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RADIATION MONITORING SYSTEM

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ABSTRACT

Design of a portable low-power multichannel analyzer with wireless connectivity for remote radiation monitoring, powered from a solar panel with a internal battery to be operated in field. The multichannel analyzer is based on a single microcontroller which performs the digital functions and an analog signal processing board for implementing a Gaussian shaper preamplifier, a Gaussian stretcher, sample and hold, pile-up rejector and a 10 bit ADC. Now this design is to be used with a NaI(Ti) scintillator detector.
This multichannel analyzer is designed to be a part of radiation monitoring network. All of them are connected, by radio in a radius of 10 kilometers, to a supervisor computer that collects data from the network of multichannel analyzers and numerically display the latest radiation measurements or graphically display measurements over time for all multichannel analyzers. Like: dose rate, spectra and operational status. Software also supports remotely configuring operating parameters (such as radiation alarm level) for each monitor independently.

1. INTRODUCTION

In nuclear accidents leaking fission products from the core of the reactor, it is very important to know what radiation exposure rate and what are the elements emanating, which will be passed to the environment, see the Chernobyl and Fukushima accidents. Under normal operating conditions, nuclear plants release small amounts of radioactive waste throughout its useful life. In the unlikely event of a severe accident, followed by successive failures of physical barriers and problems in the reactor control and protection systems, release of radioactive material can become significant. The problems generated from these catastrophic events can lead to the achievement of high levels of radioactivity in the vicinity of the plant, posing a threat to human beings, society and the local life.
There is also the same problem in low-power nuclear facilities, such as radioisotope production facilities for nuclear medicine, uranium enrichment facilities and low power research reactors, as they may also emanate radiation to the environment. Another reason to monitor radiation in area, is related to major events. It is necessary to monitor the area so you can detect any radiation from any intention to contaminate this event, due to a terrorist act.

Therefore, this project aims to measure the radiation that can be issued in a large area around these facilities.
The radiation monitoring system will consist of radiation monitors that will measure the intensity of the radiation rate and what specific radionuclides of this radiation emanation. These monitors have a NaI(Ti) scintillation probe, which captures a radiation from a sodium iodide crystal and converts the radiation into photons, which are then amplified in photomultiplier unit (Smith, 2005 Tauhata et al, 2003), to have a high sensitivity detection in low radiation rate.
Each monitor will provide full radiation rate in counts per second and the emanation of the energy spectrum. This spectrum which will contain the energies emanating from the radiation. These energies represent what radionuclides that are present in the environment, such as cesium, cobalt, americium, etc., so that the radiation protection staff to identify what type of radiation released into the environment and how it is harmful to the population.
These monitors will be interconnected in a wireless network to a supervisory computer. This network can be adapted to distance the user wants. Basically the greater physical distance between a monitor to the supervisory computer will be 10 km, but if the distance of a supervisor's request for sending data from a monitor is greater than 10 km, the network will have the ability to pass data from a monitor to other monitor to be sent finally to the supervisor.
Viewing this system will be made with simultaneous data collection of all monitors in a constant period of time and presented at the supervisory computer screen and that can be passed to another any connected to the Internet. In this way the movement and concentration of the intensity of the radiation plume may be displayed.

2. OBJECTIVE

The objective of this work is to design and build a large area radiation monitoring system. This system will consist of various radiation monitors connected in a large wireless network and with the intention to design the monitors at the lowest possible cost.

3. METHODOLOGY

The methodology applied to this project comes down to design the system following units:

a) multichannel analyzer for a NaI(Ti) scintillator probe.
b) battery charge controller, using a solar panel.
c) Network tcp / ip wifi great distance.
d) data visualization software.

4. SYSTEM UNITS

4.1 Multichannel Analyzer

A multichannel analyzer is a device used in applications that make use of nuclear spectrometry. Basically it converts the energy of the radionuclide in electrical voltages, proportional energies. These voltages are passed to a digital analog converter (ADC) and the result of this conversion will address a memory location in a computer, which is called channel, and increase it. This process is repeated continuously forming a histogram in computer memory.

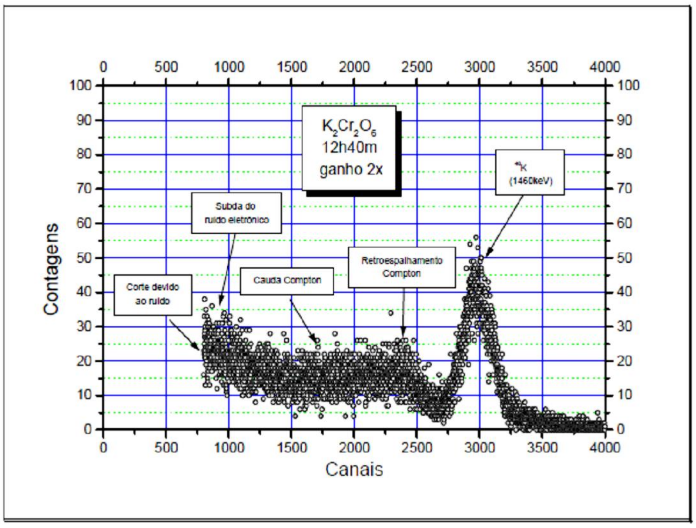

Figure 1: Nuclear Spectrum 40K, which has an energy 1460 KeV (Silva N. 2005)

The NaI(Ti) scintillator probe is a sensor which detects radiation in a sodium iodide crystal and converts the radiation into photons, which are then amplified in photomultiplier unit (Silva, 2005 Tauhata et al, 2003), to have a great detection sensitivity at low radiation rates. The probe to be used in this project has the following specifications:

- Radiation detected: gamma and X-rays
- Detector: Bicron - Monoline Model 1.5M1 / 1.5.
- Detected energy range: 50 keV to 2 MeV.
- Crystal Type: sodium iodide activated with thallium - NaI (Tl).
- Detector resolution: approximately 8% of pulse width at half maximum.
- Maximum operating high-energy detector 1250 V.
- Detector operation Power Line: about 650 V.

The high voltage is created through a train of pulses, low voltage, generated by computer. The high voltage of these pulses is through a transformer, and passes through an integrator circuit to rectify the AC voltage into continues. Thus high DC voltage is proportional to the frequency of the generated pulse train.
The preamp will provide the tensions that will be converted by the ADC monitor. This is a circuit that turns the nuclear pulse in a form of pseudo Gaussian wave. This transformation is necessary for the duration of a nuclear peak pulse is very fast and hard to be detected. One form of Gaussian waveform is continuous and therefore much easier to detect its peak, as seen in Figure 2.

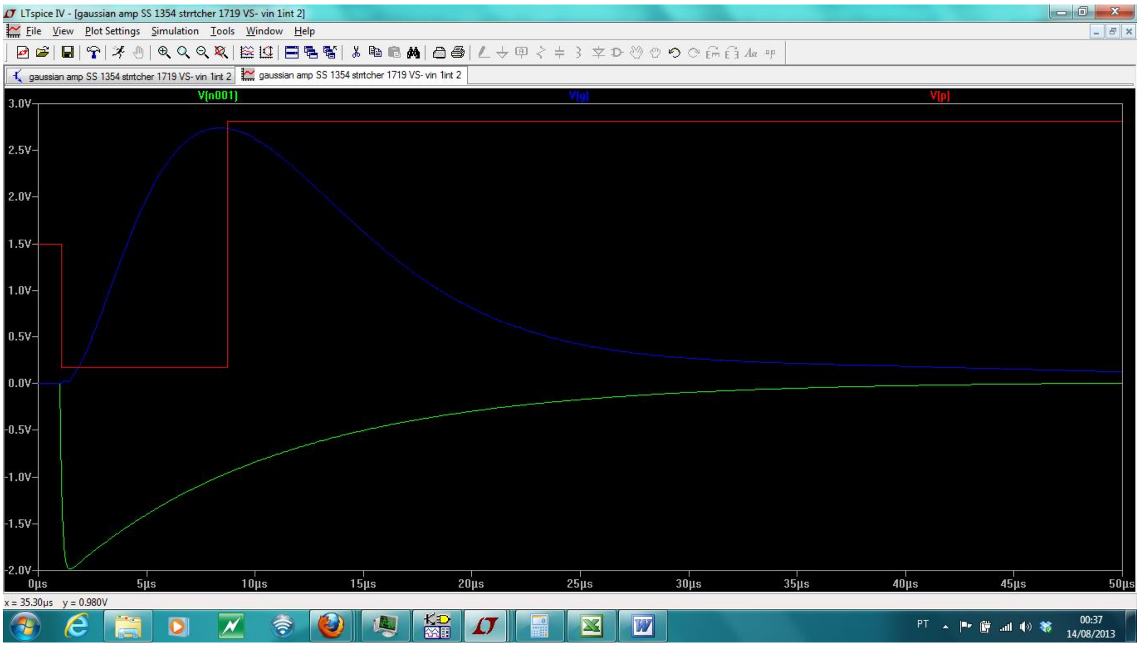

Figure 2: Nuclear Pulse (green) and its transformation into a Gaussian wave (blue) and detection of the peak (red).

It is very important that the response of this circuit is as linear as possible in all ranges of the nuclear pulse voltage. This is necessary because a energy calibration will be made versus the channel address. Initially is made a acquisition of data using radiation sources with a known energy and calculates a calibration curve (energy versus channel), so that in future we can know any radionuclides energy nature that are released into the environment and detected by multichannel analyzer.

The computer used to manage the needs described above is a microcontroller from Texas Instruments, the MSP430 class. This microcontroller has as its best quality low-power consumption operation and a large amount of peripherals to interface with the outside, such as internal volatile memories or not, ADC, comparators, counters, pulse generators and output channels serial, fundamental to the execution of this project.
It has a 10-bit ADC (1024 memory addresses), with a conversion time of approximately 4 us with a circuit "sample and hold" which retains the input voltage throughout the conversion, which is very helpful so you do not have to build an external circuit to hold the voltage peak of the Gaussian.
It has the possibility of having 8 channels accessed via a multiplexer. The analog output of Gaussian shaping circuit is connected to an input multiplexer and a channel this consequently sent to the ADC. The signal V (p) of Figure 2, which is the pulse shaping circuit detector is connected to the microcontroller and the increase of the pulses is immediately started to digital conversion of the voltage shaping circuit. At the end of the conversion is generated an interruption of the microcontroller program memory and is incremented position on this digital conversion.
This project will use a multichannel 256 channels (8 bits), with 2-byte capacity for each channel (64535 counts). This intention is to have a smallest possible amount of data for data transmission with the host computer. However, nothing prevents this amount of data is increased, provided for a option for a larger version of this microcontroller.

Each generated nuclear pulse is connected to a microcontroller counter. Through an internal timer is seen every 1 sec, which is the count, thereby taking the integral of all radiation pulses which have been captured by the NaI(Ti) scintillator probe, in counts per second.
In the case of the high voltage power supply to the probe, microcontroller generates pulses which will go to the high voltage transformer. This DC voltage generated is reduced to levels through a resistive divider to the maximum analog voltage permitted to the microcontroller ADC and this is analyzed every 1 s. The microcontroller through a software algorithm analyzes whether to raise or lower the frequency of the pulse train to maintain stable voltage to the desired level.

4.2 battery charge controller, using a solar panel

Each radiation system monitor is powered by a 12V lead acid battery charged by a solar panel. With the microcontroller option to have multiple input channels on your ADC is possible you can do the battery charge control. When a lead acid battery is being charged to its maximum voltage can not exceed the voltage of 14.1V. The microcontroller tests every 1s this tension through one of its ADC channel if this voltage is exceeded the microcontroller opens a solid state relay which is in series between the output of the solar panel and the battery, interrupting the electrical current coming from panel and avoiding battery damage. Also a diode is placed in series between the panel and the battery before the relay, with the anode facing the battery, so that when the panel voltage is less than the battery, battery current does not return to the panel.
The microcontroller consumption estimation is very low, of the order of 80 mW, however the WiFi router consumes at least 4W, even without transmitting data.
Will adopt a criterion for safe transfer of nuclear data, the battery has to supply power for four days without being charged by solar panel, for climatic reasons or failure on the panel, and not fall below its half load to not impair their useful operating life. With this criterion was the battery having a power of approximately 70 A / h.
Using a feature to turn off the wifi router and only transmit the data every five minutes and the router need 1sec to connect the network, a monitor can consume a quarter of the previous power, which can feed the circuit with a battery approximately 17 / hr. This proposal will be tested during the project development.

4.3 Network tcp / ip wifi great distance

The radiation monitors are interconnected in a wireless network to a supervisory computer.
The peripheral microcontroller has a serial data output. It will be used to pass the data to a wifi router high power to transmit data at a great distance. The principle will be used a router company Ubiquiti nano model loco 5, which has the ability to convert this data and turn them in standard TCP / IP, which is the protocol adopted in WiFi networks. This router has the ability to transmit data at up to 10 km away.
This network can be adapted to distance the user wants. Basically the greater physical distance between a monitor or other supervisory or computer will be 10 km, but if the distance of a supervisor's request for sending data from a monitor is greater than 10 km, the network will have the ability to pass data from a monitor to other monitor to be sent finally to the supervisor.

4.4 Data Visualization Software

The supervisory computer is the central element of the access network to system radiation monitors.
The viewing of this system will be made with simultaneous data collection of all monitors in a constant period of time and presented at the supervisory computer screen and that can be passed to another any connected to the Internet. Thus the movement and concentration of the radioactive intensity of the radiation plume may be displayed.
At first the supervisor collects data from all monitors every 5 min., But displays the ability to inform the supervisor if it occurs greater intensity in radiation measured and thus reduce data collection time, to have a display more accurate.

5. CONCLUSIONS

This project intends to be more cheaper and equal quality option to imported systems of radionuclides monitoring system. Now seeing the nuclear accidents of Chernobyl and Fukushima, we must have a necessity to measure the concentration and the movement of the plume of a possible nuclear accident to analyze and prevent problems for the population around of nuclear installations.

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