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THE DELAY WIRE CHAMBER (DWC) DESCRIPTION

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CONTENT

1. INTRODUCTION

A new type of multiwire proportional chamber, using a delay line read-out and called later on DWC, has been developed to satisfy the needs of several experimental groups to measure the position of incident particles in low intensity secondary beams.

The design was focused on two main parameters : simplicity of operation and low cost.

The DWC offers, compared to other solutions, a simpler mechanical and electronic construction : it associates an auto-trigger facility with an excellent spatial resolution (.2 mm), a good behaviour to moderate rate (2×10^5 p/s) and bi-dimensional measurement. The use of nonexplosive gas mixture makes it very safe to handle.

2. WORKING PRINCIPLE

The chamber is composed of a sandwich of two cathode-wire planes orthogonal to a central anode-wire plane (Fig. 1). The cathode wires are, on one side, connected to a tapped delay line, which is terminated on both ends by its caracteristic impedance and connected to two pre-amplifiers.

The chamber works in the proportional region so that a particle passing across it will produce electron pairs, which drift to the anode. In the vicinity of the wires, an avalanche process takes place and electrons are multiplied just as in a normal MWPC.

At this time an image current is induced, symmetrically to the impact point, on several cathode wires, with an amplitude inversely proportional to the distance from the wire to the impact point.

When these signals reach the delay line (Fig. 2) they split into two equal parts on each side which respectively add together with a time difference equal to the delay per tap.

They travel through the delay line before reaching the amplifiers and the time difference at this point is proportional to the position of the impact relative to the center of the chamber.

Pulse rise time is proportional to the percentage of the contribution of the different cathode wires and the delay per tap of the delay line; due to the time integration of the pulse envelope, the position resolution is much smaller than the cathode wires pitch (one order of magnitude in our case). It would not be the case, if the cathode wires were parallel to the anode wires.

Signals coming from the amplifiers can directly drive a TDC with internal discriminator for direct read-out of the position. For better performances on the absolute position measurement it would have been desirable to first differentiate the pulses and then use a zero crossing discriminator before driving a TDC. It is clear that when using a classical TDC (i.e. double ramp) one has to delay one signal by a time at least equal to the transit time in the delay line.

3. CHAMBER DESCRIPTION

The DWC is built in an aluminium case (Fig. 3A) of 220 x 220 x 50 mm^3 with two kapton windows of 110 x 110 mm^2 and a thickness of 25 µm.

It contains a sandwich of two (x, y) times three insulated frames (Vetronite), each 5 mm thick (Fig. 3B). The cathode planes are made of 55 bronze-beryllium wires of 100 µm, with 2 mm spacing, while the anodes are made of 28 tungsten gold-plated wires of 20 µm, with 4 mm spacing.

The two cathode planes, which are perpendicular to the anode, have their wires interconnected via a 60 pin Scotchflex cable in order to double the weak cathode signal and extend the high voltage plateau by 180 V. The 51 central wires are also connected to the taps of the delay line while the others are grounded.

The lumped delay line is composed of 50 cells of 5 ns with 200 Ohms characteristic impedance (Fig. 4). It has been specially designed to guarantee a high linearity (.2 %) and a good figure of merit (Delay/Rise Time >= 15) in order to reduce the non-linearity errors caused by the degradation of the rise time.

The delay line is matched at each end by the apparent input impedance of two feedback pre-amplifiers (cooled termination). The low noise two stage video pre-amplifiers have a total transconductance gain of 50 Kohms, a rise time < 15 ns and an equivalent noise input current I_n < 40 nA rms.

The printed circuit boards supporting the delay line, the cathode pre-amplifier stages and the anode pre-amplifier are mounted, for each plane, inside the chamber.

The anode wires are connected together on the main frame PCB and the collected signal via a decoupling capacitor and a pre-amplifier, is available at the output. It can be used as earlier trigger for the TDC or other logic.

The DWC is provided with four calibration inputs (three for the cathodes and one for the anode), which allow checking and calibration of the complete set-up.

4. GENERAL SET-UP

The DWC can be mounted on the same mechanical support we have developed for another type of chamber*). The same alignment jig and procedure may be used.

We have been investigating a limited number of different gas mixtures such as Argon and CO_2 with different percentages, with or without Freon, and Argon plus Isobutane. In all cases we obtained chamber gains of a few 10^5, which are suitable for a good operation of the chamber. The gas mixture we have retained for nearly all the beam measurements performed in the West Experimental Area of the SPS, is Argon (50 %) + CO_2 (50 %); the reason of this choice was mainly dictated by the fact that this corresponds to the standard gas mixture we use for all the other MWPC's we have installed in the experimental areas.

We would not expect any deterioration of the DWC performances, if different gas mixtures were used, provided the same chamber gain and an equal high voltage plateau, are maintained.

The gas connection is made through a fast plug-in (Serto) which is standardized for all types of MWPC we use. Considering the moderate rate at which the chamber will work, a gas flux of 10 cc^3/min is sufficient.

A differential pressure monitor with an alarm contact, indicating the correct flux of the gas in the chamber, can be supplied with the chamber, if needed.

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*) Integrating Wire Chamber for Experimental Area SPS/EA/78-4, 14.02.1978.

The cathodes being at a ground potential, we need a positive high voltage power supply (3.5 kV/100 µA) and a cable with SHV connectors. The dark current is less than 100 nA up to the limits of the proportional region (3.2 kV in A + CO_2).

The pre-amplifiers need a bipolar power supply of ± 6 V/100 mA (LEMO Ø 2 pins, pin 1 = -6 V, pin 2 = +6 V).

Figure 5 shows a typical set-up. The output signal, from the internal pre-amplifiers, cannot be transmitted over long distances because the rise time would deteriorate and the induced signal noise would reduce the measurement resolution : it is necessary to discriminate the signals before a long transmission and we advise the use of RG-58 cables, shorter than 30 m, with Lemo 00 type connectors on the chamber side.

The discriminator can be of any type provided it has an independent threshold adjustment for each channel and a minimum sensitivity of -30 mV. If these conditions are fulfilled by the TDC itself, the discriminator may be suppressed. For even better performances the use of a constant fraction discriminator (EGG 934, etc.) or a differentiating network followed by a zero-crossing discriminator is suitable.

The discriminator output can drive good quality cables (RG-213) up to a length of 200 m, if one re-shapes the pulse at the end before entering the TDC. This possibility is very useful for delaying DWC signals in case the decision is too slow.

The anode signal, in an analogue form, is also available at the chamber output and is the OR of all the wires. It can be used as a general trigger having a maximum time jitter of 50 ns (10 ns rms); possible applications are as START of the TDC when the two cathode signals are used as STOP or in a decision logic or for counting purposes.

According to the incident particle position, the time difference between the two cathode signals can be either positive or negative. When using a classical TDC (i.e. double ramp) two solutions are possible to solve the polarity ambiguity. The first consists of using as start the anode signal as mentioned above or any other trigger : the second consists of delaying one of the two cathode outputs by a total amount bigger than the maximum delay of the delay line (250 ns). Both solutions have some drawback : long or additional cables, slow conversion rate, instability of the absolute measurement.

An alternative, which we strongly recommend, is to use a digital TDC (LRS 4208, etc.) where none of the above mentioned problems is present. The time resolution must be <= 1 ns and the range <= 500 ns.

5. CALIBRATION

As the DWC is a linear detector, we can calculate the absolute position by the relation

$$P = a + b\,t$$

where "a" is the pedestal and "b" the slope.

The pedestal "a" represents the propagation delay difference, between the two signals, from the cathode to the TDC. It should be either reduced to zero or compensated for each measurement.

The slope "b" is function of fixed parameters like the cathode wire spacing, the delay per tap and the figure of merit of the delay line, the pre-amplifier rise time and gain; it also depends on variable parameters like discriminator threshold and chamber gain.

We have provided on the DWC three calibration inputs corresponding to the center and to plus or minus 30 mm; the positive calibration signal must have a triangular shape with a rise time of 10 ns, a flat top of 20 ns, a fall time of 60 ns and a repetition rate between 10 and 100 kHz.

The following procedure may be applied to the calibration :

1. Connect the discriminator outputs (left, right, up, down and anode) to a multichannel scaler.
2. Send a permanent calibration to the mid input, then adjust the signal amplitude to roughly -30 mV at the discriminator inputs and set their thresholds to 50 % efficiency on all four channels.
3. The anode calibration should be sent separately and its output will be used as reference. Check that the noise rate at each output is reasonably low (< 1 kHz).

4. With the beam on, make a high voltage plateau curve using an external reference trigger. Select the high voltage corresponding to an efficiency of 95 % and add 150 V; for A + CO_2 (50 % + 50 %) this corresponds to 2750 to 2900 V.

5. Measure the pulse height of the signal at one of the discriminator input and adjust the calibration pulse generator to produce the same value.

6. The pedestal measurement and the standard deviation (SDEV), for that particular working condition, can now be easily determined, if one takes a reasonable number of data using the TDC.

   In order to avoid spurious triggers, mainly due to electronic noise, the TDC should be gated using either the pulse generator trigger or the anode signal output.

7. For the linearity measurements, simply repeat the calibration for the three inputs, sending the same number of triggers in each. Because we know exactly at which physical position the calibration is injected, we can fit the best straight line through the measured points and determine the slope "b" and the non-linearity.

A more realistic simulation, hence a more accurate measurement, can be obtained, using a pulse height distribution of the calibration signal as indicated in Fig. 6.

Because the chamber reliability and M.T.B.F. will decrease very rapidly with the increase of the high voltage, a good compromise in the setting of the H.V. is to select the value which gives the same magnitude for SDEV and non-linearity measurements.

To protect the chamber against H.V. overdrive it is suggested to fix a hardware limit on the power supply corresponding to a current of .5 µA; for A + CO_2 this value correspond to 3100 V.

6. SPECIFICATIONS

Overall Dimensions : 220 x 220 x 50 mm^3

Chamber Acceptance : 120 x 120 mm^2

Active Area : 100 x 100 mm^2

Linear Region : 80 x 80 mm^2

Gas Mixture : A + CO_2 (50 % + 50 %)

Gas Pressure : <= 1.1 atm.

Gas Flux : >= 10 cc^3/min

Windows : 2 x 25 µm Kapton

Maximum High Voltage : 3200 V

Operating High Voltage : 2800 to 2900 V

High Voltage Plateau : > 300 V

Dark Current : < 100 nA

Detection Efficiency : > 99 %

Accuracy : < ± 1.5 %

Spatial Sensitivity : 187 ± 2 µm/ns

Integral Linearity : <± 1 % in the Linear Region
<± 5 % in the Active Area

Differential Linearity : <± 7 %

Resolution : < 200 µm rms

Maximum Rate : 2 x 10^5 p/s for a rejection < 10 %

Chamber Dead Time : < 250 ns

7. ACKNOWLEDGEMENTS

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FIGURE CAPTIONS

Fig. 1	DWC expanded view
Fig. 2	DWC working principle
Fig. 3A	DWC detector. Signal connectors are all grouped in one side opposite to H.V. connector. Gas inlet and outlet are visible on the cover. The two M5 screws are used to support the chamber.
Fig. 3B	DWC internal view. The six frames composing the two orthogonal chambers are fixed on 4 dowells. Delay line and pre-amplifiers are visible on the front.
Fig. 4	50 cell lumped delay lines before and after molding.
Fig. 5	Typical DWC set-up.
Fig. 6	Pulse height distribution of the pre-amplifier output signal for multi-GeV electrons in $A + CO_2$ (50 % + 50 %) with HV = 2'800 V.

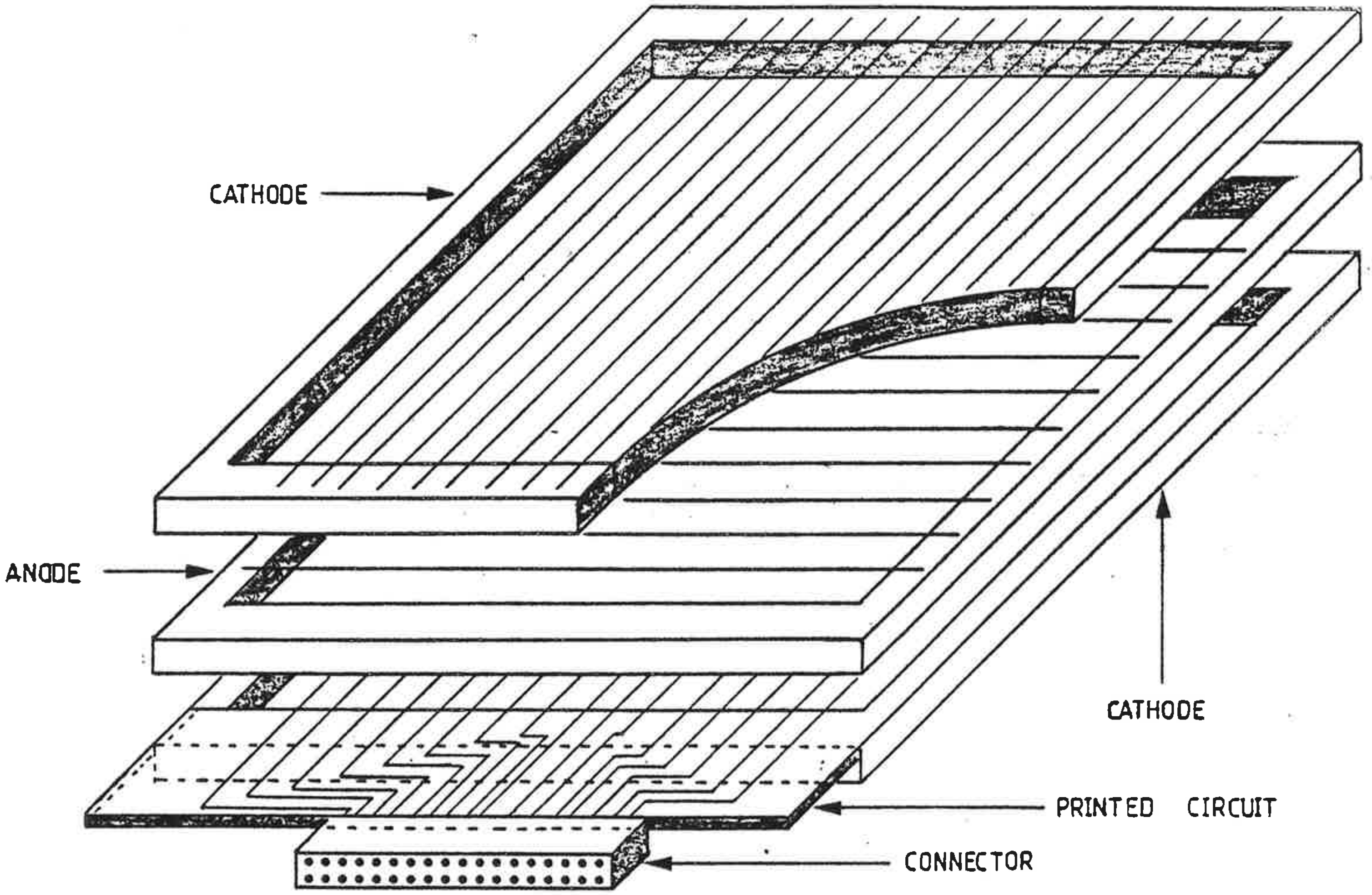


Fig. 1

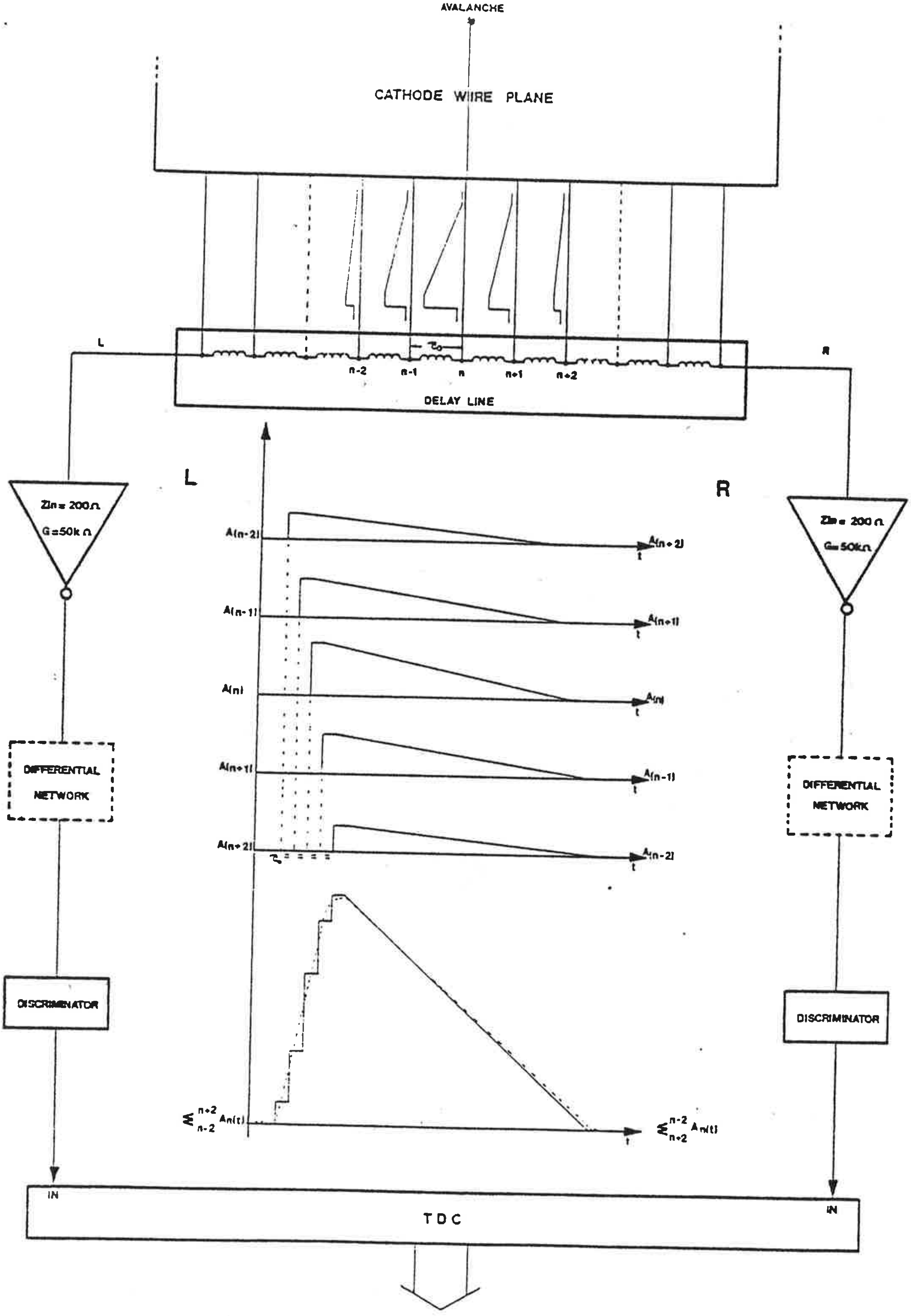

AVALANCHE
CATHODE WIRE PLANE
L
R
τ_0
n-2
n-1
n
n+1
n+2
DELAY LINE
L
R
Zin = 200 Ω
G = 50k Ω
Zin = 200 Ω
G = 50k Ω
A(n-2)
A(n+2)
t
A(n-1)
A(n+1)
t
A(n)
A(n)
t
A(n+1)
A(n-1)
t
A(n+2)
A(n-2)
t
τ_0
$\sum_{n-2}^{n+2} A_n(t)$
$\sum_{n+2}^{n-2} A_n(t)$
t
DIFFERENTIAL NETWORK
DIFFERENTIAL NETWORK
DISCRIMINATOR
DISCRIMINATOR
IN
IN
TDC

Fig. 2

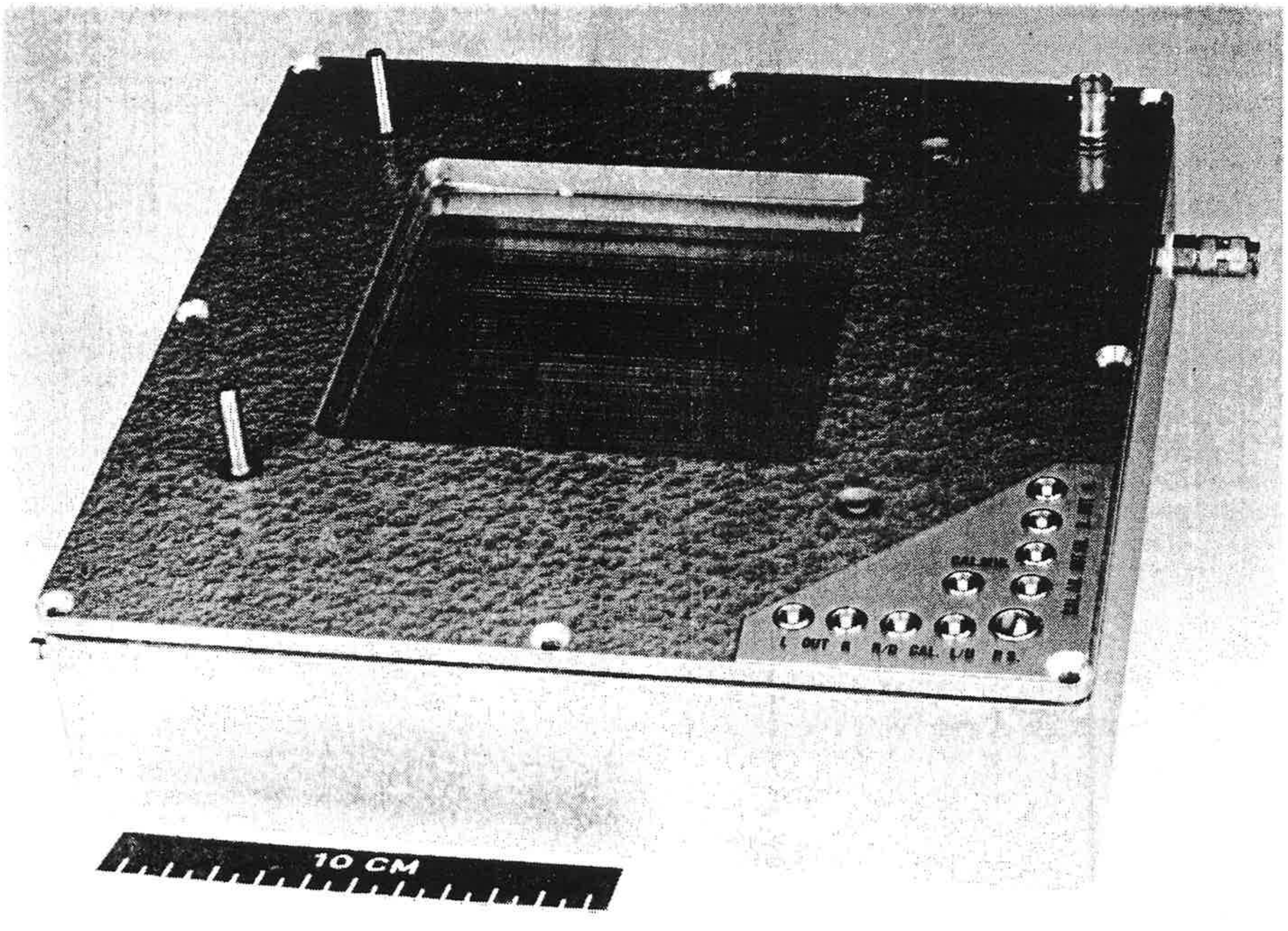


Fig. 3A

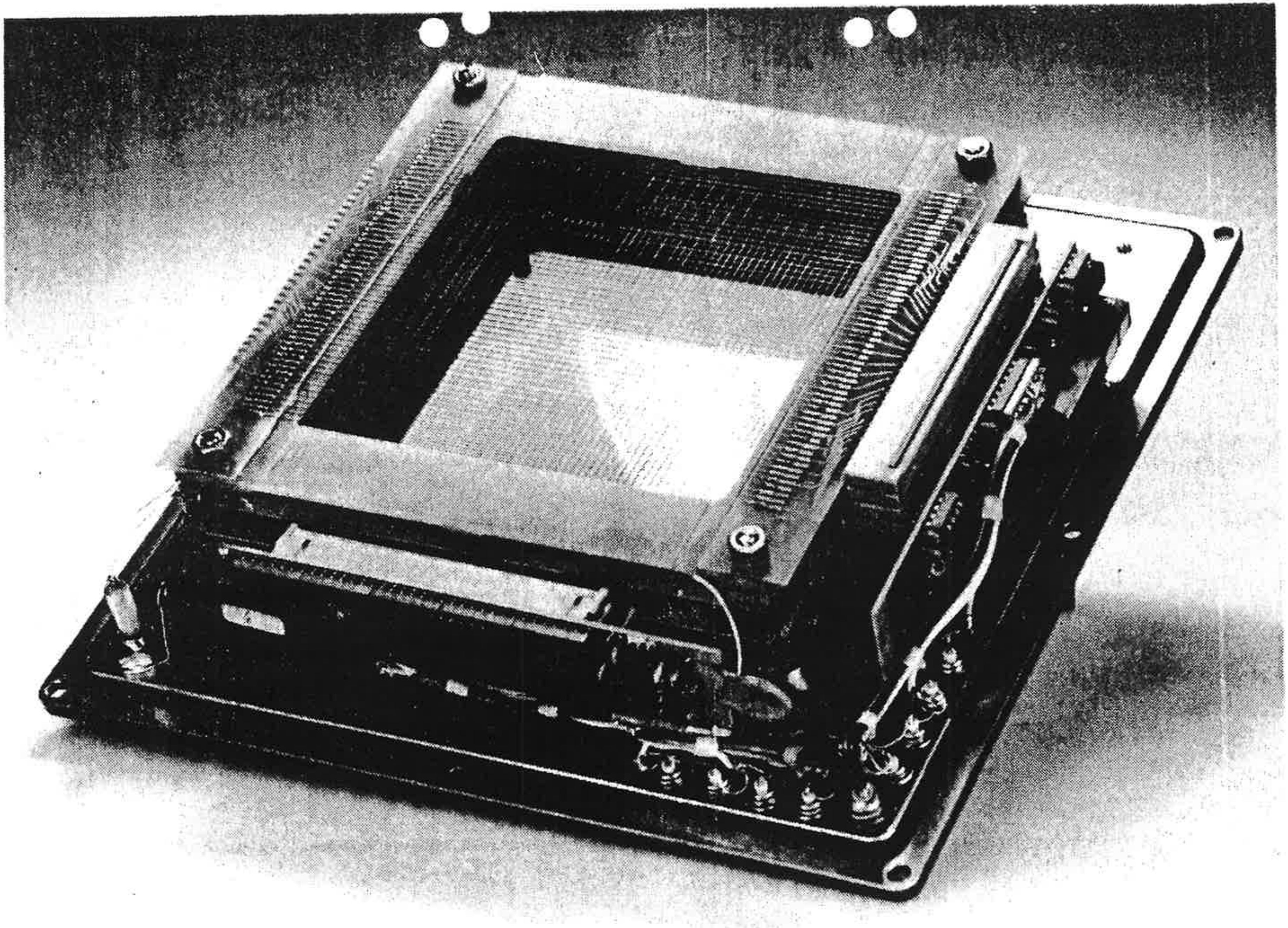


Fig. 3B

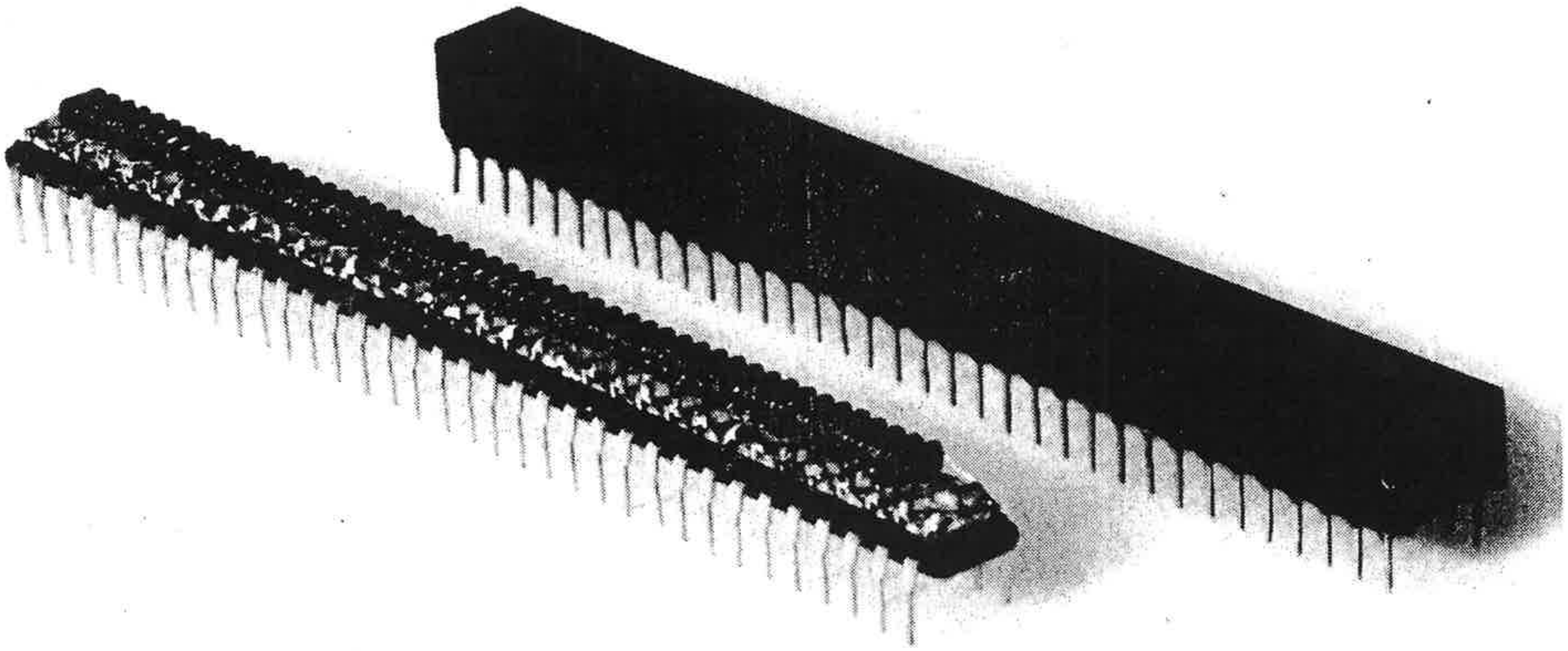
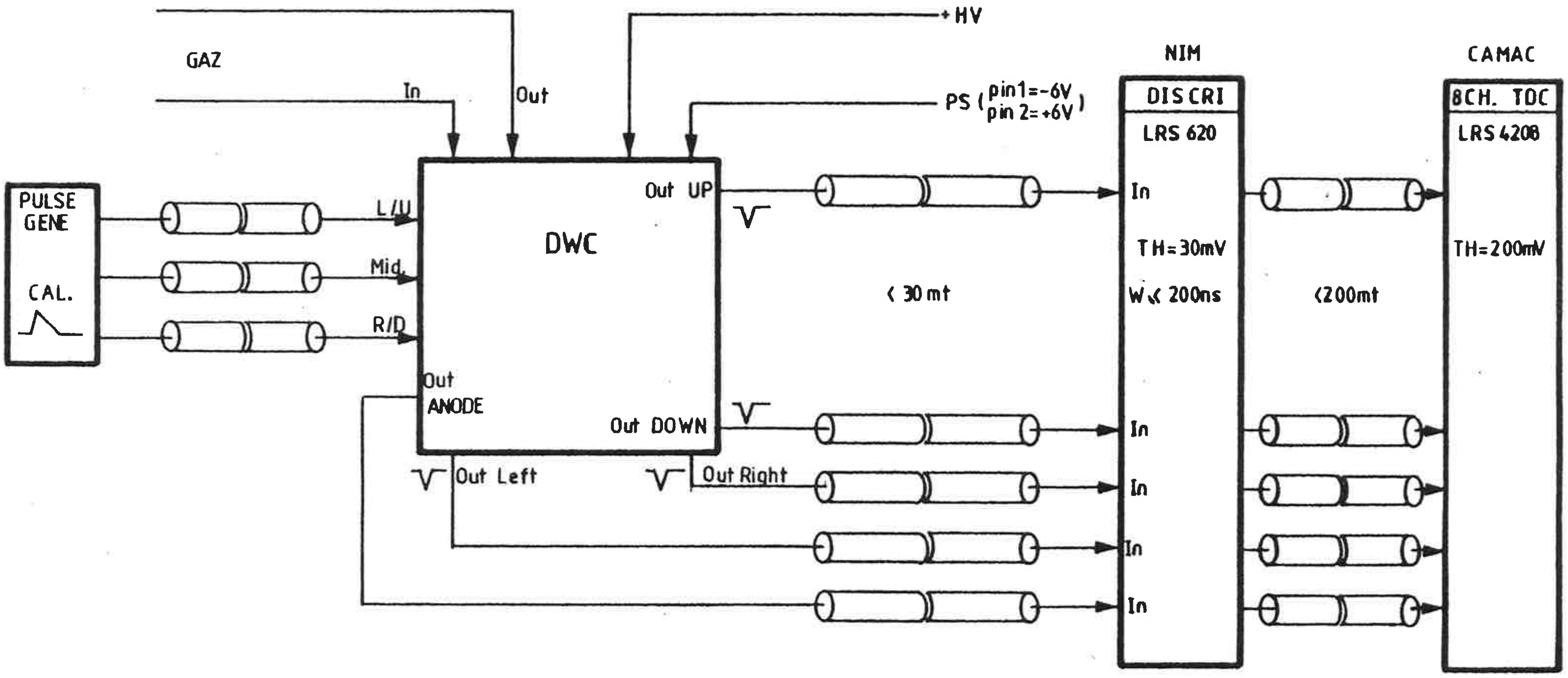


Fig. 4


GAZ
In
Out
+HV
PS (pin1=-6V pin 2=+6V)
NIM
CAMAC
PULSE GENE
CAL.
L/U
Mid
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DWC
Out UP
Out ANODE
Out DOWN
Out Left
Out Right
< 30 mt
DISCRI
LRS 620
In
TH=30mV
W < 200ns
In
In
In
In
<200mt
8CH. TDC
LRS 4208
TH=200mV

Fig. 5

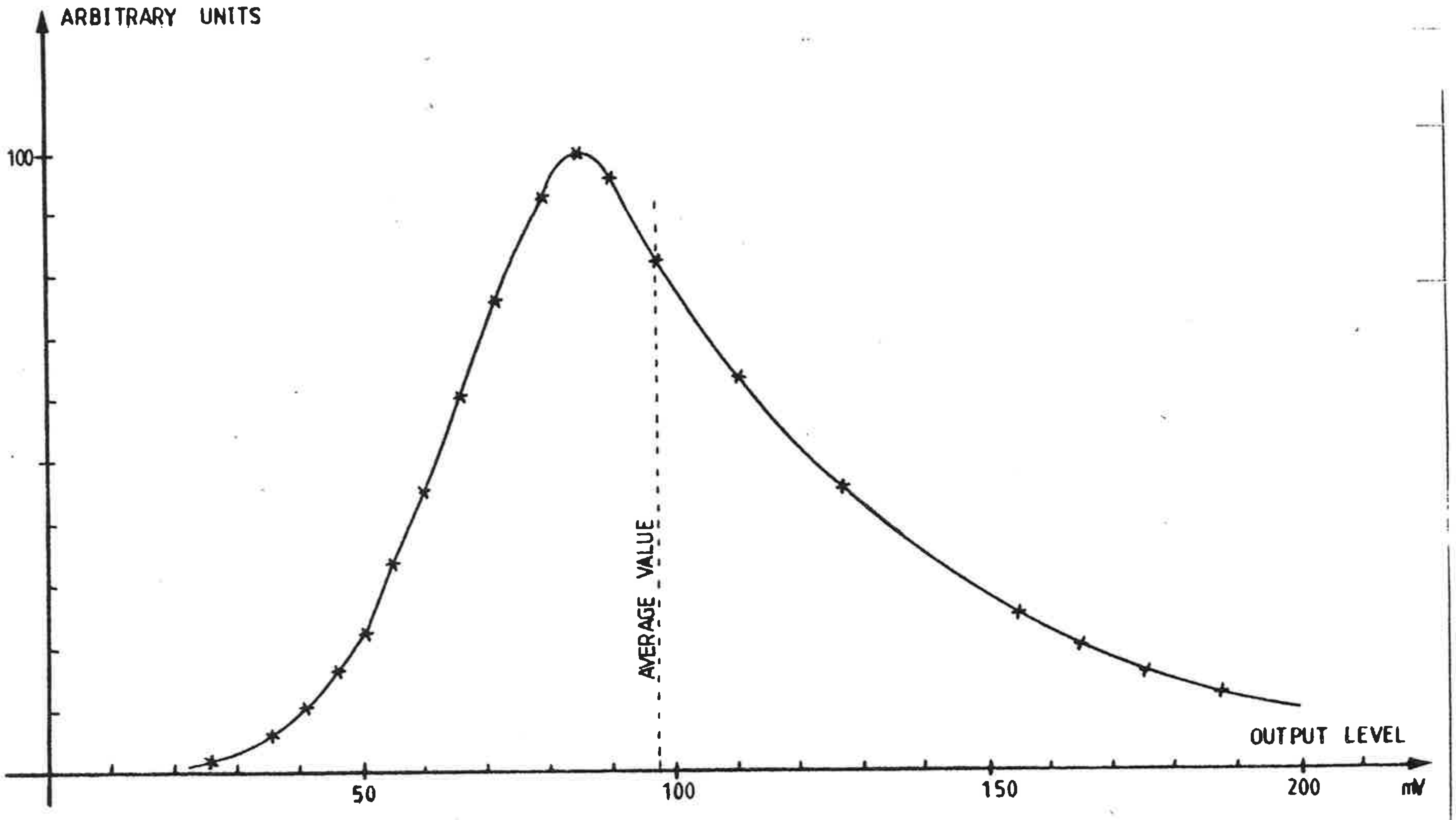
ARBITRARY UNITS
100
AVERAGE VALUE
OUTPUT LEVEL
50
100
150
200
mV

Fig. 6