

A Transient Digitiser for Fast Air Shower Events

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1. Introduction Measurements of air shower structure often have to be made on time scales of a few nanoseconds. Longitudinal disk structure near the core is of the order of metres in dimension, air Cerenkov pulses have full widths at half maximum of the order of tens of nanoseconds, and fast timing over typical arrays is usually measured to nanosecond accuracy. Measurements over these time scales are neither easy nor cheap. Oscilloscopes can be used but have very limited dynamic range (see eg. Liebing et al, 1984) and can be expensive if measurements down to a few nanoseconds are to be made. For our fast Cerenkov work, we needed an instrument with better dynamic range than an oscilloscope and with a time resolution sufficient to enable us to make measurements limited only by our system risetime of a few nanoseconds. We have built a 16/32 channel, 8 bit, fast transient digitiser which can be run at sample intervals down to ~ 1 nanosecond per channel. The system cost for 16 channels was less than US\$ 2000.

2. System Description The digitiser is based on a series of sample and holds which are gated almost at the same time by a trigger pulse and which sample a progressively delayed signal. The signal delay medium is coaxial cable and the time between samples can be as low as ~ 1 nanosecond. We investigated a number of possible fast sample circuits, such as a gated double balanced mixer, but were generally unable to obtain our required 100:1 or better dynamic range. We finally found a system described by Baldis and Aazani-Zangareh (1973) which uses sampling gates based on a matched Schottky diode bridge (see fig 1). The bridges are gated by the application of both a positive and a negative sub-nanosecond pulse which are applied along striplines on the circuit board as indicated. The gated sample of the signal is then amplified and applied to a slow sample and hold/8-bit digitiser. The sub-nanosecond sampling gate signals are produced by an fast impulse generator and power splitter (Avtech Electrosystems, Ottawa, Canada). These represent the major part of the gating system expense and were the parts we found most difficult to produce ourselves. The digitiser output is transferred to a Commodore 64 microcomputer for storage and handling.

The system has a bandwidth (≥ 300 MHz) determined by the total of the successive gate capacitances. For 16 channels this is sufficient to place an impulse completely ($>10\%$ amplitude) within a single one nanosecond sample interval. One bit corresponds to a few millivolts in amplitude but, more importantly perhaps, the system dynamic range is close to being a true 8-bit range with long term drift and noise being of the order of the one bit level.

The digitiser can be run as a triggered oscilloscope with an event rate of up to ~ 3 Hz into the Commodore 64 microcomputer or as a logic gated device with a possible reset whilst an analog sample is held in a

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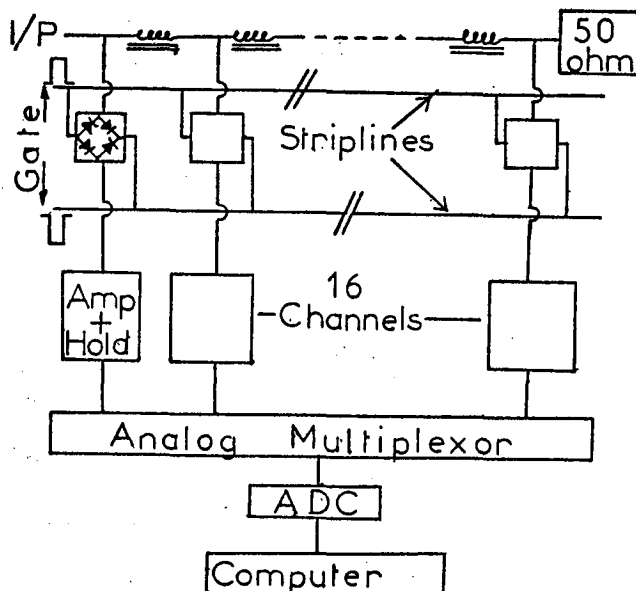


Fig. 1 Schematic of the transient digitiser. The signal is delayed by external cable between the sample gates.

sample and hold before digitisation. In this case a 30 kHz trigger rate is possible with selection of the events which we require to digitise by the input of an appropriate external gate. The latter mode is of particular interest for air shower work where a photomultiplier output can be sampled and one can then wait up to 5 μ s to determine whether or not an air shower of interest has also been detected. These rates should be compared to an oscilloscope previously used by us for similar purposes, the Tektronix 7834 storage oscilloscope. This device has a maximum useful trigger rate for photographic recording of poorer than 1Hz and has a dynamic range of much less than 50:1 for high speed operation.

In conclusion, we have built a fast transient digitiser which can digitise 16 channels at intervals down to 1ns with a dynamic range of $\sim 200:1$. The device is particularly useful for air shower transient studies at a cost which is affordable on a quite modest budget.

Acknowledgement

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References

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 Liebing, D.F., Clay, R.W., Gregory, A.G. and Patterson, J.R. (1984) *J. Phys. G.*, 10, 1283