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# Printed Low Velocity Delay Lines for Cathode Readout of Proportional Chambers*



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MASTER

## SUMMARY

### Introduction

In proportional chambers, longitudinal position readout by time delay measurement on the cathode induced signals has been widely used[1,2].

We shall describe here a readout which simultaneously insures a correct electric field, a satisfactory induced signal, the delay function itself and low particle scattering.

This readout technique is intended for medium precision (5 to 10mm) position measurement of the second coordinate with low dead times (100 to 200 ns), a situation often encountered in high energy physics experiments.

The delay line which is geometrically flat and constructed by printed circuit techniques is used as a cathode and run in strips

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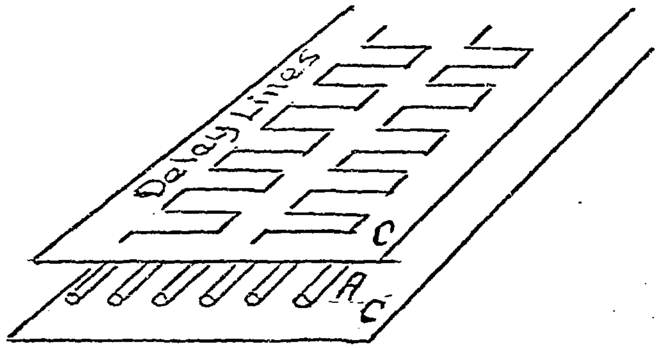
parallel to the anode wires as illustrated in the following sketch.




To increase the delay time $\tau$ per unit length along the anode wires a novel zig-zag structure on two sides of a dielectric sheet was used, which also results in a well defined characteristic impedance Z.

When dealing with such lines, following electrical parameters have to be considered:

1) The delay time $\tau$;
2) The achievable characteristic impedance Z;
3) The 0 to 50% risetime $t_{50}$ of the line in response to a step-function input;
4) The signal coupling efficiency $\eta$ or that fraction of the anode signal charge seen by the line.

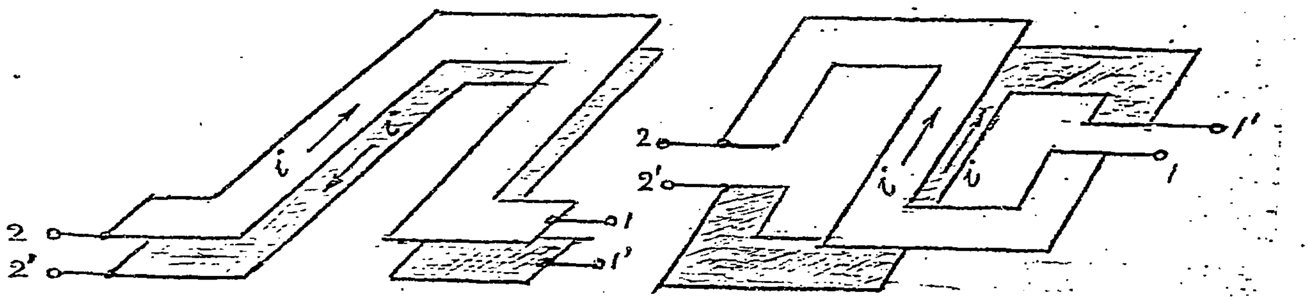
The delay time is chosen as a compromise between the conflicting requirements of position resolution and short dead time. The characteristic impedance is made high for two reasons:

- The signal-to-noise ratio (noise due to line terminating resistance or, in the case of "electronically cooled" termination, series equivalent amplifier noise) varies with the square root of the line impedance.

- The risetime to half amplitude $t_{50}$ determined primarily by the signal dispersion due to skin effect varies inversely with the square of Z for a particular conductor shape and resistivity(3).

## The Shifted Zig-Zag Line

The impedance Z of a zig-zag strip line configuration can be increased either by decreasing the capacitance or by increasing the inductance per unit length. If one tries to decrease the capacitance by increasing the thickness of the dielectric separating the two conductors, the ratio of bridging capacitance to distributed shunt capacitance increases and a fast propagation mode produces precursor signals. There is, however, an efficient way to increase inductance: the return plane instead of being a ground surface is made with another zig-zag shifted by half the geometrical wavelength. The two following sketches illustrate the situation:




If terminals 2 and 2' are short-circuited, the configuration at the left is seen to have the low inductance typical of a hair pin because the currents flow in opposite directions in the two layers. In the shifted configuration at the right, on the other hand, high inductance current loops are formed because the current components are in the same direction in the superimposed wire segments and the two magnetic fields add. The inductance and the delay can be continuously varied by changing the geometrical phase shift between the conductors from $0^\circ$ to $180^\circ$.

Inductance increases of as much as a factor of 70 have been obtained. There is also a slight decrease in capacitance because the narrow connecting segments are no longer superimposed. For example, consider a zig-zag 5 cm wide with 5 mm full period made with 1 mm wide conductors: the unshifted impedance Z is found to be $5\Omega$ and $\tau$ is 1 ns/cm. In the shifted arrangement these values increase to $50\Omega$ and 7 ns/cm respectively.

## Anode to Cathode Coupling Efficiency $\eta$

With typical proportional wire chamber geometries about 25% of the anode charge is induced on each cathode plane, the remainder being induced on the neighboring anode wires. Most of this charge is induced on the inner surface of the zig-zag line but, because of the electrical transparency of the space between conductors, some of the charge is also induced on the outer conductor. Since the shifted zig-zag line is balanced it must be read differentially to avoid a relatively fast common mode wave. The effective signal is, therefore, the difference between the two induced signals. If the two capacitances between anode and the front and back zig-zags are $C_f$ and $C_b$ respectively, the charge coupling efficiency $\eta$ is proportional to $(C_f - C_b)/(C_f + C_b)$. This ratio can be made larger by making the inner zig-zag with a wider conductor than the outer zig-zag. This leads to only a slight decrease in delay and impedance.

Electronics

As we are only concerned with the slow differential propagation mode, balanced to unbalanced transformers have to be used to couple to the amplifiers. Bifilar wound transformers can provide rise-times of 1 to 2 ns with decay times of some μs. The amplifiers themselves are of integrating type which provide a low noise electronically "cooled" terminating impedance[4]. When followed by a differentiating filter and some integration that approximately reconstitutes the original current waveform, a noise line width of about 5000 electrons FWHM was achieved with a line impedance of 100Ω.

Experimental Results

Several lines forming a cathode plane were fitted on a small proportional chamber. The lines were from 20 μ double copper clad 125 μ mylar, with the following dimensions per line:

overall width: 15 mm

conductor width: 0.5 mm

full zig-zag period: 1.25 mm

As expected from theory, the delay was 1.5 ns/cm and the impedance, 100Ω. The temperature coefficent of the delay was 0.02%/°C. Position resolution with 5.9 Kev x-rays of about 5 mm FWHM was achieved with a gas gain of about 7000. Measurements with minimum ionizing particles are under way.

Because of the substantial velocity difference between the common and differential modes, and the possibility of external magnetic coupling to each loop of the line, this line also has other interesting potential applications, some of which will be described.

## References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