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N. Ford

Z. Hajduk

A.P. Jeavons

B. Lindberg

C. Parkman

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TWO-DIMENSIONAL PROPORTIONAL CHAMBER READOUT
USING DIGITAL TECHNIQUES

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TWO-DIMENSIONAL PROPORTIONAL CHAMBER READOUT USING DIGITAL TECHNIQUES

A.P. Jeavons, N. Ford, B. Lindberg, C. Parkman and Z. Hajduk
European Organisation for Nuclear Research
Geneva, Switzerland.

Abstract

Two systems of two-dimensional proportional chamber readout are presented, using digital hardware techniques. Centre-of-cluster readout is simple, cheap and very fast: 100 nsec dead-time. Centre-of-gravity readout is slower, with a dead-time of 1 μ sec, but capable of considerable electronic spatial resolution: 10 μ m FWHM from 3 mm spaced channels. With this resolution the asymmetry of avalanche formation on anode wires has been observed.

Introduction

Various methods have been described for determining the position of an electron avalanche along the anode wire of a proportional counter. Usually they are based on rise-time¹⁾ or charge-content²⁾ of the negative pulses detected at each end of the wire. Attempts to extend these techniques to the two dimensions of a proportional chamber, by connecting anode wires in series, generally encounter problems of insufficient spatial resolution and a slow data rate. Recently, charge-division has been employed for a thermal-neutron detector³⁾. More accurate two dimensional readout is achieved by recording the positive pulses from the cathode wires. Well-known is the use of an external delay-line⁴⁾.

Digital amplifier-per-wire techniques, commonly employed for anode wire readout, are not immediately applicable to the cathode pulses: the pulses are spread over many wires and spatial resolution is badly degraded⁵⁾. However, this pulse spread may be used to good advantage. If the end channels of the pulse distribution are located, then the centre may be calculated. Either the simple mean -the centre of cluster- or, for more accuracy, the weighted mean -the centre of gravity- may be taken. Two dimensional proportional chamber readout, with these ideas implemented in digital hardware is now described. The abbreviations DCC and DCG will be used for digital centre-of-cluster and centre-of-gravity, respectively.

Centre-of-Cluster Readout

Method

From Fig. 1 it may be seen that the centre-of-cluster, X , is given by $X = (N \cdot X_1 - X_2) / 2$, where X_1 is the distance of the farthest channel of the distribution from one side of the chamber and X_2 is the distance of the farthest channel from the other side. N is the total number of channels. X_1 and X_2 may be found with priority encoders, and the calculation performed with a digital hardware processor. Such a system will be very fast: X_1 and X_2 may be found in 60 nsec and X in 40 nsec, using TTL logic. A 100 nsec dead-time is obtained and 30 nsec would be possible using ECL logic. Overall event rate is limited either by chamber considerations, or by data recording speed.

Fig. 1.

The accuracy of measuring X should be one-half of the channel spacing because X is the average of two measurements.

Practical Realisation

A readout box has been constructed for two chambers: each chamber has 96X and 96Y channels. The block diagram for one chamber is presented in Fig. 2. Cathode pulses are amplified in two stages. Simple charge-sensitive preamplifiers are mounted on the chamber: voltage amplifiers with a gain of 40 follow. TTL-level pulses are established with voltage comparators that discriminate against noise. The gain of each voltage amplifier and the common level of the comparators are adjustable to facilitate tuning the system. The comparator outputs are fed to the two priority encoders and a general "OR" is taken to provide a trigger. Latches after the encoders hold the data steady during the calculation and transfer of the result to the computer. The processor has two fixed inputs: N , the number of channels, which is selected by "jumpers" and W , the maximum permitted event width which is set by front-panel thumb switches. The selection of W serves to eliminate spurious events which give a greater than normal cluster size. Data is transferred to a PDP 11/20 computer by DMA, and displayed on a Tektronix 4010 storage display terminal. To take full advantage of the speed of the readout, a variable-persistence oscilloscope has been directly connected via digital to analogue converters. The display of dynamic X-ray images is now possible.

Fig. 2.

Results

Detailed results may be found elsewhere⁶⁾. Here they are summarised in Figs. 3 and 4. Figure 3 shows the spatial resolution obtained from the 5.9 keV X-rays of ⁵⁵Fe, collimated to 0.5 mm. As expected it is 0.5 mm: one-half of the channel spacing of 1 mm. Figure 4 shows the result of two-dimensional imaging. The anode wires of the chamber, spaced at 3mm, are clearly visible.

Fig. 4.

Centre of Gravity Readout

Method

DCC readout may be considerably refined by recording the pulse height, A_i , from the channels and calculating the weighted mean or centre-of-gravity, X , of the distribution: $X = \sum A_i X_i / \sum A_i$. Some results of this method using software^{7,8)} and analogue processing⁹⁾ to perform the calculation have already been published. Here a digital hardware implementation is described, which overcomes the data rate restriction imposed by software.

Fig. 3.

Fig. 5.

Practical realisation

Fig. 5. shows the block diagram of the DCG system. The DCC encoding technique is used to find the three central channels of the cluster. These channels are then routed by analogue switches to three 10-bit ADCs working in parallel to maximise the data rate. The digital results are transferred to the arithmetic processor which calculates the offset of the centre-of-gravity from one side of the cluster:

$$X = X_1 + (A_2 + 2A_3) / (A_1 + A_2 + A_3).$$

The processor takes 300 nsec to calculate to an accuracy of 8-bits. Fast division in 100 nsec is obtained by taking a pre-programmed reciprocal, $1/(A_1 + A_2 + A_3)$, from a read only memory, and then multiplying by $(A_2 + 2A_3)^{10}$. Display is, as before via a PDP 11/20 computer.

Fig. 6.

Because of the interpolating nature of DCG readout, one can work with quite wide channels on the chamber. Figure 6 shows the result from a collimated ^{55}Fe source, using 3 mm channels. The usual spatial resolution of 300 μm FWHM - limited by the photoelectron range in the chamber - is obtained. Work continues to fully evaluate the possibilities of the system.

Spatial resolution

The DCG technique is capable of considerable spatial resolution. Some additional results have now been obtained with the software system.⁷⁾ By connecting a pulse generator to one anode wire, an electronic resolution of 10 μm FWHM has been measured with 8-bit ADCs and 3 mm channels: an interpolation of 1/300, see fig. 7.

Fig. 7.

This has enabled the direct observation of the asymmetry of avalanche formation on an anode wire. Figure 8. shows the result of a uniform irradiation of the chamber with ^{55}Fe X-rays. The normal peak in the distribution around an anode wire is quite clearly split. The interpretation is the sensitivity of the readout to avalanches forming on the left or right side of the anode wire. One can see, in effect, the shadow of a 20 μm wire. If such resolution could be obtained with high-energy beams and particles, much smaller and cheaper detection systems might be possible.

Fig. 8.

Conclusion

Due to their multichannel, digital nature, DCC and DCG readout offer a number of advantages over other techniques:

Cost

Full advantage may be taken of the cheapness and availability of digital chips and components. A compact, DCC system is being constructed for a material and assembly cost of 15-20 swiss francs per channel.

Stability

Once the channels have been adjusted, the systems are completely stable: DCC particularly so, since it has no critical timings. There are no delicate adjustments or components involved.

Dead-time

DCG readout is particularly fast. With a dead-time of 100 nsec, it is an order of magnitude faster than rise-time and delay-line methods; and 30 nsec would be possible. The acquisition of data at these speeds could be done with large shift registers - a "data-sink" ¹¹⁾ - making dynamic X-ray studies possible. DCG dead-time, 1 μsec , is still good and could be diminished by using faster ADCs.

Local measurement

In common with other amplifier-per-wire systems, the performance is independent of the number of channels, except for a slight increase in encoding time. Large chambers would not present linearity or dead-time problems.

Sensitivity

Noise problems are minimised by direct coupling of the chamber wires to the readout, via charge-sensitive amplifiers.

Spatial resolution

For DCC readout the spatial resolution is one half of the channel spacing. Hence the number of channels may be chosen to obtain the desired resolution. With DCG readout considerable channel interpolation is possible. An increase in complexity and dead-time is incurred. But the cost is not necessarily greater, since the number of channels is much reduced.

Additional Information

The readout information may be used for more than X-Y coordinates. Checking event width allows discrimination against noise, cosmic rays and spurious background events. Pulse height information permits the correlation of X and Y coordinate pairs, in situations where simultaneous events are recorded. The integrated X and Y pulse heights for each event will show a constant ratio because they are produced by one avalanche. This is an important aspect for high-energy physics applications.

The choice between DCC and DCG readout depends on the basic requirements for any particular application: speed, spatial resolution and cost. Applications to gamma-ray imaging ¹²⁾ and high energy beams and particles are under study.

References

1. C.J. Borkowski and M.K. Kopp, Rev. Sci. Instrum. 46, No. 8, 951 (1975).
2. W.R. Kuhlmann, K.H. Lauterjung, B. Schimmer and K. Sistermach, Nuclear Instrum. Methods 40, 118 (1966).
3. J. Alberi, J. Fischer, V. Radeka, L.C. Rogers, and B. Schoenborn IEEE Trans. Nuclear Sci. 22, 255 (1975).
4. V. Perez-Mendez and S.I. Parker, IEEE Trans Nuclear Sci. 21, 45 (1974).
5. G. Fisher and J. Plch, Nuclear Instrum. Methods 100, 515 (1972).
6. C. Parkman, Z. Hajduk, A. Jeavons, N. Ford and B. Lindberg, presented at second Ispra Nuclear Electronics Symposium (1975).
7. G. Charpak, A.P. Jeavons, F. Sauli and R.J. Stubbs, CERN 73-11 (1973).
8. G. Charpak, Z. Hajduk, A.P. Jeavons, R. Kahn, and R.J. Stubbs, Nuclear Instrum. Methods 122, 307 (1974).
9. G. Vuilleumier and C. Demierre, presented at second Ispra Nuclear Electronics Symposium (1975).
10. C. Parkman, CERN, private communication.
11. B. Lindberg, C. Parkman and A. Jeavons, CERN internal report -Omega Hardware Technical Note- 3 (1974).
12. A.P. Jeavons and C. Cate, presented at this conference.

Figure Captions

- Fig. 1. The principle of centre-of-cluster readout. Priority encoders find the end channels (X1, X2), of the pulse distribution on the cathode plane. The centre (X) is then calculated.
- Fig. 2. Block diagram of centre-of-cluster readout for 96X and 96Y channels.
- Fig. 3. Spatial resolution obtained for a ^{55}Fe source collimated to 0.5 mm, with DCC readout. Tick marks every 1mm.
- Fig. 4. Two dimensional imaging with DCC readout, for ^{55}Fe . The vertical lines are the chamber anode wires spaced at 3mm.
- Fig. 5. Block diagram of one coordinate of centre-of-gravity readout, for 96 channels.
- Fig. 6. Spatial resolution obtained for a ^{55}Fe source collimated to 0.5 mm, with DCG readout. Tick marks every 3 mm. FWHM is 300 μm , limited by the range of the photoelectron in the chamber.
- Fig. 7. Electronic resolution measured with the software centre-of-gravity system. The two tick marks indicate 1 mm. FWHM approximately 10 μm .
- Fig. 8. Uniform illumination with X-rays from ^{55}Fe . The two tick marks indicate 1 mm. The peak at the anode wire is split due to sensitivity of the centre-of-gravity readout to avalanches on the left or right of the wire.