

An Extensible Induced Position Encoding Readout Method for Micro-pattern Gas Detectors

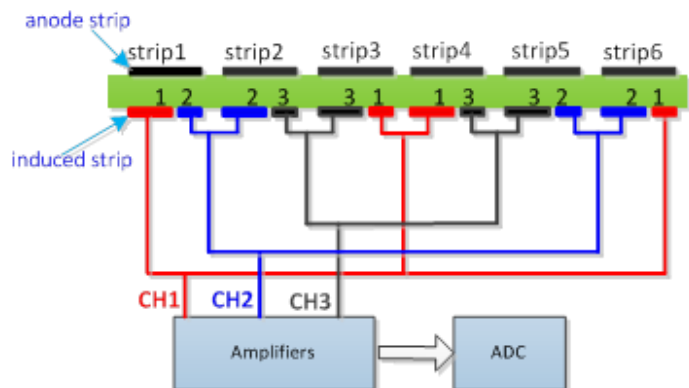


Fig. 1. Induced position encoding readout schematic

Chanel:comparsion	Strip:position
CH1>CH2	Strip 1
CH2>CH3	Strip 2
CH3>CH1	Strip 3
CH1>CH3	Strip 4
CH3>CH2	Strip 5
CH2>CH1	Strip 6

Table. 1. Decoding table of 3 readout channels

Row	Encoding list						
1	12	21					
2	13	32	23	31			
3	14	42	24	43	34	41	
k-1	1k	k2	2k	k3	3k	k4	...

Table. 2. The encoding list of n readout channels

$$(xy)_i = \begin{cases} n, k & R = 1 \\ \left(k, \frac{R}{2} + k\right) & i = \text{even number} \\ \left(\frac{R-1}{2} + k, k\right) & i = \text{odd number} \end{cases}$$

$$i_{(x,y)} = \begin{cases} (y-1)(2n-2y) + 1 & \text{encoding: } ny \\ (y-1)(2n-y) + 2(x-y) + 1 & \text{encoding: } xy (x > y) \\ (x-1)(2n-x) + 2(y-x) & \text{ending: } xy (x < y) \end{cases}$$

Decoding formula

Poster

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Experimental and results

An Extensible Induced Position Encoding Readout Method for Micro-pattern Gas Detectors

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1. Introduction

Over the past 20 years, Micro-pattern Gas Detectors (MPGDs) are widely used in high-energy physics, and have expanded to astrophysics, nuclear physics and medical imaging. The conventional readout techniques employ a large number of electronic channels, which poses a big challenge to the further applications of MPGDs. By changing the readout electrode structure and multiplying the readout channels, a readout-position encoding technique for micro-channel plate detector was developed by D. Katsura et al. in 2007. The technique was used for MPGDs by R. Xu et al. in 2011, where a preliminary feasibility test was implemented with Microegas. This technique can significantly reduce the number of readout channels, but the foregoing works didn't provide an extensible encoding method and the decoding is complicated. In this paper, an extensible induced position encoding readout method for MPGDs is presented. The method is demonstrated by the Eulerian path of graph theory. A standard encoding rule is provided, and general formulae of encoding & decoding for n channels is derived. A prototyping design is implemented on a 5×5 cm² ThickGEM, and verification tests are carried out on a ⁵⁷Co/⁵⁵Fe X-ray source with 100µm slit.

2. Principle and Method

Fig. 1. Induced position encoding readout structure.

Channels combination	Strip position
CH1>CH2	Strip 1
CH2>CH3	Strip 2
CH3>CH1	Strip 3
CH1>CH3	Strip 4
CH3>CH2	Strip 5
CH2>CH1	Strip 6

Table 1. Decoding table of 3 readout channels.

The simplified schematic is shown in Fig. 1, where 6 strips are readout by 3 encoded multiplexing channels. Charge from detectors is collected by an anode strip and split across two induced strips which correspond to the respective readout channels. Due to the different width, charge is split unequally between the two induced strips, where the amplitude on one always higher than on the other. Based on the signal's amplitude in corresponding channel, the hit position could be uniquely decided as seen in Table 1.

As shown in Fig. 1, 3 readout channels have 3² ordered doublets combinations {1,2}, {2,1}, {2,3}, {3,2} which corresponds to 4 doublets. The technique requires that any ordered doublets combination of channels appeared exactly once, and formed head to tail as an encoding list. Generally, the principle described above is a graph theory problem that whether there is an Eulerian path, where the doublets combinations represent the edges and the readout channels represent the vertices. Fig. 2 shows an Eulerian path of the 3 readout channels in Fig. 1. According to Eulerian path theorem, it can be proved that there is an Eulerian path for a channels induced position encoding readout, as all of its vertices have an even degree. In other words, it channels can encode readout a maximum 3² anode strips.

3. Encoding and Decoding

Fig. 2. An Eulerian path.

Row	1	2	3	Encoding list
1	1	2	2	
2	1	3	3	
3	1	4	4	
4	1	5	5	
5	1	6	6	
6	2	1	3	1, 2
6	2	3	1	2, 1
6	3	1	2	3, 2
6	3	2	1	3, 2
6	4	1	3	4, 3
6	4	3	1	4, 3
6	5	1	4	5, 4
6	5	4	1	5, 4
6	6	1	5	6, 5
6	6	5	1	6, 5

Table 2. The encoding list of a readout channels.

It turns out that there are more than one constructions of Eulerian path. We need to make appropriate constraints to construct a regular and extensible encoding method so as to easily decode and design. As shown in Table 2, it is an extensible encoding list for n channels, where the list is organized in rows. The encoding form, X_i means that the signal's amplitude of channel X_i is higher than channel X_j .

According to the Table 2, the encoding formula (1) and decoding formula (2) can be derived as follows:

$$(x_i, y_j) = \begin{cases} n, k & R = 1 \\ \left(\frac{n}{2} + k, \frac{n}{2} + k \right) & i = \text{even number} \\ \left(\frac{n}{2} - k, \frac{n}{2} - k \right) & i = \text{odd number} \end{cases}$$

$$i = \begin{cases} \frac{(y_j - 1)(2n - y_j + 1)}{2} & \text{encoding: } ny \\ \frac{(x_i - 1)(2n - x_i + 2y_j + 1)}{2} & \text{encoding: } (y_i > y_j) \\ \frac{(x_i - 1)(2n - x_i + 2y_j - 1)}{2} & \text{ending: } (y_i < y_j) \end{cases}$$

4. Verification Test

Fig. 3. Experimental setup.

Fig. 4. Charge distribution for different strips.

Fig. 5. Spatial resolution result of the detector.

Fig. 6. Hit position results for different events.

In order to verify this method, a prototyping readout board was manufactured and equipped for a 5×5 cm² ThickGEM detector. To solve the case that each particle usually showers the signal on several neighboring strips, the neighboring strips are separated into three groups to encode respectively. Based on the encoding list shown in Table 2, the prototyping board has 47 one-dimensional 1.07mm strips which readout by 15 channels. According to the decoding formula, the hit strip can be decoded by the first channels.

As shown in Fig. 3, verification tests were carried out on the ThickGEM detector using a ⁵⁷Co X-ray and ⁵⁵Fe/⁵⁷Co X-ray sources. A 100 µm slit is a thin sheet was used to produce a monoenergetic X-ray beam. A manual movable platform was used for the position scanning test. The electrons is based on the VEGAS100 chip.

Fig. 4 shows the signals recorded on all 15 channels when an event hit. Considering the noise of electronics is about 7%, the channel 2 and 4 are valid, and it can correctly to decode the hit position by the encoding form (24). Fig. 5 shows the decoded spatial resolution result of the detector is 0.4 strip (0.43mm). During the position scanning test, the detector was normal with a step size of 0.5 mm in a 20 mm range. Fig. 6 shows the results of spatial resolution in the position scanning test.

4. Conclusion

A novel method of encoded multiplexing readout for micro-pattern gas detectors is presented in this work. The method is demonstrated by the Eulerian path of graph theory. A standard rule for encoding is provided, and general formulae of encoding & decoding for n channels are derived. Under the premise of such rule, a two-dimensional position encoding readout circuit boards is designed based on a 5×5 cm² ThickGEM, and a verification test is carried out on a ⁵⁷Co/⁵⁵Fe X-ray source with 100µm slit. The test results indicate that the method can correctly decode the hit position, and have a good spatial resolution and linearity in its position response. The method provides an attractive way to significantly reduce the number of readout channels. Notably, the method has some disadvantages, such as lowering the signal to noise ratio (SNR) and lowering the detector's rate capability.

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