MICROCONTROLER BASED PORTABLE DOSEMETER FOR x AND γ RADIATION

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Abstract: Basic concepts and arising design problems of autonomous portable dosemeters are presented in the introduction. The construction of a portable microcontroller based instrument for x and γ radiation is described regarding basic principles and performances. The connections between different subunits are given in respect of interoperability of incoming signals from sensing device and their further processing. The dual nature of the instrument is presented, and all constrains origining from this concept are discussed in more detailed way, especially regarding the reliability of the measuring results. The measuring range of the instrument is from 50 keV to 1,3 MeV. The dose rate could be successfully measured starting from zero level to 500 mGy/h, and the dose measurement is possible up to 999 mSv. The unit was tested in various conditions. High reliability was obtained which makes this instrument attractive solution for a personal dosemeter.

1.Introduction

Portable personal dosemeters represent a must for monitoring the ambient conditions where ionizing radiation is expected. There are various solutions for performing radiation measurement, starting from classical film dosemeters, electroscopic and termoluminscent meters ending with electronic meters with superior performances. The classical solutions suffer from theirs inability to perform real time measurements. This problem however is easily overcome with electronically based measuring instruments.

There are different types of electronically based measuring instruments regarding the nature of the radiation, expected accuracy, measuring range etc. so portable meters with different sensors could be find. Among others, most popular solutions are based on pulse GM detectors, p-i-n diodes, MOS detectors and CdTe based sensors. This indicates that there is no superior radiation sensor for portable instruments, so specific auxiliary electronical solutions are developed in order to minimize some of the sensor's weaknesses and in the same time offer real time operation. This makes this type of instruments to be attractive for practical application and in the same time they are object of constant design interest. The first solutions have pour indication facilities, i.e. they had only audio warning, the next generation had display units but they were performing fixed time interval measurements and the most recent designs are DSP based and perform very complex calculations offering highest performances.

For personal dosemeters however, simplicity in design and high reliability are the most important parameters. There are also other constrains that are connected with the construction of this type of instruments in respect of power consumption, in active and standby mode, overall dimensions and weight.

Having in mind the nature of the measuring phenomenon, meters that have fixed measuring time interval will have fluctuation of the final results. It could be shown that the relative error of the measurement is decreasing with the total number of detected pulses from the sensor unit. If certain accuracy range is desired, for example 68%, [1], for the relative standard error the following expression is valid:

$$\delta_k \approx 1/(kx)^{0.5} \qquad (1)$$

where k represents the number of samples and x represents the number of output pulses from the sensor unit. This expression could be slightly modified if new variables are introduced. Denoting with n the mean number of generated pulses from the sensor in a time unit and representing with T the active measuring interval of the instrument, having in mind that $T=k\Delta t$, the previous formula becomes:

$$T=1/(n\delta^2_k) \qquad (2)$$

The last expression clearly indicates that the measuring interval is proportional to the relative error and further leads to compromise in the designing phase of the construction of the instrument. The time interval should be short enough to satisfy some security regulations for early warning [2], and in the same time long enough to maintain the relative accuracy. In this paper construction of a portable measuring instrument with fixed time interval and some extra facilities is presented. The operation of the unit was tested for a period of one year and some of the obtained results are included.

2. Structure and characteristics of the solution

This instrument is designed to perform two measuring activities, dose measurement and dose rate measurement. The dose measurement has possibility for cascading by storing the values in the EEPROM memory of the microcontroller. After insertion of new batteries the RAM contents is corrupted so the values in the EEPROM section are used as initial conditions if only this is desired by the operator. If the power on button is pressed simultaneously with the disp on button, then the measurement is cumulative, otherwise zero initial conditions are assumed. The instrument constantly monitors the incoming signals for superseding the prestored alarm values. If any alarm condition is met than, sound alarm is activated. The source of the alarm is clearly noted on the display in text mode. The two main goals of the design were to obtain portable operation from two AA sized batteries for a period of 30 days and in the same time to have good linearity of the response in wide energy range of the incoming radiation. Considering different options, finally G.M. tube was chosen. This approach has good measuring performances but requires high operating voltage, so very careful design of the high voltage section was performed to satisfy the low power operation. The main problem in this section was the design of the feedback loop with minimal loading of the generated high voltage. Resistor dividing network was dissipating too much power, while indirect sensing was to inaccurate so special design approach was taken which has both advantages.

The operation of the instrument is from two regulated lines and an unregulated line directly supplied from the batteries. The high voltage section generates 550 V, and has typical power consumption of 0,1 mA. The display section is powered from 5V line generated from a D.C. to D.C. converter capable of supplying up to 250 mA. The battery voltage is directly used for the two microcontrollers. This arrangement was used to obtain operating conditions with minimal power requirements. The two microcontrollers are set in master slave arrangement, where the slave controller is used only for timing purposes, generating pulse trains with periods of 1s, 10s and 3600s. This solution guaranties that the proper time intervals would be generated irrespectively of the microcontroller activities, a condition that directly influences the measuring performances. In this design according to the values obtained from expression (1), a fixed time interval of ten seconds was adopted. The construction of the instrument in a simplified way is given on Fig. 1.

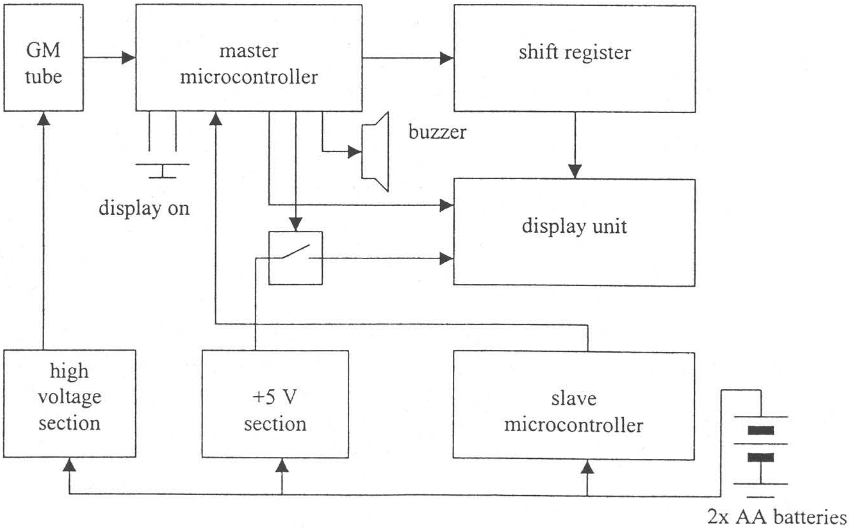

Fig. 1 Main building blocks of the dosemeter

The processing of the incoming signal from the G.M tube is performed in linear manner by direct interfacing to the interrupt input line of the microcontroller. The processing capacity is limited from the execution speed of the microcontroller, which operates at 4MHz clock rate. Having in consideration all the necessary activities that are to be performed within one cycle, it could be easily calculated that the cycle duration is approximately 50 μs. This enables proper operation for input pulse rates up to 20000 pulses per second which determines dose rate measurement limitation. For the dose measurement, the limitation results only from the memory capacity, if the measurement conditions for the whole interval are beyond the maximum pulse level limitation.

The software support is purely based on interrupt service routines. When the program was in development phase, in order to gain minimum power consumption the microcontroller was normally put in sleep mode and external interrupts were expected. This was real energy saving, but it turnout that in that mode the system was capable to measure signal with pulse rates up to 20 pulses per second. This was due to very long time required to finish the wakening process of the microcontroller which usually takes up to 2000 clock cycles, so in the final design the microcontroler was put in an idle loop and waits for any interrupt condition. In the same time, there is also solution that uses the sleep mode and takes advantages of the nature of the measuring signal with prolonged ending of the "go to sleep mode" routine. In this way when a single pulse is detected, the microcontroller is not going to sleep mode after necessary calculations, but it rather waits for an interval of 10 seconds. This enables adequate response to input pulses that are grouped together.

The design was based on PIC microcontrollers, particularly 16F84 were used. The lack of output pins of the microcontroller imposes a nonstandard solution for display activation. In this system a matrix alphanumeric L.E.D. display is used to obtain best visible results in all operating conditions. The penalty that has to be paid for this option is the power consumption that is about 200 mA when the unit is in active mode. Even, in power down mode this unit requires a supply current of few mA, that is also unacceptable, so special power management was introduced. The supply line of the display is controlled from the microcontroller and it is only activated when the user wants to check the measured values. The operation of the display is limited to 4 seconds and after that the power is cut down. Along with this operation proper resetting at the start of each operation should be performed which requires an extra output pin. The data communication is performed in serial manner, using two output pins for control of the serial to parallel shift register. Finally one output pin is used for select purposes making total of 5 output pins of the microcontroller.

The extension of the measurement range is possible in few different ways. The first approach is by inserting a prescaler counter between the output of the G.M. tube and the input of the microcontoller. This solution should be carefully used because too great prescaling factor might lead to delay in calculation for the dose rate. For avoiding this problem, two different inputs should be considered, i.e. direct and prescaled one and according to the obtained results software switch should be implemented which complicates the data processing and inserts longer response time of the system. The PIC 16F84 microcontroller has rather limited performances, so the upgrade in respect of range extension is possible probably by redesigning the system using different microcontroller with greater possibilities.

3.Measurement results

For test purposes ten identical units have been constructed, all equipped with ZP1310 subminiature detectors suitable for X and γ radiation in energy band from 50keV to 1,3 MeV, although this detects β radiation with energy greater then 0,5 meV.

The measurements were performed in laboratory environment with two different sources.

•i Controlled field of X radiation supplied from X-ray equipment ERESCO-200 in energy range from 40 to 200 keV. Permanent monitoring of the radiation was performed via direct measurement of the half thickness of the copper adsorbent and beam distribution out of focus.

ii Controlled field of γ radiation origining from ^{60}Co equipped with collimator. This unit was used to supply radiation with exposition strength from 7pA/kgs to 70 μC/kgs at distances from 1 to 5,5 m.

The stability of the radiation was monitored according to guidelines found in reference [3]. The control measurement of the radiation sources were performed with reference unit of type SGM 29 equipped with detector type NE105, scintillator 25x25 mm and photomultipicator EMI 9734A.

The test results show good repetitivity and acceptable measuring uncertainty. The ten units have doserate measurement variation of 5%, while dose measurement results for 24 hours exhibit variation less then 1%.

After the tests have been completed, the following characteristics were verified:

- measuring range for dose rate measuring
- measuring range for dose measurement
- audio warning alarm for the following conditions: dose rate at 25 μGy/h (hour based) and 1mGy/h (week based)
  dose rate at 25 μSv (hour based) and 1mSv (week based)
- typical power consumption (without input radiation, less then 0,5 mA)

4.Conclusion

The test results exhibit stable measuring performances, mainly influenced by the sensor type, and acceptable reliability. This results along with audio warnings facility and user friendly alphanumeric display make this instrument to be an attractive solution for practical application.

References

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