CONTROL SYSTEMS FOR ION BEAM APPLICATIONS BABY CYCLOTRONS

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Abstract

CYCLONE 30 and CYCLONE 10/5 are controlled by an industrial programmable logic controller (Simatic S5 Siemens). An industrial system gives reliability as well as flexibility. However, the relative simplicity of CYCLONE 3D has led us to choose a STEbus based microcontroller built around the Intel 8052 processor which is programmable in Basic or assembler. The STEbus allows the 8052 to access a large range of peripherals including digital and analog I/O boards and various user interface modules. A major concern in the design of our control systems is to provide a user friendly cyclotron interface. Since CYCLONE 3D and CYCLONE 10/5 are parts of radiochemical production units rather than cyclotron only, their control systems also take care of the chemical synthesis processes. The design of these systems is reviewed in this article.

CYCLONE 10/5 control system

Introduction

Firstly, the CYCLONE 30 (1) and CYCLONE 10/5 (2), (3), (4) control systems are safety systems based on 24 V relays signals. The reliability i.e. the lowest possible failure rate and the capability to operate in an industrial environment, is the first selection criterion.
Secondly, the control system has to be able to operate the entire facility. Start-up, shut-down, and switch-over must be very fast and must include sequencing, fault detection, analysis and auto-tuning. The user interface must be of the highest quality to ensure easy diagnostic of the cyclotron components and ancillaries, simple commands for cyclotron operation, easy maintenance ....
The effective cost is also an important criterion. This includes easy development, debugging and maintenance, and also extension facilities.

Goals and requirements

The following functions should be provided :

- A safety chain ensuring that the cyclotron works properly
- Basic commands for start-up, stop, standby, target and chemistry box washing ...
- Analog parameter control i.e., measurements and their processing allowing regulation, optimization of the beam current, ...
- Flexible User-friendly interface which enables the user to choose different operation modes.

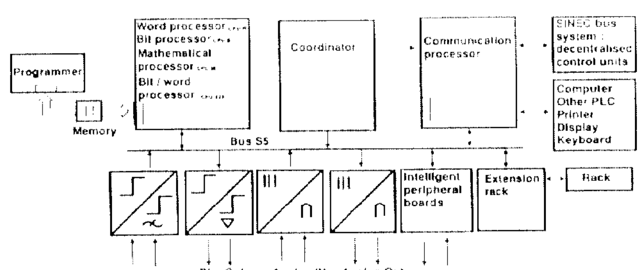
  Help to the user in case of failure and provide him with a safe fault finding procedure.
- A logbook recording normal operation parameters and failure events.
- Interface with some peripherals, such as printer, modem, computer,....

Architecture

Considering the criteria and functions mentioned above one of the best configuration is an industrial Programmable Logic Controller (PLC). PLCs are designed to work in industrial environments, their behaviour is well-defined even in extreme conditions, wiring is easy and simple. In order to have a compact system, the final choice is a centralised system. This is based on the PLC SIEMENS - Simatic S5, type 135-U (5).
At the time of the CYCLONE 30 development, the major disadvantage of PLCs was the relatively low processing speed. However, the selected PLC allows multi-processor operation and offers "task dedicated" processors (bit processing, byte processing or arithmetic computing), ensuring a fast global processing. A new processor combining quick bits and bytes processing is now available.
The system expansion necessary to meet the requirements of future developments and system upgrade simply involves adding new boards (digital or analog I/O boards, additional processor...).
The hardware configuration is shown in figure 1.
CYCLONE 10/5 including Cyclotron, targets and chemistry control system includes :

- -1 CPU R/S (bit and byte processing oriented)
- -1 Communication processor for a command / control unit (Keyboard, screen) and a Serial line controller (printer).
- -3 digital input boards (32 inputs/board)
- -12 digital output boards (32 outputs/board)
- -1 x 8 analog input board
- -1 x 8 analog output board.

CYCLONE 10/5 AND 30 CONTROL SYSTEM



Software tools

The PLC manufacturer provides a user-oriented programming language. User programs ("program and function blocks") can be written in the "statement list (STL)", "ladder diagrams (LAD)", "control system flowchart (CSF)" or Graph 5 methods of representation (5).
LAD is based on conventional schematic diagrams but is not used in our case.
CSF is a graphic representation of automation problems. It uses symbols representing logic gates, flip-flops, timers, counters . The vacuum control is a typical example of what can be represented using boolean algebra tools.

STL is a programming language approaching Assembly language, it offers a great amount of freedom and flexibility. It is used for analog parameter processing and for higher level commands.
For the sequential commands, the Graph 5 (similar to the french standard CEI GRAFCET) may be used. This language recognises two types of modules : The "sequence step" modules (where the program is executed) and the "transition conditions" (conditions allowing the passage from the sequence step n to the sequence step n+1 whereby the step n+1 begins only if the step n is successfully finished). Each step and each transition condition is programmed in any of the three types of representations described above. For the chemical synthesis, this way of programming allowing parallel and synchronised sequences is very useful.
In addition to the program and function blocks, Siemens provides tools to allow structured programming. Those tools may be "organisation blocks" for the cyclic running of the program or for a pre-programmed response following an interruption of the cyclic processing. This interruption may be prompted by any incident (power off, reset, ...).
The program or a part of it may be executed in a cyclic way or triggered by an alarm signal or started by a timer.
The possibility to program the system "on-line" and to visualise the process dynamically are very powerful tools.

User oriented features

Since CYCLONE 10/5 is a radiochemical production unit rather than a cyclotron only, the user interface enables the user.to choose the chemistry process without intervening in cyclotron operation. However, the cyclotron parameters can easily be visualised and/or modified by service people. The control station includes a high resolution color monitor to display the status of the chemistry as synoptic "pages". Other "pages" dedicated to cyclotron status are also available but not automatically.
The keyboard is used to send direct commands to the system. For each "page" of the screen a menu of programmed commands is assigned to the 16 function keys. An operation log sheet containing data calculated by the PLC and comments typed by the operator can be printed.
The operating modes are :

Automatic mode : This corresponds to the automatic start-up of all systems. The operator selects the desired product and the chemistry process is automatically started in connection with the cyclotron. Target and cyclotron parameters are automatically chosen.

Semi-Automatic mode : This corresponds to the automatic start-up of all systems on the basis of parameters given by the operator.

Manual mode : This mode is not normally used to start the cyclotron, it is mainly used for custom developments, or for some maintenance jobs.

Stand -by mode : This mode keeps the cyclotron and the targets ready to start i.e. the cooling and the vacuum systems stay on.

Vacuum stop mode : This status keeps the vacuum system in standby mode.

Total stop mode : This shuts down all systems.

All the security checks are controlled by the PLC. Although, it is possible to see the status of those interlocks during normal operation, display would occur automatically in case of failure.
This automatic checking procedure enables a safe start-up of the system.

CYCLONE 3D control system

Introduction

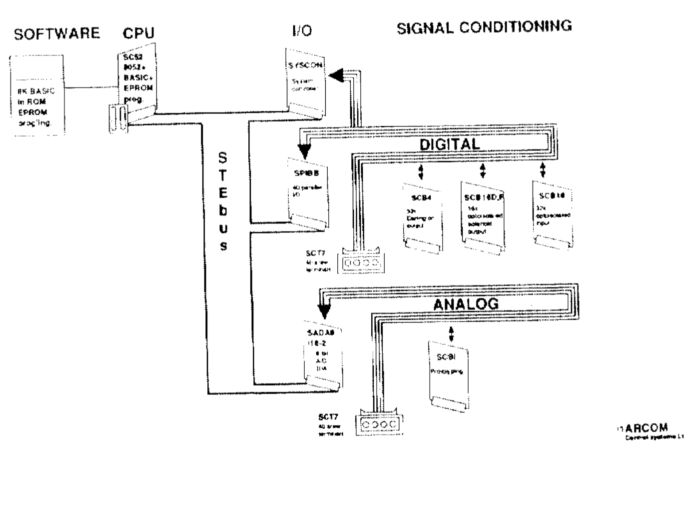
The relative simplicity of CYCLONE 3D has led us to reconsider the control system goals and requirements. The main requirement is a totally automated control without process visualisation. The user interface is reduced to a few commands (start-stop and the choice between one of the three available chemistry processes) and a minimum number of messages to display the cyclotron status.
We found that the performances offered by a PLCs and/or its user interface did suit our.
A bus-based industrial control system including a processor dedicated to the process control was choosen.

Hardware

The system is based on the STE bus.This is a high performance 8-bit bus standardized by the IEE 1000 in 1987. There are three types of boards : Processor boards (bus masters), peripheral I/O's (bus slaves), signal conditioning boards (to modify signals in order to make it readable by the peripheral boards). Backplane is used to connect bus masters and slaves, it has an eight-bit data path, with 1 Mbyte of memory space, 4 Kbytes of I/O space and board position independence.
The bus has multiple-master capability, up to 3 processors may work in the system using a bus arbiter. STEbus uses asynchronous handshaking to overcome possible problems due to the processor speed increasing.

The processor board is based around an INTEL's 12 MHz-8052 microprocessor with a one-chip Basic interpreter (MCS BASIC-52). It can be programmed either in basic and/or assembly language (the next generation is programmable in C). The programs can be stored in an EPROM to create a system which auto-starts from power-up. Peripheral boards include analog/digital inputs and outputs, real-time clock with RAM (or EPROM) and a system controller. Communication between the peripheral and the processor is via the STE bus backplane. The SPIBB® board has 40 digital I/O lines, 32 of these are buffered with 24mA TTL drivers. Directions for the drivers are controlled by software.
Signal conditioning boards (SCB) are designed to convert external equipment signals into voltage or logic levels that the peripheral boards can read. Connection between a peripheral and a SCB board is made using 50 way ribbon cables. Our hardware configuration is shown on fig. 2.
The chosen STE boards are designed by Arcom control systems ltd..

CYCLONE 3D CONTROL SYSTEM



Software

The software is developed in Basic. In addition to the standard Basic commands and functions , MCS® BASIC - 52 (Intel corporation) contains many features as bit-wise logical operators, such as AND, OR, Exclusive OR and hexadecimal arithmetic. As MCS BASIC-52 is an interpreted language, the programs can be developed in a interactive way without the repetitive process of editing, assembling, loading and running.
The user interface is via a pocket size micro-computer with an LCD screen. This small computer is connected to the processor via the RS232 port on the CPU board connecting also the terminal during the program development phase.

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