Design Architecture of Custom Configurable Process Automation System for Small Scale Industries

R. Sindhu, Anish Sathyan, and Vijaya Bhaskara Rao

***Abstract*—Process control systems deals with architectures, mechanisms, and algorithms for monitoring and controlling the intake and output of a specific process. Automation has had a notable impact in wide range of industries beyond manufacturing. Limited access to financial and technical resources is the major barrier in adopting advanced process control technologies in small scale industries. This paper describes the design aspects of Industrial System Monitoring Autonomous Remote Terminal (iSMART): Multi Loop Controller designed and developed by CDAC. The iSMART is equipped with modern data acquisition facilities, new generation control algorithms, and next generation communication interfaces. Custom configurable system provides freedom for the end users to selectively choose the most appropriate module for their application. iSMART could be used for the real-time implementation of feed forward or cascade control schemes, self-tuning or adaptive algorithms or optimization strategies. The iSMART is designed in such a way that it competes with the products of pioneers in automation in terms of the salient features and tops the above with respect to cost-effectiveness. The developed module provides a progressive path of adaptive migration to tomorrow's advanced Automation Systems Technology especially for small scale industries**

***Index Terms*—iSMART, real time operating system, scada, freertos, configurator, human machine interface**

I. Introduction

Automation is the use of control systems and information technologies to reduce the need for human work in the production of goods and services. The overriding motivation for automatic control system is safety, which encompasses the safety of people, the environment and equipment. Automatic control systems enable a process to be operated in a safe and profitable manner. Typically, an Automation system consists of input/output signals and data acquisition hardware, controllers, Human Machine Interface (HMI), data communication, communication networks, database systems and software. In the scope of industrialization, automation is a step beyond mechanization [1]. Whereas mechanization provided human operators with machinery to assist them with the muscular requirements of work, automation greatly decreases the need for human sensory and mental requirements as well.

In this paper the design features of iSMART is presented. The module is capable of acquiring both Analog Input(AI) as well as Digital Input(DI) signals. It can provide Digital Output(DO) as well as Analog Output(AO) signals based on the control loop execution. The controlled variable is first measured and an electrical signal is created to allow an independent closed-loop controller to control the variable. The measured value in the controller must then be compared with the desired value or the desired-value curve. The result of this comparison determines any action that needs to be taken.

Fig. 1. iSMART: multi loop controller

iSMART is equipped with powerful communication interfaces such as IEEE 802.11b/g (Wi-Fi), high speed USB interface, IEEE 802.3 Ethernet interface. Multi Loop Controller is operating with a tiny Real Time Operating System (RTOS) namely freeRTOS, synchronizing its operations with the real world situations, and enables an embedded web server which provides plant data wirelessly to any Wi-Fi enabled hand held device. The front fascia is equipped with two bar-graphs, LCD and a keyboard interface. The bar-graph indications give the status of the control loop execution and the LCD and keypad interface adds the autonomous property of the iSMART.

The iSMART can read and execute the configuration from its internal flash. The aim of any closed-loop control is to maintain a variable at a desired value or on a desired-value curve. The variable to be controlled is known as the controlled variable. Complex control loop algorithms can be developed using the loops and block diagram.

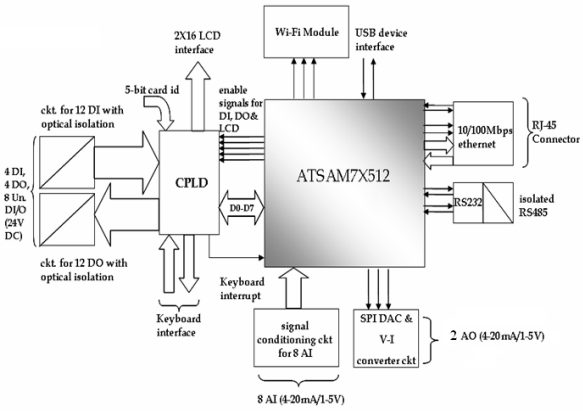

Fig. 2. iSMART architecture

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II. ISMART HARDWARE DESIGN

Multi Loop Controller is built around powerful AT91SAM7X512, 32-bit ARM RISC processor. It is having Internal High-speed Flash of 512Kbytes and High-speed SRAM of 128Kbytes. The entire hardware of Multi Loop Controller is housed inside a ¼ DIN panel mountable box. The block diagram representation of the system architecture is shown below.

iSMART interacts with the field devices, collects data, processes it and can send the processed data to the computer for better user interface. The manipulated variable of the continuous action controller changes continuously dependent on the system deviation [2].

iSMART gives the value of the system deviation as a direct actuating signal to the manipulating element. The peripheral blocks shown in the diagram gives a direct interface to the outside world.

A. Processor Module

Processor module consists of the processor AT91SAM7X512 and its associated circuits. The circuits include, the power supply unit, CPLD [3] interface for accommodating maximum number of field interfaces, and communication interfaces such as RS232/RS485, USB and Ethernet interface.

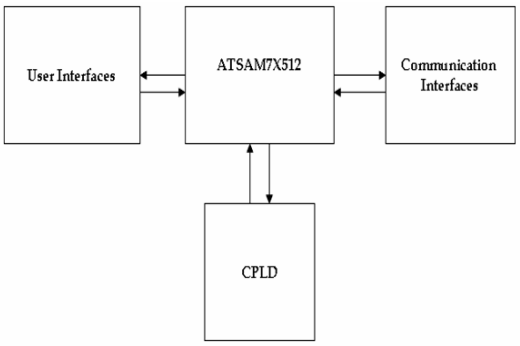

Fig. 3. Processor module

The CPLD is programmed such that it multiplexes various input / output signals with the processor I/O pins. The user interface mechanisms such as the LCD, and 2X4 keypad interface is also provided in the processor card itself.

B. Input/ Output Module

The Input / Output module comes in three flavors. The modules are of user configurable as per the requirement.

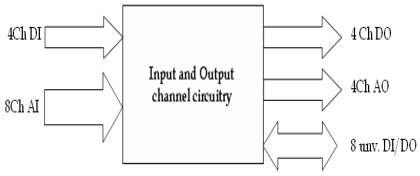

Fig. 4. I/O Module block diagram

The mixed I/O module is with analog as well as digital signal processing elements, whereas the Digital I/O module is for purely digital signal applications. The I/O module also includes the interface circuit for the Wi-Fi interface. The Serial Peripheral Interface is used for synchronous serial data communication between AT91 ARM Microcontroller and RCM4400W RabbitCore Wi-Fi module. The benefits of a Wi-Fi network includes extended access, cost reductions, and mobility.

III. DATA PROCESSING

The firmware for the Multi Loop Controller is developed on a low foot print RTOS called freeRTOS. The freeRTOS is one of the royalty free RTOS available. The entire functions of the iSMART is scheduled and controlled by the core of the freeRTOS. [4] The block diagram representation is shown below.

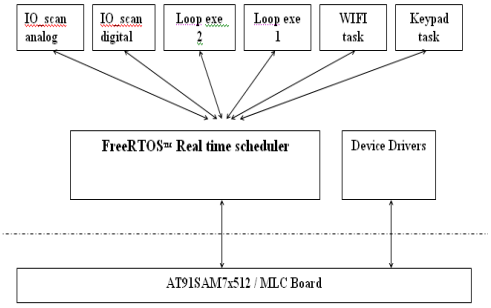

Fig. 5. Firmware architecture

The main functionalities of the iSMART is split into six different tasks. A simplified view of the operation of an iSMART and the function of the elements is as follows.

IO_Scan Analog
IO_Scan Digital
Looop Exe1
Loop Exe2
WiFi Task [5]
Keypad Task

Switching from a "one-big-loop" style of programming to a multithreaded real-time operating system (RTOS) can make sense in many applications. An RTOS can switch between multiple tasks, or threads of execution, so it appears that the tasks are running concurrently. Although the processor can execute only one task at a time, RTOS task switching gives the illusion of concurrent execution and gives the system a real-time appearance. The used round-robin scheduling algorithm attempts to share the CPU fairly among all ready tasks of the same priority. Round-robin scheduling achieves fair allocation of the CPU to tasks of the same priority by an approach known as time slicing.

IV. CONCLUSION

The ultimate goal of the iSMART is to assure the specified operational, safety and environmental compatibility of a specified industrial process. iSMART aims at affordable process control for small scale enterprises. iSMART can be function as a standalone module or can act as a part of a centralized SCADA system. The iSMART provides, in a single compact controller the advanced control features, network connectivity, communication features, device inter operability, and cost effectiveness. With these features iSMART had a notable impact in wide range of industries

beyond manufacturing and is going to be an integral part of meeting the new and diverse requirements, demanded in modern industrial applications.

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Sindhu R. Graduated in Electronics & Communication Engineering from College of Engineering, Trivandrum (Kerala, India) and currently employed as Associate Director in Centre for Development of Advanced Computing, Thiruvananthapuram, one of the premier Research & Development organisations under the Department of Information Technology. Over twenty five years of professional experience in product design and development of microprocessor based systems for process control applications, power distribution automation and vehicle tracking applications. Wide exposure to international state-of-the-art development activities. Good project management skills with ability and experience in managing project teams Started my professional career as a hardware/firmware (HW/FW) engineer in ER&DC (Electronics Research & Development Centre), KELTRON under Kerala State Electronics Development Corporation, later taken over as ER & DC (I) by Govt. of India. ER & DC (I) was one of the premier Research Institutions under Department of Electronics, Govt. of India and recognised as a National Centre of Excellence. During the initial years, had done HW/FW design work for Control Systems like DCS (Distributed Control System), APACS(Advanced Process Automation and Control System) and Energy Management System using processors like 8051and 80188. Later, led the project team in successfully implementing technologically innovative and state-of-the-art projects .

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Vijya Bhaskara Rao joined CDAC in 2004 and currently working as Scientist - C in CDAC, Thiruvananthapuram. The 7 years experience focuses on Research & Development, Installation and Commissioning in the area of Intelligent Process Controllers and Distributed Control Nodes that form part of the Intelligent SCADA System developed by CDAC, thiruvananthapuram. Successfully Instaklled power DCNs for the Teesta Canal Fall Hydel Power Station – II& III at West Bengal. Presently, working in the project Embedded Controllers under the ASTeC (Autonomus System technology Center), programme. As part of the ASTeC program, designed and developed iCON, industrial Controller, with new generation communication interfaces and with next generation control algorithms. Received 'Best Scientist Award–2011' of CDAC Trivandrum for the multi oriented performance during the period 2009-2011.