# Upgrading a Small Accelerator Control System

Li JiaQing, Zhang Lin, He MianHong, Lu ChengRong, Sun ChuanChen

Accelerator laboratory , Fudan University

Shanghai 200433 , China

## 1 How the question is raised

Fudan is one of the institutions that built and developed a single stage VDG in China as early as  the 1960 s. In 1987, Fudan imported a 9SDH-2 tandem accelerator with terminal voltage of 3MV from the NEC, USA. It has been running in good condition for ten years, and is playing an important role in the fields of nuclear physics, ion beam analysis, ion beam materials modification,  archaeology, and medical science.

The accelerator control system consists of four large instrument panels and includes more than 30 control units. Experienced technicians are needed in operation and in daily maintenance.

In 1995, we germinated an idea to upgrade the machine control system with computer aid so as to improve the feature of machine operation. Running parameters, such as ion species, beam energies, etc., are input through a keyboard in advance according to the requirements of an experiment. Operational data of the same type of experiment are then picked up from the database, which keeps the accelerator running in a normal and steady condition. What one has to do is to turn the power on, and the rest will be taken care of by the programmed computer.

## 2 Minimum control system

At the early stage of upgrading, we selected an "automatic energy scanning system" as our first goal of the whole long range plan,  because it related to less adjustment parameters, and addressed a series of key problems to be dealt with. From the system we can expect to get more experiences in hardware and software production and database management for further upgrading to the original control system later.

The output beam energy E is $E=E_0+(1+q)eV$, where $E_0$ is the initial ion energy, V is the terminal voltage, and q is the charge state after stripping. Therefore, there is a linear dependence of the energy E on the terminal voltage V. We can change V at equal intervals in order to change E, also at equal intervals.

The running process of the  automatic energy scanning system is as follows:

1. Turn on the accelerator manually, adjusting the ion beam to the target according to the  requirements of an experiment.
2. Input running parameters,  such as the initial, final, and interval energies, through a keyboard.
3. Start the automatic energy scanning system. Now the system is computer controlled rather than controlled by hand.
4. Check whether the situation meets the needs of the experiment.
5. Send a pulse signal to the digital beam current integrator and the counting system on the beam line to start.
6. Specific terminal voltage and beam current are controlled and stabilized by computer during the process.
7. The automatic energy scanning system automatically changes the terminal voltages, in turn, until reaching the end.

The automatic energy scanning system is reaching of great use in accelerator technique and nuclear physics experiment. It can precisely and automatically adjust the energies of accelerated particles, with a tolerance of less than 2 keV, which makes it convenient in the measurement of  an energy excitation curve.

## 3 Hardware and software development

The computer control system is composed in Master-Slave architecture. The main part in Master is a personal computer. It manages the user friendly interface, database management, communicating with Slave through a serial port RS232 and monitoring the readout acquired from Slave, etc. The Slave is a STD bus microcomputer system used for A/D conversion , D/A output, I/O interface, on-line monitoring terminal voltage and beam current and carrying out its PID control, etc. The STD bus is a main product in industry control field, which adopt the concept of functional modular. and is convenient to extend I/O interface. All of its pins have specific definitions, which makes it easy to design an I/O interface.

We designed two modular boards: FDAC-01, FDAC-02, according to the STD standard. The FDAC-01 is used to do A/D conversion, D/A conversion, I/O, etc. It is drawn forth to another  INTERFACE through two sockets of D model. It can be used to measure physical parameters from every control unit on the accelerator, and also to control the output voltage obtained from the computer. FDAC-02 is used to measure terminal voltage with a precision of 16 bit. It is also used to send a starting signal to digital current integrator and to receive a signal sent back from this integrator through four I/O channels .

FDAC-01 modular board has four parts: 16 channels A/D, 16 channels D/A, 16 channels IN and OUT. It uses an IC-74LS688 and DIP switches to set the board-select address and is linked with the high 8 bit address bus. (Every board has a unique address on the STD bus). 3-8 decoder is an IC-74LS138 which is used as a Chip-Select component. Chip-Select address is set by a LA4-LA6 in the low 8 bits of an address bus. MAX306 is a 16-channel CMOS Analog Multiplexer which is used to select the channel of A/D. AD574 is used to A/D conversion. Data is output in a parallel mode. A/D channels are directly linked
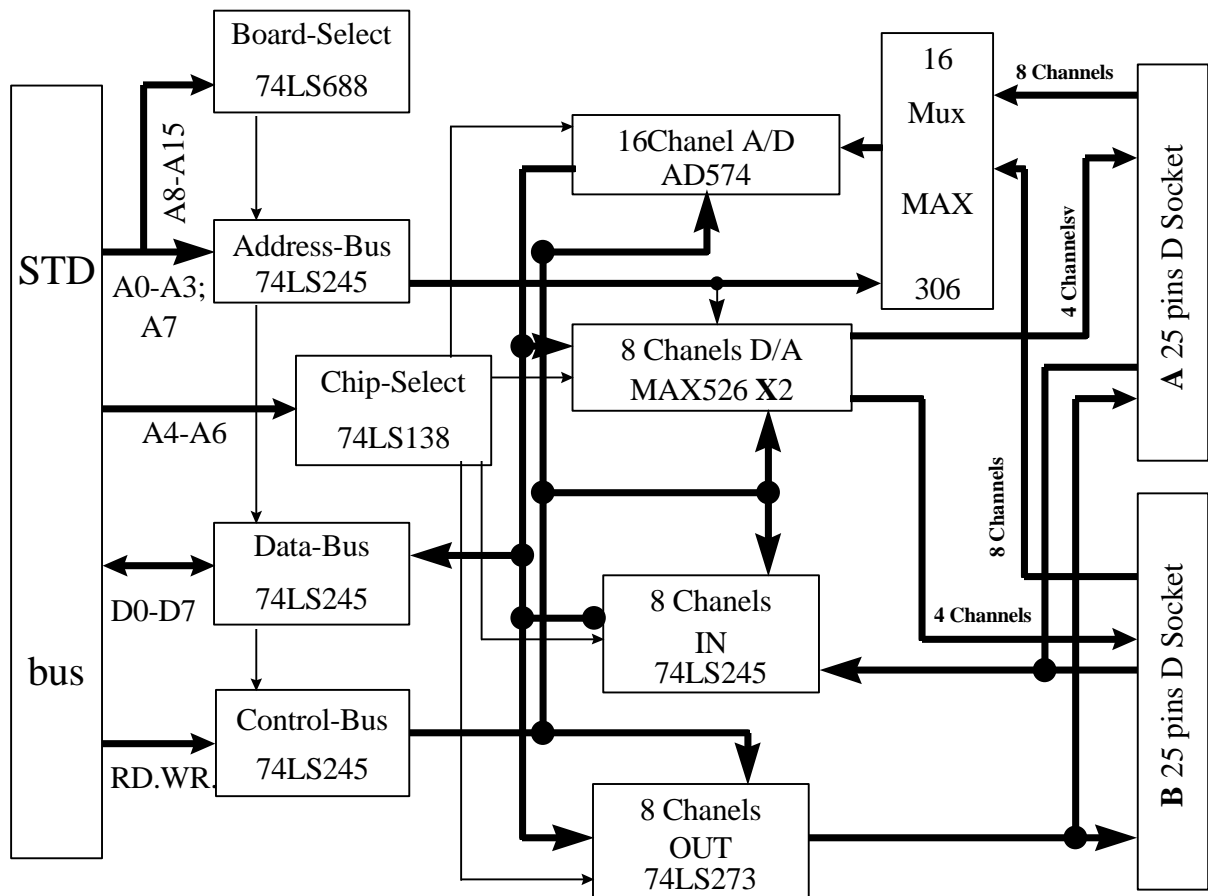
Fig.1 FDAC-01 Circuit Diagram

with the objects being controlled. MAX526 is used to D/A conversion (also in a parallel mode), which has 4 channels output, with 24-PIN , 300 mil plastic DIP, wide SO packages. It is convenient in hardware development.

FDAC-02 uses MAX195 from *MAXIM*, which is a 16-bit self-calibrating, 10 μs sampling ADC and has some properties: *Three-State Serial-Data Output, * Unipolar and Bipolar Input Range, *Small 16-Pin DIP and Wide SO Packages, etc.

We also designed an INTERFACE modular board, on which were assembled five relays and DaLinDun driving circuit. We put this board in the control box on accelerator as a interface between the STD system and the original control circuit system on accelerator .It is also used to transfer the control mode between the original man-mode and the computer-mode .When it is in man-mode all control parameters are gotten from the control units on the accelerator, when computer-mode , the control units on the accelerator are controlled by the STD machine directly. The states of relays can be known by 8 LEDs from IN1-IN8.

FDAC-01 and MCS51 CPU modular board are linked by a STD bus. Two 25-Pins D sockets are linked to INTERFACE board. The signal lines can be changed by some jump-switches on board according to the concrete conditions .

Software on the STD slave machine is written in ASM assemble language and includes D/A, A/D, I/O , WatchDog, etc. Timer, interrupt, and communication are used. While numerical value filter, PID control, etc., are used in data processing.

Software on the PC master machine uses *Visual Basic 4.0 and Window95*. It includes three parts: 1. man-machine interface 2. on-line monitoring physics parameters from the STD slave machine 3. database management. It involves some problems as follows:

1. At first, construct virtual instrument(VI) on PC s screen with *VB*. Beam current, energy, terminal voltage, magnet current and steering voltage must be on-line controlled and monitored . These can be done by using a series of visual custom control objects in *VB*. For example, "Label" can display data, "Graph" can display diagrams, "Slider" can be used as a knob to a control instrument.

2. Write event-driven code in *VB*. Transfer data and commands between the PC master and STD slave machine.

3. On-line display of experiment parameters and running conditions. These data can be saved in a run-time database so that we can resume to a certain state

according to the previous data stored in a database.

## 4 How the work proceeds

The automatic energy scanning system is composed of a master-slave architecture, which is a distributed control system. The master is a PC and the slave is an STD bus microcomputer system. In order to guarantee the hardware and software can work properly, we also made simulation equipment to simulate the actual running process in the automatic energy scanning system. We test the hardware and software with this simulation equipment before we can test it on the accelerator. We have finished the test work with FDAC-01 and INTERFACE board and found that the PC master and STD slave communicated properly with each other. The PC displays various on-line data including meter readings from the STD slave. Also, it controls the instruments linked with the STD slave according to a certain control algorithm such as PID, etc. The control algorithm is to be improved with the expandson of the controlling range.

It was the first time that we attempted to upgrade the control system of an imported tandem accelerator. Subjected to the difficulties, such as lack of experts, limit financing, and busy beam time to the machine in the laboratory, the whole process of the upgrading have to go on step by step from the very beginning. On the premise of keeping the integrity of the original control system and not interfering with the experiment work in the laboratory, we developed the needed hardware and software so as to have an easy transfer between the manual mode and the computer mode. The design idea that originated one year ago is being realized. After the design of a minimum control system, we are planning to expand the control range step by step to achieve the goal of controlling the accelerator by computer network.

## References

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