A MICROCOMPUTER-BASED VERSATILE PROFILE MONITORING SYSTEM

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Abstract

An inexpensive and versatile profile monitoring system developed for the MGC cyclotron of the ATOMKI is described. Rotating wire scanner units driven by stepping motors measure the beam intensity distribution with 1 mm resolution. The units have no sliding contacts, so noise problems at low intensities are avoided and beam profiles at any practical current value (100nA - 100μA) can be displayed. Intensity measurement and automatic range selection are also implemented. The system is built around a low cost microcomputer with high graphic capability and user--friendly software supports the operation. The hardware configuration and the software features of the system are given in this paper.

Introduction

The MGC cyclotron of the Institute of Nuclear Research of Hung. Acad. Sci. has been in operation since the end of 1985. There are 10 transport channels to the different target locations, some of them has a length of more than 20 meters and is equipped with a large number of focusing and correction elements[1]. The fields of application extend from nuclear spectroscopy measurements with low intensity beams to radioisotope production with maximum beam power.

To make the transportation easier, a profile monitoring system has been designed which gives the operators the necessary information about the beam shape and position in both transverse planes. Our design goal was to create a system which handles at least 16 scanning units and can produce profile distribution with 1 mm spatial resolution in a wide range of beam intensity.

Design considerations

At most accelerators moving scanners or/and harps are widely used to measure the beam profiles in the transport system. Scanners are usually preferred when high intensity beams have to be monitored. Recent results at TRIUMF[2] showed the capability of this profile monitor to measure beam current as high as 200μA. Among the different types of moving scanners the rotating ones are of simpler construction because they can be driven directly by the motor without any additional mechanism. But scanners have a serious drawback when the beam has macrostructure in time, because the scanning cycle has to be synchronised to the RF modulation and relatively high-speed rotation is required. Another approach is to step the scanner as slowly as the repetition rate and integrate the current value over the period of the RF modulation[3].

The latter solution was applied at our system. The RF modulation frequency of the MGC is 100 Hz, so the scanner has to remain in one position as long as 10ms. The simplest way of producing such low--speed motion is a stepping motor drive. In our system the motor movement, the data collection and the profile displaying is under computer control, which made possible to rotate the scanner back and forth between two final positions and to avoid the application of sliding connection. Not only reliability has been increased this way, but a possible noise source has been excluded, too.

Profile Monitor

Rotating wire scanner was chosen as profile monitor because of the simplicity in construction and reliability in oper-

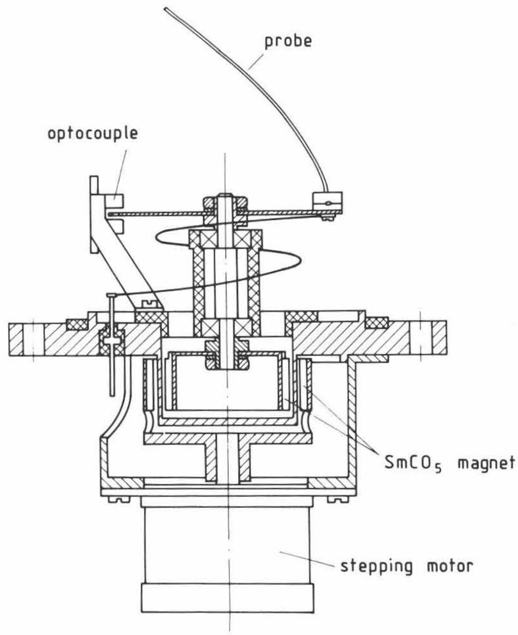

Fig. 1. Construction of the scanner head

ation. In order to obtain both profiles with one unit, the helical wire scanner[4] was applied.

The unit was designed to fit into the standard diagnostic boxes rotated by 45° around the beam axis. Where the diagnostic box cannot be rotated (e.g. because of the ion getter pump connection), a special auxiliary box of simple construction can be attached to it.

The scanner construction is shown in Fig. 1. A low-power stepping motor, making 200 steps in a revolution, drives the mechanism. The rotation is transferred into the vacuum by a magnetic clutch. The mass of the rotating parts was kept as low as possible and the power consumption of the motor is below 2 W.

The current pickup probe is a 1 mm diameter tungsten wire bent around with 45 mm bending radius. The region to be covered by the probe is 63 mm in diameter and the transversal displacement of the wire is 1 mm during one step.

The unit is equipped with an optocouple which signs the final positions of the rotating wire. The control circuit changes the direction of rotation automatically when this signal goes on and thus prevents the scanner to step out from the allowed range. The parking position of the probe is outside the beam aperture.

Hardware Configuration

The system hardware scheme is shown in Fig. 2. The microcomputer is a low cost Z80-based machine with 128 kbyte memory (Enterprise 128), which is connected to the system electronics through a bus driver. The hardware may be divided into three main parts, as motor control circuit, current amplifier and analog to digital converter. An interface circuit, built on standard I/O devices like Z80 PIO and CTC, links them to the computer. It also contains the required multi- and demultiplexers to handle 16 units.

The motor control circuit is placed together with the amplifier near the scanner head. It was designed to have minimum number of lines to the interface and has a local pulse generator and single step manual control as well for test and maintenance.

The current amplifier works as an integrator. The integration time is just the period of the RF modulation. Controlled current output is used to reduce the effect of electromagnetic interference and the ground loop noise. Only the selected scanner amplifier output is active during an analog to digital conversion cycle, so all outputs may be connected to a common coaxial cable. Since beam profiles have to be measured at very different intensity levels, the gain can be varied by the PC with two orders of magnitude. The full scales applied for the picked-up current are 0.05, 0.5 and 5μA respectively.

The integrated current values are converted into digital data by a 10 bit ADC with conversion time of about 15μs.

Software Features

The Enterprise 128 has some very attractive graphical features which can be used by simple calls of the EXOS operating system. Low resolution video pages with size of 336 x 117 pixels are used for displaying the measured profile and intensity data. When using two scanners simultaneously, two different pages are defined to the units and they are displayed together on the screen.

The main tasks are carried out by routines written in machine language because of speed requirements. A Basic programme provides the user-friendly environment around the machine routines and performs all functions which have enough time to be done.

The programme begins its run by the initialization routine. Each scanner is moved to its starting position and the code numbers of the active scanners are determined. Then the control returns to the

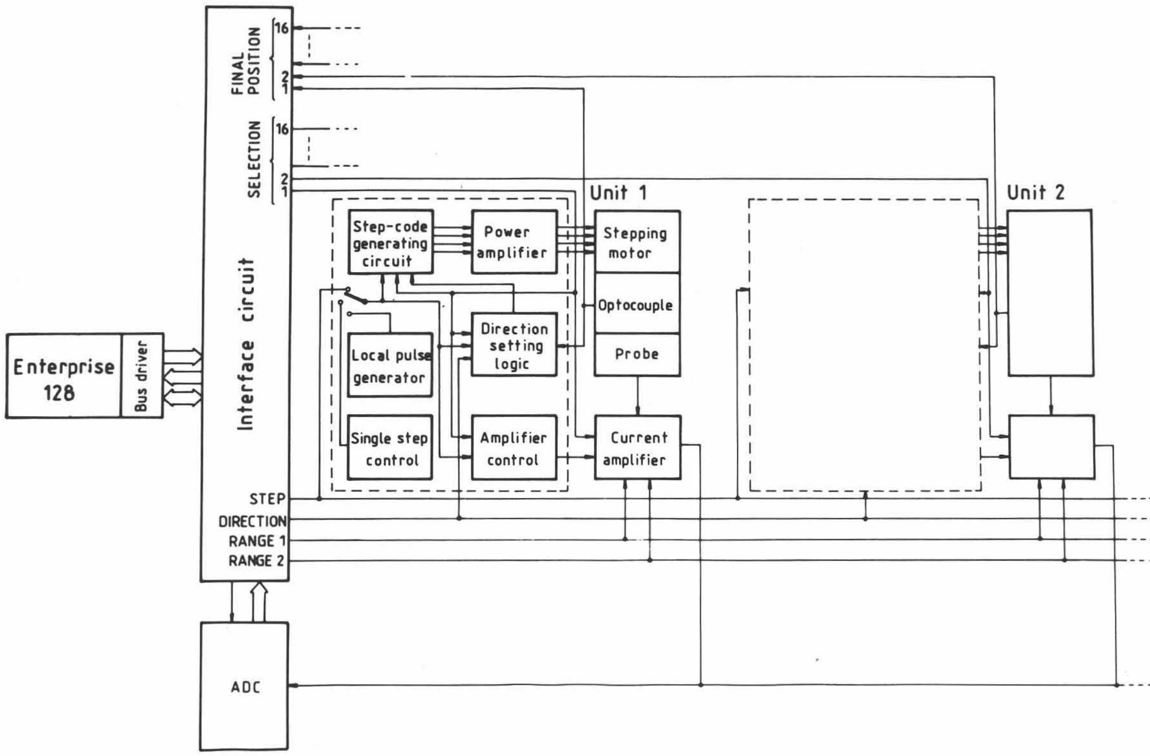

Fig. 2. System hardware

main Basic programme, which displays the menu and the list of the active scanners.

All the functions can be selected by single key action. Until now the following functions have been implemented:

- single or continuous scanning of one unit,
- single or continuous scanning of two units simultaneously,
- scanning and comparing with a stored picture,
- enlargement or reduction of the profiles,
- loading or storing a picture from/to a storage device and
- printing a hardcopy from the screen.

Before the data collection begins in a scanning cycle, the gain of the current amplifier is set according to the maximum value of the previous cycle. This method provides the intensity to be always measured in the optimum range.

The current picked up by the probe is summarized over the scanned region and an approximate total beam intensity is obtained. Its value is displayed between the horizontal and vertical profiles, as seen in Fig. 3. The picture shows two beam profiles taken at very different intensity levels. The lower one is a good evidence of getting high-quality beam profile and position information even at currents as low as 50nA.

Status

All the electronics and the system software have been completed and debugged. The prototype of the scanner head has been manufactured and installed in a transport channel near the cyclotron exit. Test measurements have just started and the first experiments with the system gave very promising results.

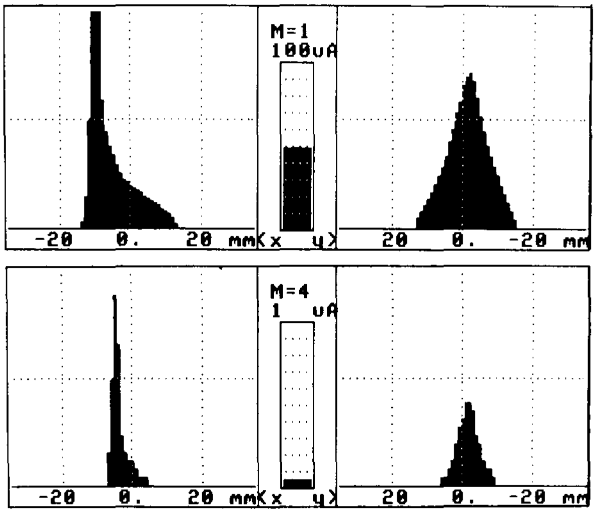

Fig. 3. Profiles of the 15 MeV proton beam at 50µA and 50 nA total intensities. The lower profiles are enlarged by 4.

Acknowledgements

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References

1.) Galchuk A.V. et. al., "Cyclotron Laboratory in the INR of Hung. Acad. Sci.", in Proc. 9th All-Union Accelerator Conf., Dubna, 1985, pp. 40-42.

2.) Bloemhard P. and Gelbart Z., "High Current Beam Profile Monitor (Wire Scanner)", in Proc. 11th Int. Conf. on Cyclotrons and their Appl., Tokyo, 1987, pp. 465-467.

3.) Zheng G.Q. et.al., "A Micro-Processor Based Measuring System for Cyclotrons", ibid, pp. 440-442.

4.) Hortig G., "A Beam Scanner for Two Dimensional Scanning with One Rotating Wire", Nucl. Instr. Meth., Vol. 30, 355 (1964)