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TENTATIVE ELECTRONICS WITH INTEGRATED CIRCUIT ELEMENTS FOR NUCLEAR PHYSICS EXPERIMENTS

M. COLI and A. ZALLO

Laboratori Nazionali di Frascati del CNEN, Frascati, Italy

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The use of conventional elements of the integrated circuit TTL families is analysed with regard to the problem of resolving time and operating frequency for nuclear physics experiments.

Quantitative results to evaluate the differential and integral resolving time and the maximum operating frequency was reported. A low cost special purpose electronics seems to be realistic for multichannel on-line experiments. A neutral event detection in an η-meson photoproduction experiment is given as an example.

Integrated circuit elements are nowadays currently applied in the interface electronic systems for the storage and the elaboration of data in nuclear physics experiments. Our purpose is to refer to some measurements on integrated circuit elements performing a direct handling of the information from particle detectors. The system proposed shows to have the performances of the fast modern modular electronics, with the advantages of larger flexibility and greater economical convenience. The main problems arising in the design of fast logic systems for nuclear physics data handling, are concerned with the maximum repetition rate of input pulses* and with the resolving time†. The actual values of dead time for the modern families of integrated logic circuits do not seem to put severe limitation for the input rates in experiments with particle accelerators (repetition rate of the order of 10 MHz or less in the most of experiments). The same argument is still more valid if we consider the experiments with storage ring machines. Furthermore the resolving time for the more typical logical I.C. families is of the same order of that showed by a conventional modular fast electronic equipment, as will clearly result from the following. Our analysis has been intentionally restricted to not consider the more modern and faster families of E^2CL I.C.

Differential resolving time: Some gates of the TTL se-

* The maximum repetition rate is that of a continuous waveform of pulses of fixed amplitude and width, for which the system is able to give the correct output features.

† Time resolution is referred as integral and differential. The former is the width of the coincidence curve at fwhm; the latter is the measure of the slope typically between 50 and 90% of the coincidence curve.

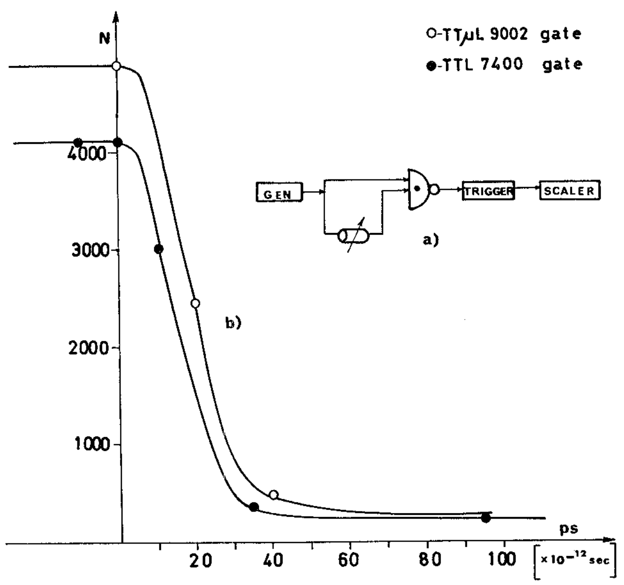

Fig. 1. Differential resolving time curves. Pulser type EH-Model 120 B. Gate 1/4 9002 (or 1/4 7400 N). Trigger threshold = 0.3 V.

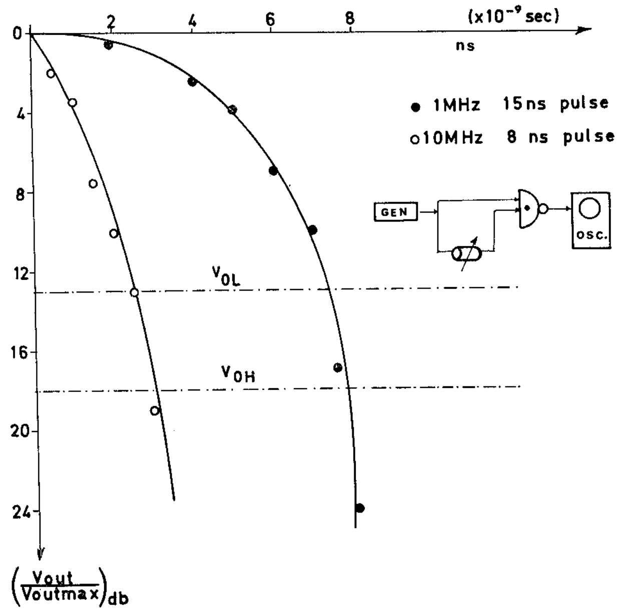

Fig. 2. Differential resolving time curves (attenuation vs delay at the output of the gate).

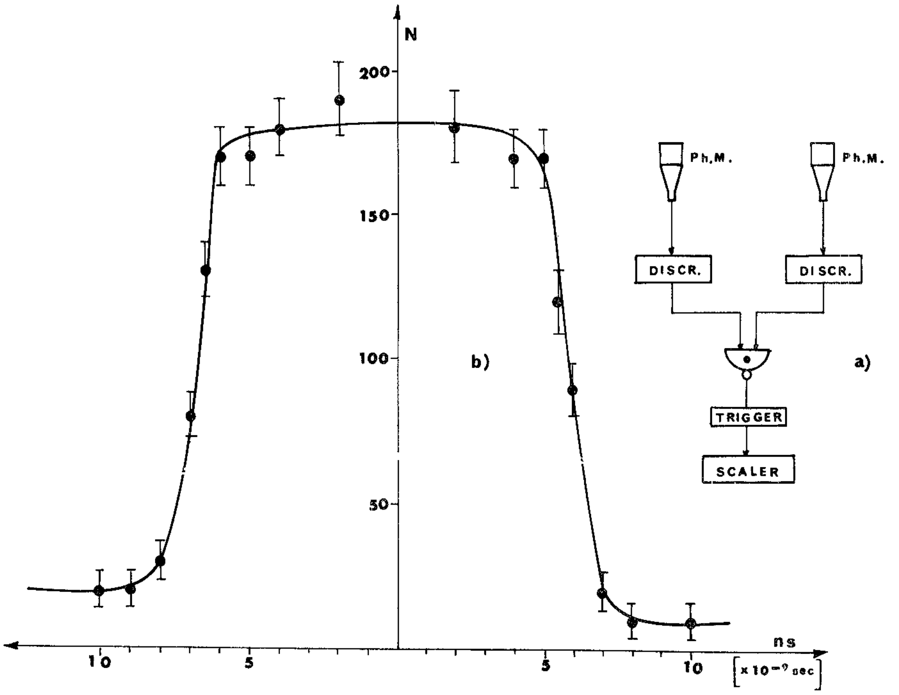

Fig. 3. Cosmic rays coincidence curve. Discriminators = 0.3 V threshold; NAND TTμL gate 9002. Scintillators 20 × 20 cm, 1.5 cm thick, 1 m distant. P. M. type 56 AVP.

ries (74 and 90) have been used to measure the differential resolving time. The NAND inputs of the positive level gate have been joined to a pulse generator in a false coincidence as shown in fig. 1a. The output was sent through a short 50 Ω cable to a shaper whose threshold was at the half of the maximum output level for superimposed pulses. The results obtained are shown in fig. 1b. The time extension of the gap of count decreasing is dependent on the threshold sensitivity of the output shaper. To obtain absolute definition of the differential resolving time independently from any threshold definition, it is more convenient to give the attenuation of the output pulse from the NAND under check, vs the time delay between the incoming pulses. Obviously the output pulse amplitude is dependent from the input pulses delay. The type of dependence is shown in fig. 2 for two different pulse input rates.

The reliability limits of the switching levels V_{OL}, V_{OH} of the TTL integrated circuit family are drawn with dotted lines on the diagram. The worst case for the serially coupling of the gates of the serie is to assume the whole difference between the two levels ($V_{OH}-V_{OL}$) as the total threshold uncertainty.

The diagrams show that the jitter of the maximum delay caused by the coupling of two circuits is contained under 0.5 ns. Furthermore within the interested area the slope of the resolution curve is about 12 dB/ns.

To confirm the results shown by the measurements a "true coincidence" circuit was set up to evaluate the differential resolving time. The input pulses were derived from photomultipliers 56 AVP with plastic scintillators 20×20 cm^2 excited with cosmic rays at the minimum

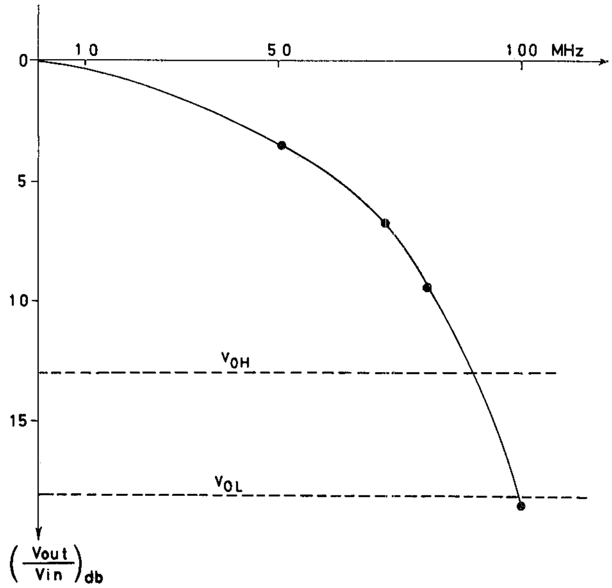

Fig. 4. Output-input attenuation curve vs frequency (1/4 TTμL 9002 gate).

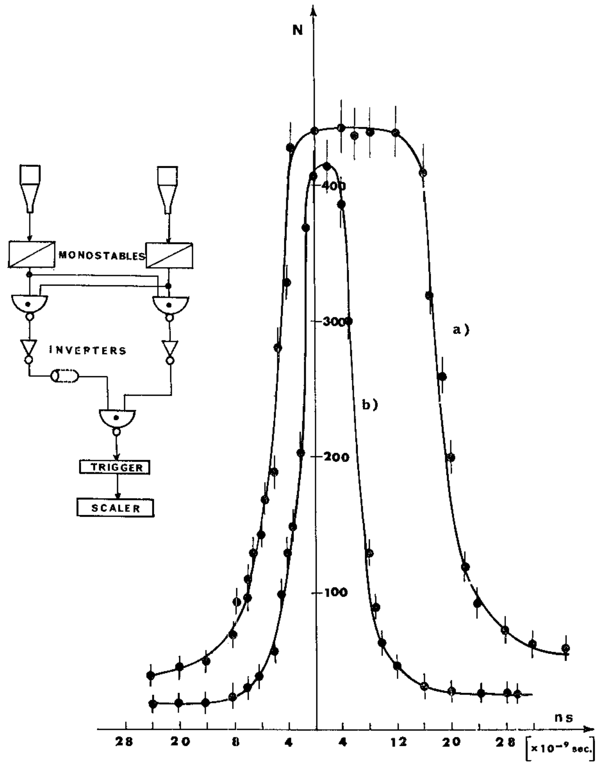

Fig. 5. Coincidence curve. P. M. type 56AVP. Plastic scintillators. ^{60}Co γ-ray source.

ionizing threshold, and passed through fast discriminators (fig. 3a). The results are reported in fig. 3b. The differential resolving time was compatible with the experimental set up (plastic scintillator dimensions, P.M. rise time, threshold jitter of the discriminator circuits, etc.).

Maximum operating frequency: The response of a gate as a function of the input pulse rate was evaluated measuring the attenuation of the output signal vs the input pulse frequency. A diagram is reported in fig. 4 for a TTL 9002 gate. The limits of the switching levels V_{OH}, V_{OL} are drawn once again with dotted lines. It shows that, increasing the input pulse rate, the output pulse amplitude varies 15 dB/octave between 50 and 100 Megapulses/sec.

Integral resolving time: From the measurements before referred we deduce that it is possible to utilise I.C. in the design of fast electronics for nuclear experiments. The logic gates that allow coincidences to be performed must be fed as in typical applications of nuclear electronics, through fast discriminators that standardise the pulse amplitude and width.

It is, in fact, important that standard widths of input pulses to the I.C. gates define, in a precise way, the integrated resolving time and allow its control: the standard amplitude on the other hand reduces the switching probability density curve, decreasing ultimately the differential resolving time[3]). We have used I.C. pulse shapers fed by linear voltage amplifiers. This is obviously required for cable matching purposes. Simple double TTL gate monostable circuits allow a minimum width of 40 ns without excessive width jitter and overdrive on the logic minimum threshold. With a ground-base fast transistor stage, thresholds as low as 100 mV may easily be achieved. The minimum integral resolving time for a double coincidence is therefore of 80 ns and the percentage of spurious counting is very high in a typical experiment with accelerators. As a way of decreasing the integral resolving time we suggest the "differential coincidence"[4,5]) technique. The complexity involved in this solution is minimized because all the coincidence circuits are integrated. Furthermore it is

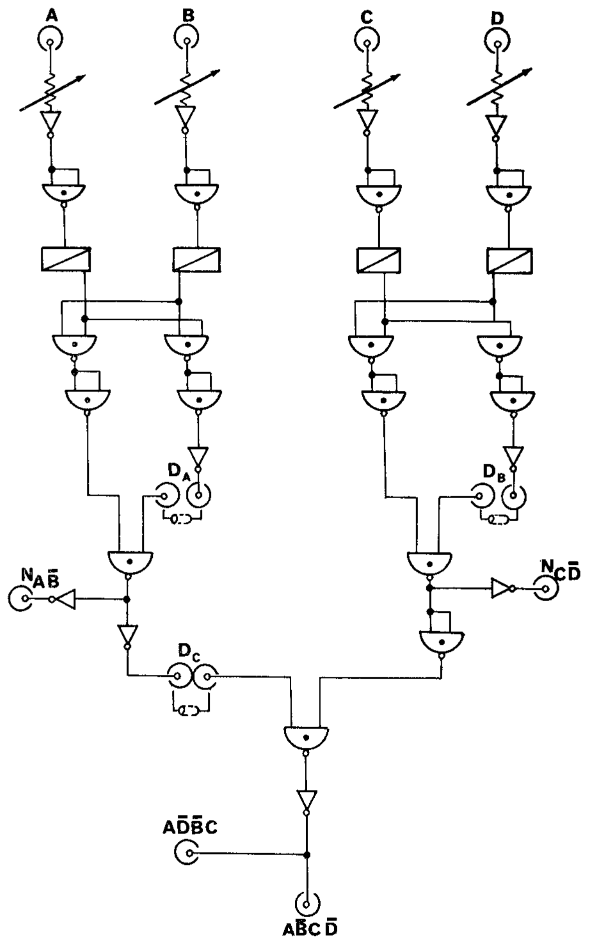

Fig. 6. Logic block diagram of the η-photoproduction experiment.

known that the differential resolving time is dependent on the coincidence efficiency[6]). From what is shown before (fig. 3) with I.C. one could expect no appreciable loss of efficiency in the coincidence. Therefore the differential coincidence technique may be introduced for effective reduction of the integral resolving time.

As an example we report in fig. 5 the coincidence curves relative to channels activated by ^{60}Co γ-ray sources. The curve b was obtained summing a 10 ns delay on a channel of the differential coincidence. The delayed coincidence curve shows a better differential resolving time. The lowering of the number of counts at the top is compensated by the decreasing of the spurious coincidences due to the integral resolving time reduction. The monostable shapers obviously reduce more the maximum rate of the input channels. In fact in the circuits with linear recovering the level restoration is longer by a factor from 3 to 5 than the width of the output pulse[7]). This handicap can be over jumped settling set reset flip-flop shapers at the input. The reset pulse of the input shapers can be derived in this case, from any point of the logical chain and utilized via a cable that guarantees 15 ns delay minimum that is the propagation time of a TTL R-S flop-flip. Input rate up to 30 MHz may be allowed with double gate ac coupled set-reset flip-flop shapers.

Experimental set-up: The results obtained measuring the I.C. TTL gate properties have encouraged to set-up a channel of analysis for the experiment of meson photoproduction at the Frascati electrosynchrotron. A coincidence is derived for neutral events detected by two Čerenkov detectors followed by plastic-scintillators. The logical operation developed in the circuit is:

$$x = A\bar{B}\cdot C\bar{D},$$

being A and C the pulses from the Čerenkov detectors and B and D the pulses from the plastic scintillators selecting the charged particles. The integral resolving time of the two anti was of about 10 ns and the same was for the final coincidence.

The circuit schematic is in fig. 6. The results obtained are congruent with the measurements before described and in a good agreement with previous results acquired on the same experiment with modular fast electronics.

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