EXTENSION OF THE MEASURING RANGE OF GM TUBE BASED RADIATION DETECTORS

Cvetan Vladimir Gavrovski, Mario Andon Makraduli
Department of Electrical Engineering, The St. Cyril and Methodius University
P.O.B. 574, 91000 Skopje Republic of Macedonia

ABSTARCT: *Accuracy problems of GM tube based radiation dose instruments are discussed in this paper. Upper limits for dose rate measurement within specified tolerance are presented for conventional signal processing, and a cost effective solution that extends measuring range is presented. The performances of the proposed circuit are graphically presented in comparation with the ones of the conventional designs.*

Measuring radiation doses with GM tubes introduces systematic errors due to imperfection of the sensor units. This problem is known as dead time saturation and imposes tube's inability to distinguish external actuations that are closely spaced in time domain. The introduced error is directly proportional to the duration of the dead time, but it's also dependent on radiation source properties. The amount of the error resulting from finite dead time interval could be easily calculated if uniform distribution of the measured signal is assumed. This implies that GM tube based radiation detectors, in fact measure reduced radiation dose value which is related to the original one with the following equation: [1]

$$N_{eq} = \frac{N}{1 + N\tau}$$

N - original dose rate
N_{eq} - measured dose rate
τ - dead time

In this equation τ denotes equivalent time interval in which the GM tube is insensitive to respond to further excitations. If simple analog processing of the input signal is performed then further errors are accumulated due to finite length of the recovery interval of the GM tube. This means that an external event that is positioned in the mentioned interval would also be undetected. Using the previous assumption for the input signal distribution, the upper value for dose rate measurement could be computed. For virtually extended dead time interval to 1.5 τ, the maximum value of the external dose rate that could be measured within 90% accuracy is found to be 15 10^3 pulses per second, for tubes with dead time of 15 µs. If higher dose rates are expected, then simple analog processing that consist of signal comparation is not adequate, and some sort of correction is necessary.

In this paper a cost effective solution for equivalent shortening of the dead time interval is presented. The basic idea for the solution was derived from the wave shape of actually measured signals that are presented on Fig.1. On this diagram the mentioned signal is shown in solid line style. This signal was measured on a digital storage scope.

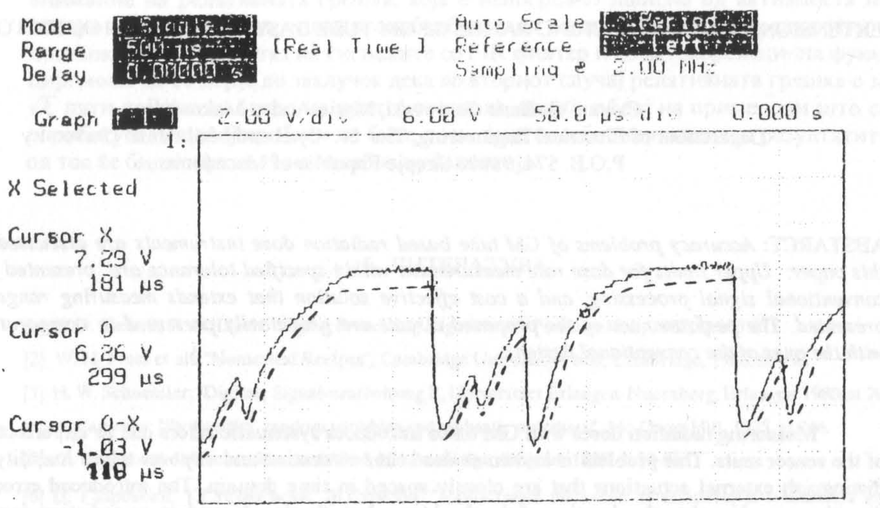

Fig.1 Response of a conventional GM tube sensor for high input dose rates

This diagram represents practical situation when more then one external excitations are present within dead period of the sensor unit. If conventional comparation of this signal is taken its most likely that only one pulse would be detected. In order to design measuring system with greater accuracy its necessary to extract further information from the actual wave shape. Two approaches are visible for this problem. The first one is in the domain of digital electronics and requires circuits that could perform pulse duration measurement, and enter further correction according to previously stored values in a look-up-table. This solution is suitable if it could be realized in a single semi-custom chip, which imposes great production quantities. In our solution analog signal processing was chosen because of the cost effective limitations. There are various ways in which this problem could be solved and the one that was realized here benefits from small signal peaks present in the recovery portion of the measured signal. Special care should be taken in order to distinguish peak variations that result from current fluctuation to the ones that are produced by external excitations. Having all this elements on mind, a simple circuit was designed that utilizes presetable peak level detector and a conventional voltage comparator. The prestable peak level detector is a modification of the conventional application and has an option for output signal initialization. This mechanism is provided with an analog switch inserted directly to the output hold capacitor. As the range of the input signal variation is known, proper circuit configuration is used to avoid output conflict of the low resistance power sources. In this application reinitialization is performed whenever input signal equals reference voltage. In order to get satisfactory noise immunity, adjustable level for the comparator is necessary. Because the reference voltage is chosen to be lower then the input signal, DC shift for the input signal is necessity. The inserted offset should be great enough to overcome problems arising from recovery current fluctuation, but at the same time this level should be smaller then average peak variation. The exact value for this voltage offset was derived on experimental bases. On Fig.2 block diagram of the solution is presented.

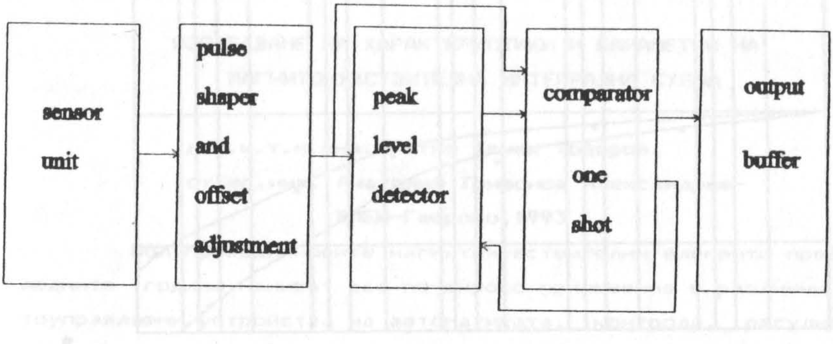

Fig.2 Block diagram of the analog signal conditioner

Input information provided from the GM tube sensor stage one, is amplified and shaped in the succeeding stage. Here adjustable offset is imposed on the signal in order to prevent false triggering of the comparator circuit. The peak level detector positioned in this application presents a form of a sample and hold circuit. The value that is stored in the capacitor is sharply modified whenever comparator circuit triggers. On Fig.1 the signal of the capacitor is presented in dashed styled line. This approach ensures that all peak variations with amplitude greater then preseted offset reference should be successfully detected. There is only one limitation in this construction, that is the requirement for proper voltage preset of the peak level detector in time interval as short as input signal fall time. This implies careful selection of the value for the hold capacitor in peak level detector, because a large capacitor value requires faster charging circuits that are usually power vasters, and very small value may produce unacceptable voltage reference variations. The compromise is chosen according to the nature of the measured signals, or more specifically utilizing probability distribution function for the input signal. During the time interval when the output capacitor is forced to the new reference value, the circuit is not allowed to respond to external actuations, in order to privet from false triggering in the preset interval. In practice this is not a serious limitation because signal fall time is at least an order of magnitude smaller than signal rise time, which means that individual peak detection will be preserved. The described solution does not remove limitations of the finite dead time, but it is only capable to detect pulses in the recovery portion of the GM tube characteristics. This is the reason why this solution has greater accuracy then the one found in conventional designs based on straight signal comparasion.

The output pulses that are produced by the comparator circuit are with different duration, but this is not a problem since the final cumulative counter is designed to count fast enough comparable to peak signal variations. If this variation is unacceptable for difrent applications, pulses from the monostable multivibrator could be used for further processing. The output buffer is optional and is required for distant signal distribution in application where centralized monitoring of the radiation is performed.

The overall performances of this circuit are graphically presented in comparison with the ones of conventional applications. On Fig.3 relative dose rate errors introduced by the measuring circuits are presented. It is evident that the proposed solution has better performances that outperform conventional solutions for almost one decade in input dose rates. The presented results were obtained with GM tube ZP1313 produced by Philips. The fluctuation present on the graphs is because of the relatively small number of experiments, (5 per point).

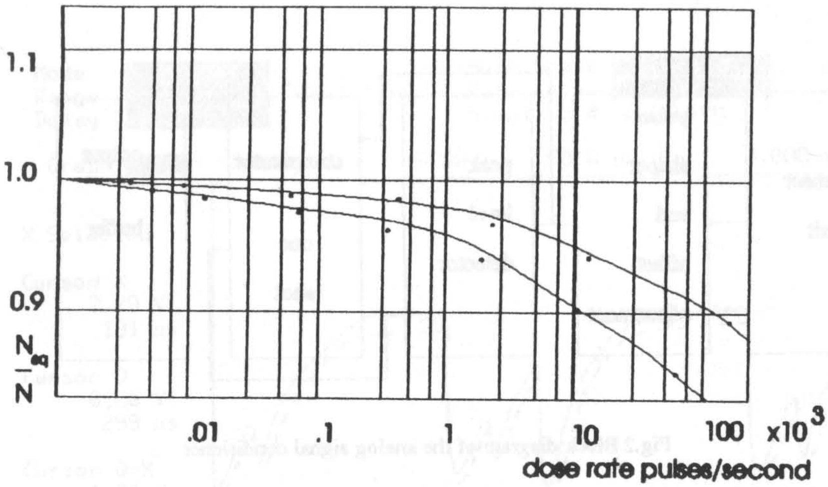

Fig.3 Relative performances of the proposed circuit

From the last figure it is obvious that correction for dose rate measurements is more critical for higher dose rates (greater then $1x10^4$), because of the increased probability for closer pulse distribution. The problems that result from the finite dead time interval present serious degradation for GM based detectors, and this element encourages new design methods based on semiconductor sensors.

REFERENCES

[1] A.R.Jones and R.M.Holford, "Application of GM counters over a wide range of counting rates", Nuclear Instruments and Methods 189 pp. 503-509

[2] GM tubes Book T6 PHILIPS Components 1986