RASPBERRY PI 3 BASED SOFTWARE AND HARDWARE SYSTEM FOR RADIATION HARDENING TESTING OF ELECTRONIC COMPONENTS

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Electronic base, designed for use in high radiation fields, such as particle accelerators, should be radiation hardened. To study the radiation resistance of such electronic components, various sources of ionizing radiation are used, with the use of which the components of the systems under study are subjected to prolonged exposure to fluxes of high-energy particles. This process often takes a long time, which also ensures the high cost of such research. The study of radiation resistance requires the creation of specialized research complexes. Such systems make it possible to assess the quality of the components' performance depending on the radiation dose and weed out elements that do not meet the radiation resistance criteria for specific tasks at the equipment design stage. The system designed to test the radiation hardening of electronic components. It is based on Raspberry Pi 3 microcomputer. Provides web-interface to acquire and express analysis of data taken. System tested in CHARM facility test area

Keywords: Raspberry Pi 3, radiation resistance, express analysis

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1. Introduction

Electronics systems intended for use in conditions of increased ionizing radiation, such as high-energy accelerators, must have increased radiation resistance to ensure functioning throughout the entire period of operation. Such radiation conditions are characteristic of accelerator complexes designed to work with beams of elementary particles in high-energy physics. Also, increased requirements for radiation resistance [1, 2] are also imposed in other sectors, such as the space and aviation industries, nuclear energy, medicine, etc.

To study the radiation resistance of such systems, various sources of ionizing radiation are used, with the help of which the components of the systems under study are exposed to prolonged exposure to flows of high-energy particles. This process often takes a lot of time, can be performed on various installations and requires automation.

Thus, the study of radiation resistance requires the creation of specialized research complexes that allow us to evaluate the reliability of components depending on the dose of radiation.

This article presents a mobile hardware and software system for measuring the characteristics of electronic components under the influence of ionizing radiation based on the Raspberry Pi3 B microcomputer.

2. Hardware & Software

The hardware part of the complex is divided into two parts located at a distance of 40 meters from each other: one is directly installed in the irradiation zone, the second in the access area of maintenance personnel. The general scheme of the components of the complex is presented in the figure (Figure 1).

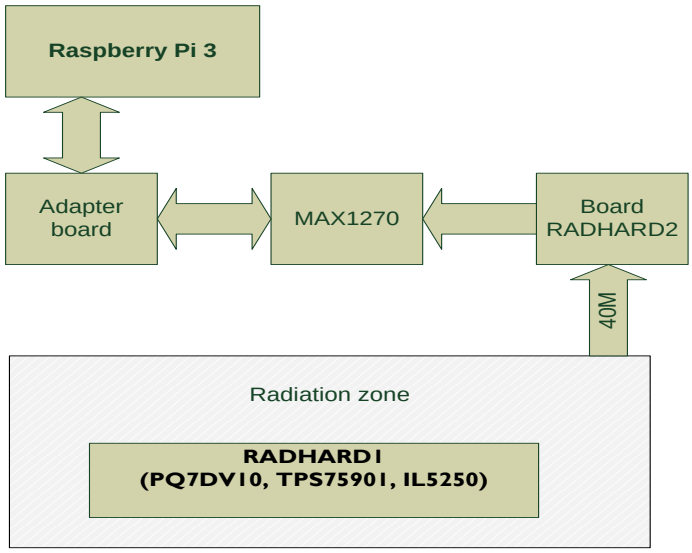

Figure 1. Schema of hardware part

The central part of the complex is the Raspberry Pi 3 single-board microcomputer. The microcomputer provides data acquisition from the LVMB board and used for processing and express analysis, and provides a WEB interface for managing the complex.

The choice of the Raspberry Pi microcomputer is determined by its low cost and wide capabilities: it is working under the control of the free operating system Raspbian based on Linux (Debian), low power consumption of the Raspberry Pi 3 can ensure the mobility of the complex when running on battery power, the availability of wireless access allows organizing remote WEB-management of the complex.

The elements under study are placed on the RADHARD1 board, the signals from which are transmitted via the communication line to the RADHARD2 adapter board, which is directly installed on the LVMB (Low Voltage Monitoring Board) board, which provides signal conversion to a discrete code.

The LVMB is designed to digitize input voltages and currents. The board has seven MAX1270 ICs [3], which allows measuring up to 56 analog channels with an accuracy of 12 bits in the range from 0 to 10V. In addition, eight digital outputs are installed to control signal sources for emergency shutdown of channels when errors are detected in the studied samples. Reading of information is carried out on the SPI interface.

The board for mounting the studied elements RADHARD1 is designed for radiation testing of specific elements. The studied voltage regulators are installed on the board: PQ7DV10, TPS75901, IL5250. Voltages and currents from the regulators are transmitted to the RADHARD2 adapter board with an S/UTP (shielded twisted pair) cable over a distance of 40 meters. At the same time, three identical boards with a connected load of 1 ohm were installed. Board elements and load resistors are cooled using a rack cooling system with water refrigerant.

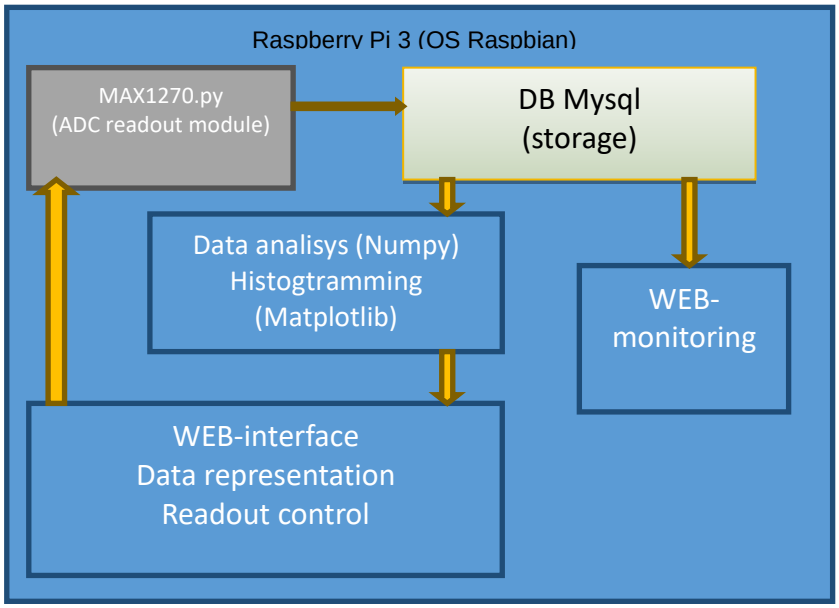

Figure 2. Schema of software part

The software part (Fig. 2) is implemented under the control of the Raspbian operating system, which is supplied with the Raspberry Pi 3 single-board microcomputer. The OS is based on Linux (Debian), which allows using a wide range of software and third-party libraries, as well as using network protocols for transferring data and external communications. The operating system is currently under active development, is constantly being improved and takes on new functions. Data from the MAX1270 chip is received by the reader and entered into the database under MySQL control, from where it is available for further analysis or for online WEB monitoring. The processed data becomes available through the WEB-interface in the form of graphs. The reader module is also controlled via the WEB interface.

For reading data using analog-to-digital converters MAX1270, a module in the Pyhton language has been developed. The module allows to set the configuration parameters of MAX1270 integrated circuits (measuring range, bit depth, etc.), read data channel or group, control eight digital outputs, determines the frequency of the ADC polling.

As a data storage, the MySQL database is chosen - a free relational database management system. The SQL query language (structured query language) allows to filter, group samples according to various criteria (time, measurement number, measurement identifier, etc.)

The received digital data is written to the MySQL database channel-by-channel (ch1, ch2, etc.) and contain additional fields: Measurement number, Measurement date and time, Measurement identifier.

To ensure data safety, regular backup of data on a remote server is provided. As a means of synchronizing files, the *rsync* program is selected, which is launched through the cron task scheduler.

For data processing external libraries Numpy and Matplotlib are used.

NumPy [4] is a Python programming language library that provides support for large multidimensional arrays and matrices. It has a large set of high-level mathematical functions for operations with various arrays. The main object of NumPy is a homogeneous multidimensional array. This is a multidimensional array of elements (usually numbers) of the same type. By means of the library, the average value and standard deviation for each read channel are calculated.

Matplotlib is a Python programming language library for visualizing data in two-dimensional graphics. The resulting images can be used for publication on WEB. For remote control of the data set created WEB-interface. It allows to execute commands to start a data set, stop a data set, start analysis, and also provides access to already processed information. The presence of the WEB interface allows operators from remote monitoring centers [5] to have quick access to experimental data and to control the process of data collection.

Implemented overlapping list of events with reference to time. To do this, create a text file format "*time: event"* (Fig. 3).

The presence of such file allows combining the collected data and notes in a time schedule.

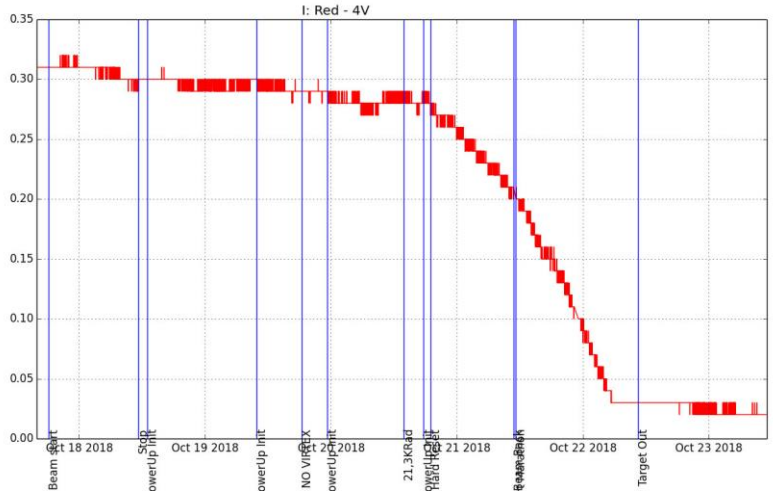

Figure 3. An example of a change in the characteristics of an element under the influence of ionizing radiation

Thus, the created software package allows quickly evaluate the data being collected, find the moment of degradation onset depending on the radiation dose received, manage the data set, etc.

The operability of the developed software and hardware complex was tested during the radiation hardness tests of electronic components at the CHARM [6] (Cern High-energy AcceleRator test facility) installation at CERN.

3. Conclusion

The mobile hardware-software complex for measuring the characteristics of electronic components under conditions of exposure to ionizing radiation has been created, tested and applied, which provides data reception, storage, processing and quick analysis of measurement results, visualization.

The complex was tested on the existing experimental CHARM (CERN) installation, during which three types of linear voltage regulators were investigated.

By the totality of characteristics, the created complex can be applied in various fields of science, such as automatic control systems, measuring devices powered by batteries, industrial control systems, data acquisition systems, robotics, medical equipment, etc.

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