State-of-the-art detector controller for ESO instruments

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ABSTRACT

The ESO NGC, New General common Controller, had his first light at the ESO Paranal Observatory in 2012. The controller has evolved over three decades from previous controller generations, namely the ESO IRACE and FIERA detector controllers. NGC is a controller platform which can be adapted and customized for all infrared and optical detectors. Recently NGC has also been deployed in adaptive optics with electron multiplication CCDs and infrared electron avalanche photodiode arrays. This paper presents an overview of applications using the NGC controller and describes the detector performance achieved with the controller. Since NGC runs all new detector systems of ESO instruments, a uniform platform is available at the observatory which facilitates operation and maintenance. An outlook will be given of future developments of the NGC controller. The prototype of the high order wavefront sensor currently being developed for the E-ELT is required to read 22 LVDS outputs at 200MHz in real time control loop. This represents new challenges in term of high speed, low noise and minimum latency

1. INTRODUCTION

The ESO NGC, New General common Controller, had its first light at the ESO Paranal Observatory in 2012. The controller has evolved over three decades from previous controller generations, namely the ESO IRACE and FIERA detector controllers. Both of these former ESO controllers are still operational and in use by many instruments at ESO telescopes. The NGC is a controller platform which can be adapted and customized for all infrared and optical detectors. Recently NGC has also been deployed in adaptive optics with electron multiplication CCDs and infrared electron avalanche photodiode arrays. Since NGC runs all new detector systems of ESO instruments, a uniform platform is available at the observatory which facilitates operation and maintenance.

Figure 1 ESO's previous and current controllers

2. NGC STRUCTURE

The NGC controller is based on the Xilinx FPGA. In comparison to the previous ESO controllers, all digital parts, like RAMs, FIFOs, and the sequencer, are fully implemented in the FPGA, so that less external components are needed. The detector front-end electronics are connected via fiber optic cables to the PCIe card of the PC. Over the same cable, commands and data are transferred using a time multiplexing technique.

3. DIFFERENT TYPE OF NGCS

Up-to-now the scientific NGC (SCI-NGC) covered our needs for all infrared and optical detectors. It is in use for readout of high speed eAPD infrared, mid-IR detectors, as well as low noise CCDs. But in the area of adaptive optics to readout e2v CCD220 detector we required a more compact, high speed controller. Our solution has a very compact footprint and therefore hardware wise required a different solution, which is called adaptive optics NGC (AO-NGC). We use the same back-end interface for both NGC types. Also the firmware could be mostly taken and adapted to the new need. However there is no single active component on the AO-NGC front-end which is used on SCI-NGC and vice versa. With the SCI-NGC and AO-NGC combinations, ESO is able to readout any type of detector.

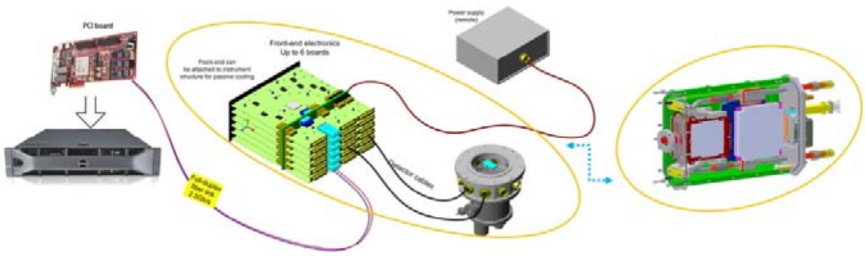

Figure 2 Scheme of the NGC

4. DEVELOPMENT

The NGC architecture is highly adaptable and flexible. Implementation and integration of new technology standards or well developed and optimized industrial components like ADCs/DACs or PCI-express can be done in a relatively short time. Since the NGC team is also directly involved in detector evaluation and development, we often get new ideas like the implementation of sub-pixel and Fowler sampling in the FPGA. So we can fine tuning the system by integrating new, better components or adding new functions into both hardware and software. This is the reason the development of the NGC is always an on-going process.

5. PCI-EXPRESS

The NGC-hardware is controlled through a PCI-express (PCIe) interface board providing up to 4 command channels and 4 multiplexed DMA-channels delivering the data through a sustained scatter-gather DMA engine (circular buffer). Currently the implemented hardware is a commercial off-the-shelf device from HTG [1], which has been adapted to the NGC. The left module shown in Figure 3 is the HTG module and the right one a 3-D model of the NGC module which under development. With the two fiber interfaces we can independently and simultaneously control and readout two different AO camera heads or two NGC front-ends. In addition there is a fiber interface with sFPDP protocol to a SPARTA real-time control system. We plan to build our own PCI-e hardware, because it will be more compact and will have five fiber optic interfaces, instead of two. With the present HTG card we were able to use one PCI-e and one PC to readout all 24 CCDS of the MUSE instrument.

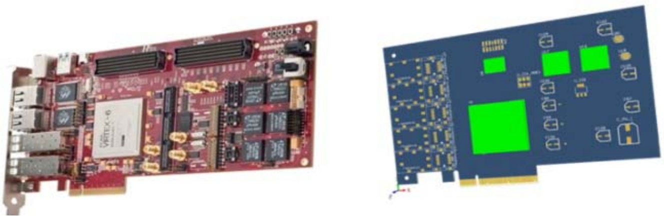

Figure 3 (left) HTG-V6-PCIE-L240, (right) on development of NGC PCIe

6. NGC VIDEO BOARD

The ESO NGC video board, as seen in Figure 4, has 32 video channels, with 16 bit ADCs, digitizing at 10 MHz pixel rates and uses a 2.5 Gbaud fiber data link. The board has fully differential input stages supplied from a 0-9V supply, shared with the preamplifiers. Each video channel has analogue switchable bandwidth and on board real time preprocessing. For example, with the SELEX AO detector, we have implemented full sub-pixel sampling plus FOWLER sampling to off-load this processing from the AO Control system. The numbers of sub-pixel and Fowler samples are also user programmable. This functionality is implemented in a Xilinx Virtex-6 FPGA which also reads the 32 ADC data streams and transmits the final data packets to the fiber transceivers. Multiple boards can be inserted into a system for a detector with more than 32 outputs such as is typical for the mid-IR.

Figure 4 NGC 32 channels video board

7. ADAPTIBILITY AND MODULARITY

The NGC controller is a modular, customizable system. Just like "Lego" blocks we can combine different modules to cover our needs. The FEB module (front-end basic module) generates 16 clocks and 20 biases and also has 4 fully differential video channels. The AQ module has 32 differential video channels, of which exists three different versions with different pixel speeds (1, 3, 10 MHz), but all are plug and play compatible. As an example the MUSE instrument uses four front-end racks, each contains six FEB modules. While KMOS has one rack with three FEBs and three AQ-1MHz modules, likewise VISIR two FEBs and four AQ-3MHz modules, so any combination of modules is possible. Figure 5 shows the main modules of the NGC and the corresponding backplane. Even the fiber link bandwidth to the PC can be increased by simply adding more fiber cables which can then be configured through software.

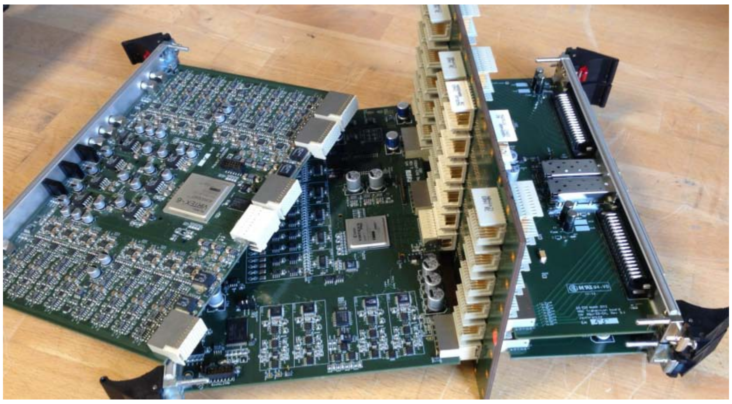

Figure 5 (left) NGC main modules, (right) coresponding transition boards

8. APPLICATIONS USING THE NGC

The NGC already had its first light at the VLT Telescope in Chile. Various ESO instruments already use the NGC. An instrument like MUSE reads out 24 CCDs simultaneously and SPHERE uses several different types of detectors like the Hawaii2RG and the Hawaii1 infrared detectors, ZIMPOL CCD and adaptive optics CCD220. Recently we achieved the best performance with the SAPHIRA MOVPE eAPD detector. The ESPRESSO instrument, with the largest clock capacitance ever handled by a controller, had its first light with the NGC.

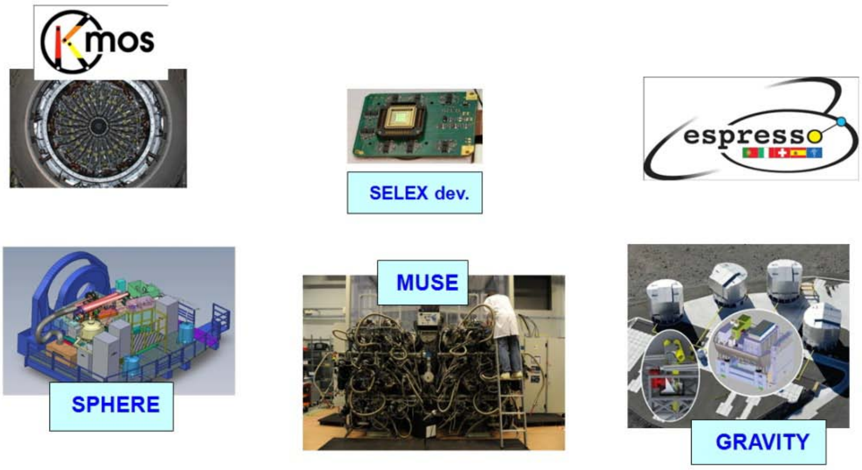

Figure 6 Various ESO instruments using the NGC

9. NGC-SOFTWARE

The NGC-software comprises the DMA and communication-port device driver, high-throughput data acquisition and pre-processing facilities and the full exposure control for scientific operations. The software can be operated as command/database driven or for stand-alone mode, through a graphical user interface. The data can be visualized in real-time on a quick-look display application. The NGC-software includes configuration packages and pixel-processing algorithms for all ESO standard detectors employed for infrared, mid-infrared, optical and adaptive optics systems. The software runs on both 32-bit and 64-bit Linux platforms (kernel version 2.6.x). Hard real-time applications can make use of the low-latency DMA device driver developed for the VxWorks RTOS running on the MVME6100 PowerPC architecture.

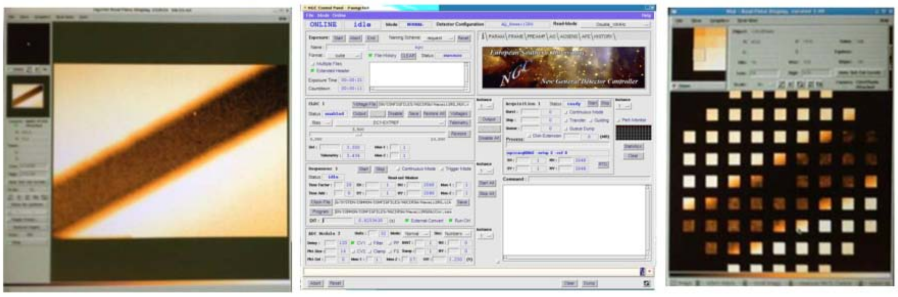

Figure 7 7 (left) NGC-RTD, (mid) NGC DCS GUI, (right) SPARTA RTD

1. Fanless housing

Due to the requirement for NGC use in the VLT Interferometer delay tunnel for the next generation of ESO instruments, we needed to implement a NGC which is vibration-free and silent. Hence the Thermacore Company [2] were contracted to design a fanless water cooled housing. The final solution is now operational and works very well. The heat from the boards is transferred away by inserting them into conduction frames which are thermally interlocked with the cold inner housing. Thermal foams have been used for a non electrical connection of the boards to the frames. Special wedgelocks allow the best thermal connection between the conduction frames and the cold wall.

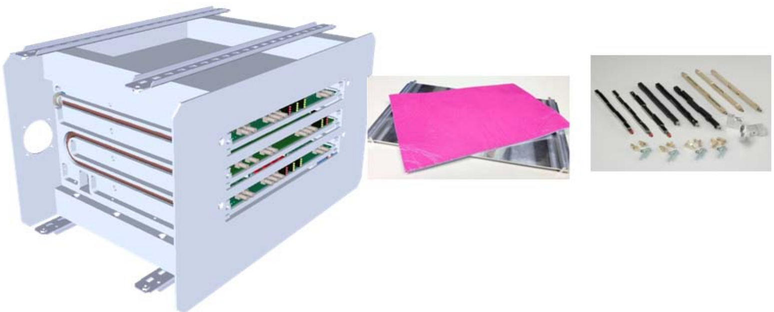

Figure 8 (left) Fanless inner housing, (mid) conduction frame, (right) wedgelocks

10. FUTURE DEVELOPMENT

Besides the usual ongoing developments we are also developing a controller prototype to readout the high order wavefront sensor currently being developed for the E-ELT. For this it is required to read 22 LVDS outputs at 200 MHz in a real time control loop. The firmware is an adaptation of the SCI-NGC and therefore the same control software can be used. Upgrading the FPGA to a more powerful version with much more integrated logic cells, like the Xilinx Virtex-7, will give us more freedom and efficiency for on board pre-processing.

11. REFERENCES

[1] HiTech Global, LLC, 2059 Camden Ave. Suite # 160, San Jose, CA 95124 USA HTG

[2] .Thermacore Europe Ltd, info@thermacore-europe.coms