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Design and Realization of Readout for Beam Loss Detector of Accelerator Particles

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***Abstract**:During construction of the accelerator machine to achieve optimal transmission, the fraction of beam particles lost has to be controlled. It is why a careful analysis of the location and time structure of possible losses has to be performed before the choice of the suitable types of beam loss monitors can be made. Beam loss monitors are very sensitive devices, which detect even a very small fraction of losses. In this work, we presented the input/outputcharacteristic of the switch configurations andthe implemented of a T-switch configurationis made to use as a Reset switch for the gated integrator. The simulation results of the realization revealed the interests of the switch configurations proposedto develop the readout for Ionization Chamber.*

***Keywords:**Beam loss, Diagnostic devices, Energy, Readout electronics, Switch configuration.*

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I. Introduction

In the normal Linear accelerators (Linacs), the lost beam particles cause some activation of the accelerator components by nuclear reactions. Moreover, the surrounding material can be damaged by the radiation, as well as by the heating due to the particles energy loss. In addition, a misaligned beam is able to destroy the beam pipe or collimators and may break the vacuum. These reasons make the Beam Loss Monitors (BLM-System) one of the primary diagnostic tools for beam tuning and equipment protection in these machines. As regular accelerator facility, these BLMare installed for the protection of the accelerator components. They are mountedoutside of the vacuum pipe at crucial locations and are relatively cheap instruments. There signals are an important information to prevent unwanted loss during the operation, e.g., caused by malfunctions of components. A careful analysis of the location and time structure of possible losses has to be performed before the choice of the suitable types of beam loss monitors can be made, see [1].

Because ECR (Electron Cyclotron Resonance) ion sources have become the most frequently used heavy-ion source for cyclotrons. They are also been used with heavy-ion linacs, synchrotrons and radioactive beam accelerators. A new heavy-ion linac based on CW 4-rod RFQ (Radio Frequency Quadrupole) as the injector for the Separated Sector Cyclotron (SSC), called SSC-Linac [2], is being constructed at national laboratory HIRFL (Heavy Ion Research Facility of Lanzhou), IMP of Chinese Academy Sciences (IMP,CAS). The SSC-Linac consists of an ECR ion source, LEBT (Low Energy Beam Transport), a 4-rod RFQ, MEBT (Medium Energy Beam Transport), IH-DTL and HEBT (High Energy Beam Transport).

During machine commissioning and at various energies during acceleration. The System should be sensitive enough to enable machine fine-tuning and machine studies with the help of BLM signals; sometimes even at low beam intensity to avoid high losses.

Therefore, one of the main issues of a BLM System is its very high dynamic range. It has to deal with two different types of losses; the regular losses that are unavoidable but suitable for beam diagnostics and the uncontrolled losses that generates additional radiation and risks [1]. The following discussion about the readout electronic circuit of BLMs will concentrate on the aspect of their dynamic range related to leakage current, charge injection and any other disturbances.

II. Ionization Chamber Operations

The ionization chamber is the most practical and most widely used type of dosimeter for accurate measurement of machine output in radiotherapy. It constitutes the signal source of the beam monitoring electronic. The accurate low current measurement circuit scheme in nowadays consists of a novel technique I/V converter and a new approach of Gated Integrator (GI) which avoid the parasitical influences.It converts the particle charges into an electric current. A gated integrator is built to receive and integrate low and fast signals with time scales between 10ps to 100µs. Moreover, a gated integrator is used to amplify and integrate the signal that is present a moment the gate is open, without noise and any disturbances that may be present at other times, see Fig.1.

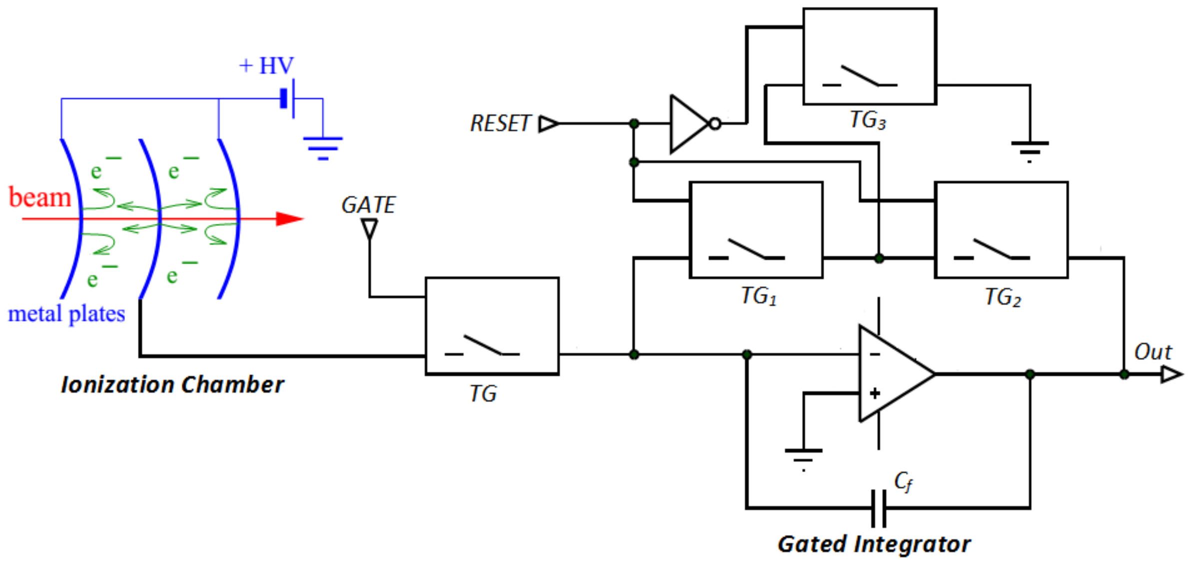


Fig.1: Ionization Chamberand Readout electronic block diagram for single channel

The GI circuitry is composed of switches, operational amplifier and capacitors, the principle of the gated integrator are well explained in [3, 5]. The non-ideal switch and amplifier will introduce additional noise and fixed pattern. The measurement system to receive the entire charge of the input beam was performed by the transmission gate (TG) switch configuration. The circuit proposed for the TG and methodology is detailed in [3].

It consists of a configuration switch shown in the figure 2. The chamber front-end electronics is generally performed by using that electronic scheme. For more precision and best accurate measurement, we use the IV102 as integrating amplifier and DG445DY for TG composed the configuration switch. It integrates low-level input current for a user determinate period storing the resulting voltage on the integrating capacitor.

Characterization of DG445DY switch

A MOSFETtransistor used as a switch is to conduct current orconnecttwo different parts of a circuit. An ideal switch has the characteristics of zero resistance when it is on, infinite resistance when it is off and no delay when it is turned on or off. A real MOS transistorswitch however, has turn-on non-zero channel resistance, turn-off leakage current, parasitic capacitances and threshold voltage. If the body and source are at the same potential, the drain to source current of a MOS transistor in the deep sub-threshold region of operation is given by:

$$I_D = KI_O \cdot \exp\left(\frac{V_{GS} - V_{th}}{\eta V_T}\right)\left(1 - \exp\left(-\frac{V_{DS}}{V_T}\right)\right) \quad (1)$$

$$I_O = \mu_n C_{OX} (\eta - 1) V_T^2$$

Where, $I_D$is the drain to source current of the transistor MOS. K is the aspect ratio of the transistor. $I_O$is the saturation current. $V_{GS}$is the gate to source voltage. $V_{th}$is the threshold voltage of a MOSFET. $V_T$is the thermal voltage. $V_{DS}$is the drain to source voltage. $\mu_n$is the carrier mobility. $C_{OX}$is the gate oxide capacitance, and η is the sub-threshold slope factor [6, 8].

According to his internal configuration, the transmission gate is a switch preventing the disturbances of the parasitic capacitances, which cause the injection charges. When the transistor MOS is on, some charges are present under the gate oxide resulting from the inverted channel and when the switch turns off, part of these charges will be injected into the capacitor C_1. For anMOS the charge under the gate can be estimated by:

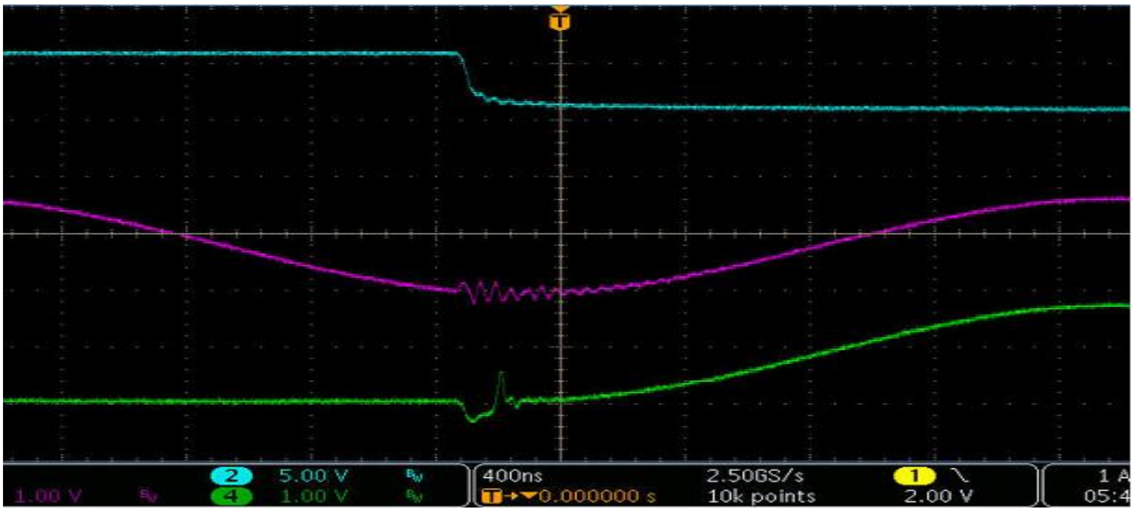
$$Q_{In} = -C_{OX} WL\left(V_{GSn} - V_{THn}\right) \quad (2)$$

and for a pMOS the channel charge is

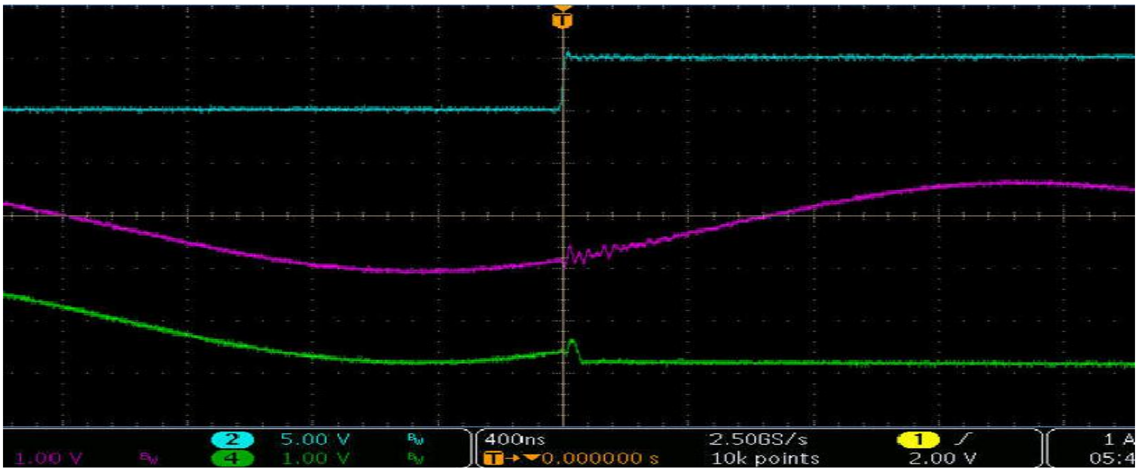
$$Q_{Ip} = -C_{OX} WL\left(V_{GSp} - V_{THp}\right)$$

(3)

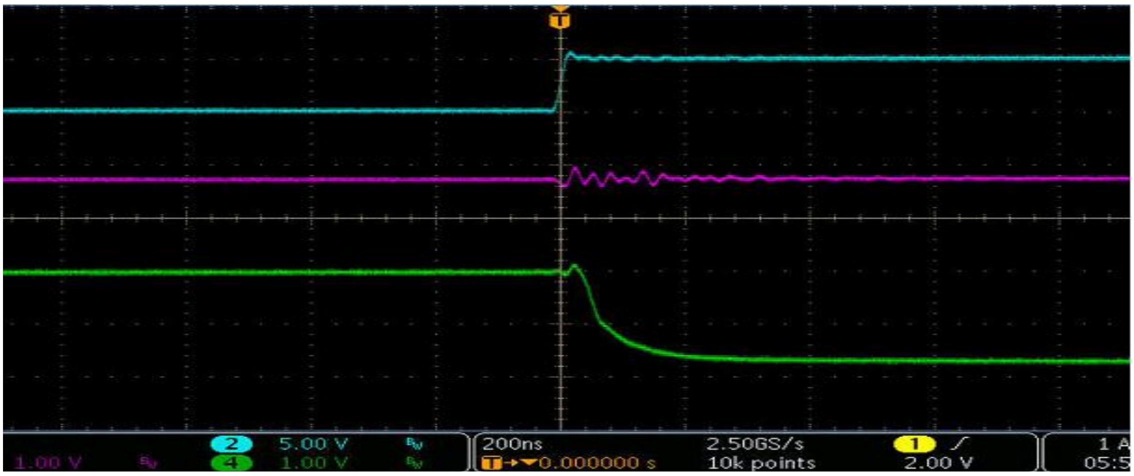
It is known that the injection charges are negative for nMOS and positive for pMOS. To solve the problem provoke by the charges injection we need the used of the transmission gate as a switch. The transmission gate is composed of anMOS and a pMOS connected in parallel controlled by complementary signals. Since it is notedthat the signs of the charges in an n-channel and in a p-channel in the Eq. 2 and 3 are opposite, the charges injected from the n-channel and the p-channel will reduce significantly if their areas of gates are carefully designed**.**Before used the TG and for better performance, the characterization of DG445DY is developing as follow:



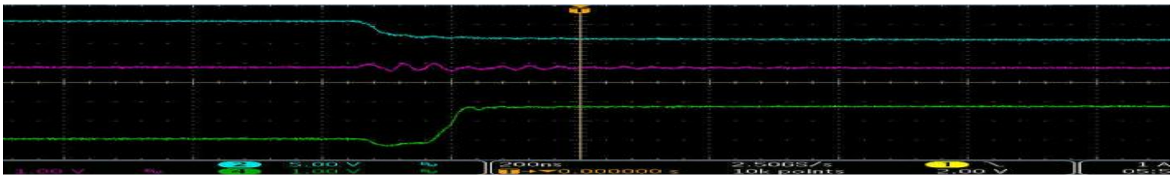
(a) A TG switch with OFF to ON transient



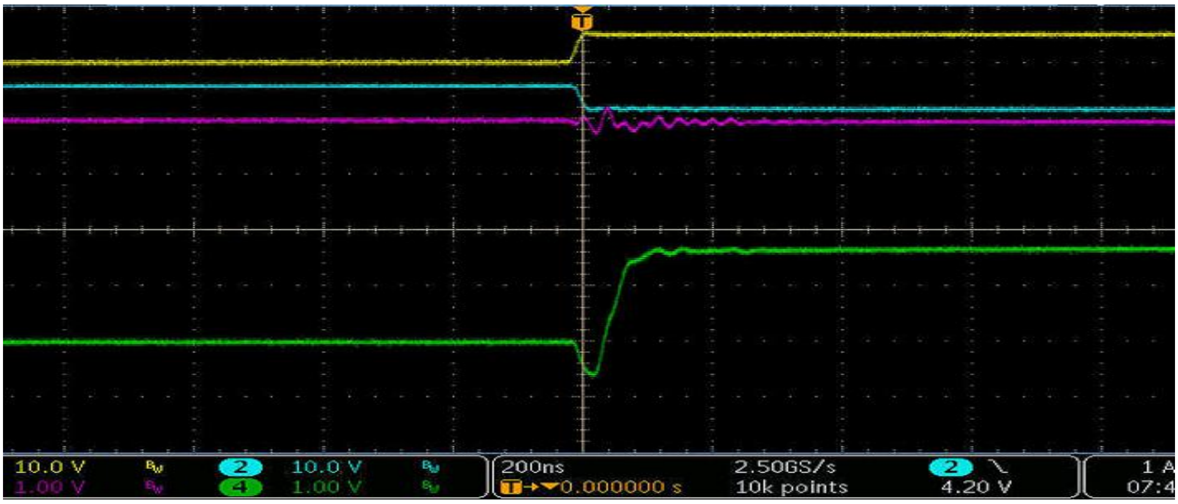
(b) A TG switch with ON to OFF transient



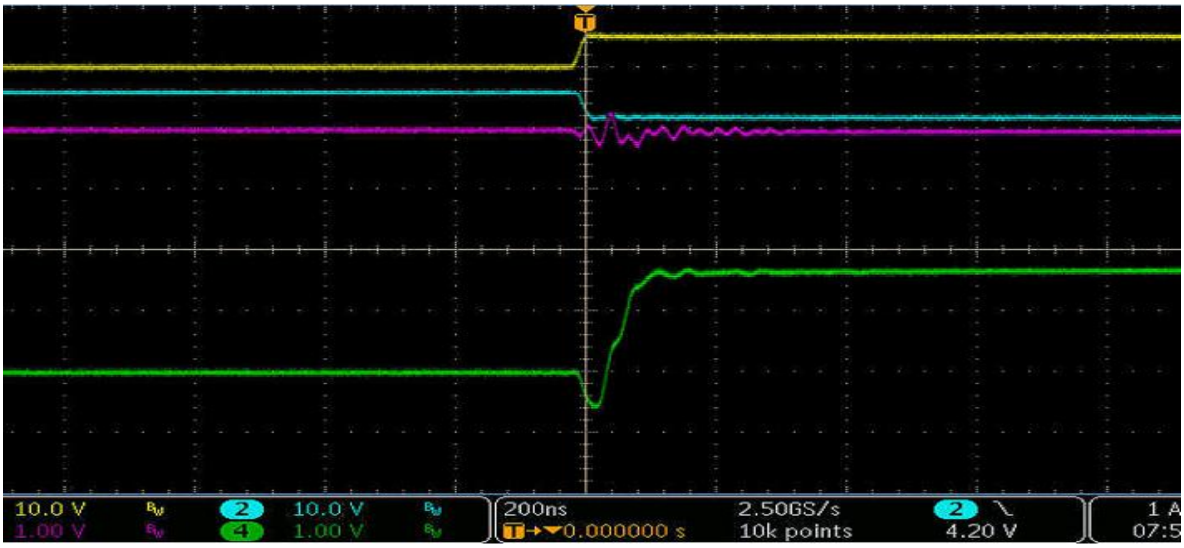
(c) A TG switch with ON to OFF transient with no load



(d) A TG switch with OFF to ON transient with no load



(e) T-switch configuration with ON to OFF transient and TG3 not connected



(f) T-switch configuration with ON to OFF transient and TG3 connected

Fig.2 Characterizations of switch configurations

It follows that the nonlinear dependence of V_{Th}upon V_{in} introduces nonlinearity in the input/output characteristic. In summary, charge injection contributes three types of errors in MOS sampling circuits: gain error, dc offsets, and nonlinearity. In many applications, the first two can be tolerated or corrected whereas the last cannot. Using TG DG445DYswitch to replace a single MOS switch allows correcting gain error and dc offsets. Fig. 2 shows different switch configurations with the effect of clock transition before commissioning as a Reset switch on the gate integrator.

T-switch configuration implementation

The proposed gate integrator functions perfectly well, see Fig. 3. The TG composed by nMOS and pMOS compensate the quantity of charge injected into inverting input of Op amp. The little noise observed on the oscilloscope traces is from the state changed that provokes a small oscillation (see Fig. 4). We can be able to collect several events during the integration phase (see Fig. 5) and the step appearance on the purple trace before the first integration represents the offset voltage.

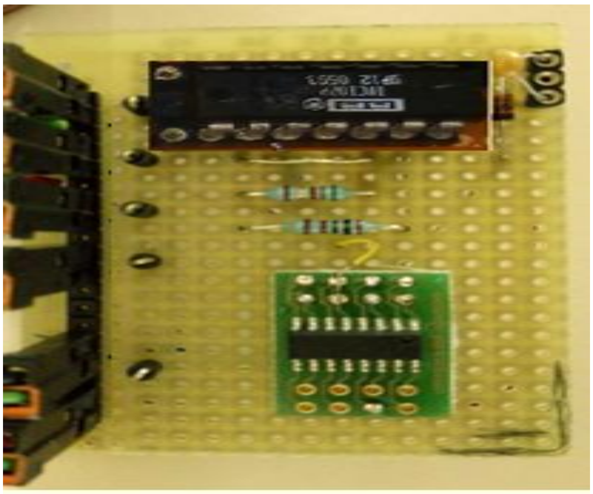


Fig .3 Picture of the gate integrator

Fig .4 Oscilloscope traces: yellow trace is anintegrating gate signal; purple trace is input signal; green trace is output signal

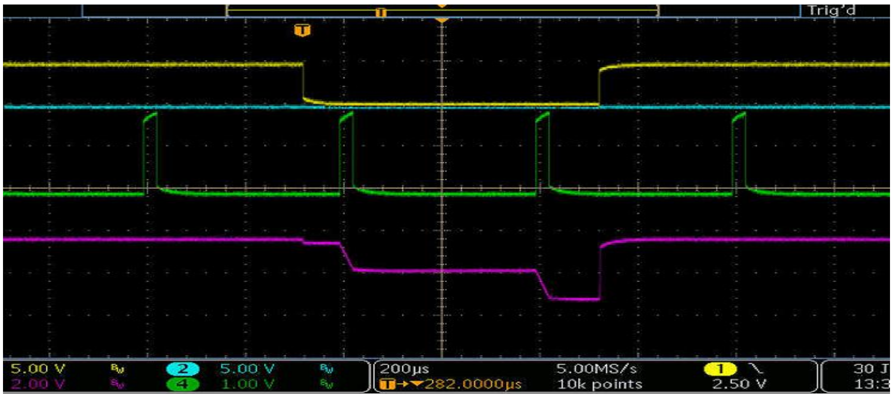


Fig .5 Oscilloscope traces: yellow trace is an integrating gate signal; green trace is input pulse; purple trace is output signal.

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III. Conclusion

The accelerator system should be sensitive enough to enable machine fine-tuning and machine studies with the help of BLM signals.To perform the stability and allow the proper used of the beam, current adjustment machine system and permanent improvement of some diagnostic instrumentation are undergoing and testto have a perfect calibration. For example, we propose and realize a gated integrator for readout electronics based on transmission gateimplemented as a switch useful for Ionization Chambers. The simulation results revealed the improvement of the switch configurations proposed, and then the structurecan beextended to a part of any beam diagnostics instrumentation.

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