Programmable Logic Controllers (PLCs) In Material Handling Applications

By

(Group No. 12)

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Introduction

PLCs are digital controllers that are used in many industries for processes which need automation and quick computations. PLCs were invented in 1968 by General Motors in order to replace sequential relay circuits. They were further improved by Allan-Bradley in 1977 through their integration with microprocessors, and since then, they have become very cost effective and versatile in terms of their capabilities. PLCs are rugged and hence are used in industries which involve extreme temperature variations, high electrical noise, vibrations, shock and other physical phenomena which could damage sensitive microprocessor-based systems if used without sufficient shielding.

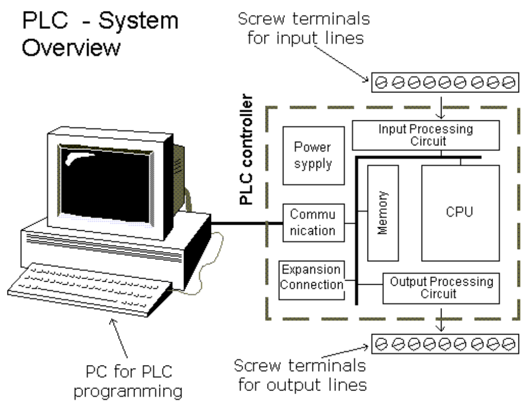

Fig. 1: A typical PLC

PLCs have multiple digital and analog inputs and outputs whose numbers could vary depending on the need in the industry. It could range from as low as a single digit to thousands of input-output terminals. Since typical microprocessors cannot handle such a huge number of ports at once and are very sensitive to environmental conditions, PLCs are preferred. There are several customized PLC modules specific to certain functions (like material handling, alarm systems, motor control, etc.) in use in the industry today and they serve as a complete package for various industrial processes.

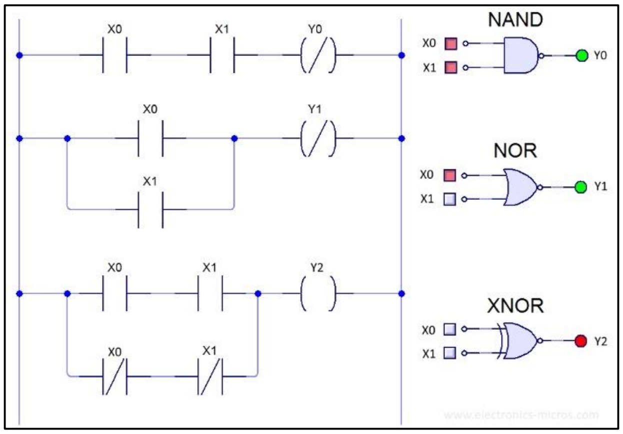

Fig. 2: An example of a ladder diagram

The basic parts of a PLC include a processor, memory, I/O devices, programming panel, and power supply. PLCs are programmed with the aid of "ladder diagrams" which involve making connections between a pair of parallel lines representing the flow of current. The components that need current and those that are used to control the flow are drawn between the two lines and the conditions required to run the components in a desired way are programmed with the help of a PLC programmer. The behaviour of a PLC can be changed by changing the program (ladder diagram) and modifying the necessary components.

In this project, we have simulated a conveyor belt system for material handling (pallet-handling) using PLCs in NI LabVIEW. We have made certain assumptions of ideality to simplify the system but the concept of using PLCs for material handling has been clearly demonstrated.

Material handling

Material Handling is the field concerned with solving the pragmatic problems involving the movement, storage in a manufacturing plant or warehouse, control and protection of materials, goods and products throughout the processes of cleaning, preparation, manufacturing, distribution, consumption and disposal of all related materials, goods and their packaging. Material handling also involves sorting and picking of objects, and may make use of automatic guided vehicles (AGVs) for carrying out transportation between two more points.

Fig. 3: A few examples of material handling equipment

Equipment used in material handling

Material-handling equipment refers to equipment that relate to the movement, storage, control and protection of materials, goods and products throughout the process of manufacturing, distribution, consumption and disposal. Material handling equipment is the mechanical equipment involved in the field of material handling. Typical examples of material handling equipment include forklifts, conveyor belts, overhead cranes, robots, etc.

Material handling equipment can be controlled with PLCs, since most of the functions to be performed by the individual components involve simple computations and actuation which can be easily controlled by PLCs.

Fig. 4: A PLC control box used to control the movement of conveyor belts in a warehouse

Since old systems involved hardwired components, even making small changes in the design was a tedious task since all connections had to be redefined. As PLCs are flexible in terms of the logic to be implemented and the connections to be made, new systems involving PLCs are much easier to operate and modifying the components is much more convenient.

PLC-based sorting using barcode scanning

Material handling involves the processes of sorting and retrieving. The sorting is carried out on the basis of certain parameters which may be modified/ changed as per the application. There are various methods to carry out the sorting operation, which include making use of conveyor belts, manually operated forklifts, automatic guided vehicles (AGVs), etc. Conveyor belts can be used to transport the packages to the pick-up points which are decided on the basis of weight, size, etc. AGVs make use of RFID tags to identify the correct loading/retrieving points, and magnetically enabled paths along warehouse floors as a guide to transport the packages to the destination which is decided by pre-determined parameters.

In this case, the sorting has been done on the basis of barcode scanning. That is, we have assumed that due to the versatile nature and applications of barcodes, each category of products will have a unique barcode which can be utilized to map the warehouse into specific storage areas and the package to be transported can be routed accordingly with the use of conveyor belts. This would effectively segregate the input packages.

Barcode scanning

We have assumed that each category of products has a unique barcode associated with it on the basis of certain predetermined parameters. For the purpose of simplicity, we have kept the number of categories of products as 4. Thus, in binary notation, the four locations can be denoted by Booleans D_1 and D_0. The values D_1D_0 can be 00, 01, 10, 11 depending on the location desired. The scanned barcode is fed as input to the PLC.

Motor control

Fig. 5: Conveyor belt controlled by DC motors

Since we are using a conveyor belt system, we have assumed the use of DC motors to run the belts. Thus, providing a robust controller for the motors would suffice for the conveyor belt operation. In LabVIEW, since the controller has been assumed to be a voltage supply controlled by the outputs of the PLC, a motor can be represented by a set of Boolean inputs. The direction of rotation is given by the states of the Boolean inputs, that is, the motor controller has been designed in such a way that there are only three states in which the motor operates – clockwise, anti-clockwise or a state of rest.

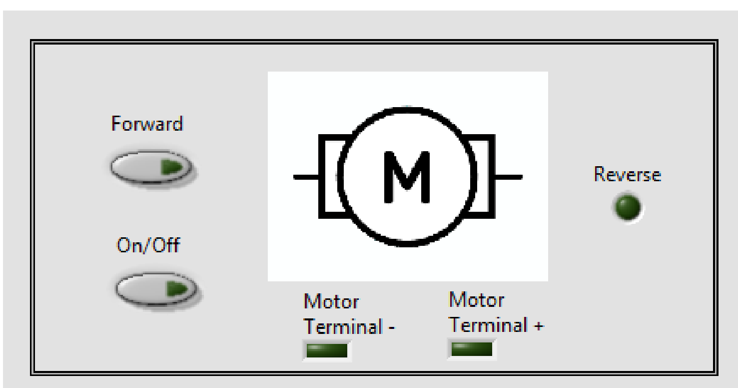

Fig. 6: Dual direction motor representation

As seen from the diagram, the motor has two inputs – ON/OFF, and Forward. Depending on the states as shown below, the direction of the motor is given:

ON/OFF	Forward	M+	M-	Output
ON	**True**	**True**	False	Clockwise
ON	**False**	**False**	True	Anti-clockwise
OFF	**X**	**X**	X	Rest

Table 1: States of the motor operation

The block diagram of the motor control operation is given below:

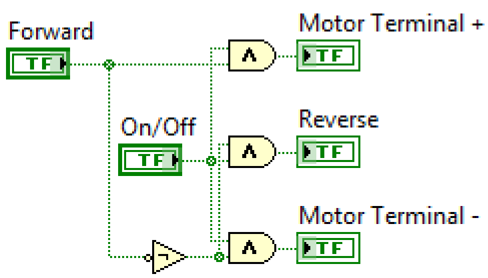

Fig. 7: Block diagram of motor

Path decider

In the real world conveyor belt system, each conveyor belt is equipped with a weight sensor/photo sensor (denoted in the ladder logic by W) so as to check the availability of goods on current belt. Since such a condition cannot be demonstrated without data acquisition, we have not included the part involving sensors in our simulation to avoid runtime errors.

This design has implemented the basic concept of Petri Nets. Initial conditions are checked before any instruction is carried out. The initial conditions to be verified are that current belt should have the goods and the next belt should be empty. Apart from this, a master control of the sorting facility is also available.

Timer

To minimize energy usage, when a conveyor belt is not in use, it should be stationary; this is done by switching off the motors when not in use. To demonstrate this concept, we have made use of timers in LabVIEW for motor control such that the motors function only during certain periods of time. The first timer decides (time interval can be set by the user) the time period for which the first belt (belt 0) should run, to place the pallet on the second set of belts (either belt 1 or belt 2). On reaching the pre-set time value, the first belt stops and the next belt begins to function. It runs for the same amount of time as the first belt, in which we assume the pallet reaches one of the four pre-determined collection zones. After this, the current belt stops and the main timer value is reset; the first belt begins moving again to deliver the next set of pallets, and the entire process repeats. The operation of the belts can be stopped at any instant using the master start/stop button.

Ladder logic

Ladder logic is used specifically in operations which involve using PLCs to run the various components. Ladder logic involves various units like coils, contacts, counters, timers, comparators, etc. which are placed according to the required algorithm between two ‘segments’ (vertical bars) which denote the flow of current, that is, when a contact is successfully made between the two segments, current flows across the components between the connected path and the circuit gets powered through the PLC. This output is used to control the voltage across specific output devices like motors, LEDs, bulbs, etc. In our case, we have assumed LEDs as well as motors as the outputs of the PLCs.

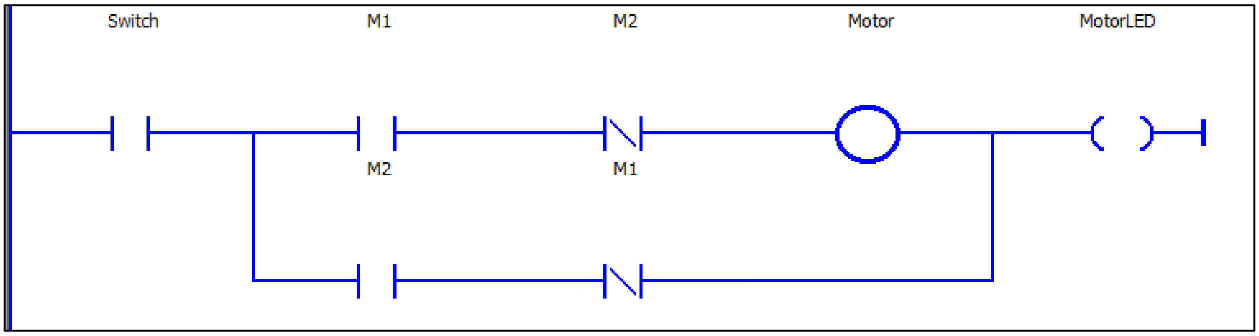

Fig. 8: Ladder logic for a simple motor

The ladder logic represented above is for a simple motor used in our simulation to run the conveyor belts.

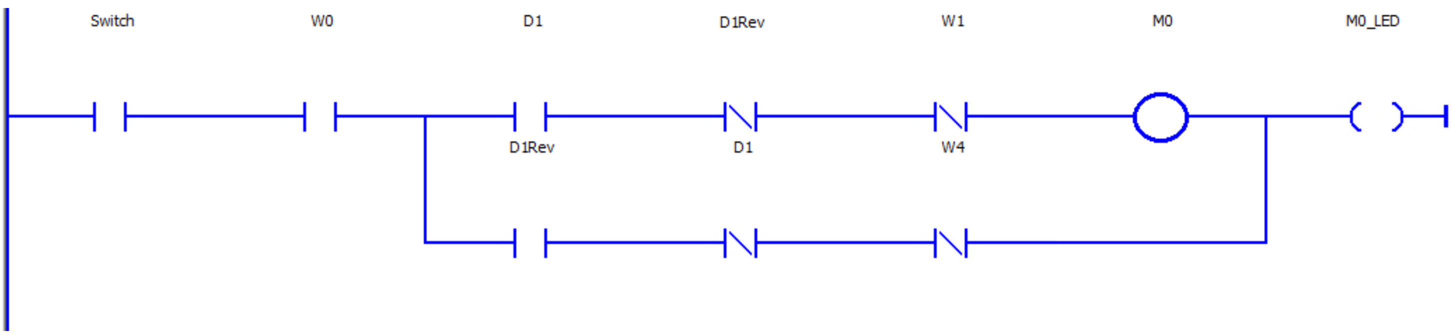

Fig. 9: Ladder logic for belt 0

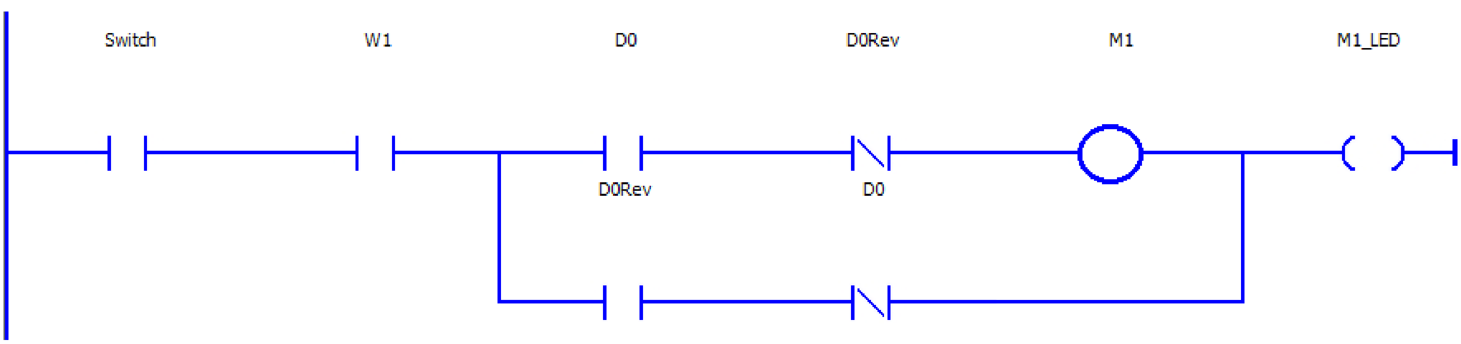

Fig. 10: Ladder logic for belt 1

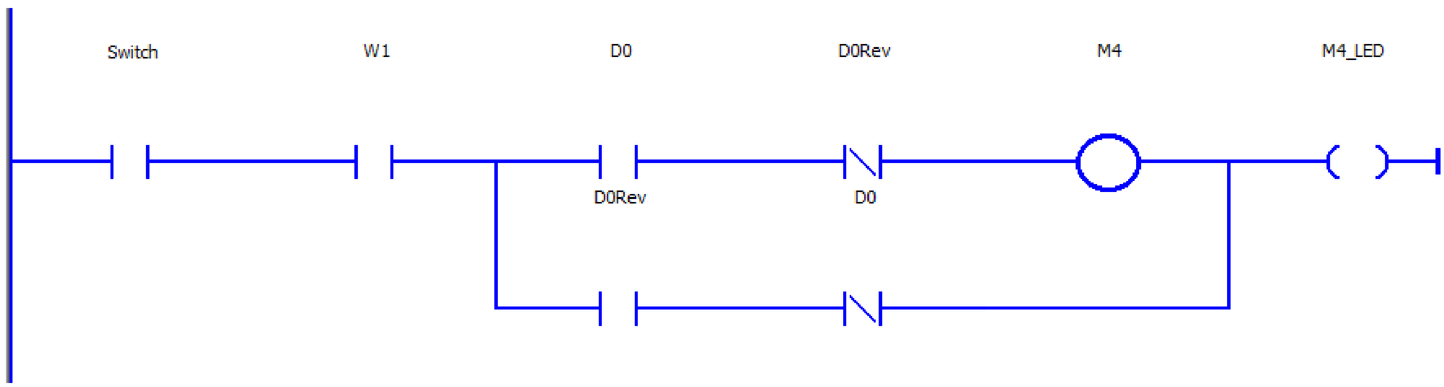

Fig. 11: Ladder logic for belt 2

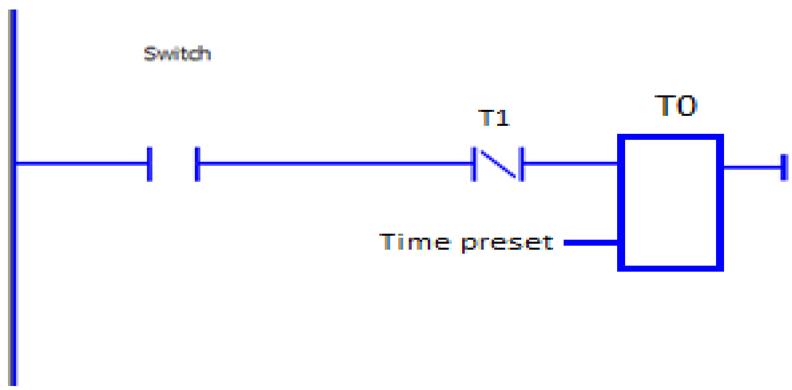

Fig. 12: Ladder logic for timer 0

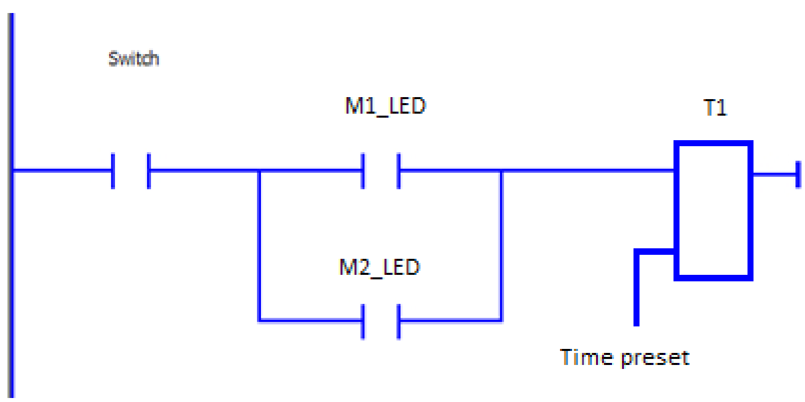

Fig. 13: Ladder logic for timer 1

Simulation in LabVIEW

LabVIEW is a software program developed by National Instruments which finds applications in the field of virtual instrumentation. Several instruments which would otherwise be difficult to conceive can be demonstrated with ease using LabVIEW and a software platform. I/O operations can be carried out using DAQ cards manufactured by NI.

We have used LabVIEW to demonstrate a simplified PLC-based sorting system which makes use of conveyor belts, motors, and timers to sort goods as per the requirement. The front panel, ladder diagram in LabVIEW and the block diagram for the system are given below:

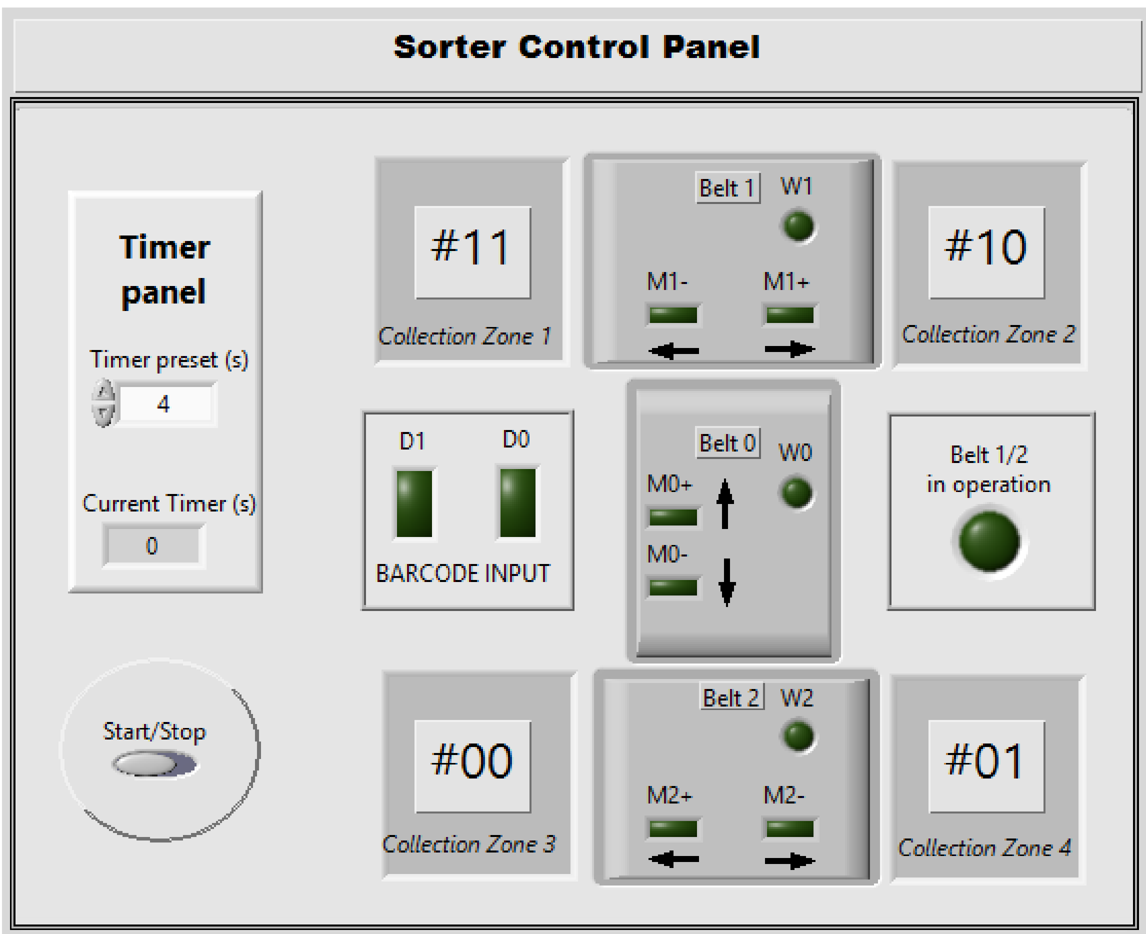

Fig. 14: Front panel for the PLC system (Sorter Control Panel)

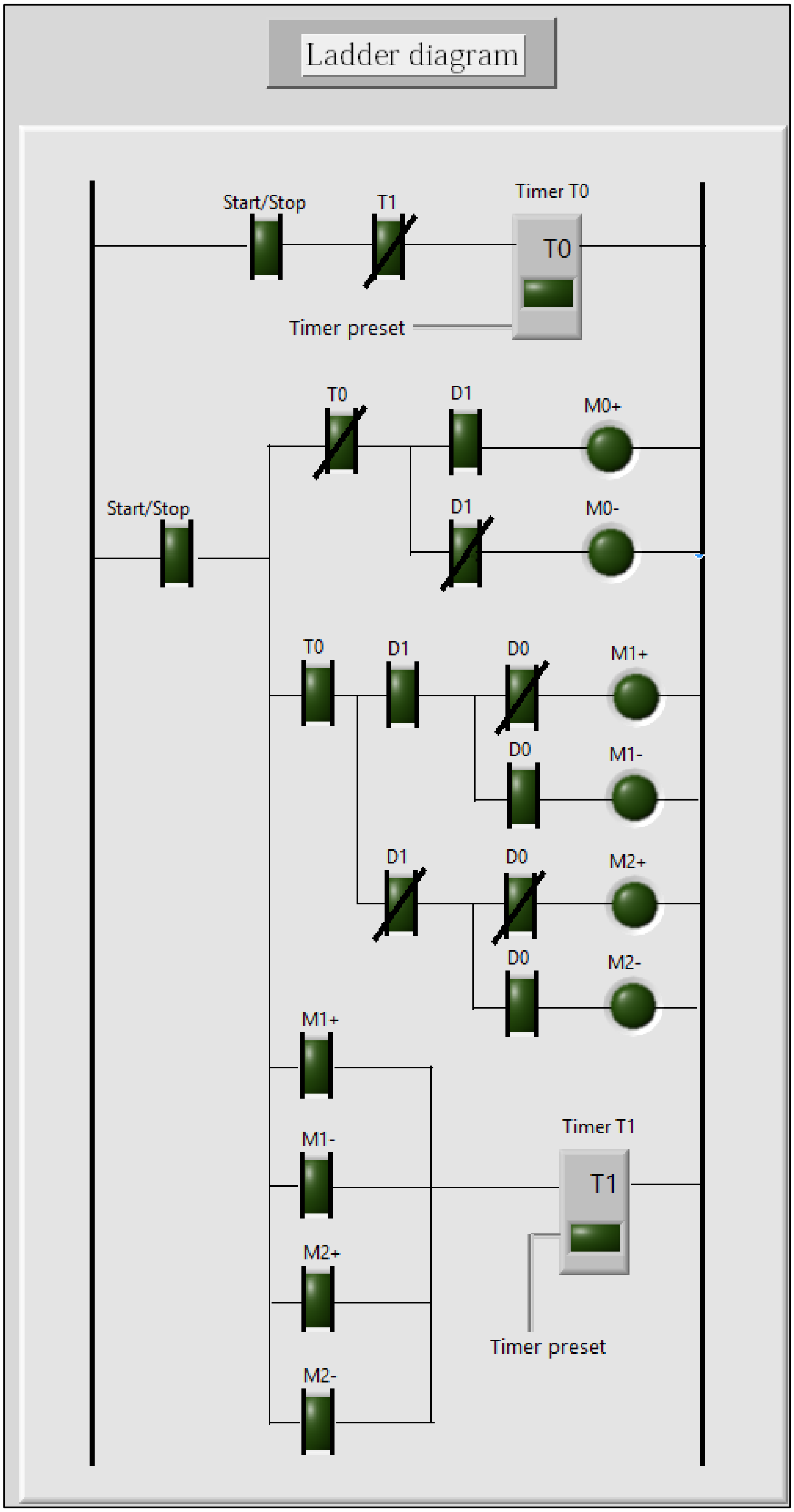

Fig. 15: Ladder diagram for the PLC system

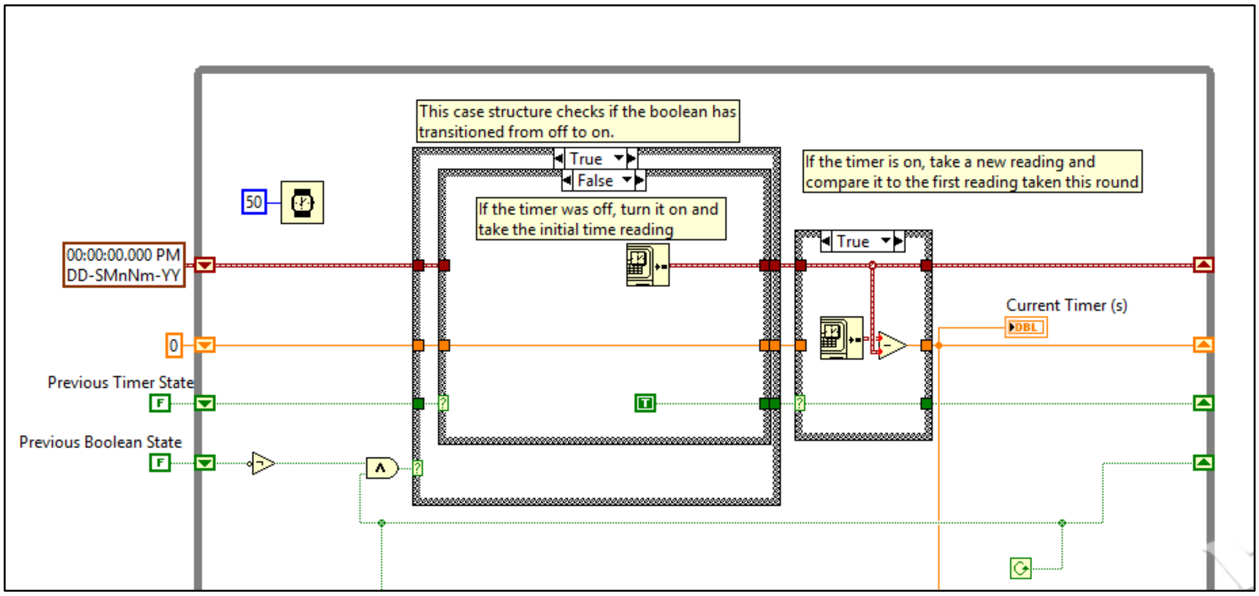

Fig. 16: Block diagram for the timer

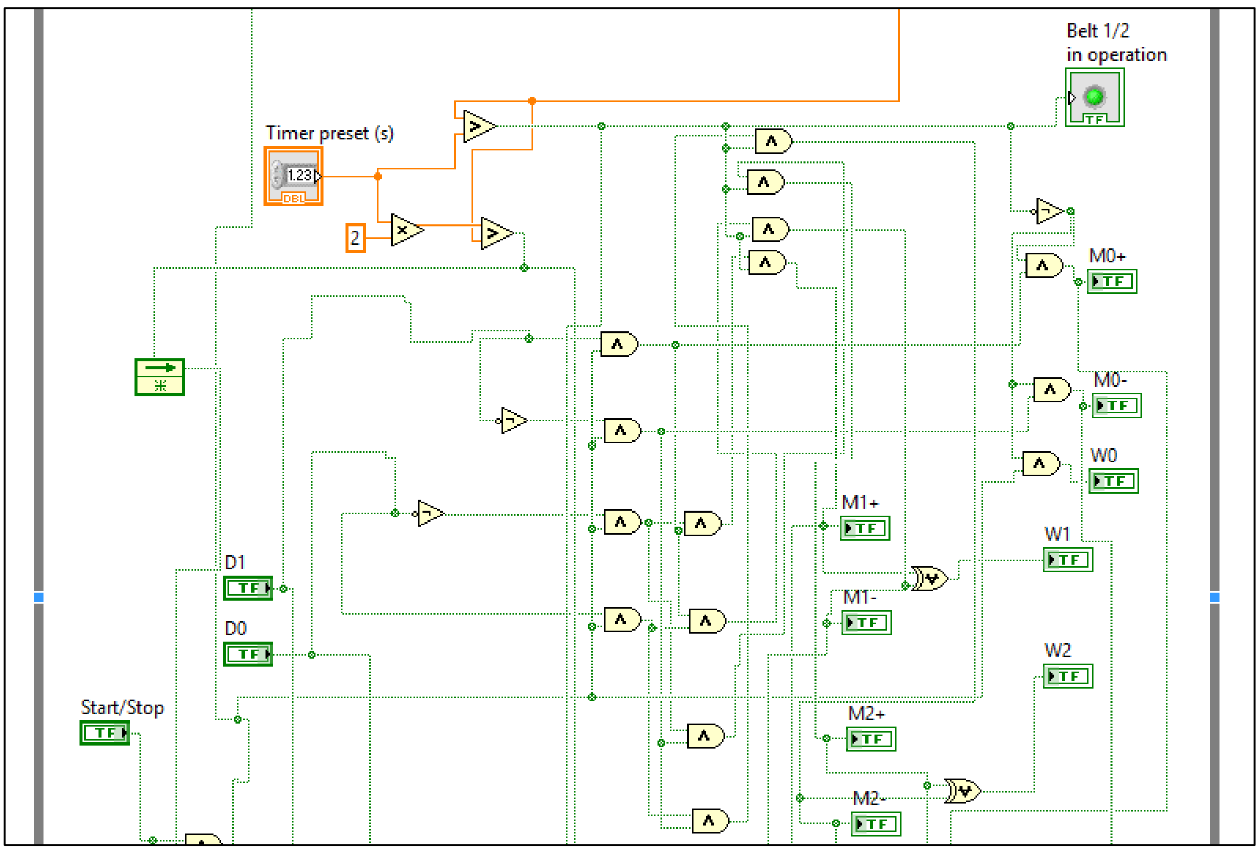

Fig. 17: Block diagram for conveyor belt system

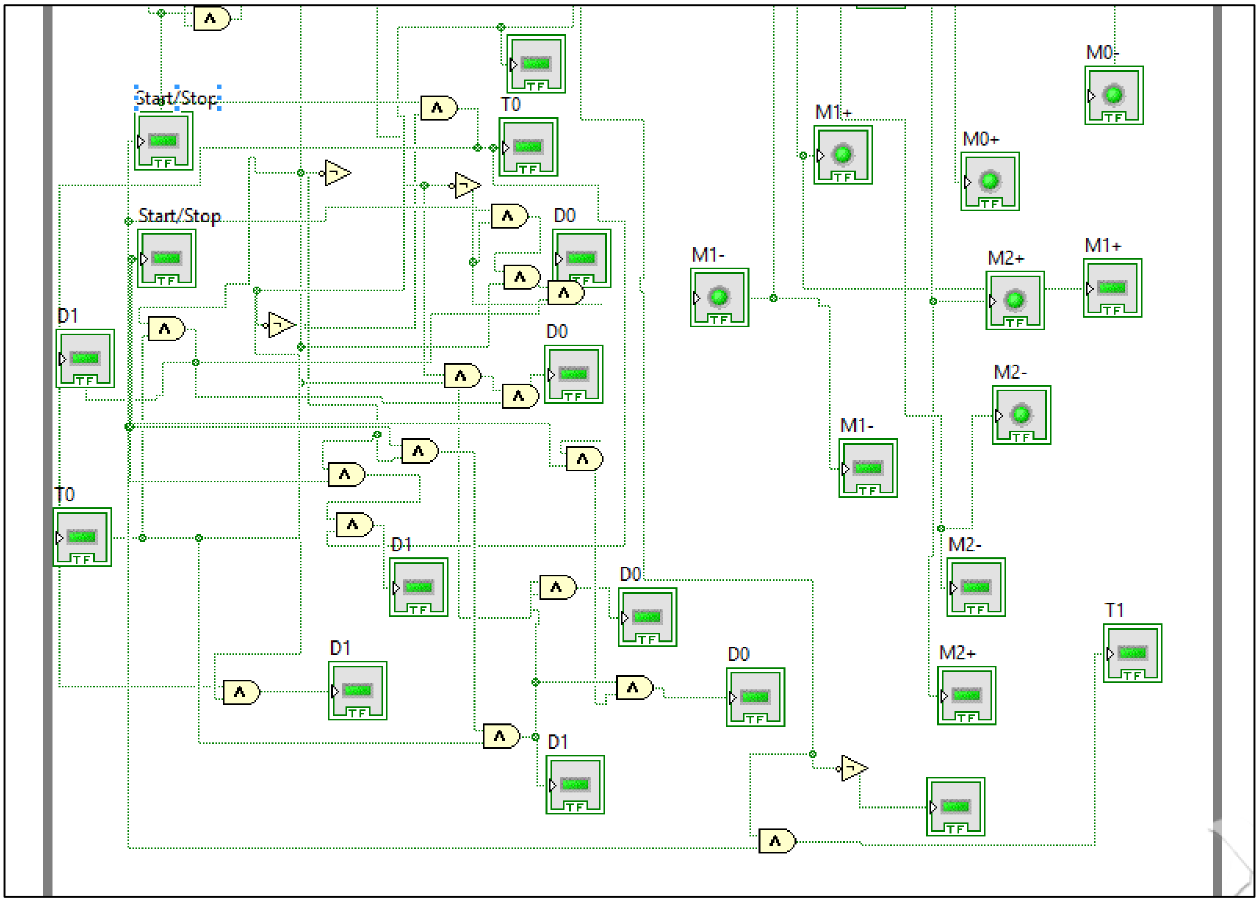

Fig. 18: Block diagram for the ladder diagram

Procedure to be followed during runtime

The timer value has to be set before the start button is pressed. On pressing it, the barcode scanner scans the barcode (here, we have used Booleans which have to be preset) and the motors make the belt move (belt 0) in the direction indicated using LEDs as per the desired located given by the barcode. On reaching the preset timer value, the belt stops moving and the next set of belts starts moving for the same amount of time, after which T0 is reset. Then, this belt stops and the first belts starts moving again, in the form of a loop, until the Start/Stop button is pressed again. The corresponding logic flow is shown on the ladder diagram on the front panel.

Limitations of the simulated model

The current model is made for direct implementation in an industry environment. Due to unavailability of data acquisition, a few parameters which are supposed to change in the physical world do not change in the simulation like the sensor values to detect whether goods are present on a given conveyor belt. To avoid runtime errors during simulation, these parameters have been removed, as mentioned before. The timer elements cause the program to run in a loop as LabVIEW does not permit an Indicator element to behave as a Control element during runtime, but we have provided a master Start/Stop button to overcome this issue to some extent.

Future aspects

The novel idea presented in this report can be applied to large warehouses. The only change will be an increase in the complexity. The complexity can be dealt with by using petri nets. Increase in the number of goods or destination is handled by effectively mapping the environment. Along with the current system of sorting, a retrieval system can be added.

Conclusion

The simulated version of a PLC-based material handling system works as desired considering an ideal environment in a warehouse. The design can be modified as per the complexity of the requirement. Automation of warehouses using such systems can greatly reduce the amount of human effort required and can also save on costs if the involved parameters are optimized for better profits. The efficiency of the system will also increase.

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