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A SIMPLE THRESHOLD AND DELAY CIRCUIT
FOR MULTI-WIRE PROPORTIONAL CHAMBERS

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Abstract

A one-shot device with input threshold of about one millivolt has been constructed and tested. The circuit, built around one quarter of the inexpensive MC-1020 integrated circuit, delivers standard squared pulses of predetermined duration. By differentiation a delayed pulse can be generated. The circuit is sufficiently sensitive to be driven directly by the chamber in which traces of Freon 13 are added, thus eliminating the need for an amplifier.

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Multi-wire proportional chambers¹ have several remarkable advantages over ordinary wire spark chambers, for instance the much greater resolving time and the shortened recovery time. However, the main drawbacks of this novel technique have been, so far, the considerable complexity and the cost of the associated electronics which have seriously hampered its extension to larger scale detectors.

Recent work^{2,3} has shown that adding traces of electro-negative gases like Freon to the ordinary chamber filling permits obtaining substantially larger pulses, easing the requirements on the threshold sensitivity of the electronics, which in the typical case of 2-mm wire spacing can be increased from about 200 - 300 μ V to a few millivolts.

This report deals with a very simple one-shot device with an input threshold in the millivolt range capable of delivering standard squared pulses of precise pre-determined duration. It is possible to drive the one-shot circuit directly from the output of the wire of the chamber, thus eliminating the need for an amplifier. The trailing edge of the (differentiated) output pulse can be set in coincidence with the general "trigger" pulse from the fast electronics, the pulse length being predetermined equal to the delay of the "decision making" electronics. Briefly, the circuit performs simultaneously the functions of threshold element and of delay.

In addition to the main negative pulse, positive pulses are induced on neighboring wires by electrostatic image effects, typically 10% - 20% of the main pulse. The sensitivity of the present circuit to positive pulses is considerably reduced. Furthermore, exceptionally large positive pulses which may induce spurious triggering because of differentiation produce only delayed, out-of-timing pulses.

The basic circuit is shown in Figure 1. The active part is one of the four differential amplifiers of the inexpensive Motorola MC-1020-P integrated circuit. The amplifier has a gain of about 5, a low output impedance and a risetime of about 7 nsec. The threshold of the trigger is determined by an external non-linear element, a pair of forward biased diodes D_1 and D_2 . The principle of using an external non-linear element in trigger circuits is not a new one. It was applied many years ago to the secondary emission tube EFP60 by Moody and recently by Tarlé and Verweij.⁴ The small signal impedance of a diode is inversely proportioned to the standing current i_D , $Z = C/i_D$, with $C = 29$ mV. The pair of diodes attenuates the output pulse of the amplifier by the factor $\frac{i_1}{i_1 + i_2}$. Let G be the gain of the amplifier alone. Whenever the overall gain of the feedback loop $G \frac{i_1}{i_1 + i_2}$ does not exceed unity, the circuit is stable. The trigger signal is applied

to the inverting input. The differential amplifier increases the current in D_1 and it decreases the current in D_2 by equal amounts, thus increasing the over-all gain of the loop. Provided the gain exceeds unity, a regenerative process will drive the amplifier completely into saturation. The duration of the pulse is determined by the time constant $R_1 C_1$. The input pulse must however be over before this one-shot circuit is flipped back. Otherwise the pulse length would be somewhat affected.

The circuit has been tested with pulses similar to the one delivered by an actual chamber ($t_R \approx 20$ nsec, $t_{\text{Decay}} \approx 200$ nsec). The dependence of the threshold voltage versus the current ratio $\frac{i_1 + i_2}{i_1}$ is shown in Figure 2. Reliable and reproducible operation is obtained down to approximately 400 μV . For an input threshold of 1.5 mV, the standing current i_1 needs to be about 1/2 of the one required to switch the circuit.

The sensitivity of the circuit is largely adequate since a "nominal" threshold of 5 mV is normally necessary at least for the new chamber fillings in which traces of Freon are added and for standard wire spacings: ≥ 2 mm.

The temperature dependence of the threshold and of the pulse length have been checked and found quite small ($\leq 0.5\%/C^\circ$). The stability of the trigger threshold is remarkably good because of the symmetric diode arrangement.

In particular, only the ratio of the two resistances R_2 and R_3 is important.

A complete circuit for processing and storage of the signal from the multi-wire proportional chamber is shown in Figure 3. All functions can be performed with the four differential amplifiers of a single integrated circuit. The number of external components is very reduced, and consists of five silicon diodes, six resistors and two capacitors. The output pulse from the one-shot is differentiated. The positive spike, related to the rise of the trigger output pulse, is available to be mixed with the output from other wires (FAST or bus). The delayed negative spike is set in coincidence with the STROBE signal from the (scintillation) counter logics.

The differential amplifier can be operated as a threshold adding circuit, off-setting the dc levels of the differential inputs slightly more than the larger of the two coincident pulses. Single pulses are not transmitted; coincident pulses switch completely the state of the amplifier. The coincident output pulse sets the subsequent unit, transformed into a bi-stable memory element, connecting the output with the non-inverting input. If the inverting input is set to the center of the transfer characteristics, the non-inverting input and the output can stay either both "high" or both "low". The transition from "low" to "high"

can be performed setting for a short time the other input below the "low" level. The reset can be enforced by bringing the non-inverting input "low" irrespective of the output level. The fourth differential amplifier is the read-out gate.

References

- ¹ For a comprehensive survey of the literature on the subject, see for instance, G. Charpak, "The Evolution of Filmless Spark Chambers", Vol. 20, Annual Review of Nuclear Science (1970).
- ² C. Grunberg, L. Cohen and L. Mathieu, Nuclear Instruments and Methods 78, 102 (1970).
- ³ G. Charpak, D. Rahm, H. Steiner, "Some Developments in the Operation of Multiwire Proportional Chambers", submitted to Nuclear Instruments and Methods, November 1969.
- ⁴ J. C. Tarlé and H. Verweij, Nuclear Instruments and Methods, 78, 93 (1970).

$D_1, D_2 = 1N914A$

$R_1 = R_2 = R_3 = R_4 = 1.5 \text{ kohm}$

$C_1 \approx 300 \text{ pF}$ (FOR 500 ns PULSE DURATION)

$C_2 = 10,000 \text{ pF}$

Fig. 1. Circuit diagram of the one-shot circuit.

Fig. 2. Input threshold versus the ratio between the currents in the two diodes, i_1 and i_2 .

ALL DIODES: IN914
 INTEGRATED CKT: MC1020P

Fig. 3. Complete circuit for processing and storage of proportional chamber pulses.

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