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Multiple signal channel read out by a single FADC

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Abstract. Fast signal shapes can be measured by using FADCs. Unfortunately, very fast FADCs are still quite expensive. Here we propose a multiplexing scheme which can allow one to measure signals from multiple channels by using a single FADC channel. One can apply the multiplexing in the experiments where a common event trigger exists and the trigger rate is not exceedingly high. We are considering to use the multiplexing principle for reading out the 600 ultrafast photomultiler (PMT) imaging camera of the 17 m ø MAGIC air Cherenkov telescope by using $1.5-2GHz$ FADCs in the projects 2nd phase. The operation of the multiplexer is simple and is based on the use of fast linear switches which sequentially connect the signal channels, after appropriate delays, to the FADC input.

1 Introduction

FADCs are commonly used in order to measure not only a single integral parameter of a pulsed signal like its amplitude (the charge or the peak voltage) but also its shape in time. Usually in multichannel detectors, which run in a common event trigger mode, one uses a single FADC channel for reading out a single signal channel. It is interesting to note that in this way only a tiny fraction of the FADC memory depth is occupied by the signal while the rest is effectively "empty". The application of FADCs can be quite important when measuring ns fast signals, for example, from fast PMTs. In order to parameterize signal shapes of a few ns duration one has to sample at least $3-4$ points which means one needs rather expensive FADCs of very high sampling rate ($\geq 1Gygasample/s$). One can use the multiplexing principle and read out multiple coinciding in time signals by using a single FADC channel. In this case one packs the signals from different channels sequentially, one after the other one, in the FADC memory. Incidentally, in the latter case the FADC memory is used more economically.

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2 Fast FADC multiplexer

Usually when using FADCs for measuring fast signals one has two options: either to use very fast FADCs, or to stretch the signals in time and use relatively slow FADCs, but always using one FADC channel per one signal channel. The disadvantage of the first option is the very high cost while the disadvantage of the second option is that whenever there exists any strong background or noise, it excessively piles up and smears the signal, especially the small amplitudes. Here we propose a third option, namely the multiplexing, which has the advantages of the first option and in addition, is substantially cheaper. The idea of multiplexing the high and the low gain signal branches onto the input of FADCs (in order to extend the dynamic range of the measuring system) is already implemented in the design of the data acquisition system of the 17 m ø MAGIC telescope (Barrio, et al., 1998). Here we propose to use the multiplexing for other purpose, i.e., in order to design an ultrafast data acquisition system where the number of used FADCs can be one (or even two) orders of magnitude less than the number of read out channels. The read out scheme is based on the use of fast switching GaAs linear gates. For example, the $TQ9155$ from *TriQuint Semiconductor* is a low cost, industry-standard switch designed for use in the $DC-2.5GHz$ frequency range. It provides rise and fall times of $2ns$. The schematic diagram of the proposed setup is shown on Fig.1. The signals from fast PMTs in a multichannel detector are amplified, discriminated and fed into the majority trigger logic unit. Each channel has its own linear gate which is normally closed. The outputs of all linear gates are fed into the analog signal fan-in. The output of the latter is fed into the single channel fast FADC. The output signal of the majority logic unit opens, after appropriate delays, the linear gates one after the other one, but always one at a time. The output of the amplifiers are split into two: one branch is fed into the discriminators and the other one, after an appropriate delay, enters the linear gates. Usual coax cables can be used as analog signal delay element. The cable length, i.e. the time delay for each channel, must exactly match in time with the opening of its linear gate. At first one has to define the number of necessary samples of the FADC for measuring the signal from a single channel. Assume one needs K FADC samples, each of duration τ. The analog signal time delay T for the channel number N must be

$$T = (N-1)K\tau + N\delta$$

where δ is the switching time of the linear gate. The latter can typically be in the range of $\sim 2ns$. For example, assume one has to measure few fast PMT channels with pulses of $\sim 2ns\ FWHM$ and $\sim 1ns$ rise and fall times. Such signals can be measured by a FADC of $\geq 2Gygasample/s$ during sampling time of $10ns$, i.e. one needs ≥ 20 samples of the FADC. So the gate of the switch number 1 must be opened after $\sim 2ns$ (which is the switching time of the linear switch) after the majority logic trigger signal, the gate of the switch 2 after $14ns$, the gate of the switch 3 after $26ns$ and so forth and the corresponding analog signals from different channels must arrive hence after the opening of their gates. Just to remind you that $1m$ of a usual cheap coax cable has a signal delay time of $\sim 5ns/s$. This means that for the delay of, for example, $26ns$ one will need a $5.2m$ long cable roll.

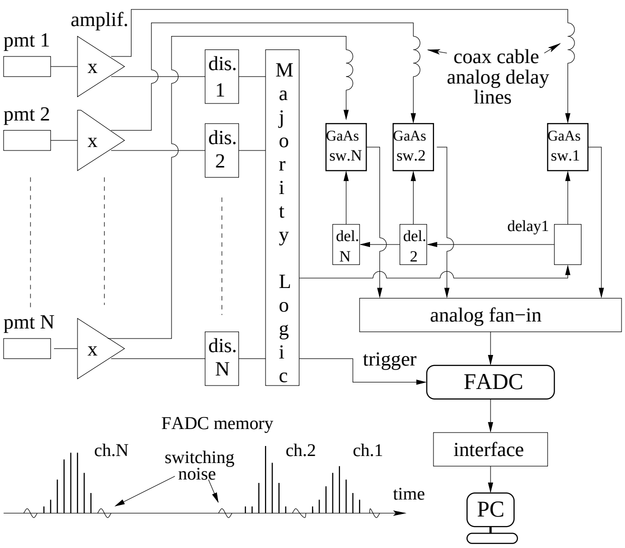

Fig. 1. The schematic use of the proposed FADC multiplexer.

3 Discussion

In the design of the electronic scheme of the multiplexer one has to allow for some dead (switching) time between the read out of any neighbor two channels. During this time the FADC will pick-up some switching noise. For the given read out scheme this noise will appear at well known time intervals and therefore can be easily recognized. It is obvious that the coax cables used for delaying the analog signals, due to their limited bandwidth will to some extent degrade the signal shape making it wider and less in amplitude (of course the integral $voltage \times time$, i.e. the charge, stays always the same). This degradation will impose a limitation, depending on the constraints on the allowed change in the signal shape, on the maximum number of channels which can be read out by a single FADC. One can use much faster cables and ”pack” substantially more channels on a single FADC. The obvious drawback is the relative bulkiness of a good cable roll which, by the way, may still be well acceptable because of the per channel cost reduction of the whole setup with increasing number of read out channels. As a matter of interest we want to mention that usual commercial coax cables used for the home satellite television, are quite cheap and provide excellent bandwidth. The authors have checked that a roll of $100m$ long, $6.9mm$ outer ø coax cable of the above mentioned type expands a pulse of $1.5ns\ FWHM$ at the input to only to $2.1ns\ FWHM$ at the output. Under given circumstances this relatively small change may be well acceptable which tells that a delay time of $100 \times 4ns = 400ns$ (the very fast cable of the above mentioned type has a delay of $4ns/m$) can be simply realized and at least theoretically, one can multiplex and measure up to 34 signal channels. Besides, because of fixed cable lengths for different channels one can precisely measure their signal transmission characteristics and by normalizing to them recover the original signal shapes. Another limitation on the possible number of multiplexed channels will be imposed by the trigger rate: the net time interval occupied by multiplexed channels should not exceed, say 1% of the mean period of the trigger. For example, if the trigger rate is $1kHz$ (i.e. the mean period is $1ms$) then the occupied by the signals memory depth of the FADC should be $\leq 10\mu s$. Because of very fast signals and possible cross-talk between multiplexed channels via parasitic capacitances and ground loops one has to carefully design the printed circuit board of the multiplexer. We think that depending on the used cable type, its signal transmission characteristics, the allowed signal degradation in time and the possible pick-up noise level one can without big difficulties read out 5-20 signal channels by using a single FADC channel. Note that FADCs are well known to consume quite some electrical power. The multiplexing will allow one to strongly reduce the consumed power and evidently also the production of excessive heat.

4 Alternative solutions

An alternative solution can be to use other type/s of analog signal delay lines. For example, one can use printed circuit board lines as analog delay element like it has been done in the HEGRA experiment. Usually such delay lines have relatively strong amplitude damping characteristics so a thorough design of the high frequency response circuit shell be mandatory. Another interesting solution can be to use the systems based on the analog signal optical fibre transmission lines. Compared to the solution with coax cables it can allow one to substantially increase the number of signal channels read out by a single FADC unit. The Vertical Cavity Surface

Emitting Laser (VCSEL) diode based optical transmission lines are quite fast and the fibre lengths of up to few hundred meters does not practically affect the fast signal shape. The use of the fibre analog transmission lines will make the setup somewhat more expensive but it may be well acceptable because of its still much lower cost compared to the price of a single fast FADC channel. Here we are not going to dwell on this topic. See for details (Mirzoyan, et al., 2001).

5 Summary

We propose a multiplexing scheme for very fast FADCs. The scheme can allow one to read out many signal channels by using a single channel FADC. This can be an economically priced solution in the experiments where a common signal trigger exists. We think that it is well possible to ”pack”, depending on the type and the bandwidth of the selected cable, 5-20 signal channels onto a single channel FADC.

References

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