ISTITUTO NAZIONALE DI FISICA NUCLEARE

Sezione di Milano

INFN/BE-80/9
2 Settembre 1980

P. Guazzoni, P. Michelato, A. Moroni, G. F. Taiocchi and L. Zetta: D. A. G., A DIGITAL TO ANALOG GENERATOR OF COINCIDENT PULSE PAIRS.

Servizio Documentazione
dei Laboratori Nazionali di Frascati

ISTITUTO NAZIONALE DI FISICA NUCLEARE

Sezione di Milano

INFN/BE-80/9
2 Settembre 1980

P. Guazzoni, P. Michelato, A. Moroni, G. F. Taiocchi and L. Zetta:

D. A. G., A DIGITAL TO ANALOG GENERATOR OF COINCIDENT PULSE PAIRS.

Servizio Documentazione
dei Laboratori Nazionali di Frascati

Istituto Nazionale di Fisica Nucleare
Sezione di Milano

INFN/BE-80/9
2 Settembre 1980

D.A.G., A DIGITAL TO ANALOG GENERATOR OF COINCIDENT PULSE PAIRS

P. Guazzoni, P. Michelato, A. Moroni, L. Zetta
INFN, Sezione di Milano, and Istituto di Fisica dell'Università di Milano

and

G.F. Taiocchi
Ditta Takes, Ponteranica Bergamo.

ABSTRACT.

This paper discusses the simulation of analog signals from a nuclear radiation detector telescope. This goal is reached by means of a generator who reads 39 pairs of digital data punched on a paper tape and presents, as output, the corresponding analog pulses at a frequency, variable up to 60 kHz.

1. - INTRODUCTION.

The identification of the mass of charged particles emitted in nuclear reactions is a constantly recurring problem (for an extensive bibliography readers are referred to ref. (1)).

Related to this problem is the manipulation of ΔE and E signals arising from a detector telescope, to optimize the parameters characteristic of a specified and more generally of the electronic and data collection apparatus.

So far, the experimental set-up was usually tested by means of standard generators (as Ortec 419, BNC PB-4, etc.) or more sophisticated pulser, as Ortec 422 Dual decade attenuator, which simulates a single pulse pair. In this way it is impossible to test the performances of the experimental apparatus as "on beam", i.e. with a lot of coincident pulse pairs, corresponding to particles of different mass and energy.

For these reasons, we have designed and built-up D.A.G., a digital to analog generator of coincident pulse pairs. It reads, by means of an optical paper tape reader, 39 pairs of digital data and converts these into analog pulse pairs, simulating the ΔE and E signals.

2. - DESCRIPTION AND BLOCK DIAGRAMS.

A simplified block diagrams of the pulse generator is shown in Fig. 1. A punched paper tape with 40 pairs of digital data is read by means of a simplified optical reader, through that the tape is runned by hand.

In this way the 40 pairs are stored on a temporary memory periodically inquired at the chosen frequency. The single digital data of each pair are shared out by a distributor to two latches and then converted, by two D.A.C. (digital to analog converter), into analog pulses, whose height corresponds to the digital values punched on the paper tape.

The analog pulses are thereafter stretched and gated in the output circuit to assure pairs of unipolar, positive and coincident pulses of fixed width.

The block diagram of the data input section is shown in Fig. 2a. For each pair, the first value is read as ΔE. the second as E. Each datum - necessarily of four figures (for example 0001) - is separated from the other by one or more not numerical characters. The first pair must be of zero content, otherwise the content is assumed as zero, because this first pair is used as a clock generator for the advancement during the data storage.

The first figures (ASCII code) of the first datum read, are stored in the temporary memory (trivially converted in BCD code).

. Automatically, the BCD-Binary conversion starts. The BCD value is decreased in step of one and correspondingly the binary memory (12 bits) is increased at a 2 MHz frequency.

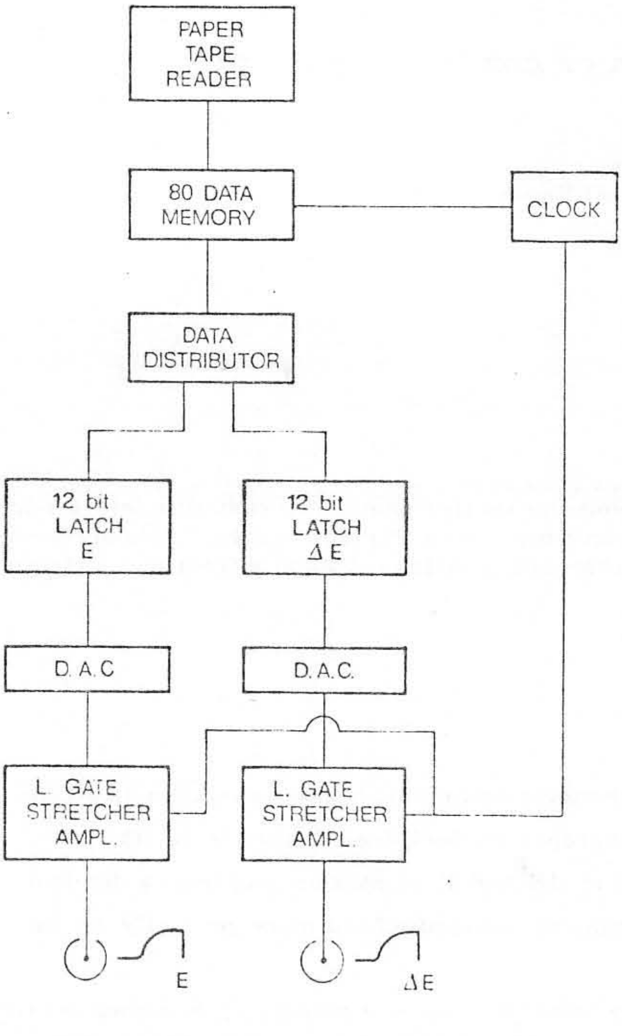

FIG. 1 - **Simplified** block diagram of the pulse generator.

The non-numerical character between the data allows the conversion and consequently the storage of the binary datum in the shift memory. In the same way the second datum of the pair is a)

b)

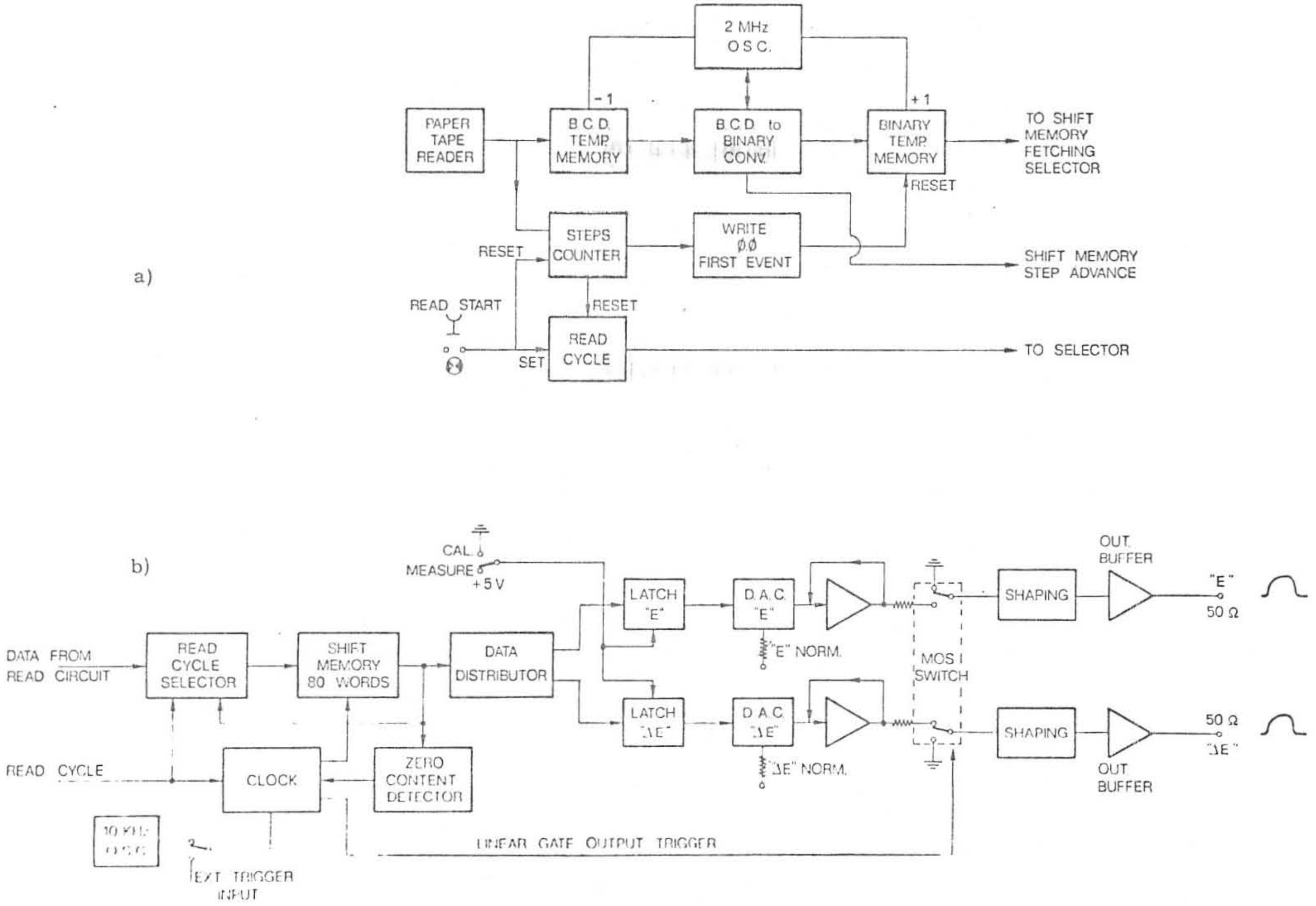

FIG. 2 - a) Block diagram of the data input section; b) Block diagram of the recycle section.

converted and stored in the shift memory.

It is clear, from the Figs. 1 and 2a, that the ΔE and E data of each pair run sequentially through the same circuit to the distributor.

The other steps of the conversion continue during the reading of the remaining data as long as the 40th pair is read. At this moment the reading circuit is stopped allowing the emission of analog data pairs. The switching off of the "READ" light informs about the right completion of the operation.

The block diagram of the recycle and output section is shown in Fig. 2b.

The timing was controlled by the transcoding circuit during the reading cycle, while in the recycle it is controlled by an internal oscillator of about 10 kHz or by an external generator. For each timing the clock causes two reading steps in the shift memory (80 words of 12 bits which constitute the 40 data pairs). Then the data are separated by the distributor in ΔE (odd position) and E (even position) terms, filling the two latches, and subsequently are processed by two D.A.C. and presented to the M. O. S. switch.

A "CAL" switch sets all the latches bits on, i. e. a datum equal to 4095 is presented to the two D. A. C. . Two ten turns potentiometers provide the gain control of the D. A. C. 's (within a range of ± 15 %). By doing so it is possible to normalize all the data pairs, for the ΔE or E channels separately.

Another trick is the zero content detector, at the output of the shift memory, used for the phase adjustment of the pulse pairs. It occurs during the computing of the first pair of data, whose content is zero. Every zero content inhibits the M. O. S. switch, causing a dead time of 5 % and a live frequency of 9. 5 kHz. As previously shown (Fig. 2b) each branch of the output circuit consists of a linear gate and stretcher, triggered by the clock signal. In our case the stretcher needs only a signal integration to simulate the pulse shape of an amplifier output.

All the outputs have an impedence of 50 Ω.

A trigger output of 4 V amplitude, coincident with linear pulses, is also available.

All the circuitry is designed and built-up with low cost standard components.

3. - OPERATING INSTRUCTIONS AND RESULTS.

Assuming the study of the interaction of a proton beam impinging on a ^{16}O target, we can simulate by means of D. A. G. the final results, as using a detector telescope.

In Table I, the Q-values$^{(2)}$ for the reactions producing protons, deuterons, tritons, Helium-3 and alphas, are reported.

TABLE I .

Reaction	p, p	p, d	p, t	p, ^{3}He	p, α
Q-value MeV	0	- 13.4434	- 20.4055	- 15.2426	- 5. 2175

From the specific energy loss tables for silicon(3) we have taken the energy loss in ΔE detector (for example S. S. D. thickness equal to 50 μm) for the different particles.

In Table II are reported the pairs ΔE and E_{tot} at discrete values of the total energy, ranging from the intrinsic threshold of the ΔE detector to the maximum energy due to the kinematics (for example E_p = 36 MeV, ϑ_{lab} = 30^o).

TABLE II

p,p'		p,d		p,t		p, ^{3}He		p,α	
E_{tot}	ΔE	E_{tot}	ΔE	E_{tot}	ΔE	E_{tot}	ΔE	E_{tot}	ΔE
2.4	1.505	3.0	2.084	3.2	2.694	7.6	6.714	8.4	7.659
3.0	1.154	3.4	1.791	3.6	2.314	7.8	6.320	8.6	7.252
3.6	0.964	3.8	1.593	4.0	2.066	8.0	6.003	8.8	6.922
4.2	0.840	4.2	1.447	4.4	1.882	8.2	5.741	9.0	6.642
5.0	0.722	4.6	1.330	4.8	1.735	8.4	5.524	9.2	6.407
5.6	0.656	5.0	1.237	5.2	1.616	8.6	5.333	9.4	6.199
6.0	0.619	5.4	1.156	5.6	1.518	8.8	5.156	9.6	6.010
6.6	0.573	5.8	1.089	5.8	1.473	9.0	5.003	9.8	5.837
7.0	0.546	6.2	1.030	6.0	1.431	9.2	4.863	10.0	5.678
7.4	0.522	6.6	0.979	6.2	1.394	9.4	4.729	10.5	5.343
8.0	0.488	7.0	0.933	6.4	1.356	9.6	4.609	11.0	5.057
8.6	0.463	7.4	0.891	6.6	1.324	9.8	4.498	11.5	4.815
9.2	0.437	7.8	0.854	6.8	1.292	10.0	4.394	11.7	4.700
10.0	0.409	8.2	0.821	7.0	1.261	10.2	4.300	12.0	4.601
11.0	0.379	8.6	0.790	7.2	1.233	10.5	4.165	12.5	4.409
12.0	0.354	9.0	0.762	7.4	1.206	10.8	4.030	13.0	4.243
13.0	0.330	9.4	0.736	7.6	1.181	11.0	3.965	13.5	4.085
14.0	0.312	10.0	0.703	7.8	1.156	11.3	3.840	14.0	3.950
15.0	0.293	10.5	0.673	8.0	1.133	11.5	3.785	14.5	3.820
16.0	0.280	11.0	0.649	8.2	1.112	11.7	3.700	15.0	3.700
17.0	0.268	11.5	0.628	8.4	1.091	12.0	3.620	15.5	3.592
18.0	0.256	12.0	0.609	8.6	1.071	12.3	3.520	16.0	3.489
19.0	0.245	12.5	0.585	8.8	1.051	12.5	3.485	16.3	3.400
20.0	0.235	13.0	0.568	9.0	1.033	12.8	3.400	16.5	3.395
21.0	0.226	13.5	0.553	9.2	1.015	13.0	3.358	17.0	3.308
22.0	0.218	14.0	0.538	9.4	0.998	13.3	3.300	17.5	3.226
23.0	0.210	14.5	0.524	9.6	0.981	13.5	3.242	18.0	3.145
24.0	0.203	15.0	0.509	9.8	0.966	14.0	3.134	18.5	3.071
25.0	0.197	15.5	0.494	10.0	0.950	14.5	3.036	19.0	3.003
26.0	0.191	16.0	0.486	10.5	0.915	15.0	2.945	19.5	2.933
27.0	0.185	16.5	0.470	11.0	0.882	15.5	2.860	20.0	2.872
28.0	0.181	17.0	0.462	11.5	0.852	16.0	2.780	21.0	2.757
29.0	0.175	17.5	0.448	12.0	0.822	16.5	2.708	22.0	2.653
30.0	0.171	18.0	0.441	12.5	0.802	17.0	2.637	23.0	2.553
31.0	0.166	18.5	0.431	13.0	0.776	17.5	2.571	24.0	2.465
32.0	0.163	19.0	0.422	13.5	0.756	18.0	2.510	25.0	2.385
33.0	0.158	20.0	0.404	14.0	0.732	18.5	2.453	26.0	2.309
34.0	0.155	21.0	0.391	14.5	0.714	19.0	2.397	27.0	2.238
35.0	0.151	22.0	0.375	15.0	0.694	19.5	2.345	28.0	2.175

All the energy values are in MeV.

The above values must be converted into mV, using for instance a 0.1 mV/keV conversion, before punching the papertape.

The Fig. 3 shows a photograph of the oscilloscope trace of the ΔE and E signals corresponding to the alpha particles.

In Fig. 4 is shown, for all the particles of Table II, the three-dimensional display of the ΔE vs the E signals. These results have been obtained directly connecting the ΔE and E outputs of D. A. G. to the Y and X inputs of a Multichannel Analyser.

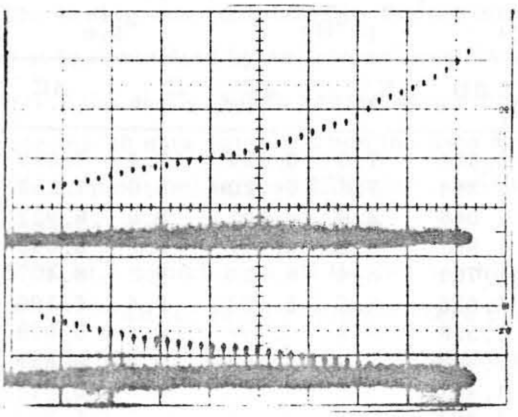

FIG. 3 - A photograph of an oscilloscope trace for ΔE and E outputs for the alpha particles reported in Table II. The horizontal scale is 1 ms/large division.

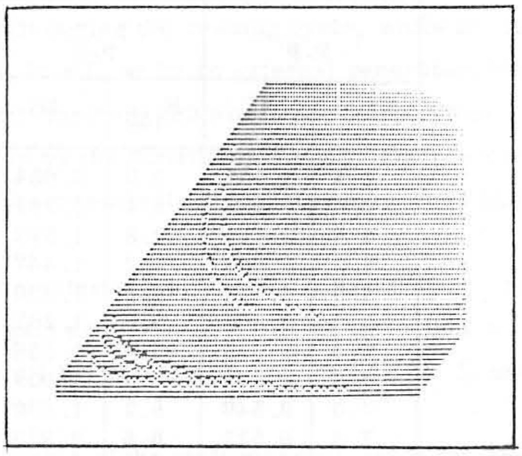

FIG. 4 - A photograph of a three-dimensional display of the ΔE energy loss vs the E energy loss for all the particles of Table II.

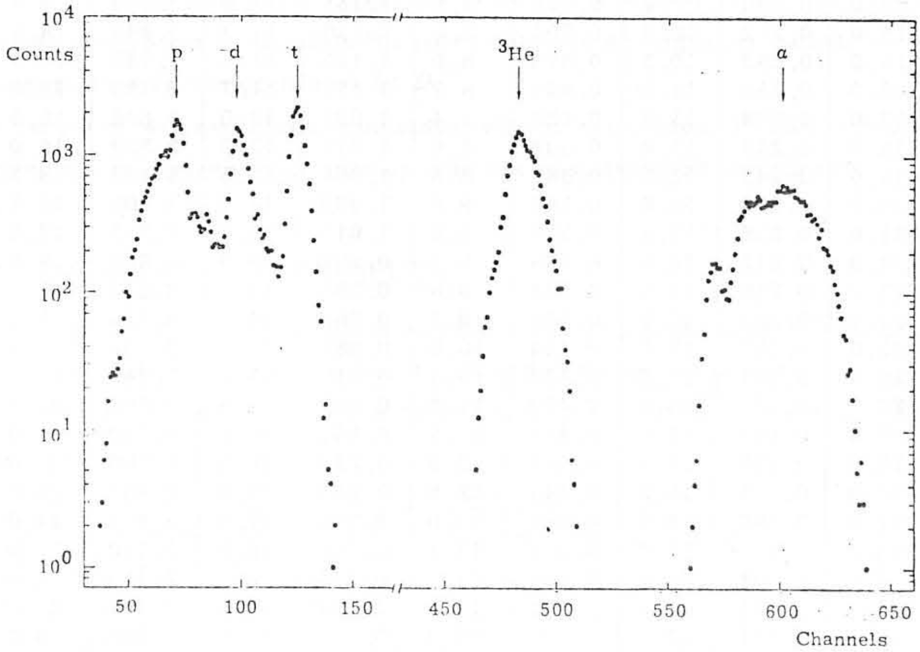

FIG. 5 - The mass identification spectrum obtained with a 423 Ortec Particle Identifier and the input values listed in Table II.

Fig. 5 shows the mass identification spectrum from a 423 Ortec Particle identifier. The D.A.G. outputs were connected directly to the corresponding 423 linear inputs and the suitably delayed trigger output to the enable input. The input data are those of Table II. The exponent value of the algorithm used by 423 was set at 1.76.

Another useful application of D.A.G. may be the calibration of the analog to digital converters (A.D.C.) used with computers on line or multichannel analyzers. In this case only one output, directly connected with the A.D.C., is employed. We have used, for this purpose, 39 values equispaced from 100 mV to 3900 mV, as shown in Fig. 6.

The data, converted by an A.D.C. SILENA mod. 7420, have been analyzed with linear regression methods. The results compared with those obtained with a BNC PB-4 pulse generator, are shown in Table III.

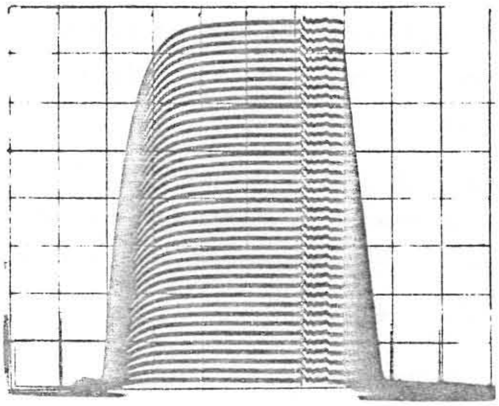

FIG. 6 - A photograph of 39 pulses ranging from 100 mV to 3900 mV in step of 100 mV. This pulse sequence is used for A.D.C. calibration. The horizontal scale is 0.5 μs/large division, the vertical one is 0.5 V/large division.

TABLE III

Pulser	BNC - PB-4	D.A.G.
Parameters		
Offset, mV	- 22.0186	- 22.0087
Conversion gain, mV/ch	0.4567	0.4527
Regression coefficient	0.999999	0.999986

4. - GENERAL SPECIFICATIONS.

The primary parameters of the generator described in the present work fulfil the following requirements.

Triggering: the pulser has two triggering modes, internal and external.

Trigger output: this output is a logical positive unipolar pulse with amplitude 4 V and width 3 μs. It is coincident with linear pulses ; its impedence is 50 Ω.

ΔE and E outputs: these are two linear, positive, unipolar, coincident pulses of variable ampli tude and impedence 50 Ω. In Fig. 7 is shown a typical single pulse.

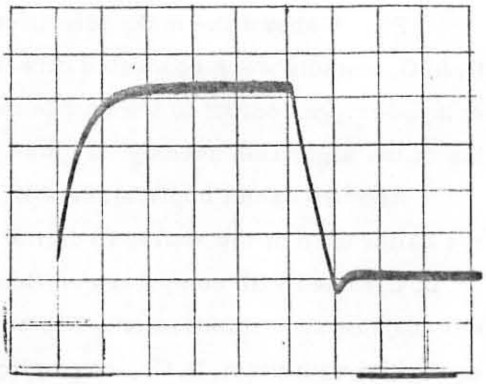

FIG. 7 - A photograph of typical calibration pulse. The scales are the same as in Fig. 6.

Frequency range : in the internal mode the trigger has a fixed frequency of 9.5 kHz, while in the external the frequency may range from $<$ 0.01 Hz to 60 kHz (random and periodic mode).

Amplitude range : from 0.01 V to 4 V, the amplitude of linear pulses can be adjusted by step of 1 bit, i. e. the minimum step of converted signal is 1 mV.

Rise time : 500 ns.

Pulse width : 3 μs.

Amplitude stability : better than 1 mV/72h.

All the normal input and output signals of the module are BNC connectors and the input power is via the AMP 202515-3 connector on the rear panel. The dimensions are conforming to 1-unit NIM module.

The Figgs. 8 and 9 show the front and side view respectively of the pulse generator.

REFERENCES.

(1) - F. S. Goulding and B. G. Harvey, Ann. Rev. Nuclear Sci. 25, 167 (1975).
(2) - C. Maples, G. W. Goth and J. Cerny, Nuclear Reactions Q-values, UCRL-16964.
(3) - J. Picard and G. Souchere, Rapport CEA-R3371.

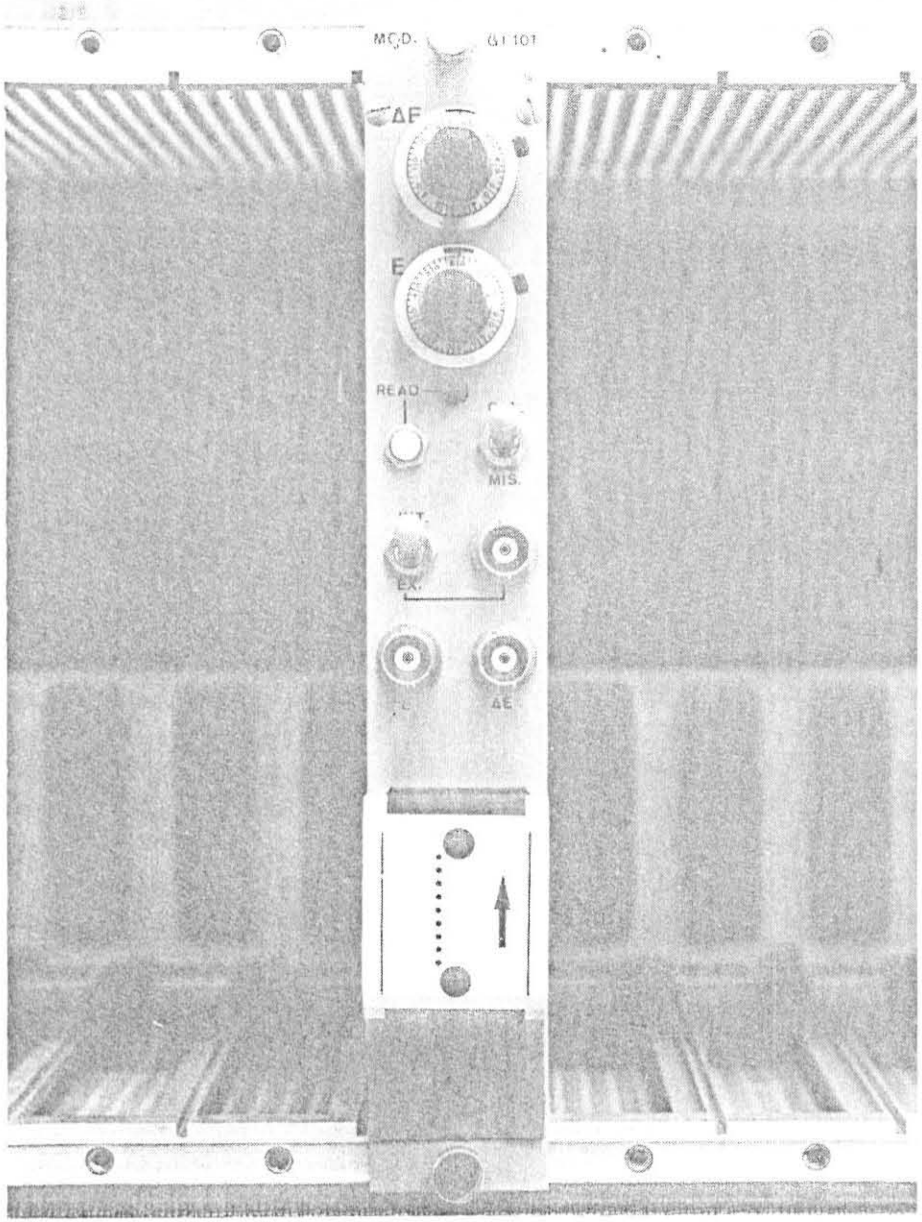

FIG. 8 - A photograph of the front view of D. A. G.. At the bottom can be seen the optical reader.

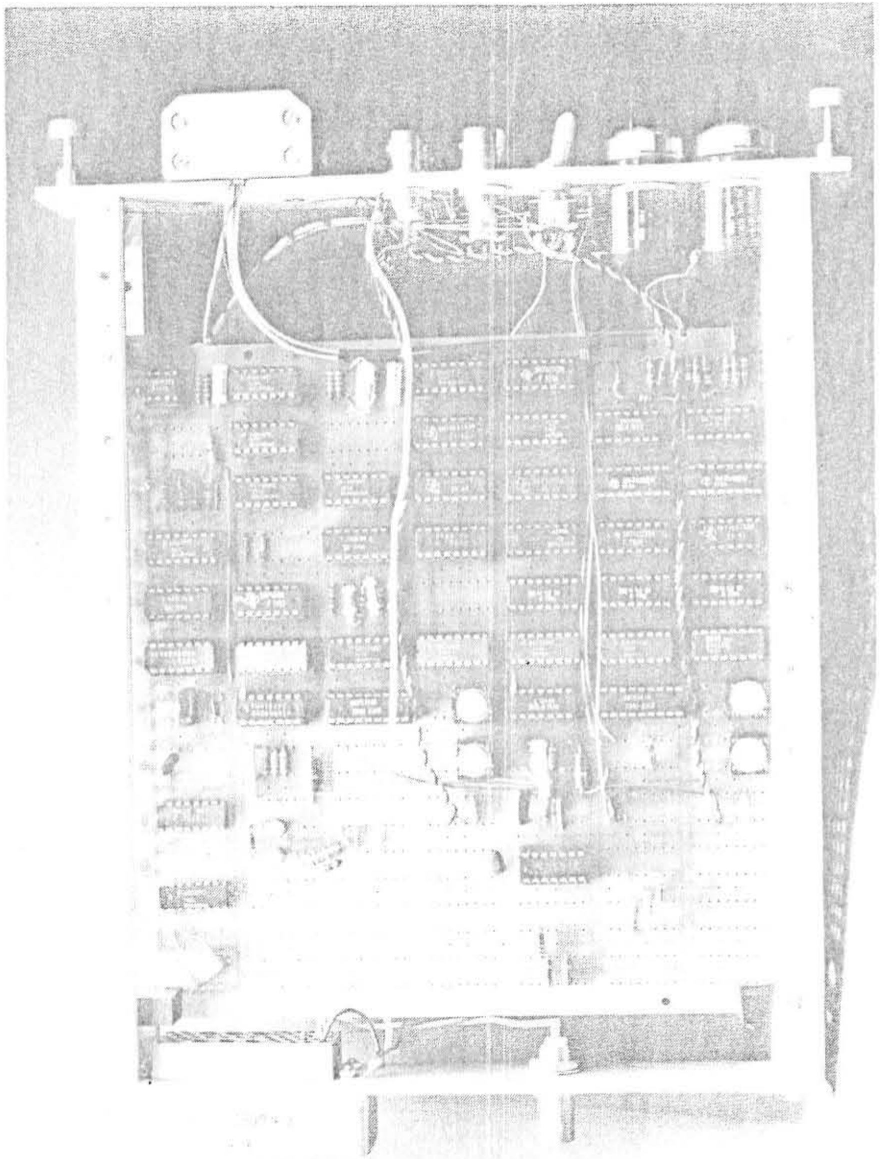

FIG. 9 - A photograph of the side view of D. A. G., showing the components.