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ONLINE RADFET READER FOR BEAM LOSS MONITORING SYSTEM

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Abstract

To investigate the beam loss and its distribution during operation of synchrotron light sources at NSSRC, a sixteen-channel readout box is designed and implemented to read the threshold voltage of the RadFETs installed at the accelerator tunnel. To simplify the design, the reader plays a role of remote I/O for EPICS IOC. The IOC collects voltage from readers distributed in the accelerator to deduce the integrated dose and dose rate. User interface is shown in the control console for real-time display, and the archived data are processed off-line.

INTRODUCTION

The radiation-sensing field-effect transistor (RadFET) is a discrete p-channel metal-oxide-semiconductor field-effect transistor optimized for ionizing radiation [1]. The threshold voltage between the gate and source changes due to radiation-induced charges in the oxide layer when applying a constant drain current. The reader of the RadFETs acts by applying constant drain current and read the threshold periodically. The voltage is proportional to accumulated exposure dose, and the slop of the accumulated dose is dose rate. Many different designs are reported for high energy detector and accelerator systems [1,2,3] with various considerations. Some are with simple interfaces and some are with intelligence ones. For a synchrotron light source, the RadFET will be a useful device to detect beam loss caused by the various mechanisms. A simply and low cost reader designed and implemented for beam loss study will be summary in following paragraph.

OVERVIEW OF THE READER IMPLEMENTATION

In order to achieve the high-density installation of the RadFETs, the reader is designed to link up to sixteen RadFETs using unshielded-twisted-pair network cables with standard RJ-45 connector, as shown in Fig. 1. In the radiation exposure period, the gate voltage is zero-biased or apply specific positive bias to increase sensitivity. In the readout period, a constant specific current is applied to the drain of RadFET to measure the threshold voltage (V_{th}) of the reader. The readout period is one minute now and the threshold voltage is readout one by one through a 24-bit analog-to-digital convertor (ADC). The control processes are programmed in the input/output controller (IOC) of the experimental physics and industrial control system (EPICS) and PVs are published into the control network, shown in Fig. 2. An operation interface is designed to show the threshold voltage of each RadFET, accumulated dose, dose rate even dose rate distribution. The threshold voltage of each RadFET is recorded in the archive server for the further analysis.

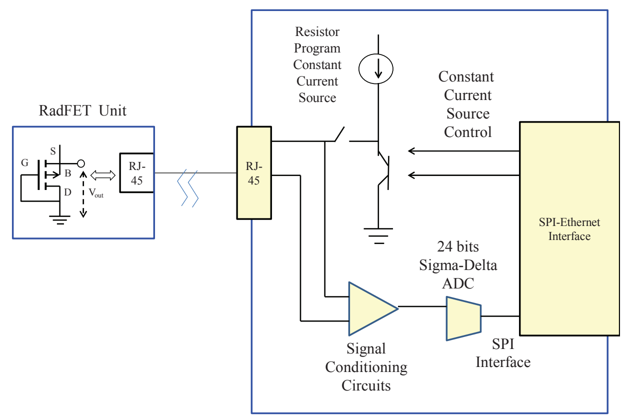

Figure 1: Simple schematic diagram of an individual RadFET reading hardware.

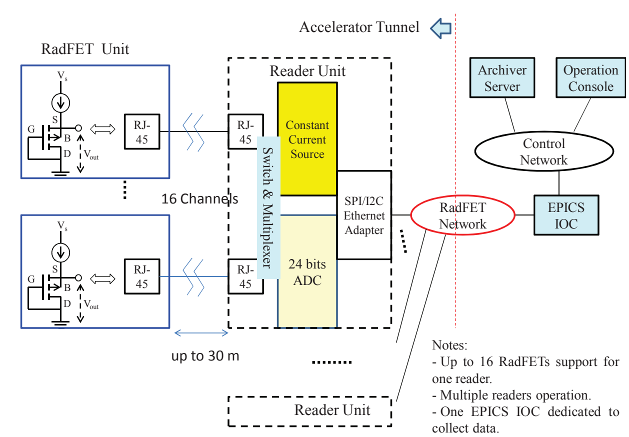

Figure 2: Block diagram of the RadFET readers system.

HARDWARE CONSIDERATION

Several issues have been identified during functionality discussion phase. To simplify software development cycle, it was decided that the reader just plays as roles of remote I/O units without local intelligence from viewpoints of control system. It needs not to do software programming at the reader side. To make easily cable to the data acquisition controller, the interface is Ethernet. Minimizing the interconnecting inside the reader is achieved by SPI interface to read threshold voltage of

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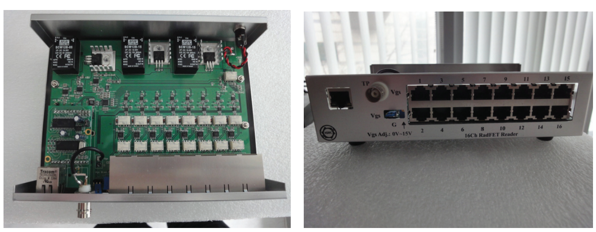
RadFET in the ADC and to enable/disable current source in the digital input and output. Resistor programmed current source LM334 is chosen to deliver a constant current, the current can be changed depending on different models of RadFET sensors to minimize its temperature dependence. AD7194 is a 16 channel, 24 bits sigma-delta ADC and low noise device [4]. The voltage input is reduced by factor 3 to allow measuring voltage up to 15 V at this moment. SR01E12 [5] Ethernet to SPI/I2C/GPIO interface is chosen. Due to no POE support power over Ethernet for SR01E12, current version of this reader needs to apply 24 V externally. Internal DC-to-DC converter and LDO regulator are used to generate various voltages for internal circuitry.

The RadFET is mounted on a small printed circuit board (Fig. 3). Several kinds of RadFETs form REM and Tyndall Works [6,7] have been tested. Up to 10^4Gray dose accumulate of these sensors are possible in centigray (cGy) resolution. The sensor head connect to reader is via twisted pairs network cable for its convenience and easy to installation. RJ-45 connectors are used on the sensor head and readers side. The sensor head is fixed to the specific site by Kapton tapes as shown in Fig. 4.



(a) Inside (b) Front Panel
Figure 3: Photo of the 16 channel RadFET reader.

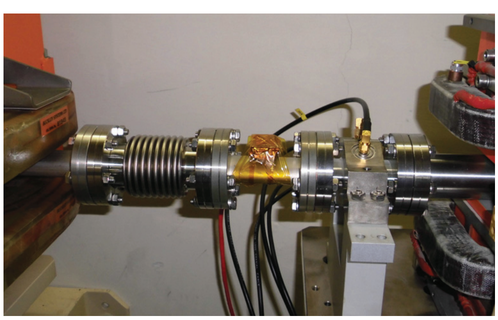


Figure 4: Typical installation for RadFET sensors.

SOFTWARE STRUCTURE

Reader side is only support simple interface conversion without embedded software to minimize the development efforts. All readers are linked by a virtual local area network (VLAN) to avoid interference by the busy control network. The VLAN is accelerator wide to support distributed readers installation. One EPICS IOC is dedicated to collect threshold voltage from readers. Exposure time and readout time can be configured according to specific requirements. The EPICS IOC accesses readers by use of TCP/IP protocol to set and to read registers of devices. The EPICS IOC performs data acquisition, calculation, and publishes EPICS PVs of dosage. Dosage rate is calculated by the EPICS record processing. All of the threshold voltage values based on the EPICS PVs access can be stored into the PostgreSQL RDB (Relational Database) archive server for further off-line data processing. The archived data can be retrieved in a form of graphical representation using the CS-Studio based data browser to observe the trend. The Matlab toolkit can be also used to analyze the threshold voltage data which were read back from the RadFET and retrieved from the RDB archive system directly. The control system also provides on-line display for virtualization usage. Figure 5 shows the relationship of software functional blocks. Figure 6 shows dosage value on accelerator synoptic display. Dosage distribution alone accelerator components can be display as shown in Fig. 7. Figure 8 and 9 shows the data trend real time and the archived data from RDB.

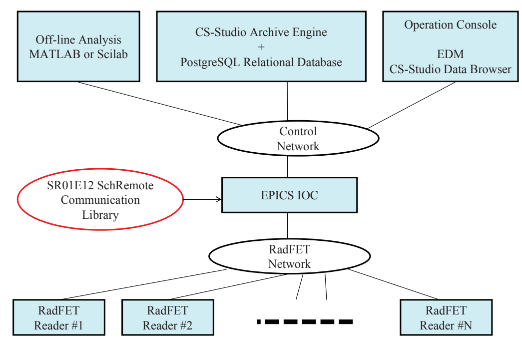


Figure 5: Software support for RadFET reader.

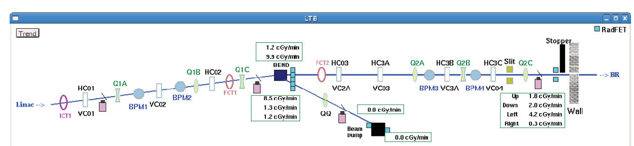


Figure 6: Value display along accelerator synoptic display.

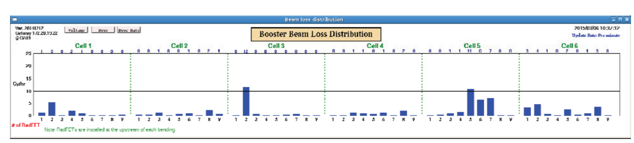


Figure 7: Bar chart display.

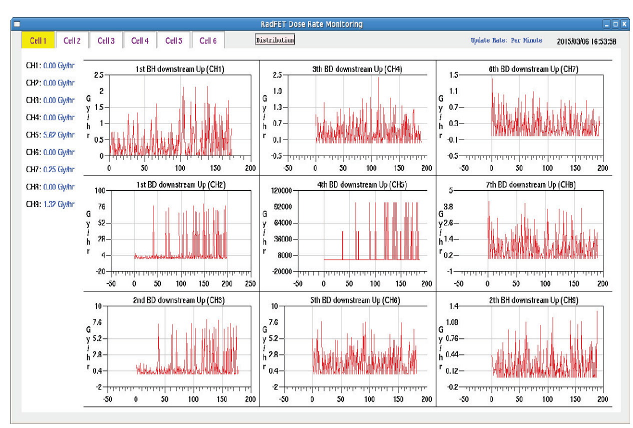


Figure 8: Real-time trend display.

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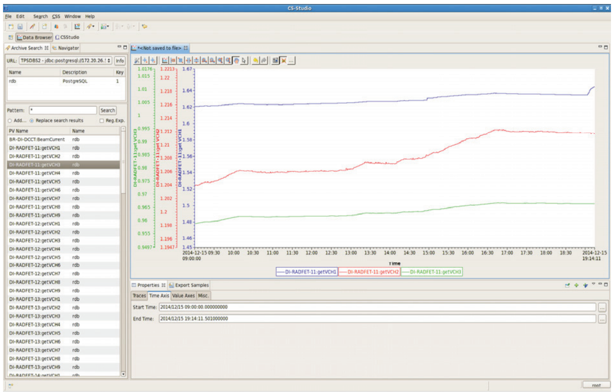

Figure 9: Archived data retrieve.

READER PERFORMANCE

When applying the power to the reader, it needs about 30 min to warm up and achieve stable reading. Reading performance can be examined by analyzing the historical threshold voltage of the RadFET. Annealing effect makes the threshold voltage of the RadFET decay exponentially after exposing the radiation. Figure 10 shows a typical annealing curve of a RadFET. Figure 10(a) is a typical recorded 12 hours data without exposure to radiation. As the data is fitted and subtracted by an annealing curve, the noise level of the reader can be extracted. A annealing curve, $V = V_0 + V_1 * \exp(-t/T_0)$, is used for fitting with three parameters, i.e. $V_0 = 3.232$V, $V_1 = 0.06571$V and $T_0 = 20.9$ hour. Variation of the difference between raw data and fitted curve is shown in Fig. 9(b). Data variation is about +/- 100 μV (~ 50 μV in RMS) corresponding to cGy of the dosage. During the measurement the ambient temperature is keep within 1 ^{o}C variation. There is no obvious drift observed.

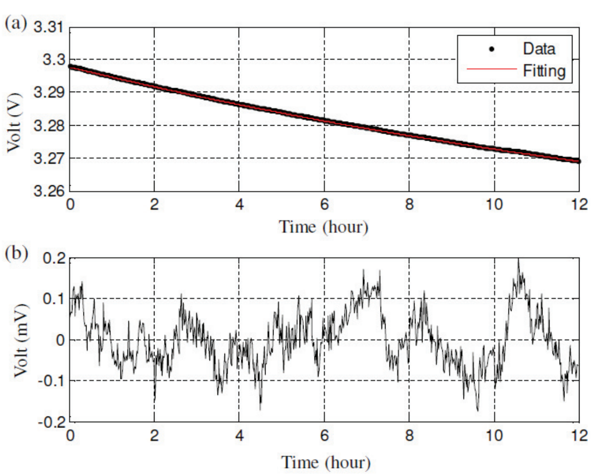

Figure 10: (a) Threshold voltage and its fitting curve during non-radiative period. (b) Voltage fluctuation within 12 hours.

CONCLUSION

High-density channels of a RadFET reader is designed and implemented. It allows deploying large quantity of sensors inside the accelerator tunnel especially for loss distribution with high spatial resolution. Data collect by an EPICS IOC from multiple reader units via Ethernet. The reader system has been provided preliminary beam loss study at TLS during routine operation [8] and commissioning of the TPS booster synchrotron [9]. Satisfied results were concluded.

REFERENCES

[1] D. Zontar, "Radiation Monitoring at Bella", Nucl. Instr. And Meth. A501 (2003) 164-166.
[2] L. Frohich, et al., "Online Monitoring of Absorbed Dose in Undulator Magnets with RADFET Dosimeters at FERMI@Elettra", Nucl. Instr. and Meth. A 703 (2013) 77-79.
[3] L. Frohich, et al., "DOSFET-L02: An Advanced Online Dosimetry System for RADFET Sensors", Proceedings of IBIC2013, TUPC45, pp. 481-484, Oxford, UK, (2013).
[4] http://www.adi.com.
[5] http://sch-remote.com
[6] http://www.tyndallworks.com
[7] http://www.radfet.com
[8] C. H. Huang, et al., "Beam Loss Study of TLS using RadFETs", these proceedings, IPAC 2015, Richmond, USA.
[9] C. H. Huang, et al., "Diagnostics of the TPS Booster Synchrotron for Beam Commissioning", Proceedings of IBIC 2014, Monterey, CA, USA.