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A MULTICHANNEL INTEGRATOR AND SCANNER FOR WIRE PLANE BEAM PROFILE DISPLAYS*

F. HORNSTRA, JR.† and J. R. SIMANTON+

Accelerator Division, Argonne National Laboratory, Argonne, Illinois, U.S.A.

High Energy Facilities Division, Argonne National Laboratory, Argonne, Illinois, U.S.A.

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A multichannel analog integrator followed by an electronic scanner routinely generates oscilloscope displays of external proton beam profiles from wire plane monitors at the Zero Gradient Synchrotron. The profiles are generated each machine cycle of the synchrotron or more frequently. Beam line monitoring is now possible by directly sensing the fundamental properties of the beam such as beam position and size. As a result, a simple, meaningful, quantitative monitoring tool is provided as an alternative to monitoring all beam transport elements.

1. Introduction

A simple multichannel analog integrator followed by an electronic scanner routinely generates oscilloscope displays of external proton beam profiles from wire plane monitors[1]) at the Zero Gradient Synchrotron (ZGS). The system simultaneously samples all wires, dispensing with the digital memory required by our previously published sequential scanner[2]). Simultaneous sampling has the important advantage of eliminating beam intensity structure distortion of the profile data. The output profile is always normalized; that is, the area under the profile is proportional to the amount of beam which passes through the chamber during sampling duration. These profiles are generated

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† Present address: Meson Physics Division, Los Alamos Scientific Laboratory, Los Alamos, New Mexico, U.S.A.

+ Present address: National Accelerator Laboratory, Batavia, Ill., U.S.A.

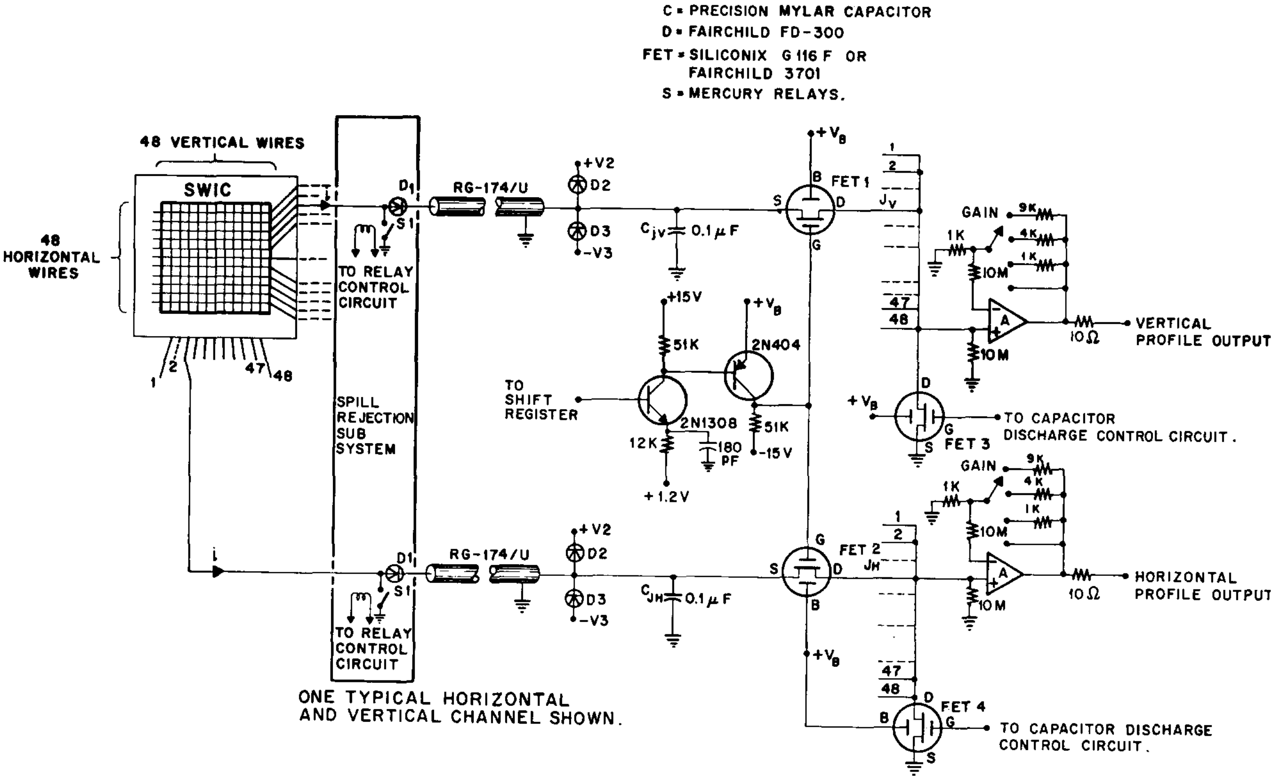

Fig. 1. Integrators and scanning system for segmented wire ion chamber (SWIC).

each machine cycle of the ZGS, or more often, depending on the duration and quantity of beam current. A feature of the system allows unwanted or arbitrary portions of the beam current to be rejected from the profile.

2. Description and operation

The integrator, scanner, and the spill rejection system are depicted in fig. 1. Neglect for the moment the relays S1 and diodes D1 (the spill rejection system) near the chamber. Each wire of the chamber is essentially connected to a miniature coaxial cable (RG-174) to bring the signal out of the proton beam shield wall to the scanner. The cable is connected to a 0.1 μF precision mylar integrating capacitor with the cable capacitance forming part of the integrating capacitance. As a protection to the electronics, low leakage diodes D2 and D3 in series with voltages V2 and V3, respectively, form a limiting circuit to prevent the capacitor voltage from exceeding safe values in the event that the capacitors do not get discharged periodically for any reason.

The interconnection of the signal cable and the capacitor is connected to the source of a MOS FET (Metal Oxide Substrate Field Effect Transistor) which is characterized by a high "off" resistance ($>10^{10}$ Ω) and a low "on" resistance ($<10^3$ Ω). All drains of the FETs associated with the horizontal array are connected together as are the drains associated with the vertical array. The drain interconnection of each array is connected to an output amplifier which has a high input impedance ($\sim 10^8$ Ω) compared to the "on" resistance of the FET. As a result, small error in the sampled voltage exists and the droop in capacitor voltage is negligible during the sampling time.

The gates of the FETs are driven by a two-transistor buffer amplifier whose output swings from 15 V positive (FET off) to 15 V negative (FET on). The buffer amplifier is controlled by a micrologic shift register which, on command, sequentially turns on, then off, each FET at a 10 kHz rate. Accordingly, a scan is completed in less than 5 msec. A gap of approximately 5 μsec is provided between the turn-off time of one FET and the turn-on time of the next to prevent a capacitor in one channel from coupling into an adjacent channel. As indicated in fig. 1, each buffer amplifier drives two FETs, one in the horizontal array and one in the vertical array, so that the horizontal and vertical profiles are generated simultaneously. Such an arrangement not only offers considerable savings in hardware and circuitry, but independent gain in each output is available for unsymmetrical beam profiles.

The capacitors are discharged by continuously cycling the shift register for a 100 msec period while FETs 3 and 4 are turned on to clamp the drain interconnections at ground.

The mercury relays S1 and diodes D1 mentioned earlier, provide a spill rejection system. When the relays are energized, unwanted portions of the beam spill are shunted to ground while the diodes D1 preserve any previous accumulated charge on the capacitors. All relays operate in unison so that a normalized profile will always result. Relatively small portions of a long spill may be either preserved or rejected since the relays operate in 1 msec. Placing the relays close to the chamber is important as any capacitance between the chamber and the relay must be discharged each time they are operated.

The capability to reject portions of the beam current is desirable for a number of reasons. At the ZGS, beam targeted on targets other than the extraction target results in some protons being extracted which are off axis and off momentum. Normally, EPB experimenters gate off their instrumentation during the duration of this unwanted proton beam; therefore, to reject this unwanted beam from the measured profile is desirable. It has now been established that the relatively small amount of beam in these parasitic spills contributes no measurable distortion to the profile.

Secondly, the spill rejection system allows beam profiles to be determined for arbitrary portions of a long duration ($\sim$0.1 to 1 sec) beam current. The undesired portion can be simply rejected and the scan will yield a profile corresponding to the remaining spill. Preliminary studies so far have indicated no significant change in the beam size between the first half and the second half of extracted beam from the ZGS.

3. Results

Figs. 2 and 3 are beam profiles obtained with this system at the zero focus of the external proton beam, while figs. 4 and 5 are those at the second focus. Approximately 2×10^{11} protons distributed over 500 msec generated the signal in these figures. Intensities lower than 1×10^{10} distributed over the same period generate good quality profiles.

4. Discussion

Beam line monitoring can now be undertaken by directly sensing the fundamental quantities of interest, i.e., beam position and size. In the simplest form of monitoring, the behavior of an entire, multiple focus proton line can be conveniently checked at the last focus. Correct conditions there virtually assure that everything is satisfactory along the beam line and with

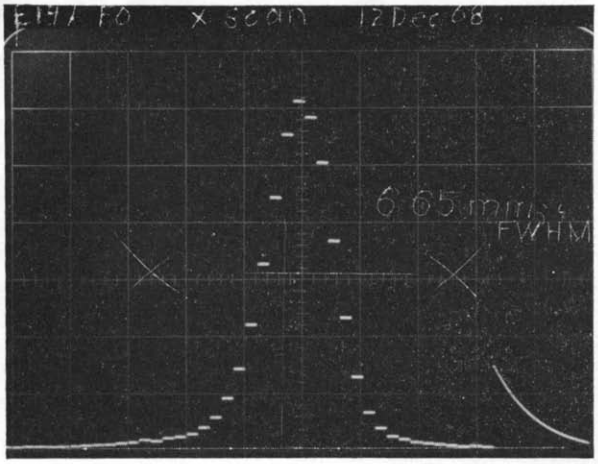

Fig. 2. Horizontal profile of external proton beam at F0.

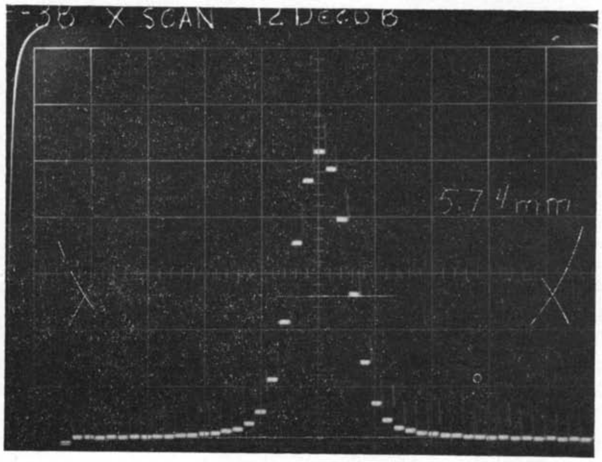

Fig. 4. Horizontal profile of external proton beam at F2.

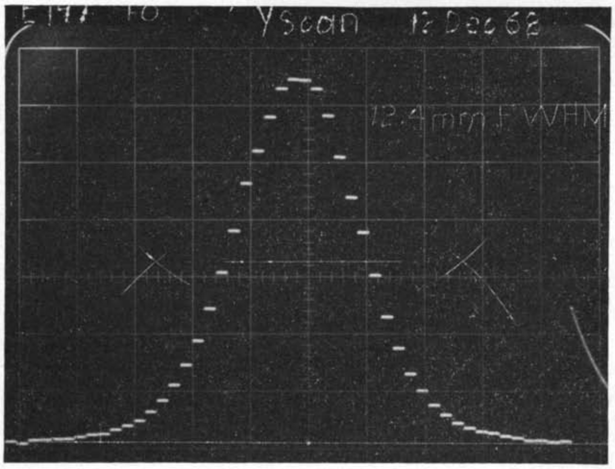

Fig. 3. Vertical profile of external proton beam at F0.

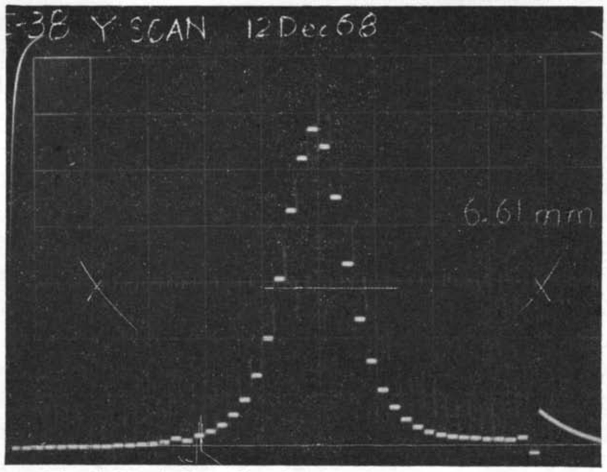

Fig. 5. Vertical profile of external proton beam at F2.

the extraction system. In practice, one monitors at intermediate foci for use of the experimenters concerned and for conveniently isolating the offending area should trouble develop. In all cases, this instrumentation offers a simple, meaningful, quantitative monitoring tool as an aid or alternative to monitoring all beam transport elements.

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References

[1] F. Hornstra, Jr. and J. R. Simanton, Nucl. Instr. and Meth. **68** (1969) 138.

[2] J. R. Simanton et al., Nucl. Instr. and Meth. **68** (1969) 209.