The Proportional Ion Chamber and its Corresponding Circuit

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Abstract

High pressure electric current type ionization chambers have been used for pulsed radiation field measurement of accelerators for long time. The ion chamber like proportional tubes may improve the sensitivity and lower the cost of the ion chambers system. An amplify factor of 1,000 to 10,000 is introduced in the proportional area. With which the sensitivity of the tube is much higher than the ion chamber. At the ion chamber area, it fits the needs of very high radiation field.

As the corresponding circuit, a low cost high sensitivity current digitizer has been designed and tested. It can respond to the weak current of 1 x 10^{-13} A and has nice linearity between 5 x 10^{-13} to 2 x 10^{-7} A. The system covers 10^8 order of radiation field.

According to the level of radiation field, the high voltage on the tube is switched between proportional area and ion chamber area. A micro controller is employed for read out and the switch control. The system can be used for accelerators pulse radiation monitor and can also be used for beam loss measurement.

1 The detector

1.1 The structure of the detector

The Xe gas filled proportional ion chamber is made by Dr. Li Jiyuan in another Institute in Beijing. The thin copper tube chamber has a gilded tungsten filament in diameter of 5 μm for central pole. A protection ring on the isolator is used for grounding the detector. The detector has a size of 220 mm long and 50 mm in diameter. The sensitive volume is approximately equal to:

$$V = \pi r^2 \times h \times 0.8 \approx 7 \times 10^{-4} m^3.$$

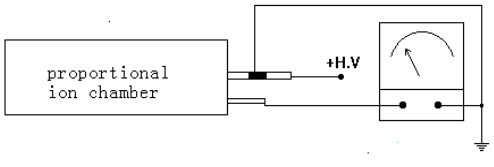

Fig. 1 The proportional chamber test circuit

The isolation resistance of the isolator is higher than $10^{14}\Omega$.

The detector is tested with a electrometer. The test circuit shows as fig. 1. The central wire is connected to high voltage plus. Electric current signal is extracted from the wall of the chamber. The High Voltage can be adjusted from 0 to 2000V with steps of every 50V between 0 to 1000V and every 100V between 1000V to 2000V.

1.2 The testing of the detector

To test the detector with radiation source, a radiation source of 7mCi Ra226 is at the distance of 0.5 m. Fig 2 and fig 3 shows the relationship between High Voltage and signal current at ionization area and proportional area. We can see the detector has a good linearity in proportional area and while in the ionization area, the curve is flat enough.

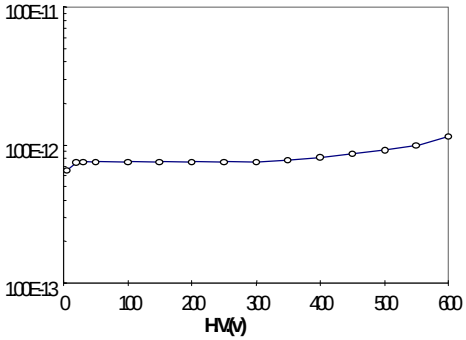

Fig. 2 The function curve of detector at the ionization area.

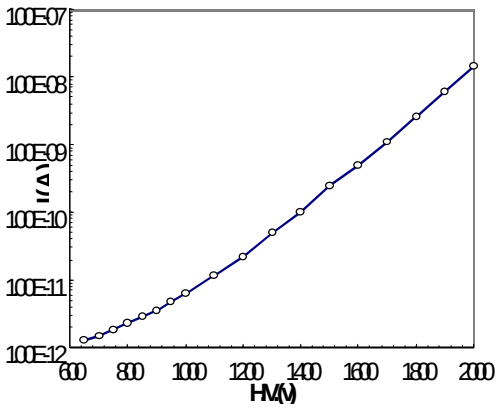

Fig.3 the function curve of the detector at the proportional area

1.3 The sensitivity at different areas

The sensitivity of the detector is tested also with above instrument and circuit by moving out the radiation source. At the background level, the radiation is roughly equal to 0.13μSv/h. In the ionization area, a $2x10^{-14}$ A current signals was observed, when the high voltage was around 300V. In the proportional area, the current signals were 1.2×10^{-13}A, 1.0×10^{-12}A and 1.2×10^{-10} A, when High Voltages were at 1000V, 1600V and 2000V.

The measurement of the proportional ion chamber shows from 200V to 400V, it has excellent ion chamber characters. While as the high voltage over 800V, typical proportional tube characters are measured as Fig3. If gives very nice linearity and sensitivity

2 The digitizer

2.1 Principle of the digitizer

Digitizers, sometimes it is called I/F converter . Normally a charge bump circuit or current integration circuit is used for digitizing the very weak current. The principal of the circuit is show on Fig. 4:

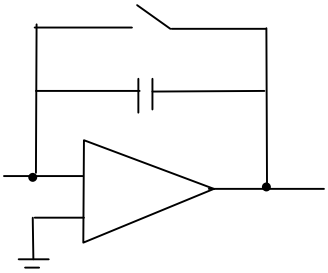

Fig4: The circuit principle of I/F converter

The electronics circuit block diagram of the digitizer showed as Fig 6.

2.2 The key components

Fig 5 shows the two stage amplifiers. The first stage is a current integration circuit. The key components of the circuit is low bias current amplifiers and low leakage current capacitor and diodes. The LMC662 from National Semiconductor was selected for the first stage amplifier. The main characteristics are as follows:

- Voltage gain — 126dB
- Input offset voltage — 3mV
- Offset Voltage drift — 1.3μV / °C
- Input bias current — 2fA

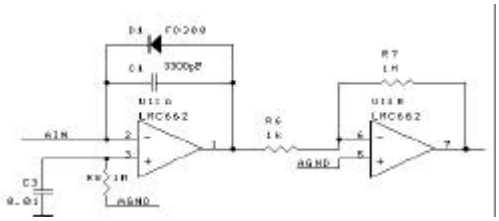

Fig 5 The two stage amplifiers

2.3 The discharge circuit

The fig. 7 shows the discharge circuit. An amplify factor of 1,000 is introduced be the second stage amplifier. When the signal output from the amplifier reaches the threshold of the D type flip plop, a discharge pulse, regulated by the clock circuit, is generated. The pulse introduce through the R10. The discharge pulse injects to the integrate amplifier though the D2 and R2.

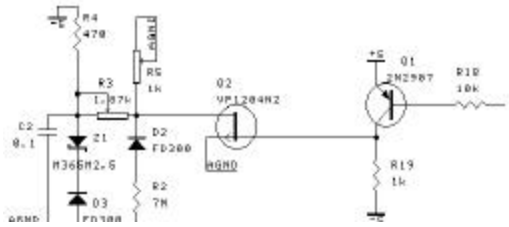

Fig7: Discharge circuit

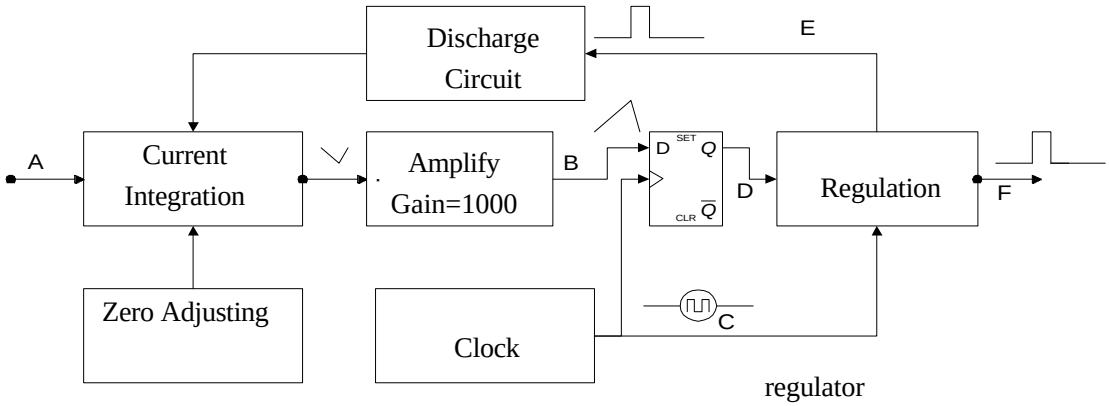

Fig6: The block diagram of the digitizer

4 The read out instrument

A Digital Data Logger (DDL) is used for system read out. The original idea of DDL is from Radiation protection group at CERN. It was developed in the earlier of 1980th. The microprocessor Intel 8080 was used for DDL. In the middle of 1980th, when The Beijing electron positron Collider and the synchrotron radiation facility in Hefei was built, we designed our own DDL for radiation monitoring system. Motorola micro processor 6809 was employed in the DDL. During the upgrade project of the above two accelerators in the earlier of 1990th, a new DDL was designed and built with MC68HC11. The performances of the DDL are improved grately.

5 Testing and result

The complete system has been well tested. When HV=1300V, local radiation background level = 0.13μSv, the system gives 41 count/min. It means the sensitivity of the tube and the digitizer is good enough. While measuring with radiation source 564mCi ^{137}Cs and at the distance 1.5, 2, 3m, the linearity is also excellent. The testing result shows as Fig. 8.

Acknowledgement

We would like to thank Dr. Li Jiyuan, who made the very nice detectors for us.

In fact the most system testing was be done in the Institute of High Energy Physics. The Dr. Li jianping and many members in his group, such as Mr. Liu Liefu, Liu Shudong, supported us strongly to all of the project.

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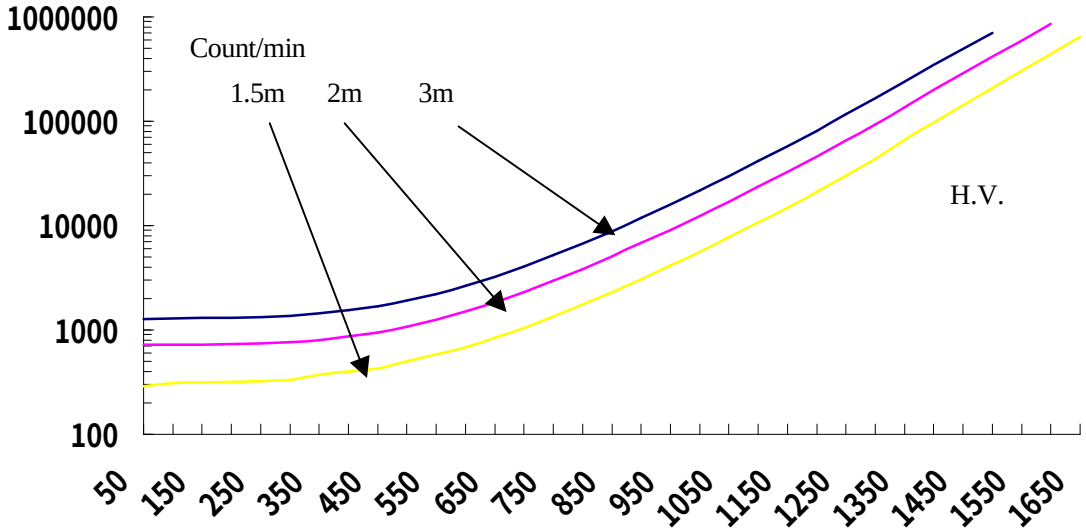

Fig8. Testing with 564mCi ^{137}Cs and at the distance 1.5, 2, 3m