Implementation of Embedded PLC for Batch Mixing System by using ARM Controller

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Abstract— These As a result of rapid advancement of technology, complicated control tasks are accomplished with a highly automated control system. With current advancements and reconfigurability of manufacturing, programmable logic controllers (PLCs) have become an integral part of nearly all of today's industrial processes. A Programmable Logic Controller (PLC) is a specialized computer used for the control and operation of manufacturing process and machinery. PLC's are very important to automate any system. Embedded Systems are hardware and software components working together to perform a specific application. The conceptual design of Embedded PLC combines the advantage of PLC and Embedded system together. Embedded PLC is designed and developed for system automation. This Embedded PLC is ARM based system for processing the IO's. Embedded PLC makes powerful combination of LabVIEW software with LabVIEW Embedded Module for ARM Microcontroller. The features of the proposed PLC are flexible to design and make it relatively easy to learn programming and cost effective with high speed. The implementation of Embedded PLC is discussed and evaluated. For the testing of Embedded PLC prototype is developed as Batch Mixing System is implemented.

Key words: PLC, ARM

I. INTRODUCTION

Generally, PLC can be defined as a digital electronic device that uses a programmable memory to store instructions and to implement functions such as logic sequencing, timing, counting and arithmetic in order to control machine and processes. The term logic is used because the programming is primarily concerned with implementing logic and switching operations. PLC is designed for multiple inputs and output arrangements, extended temperature ranges, immunity to electrical noise, and resistance to vibration and impact. Programmable Logic Controllers are used in almost every aspect of industry to expand and enhance production. Where older automated systems would use hundreds or thousands of electromechanical relays, a single PLC can be programmed as an efficient replacement. The functionality of the PLCs has evolved over the years to include capabilities beyond typical relay control. Sophisticated motion control, process control, distributive control systems, and complex networking have now been added to the PLC's functions. Therefore, PLCs provide many advantages over conventional relay type of control, including increased reliability, more flexibility, lower cost, communication capability, faster response time and convenience to troubleshoot. To have an effective control, PLCs must be real time. A good definition of real time is "any information processing activity or system which has to respond to externally generated input stimuli within a finite and specified period".

The embedded system is designed to perform a specific task whereas as per definition the general purpose computer is meant for general use. It can be used for playing games, watching movies, creating software, work on documents or spreadsheets etc. Application specific requirements are key factor for the Embedded System.

Embedded PLC presented here is a combination of many features of PLC and Embedded System. Embedded PLC is an ARM microcontroller based system which incorporates the several modules such as wireless modules, sensors to accomplish specific task. ARM microcontroller is used to develop embedded PLC because it is widely used across many embedded designs due to its low price, low power consumption. The architecture of embedded PLC is being developed by using LabVIEW Embedded Module for ARM. By using Embedded Module for ARM lower development costs and faster development times is achieved. Batch mixing system is implemented by using proposed system.

II. LITERATURE SURVEY

Early PLCs, up to 1980s, were programmed using programming panels. It can be also uses the special-purpose programming terminals, which having dedicated function keys for the representation of the logical elements of PLC programs [2]. Ladder Diagram (LD) is one of the important techniques for the PLC programming. When system architecture becomes more complex, LD implementation for the system becomes very hard. Therefore the performance of the PLC decreases in such a situation because PLC processor does not having capability to perform complex computations [3]. For understanding ladder logic, only experienced engineers are required for troubleshooting the problems. Fresher or inexperience person who does not having more knowledge about the ladder logic results in increase downtime of PLC. For the execution of complex ladder diagram dedicated processor is required which requires large memory to store this ladder diagram [4]. There are different manufacture provides different software for PLC, but the same programming software is not supported for other PLC. Mostly for the PLC's I/O's are digital in nature, therefore for the conversion ADC and DAC are used, and then I/O's are applied to the PLC. By adding such extra circuitry makes complications for PLC design. PLC has limited transmission speed, it is normally in Kilobytes. That's why such a PLC not efficient for the high frequency application. This speed is not sufficient when your PLC is connected over the network or connected to internet. The most serious problem is attenuation of signal, distortion of transmitted signal & noise. Therefore by

assuming all these limitations PLC's are limited to several area applications.

Therefore to avoid such limitations of the existing system an Embedded PLC is developed. Such a proposed system is ARM based System. It uses the LabVIEW software with FBD programming language.

III. BLOCK DIAGRAM OF PROPOSED SYSTEM

To overcome all limitations of existing system & make Industrial Process automation smothers & flexible we propose new kind of system "Embedded PLC." Embedded PLC is actually an advanced industrial microcontroller system where you have hardware and software specifically adapted to industrial environment. Today, traditional PLCs are still in use at most plants, but windows-based PCs using the LabVIEW software are increasingly becoming the preferred control mechanism for new installations.

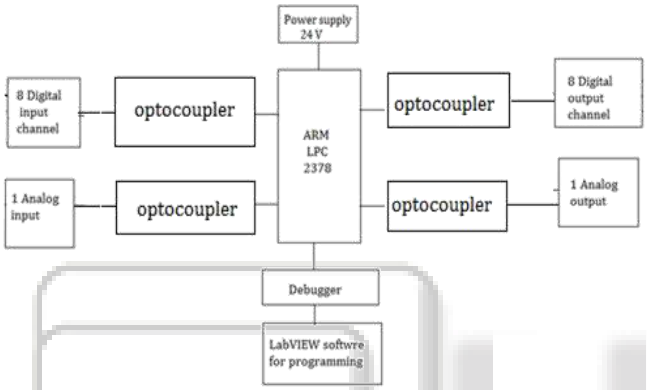

Fig. 1: Block diagram of Embedded PLC

For the implementation of Embedded PLC ARM microcontroller used. It has many advantages over the other controllers such as low price, low power consumption, and wide variety of peripherals. The input and output signals from the Microcontroller board are limited at 3.3V, so its re-design of input and output of embedded PLC to allow for usage with external industrial equipments, as shown by Fig.1.

For the analog input, the standard voltage output of the sensor has voltage range between 0 to 10V so, require to reduce voltage to 3.3V therefore voltage divider circuit is used. Similarly for the analog output, analog voltage output from the Microcontroller is 3.3V. Therefore, to amplify the voltage from 0-3.3 to 0-10V, voltage amplifier is used.

For the digital input, equipments to be connected to digital inputs use 24VDC such as switches, proximity sensor etc, therefore isolation is required to reduce the signal. Similarly for the digital output, 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.

The LabVIEW Embedded Module is used for graphical programming of the ARM microcontroller. Besides the LabVIEW Embedded Module for ARM Microcontroller includes support for the RealView µVision ARM simulator, which provides cycle accurate timing and logic simulation. With this capability, a large portion of the application could be developed and tested before the hardware design is complete.

IV. HARDWARE

ARM (Advanced RISC Machine) is the industry leading processor which provides high performance with common RISC (Reduced Instruction Set Computing) architecture .This processor is preferred more because of the load-store instructions, that process data on instruction and access memory on separate instruction and can access all 32 registers that are inbuilt. In this work, ARM7TDMI processor is used because it supports 3-stage pipelining and uses Von-Neumann architecture for achieving minimized energy consumption.

An opto-isolator or optocoupler, is a component that transfers electrical signals between two isolated circuits by using light. Opto-isolators prevent high voltages from affecting the system receiving the signal. Commercially available opto-isolators withstand input-to-output voltages up to 10 kV and voltage transients with speeds up to 10 kV/µs

The MAX232 is an IC that converts signals from an RS-232 serial port to signals suitable for use in TTL compatible digital logic circuits. The MAX232 is a dual driver/receiver and typically converts the RX, TX, CTS and RTS signals.RS-232 is a standard communication protocol for linking computer and its peripheral devices to allow serial data exchange. In simple terms RS232 defines the voltage for the path used for data exchange between the devices. It specifies common voltage and signal level, common pin wire configuration and minimum, amount of control signals.

The 78xx (sometimes L78xx, LM78xx, MC78xx...) is a family of self-contained fixed linear voltage regulator integrated circuits. The 78xx family is commonly used in electronic circuits requiring a regulated power supply due to their ease-of-use and low cost. For ICs within the family, the *xx* is replaced with two digits, indicating the output voltage (for example, the 7805 has a 5-volt output, while the 7812 produces 12 volts). The LM1117 series of positive adjustable and fixed regulators are designed to provide 1A with high efficiency.

V. SOFTWARE REQUIREMENT

The LabVIEW is a graphical programming language that uses icons instead of lines of text to create applications. In contrast to text-based programming languages, where instructions determine program execution, LabVIEW uses dataflow programming, where the flow of data determines execution. LabVIEW (short for Laboratory Virtual Instrumentation Engineering Workbench) is a Platform and development environment for a visual programming language from National Instruments. LabVIEW is a graphical programming language that uses icons instead of lines of text to create applications. In contrast to text-based programming languages, where instructions determine program execution, LabVIEW uses dataflow programming, where the flow of data determines execution. In LabVIEW, you build a user interface with a set of tools and objects. The user interface is known as the front panel. You then add code using graphical representations of functions to control the front panel objects. The block diagram contains this code. In some ways, the block diagram resembles a flowchart.

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 logical organization of operations [5]. IEC 61131-3 software can be structured into Program Organization Units (POUs), e.g. function blocks (FBs). FBs capture the structure and behaviour of a collection of objects used in automation projects. IEC 61131-3 FBD is evidently the need for a well-known comparison basis from industrial practice for empirical experimentation [5]. FBD: Function Block Diagram programming (IEC 61131-3) can be best predicted by the grade in mathematics, programming experience, and cognitive demand [5]. In this, we use the FBD programming language for control of embedded PLC because the LabVIEW Embedded Module for ARM Microcontrollers is a comprehensive graphical development environment for embedded design. This module seamlessly integrates the LabVIEW graphical development environment and ARM microcontroller. We can lower development costs and achieve faster development times by using the Embedded Module for ARM Microcontrollers to program ARM targets.

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 an interactive debugging interface. With the Embedded Module for ARM Microcontrollers, we can optimize linking and view live front panel updates using JTAG, serial, or TCP/IP. The Embedded Module for ARM Microcontrollers includes the LabVIEW C Code Generator, which generates C code from the LabVIEW block diagram [6].

VI. IMPLEMENTATION OF EMBEDDED PLC

An Embedded PLC is implemented by using LPC2378 ARM Controller. 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, the present we can use the LabVIEW Embedded Module for graphical programming to ARM microcontroller also. Besides the LabVIEW Embedded Module for ARM Microcontroller includes support for the RealView µVision ARM simulator, which provides cycle accurate timing and logic simulation. With this capability, a large portion of the application could be developed and tested before the hardware design is complete.

In this, we use the FBD programming language for control of embedded PLC because the LabVIEW Embedded Module for ARM Microcontrollers is a comprehensive graphical development environment for embedded design. This module seamlessly integrates the LabVIEW graphical development environment and ARM microcontroller.

We can lower development costs and achieve faster development times by using the Embedded Module for ARM Microcontrollers to program ARM targets.

Fig. 2: Embedded PLC for Batch Mixing System

Fig.3 shows the function block diagram for the system. The FBD code for the proposed system is generated by LabView Embedded Module used for ARM with the help of LabView software. This diagram gives the backend view for proposed system diagram. The backend defines internal structure of front window. It shows the inputs and outputs associated with ARM for batch mixing system. From the function palette components are selected.

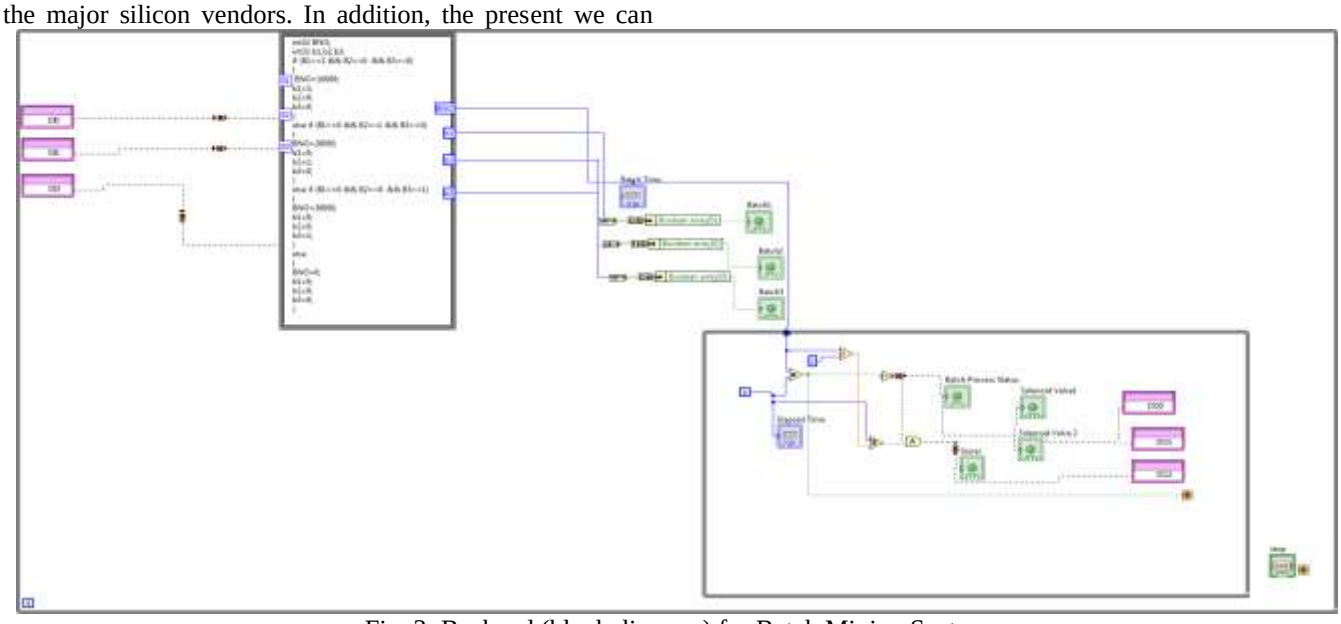

Fig. 3: Backend (block diagram) for Batch Mixing System

VII. RESULT

Batch mixing system is implemented by using proposed Embedded PLC. In Batch mixing system two liquids are mixed together with the help of mixer. There are two solenoid valves used for flow of water coming from two funnels. In such a batch mixing system the proportion of liquids flow is already fixed with the help of FBD language. Only control the time of flow is important task.

There are three push buttons are selected for three different proportions.

- 1st push button is set for the 50 ml amount of liquid
- 2nd push button is set for the 100 ml amount of liquid
- 3rd push button is set for the 150 ml amount of liquid

A. Process:

- The PLC program simulates a process of mixing two liquids coming from two different solenoid valves.
- The mixer will start whenever the start process button is enabled and the 50% amount of liquid coming from two different solenoid valves and collected into the tank.
- After collecting 50% liquid into the tank, mixer starts and it will run for remaining 50% amount of liquid collecting in tank.
- It means that mixer will shut off when 100% amount of liquid coming from two solenoid valves collected into the tank.

Fig. 4: Front Window for Application of Batch Mixing System

Fig.4 shows the front window for proposed system. There is simple presentation of working of proposed system is shown. In this diagram there are three push buttons are selected for proportion to form a batch. Also stirrer is used for mixing of two liquids. For that purpose two solenoid valves are used. From the control palette all this components are selected.

Sr. No.	Fixed Liquid Level (ml)	Desired Quantity(ml)	Measured Quantity(ml)
1	50 ml	25ml	23ml
2	100 ml	50ml	46ml
3	150 ml	75ml	69ml

Table 1: Readings for Liquid Flow Analysis

Table 1 shows the liquid flow analysis which gives liquid flow details for batch mixing system.

Sr. No.	Water (ml)	Process Time Desired	Process Time Measured
1	50 ml	10 Sec	9.36 sec
2	100 ml	16 Sec	17.99 sec
3	150 ml	23 Sec	26.09 sec

Table 2: Readings For Time Analysis

Table 2 shows the timing analysis which gives time period analysis for batch mixing system.

The response for Embedded PLC is given by mechatronics students [1] in the form of remarks like poor, fair, good, very good, excellent. The remarks based on following statements

- The embedded PLC and all the other hardware are safe.
- The embedded PLC is setup in a relatively easy to understand and use format.
- The programming language has typical functionality such as logic, latching, timing, mathematics, etc.
- Input/output were appropriate.
- Able to interface with PC.
- To simulate the functionality of designed program before actual usage.
- PLC program file was easily downloaded to the embedded PLC.
- Able to interface with common industrial electrical components.
- Stability and reliability of embed PLC.
- Appearance of embedded PLC motivates to usage and experiment.
- The time to study and learn not long.
- Able to translate engineering ideas from theoretical description to laboratory experiment.
- Able to enhance learning.

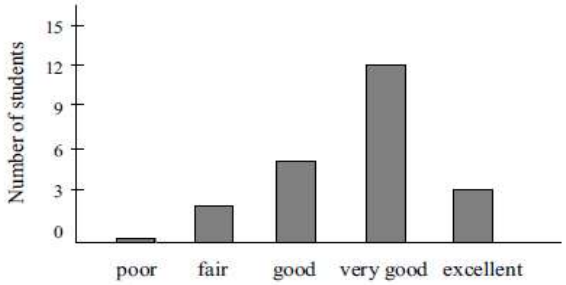

Fig. 5: Number of Students Who Score an Opinion on the Embedded PLC.

VIII. CONCLUSION

A cost-effective solution for an embedded Programmable Logic Controller (PLC) is the use of an Integrated Circuit (IC) that is a complete PLC. Using a single-chip PLC, development time is greatly reduced because the software drivers for various types of I/O are already embedded on the chip. Once the system I/O has been defined, the appropriate interface circuits can be added to the design and programming can be completed easily using the functional block diagram programming language and software such as LabView.

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