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CHARGE DIVIDING MECHANISM IN POSITION-SENSITIVE DETECTORS

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A complete charge-division mechanism, including both the diffusion and the electromagnetic wave propagation on resistive electrodes, is presented. The charge injected into such a transmission line divides between the two ends according to the ratio of resistancies and independently of the value of the line resistance, of the propagation mechanism and of the distribution of inductance and capacitance along the line. The shortest charge division time is achieved for $R\ell = 2\pi (L/C)^{\frac{1}{2}}$, where R, L, C are resistance, inductance and capacitance per unit length and ℓ is the length of the line.

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SUMMARY

Position determination of the particle along the anode wire via charge division has been reported by several authors in past years. The underlying physical processes, however, have been studied using only diffusive approximation of the transmission line equation which neglects completely the inductance of the line.

As is shown in Fig. 1, the anode wire with the surrounding electrodes can be considered as a transmission line with the distributed R, L, C parameters (resistance, inductance, and capacitance per unit length, respectively, and $G = 0$. The propagation of signals along such a transmission line is studied. It is shown that for any anode line with $R \neq 0$:

(1) there are two different propagation mechanisms always present,

(a) electric diffusion

(b) electromagnetic wave propagation.

The relative importance of each propagation mechanism depends on the line parameters. If the total ohmic resistance $\ell \cdot R$ of the anode is larger than the critical resistance $R_c = 2\pi\sqrt{L/C}$ the electric diffusion mode of propagation dominates. If $\ell R < 2\pi\sqrt{L/C}$, the electromagnetic wave propagation is the dominant propagation mechanism. For the critical value of the anode resistance, both

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mechanisms are equally important.

It is shown that for the critical value of the anode resistance, the deterioration of the signal rise time due to the diffusion properties of the resistive anode is negligible for all practical applications. Moreover, it is shown that the critical value of the anode resistance minimizes the discharge time of the line, that is the time needed for the charge division method to give its asymptotic value which depends only on the position of the incident particle.

(2) Asymptotic ratio of charges flowing out from the two ends of the anode wire is the inverse ratio of the wire resistances between the injection point and the wire ends. ($Q_A/Q_B = r_B/r_A$. See Fig. 1.) This ratio does not depend on L or C of the line even in the general case when both L(x) and C(x) are functions of the position along the anode (including the lumped L_1C added to the line). Only the time needed to reach the asymptotic ratio depends on all parameters of the line.

The first point proves the compatibility of the charge division method with the drift time measurement allowing the construction of the drift chamber with the unambiguous second coordinate readout via charge division. The anode resistance can be chosen close enough to the critical value so the rise time of the signal at the end of the anode wire is practically uneffected and does not deteriorate the drift coordinate measurement.

The second point proves suitability of the charge division method for a large detector system with many wires.

The uniformity of the wire specific resistances can be easily checked and is good enough for the majority of the commercially available wires. If the charge collection time constant is made long enough to measure the asymptotic value of the charge ratio, the measured ratio is simply related to the particle position along the anode wire. The relation is the same for each wire of the system regardless of eventual differences in the L and C parameters of the individual wires.

Figure Captions:

Fig. 1. Resistive anode with surrounding electrodes represents a transmission line with distributed R, L, C parameters. The charge Q_s is injected into the line at the position of the incident particles.

Fig. 2. Voltage along the 2 m long anode wires 3 ns after an infinitely sharp charge was injected at the wire center for the wire with total ohmic resistance ℓR,

(a) equals ½ of the critical resistance (underdamped)

(b) equals two times the critical resistance (overdamped)

(c) equal to the critical resistance (critically damped).

Direction of the front wave propagation is shown. Relative importance of the diffusion and electromagnetic wave propagation can be seen.

Fig. 3. The same as Fig. 2 but after 6 ns. Electromagnetic wave was reflected from the ends of the wire (shorted). In the case (a) the total stored charge in the line changed the sign during the reflection; in case (b) wave is practically invisible and diffused charge is sitting in the line; for the critical case (c) the total charge does not change the sign and the line is almost discharged.

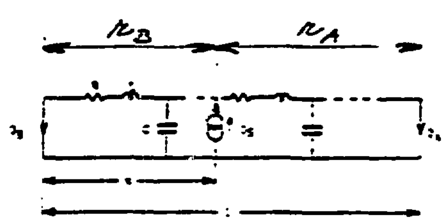

Fig. 1.

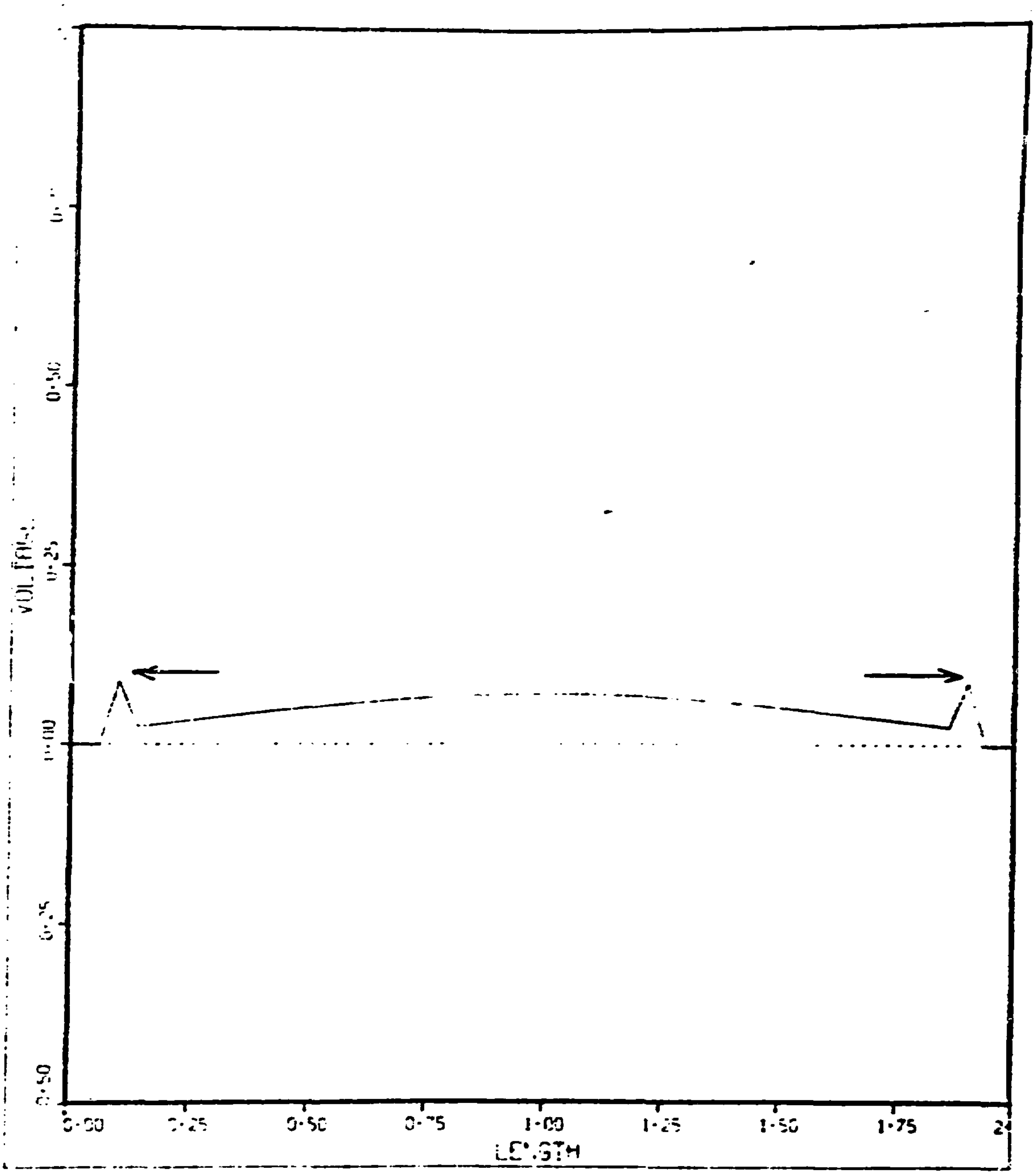

Fig 2a

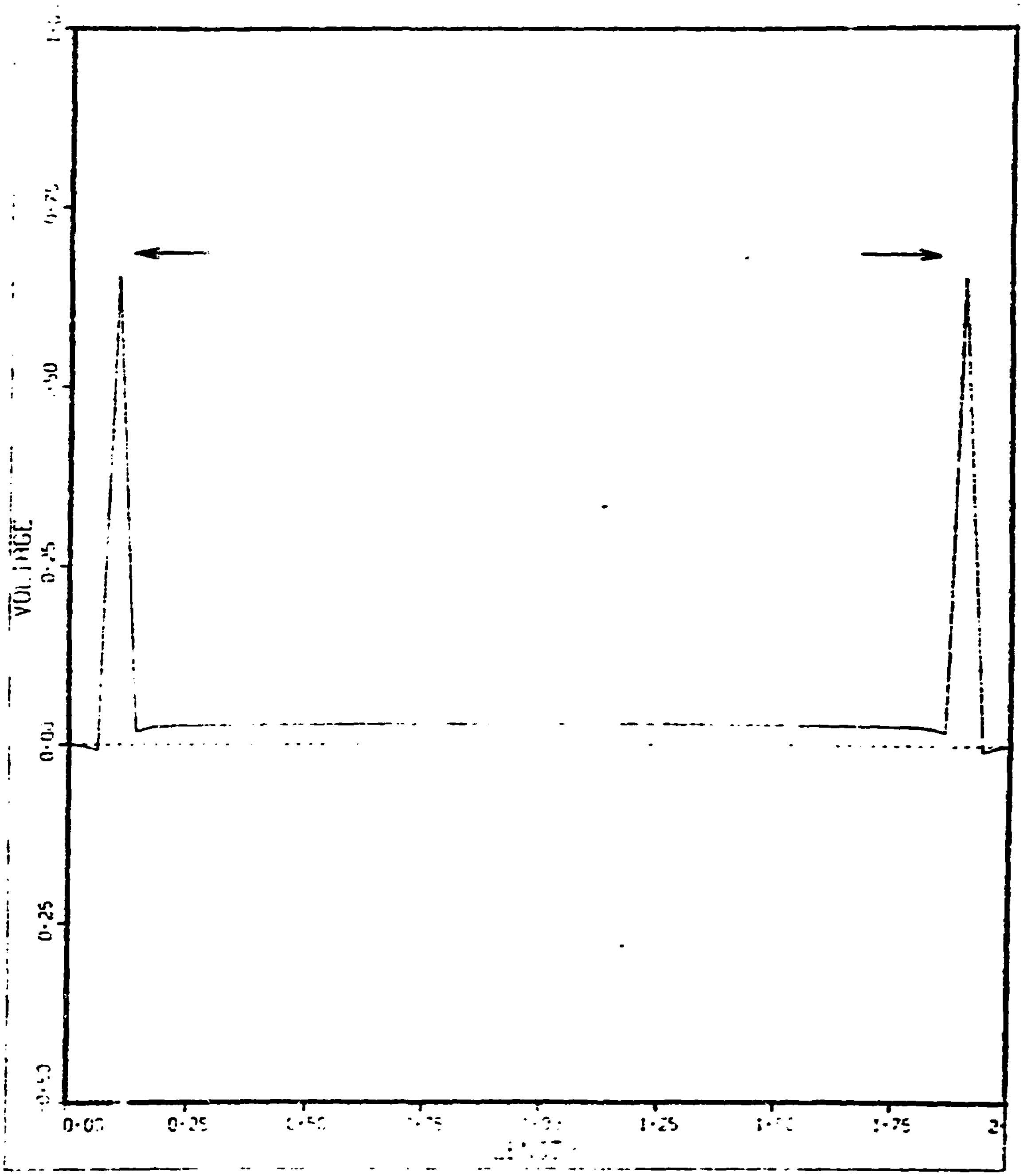

Fig. 2b

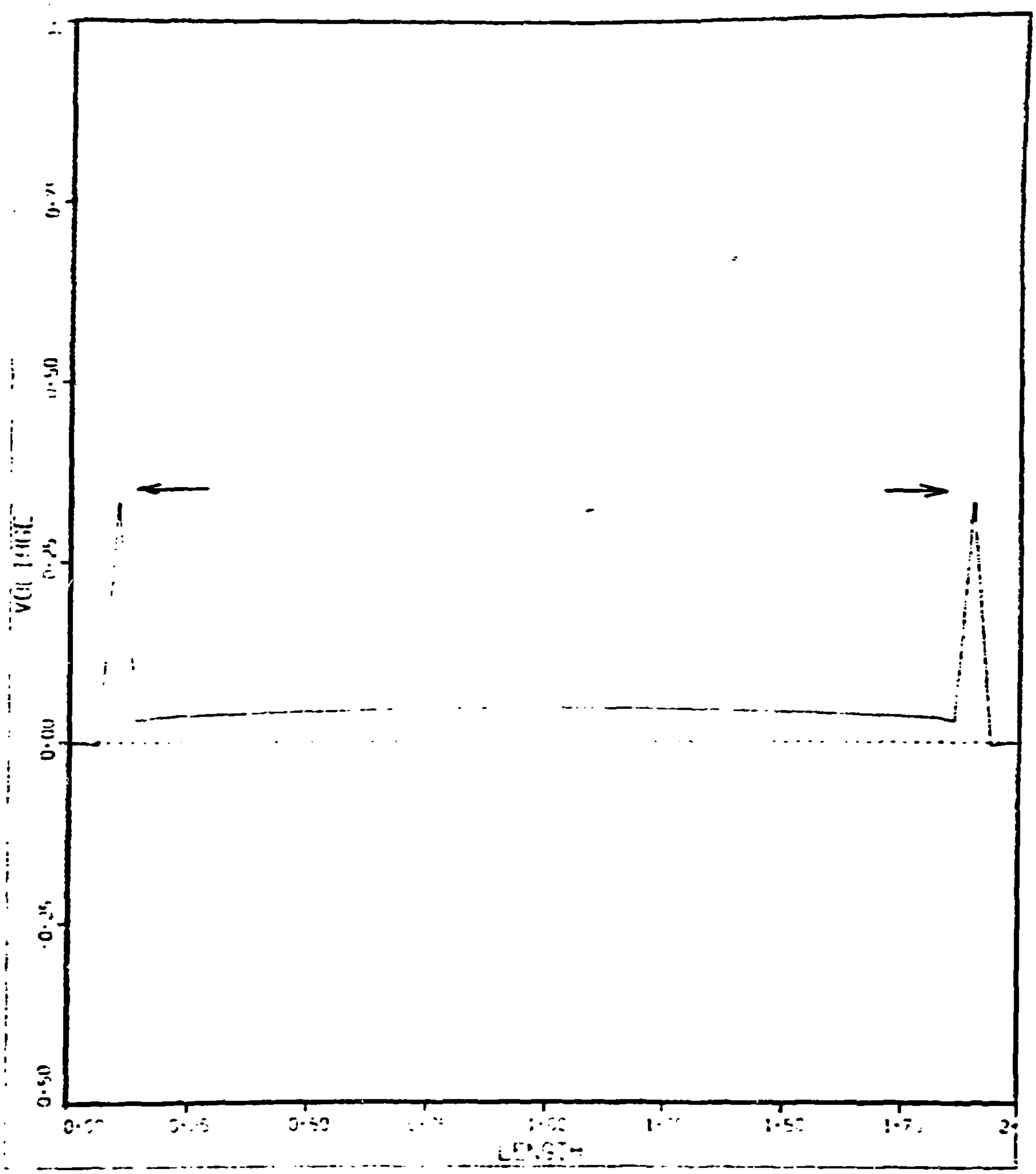

Fig. 2c

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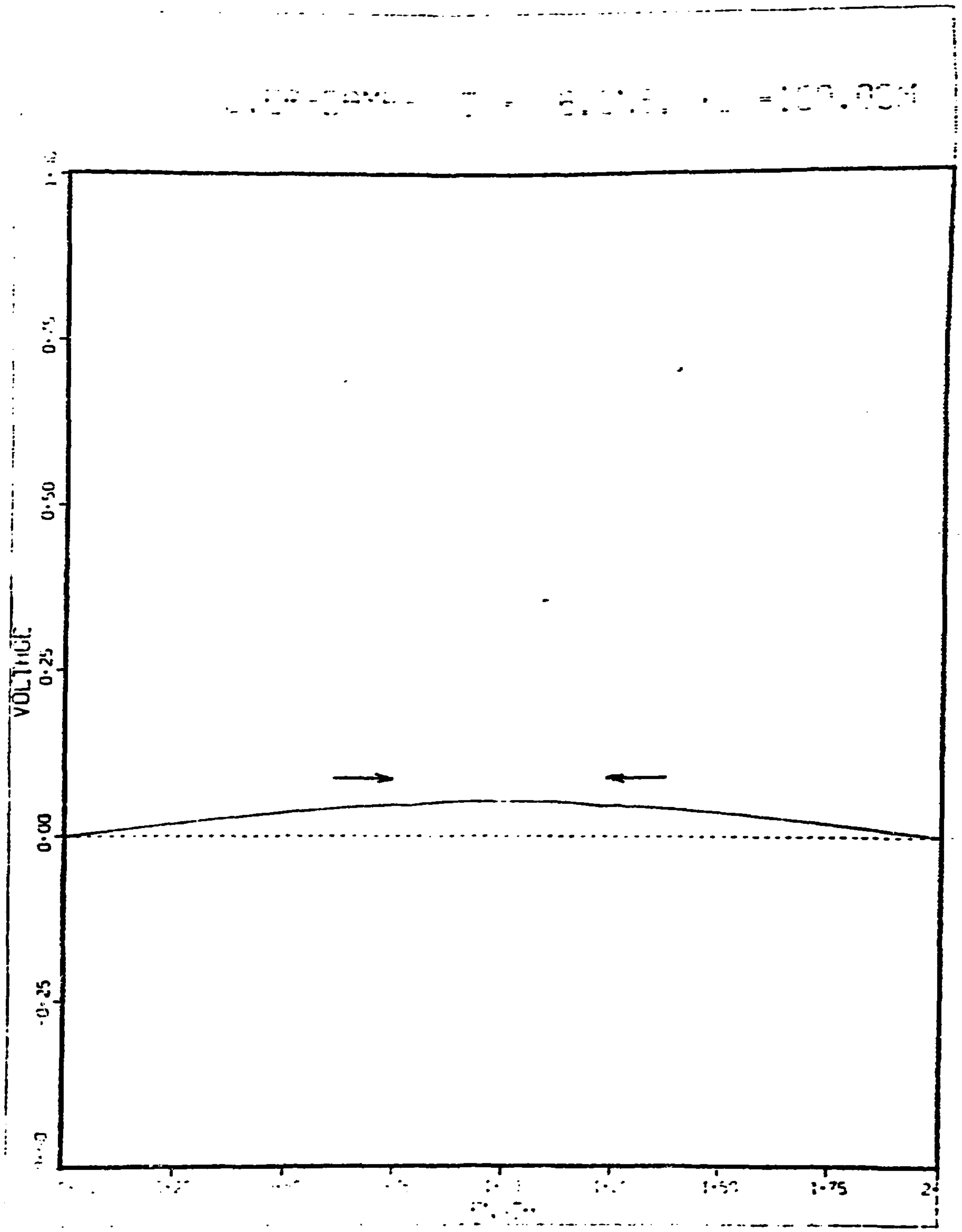


Fig. 3a

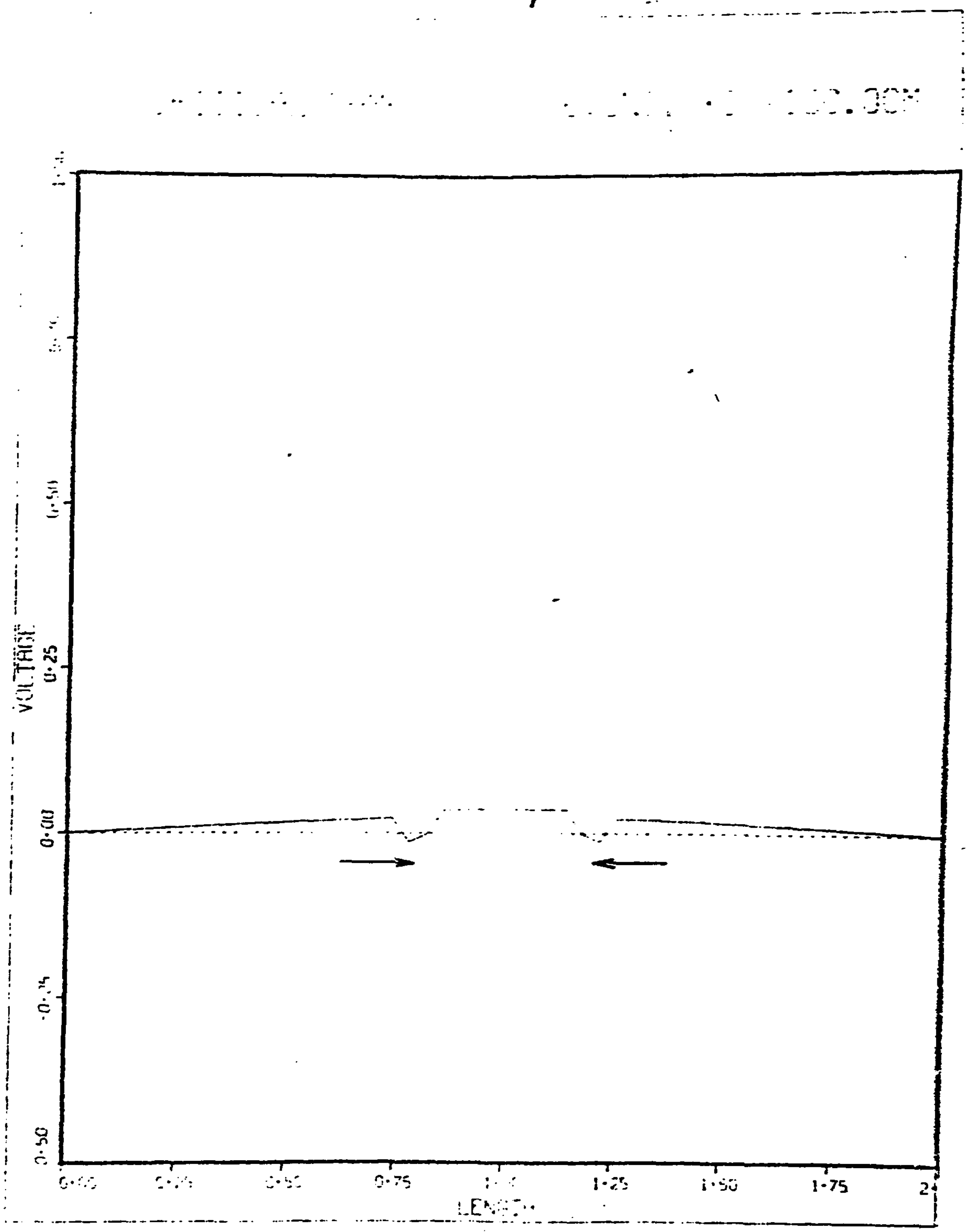
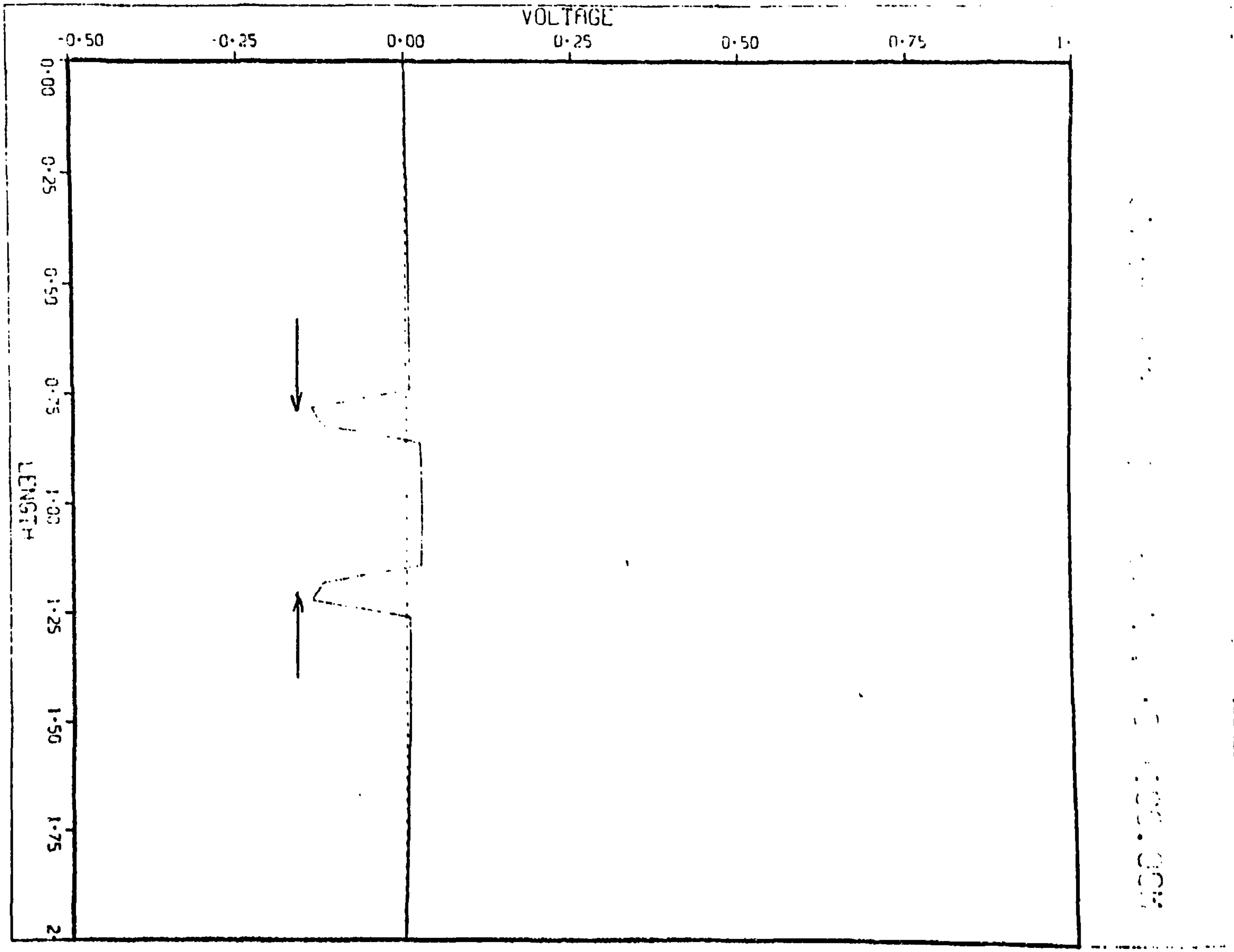


Fig. 3b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-0·25
0·00
0·25
0·50
0·75
1·
LENGTH
0·00
0·25
0·50
0·75
1·00
1·25
1·50
1·75
2·

Fig. 3C.