

CONTROL SYSTEM OF THE SMALL ISOCHRONOUS RING*

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Abstract

The purpose of this paper is to describe the control system of the Small Isochronous Ring (SIR) developed and built at the National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University (MSU). SIR is a small-scale experiment that simulates the dynamics of intense beams in large accelerators. A 20 to 30 keV hydrogen or deuterium ion bunch is injected in the ring, extracted after a variable number of turns and its longitudinal profile is studied. Information about the electronics used and software written to control different injection line, ring and extraction line elements is included.

INTRODUCTION

Figure 1 shows a simplified schematic top and side view of SIR. Please refer to references [1], [2], [3] and [4] for additional details on the project. Results of simulations of the beam dynamics in the injection line and in the ring can be found in [5] and [6] respectively. Different diagnostic elements are described in [7] and latest experimental results in [8].

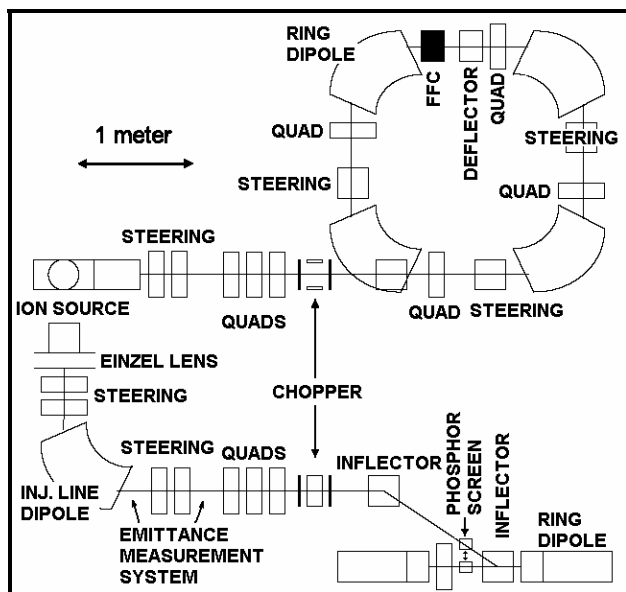


Figure 1: Top and side view of SIR.

ELECTRONICS AND CONTROL SYSTEM

Scanning Wires

Two pairs of scanning wires driven by stepper motors powered by a National Instruments MID-7604 power drive controlled by a National Instruments PCI-7334 motion controller can be used to measure transverse beam profiles in the ring. The beam current is read by a

Keithley 6485 picoammeter after the right signal is selected with a Keithley 7001+7158 low current switch. The analog output of the picoammeter is redirected to one of the analog inputs of a National Instruments PCI-6036E DAQ for further analysis. Both the picoammeter and the low current switch are controlled by a PC using GPIB communications.

A LabVIEW program is used to synchronize the data acquisition with the motion of the scanning wires.

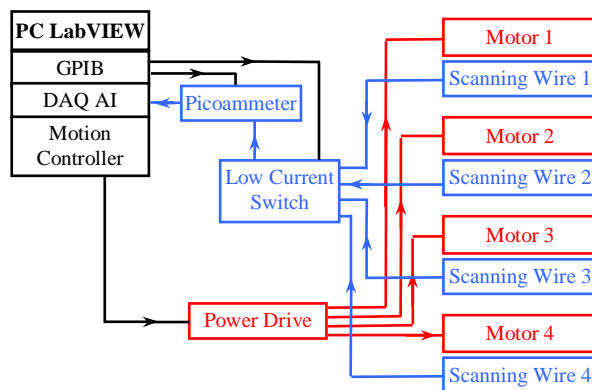


Figure 2: Layout of the Scanning Wires and their associated control electronics.

Emittance Measurement System

The Emittance Measurement System consists of a couple of movable slits. The portion of the beam that goes through both slits is collected by a shielded Faraday cup. The system is duplicated in the vertical and horizontal plane.

The layout of the control system is very similar to the one used for the scanning wires of the ring.

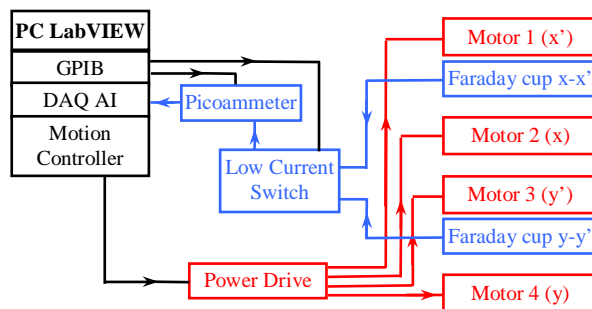


Figure 3: Layout of the Emittance Measurement System and its associated control electronics.

A LabVIEW program was written to automatize the data acquisition. By taking data as the slits move, complete scans (typically 125 x 50 points) can be performed in less than ten minutes. This same program

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also fits the measured data to an ellipse and displays its parameters. This information is later used to adjust the triplet of quadrupoles and the Einzel lens to match the injected beam to the close orbit solution of the ring.

Chopper, Inflector and Deflector Timing

A Thorlabs DG100N digital delay line is in charge of triggering the six DEI PVX-4140 high voltage fast switches at the right time. These switches produce up to ± 3.5 kV, down to 100 ns short pulses that are used to drive the chopper, inflector and deflector plates. Using a Tcl/Tk program running in a PC, that communicates with the digital delay line through the network and a LanTronix UDS-10 TCP/IP to Serial Port converter, parameters such as the length of the bunches that we want to inject as well as how many turns we want to keep in the ring before extraction can be changed.

The voltage monitor of the high voltage switch of one of the chopper plates is used to trigger the acquisition of the beam profiles in the oscilloscope.

The dc high voltage is provided by the CAEN SY2527+A1733 power supply that is also controlled through the network.

A square wave generated with a Leader LG1311 waveform generator is used to trigger the digital delay line. A HP-53131A frequency counter is used to precisely measure this frequency that determines how often bunches are injected in the ring (~ 1 kHz).

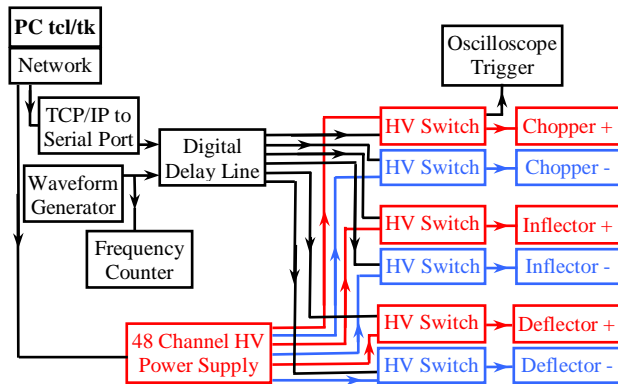


Figure 4: Layout of the Chopper, Inflector and Deflector and their associated control electronics.

Fast Faraday Cup

A movable Fast Faraday Cup (FCC) is used to measure the longitudinal profile of the extracted bunches. The FCC is moved by a stepper motor powered and controlled with the same power drive and motion controller as the scanning wires.

The beam current as a function of time is measured by a LeCroy LC-684DXL digital oscilloscope (1.5GHz bandwidth, 8GS/s, 16MPoints memory) after it is amplified with a Miteq AM-1309 / Miteq AM-1607-1000 broadband amplifier (50/40dB gain, 8/12dBm maximum output power, 10kHz-1GHz Bandwidth). The voltage monitor of the high voltage switch of one of the chopper

plates is used to trigger the oscilloscope. The data can be downloaded from the oscilloscope using GPIB communications.

The e^- suppressor can be biased to measure real beam current or it can also be used to further amplify the signal adding to the incoming proton beam current the outgoing secondary e^- current.

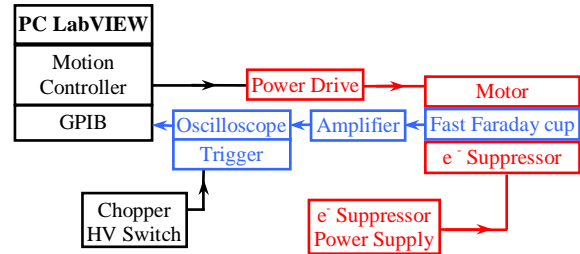


Figure 5: Layout of the Fast Faraday Cup and its associated control electronics.

Dipoles, Quads, Steering, Einzel lens and Extraction Power Supplies

Since the energy of the beam is lower than 30keV we were able to effectively use a number of electrostatic elements (a triplet of quadrupoles in the injection line, a quadrupole in between dipole magnets in the ring, six pairs of steering plates, chopper, inflectors and deflector). A modular CAEN SY2527+A1733 was chosen because of the relatively high number of high voltage power supplies needed. Control software with basic functionality was provided by the manufacturer. A LabVIEW program to store and recover the status of all the channels was written.

Two 30kV/5mA Spellman power supplies are used to bias the Ion Source and the Einzel lens. These units include analog outputs proportional to the voltage and current that were connected to the analog input channels of a National Instruments PCI-6036E data acquisition card in a PC. They also include an analog input that can be used to set the voltage of the supply.

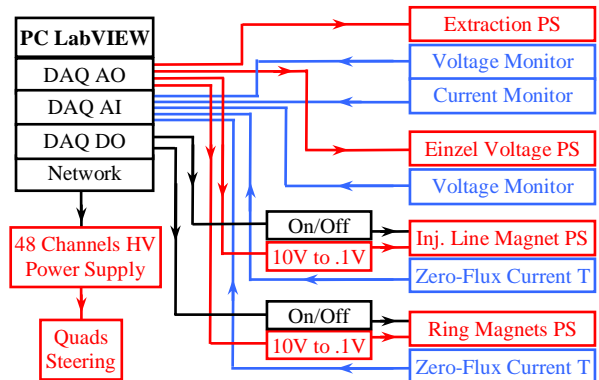


Figure 6: Layout of some of the power supplies used in SIR and their associated control electronics.

Two 135A/20V TCR Electronic Measurement power supplies are used to drive the four ring dipole magnets connected in series and the injection line dipole magnet.

Two Holecch Zero-flux current transformers are used to precisely measure the output current produced by the supplies. The output of the controllers of the current transformers is connected to the analog input of the DAQ card.

A LabVIEW program was written to set and monitor the Einzel lens and extraction voltages as well as the dipole currents.

Phosphor Screens

Two phosphor screens provide visual information about the position and transverse profile of the beam. The first one is movable and is located in the injection section of the ring. It can be used to observe at the beam either coming from the injection line or in the median plane after a single turn. The second one is permanently located above the medium plane of the ring, opposite to the Fast Faraday Cup. The deflector plates can be used to kick the beam off the medium plane and direct it to the screen that can also be used as a non-shielded Faraday Cup.

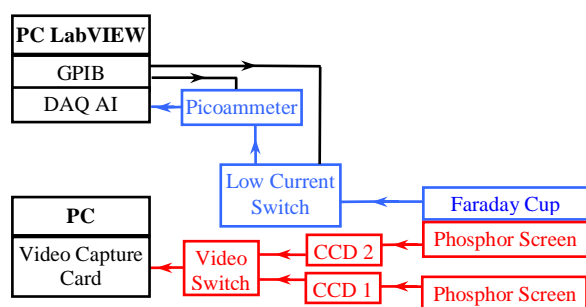


Figure 7: Layout of the Phosphor Screens and their associated control electronics.

Two CCD cameras connected to a generic video capture card through a video switch allow us to take digital pictures or movies using software developed at the NSCL.

The fixed phosphor screen is connected to one of the channels of the same low current switch used for the scanning wires and the emittance measurement system.

Other Systems

There are other systems that are not currently computer controlled. Some of them are:

- Magnetic Quadrupole Correctors
- Magnetic Dipole Correctors
- Ion Source instrumentation
- Pressure Gauges

Two bipolar 12A/36V Electronic Measurement power supplies are used to power the magnetic quadrupole corrector coils. They could be computer controlled if necessary. Four 3A/15V Agilent E3610A power supplies are used to power the magnetic dipole corrector coils. They do not have any kind of remote control capabilities.

The Ion Source instrumentation includes a filament power supply, an arc power supply and a Pirani gauge. They are all biased to the extraction voltage ($\leq 30\text{kV}$). At

this time, they are operated manually using insulating rods attached to the different knobs. A fiber optic transition between high voltage and ground could be used to operate them remotely in the future if necessary.

Up to five ion gauges are used to monitor the pressure in different parts of the accelerator. The ion gauge controllers (Varian Ratiomatic 843) have analog outputs that could be used to record the pressure as a function of time.

CONCLUSION

An inexpensive PC-based control system for SIR has been completed. A good number of electronic components previously available in the lab have been reused further lowering the overall cost of the project.

The performance is considered satisfactory and able to cover all present needs. Later upgrades are possible if considered necessary in the future.

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