Rejuvenation of the ATLAS barrel alignment controls

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1. Introduction

The barrel alignment system of ATLAS consists of around 5800 optical channels, each built up of a camera, a light source, a coded mask and a lens. The channels are connected to several multiplexers in the cavern and are finally connected to 8 so-called TopMux's in USA15. The channels and multiplexers will be used during the lifetime of ATLAS. There are no plans to upgrade and/or replace them.
The control part of the system is located in USA15 rack Y.28-19A1. Together with the 8 TopMux's, 8 PCs are mounted inside this rack. Each TopMux is controlled by one PC and each PC is equipped with a frame grabber (Data Translation DT3162). The frame grabber is the key element of the readout system. For more detailed information about the setup and controls please refer to the reference guide: http://www.nikhef.nl/~robert/docu/BalignRefGuide_v12.pdf

2. Controls

The controls part of the readout system, 8 PCs with frame grabbers, are running now for more than 10 years. Considering the age it became more and more important that the PC's and grabbers should be replaced (the original plan was to do the replacement during LS1). The following considerations have to be taken into account:

1. Data Translation stopped the support of the DT3162. The latest driver available is still the one for Windows-XP. Hence the alignment PCs still run Windows-XP!
2. The DT3162 is a PCI-board old style (5V).

Although the DT3162 is a perfect grabber and there are plenty of spares, we cannot use it anymore. Windows-XP is not supported anymore and it will be very hard to find a replacement for a rack-mountable PC with an old style PCI-slot.

3. Alternatives

The following requirements are mandatory for a frame grabber:

1. Compatible with camera VV5430 CMOS sensor from vision.
2. Synchronous frame grabbing, using a (free running) pixel clock, generated by the camera.
3. The pixel clock has a frequency of 7.3728 MHz, with an interlaced video signal.
4. Images have the following dimensions: width 384, height 287 pixels.
5. No PCI-board, but a PCI-Express-board or USB or ethernet solution.

The market for frame grabbers is quite large. However, due to our demand of a pixel clock generated by the camera, the choice is very small. Furthermore the cameras are, due to the old technology, out of date. The video signal is analogue, they use a low frequency and not much pixels. Perhaps they are too simple now. After an extensive survey, only one candidate was found: the Matrox Solios eA, a PCI-Express board designed for 32/64-bit Windows-XP /7 and 32/64-bit Linux.
Our software was easily ported and at Nikhef tested. However, a major problem emerged. The external clock did not work. After consultation with the engineers of Matrox, they came with a modified configuration file, by which the external clock worked, but not always. Sometimes the grabber missed the first video line, which corresponds to a jitter of 12 μm[1] in the vertical direction. Several boards were used and tested (even in USA15), but the problem persisted. After almost a year of testing and consultation with Matrox, it was decided at Nikhef not to use the Solios eA.

It became clear that commercial frame grabbers are not available. An alternative would be to design a grabber at Nikhef by ourselves. It was rejected, because we do not have the expertise, nor the manpower.

Outsourcing is another possibility. There are enough companies specialized in video processing. Three companies showed interest and one of them, Topic, came with the most interesting offer and is chosen to be the replacement of the control part of the barrel alignment system for the next 10 to 15 years.

4. Ethernet based frame grabber

The company ***Topic Embedded Products*** (http://topic.nl) will develop, in close cooperation with Nikhef, an ethernet based frame grabber meeting our requirements. The choice of ethernet makes the system more flexible (compared to PCI-like boards) and guarantees in terms of technology a longer lifetime. It will be based on their 'standard' modules, including a custom designed peripheral (an FPGA containing the functionality of the grabber). The main module, called 'Miami', contains a Xilinx Zynq Z7015: dual core ARM Cortex A9, which itself is mounted on a 'Florida' GEN carrier board containing the peripherals like GBit Ethernet, USB, etc. Information about these boards can be found at:
http://topicembeddedproducts.com/products/system-on-modules/
and
http://topicembeddedproducts.com/products/boards-kits/
A block schema of the hardware is shown in figure 1.

[1] The barrel alignment system claims to be better than 5 μm.

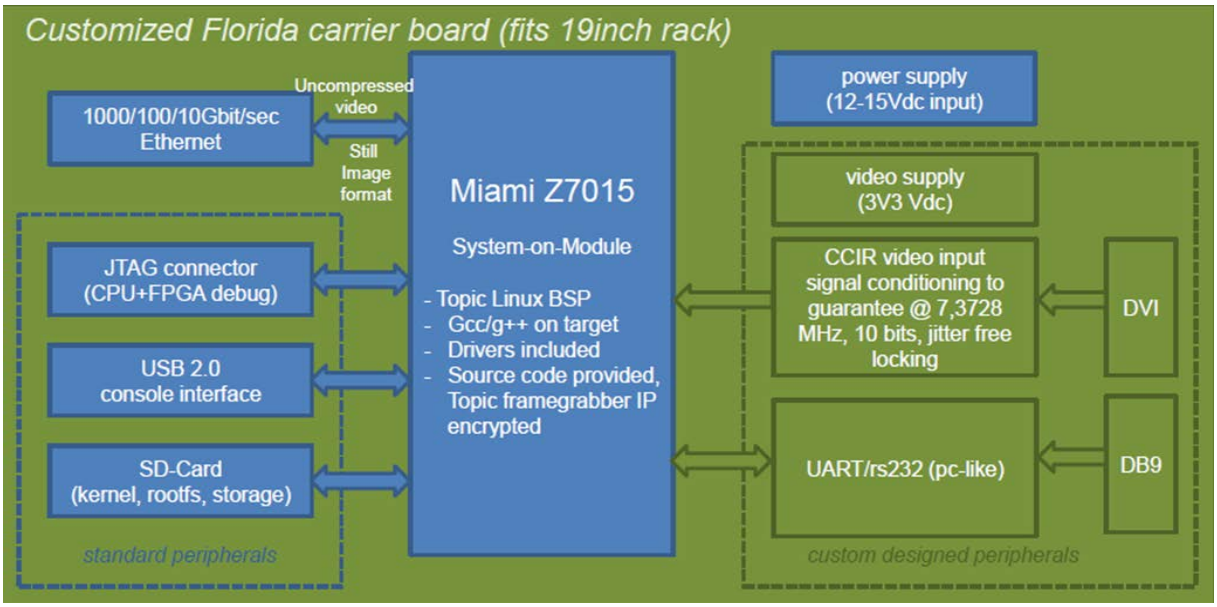

Figure 1: Hardware lay-out

The frame grabber and TopMux have 2 connections. One (DVI) for the video signal and the other (DB9: a COM-port) for the control and selection of the channel.

The current software to control the TopMux (i.e. select channel, get the image, analyze the channel and send the results back) also known as the *Rasdim* server (using the DIM[2] communication protocol), has to be ported to Topic Linux BSP. The current client software (i.e. WinCC projects running on other machines) will not be affected.

The Linux kernel is known as: Topic Linux 3.x kernel and the entire source can be found on GitHub: https://github.com/topic-embedded-products/linux
The standard distribution BSP (board support package, which will be used) is built from OpenEmbedded (meta-topic on GitHub): https://github.com/topic-embedded-products/meta-topic
The kernel is a fork of the mainline kernel with adjustments of Xilinx, ADI and Topic, in order to support the features of the board. If required, it is possible to create a final system, which is completely closed with signed and encrypted firmware. Both kernel and distribution are available under GPL.

5. Timeline/Planning

The following timeline is tentative:

- a prototype was expected before end of October 2015, but arrived middle of December 2015
- meanwhile a dummy board is purchased in order to get acquainted with their embedded system
- end of 2015, beginning of 2016: testing at Nikhef
- Spring 2016: feasibility test in USA15
- before 2017: implementation of all systems (during a technical stop)

[2] http://dim.web.cern.ch/dim/

6. Connecting to ATCN

At Nikhef we are aware of the fact that our proposed solution does not apply a CERN approved and supported OS. Nevertheless, circumstances forced us to choose for this solution. The CERN document CNIC SECURITY POLICY FOR CONTROL - V2.4 (EDMS 584092) does not explicitly prohibit it, but only if certain conditions are fulfilled, which we are willing to accomplish.

6.1 Configuration and Monitoring

It will be possible to monitor the devices, but details will be provided later. The boards can be configured using a predefined IP address. The TDAQ SysAdmins will be granted sufficient administrative access and rights to verify the status and configuration of the systems.

6.2 Updates and Responsibilities

As mentioned before, the entire kernel can be found on GitHub:
https://github.com/topic-embedded-products/linux
from which a distribution can be compiled. The result (an image) is written to an SD card.

Updates are performed at every occurrence of an update or important and relevant security issue of the OS within 7 days after request of the TDAQ Sysadmins and in any case during the yearly Winter Shutdown. The manufacturer will notify the responsible of the project concerning new relevant updates and they will provide a new image, hence new SD cards. It is likely that the generation of the image and SD cards will be taken over by Nikhef. The topic-embedded-products repositories inside GitHub are owned and maintained by Topic.

In case Topic will not be able to supply security updates Nikhef Institute will take over to supply such responsibility. The person responsible for system and security updates ensures that they are applied in the shortest time possible (in any case in less than 7 days). Updates are performed by the responsible person, the technician or representatives listed in section (6.4).

The update is performed by the following manual (mechanical) change of the SD card[3]:

1. Shutdown the Linux system
2. Disconnect the 12V power supply cable
3. Remove the SD card
4. Insert a new SD card with an updated Linux OS
5. Reconnect the 12V power supply (Linux and alignment server will startup automatically)
6. Repeat step 1-5 for all (8) alignment systems

[3] Remote installation of updates is at the moment not considered..

6.3 Product lifetime

Both Nikhef and Topic have signed a 'Sale and Development Agreement' in which Topic estimates that the lifetime of the board is at least 10 years when used in normal environmental circumstances, solid casing and ventilation. These are embedded systems and do not need a lot of support or maintenance. The lifetime expectancy is based on the availability of replacement parts.
Ending support of these boards would be a decision made by Topic and Nikhef together, not some external party.
Topic is established 20 years ago and currently (March 2016) employing around 160 people. The company is built on consultancy services, project execution and standard products. The products they deliver are based on Xilinx FPGA devices, which guarantee a very long lifecycle. The intellectual property (IP) of the products is secured in a separate company. Whenever Topic Products goes out of business for some reason, the IP is available for existing customers to continue their business. The IP subject is included in the 'Sale and Development Agreement' between Topic and Nikhef.

6.4 Responsible person, technician and other contacts

Responsible Person:

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