussion of such relays in the context of set and reset coils.

As an example of the use of such a relay, Figure 7.8 shows a ladder diagram for a system designed to cope with a power failure. IR 1 is a battery-backed internal relay. When input 1 contacts close, output IR 1 is energised. This closes the IR 1 contacts, latching so that IR 1 remains on even if input 1 opens. The result is an output from Out 1. If there is a power failure, IR 1 still remains energised and so the IR 1 contacts remain closed and there is an output from Out 1.

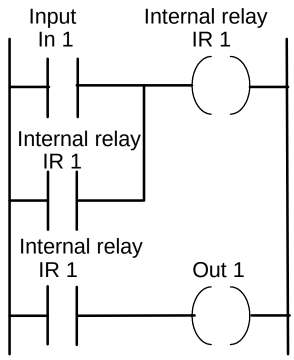


Figure 7.8 *Battery-backed relay program*

7.4 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, i.e. one scan through the ladder program. Hence it provides a fixed duration pulse at its contacts when operated. This function is often termed *one-shot*. While some PLCs have such a function as an entity as part of their programs, such a function can easily be developed with just two rungs of a ladder program. Figure 7.9 shows such a pair of rungs. When the trigger input occurs, it gives a trigger output in rung 1. In rung 2 it gives a cycle control output on an internal relay. Because rung 2 occurs after rung 1, the effect of the cycle control is not felt until the next cycle of the PLC program when it opens the cycle control contacts in rung 1 and stops the trigger output. The trigger output then remains off, despite there being a trigger input. The trigger output can only occur again when the trigger output is switched off and then switched on again.

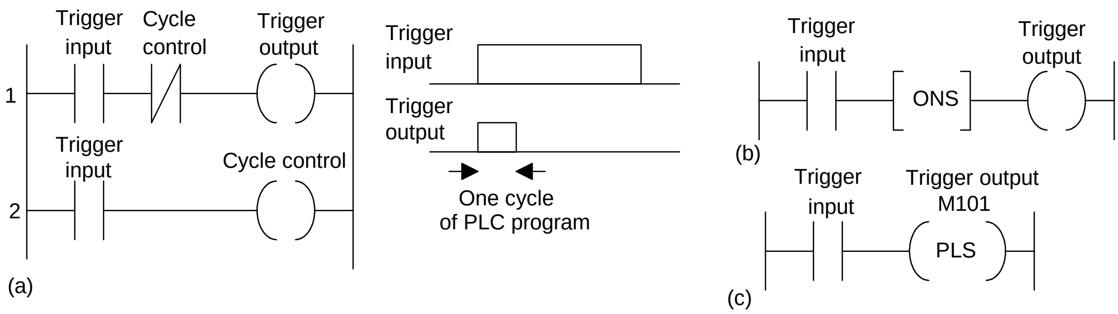


Figure 7.9 *One-shot (a) program, (b) facility in an Allen-Bradley PLC, (c) facility in a Mitsubishi PLC*

With the Mitsubishi PLC, the output internal relay, say M100, is activated when the trigger input, say X400, contacts close. Under normal circumstances, M100 would remain on for as long as the X400 contacts were closed. However, if M100 has been programmed for pulse operation, M100 only remains on for a fixed period of time, one program cycle. It then goes off, regardless of X400 being on. The programming instructions that would be used are LD X400, PLS M100. The above represents pulse operation when the input goes from off to on, i.e. is positive-going. If, in Figure 7.9(c), X400 is made normally closed, rather than normally open, then the pulse occurs when the input goes from on to off, i.e. is negative-going.

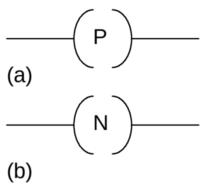
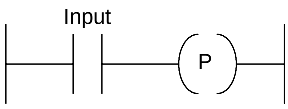


Figure 7.10 *(a) Positive transition-sensing coil, (b) negative transition-sensing coil*

The IEC 1131-3 gives standards for positive transition-sensing and negative transition-sensing coils (Figure 7.10). With the positive transition-sensing coil, if the power flow to it changes from off to on, the output is set on for one ladder rung evaluation. With the negative transition-sensing coil, if the power to it changes from off to on, the output is set on for one ladder rung evaluation. Thus, for the ladder rung of Figure 7.11, with the input off there is no output. When the input switches on, there is an output from the coil. However, the next and successive cycles of the program do not give outputs from the coil even though the switch remains on. The coil only gives an output the first time the switch is on.



Evaluation	Input	P output
1	Off	Off
2	On	On
3	On	Off
4	On	Off

Figure 7.11 *Ladder rung with a positive-transition sensing coil*

7.5 Set and reset

Another function which is often available is the ability to set and reset an internal relay. The set instruction causes the relay to self-hold, i.e. latch. It then remains in that condition until the reset instruction is received. The term *flip-flop* is often used. Figure 7.12 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.

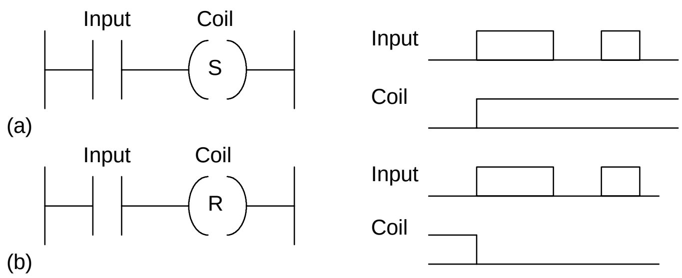


Figure 7.12 *(a) SET and (b) RESET coils*

Figure 7.13 shows an example of a ladder diagram involving such a function. Activation of the first input, X400, causes the output Y430 to be turned on and set, i.e. latched. Thus if the first input is turned off, the output remains on. Activation of the second input, X401, causes the output Y430 to be reset, i.e. turned off and latched off. Thus the output Y430 is on for the time between X400 being momentarily switched on and X401 being momentarily switched on. Between the two rungs indicated for the set and reset operations, there could be other rungs for other activities to be carried out, the set rung switching on an output at the beginning of the sequence and off at the end.

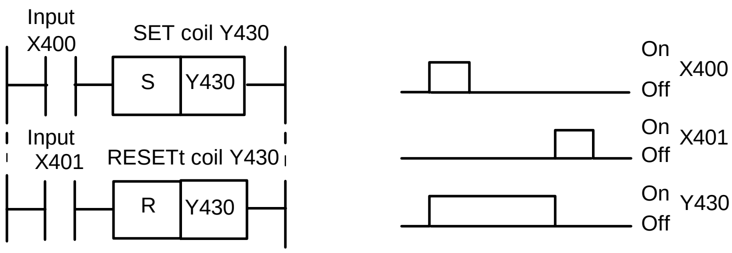


Figure 7.13 *SET and RESET*

The programming instructions for the ladder rungs in the program for Figure 7.13 are:

LD	X400
S	Y430

Other program rungs are

LD	X401
R	Y430

With a Telemecanique PLC the ladder diagram would be as shown in Figure 7.14 and the programming instructions would be:

L	I0,0
S	O0,0
L	I0,1
R	O0,0

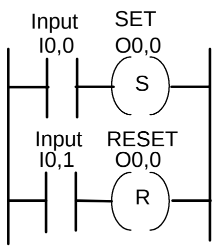


Figure 7.14 *SET and RESET*

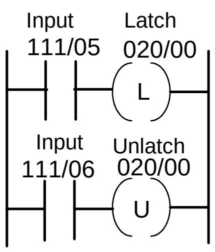


Figure 7.15 *Latch and unlatch*

With an Allen Bradley PLC, the term latch and unlatch is used. Figure 7.15 shows the ladder diagram.

The SET and RESET coil symbols are often combined into a single box symbol. Figure 7.16 shows the equivalent ladder diagram for the set-reset function in the above Figures with a Siemens PLC. The term memory box is used by them for the SET/RESET box, the box shown is termed a SR or reset priority memory function in that reset has priority. The programming instructions (F being used to indicate an internal relay) are:

A	I0.0
S	F0.0
A	I0.1
R	F0.0
A	F0.0
=	Q2.0

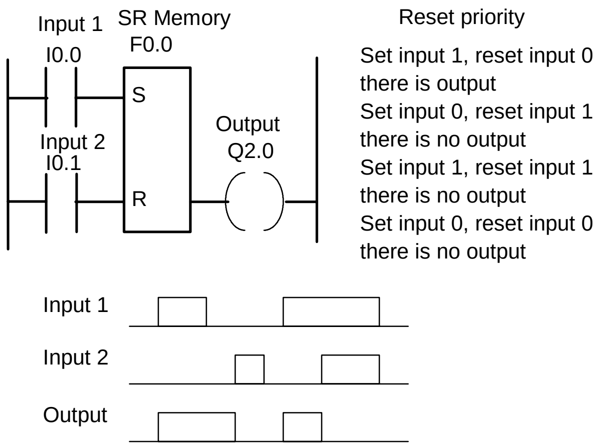


Figure 7.16 *SET and RESET, with reset priority*

With set priority (RS memory box), the arrangement is as shown in Figure 7.17.

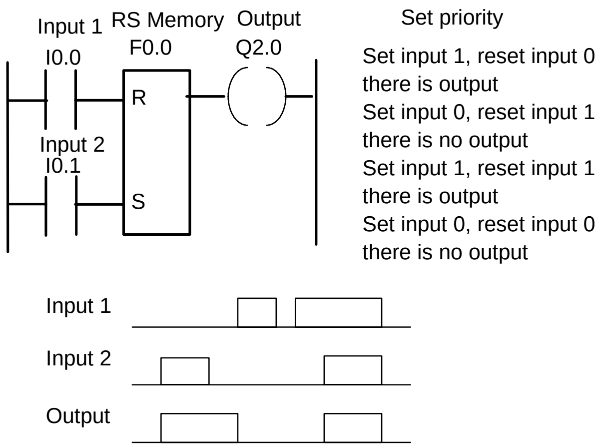


Figure 7.17 *SET and RESET, with reset priority*

Toshiba uses the term flip-flop and Figure 7.18 shows the ladder diagram.

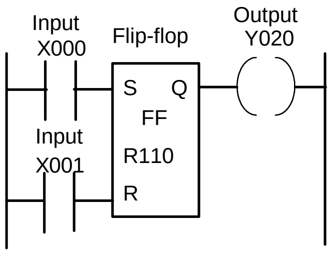


Figure 7.18 *Flip-flop*

Figure 7.19 shows how the set-reset function can be used to build the pulse (one-shot) function described in the previous section. Figure 7.19(a) shows it for a Siemens PLC (F indicates internal relay) and Figure 7.19(b) for a Telemecanique PLC (B indicates internal relay. In (a) and (b), an input (I0.0, I0,0) causes the internal relay (B0, F0.0) in the first rung to be activated. This results, second rung, in the set-reset internal relay being set. This setting action results in the internal relay (F0.1, B1) in the first rung opening and so, despite there being an input in the first rung, the internal relay (BO, F0.0) opens. However, because the rungs are scanned in sequence from top to bottom, a full cycle must elapse before the internal relay in the first rung opens. A pulse of duration one cycle has thus been produced. The system is reset when the input (I0.0, I0,0) ceases.

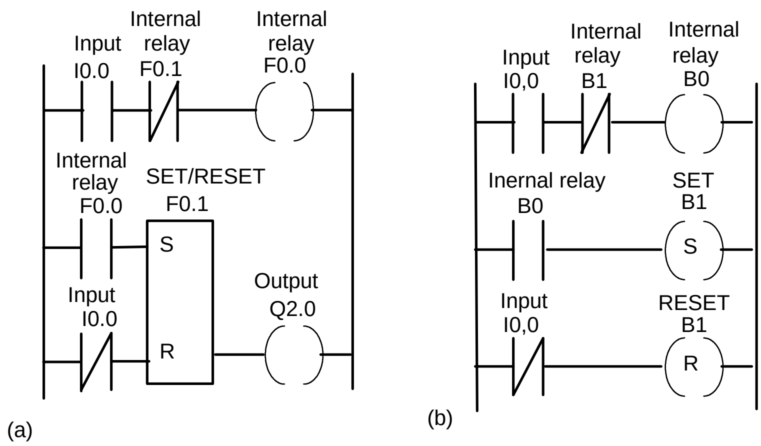


Figure 7.19 *Pulse function: (a) Siemens PLC, (b) Telemecanique PLC*

7.5.1 Program examples

An example of the basic elements of a simple program for use with a fire alarm system is shown in Figure 7.20. Fire sensors provide inputs to a SET-RESET function block so that if one of the sensors is activated the alarm is set and remains set until it is cleared by being reset. When set it sets of the alarm.

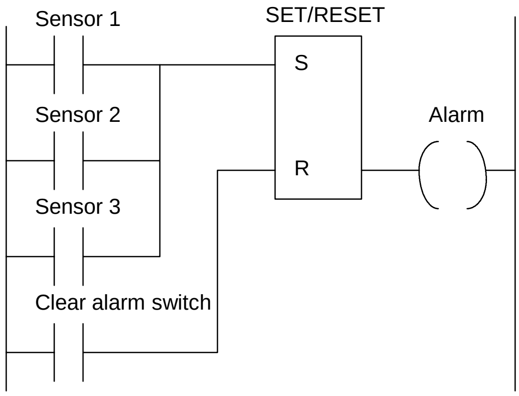


Figure 7.20 *Alarm system*

Another program showing the basic elements of a program is shown in Figure 7.21. This could be used with a system designed to detect when a workpiece has been loaded into the correct position for some further operation. When the start contacts are closed then the output causes the workpiece to move. This continues until a light beam is interrupted and resets, causing the output to cease. A stop button is available to stop the movement at any time.

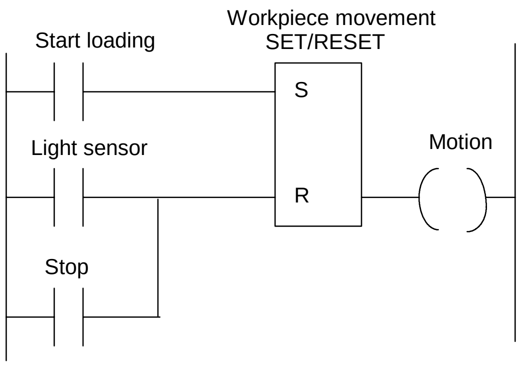


Figure 7.21 *Loading system*

7.6 Master control relay

When large numbers of outputs have to be controlled, it is sometimes necessary for whole sections of ladder diagrams to be turned on or off when certain criteria are realised. This could be achieved by including the contacts of the same internal relay in each of the rungs so that its operation affects all of them. An alternative is to use a *master control relay*.

Figure 7.22 illustrates the use of such a relay to control a section of a ladder program. With no input to input 1, the output internal relay MC 1 is not energised and so its contacts are open. This means that all the rungs between where it is designated to operate and the rung on which its reset MCR or another master control relay is located are switched off. Assuming it is designated to operate from its own rung, then we can imagine it to be located in the power line in the position shown and so rungs 2 and 3 are off. When input 1 contacts close, the master relay MC 1 is energised.