Laboratori Nazionali di Frascati

LNF-58/26 (1958)

A. Alberigi, C. Bernardini, I. F. Quercia: PROPOSAL FOR AN ANALOG TO DIGITAL ELECTRONIC CONVERTER SUITED FOR NUCLEAR PULSE HEIGHT ANALYSIS.

Estratto dal: Nucl. Instr. 3, 201 (1958)

NUCLEAR INSTRUMENTS 3 (1958) 201–203; NORTH-HOLLAND PUBLISHING CO. – AMSTERDAM

PROPOSAL FOR AN ANALOG-TO-DIGITAL ELECTRONIC CONVERTER SUITED FOR NUCLEAR PULSE HEIGHT ANALYSIS

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Received 5 August 1958

An analog-to-digital converter is proposed based on the use of delay lines as codifying elements. Application of the converter to pulse height analyzers, with one or more channels, is discussed. Preliminary experimental work is briefly reported.

1. Introduction

This paper concerns a proposal on a pulse height analysing device. The basic idea is the following: if a short pulse, of amplitude V_0, is injected at the input A of a circuit like the one shown in fig. 1, the discriminator will be triggered by a series of pulses due to the reflections at the ends of the suitably terminated line L

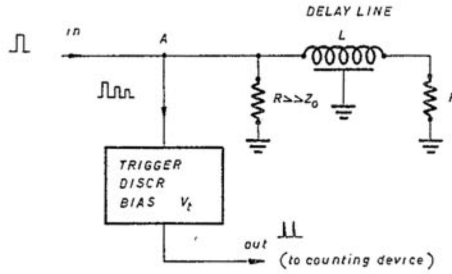

Fig. 1. Basic circuit.

and equally spaced in time by τ (the time delay of $2L$), until the characteristic attenuation of L reduces V_0 to a value less than V_t, the discriminator threshold.

If γ is the attenuation coefficient per unit length and L is the line length, the amplitude of the n-th pulse reaching the discriminator input is:

$$V_0\, e^{-2n\gamma L} \qquad (n = 0, 1, 2, \ldots)$$

while the amplitude of the last triggering pulse is such that

$$V_0\, e^{-2n\gamma L} > V_t > V_0\, e^{-2n\gamma L}\, e^{-2\gamma L}\ .$$

In principle this device could work as an analog-to-digital converter, the number n characterising a digit (a channel) on a logarithmic scale for the input amplitudes[1]).

It is easily shown that the fractional channel width of such a pulse analyzer would be constant, namely that:

$$\text{fractional channel width} = e^{2n\gamma L} - 1\ .$$

Conventional pulse height analyzers have a constant channel width, rather than a constant fractional channel width. We shall see in § 3 that it is possible to modify the basic circuit to fulfill this requirement.

In § 2 we shall show an immediate application of the basic circuit to a window-type discriminator[2]).

2. Window-Type Discriminator

Let us start by introducing the "last pulse triggering" (LPT) circuit.

Let a series of n equally spaced pulses be

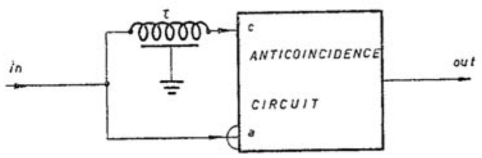

Fig. 2. Last pulse triggering circuit.

[1]) B. Åström, Nuclear Instruments 1 (1957) 143.

[2]) The use of a delay line for a one channel pulse height analyzer has been already proposed by: E. Gatti and F. Piva, Nuovo Cimento 10 (1953) 984.

injected at the input of the circuit shown in fig. 2 starting at time $t = 0$; the last pulse of the series (the n-th) is the only one that triggers the anticoincidence if the time delay τ of the line is just equal to the pulse spacing. Thus, only one pulse appears at the output of the device at the time $(n + 1)\,\tau$.

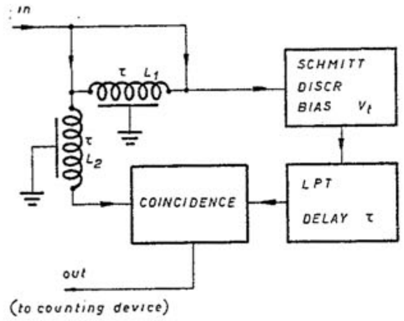

Fig. 3. Window discriminator block diagram.

Let us consider the circuit of fig. 3: we shall show that it works as a window discriminator. The circuit operates in the following manner:

(a) if two pulses trigger the Schmitt discriminator, one coming directly from the input and its τ-delayed partner coming from the line L_1, the LPT fires at the time 2τ: this pulse however is blocked by the coincidence because a pulse appears at the other input of the latter at the time τ, due to the delay line L_2. This happens if

$$V_0\,e^{\gamma L_1} > V_t\,.$$

(b) if $V_0 < V_t$ the Schmitt does not fire at all.

(c) if, however, the input pulse but not the attenuated one triggers the discriminator, then the LPT fires at time τ; at the same time there is a pulse at the other input of the coincidence through the delay line L_2 and a pulse is produced at the output.

The circuit selects those pulses the height of which lies in the interval.

$$V_t < V_0 < V_t\,e^{\gamma L_1}\,.$$

The width of the window, $V_t\,(e^{\gamma L_1} - 1)$ is not constant but varies proportionally to the discriminator bias V_t.

3. Multi-Channel Analyzer

Returning to the constant-width pulse height analyzer, it is easy to see that one can obtain any desired combination of delay and attenuation by means of a network like the one shown in fig. 4; the attenuation is obtained by the dividers (R_k, r_k) together with the characteristic attenuation of the delay lines. Now, it is possible to arrange things so that a pulse, of amplitude V_0, injected at A_k, appears at the output at the time $k\tau$ with an amplitude $V_0/(k + 1)$ (k being an integer ranging from 0 to n).

Let us consider the following diagram (fig. 5):

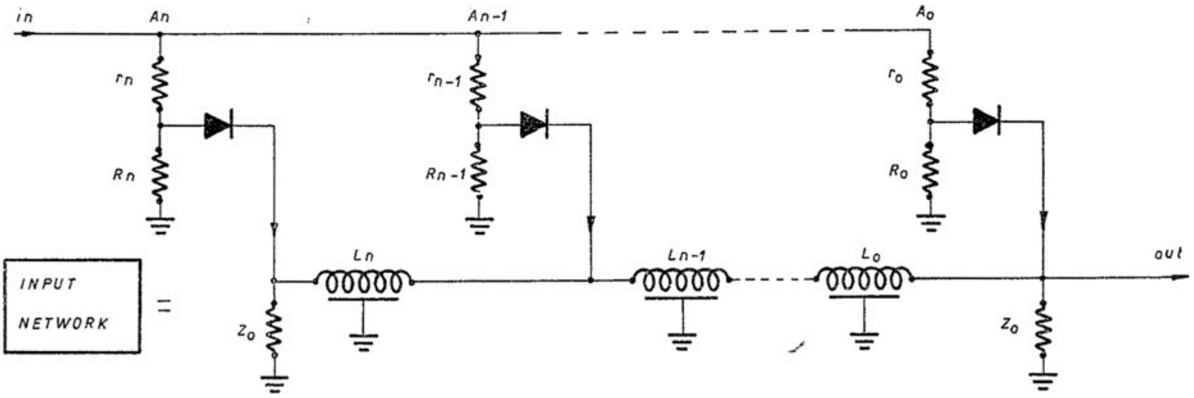

Fig. 4. Basic network for linear amplitude to-delay conversion.

Writing $V_0 = (k_0 + \varepsilon)\,V_t$, where k_0 is an integer and $0 < \varepsilon < 1$, a standard pulse appears at the LPT output at the time $(k_0 + 1)\,\tau$. This is the last pulse which has triggered the discriminator since the succeeding pulse at the discriminator input has an amplitude:

$$\frac{V_0}{k_0+1} = \frac{k_0+\varepsilon}{k_0+1} V_t = \left(1 - \frac{1-\varepsilon}{1+k_0}\right) V_t < V_t .$$

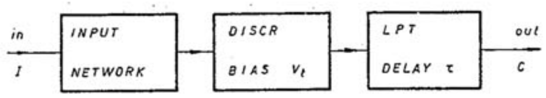

Fig. 5. Block diagram of the analog to digital converter

The "first digit" k_0 of the input pulse has been converted in this way into a time delay $(k_0 + 1)\,\tau$. The pulse can now be conveyed to the k-th counting channel of a storage system according to the diagram of fig. 6.

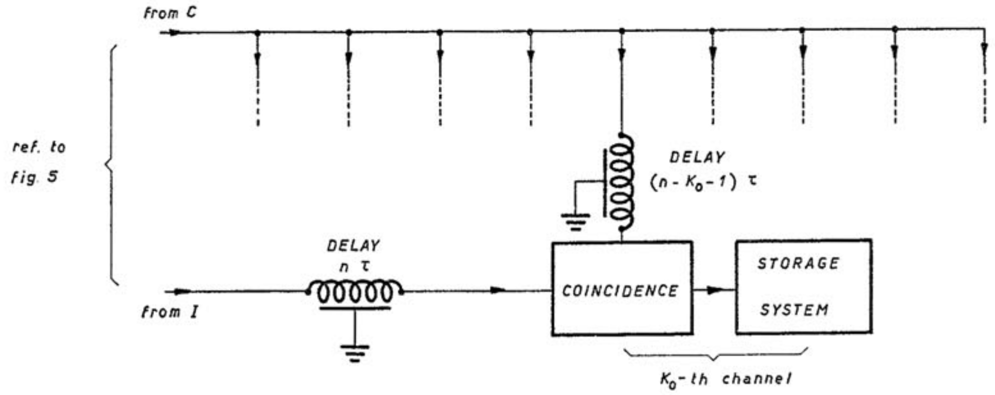

Fig. 6. Decoding and storage system.

Only that coincidence the input of which is delayed by $(n - k_0 - 1)\,\tau$, is triggered by the input pulse delayed by $n\tau$, and by the analyzed pulse delayed by $(k_0 + 1)\,\tau$.

In this way pulses are collected in the channels

$$V_t < V_0 < 2V_t;\ \ 2V_t < V_0 < 3V_t;\ \ldots\ (n-1)\,V_t < V_0 < nV_t$$

that is, the analyzer has $n - 1$ channels of constant width V_t.

4. Preliminary Experimental Work

Preliminary experimental tests have been made of the "Input network" shown in fig. 4.

A four-channel network has been tested using a "Hochental type HH 2 500" delay line (characteristic impedence $Z_0 = 2.700$ ohm, delay 1.9 μs/m, $\gamma = 0.055$ m^{-1}). The lines L_0, L_1, L_2, L_3, all of the same length were adjusted for 2 μs delay. The pulse injected at the input network had a length of 1 μs, and rise and fall times < 0.1 μs. The four output pulses have been carefully checked as regards the amplitude ratios: these ratios were observed to remain accurately constant (within 1%) for large variations of the input amplitudes. Reflections at injection points were found to be completly negligible.

A 16-channel linear pulse height analyzer, and a window analyzer of the types described in §§ 2 and 3 are now being designed. Satisfactory tests of elementary circuits, e.g. the LPT circuit, have been performed. Up to now we have tested the circuits in the 1 μs range, because of the speed limitations of the conventional Schmitt circuits employed as discriminators. To reach shorter analyzing times we need faster discriminators; at present we are studying the latter.