Readout Electronics for Time-of-Flight Mass Measurements at ESR

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The Time Recording System TRS is a fast multistop Time-to-Digital Converter (TDC) designed for use in direct mass measurements at the experimental storage ring ESR of the GSI as a readout electronics for the channel plate time-of-flight detector [4]. This detector was used in summer 1999 for the first time in a production beam time with great success [1]. However, it was shown during this beam time, that data quality and efficiency was limited mainly by the readout electronics available and therefore the electronics development of the TRS was reinforced. End of 1999 a first prototype of a new generation TRS was finished. First tests show that the designed specifications will be reached, which include:

- pulse pair resolution less than 5 ns
- timing accuracy in the region of some 10 ps
- storage capacity of 16 k stop events per cycle.

For a typical mass measurement experiment, this means that some 10 particles stored in the ESR simultaneously can be detected with an efficiency limited only by the channel plates over several 100 turns. For comparison: the commercially available electronics used during the last beam time was capable to process up to 4 particles with an efficiency of less than 50 %. The design of the new TRS consists of 8 circuits, each of them acting as a TDC with 40 ns dead time between stop events and a storage capacity of 2 k events. The detector signals are multiplexed to these circuits by a fast shift register unit specified to a jitter of less than 3 ps. For our special purpose of signals produced by a couple of ions circulationg in the ESR, each single circuit has already specifications far beyond all commercially available TDCs. This is achieved by a special architecture developed for the TRS some years ago [2,3]:

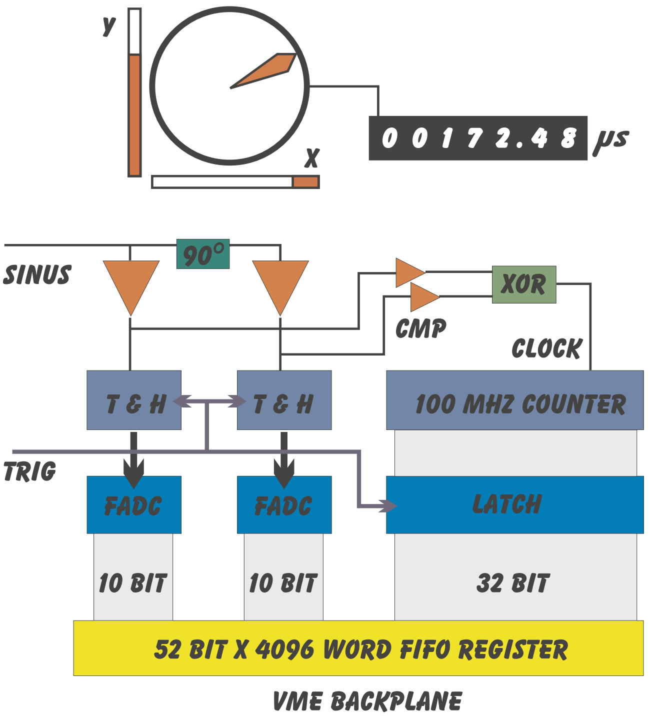

Fig. 1: TRS circuit diagram

A coarse time measurement is done by a 100 MHz counter which is read into a fifo buffer on every stop event. This counter gives a time resolution of 10 ns. To interpolate this long interval of 10 ns in order to achive an improvement of resolution of a factor of 1000, a 50 MHz sine wave is sampled synchroneously to every stop event. The amplitude of the sine, combined with the amplitude of a 90 degree shifted sine, gives the coordinates of a digit circulating once in 20 ns. Due to the resolution of 10 bit in each ADC, the position of this virtual digit can be measured with a 1000th half turn accuracy leading to a time resolution of 10 ps. The measurement schematic is shown in fig. 1.

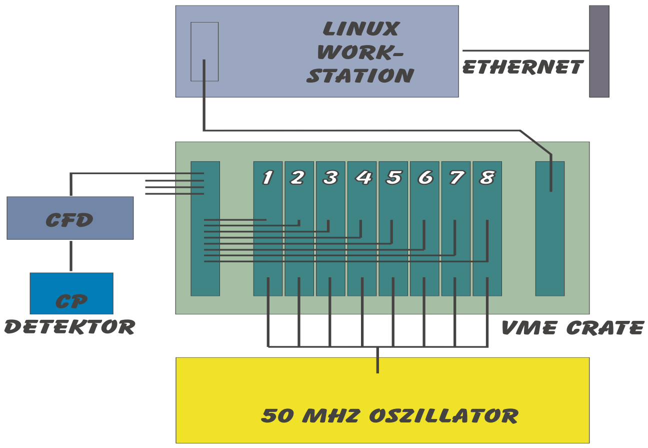

Fig. 2: TRS signal processing schematics

The TRS, as shown in fig. 2, consists of a stabilized 50 MHz sine oscillator, a multiplexer for the sine signal, a digital multiplexer for the CP signals, the eight ADC circuits, a VME to PC interface, and a Linux PC for measurement controlling and data handling, storage and forwarding to ethernet.

As an alternative to TDC signal processing, a high speed sampling oscilloscope was tested during the last beam time [1]. This gives an advantage versus TDC because not only the time, but also the shape of the CP pulse is registered. On the other hand, the digital time resolution is much smaller (4 gigasamples give a channel resolution of 250 ps) and the measurement time is limited to 1 ms. In addition, the data handling and analyzing is much more difficult because of the large amount of data to be written. But this disadvantages may be overcome in the future. So the TRS development as well as sampling scope data acquisition have to be further improved and investigated until a decision can be made which system is more suitable for the measurement.

References

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