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Embedded PLC Trainer Kit with Industry Application

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Abstract*— The major obstacle to teaching Programmable Logic Controller (PLC) is a variety of PLCs and the rapid pace of technological development with new models and innovations .Moreover, costs incurred in the setting up of comprehensive and modern PLC laboratory facilities, and in the required period, updating of teaching material and equipment are, as are such, very high. After investigating the conception and features of PLC and embedded system, the development of the embedded PLC for teaching students is proposed in this paper with the seamless combination of the LabVIEW software and the AVR Microcontroller with the VB modules. The flexibility of the proposed PLC makes it relatively easy and less costly to teach the basic principle of different kinds of PLCs due to their variety and rapid change..The implementation of the embedded PLC is discussed and evaluated. The results of evaluation shows that embedded PLC can be taught satisfyingly and this Embedded PLC can be used for small scale industry for dedicated application. In this paper we are going to built bottle filling plant as an application.

Index Terms— **Programmable Logic Controller; Embedded System; Embedded PLC.**

I. INTRODUCTION

Programmable logic controllers (PLCs) are a specialized type of systems used to control machines and processes. They have been introduced in the early 1970s to replace the existing relay control logic that became obsolete and expensive for implementing systems at that time. On the other hand, PLCs have offered flexibility, higher reliability, better communication possibilities, faster response time, and easier troubleshooting. So far, PLCs have been mainly of interest for industrial control engineers that introduced, developed, and standardized their own design methods and programming languages [1], [2].

According to data mentioned above, a detailed understanding of the operation and use of PLCs is important for many undergraduate students, particularly those who seek eventual employment in these industries. However, problems and obstacles in the study and experiment on PLC is the rapid pace of PLC technological development, with new models and innovations continually being introduced by manufacturers. Future, PLCs are dedicated industrial controllers and, once purchased for laboratory use cannot be employed for a wide range of other useful applications. Costs incurred in the setting up of comprehensive and modern PLC laboratory facilities, and in the required periodic updating of teaching material and equipment are, as a result, very high [1].

Concept of PLC

An embedded system is a computer system designed to perform one or a few dedicated functions often with real time computing constraints. It is embedded as part of a complete device often including hardware and mechanical parts. By contrast, a PLC is designed to be flexible and to meet a wide range of end-user needs for industrial control application. Embedded systems control many devices in common use today. Embedded systems are controlled by one or more main processing cores that are typically either microcontrollers or digital signal processors (DSP). The key characteristic, however, is being dedicated to handle a particular task, which may require very powerful processors. Since the embedded system is dedicated to specific tasks ,design engineers can optimize it to reduce the size and cost of the product and increase the reliability and performance[2],[3],[4].

Concept of Embedded systems

Embedded system is based on computer technology, the software and hardware can be cut, makes it feasible to fit for different application system, in another point view, it is a special computer system which has strict requirements in reliability, cost, size and power consume. It is the outcome of combination of technology development, such as computer, semiconductor, communication, electronics and automation control. Embedded

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system has been widely used in computer network, telecommunication, consumer electronic product, industrial control fields, medical apparatus, aeronautics and astronautics, national defense industrial fields, and so on. The features of embedded system are as follows: (1) Embedding. (2) Special system. (3) Extended interface .But there are still difficulties in applying embedded system in control field. The problems include: (1) The design problem of embedded control system. (2) The reliability problem of embedded control system. (3) The compatibility problem of embedded control system.

Concept of Embedded PLC

Having investigated the conception and features of PLC and embedded system, in this paper the development of low-cost embedded PLC for teaching along with one small scale industry application is proposed. The conceptual design of embedded PLC combines the advantage of PLC and embedded system together. The architecture of embedded PLC is being developed by the LabVIEW with VB Module for AVR Microcontroller. The work of this development involves:

1) To design a PLC based on embedded system technology.
2) To develop a prototype embedded PLC.
3) To implement the prototype with some experiments for students.
4) To evaluate the embedded PLC by one dedicated application.

II. DEVELOPMENT OF EMBEDDED PLC

The aims of the embedded PLC are that it must support the sub-disciplines of software engineering, computer programming and panel wiring. While the basic system must support digital I/O, it should be expandable to support analogue handling. The detailed objectives being that it must [5]:

1. Be safe;
2. Be low cost;
3. Interface to a PC
4. Incorporate an industrial standard PLC
5. Support the IEC 6-1131 programming languages
6. Interface with common industrial electrical components
7. Be able to translate engineering ideas from theoretical description to practical tutorials

A. Hardware Design

We select to use the AVR microcontroller to develop embedded PLC because it is widely used across many embedded designs due to its low price, low power consumption, and wide variety of peripherals for many of the major silicon vendors. In addition, we can use the LabVIEW Embedded Module for graphical programming to the AVR microcontroller also. At the same time, the properties of the Atmega328P microcontroller of Atmega will be used as a determinant specifications and features of embedded PLC, as shown in Fig. 1 and Table I respectively.

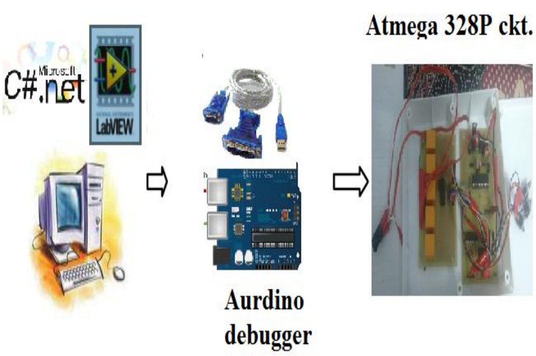

Fig. 1 Main components used in this work

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Besides the LabVIEW Embedded Module for AVR Microcontroller includes support for In-System Programming by On-chip Boot Program True Read-While-Write Operation and Programming Lock for Software Security. With this capability, a large portion of the application could be developed and tested before the hardware design is complete [6].

Feature	Atmega 328P 20 MHz core speed
Flash Memory	32 Kbyte
SRAM	2 Kbyte
Digital Inputs	6-Sink/Source, 24V DC
Digital Outputs	6-Sink up to 200mA each, 24V DC
Analog Inputs	6-Ch. 10-bit resolution, input range 0-10V
Analog Outputs	6-Ch., 10-bit resolution, output range 0-10V
Serial Ports	RS-232

Table I Specifications of Embedded PLC

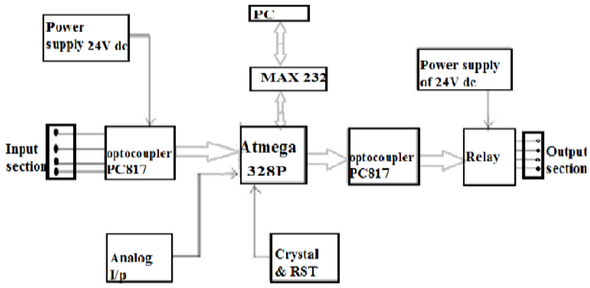

Fig. 2 The architecture of an embedded PLC

1) Digital input

Most equipment to be connected to digital inputs use24VDC such as switches, proximity sensors etc., therefore they require a circuit to isolate and reduce the signal. Fig.3 shows the internal circuit of the digital input.

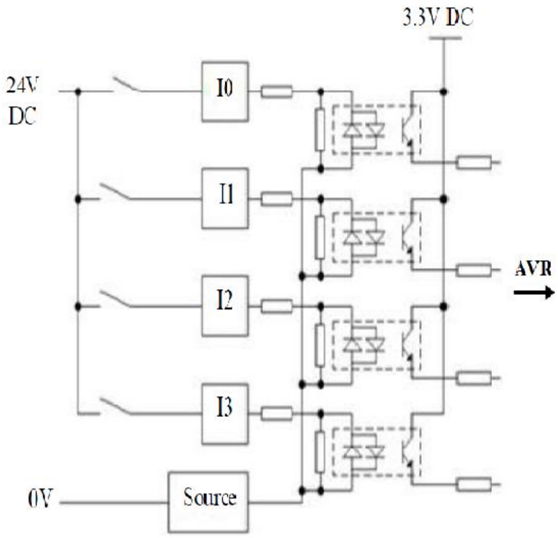

Fig. 3 Internal circuit of the digital input

2) Digital output

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Similarly to the digital input, most equipment to be connected to the digital output use 24VDC such as relays, solenoid valves of pneumatic and hydraulic system etc, therefore, they require a circuit to isolate and amplify the signal. Fig. 4 shows internal circuit of the digital output

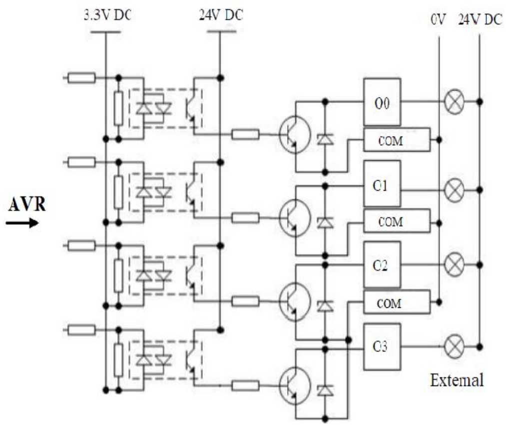

Fig.4 internal circuit of the digital output

3) Analogue input

Since the standard of voltage output of the sensor to be connected to the analogue input has voltage between 0 to 10V, it is required to reduce that voltage to 3.3V for the controller. For this, we use the voltage divider circuit, as shown in Fig. 5 (a).Also for converting purpose we can use zener regulator. The benefit is loss across resistors can be minimized and it will provide constant voltage.

4) Analogue output

Analogue voltage output from the Microcontroller is3.3V. Therefore, it is necessary to use the circuit to amplify the voltage from 0-3.3 to 0-10V, as shown in   Fig. 5 (b).

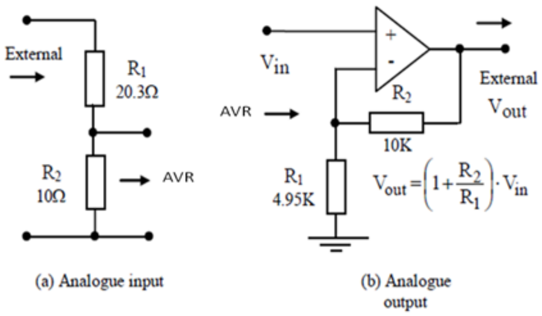

Fig.5 Internal circuit for analog input & analog output

B. Software Design

IEC 61131-3 currently defines five programming languages for programmable control systems: FBD (Function block diagram), LD (Ladder diagram), ST (Structured text, similar to the Pascal programming language), IL (Instruction list, similar to assembly language) and SFC (Sequential function chart). These techniques emphasize on logical organization of operations [7].

In this work, we use the FBD programming language for control of embedded PLC because the LabVIEW Embedded Module for AVR Microcontrollers is a comprehensive graphical development environment for embedded design. This module seamlessly integrates the LabVIEW graphical development environment and AVR microcontroller. This module builds on LabVIEW Embedded technology which facilitates dataflow graphical programming for embedded systems and includes hundreds of analysis and signal processing functions, integrated I/O, and interactive debugging interface. With the Embedded Module for AVR Microcontrollers, we can optimize linking and view live front panel updates using JTAG, serial, or TCP/IP. The Embedded Module for

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AVR Microcontrollers includes the LabVIEW C Code Generator, which generates C code from the LabVIEW block diagram [6].

For the creation of FBD language, we use the available tools in LabVIEW, as shown in Fig. 6.A basic function of FBD language is created according to IEC 61131-3 standards required for PLC which can be shown in Table II and Fig. 7 respectively.

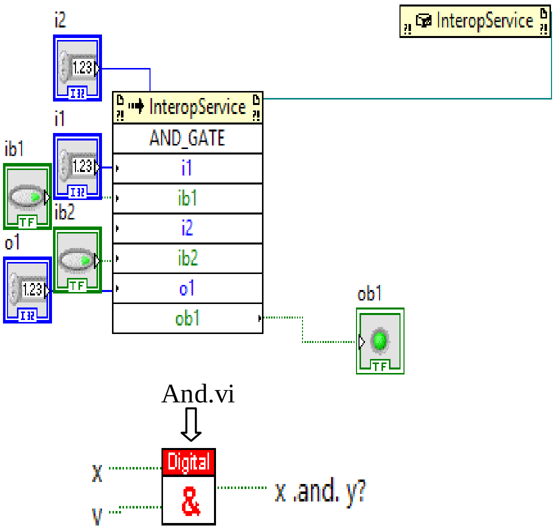


Fig. 6 Creating functions of FBD language

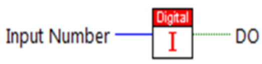
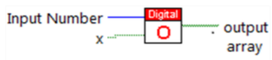
NOT	
AND	
OR	
DI	
DO	
AI	
AO	

Table II Examples of FBD language

III. IMPLEMENTATION OF EMBEDDED PLC

For the purpose of prototype testing, the system architecture has been implemented for students by testing some experiments like basic gates (AND, NOT, OR) along with some conditional examples. Architecture, operation, and programming language of PLC is observed. Moreover, parts of programming and control exercises were

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conducted also. The laboratory exercises included developing a FBD based on a scenario, testing it via the "simulated" model, after transfer proven program to the embedded PLC, then interfacing external equipment to embedded PLC, and finally executing the PLC program on the physical system. Fig.7 shows steps of implementation of embedded PLC.

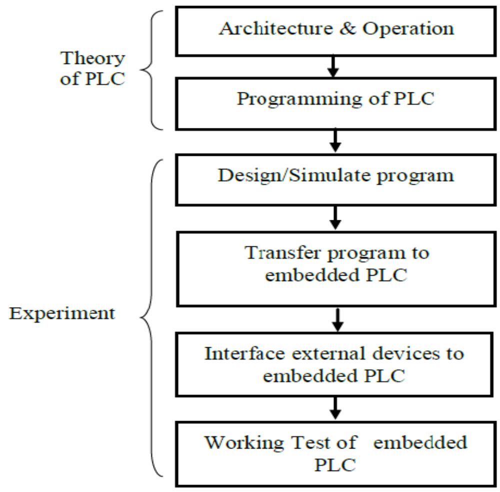

Fig. 7 Steps of implementation of embedded PLC

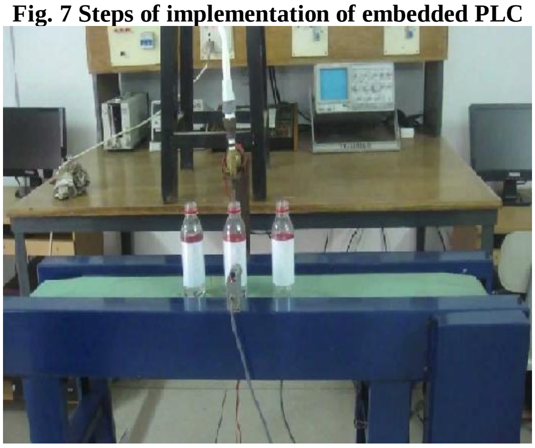

Fig.8 Application of embedded PLC

The example of interfacing industrial equipment to embedded PLC: Fig. 8shows the application of embedded PLC to control the bottle filling system.

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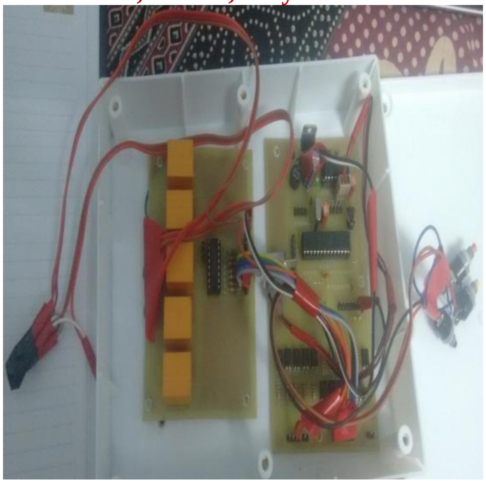

Fig. 9 depicts the actual Circuit i.e. embedded PLC to control the Bottle filling system.

IV. EVALUATION OF EMBEDDED PLC

After completing various laboratory exercises, we found various possible conditions consisted of thirteen statements broadly gauging the effectiveness of the embedded PLC. For each statement, we verified the condition. And according to that results are listed in Table III

Sr.No	List of Questions	Result
1	The Embedded PLC & all other hardware are safe.	YES
2	The embedded PLC is setup in relatively easy to understand and use format.	YES
3	The programming language has typical functionality such as logic, latching, timing, mathematics, etc.	YES
4	Input and output were appropriate	YES
6	To simulate the functionality of designed program before actual usage.	YES
7	PLC program file was easily downloaded to the embedded PLC.	YES
8	Able to interface with common industrial electrical components	MOST OF THE
9	Stability and reliability of embedded PLC.	MODERATE
10	Appearance of embedded PLC motivates to usage and experiment	SATISFACTORY
11	The time to study and learn	LESS
12	Able to translate engineering ideas from theoretical description to laboratory experiment	YES
13	Able to enhance learning	YES

Overall, Embedded PLC withstand very good to the questionnaire. The simplicity of Embedded PLC along with good reliability, which demonstrates the success in generating interests among the students. The questionnaire, as well as the discussions with the users, showed that the students were able to learn at their own pace owing to the user friendly and open architecture of the system. Feedback received during the embedded PLC is being explored to improve the overall user-experience and the system functionality .Also by using this Embedded PLC various dedicated applications can be implemented, as this Embedded PLC can sustained to better accuracy without using actual PLC.

V. CONCLUSION

The variety and the high cost in setting up PLC laboratory make it difficult to teach PLC to students. In this paper the development of a low-cost embedded PLC for teaching along with one dedicated application for small scale industry is proposed. The conceptual design of embedded PLC is combines the advantage of PLC and embedded system together. The architecture of embedded PLC is being developed by an AVR Microcontroller. The reason for the selection of the AVR microcontroller because it is widely used across many embedded designs due to its low price, low power consumption, and wide variety of peripherals for many of major silicon vendors. In addition, we can use the LabVIEW Embedded Module for development of standard language to AVR microcontroller (embedded PLC) also, using design the FBD language. The implementation of the embedded PLC is discussed and evaluated. The results of evaluation show that the developed embedded PLC is an effective teaching tool for students. So that by using this Embedded PLC one can do automation in industries also.

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