DATA ACQUISITION AND PROTECTION SYSTEM FOR A MULTI-MHZ NEUTRON DETECTOR

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Abstract

At the "KWS2" small angle scattering instrument at the "FRM-2" neutron source at Garching, Germany a new 3He neutron detector was installed and commissioned in 2015. It is built of 18 "8-pack" modules from GE Power / Reuter-Stokes. Each of these modules has its own data acquisition and slow control processor, using only Gigabit Ethernet as its connection to the outside world.

We show how data acquisition, time synchronization and interaction with the slow control system are laid out, as well as some first results and performance data.

INTRODUCTION

To obtain sufficient angular coverage, the detector needs to fill the instrument tube's profile as completely as possible. For a modular, reusable design, the detector is made of modules with different lengths, each holding eight gas tubes, called "8packs".

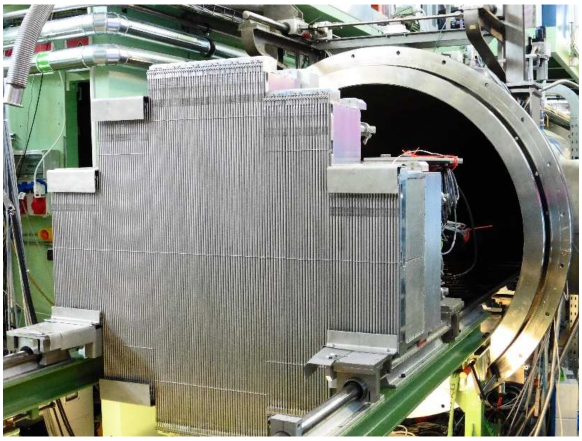

Figure 1: The new detector in front of the instrument vessel.

Fig. 1 shows the complete detector in front of the instrument's vacuum vessel. There are 18 "8pack" modules of three different lengths.

The concept of "8packs" is based on a detector design developed previously at Oak Ridge National Lab, and has been presented at various conferences (see eg. [1]). The detector electronics have been redesigned completely by GE.

A major design objective for the new front end electronics was to reduce the number of cables to the outside as much as is feasible. Connections are needed for control, data transport, time synchonization and power supply. This is all handled by Gigabit Ethernet and its PoE (Power over Ethernet) and PTP (Precision Time Protocol, IEEE1588) companion standards.

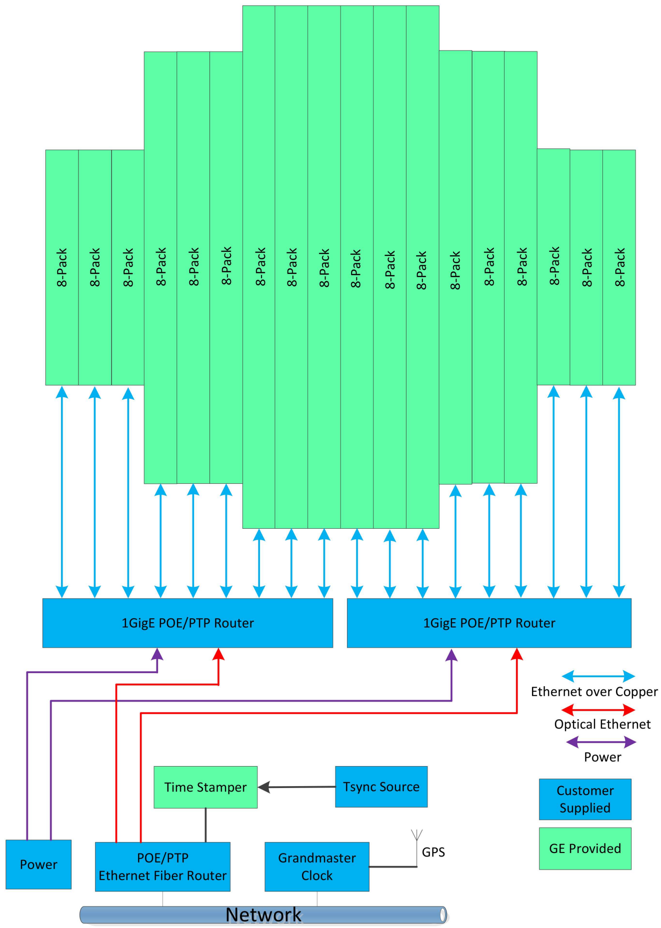

Figure 2: Components and interconnections of the new detector system. (picture from GE)

Fig. 2 shows an overview of the electronics components and cables. Two Gigabit Ethernet switches with PoE and PTP capability are mounted directly at the detector modules, within a special air cooled box. It was necessary to use two rather than just one because the 18 detector modules draw more electrical power than a single switch could deliver via PoE.

Details are explained in the following chapters.

DATA ACQUISITION

Each "8pack" uses a XILINX "ZYNQ" FPGA-CPU combination as its main control and processing component.

This is a comparably fast and energy-efficient embedded computer. The CPU operates a Linux kernel which in particular supports powerful TCP/IP-based networking.

For each detected neutron, the position along the tube is calculated (using the measured pulse size at both ends of the tube, employing a center-of-mass-like algorithm). This information, together with information about the tube and a time stamp, is packed into a so-called "event" structure and sent through a TCP/IP socket connection to the outside data acquisition computer.

The data acquisition computer keeps a TCP connection to each of the 18 detector modules, reading event data as fast as possible to avoid congestion inside the detector modules. A good reason for this is that memory is much more plentiful and cheaper in a modern PC than in an embedded computer. Data are immediately sorted into a histogram, to support a live display for the operator and help with statistics gathering and to emulate the behaviour of other detectors. (There is an option to store the original data stream for diagnostic purposes. Its use is limited by the disk space available.) The histogram is three-dimensional: the tube number and position along the tube comprise the x/y coordinates. The third axis consists of the time difference relative to an external event, eg. the chopper's zero crossing.

The data histogramming program is coupled to a TACO server – TACO [2] is used as measurement control middleware currently at this instrument. A transition to TANGO [3] is in preparation.

TIME SYNCHRONIZATION

To get accurate timing information relative to external events, all "8packs" need to run with well synchronized system timers, and external events need to be recorded with the same accuracy. To support the latter, we are using a "time stamper" module also offered by GE. This contains a base processor similar to the one used in the "8packs". The inputs are general purpose TTL signals, allowing interfacing to synchronization signals from the chopper or other machine components such as sample environments.

These front end components are connected to Gigabit Ethernet switches supporting PTP. The time jitter achieved this way is in the tens-of-nanoseconds order of magnitude which is fully sufficient for neutron scattering and the neutron speeds and interaction lengths which are typical here.

The root of the PTP time distribution is a so-called "grandmaster" clock. For this, we are using a Meinberg GPS controlled clock. The original intent was to use GPS as a timing reference, but this was problematic due to construction and regulation problems. We were not allowed to install a GPS antenna outside the instrument hall and to lay a cable through the wall. Thus we are now operating the Meinberg clock in free-running mode. The built in oscillator is temperature controlled and very stable. We have not been aware of any drift in normal operation.
temperatures. For this, GE decided to use the EPICS [4] control system. This information is accessible as process

SLOW CONTROL – DETECTOR CONTROL

The detector modules need some slow control such as when setting of thresholds and high voltage, or monitoring variables using the standard EPICS "channel access" protocol. Additionally, there are various parameters controlling the calculation of neutron event positions from pulse height information measured at both tube ends. These parameters can be adjusted after calibration measurements to make the data from different tubes fit together exactly.

SLOW CONTROL – MACHINE PROTECTION

The detector is an expensive and critical instrument component. This makes it necessary to protect it from technical faults and operator errors as far as possible. There are at least three possible problems to look at:

- Overheating due to insufficient air cooling
- Neutron event rate higher than expected, possibly caused by being hit by the direct beam (beam stop fault or operator error)
- Detector movement while high voltage is switched on

We are using a PLC to deal with this. The "8packs" send so-called "heartbeat" network packets (UDP datagrams) to the PLC (which is equipped with an Ethernet interface). These packets contain information about temperature, count rates and high voltage state. The PLC has access to motion control of the instrument's mechanical axes. It can also switch off the power supplies for the detector front end, and initiate the closing of the instrument's beam shutter. This way, it can handle the three problems mentioned above adequately.

CONCLUSION

The detector's operation has been proven in tests and real measurements. Data acquisition and control system interaction worked well.

In a test, we achieved a neutron event rate of about 5MHz at a dead time of about 10 percent. This means that the detector is among the fastest in the world used at neutron scattering instruments.

REFERENCES

[1] R. Cooper, DET1.6 The Multitube SANS Detector System at Oak Ridge National Laboratory, SAS2009, Diamond Light Source, Oxfordshire, UK, September 2009

[2] TACO control system, http://www.esrf.eu/

[3] TANGO control system, http://www.tango-controls.org/

[4] Experimental Physics and Industrial Control System, http://www.aps.anl.gov/epics/