

THE USE OF CHARGE COUPLED DEVICES FOR NUCLEAR DATA ACQUISITION

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ABSTRACT

The use of Charge Coupled Devices in some high energy physics experiments which require large number of detectors is discussed. A developed system to measure the Transfer Inefficiency of Charge Coupled Devices is described. Nuclear radiation effects on the Transfer Inefficiency are investigated and some experimental results are presented.

ÖZET

Bu yazıda, çok sayıda detektör gerektiren yüksek enerjili fizik deneylerinde Yük Geçişli Düzenlerin Kullanılması tartışılmıştır. Yük Geçişli Düzenlerin Geçiş Verimsizliğini ölçmek için geliştirilmiş olan bir sistem anlatılmıştır. Nükleer radyasyonun Geçiş Verimsizliği üzerindeki etkileri incelenmiş ve bazı deneysel sonuçlar verilmiştir.

INTRODUCTION

Charge coupling is an extremely powerful but simple concept /1/. Basically a Charge Coupled Device consists of a number of contiguous cells, together with a mechanism for transferring electrical charge from one cell to the next. The device is fabricated in a chip of silicon using the Metal-Oxide Semiconductor (MOS) technology. In operation, information is represented by a quantity of electric charge.

In many high energy physics experiments multiparticle reactions take place. The analysis of such reactions mainly depends on the reconstruction of particle tracks. A particle detector ideally should be able to identify a particle passing through it, must give the particle's position and time of arrival with accuracy,

it should be sensitive to charged and uncharged particles. Drift chambers are ideal for this purpose /2/. The use of CCDs as an analog delay lines to store data from drift chambers allows the acquisition of the multiparametric information from the chamber in real time. It also allows us the use of a delayed trigger before any processing of the stored data and to read out the data at a slower rate than the read-in rate.

EXPERIMENTAL SET UP TO MEASURE THE TRANSFER INEFFICIENCY

Transfer inefficiency, ϵ is the most important parameter of a CCD, which ultimately determines the usefulness of the device /3/. The transfer process within the CCD, whereby signal charges are shifted from one cell to the next is not perfectly efficient. The fraction left behind during the transfer is called as Transfer Inefficiency. It influences directly the fidelity of wave shapes of the signals. Due to the finite value of ϵ , a signal shape distortion takes place in CCD. Errors arise in the determination of shape, peak value and time of arrival of input signals. If the nature of ϵ is known, corrections can be done. Although ϵ is the most important parameter of CCDs, generally no data are given by the manufacturers.

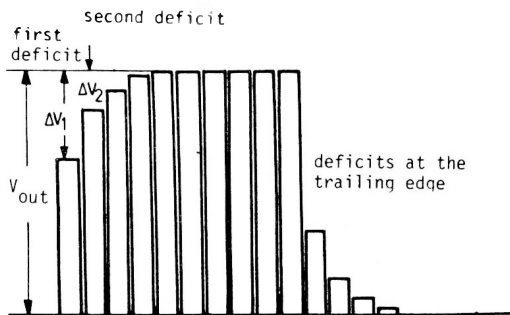


Fig. 1. The output signal, when a square pulse voltage is applied to the input of the CCD.

If a square pulse voltage signal is applied to the input of a CCD, the output signal is shown in Fig.1. The deviations from a square pulse at the output are due to ϵ . Transfer Inefficiency can be determined by the ratio of the leading edge deficits sum to V_{out} . Fig.2 illustrates the block diagram of the experimental set-up used for the Transfer Inefficiency measurements in CCD /4-5/.

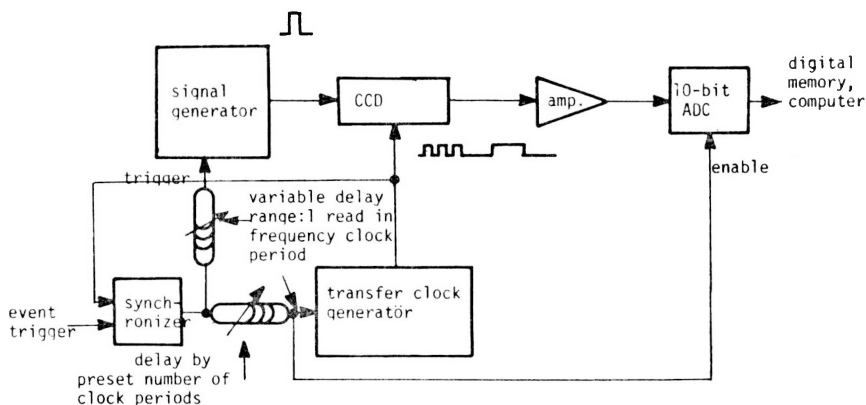


Fig. 2. Block diagram of the experimental set up.

The transfer clock generator normally generates clock signals at the chosen read in frequency, upon receipt of a shift frequency signal the transfer clock generator shifts to the pre-selected read frequency for n cycles, where n is the number of cells in the CCD. Trigger pulse generator, synchronized with the clock, triggers the signal generator at a constant, but controllable, phase of the clock signal. The synchronized event trigger is also delayed by a present number of clock cycles to cause the shift frequency signal to occur, enabling the analog digital outputs of the analog digital converter. At the end of these sequence, the digital memory contains n 10-bit words of data which corresponds to the complete set of information contained within the CCD at the instant the shift frequency signal occurs. The data in the digital memory is later transferred to a digital computer via a CAMAC system for analysis. This experimental technique is capable of several different kind of measurements such as transfer inefficiency, noise, dark current etc. of CCDs. Since the response of a CCD in time domain can be stored and processed in a digital memory and computer, by only changing the software any particular measurements can be taken easily.

CCDs (Fairchild CCD 311) are irradiated using a cobalt-60 (Co^{60}) source. Measurements are taken after the irradiation. The procedure to measure the ϵ is fully explained in ref./5/. The computer program which is used to obtain the ϵ is given in ref. /6/. Measured Transfer Inefficiency Product ($n\epsilon$) values versus output levels are shown in Fig. 3. Where n shows

the cell number of CCD (n is 260 for Fairchild CCD 311) Measured Transfer Inefficiency values versus radiation are given in Fig. 4. A significant increase in ϵ observed up to 10^3 rad(Si). Above 10^3 rad, no measurements can be taken. No noticeable change in ϵ has been found in the frequency range of 0,5 - 10 MHz. It has been shown that experimental error in the measurements of ϵ is less than 7 %. ref. /5,6/

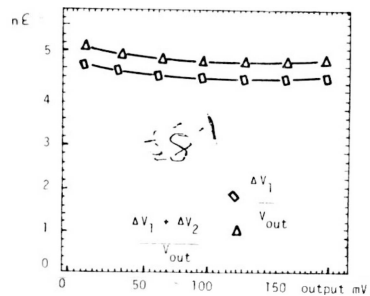


Fig. 3. Transfer Inefficiency product versus Frequency.

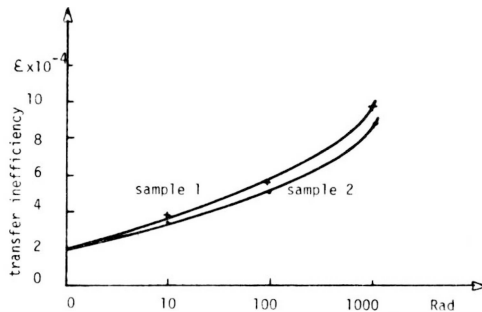


Fig. 4. Transfer Inefficiency versus Radiation.

DISCUSSION

Let us consider an n-channel buried type CCD with an uniform density N_t of bulk traps at energy level E below the conduction band. Using the Shockley-Read-Hall relation /7/ the rate equation

$$\frac{dn_t}{dt} = \frac{N_t - n_t}{\tau_t} - \frac{n_t}{\tau_e} \quad (1)$$

can be written, where n_t is the number of the trapped

electrons.

$$\tau_t = \frac{1}{V_{th} n_o} \quad (2)$$

$$\tau_e = \frac{1}{V_{th} N_c \sigma} \exp (E/kT) \quad (3)$$

are trapping and emission time constants, respectively. σ shows the trap capture cross section for electrons, V_{th} is the average thermal velocity of the mobile electrons, N_c is the effective density of the states per unit volume in the conduction band and n_o shows the volume density of mobile electrons. For low and moderate frequencies, the trapping time constant of most traps are much less than the re-emission time constant. The charge stored in these bulk traps under an electrode and occupying a volume V_s from a signal which is a passing through the CCD can be given by

$$q_t = \int_{V_s} \frac{eN_t dv}{1 + \frac{N_c}{n} \exp (-E/kT)} \approx N_t eV_s \quad (4)$$

The amount of trapped charge which is not joined the original charge packet will be

$$q = eN_t V_s e^{-(T/\tau_e)} \quad (5)$$

where T is the period. Eq. 5 shows that, due to the radiation, τ_e decreases, causing an increase in Transfer Inefficiency.

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