An embedded beam diagnostic electronics for 230 MeV superconducting cyclotron radial probe and scanning wires

Tianyi Jiang, Zhiguo Yin, Yang Wang, Qiqi Song, Xueer Mu, Ping Liu, Tianjue Zhang

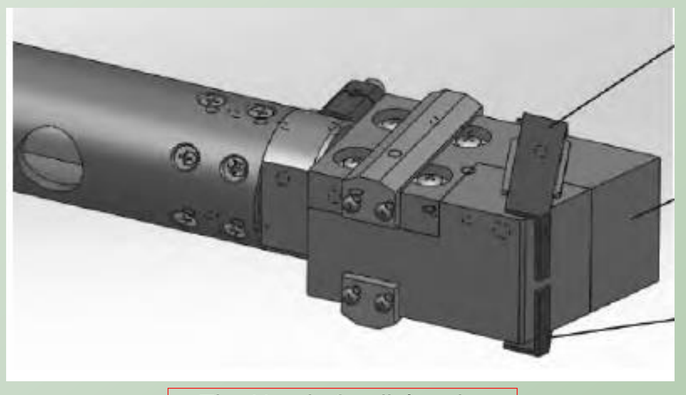
China Institute of Atomic Energy, P.O. Box 275(3), Beijing 102413

Abstract

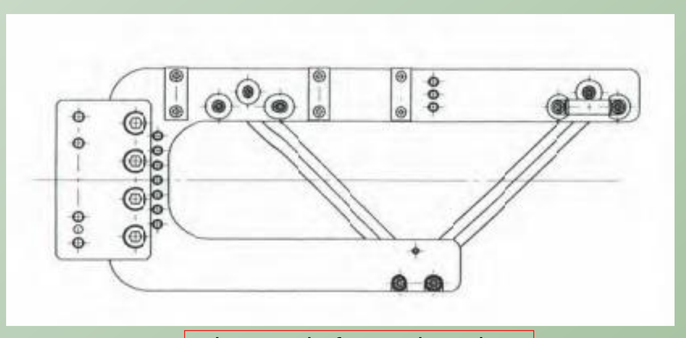
For the 230MeV superconducting cyclotron, once again, the differential radial probe has been proven to be crucial for the beam commission procedure. It can provide various information about the particles inside the cyclotron, such as the vertical position, the relative intensity as well as the oscillation frequency and radius, etc. In practice, however, the electronics system suffered from the leaking alternating RF field as well as the static magnetic field. Besides the EM shielding, an absorptive high-frequency filter has been included as the first element of the readout electronics. A high dynamic range readout electronic unit has been included to adapt to the fluctuation of the beam in the hole commissioning phase. The electronics box is designed as a network-attached embedded device so that it can be powered by a POE switch and transmits measurement results via MODBUS protocol. A dedicated digital signal processor and calibration units are also included, together with the ADCs, to facilitate the daily calibration process. The same electronics are used for the beamline wire scan system to determine the position of the beam, with a small improvement at a lower range. The design of this multi-purpose beam diagnostics electronics will be reviewed in this paper, together with several measurement results inside and outside of the cyclotron.

General description of radial probe and scanning wires

The radial probe is used to dynamically measure the state of beam with a radius of 300mm to 850mm within the accelerator. The drive unit of the radial probe is mounted on a stand and the target rod drives the radial target head, which is fixed to the drive unit. The drive unit drives the target head in a reciprocating motion inside the accelerator and a potentiometer determines the position of the head movement.
Scanning wires are used to determine the position of the beam.



The Head of radial probe

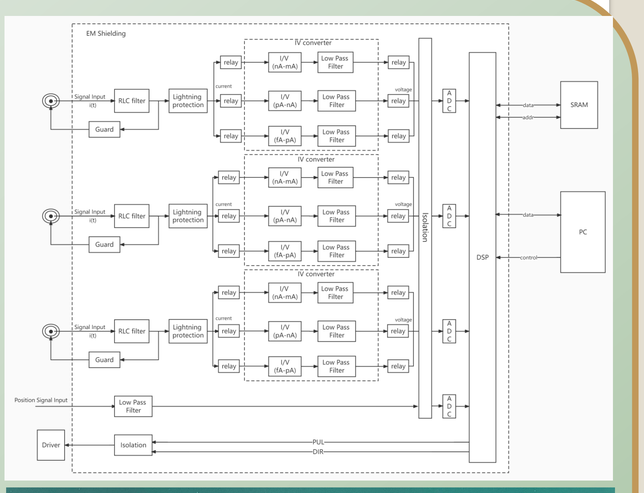


The Head of scanning wires

Design Overview of the beam diagnostic electronics

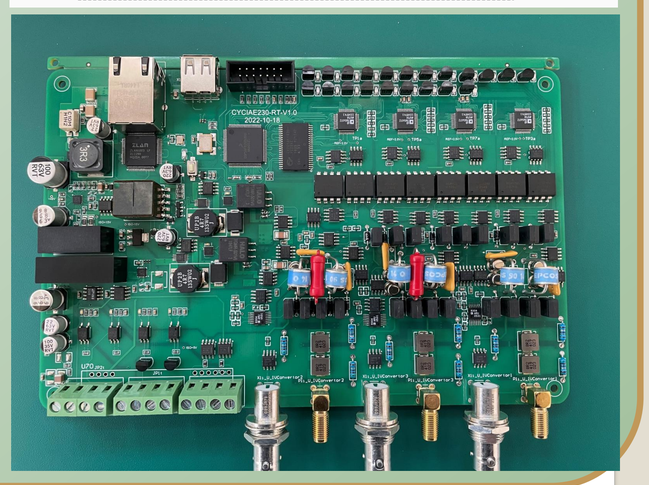
The electronics system:
- High-frequency filter
- Lightning protection
- I/V converter
- ADC, DSP
- POE power supply

The system transmits measurement results via MODBUS protocol. The core part of the electronics is the I/V conversion circuit



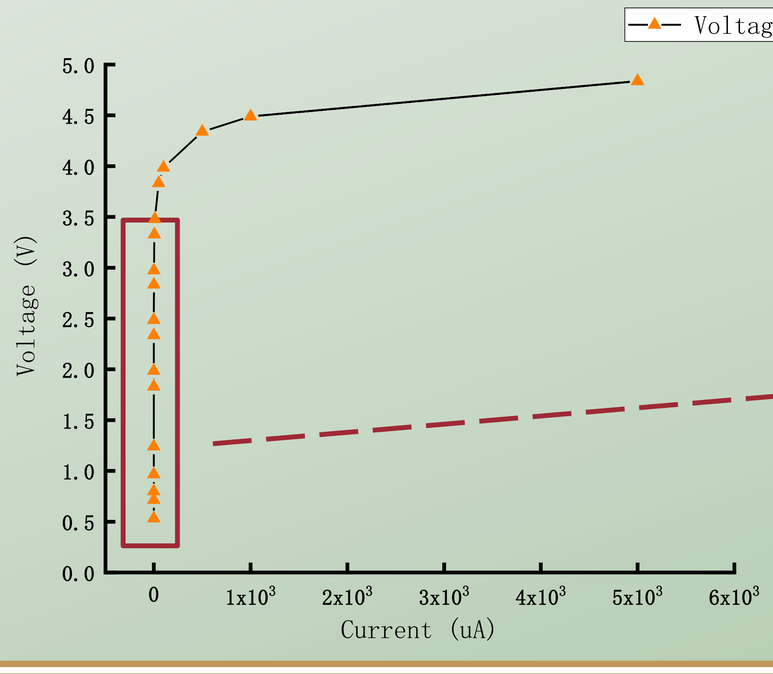
An ultra-wide range I/V converter circuit is used for the acquisition of radial probe signals. It is based on a logarithmic amplifier, and current from 0.1nA to 5mA can be measured.

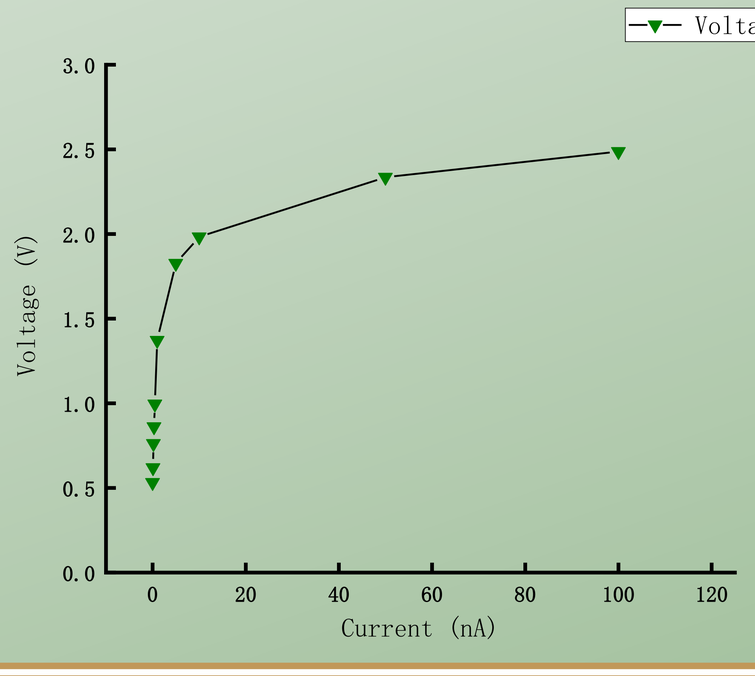
A weak signal I/V converter circuit is available for the beamline wire scan system. It is based on a transimpedance amplifier circuit and enables signal acquisition in the fA-pA range.



Experimental results

The results of the ultra-wide range IV conversion are shown in the figure. The figure on the left shows input currents from 0.1nA to 5mA, corresponding to output voltages from 0.5V to 5V. The figure on the right shows in more detail the output voltage corresponding to an input current below 100nA. It can be seen that the input current is logarithmically related to the output voltage, and the I/V converter sensitivity is high when the input current is weak.





Conclusions

The 230MeV superconducting cyclotron commissioning procedure requires the use of a radial probe to obtain the state of the beam inside the accelerator. A high dynamic range readout electronics unit was designed to accommodate the beam fluctuations during the hole commissioning phase. An ultra-wide range I/V conversion circuit based on a logarithmic amplifier enables high dynamic range signal acquisition in the nA-mA range. In addition, A weak signal I/V converter circuit are used for the beamline wire scan system. Use of electronic shielding and high frequency filters to protect electronics from RF field and magnetic field.