E U R O P E A N S O U T H E R N O B S E R V A T O R Y

Organisation Européenne pour des Recherches Astronomiques dans l'Hémisphère Austral

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VERY LARGE TELESCOPE

ESO New General Detector Controller

Base Software

Design Description

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1 INTRODUCTION

1.1 Purpose

The document describes the design of a common base software for the ESO New General detector Controller (NGC). It addresses to the hardware developer in the lab, to the detector specialist, to all instrument users including those of external consortia and to all software developers designing applications based on NGC.

1.2 Scope

The new general detector controller will be used for both optical and infrared applications. While the low level interfacing to the controller is the same in both cases, there are a lot of differences concerning how the controller is actually used. This especially concerns data pre-processing and exposure handling. The base software shall provide a transparent implementation of the NGC hardware modules, giving access through software functions to all features provided by the NGC and still leaving full freedom in the applicable range of the NGC detector front end. The application specific parts are described in the design documents [RD10] (optical) and [RD11] (infrared).

The scope of this document covers all NGC software functionality, which *can* be used in all cases, even though this does not mean that all of this functionality finally will be used in all specific applications. Especially the parallel pre-processing software (section 7) may be used where required, while for less challenging tasks a more simple approach may be adequate to avoid overkill solutions and to ease software maintenance.

Although not being part of the software design, there is a short overview of the NGC hardware, but only to an extend of what is required to understand the software methods. A detailed description of the hardware is given in [RD15].

1.3 Applicable and Reference Documents

All applicable and reference documents are listed in the “NGC Project Documentation” document, VLT-LIS-ESO-13660-3906.

1.4 Glossary

See NGC Project Glossary [AD63].

1.5 Abbreviations and Acronyms

See NGC Project Acronyms [AD64].

2 HARDWARE OVERVIEW

The NGC hardware consists of a modular assembly of back-end and detector front-end modules. The back-end module is a PCI-Bus interface card connecting the local control and data acquisition computer (NGC-LCU) to the front-end modules which are creating and receiving the detector signals. The hardware module providing the clock timings is called sequencer. The hardware module providing the needed clock voltage levels and the additional detector biases is called CLDC. The hardware module doing the analog to digital conversion of the detector data is called ADC module. Data and control signals between back-end and front-end are on fiber-optic link(s) with transmission rates of 2.5 GBit. Detailed descriptions of the hardware modules functionality are given in [AD8].

2.1 Detector Front End

The detector front-end consists of at least one main-board and an arbitrary number of additional boards. The boards may contain only a sequencer-/CLDC-module or only an ADC-module (converting the detector output signals) or possibly any combination of those. The number of ADCs on each ADC-module is also configurable. The boards are linked together in a network-like structure (see Figure 1). Current hardware only supports linear chains (i.e. header 0x5).

Each board is equipped with a temperature sensor, which can be read-out through a dedicated register. Each board also provides through register value(s) its own serial-number, a product code and a revision number.

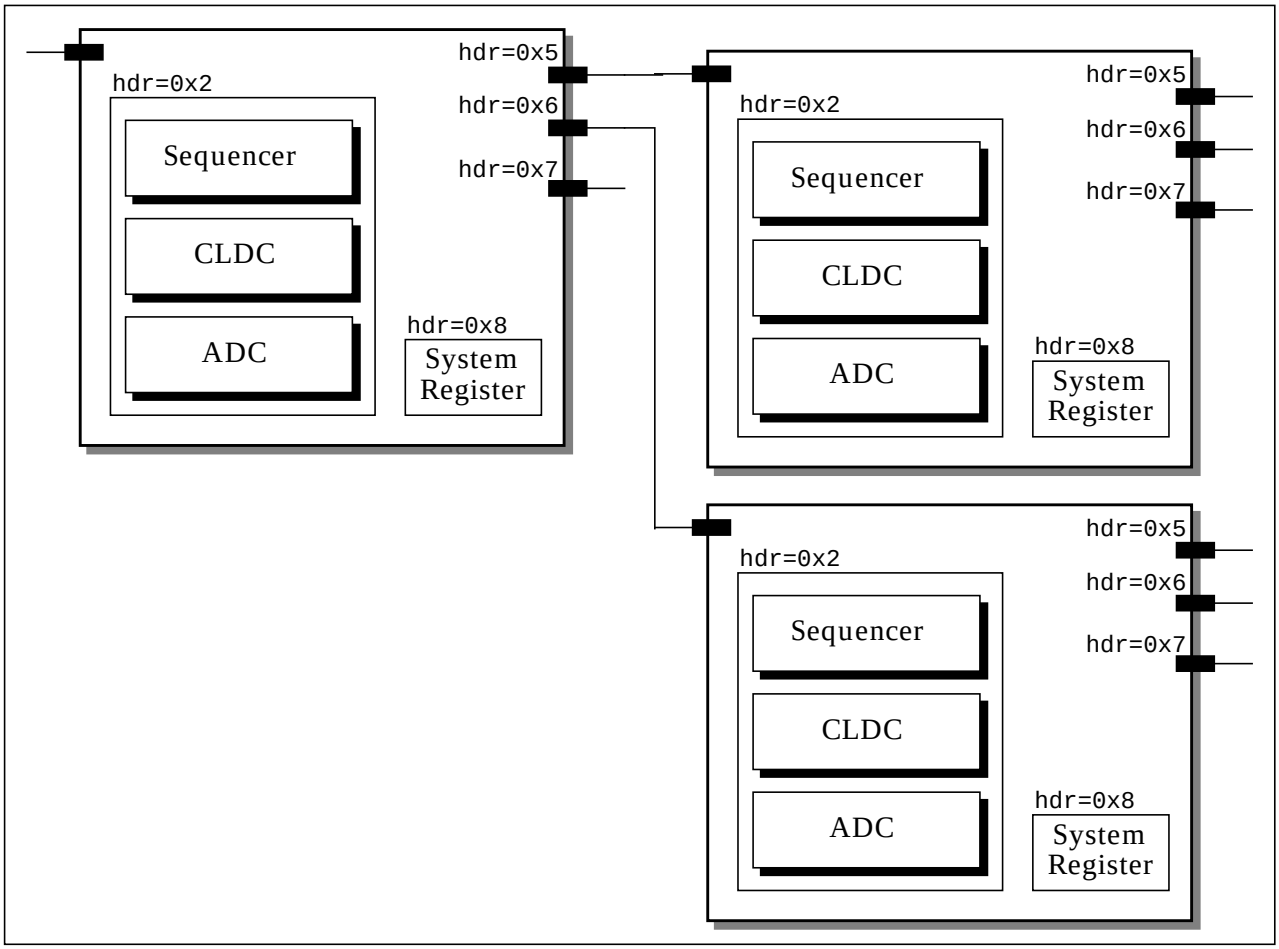


Figure 1 NGC Hardware

2.2 Computing Architecture

The NGC will be controlled remotely from an instrument workstation (IWS). The physical interface to the hardware (PCI-Bus back-end card) resides in a local computer (NGC-LCU), which is also used for the data acquisition and pre-processing. Currently the local computer is a PC running a Linux operating system (kernel 2.4 or higher). In case the maximum nesting depth inside the NGC module network has been reached, the system needs to be accessed through additional PCI-Bus back-end cards. This may imply the usage of more than one NGC-LCU, also in case the computing or peripheral bus bandwidth of the NGC-LCU is not sufficient. So the configuration range covers a simple system controlling one detector via one PCI-Bus interface card as well as large detector mosaics distributing their data via a huge number of channels among several computers.

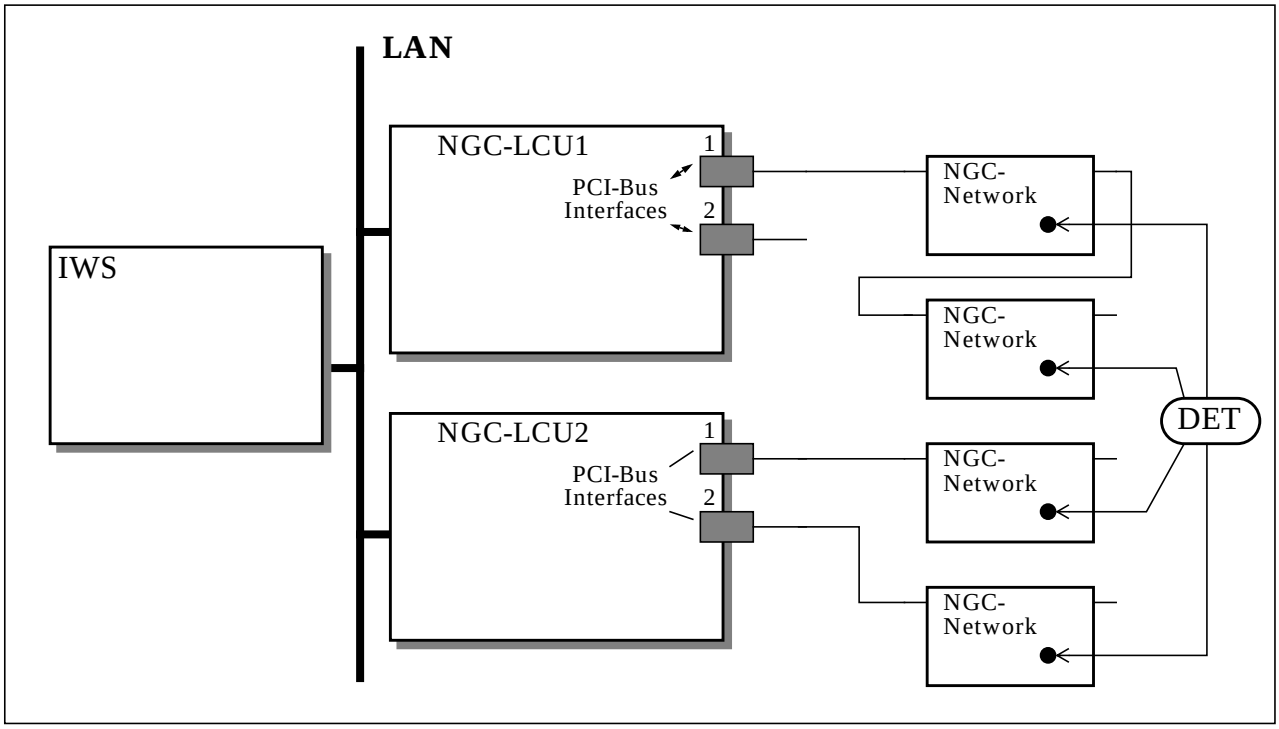


Figure 2 Computing Architecture

2.3 Communication Protocol

The communication between back-end and front-end modules is based on packet transmission over serial links. A packet structure is defined to address a function (i.e. a register or memory in a front-end module) for reading or writing. The package is first sent to the back-end transmitter-FIFO and then the transmission is activated upon raising a run-bit in the back-end control register. A packet which has reached its destination is acknowledged in the back-end status register as soon as the addressed function has been executed. In case of a “read” operation the acknowledge is sent once the requested data is available in the back-end receiver-FIFO. This limits the size of a single read / write operation to the size of the transfer FIFOs.

A package consists of a number of headers in the range of [0x2 to 0x8] followed by the address to write to or to read from, followed by a command code (write = 0x0, read = 0x8000000). In case of a write operation a number of data words up to FIFO size can be appended. In case of a read operation the command code is or’ed with the number of data words to be read.

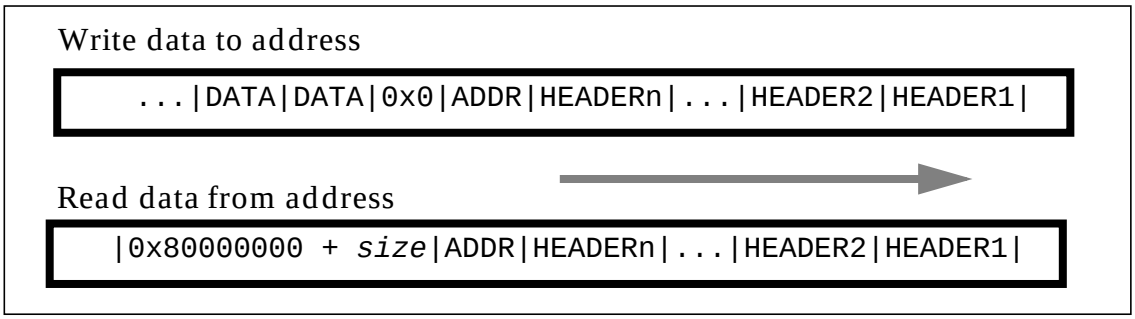


Figure 3 Packet Structure

The packet follows the route through the front-end network as described by the headers until header *0x2* or header *0x8* is reached. Header *0x5, 0x6, 0x7* lead to the next board connected on the associated link. Header *0x2* means, that a function on this board is addressed. Header *0x8* addresses the configuration register on this board (for resetting or link configuration). The configuration register is write-only and does not send an acknowledge back. The header *0x8* is directly followed by the register value (no address, no command code) and therefore it is an exception in the protocol.

2.4 Voltage Programming

The CLDC module is able to drive 16 clock- and 20 bias voltages (bias 17 to 20 are reserved for high voltages). The voltages are set via two 14-bit DAC modules. Each DAC module houses 32 output channels and one programmable negative offset. The channels of the first DAC lead to clock low and clock high of the 16 clocks (pairs to clock low and impairs to clock high). The 20 bias voltages are generated by the first 20 channels of the second DAC module. There are two clock monitor outputs on the module. The two clocks to be monitored can be selected via a two registers. There is also a programmable monitor for the video channels on the ADC module. A voltage telemetry of the DAC channels can be done with 16 bit accuracy. The channel to be measured is selected via a register. An A / D conversion is done upon a write to the telemetry channel register. Afterwards the converted 16-bit data can be read from the telemetry data register. Special telemetry channels are foreseen to perform bias voltage current measurements.

2.5 Sequencer Programming

The NGC sequencer configuration is divided into two parts: clock pattern setup and sequencer program.

2.5.1 Clock Pattern RAM

The clock patterns are stored in the sequencer pattern RAM. The size of the pattern RAM is 2 x 2048 x 32 bits, which can be divided into an arbitrary number of patterns. The RAM is organized in two blocks: low-RAM and high-RAM. The low-RAM contains clocks 1 to 32, the high-RAM contains the convert pulse, some utility signals and special flags marking break-points, "*wait for trigger*" statements or "*end of program*" / "*end of pattern*". Each word in the low-RAM together with the corresponding word in the high-RAM forms one sequencer state. The duration time of the state (dwell time) is given in ticks in 16 bits (12 to 27) of the high-RAM word. Some bits in the high-RAM word are foreseen to disable for each individual state a contiguous sections of clock- and / or utility-signals (i.e. the signals remain in their current state until they are enabled again).

2.5.2 Sequencer Program RAM

The sequencer program consisting of ***LOOP***- and pattern ***EXEC***-tokens is stored in the sequencer program RAM. The main entry point is the first instruction stored in the program RAM base address. The RAM can be freely divided into subroutines accessed via a ***JUMP-SUBROUTINE*** (***JSR***) token. The program pointer jumps back from the sub-routine to the calling address when reaching a ***RETURN***-token. The subroutines help to keep the required program memory small, as repeating parts do not need to be resolved each time they appear in the program loop.

Each word in the RAM consists of a 3-bit command token, an 11-bit address and a 16-bit repetition counter. 2-bits are reserved for expansion of the address range or further command tokens. The address field is only used for the ***EXEC***- and ***JSR***-tokens. The addresses are relative to the low / high RAM (***EXEC***-token) respectively to the sequencer program RAM (***JSR***-token). The 16-bit repetition counter is only valid for ***LOOP***- end ***EXEC***-tokens, otherwise it should be set to zero. For infinite loops a special ***LOOP INFINITE*** token is reserved. The program runs until it reaches a ***PROGRAM END*** token or until it is interrupted via a command sent to the sequencer control register.

Sequencer Program RAM

BIT 10..0	Pattern Address / Subroutine Address
BIT 26..11	Repetition Counter
BIT 27	reserved
BIT 30..28	Token
BIT 31	reserved

Sequencer Program Tokens (Bit 30..28)

000	PROGRAM END
001	EXEC pattern
010	LOOP
011	LOOP END
100	LOOP INFINITE
101	JSR (jump to subroutine)
110	RETURN (from subroutine)
111	reserved

2.6 Sequencer Control

The sequencer is started by setting either the *start bit* or the *start-sync bit* in the sequencer control register. If the *start-sync bit* is used, then the synchronous start signal is raised and all sequencer instances will be started synchronously unless they have the *external-run-control disable bit* set in their control register. This also applies to the initiating sequencer (i.e. the sequencer may raise the *start-sync bit* but not start itself when the external run-control is disabled). The normal *start-bit* will always start the sequencer, even if external run-control is disabled.

The sequencer stops after the dwell time of the pattern currently executed in the following cases:

- The address FIFO becomes empty (error condition).
- The stop bit is set in the sequencer control register.
- A ***PROGRAM END*** token is executed.
- The break bit is set in the sequencer control register and a pattern state is executed, which has also the break bit set in its high RAM word. The reaching of such a break point can be traced by polling the sequencer status register.

2.7 Synchronization

The program execution is suspended when a pattern state was executed, which had the "*wait for trigger bit*" set in its high RAM word, and the trigger mode is enabled in the sequencer control register. Program execution is resumed upon the reception of the external trigger signal or when the *trigger bit* is set by software in the sequencer control register. By using the "*wait for-trigger bit*" it is possible to synchronize detector read-outs with external events or also to synchronize programs running on multiple sequencer modules with high accuracy. The external trigger signal has to be generated by an external dedicated hardware. Using the VLT TIM for this purpose allows externally controlled timings which are synchronous with the VLT time reference signal. As the "*wait for trigger*" state can also be disabled by setting the *trigger-mode bit* in the sequencer control register to zero, it is possible to run exactly the same clock pattern sequence either continuously or triggered externally.

Some signal lines in the sequencer clock pattern RAM can be used to create feed-back signals ("*end of read-out*") to in turn trigger external devices.

3 SOFTWARE ARCHITECTURE

3.1 Hierarchy

The software can be classified hierarchically as shown in Figure 4.

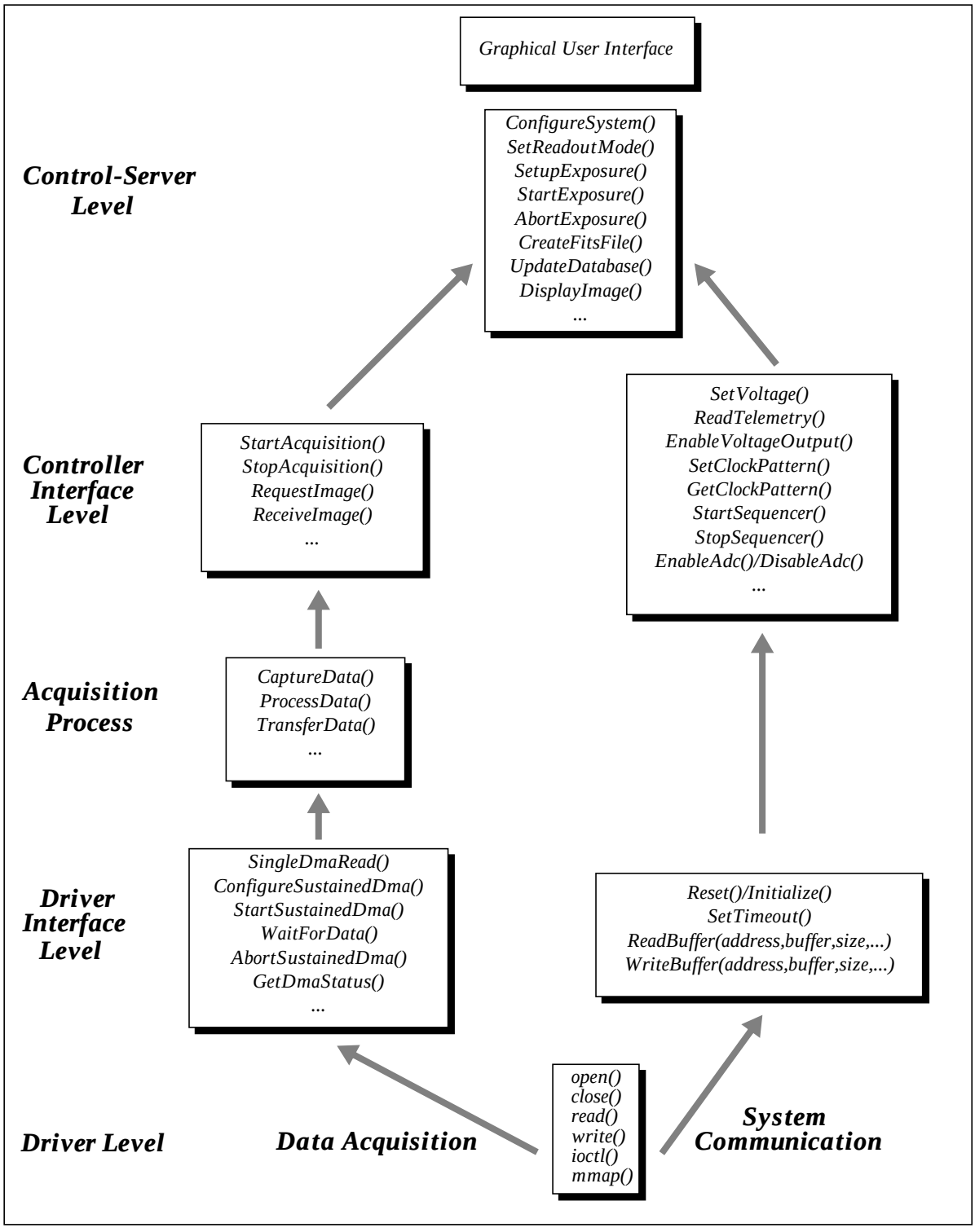


Figure 4 Software Hierarchy

3.2 Software Modules

All software modules are under CMM configuration control. The base software contains the following software modules:

- ***ngcdrv*** - The device driver for the PCI-Bus back-end card.

- ***ngcb*** - The NGC basic software module containing the driver interface library (***ngcbDrv***) for communication and DMA, some basic i/o tools, a portable threads- and priority-control implementation and the C++ base classes for general system access. This module also provides a hardware simulation mechanism for the NGC controller (see section 5.3).

- ***ngcpp*** - The DMA data-acquisition and pre-/processing module.

- ***ngcdcs*** - The NGC detector control software base module implementing the classes for the NGC hardware modules and the interfaces to the data acquisition (Figure 5).

A dictionary, which is common to both infrared and optical systems, is stored in the ***dicNGC*** software module.

The software module ***ngcarch*** provides automatic installation procedures for all the mentioned software modules (see Figure 6).

3.3 Test Software

Test scripts for the TAT (see [RD41]) are developed in parallel to the software module code generation. Test configuration files are created for various virtual system architectures and detector assemblies to cover all possible ranges of complexity. The DMA data-acquisition and pre-/processing module ***ngcpp*** does not contain TAT test scripts, but fully working test/template acquisition processes instead, which are then embedded in the test scripts and test configuration files of the higher level ***ngcdcs*** module.

3.4 Class Structure

The Sequencer-, CLDC- and ADC- hardware modules are modelled in the ***ngcdcs*** software module as C++ objects (***ngcdcsSEQ***, ***ngcdcsCLDC***, ***ngcdcsADC***). They all inherit from a base module class (***ngcbMOD***, see 6.1), which keeps the physical interface (***ngcbIFC***, see 5.1) including the route to the module. Hardware simulation is implemented via a simulator class (***ngcbSIM***, see 5.3), which is an object within the ***ngcbIFC*** class. The ***ngcdcsCTRL*** class is a container class for all these hardware modules. Interface classes for controlling the data acquisition process (***ngcdcsACQ***) and for the data transfer (***ngcdcsACQ_DATA***) are also part of the **ngcdcs** module. The ***ngcbOBJ*** class is a base class unifying some common tasks for the controller classes and the acquisition module classes.

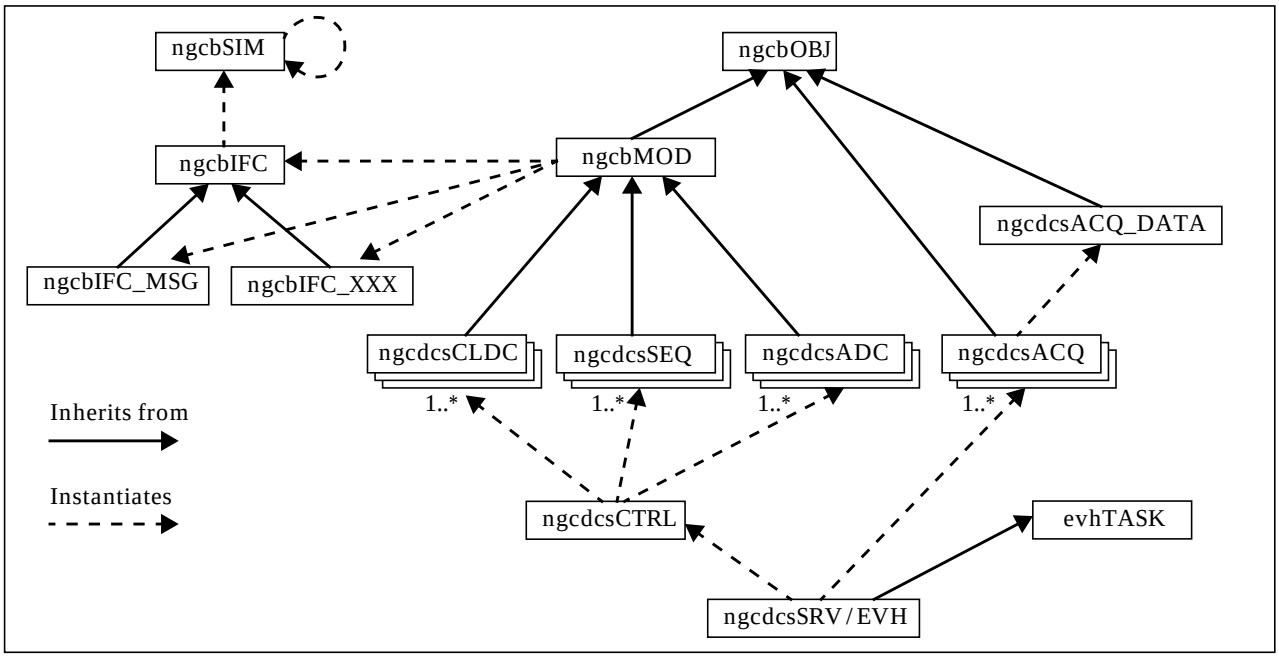


Figure 5 Class Structure

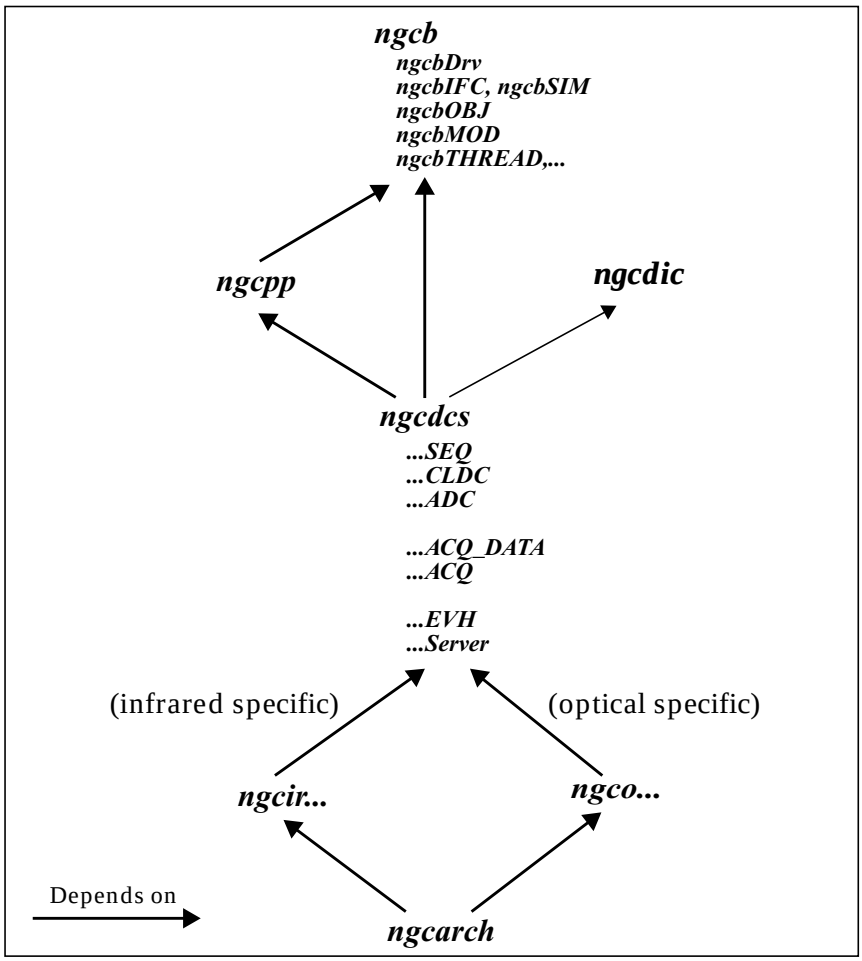


Figure 6 Module dependencies

3.5 Verbose Mode and Logging

Verbose messages can be printed on the standard output stream of each process. The detail is given by a verbose level, which is also passed as parameter to the respective sub-processes. To make the messages of the sub-processes visible, it is required to start those processes in a separate terminal.

Error - logging will be done with the standard CCS error logging facility, which includes the automatic logs like tracing of any received / sent command (see [AD27], [RD32]). Additionally the verbose output can be logged in a detail depending on a given log-level for maintenance / debugging purposes. Operational logs are TBD.

3.6 Error Handling

The CCS error mechanism [RD32] provides a classification scheme for application specific errors. The NGC base software uses this mechanism. The introduction of new error codes is limited to cases, where specific actions (“*reset*”, “*restart server*”, “*restart CCS environment*”, “*reboot*” etc.) are required. Other errors, which leave the system still in a valid state without further interaction (“*parameter out of range*”, “*invalid file name*”,...) are trapped by an overall system error (***ngcbERR_SYSTEM***, ***ngcdcsERR_SYSTEM***) plus an appropriate message string. The meaning of the error class and the possibly needed interactions are described in a help file (.hlp), which can be displayed with the standard CCS-tools (also with the *logMonitor*). The actual error reason (“*timeout*”, “*link channel error*”,...) is given in an associated error message string.

Error	Severity	Description
`ngcbERR_SYSTEM`	Warning	General error of informative character (“*parameter out of range*”, “*invalid file name*”, etc.).
`ngcbERR_IO`	Serious	An I/O-error on the interface to the detector front end occurred. Typically this will require at least a reset or a power-cycle of the NGC hardware to recover.
`ngcbERR_SRV`	Serious	The communication with the driver interface process has failed. The server may have died or the message system/network is down.
`ngcbERR_INIT`	Serious	The server initialization failed. The message system may not be up, or the operating system has run out of its resources. This may require a restart of the environment or even a reboot of the IWS/NGC-LCU.
`ngcbERR_WARNING`	Warning	A warning which has only very limited effect on the further system behaviour.

Error	Severity	Description
ngcbERR_DB_READ	Serious	Error when reading from the online database. This may require a rebuild of the database and a restart of the CCS environment.
ngcbERR_DB_WRITE	Serious	Error when writing to the online database. This may require a rebuild of the database and a restart of the CCS environment.
ngcbERR_DB_INIT	Serious	Error when reading from or writing to the online database during initialization phase. This may require a rebuild of the database and a restart of the CCS environment.

Error	Severity	Description
ngcdcsERR_SYSTEM	Warning	General error of informative character (“p*arameter out of range*”, “*invalid file name*”, etc.)
ngcdcsERR_IO	Serious	An I/O-error on the interface to the detector front end occurred. Typically this will require at least a reset or a power-cycle of the NGC hardware to recover.
ngcdcsERR_INIT	Serious	The server initialization failed. The message system may not be up, or the operating system has run out of its resources. This may require a restart of the environment or even a reboot of the IWS/NGC-LCU.
ngcdcsERR_WARNING	Warning	A warning which has only very limited effect on the further system behaviour.
ngcdcsERR_FATAL	Fatal	An error which cannot be recovered in any case.
ngcdcsERR_DB_READ	Serious	Error when reading from the online database. This may require a rebuild of the database and a restart of the CCS environment.
ngcdcsERR_DB_WRITE	Serious	Error when writing to the online database. This may require a rebuild of the database and a restart of the CCS environment.

Error	Severity	Description
ngcdcsERR_DB_INIT	Serious	Error when reading from or writing to the online database during initialization phase. This may require a rebuild of the database and a restart of the CCS environment.
ngcdcsERR_ACQ_IO	Serious	An I/O-error occurred when communicating with the acquisition process. The process may have died or the network connection to the NGC-LCU may be broken.
ngcdcsERR_ACQ_OVERRUN	Serious	The acquisition process was not able to process the data in time. All data are buffered in a ring-buffer to compensate operating system gitters. If data are coming in faster than they can be processed for a longer period, then the ring-buffer may overrun. Either read-out slower or add sufficient delays between the readouts.
ngcdcsERR_ACQ_OVERFLOW	Serious	The data on the physical NGC-data link are coming in faster, than they can be delivered to the computer bus. The internal FIFOs on the interface boards become full in this case. This is a hardware error. The reason may be for example crosstalk/spikes on the physical communication lines.
ngcdcsERR_EXP_IO	Serious	An error occurred during data taking. The data connection to the acquisition process may be broken (process has died or network is down).
ngcdcsERR_EXP_FILE	Serious	An error occurred when writing the exposure data to a file on the disk. The disk may be full or the directory can no more be accessed.

4 DEVICE DRIVER

The PCI-Bus back-end card is the interface between the NGC detector front-end and the PCI-Bus on the NGC-LCU. It provides both a communication channel (COM-port) for setup and status commands and a high speed scatter / gather DMA channel for ring-buffered sustained data transfer. The device driver for this module is delivered in the ***ngcdrv*** module. If no interface card is used (e.g. software is used only for simulation purposes), then the device driver needs not to be installed.

The device driver supports Linux Kernel 2.4 and 2.6 (or later). The *Makefile* of the ***ngcdrv*** module also takes care of the differences between Linux 2.4 and Linux 2.6 kernels. Compilation and installation can simply be done with "*make all install*" on both kernel version trees. A script to install (***ngcdrv_load***) and to remove (***ngcdrv_unload***) the driver is part of the ***ngcdrv*** module. The install script may be added to the /etc/rc.local file to let the driver be loaded at boot time. The compilation and installation of the driver module has to be done as user "*root*" on a directory which is local on the target computer. Path and environment need to be reset to the root home session.

CAUTION: Use "*rlogin $HOST -l root*", "*telnet $HOST*" or "*su -*", to login as root. The frequently used "*su*" (without "-") does not setup a proper root session and the loading of the driver module (***ngcdrv_load***) may fail with an error message indicating an "*invalid module format*".

The device driver provides the standard system calls (***open, close, read, write, ioctl, mmap***) for several instances (boards) installed on the host-computer. A channel to a device can be opened with the ***open*** system call. The device name is typically ***"/dev/ngc<n>_com"*** for the communication channel and ***"/dev/ngc<n>_dma"*** for the DMA channel, whereby <***n***> is the instance number (starting with 0) of the board.

```
(int) fd = open("/dev/ngc<n>_com", O_RDWR);
(int) fd = open("/dev/ngc<n>_dma", O_RDWR);
```

If the ***open*** call fails, a negative value is returned and the appropriate ***errno*** is set. The ***close*** system call is used to close a channel to a device:

```
(int) status = close((int) fd);
```

The function returns 0 in case of successful operation. Otherwise a negative value is returned and the appropriate ***errno*** is set.

The driver also supports the execution of a single DMA read. This transfer can be done through the standard ***read*** system call.

4.1 NGC Communication Channel

The communication channel is operated through the ***read/write*** system calls. A timeout for these operations can be specified via an ***ioctl*** command. The default timeout value is zero, which means that the timeout is disabled. A reset of the target device can also be performed via ***ioctl***. The ***read/write*** is done using a polling mechanism.

4.2 DMA Data Acquisition

DMA transfers are done via scatter / gather lists. Large DMA transfers are cut into small pieces and an array of DMA-descriptor blocks holds the address and the size for each part (see Figure 7). The last entry in a descriptor block contains the address and the flags of the next descriptor to be loaded into a ***DMA Descriptor Address Register***. The flags contain information about the direction of the

transfer (Local Bus to PCI Bus or vice versa) and whether an interrupt should be generated after the transfer or not. An '*end-of-chain*' flag marks the end of the list. A sustained mode (ring buffer mode) is possible by setting the address of the first descriptor in the '*next descriptor address*' field of the last descriptor in the chain (without setting the '*end-of-chain*' flag). If a ring-buffer consist of N elements specified by the calling application, the driver would divide each element into smaller pieces of DMA. An interrupt is only generated when the last piece for one ring-buffer element has been transferred. The actual layout of the scatter / gather list is fully transparent to the user.

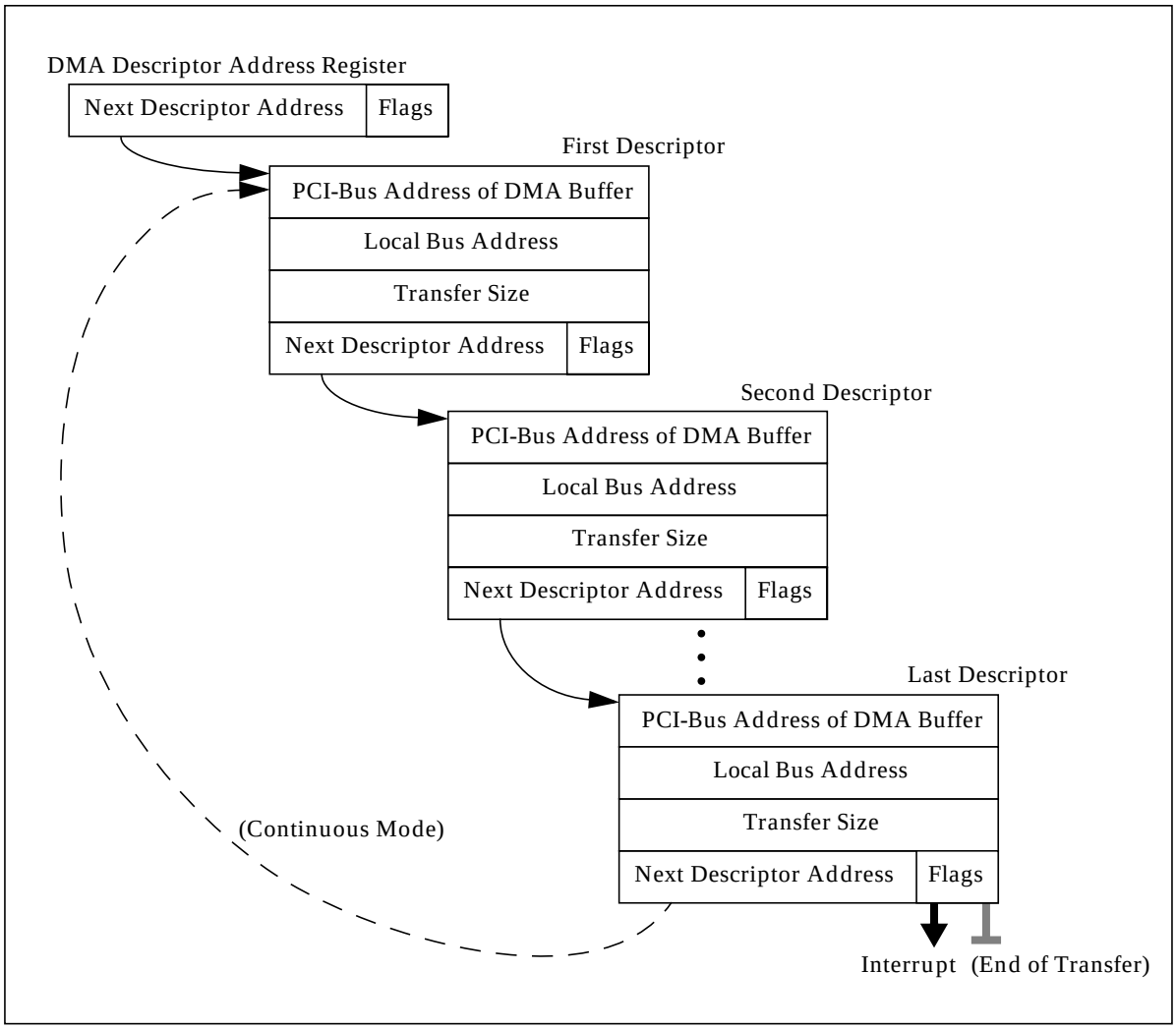


Figure 7

The DMA memory is allocated by the driver in kernel space and the corresponding pages are mapped into the user space via the ***mmap*** system call. First the driver is told via an ***ioctl*** system call how many ring-buffer elements to allocate in kernel space:

```
ngcdrv_ring_t ring;

ring.nbuf = <number of buffers>;
ring.size = <size of each buffer>;

ioctl ((int) fd, NGCDRV_DMA_CFG_BUF, (void *)&ring);
```

Then the memory has to be mapped into the user space via the ***mmap*** system call. The number of ring-buffer elements actually allocated might differ from the value passed to the driver. Therefore

the value returned in the ***ring***-structure must be used for the mapping:

```
(void *)mapArea = mmap(0,(int)(ring.size*ring.nbuf),PROT_READ,MAP_SHARED,(int)fd,0);
```

The function returns a (virtually) contiguous memory area holding the specified number of ring-buffer elements or ***MAP_FAILED*** if an error has occurred. The user space buffers are then obtained in the following way:

```
if (mapArea != MAP_FAILED)
  {
  int i;
  mapSize = ring.size * ring.nbuf;
  for(i=0;i<ring.nbuf;i++)
    {
    buffer[i] = (char *)(mapArea + (i * ring.size));
    }
  }
```

The memory is released in the user space by un-mapping the reserved area:

```
if (mapSize > 0)
  {
  munmap(mapArea, mapSize);
  }
```

The buffer addresses should be set to ***NULL*** afterwards:

```
for (i=0;i<ring.nbuf;i++)
  {
  buffer[i] = (char *)NULL;
  }
```

4.3 Commands

The ***ioctl*** system call is used to send a command to a device:

```
(int) status = ioctl((int) fd, (int) command, [(void *)argument]);
```

The function returns 0 in case of successful operation. Otherwise -1 is returned and the appropriate ***errno*** is set. The following ***ioctl*** commands are supported by the device driver. The command literals are defined in the device driver header file (***ngcdrv.h***).

- ***NGCDRV_PCFG_GET*** reads a register value from the PCI configuration space;

  The argument is a pointer to an ***ngcdrv_param_t*** structure:

  ```
  unsigned int reg;    - not used
  unsigned int value;  - returns the register value
  unsigned int offset; - PCI configuration address
  ```

- ***NGCDRV_PCFG_SET*** sets a register value in the PCI configuration space;

  The argument is a pointer to an ***ngcdrv_param_t*** structure:

  ```
  unsigned int reg;    - not used
  unsigned int value;  - register value
  ```

```
unsigned int offset; - PCI configuration address
```

- ***NGCDRV_CFG_GET*** reads a register value from the device configuration space;

  The argument is a pointer to an ***ngcdrv_param_t*** structure:

```
unsigned int reg;    - not used
unsigned int value;  - returns the register value
unsigned int offset; - offset from configuration base address
```

- ***NGCDRV_CFG_SET*** sets a register value in the device configuration space;

  The argument is a pointer to an ***ngcdrv_param_t*** structure:

```
unsigned int reg;    - not used
unsigned int value;  - register value
unsigned int offset; - offset from configuration base address
```

- ***NGCDRV_COM_RESET*** resets the target device and clears the COM-port FIFOs;

  No argument.

- ***NGCDRV_COM_TMO*** sets a timeout for subsequent ***read/write*** calls on a COM-port device;

  The argument is a pointer to an ***unsigned int*** specifying the timeout in seconds. The default value is zero, which means that the timeout is disabled.

- ***NGCDRV_DMA_RESET*** resets (clears) the DMA data FIFO;

  No argument.

- ***NGCDRV_DMA_CFG_BUF*** configures the ring-buffer mode on a DMA device (Linux only);

  The argument is a pointer to an ***ngcdrv_ring_t*** structure:

```
unsigned int nbuf;    - number of ring-buffer elements
unsigned long size;   - size (in bytes) of each buffer
```

  This command is only valid when using the Linux operating system.

- ***NGCDRV_DMA_START*** starts a continuous ring-buffered scatter-gather DMA;

  No argument.

- ***NGCDRV_DMA_WAIT*** waits for the next ring-buffer interrupt;

  No argument. The interrupts are buffered internally. If the calling function has missed an interrupt, the ***ioctl*** call returns immediately.

- ***NGCDRV_DMA_DONECOUNT*** returns the current buffer counter;

  The argument is a pointer to an ***unsigned int*** containing the current buffer counter. The counter is initialized to zero with the ***NGCDRV_DMA_START ioctl*** command. It wraps with the range of an unsigned 32-Bit integer.

- ***NGCDRV_DMA_BYTECOUNT*** returns the number of bytes left in the current DMA;

  The argument is a pointer to an ***unsigned int*** containing the current byte counter. Currently this functionality is not supported by the device hardware.

- ***NGCDRV_DMA_ABORT*** aborts a sustained ring-buffered scatter-gather DMA;

  No argument.

- ***NGCDRV_DMA_OVERFLOW*** checks the DMA-FIFO full flag;

  The argument is a pointer to an ***unsigned int*** returning a non zero value if the DMA input FIFO became full. The input FIFO full flag is cleared with an ***NGCDRV_DMA_START ioctl*** command or when a single DMA ***read*** is performed.

4.4 Driver Interface Libraries

The driver functionality is assembled in a driver interface library (***ngcbDrv***) consisting of two major parts for the communication with the system (***ngcbDrvCom***) and the DMA data-acquisition (***ngcbDrvDma***). This library is intended to give a stable procedural interface to the driver, while the device driver itself is subject to updates forced by changes in the peripheral buses and or by new kernel versions or operating system patches. See sections 1.2 and 1.3 for an overview of the supplied functions. The "*ngcbAddr.h*" header file contains all information concerning register addresses and bit-masks for register contents.

5 NGC INTERFACE CLASS

On top of the device driver interface library (***ngcbDrv***) the NGC interface class is intended to provide the basic entry point for the C++ programmer.

5.1 Interface Base Class

The physical interface is represented in the ***ngcbIFC*** class. The class provides methods for opening / closing / resetting the device and for writing data to an address or reading data from an address of a module function in an NGC front-end network which is connected through this interface. All NGC registers / memory can be accessed by calls to the *ReadAddr(), WriteAddr()* member functions. The ***ngcbIFC*** class hides all implementation details, which can be customized by overloading the *Open(), Close(), Reset(), ReadAddr(), WriteAddr()* methods. The intention is to have a transparent representation of these methods, regardless whether they are called locally on the NGC-LCU or remotely on the IWS (Figure 8), which in the latter case would implement these functions as a network protocol within a client / server environment. In case the NGC is controlled remotely from the IWS, the driver interface process running on the NGC-LCU is a lightweight process, which needs to support only a very limited set of commands like *ONLINE* (open device), *STANDBY* (close device), *RESET*, *RDADDR* (read from address), *WRADDR* (write to address), regardless of the complexity of the detector front-end system behind and regardless of the complexity of the executed function. In case the software has to be ported to whatever protocol, only the ***ngcbIFC_XXX*** class and the command handler of the driver interface process have to be replaced, while all higher level functionality can remain untouched. The methods will take care of byte-swapping between big endian and little endian computing architectures and will keep all device handles (such as file descriptors, message queues etc.) internal. So the task for the instantiating application is reduced to its actual basic function, which is read / write access to addresses in the NGC detector front end.

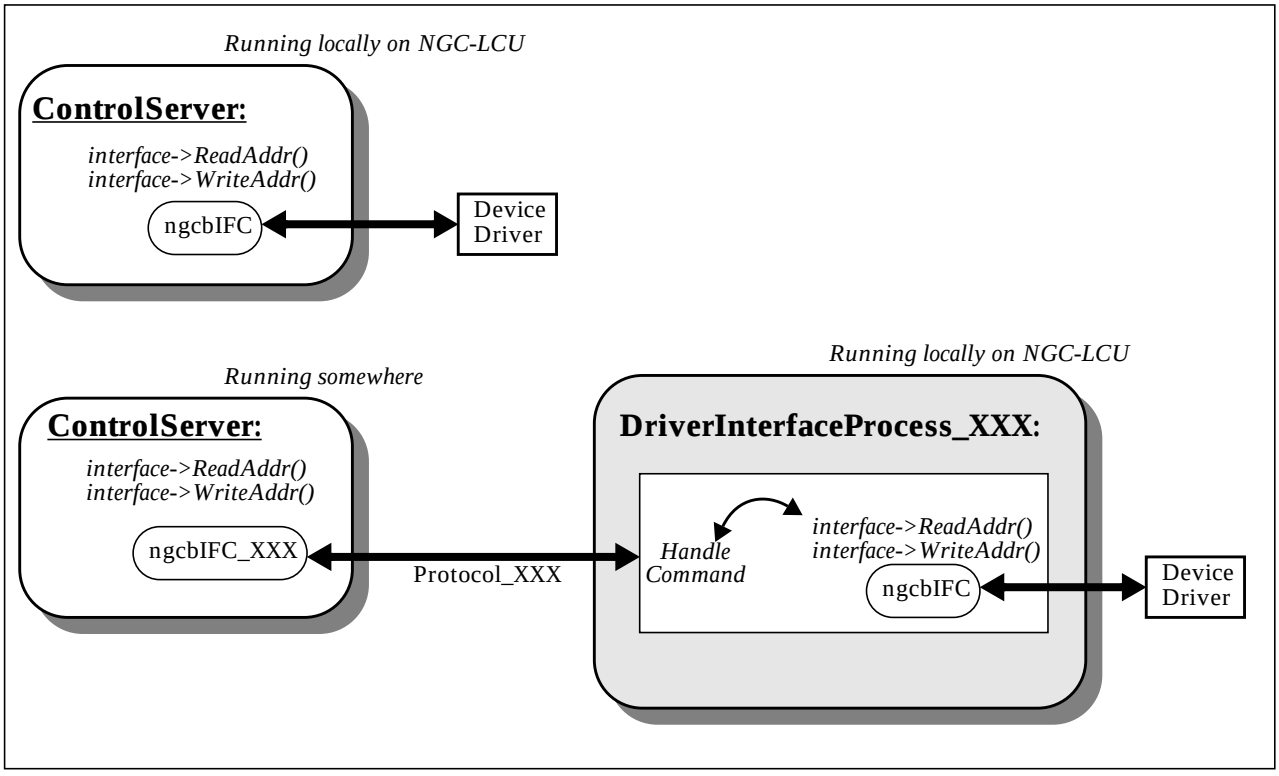


Figure 8 Interface Classes

The normal application will be to run the SW distributed on IWS / NGC-LCU. To run the control-

server locally on the NGC-LCU is mainly intended for HW-development and detector tests in the laboratory, where one does not have access to an IWS in each particular case.

Two virtual methods (*ExecServer()/KillServer()*) are supplied to execute / kill the driver interface process in an application defined way. For the default local interface implemented by the ***ngcbIFC*** class these methods are empty. In case a driver interface process is used the *Connect()* / *Disconnect()* methods will instruct this process to open / close the connection to the physical device, while the *Open()* / *Close()* methods will open / close a connection between control server and driver interface process. If the interface is local, then the *Connect()* / *Disconnect()* methods are implemented just as *Open()* / *Close()* calls. The convenience methods *Online()*, *Standby()* and *Off()* will take care to call the *ExecServer()* / *KillServer()*, *Open()* / *Close()* and *Connect()* / *Disconnect()* methods in the right way for switching the interface state regardless whether the physical interface is local or not. The method

```
int ReadAddr(ngcb_route_t route, int address, int *buffer, int size, int *result);
```

reads *size* 32-bit words from *address* into *buffer*. The method

```
int WriteAddr(ngcb_route_t route, int address, int *buffer, int size, int *result);
```

writes *size* 32-bit words from buffer to *address*.

The *ngcb_route_t* structure contains the following elements:

```
int numHdr;          - number of headers to target including the terminating <0x2>
int hdr[ngcbMAX_MOD];- array of headers including the terminating <0x2>
```

Both operations implement a 4-byte swap in case the calling computer has a big-endian architecture. The methods take care of splitting up the operation into a sequence of *read()* / *write()* calls in case the buffer size exceeds the maximum size for a single operation (Rx- / Tx-FIFO size, see section 2.3). The *result* returns a 32-bit status word for the executed operation. An error string can be retrieved via the *Result2Err()* method. The status word may have the following values:

```
ngcbRES_SUCCESS (0)   - successful operation
```

Bit 0..7 contain the operation status byte (ngcbRES_ERR_IO bit is not set):

```
ngcbRES_OP_INVALID    - invalid address or function
ngcbRES_OP_FAILURE    - operation failed
ngcbRES_ERR_HDR       - wrong header
ngcbRES_ERR_ADDR      - wrong address
ngcbRES_ERR_DATA      - wrong data
ngcbRES_ERR_XSIZE     - wrong transfer size
ngcbRES_ERR_NOT_OPEN  - device is not open
```

Bit 8..16 contain a combination of the following i / o error bits (ngcbRES_ERR_IO bit is set):

```
ngcbRES_ERR_IO        - i/o error
ngcbRES_ERR_INTR      - i/o interrupted
ngcbRES_ERR_OPEN      - error opening device
ngcbRES_ERR_RESET     - error resetting device
ngcbRES_ERR_TIMEOUT   - i/o timeout
ngcbRES_ERR_LINK_DOWN - link channel down
ngcbRES_ERR_LINK_HARD - link channel hard error
ngcbRES_ERR_LINK_SOFT - link channel soft error
```

5.2 Interface Instantiation

The interface is constructed by passing a name-string as constructor-argument. Then it can be opened and closed by calling the *Open()*/*Close()* methods with no argument. The method *Open(name)* will also open the interface, but additionally it sets a new name. The name is identical to the device name in case the interface is local. For interfaces using a driver interface process, the name is an application specific string passing the information needed to start the process on the appropriate computer. Typically the string is formed out of the host name, the environment name and the server name, where the latter may be set to a hard coded default server name when the field is missing. The driver interface process may require certain command line arguments (this could be the device name of the physical interface device). The *Arg()* methods returns a pointer to a string, which is intended to be passed to the process as command line within the *ExecServer()* method.

This instantiation scheme is not obligatory, as the *Open()*/*Close()* and *ExecServer()*/*KillServer()* methods may handle this in an arbitrary way. The basic ***ngcbIFC_MSG*** class delivered with the ***ngcb*** module uses this scheme for a client/server implementation based on the CCS-message system [AD25]. The driver interface process (***ngcb2Drv***) running locally on the NGC-LCU is based on the EVH-toolkit (see [RD33] and [RD35].

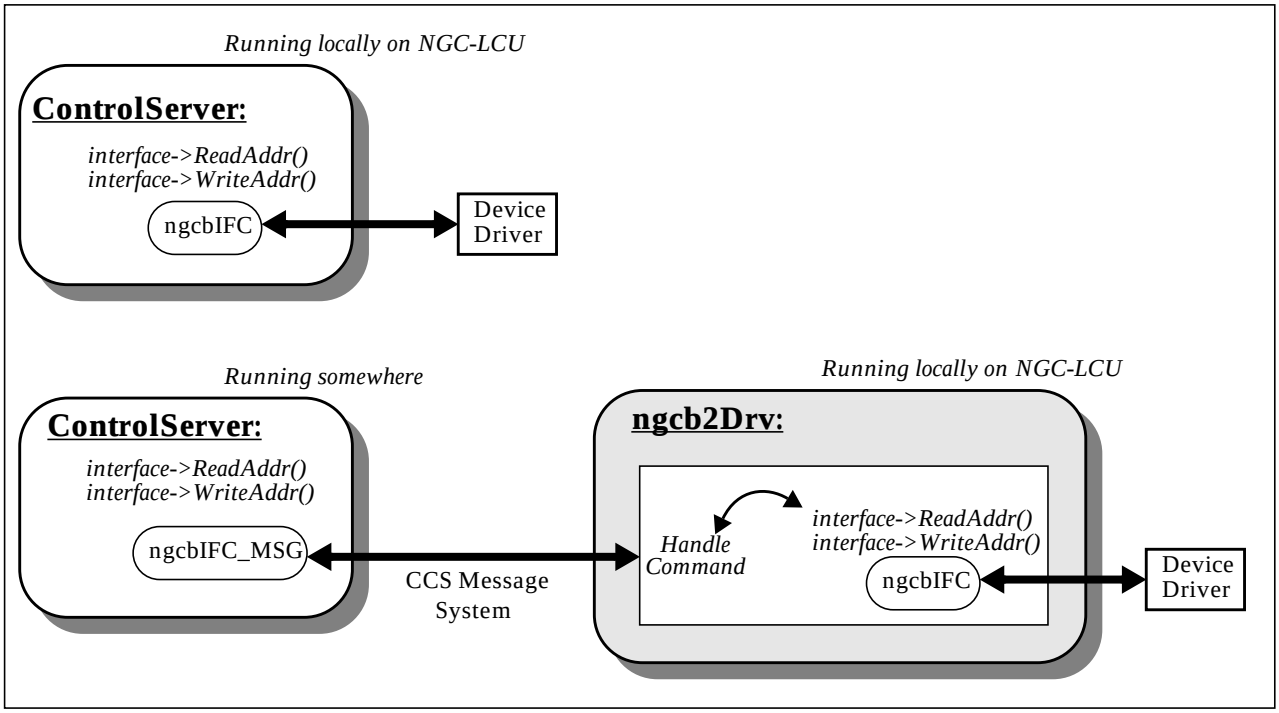


Figure 9 Interface Instantiation

5.3 NGC Simulator Class

The hardware simulation should be done at the lowest possible level to allow all higher level software functions to be tested without having access to the physical device. The IRACE approach (see [RD16]) was to have a dedicated simulator process playing the role of the electronics. Instead of writing the messages to the device driver, the i/o was done through socket communication with this simulator process. Although this is the maximum level of separation, the introduction of pure simulation specific administrative functionality (process startup, two-way protocol conversion...) imposes an unwanted heaviness to this solution. In FIERA (see [RD15]), a first approach also had been to have a process simulating the detector, with the drawback that often the real code and the simulation code were misaligned. For this reason, the dedicated process playing the role of the elec-

tronics has been soon removed. The different processes directly simulated the command execution timing before replying to the higher level software, assuming a successful execution of the command by the electronics.

The NGC hardware simulation is done through a C++ class (***ngcbSIM***), which is directly instantiated in the ***ngcbIFC*** class. This object-oriented approach still provides a good level of separation, but avoids the additional protocol conversion effort. The only costs are a few conditional statements around the basic calls to the driver interface library functions, switching between the “real” read() / write() functions and the *ngcbSIM::Read()* / *ngcbSIM::Write()* member functions of the simulator class.

An instance of the ***ngcbSIM*** class is created inside the (local) ***ngcbIFC*** interface class when calling the *Sim()* member function with the argument ‘1’. In case of a non-local interface the simulation flag has to be propagated to the driver interface process via a command (*SIMULAT* / *STOPSIM)*, which would instruct the process to call the *Sim()* method on its local ***ngcbIFC*** instance.

The simulator configures itself dynamically via the system headers sent with the *write()* system call. A new simulator object is created recursively for every NGC hardware module defined via the link configuration register (header *0x8*). It provides all NGC hardware registers including sequencer pattern- and program-RAM. The voltage setting is sloped to the telemetry values via the DAC - ADC conversion function. The message packets are routed to the right destination instance using the information in the routing headers. The result is automatically passed back recursively to the main entry point (first ***ngcbSIM*** instance). The synchronous sequencer start signal (physically on an external line) is propagated to all ***ngcbSIM*** instances. Time-outs and errors can be emulated by accessing unused addresses at any module instance:

```
ngcbTESTERR_NO_ACK (0x100)      - no acknowledge
ngcbTESTERR_IVLD (0x104)        - invalid address
ngcbTESTERR_SEQ_EMPTY (0x200)   - sequencer FIFO becomes empty
ngcbTESTERR_SEQ_IDLE (0x201)    - sequencer goes to IDLE state (sequence has termi-
                                  nated)
```

Further error cases may be added (TBD).

Once verified the ***ngcbSIM*** class allows all software including the ***ngcbIFC*** class itself to be fully tested in simulation mode.

6 NGC SOFTWARE CLASSES

6.1 Module Base Class

The NGC detector front-end is modular in a sense, that it might consist of an arbitrary number of sequencers, CLDC modules and ADC modules which are linked together in a network-like structure. To realize this modularity also in the controlling software all hardware modules are implemented in an object oriented way using C++ classes.

All hardware modules have in common, that their registers are accessed via a chain of headers leading from one physical board to the other. To access a function on a certain hardware module, one always needs to specify the register address of the function and the route of headers leading to physical board where the module resides. For large systems it will be required to spread the system control among several PCI-Bus interface cards on the same or even on different hosting computers. To support also these architectures, the hardware modules have additionally to be addressed via both the ***ngcbIFC*** object (through which this part of the front-end is accessed) and the chain of headers (route) leading to the module. The hardware module base class (***ngcbMOD***) is constructed with the arguments (`ngcbIFC *interface, ngcb_route_t route`). The sequencer-, CLDC- and ADC classes all derive from this hardware module base class and from now on their individual functions can be easily modelled using simple *ReadAddr()/WriteAddr()* calls with the only arguments **`address`** and **data[]**.

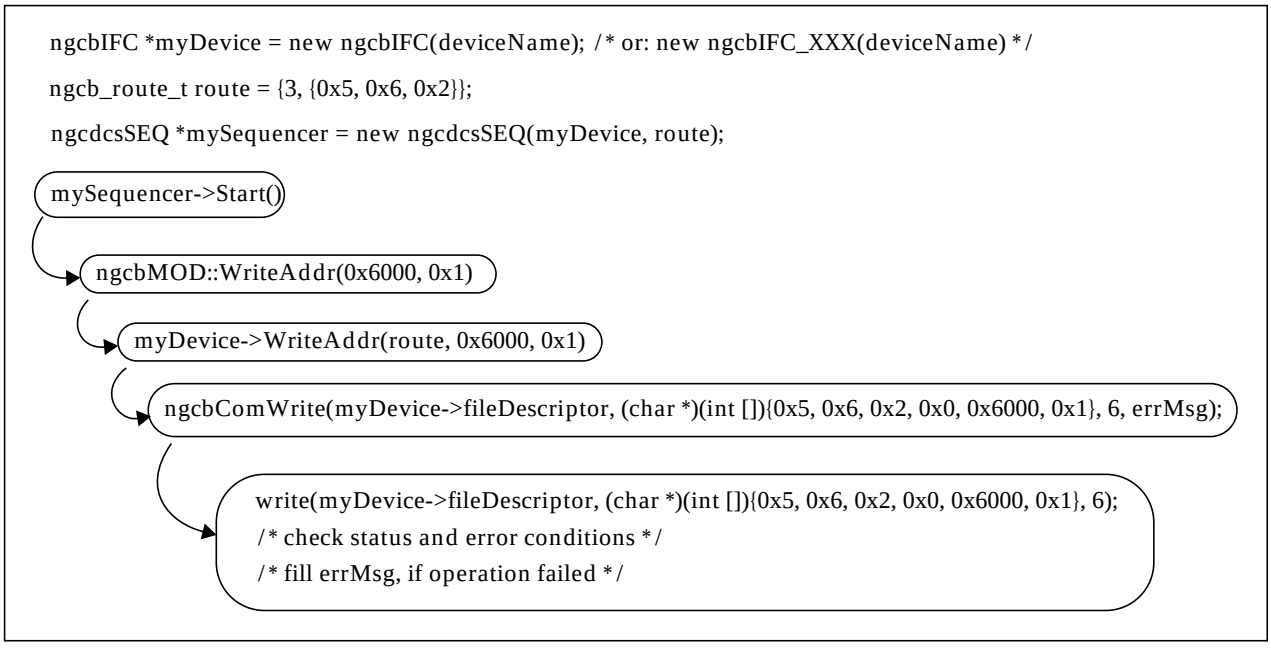


Figure 10 Module Function Call

The board temperature of each hardware module can be retrieved using the *Temperature()* member function. The *Initialize()* member function reads all relevant board information (serial number, product code, revision) from the hardware. The product information is stored in public data members and can be used to introduce revision specific behavior to the derived classes.

6.2 Parameter Model

In the NGC base software a parameter class (***ngcbPARAM***) is defined in order to associate specific behavior of the sequencer and acquisition modules to the setting of a parameter value. The parameter storage type is given in the constructor. A *Set()* method exists for all common types to set a new value. The class takes care for all possible type conversions. An internal flag traces all parameter changes. The *Get()* method always returns a formatted string value. The class contains the following public data members:

char name[64];	- parameter name
char alias[64];	- one alias name for the parameter
char format[16];	- format for output of the Get(),ValString() methods.
int fits;	- flag to put the parameter into the FITS-header
char comment[44];	- optional comment for FITS-header
char unit[8];	- optional unit string
int flag;	- storage space for application specific flags (initial value is 0)
int ctrlList;	- controller modules (sequencer), where the parameter is used. This is a bit-list maintaining up to 32 controller modules (bit 0 for 1st. module, bit 1 for 2nd. module and so on).
int acqList;	- acquisition-processes, where the parameter is used. This is a bit-list maintaining up to 32 acquisition processes (bit 0 for 1st. module, bit 1 for 2nd. module and so on).

The bit-lists (*ctrlList*, *acqList*) of a parameter help to decide whether the sequencer has to be reloaded or not after a new setup or whether for example the acquisition process has to be re-synchronized (see sections 6.3 and 7.2.2). The *format*, *unit*, *fits* and *comment* data members are intended to be imported from dictionaries by the using applications (control server).

The parameters are maintained in a dynamic linked list (***ngcbPARAM_LIST*** class). Parameters can be added and removed with the *Add()* / *Remove()* member functions. The list is always NULL-terminated. In order to walk through the list one can use the following construct:

```
for (l=list.First();l!=(ngcbPARAM_LIST *)NULL;l=l->next)
  {
  ngcbPARAM *p = l->param;
  printf("%s = %s %d %f\n", p->name, p->Get(), p->ValInt(), p->ValFloat());
  }
```

There are two convenience member functions to clear the instance bits of a sequencer module or of an acquisition module from all parameters in the list: *ClrCtrlList(instance)* and *ClrAcqList(instance)*. If both bit-lists are zero (empty), then the parameter is automatically removed from the parameter list.

6.3 Sequencer Module Class

The ***ngcdcsSEQ*** class provides all functions to setup and control a sequencer module.

6.3.1 Clock Pattern Setup

A local copy of the sequencer clock pattern RAM can be accessed directly through the public data member

```
ngcdcs_pat_t *pattern;
```

which is an array of *ngcdcsSEQ_MAX_PAT* patterns of type *ngcdcs_pat_t*. Each *ngcdcs_pat_t* object contains the following members:

```
int addr;                                - address (relative to RAM base)
ngcdcs_pat_st_t state[ngcbSEQ_MAX_STATES];- states
int numStates;                           - number of states in this pattern
int time;                                - clock pattern execution time in ticks
char name[128];                          - pattern name
```

The *ngcdcs_pat_st* object contains the following members:

```
int low;   - pattern low
int high;  - pattern high
int time;  - pattern dwell time x clock (50ns)
int mod;   - allow global dwell time modification
```

Convenience functions to initialize such a pattern, to compute its execution time, to upload it to the physical sequencer memory etc. are also part of the ***ngcdcsSEQ*** object.

By default the sequencer module contains two uploading methods for clock pattern definitions (classification will be done via filename extensions like for example ".clk", ".bclk" etc.):

- A low-level binary structured format referring to the sequencer pattern RAM directly. This allows complete clock patterns to be produced by an external tool in case the output format of this tool can be adapted to our needs. Here the aim is to have the simplest possible format (still readable but not intended to be edited by hand).

- A more user-friendly ASCII description (short FITS format), which can be edited directly by hand. Here the aim is to have the best readable format. As this description already may contain complex instructions, it is not intended to be the output of another higher level tool.

- Other formats can be implement by adding specific uploading methods.

It should always be possible to modify the dwell time of the states within a pattern via a global multiplication factor (i.e. multiply every state length by a factor of 2,3,4,...). However some critical states like the length of a conversation pulse may have to remain static. A state-length modification flag needs to be introduced to mark states to be modified by the global multiplicand.

Binary structured clock-pattern setup (.bclk):

```
# <Pattern-1>
1
0b00000000000000000001000000000000 0b00000000000000000000000100000000 1
0b00000000000000000001000000000000 0b00000000000000000000000100000000 1
0b00000000000000000001000000000000 0b00000000000000000000000000000001 0
0b00000000000000000001000000000000 0b00000000000000000000000000000001 0
0b00000000000000000001000000000000 0b00000000000000000000000100000000 0
0b10000000000000000001000000000000 0b00000000000000000000000100000000 1
!

# <Pattern-3>
3
0b00000000000000000011000000000000 0b00000000000000000000000000000010 1
0b00000000000000000011000000000000 0b00000000000000000000000000000010 1
0b00000000000000000011000000000000 0b00000000000000000000000000000110 1
0b00000000000000000011000000000000 0b00000000000000000000000000000110 0
0b00000000000000000011000000000000 0b00000000000000000000000000000010 0
0b10000000000000000011000000000000 0b00000000000000000000000000000010 1
!

#          High Word              |         Low Word                |Mod.-Flag
```

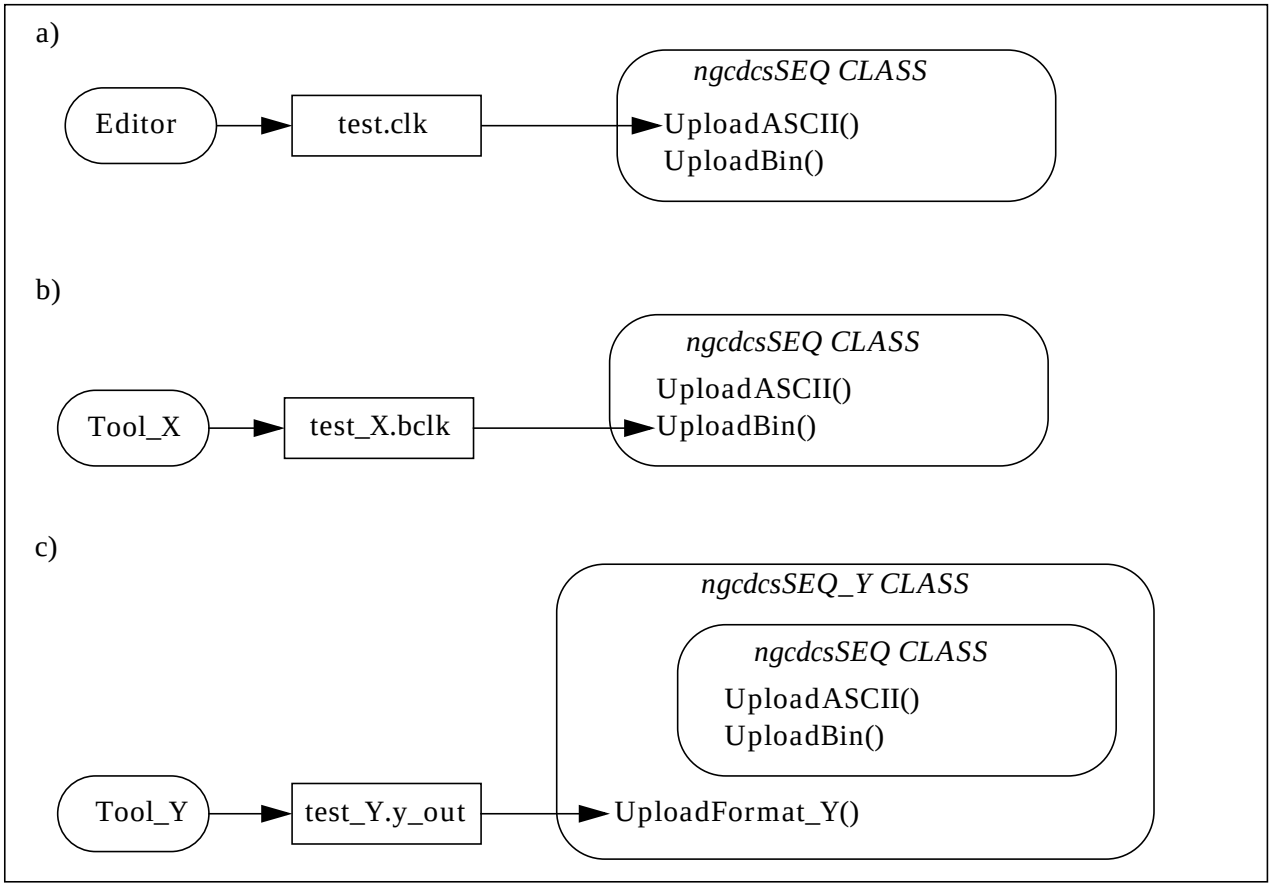
In the ASCII format described below the ***DET.PATi*** index directly gives the pattern reference index to be used in the sequencer program ASCII description (see section 6.3.2). The uploading method always has to take care of filling in the correct pattern address for each pattern object.

The clock-pattern description block may consist of up to 64 state-vectors (one for each bit in the sequencer clock-pattern RAM). In order not to specify a huge number of unused clocks, a clock mapping vector can be specified, which maps logical clocks described in the file onto physical clock lines. Clocks without map reference can also be addressed directly by their number (for example “DET.PATi.CLK62”).

Clock-pattern ASCII description (.clk):

```
################################################################################
# E.S.O. - VLT project
#
# "@(#) $Id$"
#
# who       when        what
# --------  ----------  ----------------------------------------------
# jstegmei  2005-09-05  created
#
################################################################################
# DESCRIPTION
# Example ASCII FILE for NGC sequencer clock pattern definitions.
################################################################################

# Clock mapping (can be spread over several lines).
# This maps the clocks described below onto physical clock lines.
# Mechanism is: Phys. clock line for logical clock n = MAP[n].
DET.CLK.MAP1  "1,2,3,33";   # Mapping list
DET.CLK.MAP2  "37,4";       # Mapping list

# Clock pattern definitions

DET.PAT1.NAME  "Delay";
DET.PAT1.NSTAT 5;
DET.PAT1.CLK1  "00000";
DET.PAT1.CLK2  "00000";
DET.PAT1.CLK3  "00000";
DET.PAT1.CLK4  "00000";     # Convert
DET.PAT1.CLK5  "00000";     # Start pulse
DET.PAT1.CLK6  "00000";
DET.PAT1.DTV   "2,2,2,2,2"; # Dwell-Time vector
DET.PAT1.DTM   "0,0,0,0,0"; # Dwell-Time modification flags

DET.PAT2.NAME  "FrameStart";
DET.PAT2.NSTAT 4;
DET.PAT2.CLK1  "0000";
DET.PAT2.CLK2  "0000";
DET.PAT2.CLK3  "0000";
DET.PAT2.CLK4  "0000";      # Convert
DET.PAT2.CLK5  "0110";      # Start pulse
DET.PAT2.CLK6  "0000";
DET.PAT2.DTV   "5,5,5,5";   # Dwell-Time vector
DET.PAT2.DTM   "1,1,1,1";   # Dwell-Time modification flags

DET.PAT3.NAME  "Read";
DET.PAT3.NSTAT 4;
DET.PAT3.CLK1  "0000";
DET.PAT3.CLK2  "0000";
DET.PAT3.CLK3  "0000";
DET.PAT3.CLK4  "0110";      # Convert
DET.PAT3.CLK5  "0000";      # Start pulse
DET.PAT3.CLK6 "0000";
DET.PAT3.DTV   "5,5,5,5";   # Dwell-Time vector
DET.PAT3.DTM   "1,1,1,1";   # Dwell-Time modification flags

# up to ngcdcsSEQ_MAX_PAT (=2048) clock patterns in this format...
```

Three cases may arise when configuring the sequencer clock-patterns in the way described above:



6.3.2 Sequencer Program

The sequencer program may depend on an application specific set of parameters (like detector integration time, number of samples, window parameters...), which at runtime are only known to the detector control server. In the simplest case these parameters directly fit into the repetition counters of the ***LOOP*** and ***EXEC*** instructions:

```
LOOP $DET.NREADS
  EXEC <1_second_delay_pattern> $DET.EXPTIME
  EXEC <readout_pattern> 1
END
```

Other applications may need to compute the repetition counters via arithmetic formulas:

```
N = $DET.NREADS * $DET.NCYCLES;

LOOP $N
  EXEC <1_second_delay_pattern> $DET.EXPTIME
  EXEC <readout_pattern> 1
END
```

The detector readout will typically not consist of a single pattern, but of another piece of sequencer program code which is assembled in a sub-routine:

```
N = $DET.NREADS * $DET.NCYCLES;
NX1 = $DET.NX / $DET.NCHANNELS

LOOP $N
  EXEC <1_second_delay_pattern_1s> $DET.EXPTIME
  JSR <readout>
END
RETUIRN

<readout>:
LOOP $DET.NY
  EXEC <line_start_pattern> 1
  EXEC <sample_pattern> $NX1
END
RETURN
```

The next level of complexity is reached, when the computed parameters depend on the execution time of such a sub-routine:

```
N = $DET.NREADS * $DET.NCYCLES;
NX1 = $DET.NX / $DET.NCHANNELS;
T_DELAY = (($DET.EXPTIME / $N) - Time(<readout>)) * 10.0e9

LOOP $N
  EXEC <10_nanosecond_delay_pattern> $T_DELAY
  JSR <readout>
END
RETURN

<readout>:
LOOP $DET.NY
  EXEC <line_start_pattern> 1
  EXEC <sample_pattern> $NX1
END
RETURN
```

The arithmetic formulas may use conditional instructions to compute results depending on the setting of logical parameters. It is also required that some of the computed parameters are passed back to the server. For example the “actual” exposure time or the “*minimum*” detector integration time can only be determined within this programming context, as arbitrary constant delays may be added such as chopper transition time or fixed delays after detector reset.

The evaluation of arithmetic formulas at run-time should be implemented via a simple scripting language. As the script evaluation may need to be done frequently, the startup-overhead of the script must be as short as possible. For the current implementation the TCL scripting language has been chosen, as this is the current VLT software standard and the startup overhead is very short. The script evaluation may not be required by all applications. In particular this is a main difference between optical and infrared applications. Where no script is required a simple parsing can be done. To optimize for both needs, a hybrid sequencer program format is used. The script evaluation between the ***SCRIPT***/***SCRIPT_END*** instructions can simply be skipped (as in the *test1.seq* example).

The clock patterns given as argument to an ***EXEC*** instruction are referred to by their reference index. The mapping to their actual clock pattern RAM address is done internally by the uploading

method of the clock pattern configuration (see section 6.3.1).

Sequencer program ASCII description:

```
PAT_A = 1
PAT_B = 2
PAT_C = 3

USE PARAM1 PARAM2
USE PARAM3 PARAM4

SUBRT routine1 routine2

SCRIPT
if {$svar(PARAM4)} {
set svar(new1) [expr{$svar(PARAM1)*
              ($time_r(routine1) +
              $time_r(routine2))}]
} else {
set svar(new1) [expr{$svar(PARAM1)*
              $time_p(PAT_A)}]
}
SCRIPT_END

EXEC PAT_A $PARAM1
LOOP INFINITE
  JSR routine1 3
  LOOP $PARAM2
    LOOP $new1
      EXEC PAT_B
    END
  END
  JSR routine2
END
EXEC PAT_A 1
RETURN

routine1:
LOOP $PARAM3
  EXEC PAT_C 4
END
RETURN

routine2:
INCLUDE "test1.seq"
```

test1.seq:

```
PAT_D = 4
PAT_E = 5
PAT_F = 6

EXEC PAT_D
LOOP 10
  JSR myRoutine1
  LOOP 5
    EXEC PAT_E 4
  END
END
RETURN

myRoutine1:
LOOP 3
  EXEC PAT_F 10
END
RETURN
```

The parameters defined via the ***USE*** statements, the execution times of the subroutines defined via the ***SUBRT*** statements and the script code itself are passed to the script interpreter through *stdin*. Once the script code had been executed the (possibly updated) parameters are passed back through *stdout*. The potentially used parameters are stored in an instance of the ***ngcbPARAM_LIST*** class (see section 6.2). The list is passed to the ***ngcdcsSEQ*** class via the constructor. The ***ngcdcsSEQ*** class takes care for attaching its own instance to the *ctrlList* of all parameters which are declared in the ***USE*** statement. The parameter list is intended to be maintained in a control server *using* instances of the ***ngcdcsSEQ*** class for sequencer control. The list helps the server to optimize the frequency of sequencer program re-loads.

So finally the sequencer program consists of three parts: the declaration section, the evaluation section and the actual program code. The declaration section contains the assignment of pattern names

to pattern numbers, the declaration of the used parameters and the declaration of subroutines. Normally subroutines need not to be declared. The ***SUBRT*** statement is only required in case the execution time of such a subroutine is needed in the evaluation section. The same applies to the parameter list. Parameters which are not used in the script but which are directly referred in the program code also need not to be declared. The evaluation section is enclosed with ***SCRIPT***/ ***SCRIPT_END*** statement. The whole section can be skipped if it is not required. The evaluation section is directly followed by the actual program code. Subroutines have to be labeled by a routine name. The label is just the name followed by ':'. The loop repetition factors can be either a hardcoded decimal value, the value of a parameter or ***INFINITE***. A loop repetition factor evaluated to -1 is the same as ***INFINITE***, other negative values are illegal. The ***EXEC*** instruction is followed by two arguments: the pattern number and also a repetition factor. Both can be hardcoded decimal values or the values of a parameter. A repetition factor of 1 may be omitted. The pattern number can be replaced by its name when a name was assigned in the declaration section.

Declaration Section

```
<pattern_name 1> = <pattern_number 1>
<pattern_name 2> = <pattern_number 2>
...
<pattern_name N> = <pattern_number N>

USE <parameter_name 1> <parameter_name 2> ... <parameter_name N>
USE ...

SUBRT <routine_name 1> <routine_name 2> ... <routine_name N>
SUBRT ...
```

Evaluation Section

```
SCRIPT
[SETLIB {myTclLib1 myTclLib2 ...}] # optional, can be used to embed own tcl-libraries
[Script Code]
# parameters are in $svar(parameter name)
# subroutine execution times (milliseconds) are in $time_r(routine_name)
# pattern execution times (milliseconds) are in $time_p(pattern_name)
...
SCRIPT_END
```

Program Code

```
# Nested Loops
LOOP <INFINITE|repetition_factor|$parameter_name> [LOOP... ...END]  END

# Repeated Pattern Execution
EXEC <pattern_name|pattern_number|$paramater_name> <repetition_factor|$parameter_name>

# Jump to Subroutine
JSR <routine_name> <repetition factor>

# Include another program file to this position
INCLUDE <file_name>

# Subroutine Label (Routine Name)
<routine_name>:

# Return from Main Program or from Subroutine
RETURN
```

The ***JSR*** statement jumps to a subroutine given by its name. It may optionally be followed by a repetition factor for repetitive calling of for example a “DELAY”-subroutine. The ***RETURN*** statement returns from a subroutine to the position from where the subroutine has been called. A ***RETURN*** statement in the main code (top level) will return from the whole program (exit).

The range of the counters of a ***LOOP*** construct is 16 bit integer [*0, 65535*]. The range of the “*direct*” repetition factors of the ***EXEC*** and ***JSR*** instructions is 32-bit signed integer [*0*, 2147483647], as the direct repetition factors are expanded internally to ***LOOP*** constructs.

This parameter driven program structure allows a wide range of application specific detector readouts (multiple configurable windows / regions of interest, configurable pixel sub-sampling, etc.).

For completeness the sequencer module also contains a simple uploading method for a binary sequencer program RAM description. Because of the required server interaction at run-time the applicable range of this fixed format is limited.

Binary structured sequencer program (.bseq):

```
0x4000  # start address for this piece of code
0b00010000000000000000000000000001
0b01000000000000000000000000000001

0b00010000001000000000000000000001
0b00100000000000000000000001000000
0b00010000110000000000000000000001
0b00010000011000000000000000000001
0b00110000000000000000000000000001

0b00010000010000000000000000000001
0b00100000000000000000000001000000
0b00010000111000000000000000000001
0b00010000101000000000000001000000
0b00010001000000000000000000000001
0b00010000100000000000000001000000
0b00110000000000000000000000000001

0b00100000000000000000000000001010
0b00010000000000000000000000001010
0b00110000000000000000000000000001

0b00010000010000000000000000000001
0b00100000000000000000000001000000
0b00010000111000000000000000000001
0b00010000101000000000000001000000
0b00010001000000000000000000000001
0b00010000100000000000000001000000
0b00110000000000000000000000000001

0b00110000000000000000000000000001 !
```

A local copy of the sequencer program RAM can be accessed directly through the public data member

```
ngcdcs_seqp_t program;
```

which contains the following members:

```
int code[ngcbSEQ_RAM_SIZE];              - sequencer program code
int length;                              - program code length
ngcdcs_subrt_t subRt[ngcdcsSEQ_MAX_SUBRT];- subroutines
int numSubRt;                            - number of subroutines
int stored;                              - program stored in controller
```

The *ngcdcs_subrt_t* object contains the following members:

```
int addr;       - start address (relative to RAM base)
int index;      - reference index
int length;     - subroutine code length
double time;    - execution time in seconds
char name[128]; - subroutine name (optional)
```

It is possible to modify the global program structure directly and then upload it via a *SetupPrg()* method. The *SetPrg(prg)* method uploads an externally defined program and upon success the global program structure would be a mirror of what has been loaded. The code may completely reside in the main program code without having the subroutines resolved (numSubRt = 0). Otherwise the subroutines are placed at the given addresses. Convenience methods are available for checking and optimizing the code (*CheckPrg(&prg)*) and for calculating code execution times (*ExecTime(code,size)*). The execution time calculation requires that the referred clock patterns have been uploaded before.

The program stored in the sequencer program RAM can be read back via a *GetPrg(&prg)* method. The *DumpPrg(text, prg)* member function dumps the binary program code to a formatted ASCII text of type (`char *`). The function automatically resolves subroutines and also calculates their execution times.

6.3.3 Sequencer Control

The sequencer can be started and stopped via the *Start()* / *Stop()* methods. The *Start()* method has a parameter, which defines whether to raise the synchronous start signal or whether to start only this instance (see section 2.6). A sequencer instance only goes to running state in case a sequencer program has been loaded before. The synchronous start can be enabled or disabled with the *RunCtrl()* method. The *Stop()* method will interrupt the program immediately. Sometimes it is required to stop the pattern sequence only on dedicated break points. The break points are set in a bit in the high RAM word of a clock-pattern state. The *Break()* method will instruct the sequencer to stop at the next break point. The *Wait()* method will wait with a given timeout until the program has terminated. A proper value for the timeout can be computed with a *BreakTimeout()* function, which will also cover the case that the timeout may be infinite (no break point in the program) and only the *Stop()* method can be used.

6.3.4 Synchronization

The synchronization mechanism with external events is described in section 2.7. It is fully under control of the respective clock pattern design. The *TriggerMode()* function can be used to enable or disable the "*wait-for-trigger*" state.

6.4 CLDC Module Class

The ***ngcdcsCLDC*** class provides all functions to setup the clock- and DC-bias voltages on a CLDC module. The clock- and bias voltage setup can accessed through the public data members

```
ngcdcs_clk_t *clk;      - array of clock voltages
int numClk;             - number of clock voltages
ngcdcs_dc_t *dc;        - array of bias voltages
int numDc;              - number of bias voltages
double offsetClk;       - global offset for clock voltages
double offsetDc;        - global offset for bias voltages
```

The *ngcdcs_dc_t* object contains the following members:

```
double volt;            - setup value
double range[2];        - range
double dacCorr;         - DAC correction factor
double telCorr;         - ADC correction factor for telemetry
int dacChan;            - DAC channel
int telChan;            - ADC channel for telemetry
char name[64];          - name of the bias voltage
```

The *ngcdcs_clk_t* object contains the following members:

```
ngcdcs_dc_t level[ngcdcsCLDC_DCLK]; - multi-level biases for each clock
```

The current hardware uses two-level clocks (*ngcdcsCLDC_DCLK* = 2).

An overall configuration of all voltages on the CLDC module can be done via the *LoadCfgFile()* method. The *LoadCfgFile()* method can be overloaded to support / test different kinds of setup files if required. The *LoadCfgFile()* method is intended to fill the above structures. The *Setup()* method will upload the structures to the controller. The *SaveCfgFile()* method will save the current setup to a file. Also this method can be overloaded to create other formats than the default one. The default format supported by the ***ngcdcsCLDC*** class is a short FITS format as shown below. The *SaveCfgFile()* method will keep all comments when saving a modified voltage setup to a file. The voltages can be changed at run-time individually within their defined range. It is possible at any time to restore the default values as they were given in the voltage configuration file originally loaded.

All voltages including the two global offsets can be set individually via member function calls. Voltage telemetry can be done at any time for one selected voltage. Two clock channels can be selected via the *Monitor()* method to be routed to the two clock-monitor outputs of the board. A calibration method (*Calibrate()*) can be called to compensate offset voltage errors on the individual DAC channels. The voltage output of the module can be enabled and disabled via the *Enable()* / *Disable()* methods. The voltage conversion functions *ConvertDac()* and *ConvertTel()* for the DAC and for the telemetry can be overloaded to cover the needs for board modifications for special applications.

Voltage definition file (.v):

```
################################################################################
# E.S.O. - VLT project
#
# "@(#) $Id$"
#
# who       when        what
# --------  ----------  ----------------------------------------------
# jstegmei  2005-10-05  created
#
################################################################################
#
# DESCRIPTION
# NGC voltage file. The keywords have to be defined for all used
# clock- and DC-voltages in the following format:
#
#     DET.CLDC.CLKHINMi   - Name of high clock i (optional)
#     DET.CLDC.CLKHIi     - Level of high clock i (mandatory)
#     DET.CLDC.CLKHIGNi   - Gain factor (optional)
#     DET.CLDC.CLKHIRAi   - Range of low clock i (mandatory)
#
#     DET.CLDC.CLKLONMi   - Name of low clock i (optional)
#     DET.CLDC.CLKLOi     - Level of low clock i (mandatory)
#     DET.CLDC.CLKLOGNi   - Gain factor (optional)
#     DET.CLDC.CLKLORAi   - Range of low clock i (mandatory)
#
#     DET.CLDC.DCNMi      - Name of DC voltage i (optional)
#     DET.CLDC.DCi        - Level of DC voltage i (mandatory)
#     DET.CLDC.DCGNi      - Gain factor (optional)
#     DET.CLDC.DCRAi      - Range for DC voltage i (mandatory)
#
################################################################################

# Offsets:
DET.CLDC.CLKOFF 10.0;   # Global clock voltage offset
DET.CLDC.DCOFF  10.0;   # Global DC voltage offset

# Clock Voltages:
DET.CLDC.CLKHINM1   "clk1Hi";
DET.CLDC.CLKHI1      3.000;
DET.CLDC.CLKHIGN1    1.000;
DET.CLDC.CLKHIRA1   "[-9.000, 9.000]";

DET.CLDC.CLKLONM1   "clk1Lo";
DET.CLDC.CLKLO1      0.000;
DET.CLDC.CLKLOGN1    1.000;
DET.CLDC.CLKLORA1   "[-9.000, 9.000]";

# up to 16 clock voltages like this ...

# DC Voltages:
DET.CLDC.DCNM1   "DC1";
DET.CLDC.DC1      0.000;
DET.CLDC.DCGN1    1.0;
DET.CLDC.DCRA1   "[-9.000, 9.000]";

# up to 20 DC-voltages like this ...
```

6.5 ADC Module Class

The ***ngcdcsADC*** class provides all functions to setup an ADC module. This class only contains some setup functionalities to enable / disable ADCs on the board, to select a channel to be routed to the video-monitor output of the board and to switch between the several available operation- and simulation-modes. No separate configuration / setup file is required here, as the module configuration (i.e. the number of enabled ADCs) is done within the scope of an overall system configuration (i.e. where the boards, device names, routes and number of modules are defined). This overall system configuration is outside the scope of this document, as there are huge differences between optical and infrared applications.

6.6 Selftest

All hardware module classes provide a *Selftest()* method testing the hardware functionality to the possible extend. The *Selftest()* method provides proper feed-back via the verbose-output and the logging system (see section 3.5).

6.7 Configuration Modules

All configuration files for the NGC hardware modules (clock pattern definitions, sequencer programs, voltage configuration files) are intended to be stored in instrument- or detector-specific configuration modules, which are under CMM configuration control. This also applies to maintenance and test configurations. Usually the configuration files are part of the NGC-system delivery. In cases where detector development is done outside, the respective instrumentation team is responsible for the development of the configuration files. Templates and a graphical editing tool for the clock patterns will be provided.

7 DATA PRE-PROCESSING

7.1 Concept

Basically the pre-processing task to be performed is:

- Receive data from an external device. Generally this is achieved by writing the data from the device directly to the computer memory (DMA) and generating an interrupt once a certain amount of data had been transferred (data event). The data flow is continuous.

- Compute a data-array containing the result of the pre-processing - in the easiest case by sorting and / or adding up several subsequent input arrays. The computation (“adding-up”, “sorting”) must happen in parallel to the reception (DMA) of the next input data array. The algorithms are manifold and need specific parameters to be defined at run-time (“number of input arrays to add up”,...). There are no strict real-time requirements (i.e. guaranteed response time on a data event), but the amount of data to be processed within a certain time-slot is huge (up to several hundred Mega-Bytes).

- Transfer the result array to disk and / or to a display. The target disk and the display utility usually reside on another computer (instrument workstation). Thus the transfer is done via a network interface. The transfer of the result array must also happen in parallel to both receiving and processing the next incoming data arrays (continuous data flow). Memory copies have to be avoided.

The CPU speed and the bandwidth of peripheral buses on modern “standard” computers is increasing steadily. The usage of an “off the shelve” computer plus operating system gives the opportunity to benefit from the rapid progress on the computer market and the wide range of available development and debugging tools in combination with the least possible expense for portability issues. The following sections describe how the described data acquisition task can be performed on standard computers running a UNIX / Linux operating system as it is delivered with the ESO VLTSW releases.

7.1.1 Parallel Computing Architecture

In order to improve the computing bandwidth, modern computers can be equipped with several CPUs. When a process becomes runnable, the scheduler looks, which CPU is the least busy, and then grants this CPU to the process. Once a process is running on a certain CPU, it will keep this CPU until it is re-scheduled. Re-scheduling may occur either after a certain time-slot (in case other processes are also runnable) or when the process has to wait (for example for a semaphore or for input on a socket). When processing large data arrays, the computing task has to be distributed across several processes to benefit from the multi-CPU architecture. In the simplest case with two CPUs we would execute two processes, where one was processing the first half of the array while the other was processing the second half. The operating system always takes care of the optimal CPU where to schedule a process. Once process-1 is scheduled on CPU1, the process-2 will automatically be scheduled on CPU2 (as now this is the least busy) without doing any further pre-selection. This scheme will work unless there are no other processes with high CPU-needs running on the NGC-LCU (see section 7.1.2 about how to avoid unwanted scheduling if this was the case). The two processes have to be synchronized (i.e. they have both to be triggered when a new data-array is available for processing). This master task requires at least one more process. Once the processing is

done, the result still has to be transferred to give space for the next incoming data. The transfer of the result data (to disk or to another computer) also has to be done in parallel to the processing of the next set of input data and therefore also requires a separate process. Finally both data-processing and data-transfer need some external input (commands) to be controlled (START, STOP) and to be parametrized (SETUP). This command handling must react asynchronously at any time and is the fifth process in our minimum configuration:

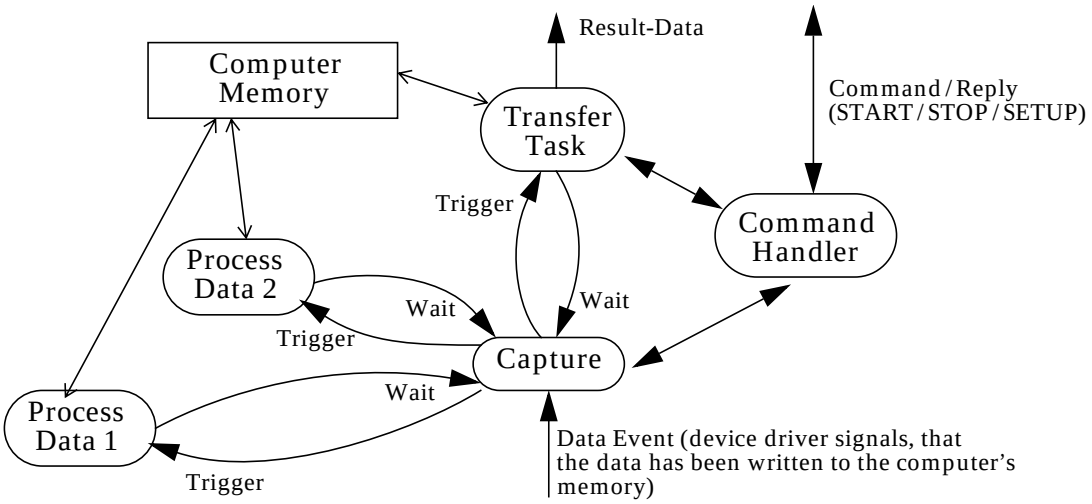


Figure 11 Parallel Data Processing

7.1.2 Priority Controlled Scheduling

By default the UNIX model grants certain time-slots to each process to guarantee a fair distribution of the computing resources. When the data processing approaches the limit of the CPUs bandwidth, a priority scheme has to be assigned in order to avoid, that less important tasks interrupt the time-critical tasks. For example the data transfer should just be done, when there is enough time to transfer. In case the processing task adds up 10 data arrays to compute their average, the transfer task has the time of 10 data events to transfer the average until the next result is available. In case of normal time-sharing scheduling the transfer-task would immediately start running after the 10th array had been processed and would compete with the processing-task for CPU-resources, where both would be granted the same amount of CPU-power. This would result in a possible loss of input data, in case the CPU-load of the processing task was more than 50%.

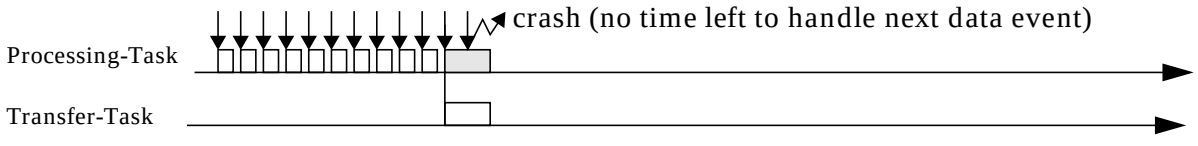


Figure 12 Non-priority-based scheduling

One possibility was to install as much physical CPUs as there are processes needed for the acquisition. For more complex processing tasks, requiring more than 2 processes (for example non-destructive read-out or computation of standard deviation), this would become expensive and would also not put all of the CPUs to effective use (for the lower priority tasks). A better way to use the full computing bandwidth of **all** installed CPUs is to assign a priority scheme to the processes:

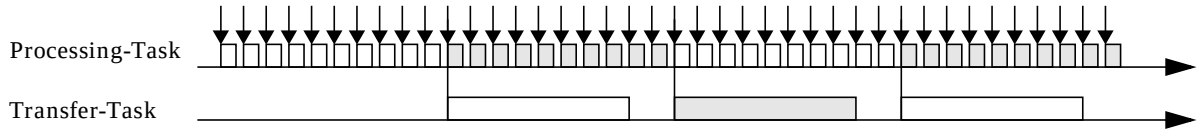


Figure 13 Priority-based scheduling

The Linux operating system provides a soft real-time scheduling technique, which allows to run processes with distinct priorities. The priority setting however requires super-user privileges. The *"sudo"* command or a dedicated installation user with the appropriate access rights may be chosen to overcome installation caveats.

The priority scheme introduces a further level of complexity into our process model, but gives more control over the scheduling. Of course we want at least to be able to stop the system at any time. This implies, that the command handling process has the highest priority in the system. The second priority is given to the capture process, as this has to react in time to the data events. The next priority level is given to the tasks processing the raw data arrays. All other tasks have a low priority sharing the remaining bandwidth.

Although this is not yet a full "real-time" system, the priority scheme guarantees a stable mean-processing time which is sufficient for all image pre-processing done outside the very fast control loops (e.g. as needed for adaptive optics). Jitters in the response time (latency) which are in the range of several milliseconds can be overcome by implementing a ring-buffer of an appropriate size for the incoming data.

The system interfaces to the outside world via two processes: the command handler and the transfer task. The processing task is supposed to deliver different types of result-data (raw frames, averaged frames, standard deviation,...). This means, that the receiving process has to decide, which data it is interested in and so the transfer-task will transfer data only upon request. Although the *request* has the nature of a *command,*. it should not be handled by the command-handler, because in this case it would be handled with the highest priority. As this is just what we intended to avoid, a second "command handling" has to be implemented within the transfer task itself. The receiving process can then start / stop / setup the system via a command sent to the command handler, but will send data requests directly to the transfer task, which then only handles this request when there is time to do so (the computed result data arrays will be queued up to a configurable size):

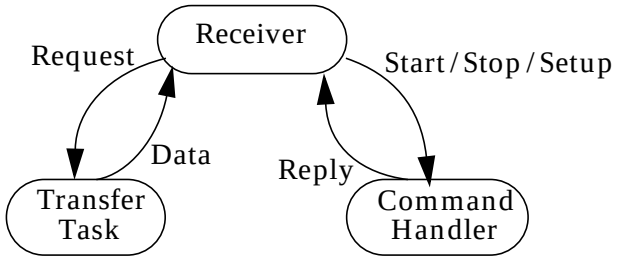


Figure 14 Data Transfer / Command Handling

7.1.3 The Threads-Model

Although the UNIX *process* model together with the IPC mechanisms is sufficient for parallelizing the data acquisition, this is still heavy to handle, as all global variables have to reside in a shared memory area, where the applications must take care to allocate and free space for all kinds of global data structures. Furthermore the cleanup of this stuff after a process crash is a complex job for itself. Linux, SUN Solaris and all POSIX-standard compliant UNIX releases support a programmatic interface, which hides all of this implementation details from the programmer. This mechanism is called *multi-threading*. A *thread* is in its functionality the same as a *process*. The difference is just, that *threads* can run within one address space and can therefore use the same memory and global variables. A main-*thread* is started like a *process* and then it starts in turn other *threads* for executing different jobs in parallel on the same data. The *threads* model also includes several internal task-synchronization features (mutexes, conditions, counting semaphores) which help to make the task-control more easy to survey. Like a *process* a *thread* can also be executed with a distinct priority.

Multi-threading gives a clear performance improvement. A *process* has five fundamental parts: code ("text"), data, stack, file I/O, and signal tables. *Processes* have a significant amount of overhead when switching: All the tables have to be flushed from the processor for each task switch. If a *process* spawns a *child process* using *fork()*, the only part that is shared is the text. *Threads* reduce this overhead by sharing the fundamental parts. Due to this mechanism switching happens much more frequently and efficiently, which is essential for our parallel data acquisition task.

The usage of global data among several threads requires mutual exclusion mechanisms in order to prevent, that for example the same variable is read and written at the same time or incremented/decremented at the same time. A routine which takes care of this is called "*thread-safe*". Thread safety can be achieved by protecting global variables and also the execution of code fragments with mutexes or semaphores. In many cases the mutual exclusion is just inherent in the functionality and can be achieved by designing a proper task distribution.

Multi-threading is supported by Linux, SUN Solaris and all POSIX-standard compliant UNIX releases. Applications based on this mechanism can very easily be ported to all of these operating systems. For simulation purposes the same acquisition process code may run on all development computers. Together with the priority based scheduling feature the system balances itself making maximum use of any number of CPUs installed. The same program, that at high data-rates would spread itself across all available CPUs, can also run on a cheap single-CPU architecture, when only low input data rates are expected. The whole data acquisition task can directly be started in one step from a UNIX/Linux command shell without requiring any further startup-script and process monitoring.

7.2 The Acquisition Process

The acquisition processes can be started as individual tasks on the NGC-LCU (in simulation mode also on the instrument workstation). The incoming data are read via DMA into a ringbuffer. The capture process provides the synchronization between the DMA-driver and the calculation process. A ringbuffer overflow is also detected by the capture process. After processing the data, the result frame will also be stored in a ringbuffer to guarantee continuous data flow. Any data transfer is fully parallel to the processing loop (i.e. while transferring the result, the next result is computed). There are no memory copies required. When the frame has been processed and should be transferred, it is given to the data server. From here the frames can be distributed in parallel to several hosts via parallel data transfer threads. The frames are transferred on request. The request may be FIFO (for science data transfer) or LIFO (for video data transfer). Different frame types can be transferred in parallel to different requesting data clients (i.e. the display shows raw frames while the averaged frame is transferred and stored to a FITS-file). Using this method the transfer capacity is only

limited by the network bandwidth and the computing power of the requesting client process. It is possible to download data sets like flatfields or bad-pixel masks. The data sets can be stored in shared memory to be shared between acquisition processes. This acquisition process framework provides a flexible mean to implement any kind of “on the fly” pre-processing (bias subtraction, fast centroiding, digital filtering, handling of chopping and / or nodding cycles, etc.).

```
Usage: ngcppXXX [options]
Options:
  -i                    enable interactive mode
  -im <input mode>      input mode (normal, sim)
                        (default: normal)
  -cmdport <portNum>    set command server port (default: 0)
  -dataport <portnum>   set data server port (default: 0)
  -nclient <numClient>  max. number of data clients
                        (default: numClient = 0)
  -dev <n> <device>     device name for device <n>
                        (default: /dev/ngc0_dma (device 0))
  -st <time>            simulation interval time in ms
                        (default: simulation time = 500 ms)
  -v                    switch verbose mode on
  -h                    show this
```

If the ‘*-i*’ option is not specified, the acquisition process starts the data capture and processing itself, using the default parameter setting (auto-start). This mode is reserved for test purposes. For using a command interface the acquisition process has to be invoked with the ‘*-i*’ option. Most acquisition processes additionally support the command line options ‘*-nx* <*n*>’ and ‘*-ny* <*n*>’ from where they derive the DMA size and the dimension of the produced data frames.

7.2.1 Initialization

The basic initialization of the DMA system is done via the *ngcppStartup()* function.

```
ngcppStartup(argc, argv, size, erms)
```

The command line arguments (*argc*, *argv*) of the process have to be passed to this routine, so that some default stuff (such as device names) can be evaluated. The third argument defines the size (in bytes) of one DMA ringbuffer element. The DMA size can be redefined within the scope of the acquisition loop if required (see section 7.2.4), but only in case the DMA is stopped at that time.

7.2.2 Exporting Parameters

The acquisition process may need to be controlled through an arbitrary number of application specific parameters. These parameters need to be made public in order to be able to set them “by name” through the command interface. A parameter structure *myTYPE* and an associated array of parameter names have to be defined by the application. Afterwards the dynamic parameter structure has to be passed to the system. This is done via the *ngcppSetupDynParam()* function. Then some default parameter values have to be set. The *ngcppParamDefault()* function informs the system, that the default parameter setup has been done. Now the command handler is able to receive a double buffered mirror of all parameters defined in *myTYPE*:

```
static char *names[] = {“DET.MYFRAME”,
                        “DET.MYPARAM1”,
                        “DET.MYPARAM2%f”,
                        “DET.SETUPID”};
typedef struct
{
  int myFrame;
  int myParam1;
  float myParam2;
  int setupId;
} myTYPE;

param = (myTYPE *)ngcppSetupDynParam(_vecsize(names), (char **)names, 0, erms))

/* Set default parameter values */
param->setupId = 0;
param->myFrame = 1;
param->myParam1 = 0;
param->myParam2 = 1.5;
ngcppParamDefault();
```

7.2.3 Frame Types

A data frame consists of a frame header and an output ringbuffer. With each frame a certain frame type (DIT, INT, STDEV...) and a data type (integer, floating point,...) are associated. There are default frame types defined within the ***ngcpp*** module:

ngcppFRAME_SNAPSHOT	- snapshot frame
ngcppFRAME_DIT	- DIT-frame
ngcppFRAME_INT	- INT-frame
ngcppFRAME_INTERMEDIATE_DIT	- intermediate DIT-frame
ngcppFRAME_INTERMEDIATE_INT	- intermediate INT-frame
ngcppFRAME_SDV	- standard-deviation frame
ngcppFRAME_SAMPLE	- sample frame
ngcppFRAME_HCYCLE1	- first half-cycle frame
ngcppFRAME_HCYCLE2	- second half-cycle frame
ngcppFRAME_TRACK	- vector for offset corrections

It is also possible to add new frame types to the system. The frame type has to be a single bit value. The least significant bits are used for the pre-defined default frames. The first unused bit can be retrieved by defining *myFRAME_TYPE* in the following way:

```
#define myFRAME_TYPE (ngcppFRAME_USER << 1)
```

To introduce a new frame type to the system, one has also to specify a frame name and a parameter name (both ASCII-strings). If the parameter string is not empty, the specified parameter should be used to switch the generation of the frame on / off:

```
ngcppAddFrameType(myFRAME_TYPE, “MYFRAME”, “DET.NC.MYFRAME”, erms)
```

Each frame has to be at least double-buffered. Science-frames (like the INT-frame), which have to be stored in any case should have three ringbuffer elements (this depends on the expected computation rate of the frame and the transfer time including storage on disk). The output ringbuffer has to be al-

located by the acquisition process. Then the frame has to be passed to the system:

```
static int *resMyFrame[2];  /* data-ring buffer of my-frame */
static ngcppFRAME myFrame;  /* frame structure for my-frame */
int numPix = nx * ny;

/* Allocate frame buffers */
for (i=0;i<2;i++)
  {
  resMyFrame[i]=(int *)malloc (numPix * sizeof(int));
  }

/* Initialize frame structures */
myFrame.h.start_x = 0;
myFrame.h.start_y = 0;
myFrame.h.nx = nx;
myFrame.h.ny = ny;
myFrame.h.dtype = ngcppDTYPE_INT32;
myFrame.h.ftype = myFRAME_TYPE;
ngcppInitFrame(&myFrame, (char **)resMyFrame, 2);
```

The ringbuffer element, that has to be used for processing the frame, is assigned by the system and is always stored in the structure element *myFrame.dptr*. So all processing has to be done on *resMyFrame[myFrame.dptr]*.

7.2.4 Acquisition Loop

After the initialization phase, the acquisition process has to wait for the start command with *ngcppWaitStart()*. After receiving the start command, it can do some further initialization steps (such as redefining the DMA size) and will then signal to the capture process, that the main process is now ready to get data. The *ngcppStartCapture()* function will enter the DMA-loop. From now on all further processing has to keep up with the incoming data flow. So the acquisition process should enter the acquisition loop immediately. With *ngcppWaitData()* it waits for the next data buffer, processes it and finally calls the acknowledge-function *ngcppAckData()*, when no more processing has to be done with the current data buffer.

```
/* Main loop */
while(1)
  {
  active = 1;

  /* Wait for start */
  if (ngcppWaitStart() == -1) continue;

  /* Some initialization if required (redefine DMA size, ...) */

  /* Signal capture process, that process is ready to get data */
  if (ngcppStartCapture() < 0) continue;

  /* Acquisition loop */
  while (active)
    {
    /* Get next data buffer */
    ngcppWaitData(dataIn);

    /* Check, if stop signal has been received */
    if (!(active = ngcppCheckStop())) continue;

    /* Now process the data somehow */

    /* Transfer computed data frames */

    /* Let capture process know, that data has been processed */
    ngcppAckData();
    } /* end of acquisition loop */

  /* Terminate processing */
  ngcppTermProcessing();
  ngcppFlushOutput();
  } /* end of main loop */
```

7.2.5 Data Transfer

To transfer a data frame an output request function has to be called:

```
myFrame.h.setupId = param->setupId;
ngcppReqOut(ngcppQUEUE_SKIP, &myFrame);
```

The *setupId* header element is used by the receiving process to identify frames belonging to a certain parameter setup. This is needed, as parameters may change, while the system is running.

The first argument of the *ngcppReqOut()* function is used to specify the behavior, when the output ringbuffer of the frame is full. It has to be one of the following values:

ngcppQUEUE_SKIP - skip frame, if queue is full
ngcppQUEUE_BLOCK - block until queue is free
ngcppQUEUE_SETERR - set an error flag in the frame header and skip

7.2.6 Importing Data-Sets

The acquisition process has the possibility to reserve memory that can be filled from remote via the

command handler. This memory area(s) may contain flatfield(s), badpixel-mask(s) or other data sets used for the pre-processing (or also the simulation) of image data. The buffer can be set from the controlling process via the *ngcppUploadBuf()* function. As the reserved memory is double buffered, the acquisition process would not block while an upload is in progress. Once all buffers are set, a synchronization command *ngcppMsync()* has to be sent to the command handler to perform the buffer swap. The memory areas can be placed in shared memory in order to be shared between different acquisition processes.

```
#define myDATA_SET_ID 4  /* has to be a single bit value */
char *myDataSet;

ngcppShDataAttch(0, erms);
ngcppShDataGetPtr((char **)&myDataSet, myDATA_SET_ID, size, erms);
while (active)
  {
  ngcppWaitStart();
  ngcppStartCapture();
  while (started)
    {
    ngcppWaitData (&dataIn);
    if (ngcppShDataIsValid(myDATA_SET_ID)
      {
      /* process data frame: frame = f(dataIn, myDataSet) */
      }
    ngcppAckData();
    }
  ngcppTermProcessing();
  }
```

7.2.7 Pixel Sorting

The structures of the detector arrays differ a lot. Ordering can be in stripes, quadrants, quadrants and stripes, from outside to inside or vice versa. The sorting and processing of the arrays might make the parallel computation algorithms quite complex. For very large arrays, which do no more fit into the cache, the sorting might additionally slow down the performance of the real-time loop. If applicable the frames can be computed as raw unsorted buffers, which are reformatted just before they are transferred. For this purpose a pixel map (*ngcppPixMap*) has to be defined. The *ngcppPixMap* is declared as *NULL* pointer by default. It is only applied if it points to a valid map. The acquisition process can allocate an integer buffer with appropriate size and fill it with a sorting table. Then the *ngcppPixMap* must be set to the defined map:

```
ngcppPixMap = myMap;
```

The map will apply the following sorting:

```
out[i] = data[ngcppPixMap[i]];
```

The transfer task also takes care of window requests. If a special frame should be transferred unsorted even though a pixel map has been defined, then the *noSort* flag must be set in the frame structure when passing it to the output queue:

```
myFrame.noSort = 1;
ngcppReqOut (ngcppQUEUE_SKIP, &myFrame);
```

7.2.8 Run-Time Flags

There are two global flags for exposure control. They are set asynchronously via the command interpreter task and can be checked at run-time within the acquisition loop. Both flags have to be reset by the application after they have been checked.

The counter-reset flag (*ngcppResetCnt*) is set, when the exposure should (re-)start while the sequencer is left running (continuous mode). Typically at this point the observing conditions have changed (telescope move etc.). This means, that the DMA-input buffer has to be flushed *ngcppFlushInput()* and the current integration has to be skipped. This has to be taken into account when estimating the exposure time. In the worst case one integration is lost.

The exposure-end flag (*ngcppEndFlg*) is set, when the exposure should end immediately. Typically now an intermediate result should be transferred.

7.2.9 Simulation Mode

The acquisition process has a built-in simulator. In simulation mode the input-ringbuffer is prefilled with default-data. The input sequence is simulated via timer functions (maximum resolution: 1 ms, maximum frequency: 100 Hz input-frame rate). The content of the data can be explicitly set by defining a function of type:

```
static void simul(short **buf, int size, int num, int *p)
```

This allows the application to fill the *num* ring-buffer elements with detector- and read-out mode-specific data. The *size* gives the number of 16 bit data-words in each ring-buffer element. The pointer “p” is reserved for future use.

Then the routine has to be assigned before the *ngcppStartup()* function is called:

```
ngcppSimBuf = simul;
```

If no buffer simulator is defined, a noise pattern will be used by default. It is also possible to upload simulation data using the import mechanism described in section 7.2.6. As in that case simulation data for all produced frame types need to be uploaded, the applicable range of this feature is limited.

7.3 Acquisition Process Interface

The previous sections have shown the principle of the acquisition process. Now we still have to provide an interface to send commands to the process and to receive data from it.

7.3.1 Data Interface

The data frames can be requested in parallel from the data transfer threads. This is needed, as the acquisition process produces various different frame types and the frame type to be displayed (video-data) and the frame type(s) to be stored on disk (science-data) are not necessarily the same. Even if the user wants to get the same data both saved to disk and displayed in the RTD, then one still needs parallel channels for smooth operations not blocking each other. The saving to disk may take longer than the display (or vice versa), the display may run anywhere else (on a dedicated host) and finally one always wants to display the most recent image while when saving to disk one needs the oldest image, which has not yet been saved. If required due to performance reasons, the video transfer

(RTD) may be stopped while taking the science-data for an exposure.

The data transfer is done via socket (TCP/IP). The *ngcppOpenDataLine()* routine distinguishes between the video- and the science-data transfer. In science mode the oldest available, but not yet transferred frame, which matches the frame-type in the request structure is transferred (FIFO). In video-mode for each frame-type matching the request, the latest not yet transferred frame is selected (LIFO). From this selection the oldest frame is transferred. In both cases *'not yet transferred'* means, that the frame has not yet been transferred to the requesting client. In video-mode additionally the retransmit flag in the request structure is checked, to allow frames of the specified type to be transmitted again. This can be used, to display different windows of the same frame during long integrations.

Format of the request structure:

```
typedef struct {
  int type;              /* requested frame type */
  int blocking;          /* block until frame is ready */
  int retransmit;        /* transfer last buffer again */
  int start_x;           /* window start-x */
  int start_y;           /* window start-y */
  int nx;                /* window nx */
  int ny;                /* window ny */
} ngcpp_req_t;
```

Format of the returned frame structure:

```
typedef struct {
  int dtype;             /* data type */
  int ftype;             /* frame type */
  int start_x;           /* window start-x */
  int start_y;           /* window start-y */
  int nx;                /* window nx */
  int ny;                /* window ny */
  int scal;              /* scale factor */
  int cnt;               /* frame counter */
  int setupId;           /* setup-id */
  int err;               /* error code */
  int overrun;           /* overrun flag */
  int frames;            /* available frame types */
  int tx;                /* track point x */
  int ty;                /* track point y */
  float expFactor;       /* exposure time factor */
  int reserved1;         /* reserved */
  int reserved2;         /* reserved */
  int reserved3;         /* reserved */
  int reserved4;         /* reserved */
  int reserved5;         /* reserved */
} ngcpp_hdr_t;
```

The sequence for the function calls should be the following:

- *ngcppPingDataLine()* (optional);
- *ngcppOpenDataLine(serverName, &socket,...)*;
- *ngcppSendDataRequest(socket, request,...)*;
- *ngcppWaitDataReply(socket, &frameHeader...)*;
- Check frame header. The frame name can be resolved with the *ngcppGetFrameNameByType()* function (optional);
- If frame type is *ngcppFRAME_NO_FRAME*, then send a new data request. Otherwise do either transfer the frame (the window parameters in the *request* may still be updated now) with *ngcppAcceptFrame(socket, request, &frame,...)* or skip it with *ngcppSkipFrame(socket,...)*;
- The frame can be scaled using the general *ngcppScale(&frame)* function (optional);
- Continue with *ngcppSendDataRequest(socket, request)*;

The socket can be used for a select() call before *ngcppWaitDataReply()*. To cancel a request one has to call *ngcppCancelReq(socket, ...)* before *ngcppWaitDataReply()* and then send a new request with *ngcppSendDataRequest()*.

If any of these functions fails, one should call *ngcppCloseDataLine()* and then try to reopen with *ngcppOpenDataLine()* to recover the data channel from failure.

The calling program should not exit with an open request. When the process is waiting for the data reply, *ngcppAbortReq(serverName, pid,...)* or *ngcppCancelReq(socket,...)* have to be called before exiting. It is recommended to add *ngcppAbortReq()* or *ngcppCancelReq()* to a signal handler.

The *ngcppAcceptFrameN(socket, request, &frame, partNo, numDiv, ...)* function can be used instead of *ngcppAcceptData()* to request a frame partition. The additional parameters *partNo* and *numDiv* have to be supplied to indicate that the partition number *partNo* out of *numDiv* sub-divisions of the frame has to be taken as base for the requested window.

The described functions are sufficient to receive data from the acquisition process. They can be used for stand-alone applications (RTD-interface) or also for various test purposes. To get this interface into the context as described in section 3.2, a more object oriented approach is needed. The ***ngcdcsACQ_DATA*** class will assemble the functions into an object, which can be configured either at creation time using the constructor or after creation using a Configure() method. The configuration is store in the following members of the *ngcdcs_acq_cfg_t* structure:

```
int dataPort;       - data server port
int transferMode;   - data transfer mode
char host[64];      - acquisition process host
```

Once configured a data connection can be established and closed with simple calls to the *Open()*/*Close()* member functions. Then data can be requested, transferred, skipped or re-transmitted in a flexible way using the class member functions. File descriptors and the request structure are stored inside the object and are transparent to the applications using the object.

7.3.2 Data Export

The acquisition process framework allows the export of data buffers for external processing (for example with higher level image processing systems):

```
void ngcppDataExport(void *buffer, int ftype, int bitPix, int nx, int ny)
```

With the appropriate counter-part in the data interface to be included by the used tool:

```
ngcppSIMPLE_HDR *ngcppImportData(void **buffer, char *erms)
int ngcppReturnData(char *erms)
```

The installation, startup and task management for these external tools is outside the scope of this framework. Generally this mechanism may introduce huge performance drops depending on the interface of the used tool. The usage of a dedicated acquisition process to perform a raw-data burst and an off-line processing with the respective tool should be taken into consideration before introducing this further complexity.

7.3.3 The Acquisition Module Class

The ***ngcdcsACQ*** class provides all functions to execute/kill an acquisition process on the NGC-LCU. One instance of the ***ngcdcsACQ*** class has to be created to control one acquisition process. The parameters exported by the process are attached to a global parameter list (***ngcbPARAM_LIST***, see section 6.2), which is passed via the constructor. The class contains functions to maintain these parameters, to upload data sets, to switch between normal mode and simulation mode, to start/stop the acquisition and to set the run-time flags (see section 7.2.8) at the proper time. The acquisition module also creates an instance of the ***ngcdcsACQ_DATA*** class in order to receive data from the launched process. The object is stored in the public member "*data*" of the ***ngcdcsACQ*** class. The configuration structure for the data interface is propagated from the more overall configuration of the ***ngcdcsACQ*** class. So the complete *ngcdcs_acq_cfg_t* structure contains:

```
int cmdPort;        - command server port
int dataPort;       - data server port
int errPort;        - error-stack server port
int numDataClient;  - number of data clients per process
int transferMode;   - data transfer mode
char host[64];      - acquisition process host
char dev[128];      - acquisition process DMA device name
int seqIdx;         - associated sequencer instance
char name[64];      - optional name for this module
```

The data transfer done by the internal *data* object would block the acquisition module during the transfer time of the image data. The applicable range of the *data* object would be limited unless one provides a mechanism for asynchronous data transfer. Without using such a mechanism the data transfer should be done by an external data transfer task. The host name and the port number returned by the *Host()*/*DataPort()* member functions of the ***ngcdcsACQ*** class can be used to configure such a task. Even though this was a standard solution, it will become complex and heavy to administrate in case of large mosaics with many acquisition processes on different NGC workstations. To use the full transfer bandwidth one data transfer task per acquisition process needs to be launched and controlled. A much more elegant way would be to use the internal *data* object from within a thread running in the scope of the ***ngcdcsACQ*** class itself. This minimizes all configuration and synchronization effort, as all needed information is simply already there and needs not to be communicated at all. However the POSIX threads interface as described in section 7.1.3 basically does not allow to create a thread by using a pointer to a C++ class member function. The solution is to put

the starter function outside of the class and declare it as extern "C". The POSIX thread creation routine allows a (void *) argument to be passed to the starter function. This can be used to pass a pointer to the application class instance to the starter function, which then in turn can safely execute the proper member function. The ***ngcb*** module contains a C++ class (***ngcbTHREAD***) which implements this mechanism. By deriving from this ***ngcbTHREAD*** class it is possible to create / kill member function threads easily via the *new* / *delete* operator:

```
myThread = new ngcbTHREAD(this, (ngcbPROCESS_T)&myClass::MyFunction, &myArg);
...
delete myThread;
```

For completeness the ***ngcbTHREAD*** library also contains a C++ style semaphore implementation where a (counting) semaphore can also be created and initialized with the *new* operator.

```
mySem = new ngcbSEM(count);
mySem->Wait();      // decrement counter, block if zero
...
mySem->Post();      // increment counter
```

For pure mutual exclusion purposes a (faster) mechanism (binary semaphore) is also included:

```
mySem = new ngcbSEM(1);
mySem->Lock();     // block, if locked
...
mySem->Unlock();   // release the lock
```

The acquisition module class derives from the ***ngcbTHREAD*** class and uses a (private) member function to perform the asynchronous data transfer. The *StartTransferring()* method will launch the thread, the *StopTransferring()* method will abort it. The transfer thread will request the image(s) from the acquisition process, receive the image data and finally call a *Store()* method to save the data to disk. Some FITS-header information is created internally at run-time (such as actual image dimension, frame type, data type and time stamps). Other FITS information (coming from a system snapshot at exposure start) is passed to the ***ngcdcsACQ*** class from outside. The FITS information is combined and stored at the right place within the *Store()* method depending on the selected file format. The *Store()* method can be overloaded to implement different file formats. Using the thread method the ***ngcdcsACQ*** class can easily be set up through member function calls to receive any type and any number of image frames from the acquisition process.

In order not to use the asynchronous data transfer the *DataConnect()* method should be overloaded with an empty function. This would prevent the ***ngcdcsACQ*** instance from establishing an (unused) data connection when launching the acquisition process.

8 MAINTENANCE SERVER

A basic control server class (***ngcdcsSRV***) is available to test the modules described in the before sections and to provide a mean for developing the NGC prototype hardware. The ***ngcdcsSrv*** server process uses an instance of this class:

```
usage: ngcdcsSrv [options]

options:
   -inst <label>       - server instance label
                         (default: label = )
   -cfg <file-name>    - load system configuration file
   -dcf <file-name>    - detector configuration file
   -sim <LCU|HW>       - start in simulation mode
   -mode <mode>        - operational mode (NORMAL|HW-SIM|LCU-SIM)
                         (default: mode = NORMAL)
   -online             - go online after start
   -start              - auto-start at online
   -poll               - enable status polling
   -gui [name]         - launch GUI (name is optional)
                         (default: no GUI)
   -ld <dictionary>    - load dictionary (repetitive)
   -det <index>        - detector category index
                         (default: index = 1)
   -xterm              - start processes in x-terminal
   -verbose <level>    - verbose level
                         (default: level = 0)
   -log <level>        - log level
                         (default: level = 0)
   -shell              - launch command shell
   -stdin              - enable stdin for command input
   -dev <cfg-string>   - device configuration
                         format of the string:
                         [type]:[host|env]:[dev.-name]
                         (default: one local device)
   -acq <cfg-string>   - acq.-module configuration
                         format of the string:
                         [host]:[data-port]:[dev.-name]
                         (default: one default module)
   -ndet <num>         - number of detectors
                         (default: num = 1)
   -port <port number> - server port number
                         (default: port number = 8030)
   -h or -usage        - show options
```

The server is foreseen for system tests and detector tests in the laboratory and gives a versatile access to all functions implemented in the module classes. The ***ngcbCmd [-port <port number>]*** tool can be used to send instructions to the server from a Unix shell. This allows the usage of dedicated test scripts. A command shell can be launched with the *-shell* command line option. The shell supports the execution of macro commands. The shell can also be launched manually by calling ***ngcbShell [-port <port number>]***. The ***NGC_PORT*** environment variable can be used for the server port number. The value will be overwritten by the *-port* command line option of both the server and the two command tools.

The command "*help*" can be used to retrieve a command list. "*help <command>*" gives an explanation of the specified command. "*help all*" gives a complete command overview.

The execution of this server does not require any special user privileges to be granted by the operating system.

For software testing it is possible to emulate various errors:

- No acknowledge from hardware module (“*no_ack*”)
- Invalid address on a NGC hardware module (“*ivld*”)
- Sequencer FIFO empty (“*seq_empty*”)
- Sequencer goes to IDLE state (“*seq_idle*”)
- I/O error on all communication links (“*io_err1,2,3*”)
- I/O error on data link (“*data_io*”)
- Error when writing data to a file (“*data_file*”)
- Server blocks forever (“*block*”)

Others may be added. The emulation can be done with the command “*simerr <identifier>*”.

1 TRACEABILITY MATRIX

1.1 NGC Requirements from [AD6]

Item	Requirement	Section
	3.7 Software	
1	Generally, software shall not limit the performance of the hardware.	6.1, 7
2	It shall be command driven.	5.1, 5.2, 8 (to a limited extend)
	3.7.1 High-level operating systems	
3	The high-level operating systems must be |compliant with the VLT requirements. However, their number and diversity shall be kept to the minimum necessary for NGC.	2.2
4	A careful attempt shall be made to define an interface layer between the NGC control software proper and the operating system(s) and so to enable porting of all software above this layer at reasonable cost.	3.1, 4.4
	3.7.2 Configuration Control	
5	At all times, all software and all parameter files shall be kept under configuration control.	3.2, 6.7
6	For critical parameter files, an additional mechanism to ensure their integrity (e.g., check sums) should be considered	TBD
	3.7.3 Programming	
7	The usage of modern code-generating tools with a view towards testing, documenting, and debugging is encouraged. Their selection should be coordinated with the Technical Division. Island solutions should be avoided.	TBD

Item	Requirement	Section
8	For each module, code and documentation shall be designed such that it can be maintained without analyzing other modules.	-
	3.7.4 Installation and start-up procedures	
9	Fully automatic installation procedures and versatile configuration tools shall be provided.	3.2
10	Execution of the standard control software in the telescope environment shall not require any special user privileges to be granted by the operating system.	8, but see remarks in 7.1.2
11	The start-up script shall not require more than 10 s for auto-recognition of the hardware and the ready-for-use initialization of hard- and software.	Not within this scope.
	3.7.5 Resource checking	
12	Software shall be able, prior to each exposure, to check the availability of all critical resources.	Not within this scope.
	3.7.6 Elementary functions	
13	The set of elementary functions shall comprise those of IRACE and FIERA.	Not within this scope.
14	The addition of further functions shall be possible without affecting the others.	6
	3.7.7 Tests	
15	Test software shall be developed in parallel to the control software itself.	3.3
16	The emulation of failures of other utilities (software, hardware, network, lack of resources, access denial) should be considered.	5.3, 8

Item	Requirement	Section
17	Standardized tests of the software corresponding to any supported hardware configuration shall be possible by merely selecting a single set of parameters.	8 (to a limited extend)
18	A sequence of tests of several hardware configurations shall be possible without operator intervention.	8 (to a limited extend)
19	Means should be considered to let NGC keep track of the frequency of usage of its key functionalities as a way to set usage-oriented test priorities.	Not within this scope.
	3.7.8 Times and timings	
20	Without the VLT TIM, all absolute times shall be correct to within less than 0.1s.	Not within this scope.
21	Relative synchronizations and time intervals shall be accurate to better than 0.1% or, for intervals less than 10s, to better than 0.01s.	Not within this scope.
22	Stricter timing requirements shall be realized using TIM.	2.6, 6.3.3
	3.7.9 Special modes	
23	Support of the following techniques (in the order of decreasing priority) should be foreseen: • nod and shuffle • subpixel sampling and digital filtering so that during an exposure the built-up of the S/N can be followed by performing a regression analysis for each pixel • drift scanning • non-destructive readout • on-chip charge shifts by a user-definable amount (e.g., for through-focus sequences)	7.2
24	Device type-specific modes offered by state-of-the-art IR detectors shall be included.	7.2

Item	Requirement	Section
25	If centroiding functions need to be supported, this shall be possible at a frame rate of 1 Hz for data arrays of up to 256 x 256 pixels using a single Gaussian fit or similar. For much smaller data arrays, rates of up to 100 Hz should be possible.	7.2
	3.7.10 Consecutive exposures	
26	If, e.g. due to on-line data processing, the time between end of detector readout and availability of the FITS file on disk becomes a significant overhead, it shall be possible to configure the software such that the next exposure begins right after the previous readout.	Not within this scope.
	3.7.11 Windowing and on-chip binning	
27	Standard windowing and on-chip binning shall be provided	6.3.2, 7.2
28	The number of windows should only be limited by the capabilities of the detectors.	6.3.2, 7.2
	3.7.12 Pixel processor	
29	A pixel processor shall be embedded in the system. Its interfaces to the remainder of the system shall be designed such that a replacement of the hardware plus operating system and/or of the processing software can be fully transparent to all other subsystems.	7
30	The following operations shall be supported from the beginning: averaging of frames with and without removal of outliers (e.g., particle events) • bias subtraction • centroiding of point sources • TBC (If performance reasons so require, the implementation may be detector dependent.)	7.2, 7.2.6
31	Close integration with NGC of a general-purpose image processing system featuring a user friendly scripting language could be considered.	7.3.2

Item	Requirement	Section
32	More desirable is an interface to the ESO DFS and the inclusion of general-purpose algorithms and recipes in the DFS CPL for re-use by data reduction pipelines.	Not within this scope.
	3.7.13 ALMA control software	
33	If this is in the general interest of ESO and supported by the Technology Division, elements of the ALMA control software may be used.	TBD
	3.7.14 Special utilities	
34	For multi-port systems, bias equalization to within better than 1% shall be possible on demand but without any further operator supervision.	7.2
	3.8 External interfaces	
35	Ideally, external interfaces (e.g., commands, databases) presently maintained by IRACE and FIERA would be supported by NGC with a minimum of changes so as to make the integration of NGC with the ESO operations scheme as seamless as possible. However, since in this regard the commonalities of FIERA and IRACE are very limited, this also limits backward compatibility. In no case shall NGC feature two different types of interfaces for the same purpose.	Not within this scope.
	3.8.1 Data format	
36	The data format shall be compliant with the Data Interface Control Document.	Not within this scope.
37	Comprehensive detector and electronics telemetry shall be included in the data headers.	Not within this scope.
38	From the FITS headers, it shall be possible to uniquely infer the complete set of hard- and software configuration and all parameter values.	Not within this scope.

Item	Requirement	Section
39	A generalized, moderately configurable interface to real-time computers, e.g. for adaptive optics or fringe tracking applications, shall be defined (in cooperation with ESO software engineers working downstream from such an interface).	Not within this scope.
40	It could be advantageous that (a possibly special incarnation of) the pixel processor can serve as the real-time computer (or vice versa).	TBD
41	Latency shall not exceed 100 us.	Not within this scope.
	3.8.3 Real-time display	
42	An interface to the RTD shall be provided.	7.3.1
43	For high frame rates, it shall be possible to request only every nth frame to be displayed.	7.2
44	Adaptive auto-selection shall be supported.	7.2
	3.8.4 VLT telescope control system	
45	It shall be possible to synchronize detector operations with the following functions: • Telescope nodding • M2 chopping • Non-sidereal tracking	2.6, 2.7, 6.3.3, 6.3.4
	3.8.5 VLT time distribution system	
46	The possibility of an interface to the VLT Time Interface Module shall be foreseen.	2.7, 6.3.4
47 - 52	Reserved.	
	3.11 Diagnostic tools	

Item	Requirement	Section
	3.11.1 Hardware self-test	
53	The hardware shall be able to execute a comprehensive self-test. It shall be possible to start it by pressing a physical button as well as by software. Due consideration shall be given to the protection of the detectors. The execution shall not exceed 5 minutes. An automatic log shall be produced.	6.6, 3.5
54	In order to save space on the electronics boards, it is acceptable to let remote software (e.g., on the xLCU) execute these tests with hardware only reporting its status. This software shall be developed in parallel to the one of the hardware.	6.6
	3.11.2 Read-back of parameter values	
55	It shall be possible to read back the actual values of all parameters set by software.	Not within this scope.
	3.11.3 Automatic identification of hardware components	
56	All LRUs (line Replaceable Unit) shall have a unique identification that is readable by software.	2.1, 6.1
57	An extension also to detectors shall be considered.	TBD, must be supported by hardware
58	Software shall be able to use this information for auto-configuration.	6.1
	3.11.4 Error handling	
59	Meaningful error messages and log files are essential; they shall enable software staff not familiar with the software or its scope to identify and fix minor problems. Different severity levels shall be distinguished. The status and options for the next actions shall be clear at all times.	3.5, 3.6
60	It shall be possible to set the severity level up to which automatic recoveries from errors shall be attempted.	Not within this scope.

Item	Requirement	Section
61	After a failed data saving, the OS shall have the possibility to recover the last frame.	Not within this scope.
62	After an interruption in the power supply, software should be able to automatically restore the status at the beginning of the last successful exposure.	Not possible.
	3.12 Support of engineering work	
	3.12.1 Engineering mode	
63	There shall be a password-protectable engineering mode. It may contain extra modules and options while otherwise may be omitted for reasons of convenience. However, modules used for normal operations shall be identical.	8
64	This mode shall offer access to all essential elementary detector control functions and allow hardware engineers rapid proto-typing of experimental software.	8
	3.12.2 Change of parameters	
65	A change of software-configurable parameters shall not require a re-start of the system and, where possible, be supported also during readout. This would also benefit multi-mode instruments where, e.g., imaging and spectroscopy require different parameter sets for optimal performance. Switching between modes shall not lead to any hysteresis.	6.2, 7.2.2
66	A mechanism shall be implemented to reduce the risk of out-of-range parameter values being set accidentally that could damage the connected detector(s). One possibility might be to let the controller hardware request a unique electronic ID (such as the serial number) from the detector.	TBD
67	An interface to BOB shall be provided that permits parameter values to be set from dedicated observation blocks / observing templates. To take advantage of this, laboratory setups would need to be able to emulate VLT-compatible instruments to the extent that VLT control software Sequencer scripts can be executed.	Not within this scope.

Item	Requirement	Section
	3.12.3 Detector library	
68	A repository with parameter files for specific detector types and their baseline operating modes shall be offered. For engineering purposes, easy copying and editing of such files shall be supported. To the extent possible, different installations of comparable detector systems shall share these data.	Not within this scope.
	3.12.4 Disabling of components	
69	It shall be possible to declare LRUs and channels defunct. In response to this, the software should be able to automatically adapt itself to the remaining hardware configuration.	Not within this scope.
	3.12.5 Special modes	
70	The following shall be foreseen: • pocket pumping • convenient connection of monitoring equipment such as oscilloscopes, multimeters, and logic analysers • determination of PTF of DC-coupled IR and CMOS devices by a capacitive comparison technique	2.4
	3.12.6 Programming interface	
71	Thought shall be given to the provision of an efficient programmer's interface, ideally with a standard scripting language such as Tcl/Tk, that permits engineers rapid proto-typing of detector control and data processing software.	6.3.2
	3.12.7 Test facility	
72	A cost-effective test facility for all types of LRUs shall be supplied. It may either be integrated into the controller or standalone.	Not within this scope.
73	Its software shall use the one of the NGC only.	Not within this scope.
74	An expandible collection of standard test functions shall be considered.	Not within this scope.

Item	Requirement	Section
75	Where applicable, test results should also be offered in graphical form with an option for hardcopies.	Not within this scope
	3.12.8 Simulation modes	
76	Standard VLT simulation modes shall be supported. Simulation should be one of the standard modes of NGC rather than an add-on.	5.3
77	To the greatest possible extent, simulation of key elements shall be supported in both soft- and hardware.	5.3, 7.2.9
78	Hardware simulators to generate programmable test pixel patterns and video waveforms shall be devised.	Not used.
79	Software simulators shall be hierarchically structured and permit the simulation of data streams with real numbers and realistic data rates so that relative timings, etc. can be tested.	5.3, 7.2.9

1.2 NGC Software Requirements from [AD7]

Item	Requirement	Section
	3.1 Functional Requirements	
	3.1.1 Common Requirements	
80	NGCSW shall handle at least TBD clocks, TBD biases, TBD preamps and TBD video channels.	6.3, 6.4, 6.5
81	NGCSW will implement, as a minimum, the commands already used by FIERA and IRACE and described in their CDTs with an interface which will allow backward compatibility.	Not within this scope.
82	The ONLINE status requires that all voltages are loaded and switches closed as well as telemetry is acquired and checked.	Not within this scope.

Item	Requirement	Section
83	NGCSW will handle multiple independent detectors.	6
84	It shall be possible to read number of windows limited only by detector properties	6.3.2, 7.2
85	Windows shall be read either in hardware through sequences or in software. The latter case implies that a full frame is read out and then a window of data is computed in memory.	6.3.2, 7.2, 7.2.7, 7.3.1
86	Telemetry shall be available at all times, with the possibility to have a separate period for logging on the VLT logMonitor.	6.4
87	NGCSW shall transfer all computed results to display (RTD) and/ or to FITS-file.	7.2
88	Display visualization is done in parallel to all other data transfers (i.e. one may look at the DIT frame while storing the INT frame to disk and while the next data is already being processed).	7.2
89	If processing- or data-transfer-bandwidth exceeds the capacity of one single computer, the task is split up to N computing units.	2.2, 7.2
90	In order to test the image data path, NGC must be able to produce pre-defined data,	7.2.9
	3.1.3 Infrared Specific Requirements	
91	Each Pixel can be read out N times and an average is computed.	7.2
92	Subsampling and digital filtering of individual pixels shall be possible.	7.2
93	The ONLINE status requires that the system also starts readout.	Not within this scope.
94	In case reference values on special channels are read out (e.g. Hawaii2RG), NGC shall be able to interpolate through rows or columns.	7.2
95	Chopping mode shall be implemented	7.2

Item	Requirement	Section
96	NGCSW shall be able to transfer bursts of raw data to FITS files.	7.2 (partially), [RD11]
97	Standard read-out modes: • Uncorrelated • Double correlated (reset-read-read) • Double correlated (read-reset-read) • Least square fit • Fowler Sampling	7.2
	3.2 External Interface Requirements	
	3.21 User Interfaces	
98	NGCSW user interfaces will be developed following rules described in [RD39].	Not within this scope.
99	The user interface for telescope operations will merge functionalities of current FIERA and IRACE user interfaces.	Not within this scope.
100	Specific graphical interface may be developed in order to ease engineer's work in the laboratory. These interfaces may be developed not following the standards if their use is confined to laboratory.	8
	3.2.3 Software Interfaces	
101	Sequencer programming shall be implemented using a scripting language.	6.3.2
102	The scripting language will allow evaluation of arithmetic formulas at run-time.	6.3.2
103	The startup overhead of the script must be as short as possible.	6.3.2
104	Where no script is required a simple parsing can be done.	6.3.2
105	A graphical tool shall be implemented in order to have also the possibility to program and visualize the sequences.	Not within this scope.

Item	Requirement	Section
106	The format on disk of the sequences shall be ASCII.	6.3.2
107	Other formats, non ASCII, for ancillary data (e.g. for graphics) could be used, but must not be required for running the system.	6.3.2
108	The sequence programming will allow free use of setup parameters.	6.3.2
109	The chopper frequency may be input parameter or output parameter of the sequencer program.	6.3.2
110	Free placement of synchronization points with external trigger.	6.3
111	Read-out of multiple windows shall be configurable in programming.	6.3.2
112	Sub-pixel sampling (N samples per pixel) shall also be possible	6.3.2
113	The sequencer programming tool will also allow to emulate the real sequencer.	5.3
114	Interface to standard RTD shall be provided.	7.3.1
115	The interface and the library to be used are given in [RD40].	7.3.1
116	If needed flat-field frame and bad pixels mask shall be uploaded to NGCSW which will then distribute them to the relevant subsystem.	7.2.6
	3.2.4 Communications Interfaces	
117	Communication between internal subsystems of NGCSW shall be implemented using VLTSW standard messaging tools as well as CCS database.	5.1, 5.2
118	Whenever not otherwise specified, the same standards will be used for all other communication interfaces.	5.1, 5.2

Item	Requirement	Section
	3.3.2 Data Transfer	
119	Data transfer rate to the IWS shall be limited only by readout speed.	7.2
120	An overhead of max. 5 seconds will be considered acceptable.	7.2

1.3 Adaptive Optics Requirements for NGC from [AD20]

Item	Requirement	Section
AONGCREQ-004	Number of detectors controlled from single NGC: 1-4	2, 6
AONGCREQ-005	It should be possible to control multiple detectors with a single NGC.	2, 6
AONGCREQ-006	The detectors controlled by a single NGC all be read with the same read-mode and frame rate. Operations such as start and stop, should operate on all detectors simultaneously.	2, 6, 7.2
AONGCREQ-007	It should be possible to synchronize the start of a read sequence between NGCs	2.7, 6.3.4
AONGCREQ-008	The synchronization should allow the start of the readout in separate NGCs to be started within the frame jitter time.	2.7, 6.3.4
AONGCREQ-009	Ability to visualise 1 of N frames asynchronously on instrument WS using standard RTD, the value of N will be chosen to allow visualisation on the WS of 1-4Hz, the maximum frame rate required to the WS will be 50Hz.	7.2
AONGCREQ-010	Ability store 1 of N frames asynchronously in FITS format on instrument WS, the value of N will be defined to allow a maximum frame rate of 50Hz.	7.2

Item	Requirement	Section
AONGCREQ-011	Ability to store a series of N guaranteed consecutive frames, where N should be sufficient to store a minimum of 2 seconds of data with a goal of 10s.	7.2
AONGCREQ-012	At least one ROI (windowing/regions of interest) per detector should be supported, as a goal multiple ROIs.	6.3.2, 7.2, 7.2.7, 7.3.1
AONGCREQ-013	It should be possible to update the ROI definition (at a minimum start coordinates) dynamically when a loop of readouts is in operation.	-
AONGCREQ-014	Ability to synchronize the start of a readout sequence with an external trigger to within 30 micro seconds.	2.7, 6.3.4
AONGCREQ-015	1x1 to 16x16 defined in steps of 1 pixel binning is the same for each window within a given detector.	6.3.2, 7.2, 7.2.7, 7.3.1
AONGCREQ-024	It should be possible to command the NGC to execute a defined read sequence for the defined mosaic	6.3.2
AONGCREQ-025	N times.	6.3.2
AONGCREQ-026	with a user definable (in microseconds) delay (from 0 to TBD) between executions	6.3.2
AONGCREQ-027	where N is a value between 1 and Inf.	6.3.2
AONGCREQ-028	A stop command for a given mosaic should stop the current loop of readout sequences at the completion of the next cycle	6.3.3
AONGCREQ-028a	It should be possible to instruct the NGC to pass a 15bit data ramp over the real time data link in a standard frame including both start and end of frame words at frame rates up to the maximum supported	TBD - must be supported by hardware
AONGCREQ-029	As a goal it should be possible to load simulated images into the NGC memory and have them ‘played back’ over the RT data link as though coming from a normal readout sequence.	Not supported by HW.

Item	Requirement	Section
AONGCREQ-030	The replay speed should be a user parameter up to the maximum possible frame rate.	Not supported by HW.
AONGCREQ-038	Define one (or more) ROIs for a specified detector with start pixel and window dimensions.	6.3.2, 7.2, 7.2.7, 7.3.1
AONGCREQ-039	Define readout mode for detector mosaic.	Not within this scope.
AONGCREQ-040	Enable/Disable storage of detector frames.	7.2.5, 7.3.1
AONGCREQ-041	Define sub-sampling of readout to be passed to instrument workstation for visualisation or storage.	7.2
AONGCREQ-042	Start readout of mosaic of detectors for N cycles, 1<=N<=Inf	6.3.2, 6.3.3
AONGCREQ-043	with optional synchronization with external synch signal.	2.7, 6.3.4
AONGCREQ-044	Stop readout of a mosaic of detectors.	6.3.3
AONGCREQ-045	Acquire and store a contiguous set of N frames from a ‘group’ of detectors.	6.3.2, 7.2
AONGCREQ-046	Upload a set of detector frames to be replayed in simulation mode.	Not supported by HW.
AONGCREQ-047	Replay previously uploaded simulated data frames at defined loop frequency.	Not supported by HW.

1 APPENDIX

1.1 ngcb2Drv - Command Definition Table

```
PUBLIC_COMMANDS

COMMAND=          BREAK
FORMAT=           A
REPLY_FORMAT=     A
HELP_TEXT=
Interrupt server.
@

COMMAND=          EXIT
FORMAT=           A
REPLY_FORMAT=     A
HELP_TEXT=
Make the server exit/terminate.
@

COMMAND=          KILL
FORMAT=           A
REPLY_FORMAT=     A
HELP_TEXT=
Send a KILL signal to the server.
@

COMMAND=          MSGDLOG
FORMAT=           A
REPLY_FORMAT=     A
HELP_TEXT=
Disable autologging of messages sent or received by the application.
@

COMMAND=          MSGELOG
FORMAT=           A
REPLY_FORMAT=     A
HELP_TEXT=
Enable autologging of messages sent or received by the application.
@

COMMAND=          ONLINE
FORMAT=           A
REPLY_FORMAT=     A
REPLY_PARAMETERS=
     PAR_NAME=    done
     PAR_TYPE=    STRING
     PAR_DEF_VAL= “OK”
HELP_TEXT=
Connect server to interface device.
@

COMMAND=          PING
FORMAT=           A
REPLY_FORMAT=     A
REPLY_PARAMETERS=
     PAR_NAME=    done
     PAR_TYPE=    STRING
     PAR_DEF_VAL= “OK”
HELP_TEXT=
Make a check of the functioning of the server and send back an
```

```
overall status message.
@

COMMAND=          RDADDR
FORMAT=           B
REPLY_FORMAT=     B
HELP_TEXT=
Binary read from a module address.
@

COMMAND=          RESET
FORMAT=           A
REPLY_FORMAT=     A
REPLY_PARAMETERS=
     PAR_NAME=    done
     PAR_TYPE=    STRING
     PAR_DEF_VAL= “OK”
HELP_TEXT=
Send a reset instruction to the interface device.
@

COMMAND=          SIMULAT
SYNONYMS=         SIM
FORMAT=           A
REPLY_FORMAT=     A
REPLY_PARAMETERS=
     PAR_NAME=    done
     PAR_TYPE=    STRING
     PAR_DEF_VAL= “OK”
HELP_TEXT=
Switch to simulation mode. A simulator will be used instead of
accessing the physical interface device.
@

COMMAND=          STANDBY
FORMAT=           A
REPLY_FORMAT=     A
REPLY_PARAMETERS=
     PAR_NAME=    done
     PAR_TYPE=    STRING
     PAR_DEF_VAL= “OK”
HELP_TEXT=
Disconnect server from interface device.
@

COMMAND=          STATUS
FORMAT=           A
REPLY_FORMAT=     A
REPLY_PARAMETERS=
     PAR_NAME=    status
     PAR_TYPE=    INTEGER
     PAR_DEF_VAL=           0
HELP_TEXT=
Get physical interface device status.
@

COMMAND=          STOPSIM
FORMAT=           A
REPLY_FORMAT=     A
REPLY_PARAMETERS=
     PAR_NAME=    done
     PAR_TYPE=    STRING
     PAR_DEF_VAL= “OK”
```

```
HELP_TEXT=
Switch to normal operation mode.
@

COMMAND=          TIMEOUT
FORMAT=           A
PARAMETERS=
     PAR_NAME=    seconds
     PAR_TYPE=    INTEGER
     PAR_OPTIONAL=NO
REPLY_FORMAT=     A
REPLY_PARAMETERS=
     PAR_NAME=    done
     PAR_TYPE=    STRING
     PAR_DEF_VAL= “OK”
HELP_TEXT=
Set a new timeout (in seconds) for the device i/o.
@

COMMAND=          VERBOSE
FORMAT=           A
PARAMETERS=
     PAR_NAME=    on
     PAR_TYPE=    LOGICAL
     PAR_OPTIONAL=YES

     PAR_NAME=    off
     PAR_TYPE=    LOGICAL
     PAR_OPTIONAL=YES
REPLY_FORMAT=     A
HELP_TEXT=
Switch verbose mode on/off.
@

COMMAND=          VERSION
FORMAT=           A
PARAMETERS=
REPLY_FORMAT=     A
HELP_TEXT=
Return the present server version.
@

COMMAND=          WRADDR
FORMAT=           B
REPLY_FORMAT=     B
HELP_TEXT=
Binary write to a module address.
@

MAINTENANCE_COMMANDS

TEST_COMMANDS

// --- oOo ---
```

1.2 ngcbDrvCom

NAME

ngcbDrvCom - NGC driver interface for communication line

SYNOPSIS

```
#include "ngcbDrv.h"

int ngcbComOpen(const char *name, char *erms)

int ngcbComClose(int fd)

int ngcbComReset(int fd)

int ngcbComTimeout(int fd, int seconds)

int ngcbComRead(int fd, char *buffer, int size, char *erms)

int ngcbComWrite(int fd, char *buffer, int size, char *erms)

int ngcbComReadStatus(int fd)

int ngcbComErrStatus()

void ngcbComErrStr(int status, char *errStr)

void ngcbComStatStr(int status, char *errStr)
```

DESCRIPTION

ngcbComOpen() opens connection to the front-end.

ngcbComClose() closes the connection to the front-end.

ngcbComReset() performs a device reset of the subsystem.

ngcbComTimeout() sets the timeout for read/write accesses in seconds.

ngcbComRead() reads a number of bytes from the device.

ngcbComWrite() writes a number of bytes to the device.

ngcbComReadStatus() returns the actual value of the communication status register.

ngcbComErrStatus() returns the saved status value of the last faulty I/O. The saved value is reset to zero on each device open/close.

ngcbComErrStr() returns in <errStr> an error message matching the given <status>.

ngcbComStatStr() returns in <statStr> a status message matching the given <status>.

RETURN VALUES

ngcbComOpen returns an open file descriptor in case of success. A value of -1 indicates an error.

If not specified otherwise all other functions return zero in case of success. A value of -1 indicates an error.

<erms> will contain an error-message in case of failure.

1.3 ngcbDrvDma

NAME

ngcbDrvDma - interface library to NGC DMA driver

SYNOPSIS

```
#include "ngcbDrv.h"

int ngcbDmaOpen(const char *devName, ngcb_dma_t *dma, char *erms)

int ngcbDmaClose(ngcb_dma_t *dma, char *erms)

int ngcbDmaAlloc(ngcb_dma_t dma,
                 unsigned char **buffer,
                 int num,
                 unsigned long size,
                 char *erms)

void ngcbDmaFree(ngcb_dma_t dma, unsigned char **buffer, int num)

int ngcbDmaInit(ngcb_dma_t *dma,
                unsigned char **buffer,
                int num,
                unsigned long size,
                unsigned int *doneCount,
                char *erms)

int ngcbDmaStop(ngcb_dma_t dma, char *erms)

int ngcbDmaClr(ngcb_dma_t dma, char *erms)

int ngcbDmaGetCnt(ngcb_dma_t dma, unsigned int *cnt, char *erms)

int ngcbDmaWait(ngcb_dma_t dma, unsigned int cnt, char *erms)

int ngcbDmaStat(ngcb_dma_t dma, int *byteCount, char *erms)

int ngcbDmaOverflow(ngcb_dma_t dma)
```

DESCRIPTION

ngcbDmaOpen() opens the dma interface driver with device name <devName>.

ngcbDmaClose() closes the dma interface driver referred to by the device handle <dma>.

ngcbDmaAlloc() allocates <num> DMA ringbuffer elements with the specified size (in bytes). The <num> buffer pointers have to be allocated by the calling application.

ngcbDmaFree() frees the DMA ringbuffer space previously allocated with ngcbDmaAlloc().

ngcbDmaInit() initiates a sustained ringbuffered DMA-read. The array of buffers has to be passed to the routine. <num> is the number of ringbuffer elements and <size> is the size (in bytes) of each buffer element. As current Linux kernel versions do no longer support DMA to user-space memory, the current implementation ignores the <buf>, <num> and <size> parameters and does the DMA to the buffers allocated/mapped in the kernel with ngcbDmaAlloc(). The parameters are left in here as user-space DMA may re-appear again and the applications may benefit from such an implementation. To keep the user space code compatible with such cases it is strongly recommended to pass the <buf>, <num> and <size> values from the ngcbDmaAlloc() routine into here. <doneCount> is set by the routine as initial buffer counter. Usually this will be zero, but the value might differ when using future driver versions.

ngcbDmaStop() stops the current DMA.

ngcbDmaClr() clears all DMA data FIFOs.

ngcbDmaGetCnt() gets the current buffer counter.

ngcbDmaWait() suspends the calling routine until the next DMA-buffer has been received.

ngcbDmaStat() sets <byteCount> to the number of bytes which are still left in the current DMA.

ngcbDmaOverflow() returns a value of 1 in case of a data FIFO overflow. Otherwise, a value of 0 is returned.

RETURN VALUES

ngcbDmaOverflow returns a value of 1 in case of an input fifo overflow. Otherwise, a value of 0 is returned.

All other functions:

Upon successful completion, a value of 0 is returned. Otherwise a value of -1 is returned and erms contains an error string.

CAUTIONS

The ngcbDmaOpen() function must always be called before any of the other functions in this set can be used. The device should always be closed before being re-opened.

SEE ALSO

ngcbDmaPci(3), ngcbDma0(3)

1.4 ngcbPrio

NAME

ngcbPrio, ngcbGetPrio, ngcbSetPrio - priority control

SYNOPSIS

```
#include "ngcb.h"

int ngcbGetPrio(int *priority, int *class, int *quantum)
int ngcbSetPrio(int priority, int class, int quantum)
```

DESCRIPTION

Priority control:

The time quantum is expressed in microseconds (only relevant for real-time class).

```
ngcbTQ_INF: infitite time quantum
ngcbTQ_DEF: default time quantum
ngcbTQ_NC: do not change previous value

classes: ngcbPRI_RT   -  real time class
         ngcbPRI_TS   -  time sharing class
```

The priority is rising with higher values.

RETURN VALUES

In case of failure -1 is returned, otherwise zero.

1.5 ngcbThread

NAME

ngcbThread, ngcbThrCreate, ngcbThrExit, ngcbThrKill, ngcbThrJoin - thread routines

SYNOPSIS

```
#include "ngcbThread.h"

int ngcbThrCreate(void          *(*startFunc)(void *),
                  void          *arg,
                  long           flags,
                  ngcb_thread_t *thread)

void ngcbThrExit(void *status)

int ngcbThrKill(ngcb_thread_t thread, int sig)

int ngcbThrJoin(ngcb_thread_t   thread,
                ngcb_thread_t  *departed,
                void          **status)

ngcb_thread_t ngcbThrId()
```

DESCRIPTION

Thread routines (behave like pthread/POSIX or thread/SOLARIS).

CAUTIONS

ngcbThread.h also provides definitions to support the same nomenclature as used for the Solaris implementation. See also the man pages for thr_create(3THR), thr_join(3THR), thr_kill(3THR) and thr_exit(3THR) on Solaris.

SEE ALSO

thr_create(3THR), thr_join(3THR), thr_kill(3THR), thr_exit(3THR)

1.6 ngcbSem

NAME

ngcbSem, ngcbSemInit, ngcbSemDestroy, ngcbSemWait, ngcbSemPost, ngcbSemTryWait, ngcbSemCnt, ngcbSemLock, ngcbSemUnlock, ngcbSemTryLock, ngcbRwLockInit, ngcbRwLockDestroy, ngcbRwRdLock, ngcbRwWrLock, ngcbRwUnlock, ngcbRwTryRdLock, ngcbTryWrLock - wrapping routines for semaphores and readers/writer-locks using the posix mutex routines

SYNOPSIS

```
#include "ngcbThread.h"

int ngcbSemInit(ngcb_sema_t  *sp,
                unsigned int  count,
                int           type,
                void         *arg)

int ngcbSemDestroy(ngcb_sema_t *sp)

int ngcbSemLock(ngcb_sema_t *sp)

int ngcbSemUnlock(ngcb_sema_t *sp)

int ngcbSemTryLock(ngcb_sema_t *sp)

int ngcbSemWait(ngcb_sema_t *sp)

int ngcbSemPost(ngcb_sema_t *sp)

int ngcbSemTryWait(ngcb_sema_t *sp)

int ngcbSemCnt(ngcb_sema_t *sp)

int ngcbRwLockInit(ngcb_lock_t *rwlp, int type, void *arg)

int ngcbRwDestroy(ngcb_lock_t *rwlp)

int ngcbRwRdLock(ngcb_lock_t *rwlp)

int ngcbRwTryRdLock(ngcb_lock_t *rwlp)

int ngcbRwWrLock(ngcb_lock_t *rwlp)

int ngcbRwTryWrLock(ngcb_lock_t *rwlp)

int ngcbRwUnlock(ngcb_lock_t *rwlp)
```

DESCRIPTION

Routines for semaphores and readers/writer-locks using the posix mutexes:

ngcbSemInit() creates a new counting semaphore. <count> specifies the initial semaphore counter value.

int ngcbSemDestroy() destroys the specified semphore.

void ngcbSemLock() acquires the binary lock associated with the semaphore. The function will block until the lock is available.

void ngcbSemUnlock() releases the binary lock associated with the semaphore.

int ngcbSemTryLock() tries to get the binary lock associated with the semaphore. If the lock is not available, the function returns (-1).

Otherwise the lock is acquired and zero is returned.

ngcbSemPost() increments the semaphore counter for the specified semaphore.

void ngcbSemWait() decrements the semphore counter for the specified semaphore. If the counter is zero, the calling process is suspended.

int ngcbSemTryWait() decrements semphore counter for the specified semaphore. If the counter is zero, the function returns (-1).

int ngcbSemCnt() returns the current counter value of the specified semaphore.

Many threads can have simultaneous read-only access to data, while only one thread can have write access at any given time. Multiple read access with single write access is controlled by locks, which are generally used to protect data that is frequently searched:

ngcbRwLockInit() initializes a new readers/writer lock. This is implemented only wihtin threads-scope and the parameters type and arg are ignored.

ngcbRwDestroy() destroys a readers/writer lock pointed to by <rwlp>.

ngcbRwRdLock() gets a read lock on the readers/writer lock pointed to by <rwlp>. If the readers/writer lock is currently locked for writing, the calling thread blocks until the write lock is freed. Multiple threads may simultaneously hold a read lock on a readers/writer lock.

ngcbRwTryRdLock() tries to get a read lock on the readers/writer lock pointed to by <rwlp>. If the readers/writer lock is locked for writing, it returns (-1). Otherwise, the read lock is acquired.

ngcbRwWrLock() gets a write lock on the readers/writer lock pointed to by <rwlp>. If the readers/writer lock is currently locked for reading or writing, the calling thread blocks until all the read and write locks are freed. At any given time, only one thread may have a write lock on a readers/writer lock.

ngcbRwTryWrLock() trys to get a write lock on the readers/writer lock pointed to by <rwlp>. If the readers/writer lock is currently locked for reading or writing, it returns (-1).

ngcbRwUnlock() unlocks a readers/writer lock pointed to by <rwlp>, if the readers/writer lock is locked and the calling thread holds the lock for either reading or writing. One of the other threads that is waiting for the readers/writer lock to be freed will be unblocked, provided there are other waiting threads. If the calling thread does not hold the lock for either reading or writing, no error status is returned, and the program’s behavior is unknown.

RETURN VALUES

If not specified differently all functions return a value of 0 in case of successful operation. Otherwise (-1) is returned.

CAUTIONS

The ngcbSemLock/Unlock/TryLock functions are intendend to speed up semaphore handling intended for mutual exlusion protection rather than for signalling. The functions behave like the pthread_mutex_lock/unlock implementation.

The ngcbSemCnt() function is not available in the Solaris semaphore implementation and will always return a value of (-1).

ngcbThread.h also provides definitions to support the same nomencalture as used for the Solaris implementation. See also the man pages for

```
       sema_init(3THR) and rwlock_init(3THR) on Solaris.

SEE ALSO
       pthread_mutex_lock(3), pthread_mutex_unlock(3), sema_init(3THR),
       rwlock_init(3THR)
```

1.7 ncgbTHREAD Class

NAME

ngcbTHREAD - C++ interface for posix threads

SYNOPSIS

```
#include <ngcbTHREAD.h>

ngcbTHREAD baseClass();
ngcbTHREAD newThread(this, (ngcbPROCESS_T)&process, (void *)arg);
```

DESCRIPTION

C++ interface for posix threads.

PUBLIC METHODS

```
ngcbTHREAD();
    Constructor method providing a base class for all applications,
    which want to use this interface.

ngcbTHREAD(ngcbTHREAD *appl, ngcbPROCESS_T process, void *arg)
    Constructor for a thread-object. This will start the specified
    process, which is declared in the application class. A pointer
    to the calling application class is passed in <appl>. <arg> passes
    a pointer to an application specific argument through to the
    called process. The <process> must be a member function of the
    application class. The <process> must be of type:

      void <appl>::Process(void *arg)

    The application class must be derived from the ncgbTHREAD class.
    A pipe is created to be able to trigger the created process via
    a select call.

virtual ~ngcbTHREAD();
    Destructor method.

irtual ngcbTHREAD *NewThread(ngcbTHREAD *appl,
                             ngcbPROCESS_T process,
                             void *arg);
    Creates a new thread object, statring the specified process.
    Procedural interface to threwad-object creation with the
    <new> operator.

int ThrCreate(ngcbTHREAD *appl,
              ngcbPROCESS_T process,
              void *arg,
              ngcbTHREAD_T *threadId,
              char *erms);
    Function to create a thread in the scope of the specified
    application class <appl>. <arg> passes a pointer to an
    application specific argument through to the called process.
    The <process> must be of type:

      void <appl>::Process(ngcbTHREAD *thread, void *arg)

    A thread-id is returned in <threadId> as a handle to be used
    in later calls to the ThrJoin() and ThrKill() member functions.

void ThrExit();
    Function to be called by a thread before exiting.

int ThrKill(ngcbTHREAD_T threadId, int sig, char *erms);
    Function to send signal to a thread specified via the handle
    <threadId>. The <threadId> is retrieved by calling the ThrCreate()
    member function.

int ThrJoin(ngcbTHREAD_T threadId, char *erms);
    Function to join a thread specified via the handle <threadId>.
    The <threadId> is retrieved by calling the ThrCreate() member
```

```
    function. The calling process is suspended until the specified
    thread exits.

int ThrKill(int sig, char *erms);
int ThrJoin(char *erms);
    Same as the above functions but these are used for killing/joining
    a thread-object constructed with the second constructor.

int Initialized();
    Returns (1) in case a thread-object constructed with the
    second constructor was created successfully.

int FdIn();
    Returns a file descriptor to be used in the thread for a wakeup
    select call.

int FdOut();
    Returns a file descriptor to be written to in order to send a
    message to the called thread.

ngcbTHREAD_T ThreadId()
    Returns own thread id.
```

RETURN VALUES

If not specified otherwise all functions return (0) in case of success. If an error occured (-1) is returned and <erms> will contain an error-message.

EXAMPLES

```
class myCLASS: public ngcbTHREAD {

  ngcbTHREAD *myThread_;

public:
  myCLASS() {
    myThread_ = (ngcbTHREAD *)NULL;

  }

  void MyProcess(ngcbTHREAD *thr, void *arg) {
    int fdThr = thr->FdIn();

    ... use fdThr in select call te get triggered for abort ...
  }

  void StartMyProcess {
    myThread_ = NewThread(this,
                          (ngcbPROCESS_T)&myCLASS::MyProcess,
                          NULL);

    if (myThread_ == (ngcbTHREAD *)NULL)
      {
      ... error handling ...
      }
    else if (!myThread_->Initialized())
      {
      delete myThread_;
      ... error handling ...
      }
  }

  void KillMyProcess {
    if (myThread_ != (ngcbTHREAD *)NULL)
      {
      delete myThread_;
      }
  }
```

```
        }
```

SEE ALSO

```
        ngcbSem(3), ngcbThread(3), ngcbSEM(4)
```

1.8 ngcbSEM Class

NAME

ngcbSEM - C++ interface for semaphores using the posix mutex routines

SYNOPSIS

```
#include <ngcbTHREAD.h>

ngcbSEM baseClass();

ngcbSEM sem(count);
```

DESCRIPTION

C++ interface for semaphores using the posix mutex routines.

PUBLIC METHODS

```
ngcbSEM();
    Constructor method providing a base class for application
    specific semaphores.

ngcbSEM(unsigned int count);
    Constructor method for a counting semaphore object. <count>
    specifies the initial semaphore counter value.

virtual ~ngcbSEM();
    Destructor method.

int Create(ngcbSEM_T *sp, unsigned int count, char *erms);
    Create a new counting semaphore. <count> specifies the
    initial semaphore counter value.

int Destroy(ngcbSEM_T *sp, char *erms);
    Destroy the specified semphore.

void Lock(ngcbSEM_T *sp);
    Acquire the binary lock associated with the semaphore. The
    function will block until the lock is available.

void Unlock(ngcbSEM_T *sp);
    Release the binary lock associated with the semaphore.

int TryLock(ngcbSEM_T *sp);
    Tries to get the binary lock associated with the semaphore.
    If the lock is not available, the function returns (-1).
    Otherwise the lock is acquired and zero is returned.

void Post(ngcbSEM_T *sp);
    Increment semaphore counter for the specified semaphore.

void Wait(ngcbSEM_T *sp);
    Decrement semphore counter for the specified semaphore.
    If the counter is zero, the calling process is suspended.

int TryWait(ngcbSEM_T *sp);
    Decrement semphore counter for the specified semaphore.
    If the counter is zero, the function returns (-1).

int Cnt(ngcbSEM_T *sp);
    Returns the current counter value of the specified semaphore.

void Lock();
    Acquire the binary lock associated with the own semaphore
    object. The function will block until the lock is available.

void Unlock();
    Release the binary lock associated with the own semaphore object.
```

```
int TryLock();
    Tries to get the binary lock associated with the oen semaphore.
    object. If the lock is not available, the function returns (-1).
    Otherwise the lock is acquired and zero is returned.

void Post();
    Increment semaphore counter for own semaphore object.

void Wait();
    Decrement semphore counter for own semaphore object.
    If the counter is zero, the calling process is suspended.

int TryWait();
    Decrement semphore counter for own semaphore object.
    If the counter is zero, the function returns (-1).

int Cnt();
    Returns the current counter value of the own semaphore object.
```

RETURN VALUES

If not specified otherwise all functions return (0) in case of success. If an error occured (-1) is returned and <erms> (if present) will contain an error-message.

CAUTIONS

The ngcbSemLock/Unlock/TryLock functions are intendend to speed up semaphore handling intended for mutual exlusion protection rather than for signalling. The functions behave like the pthread_mutex_lock/unlock implementation.

SEE ALSO

ngcbTHREAD(4), pthread_mutex_lock(3), pthread_mutex_unlock(3)

1.9 ngcbPARAM Class

NAME

ngcbPARAM, ngcbPARAM_LIST - NGC parameter maintenance classes

SYNOPSIS

```
#include <ngcbPARAM.h>

ngcbPARAM param();

ngcbPARAM_LIST list();
```

DESCRIPTION

NGC parameter maintenance classes.

PUBLIC METHODS

ngcbPARAM class:

```
ngcbPARAM(const char *paramName, char initVal);
ngcbPARAM(const char *paramName, int initVal);
ngcbPARAM(const char *paramName, float initVal);
ngcbPARAM(const char *paramName, double initVal);
ngcbPARAM(const char *paramName, const char *initVal);
ngcbPARAM(const char *paramName, const char *initVal, int type);
    Constructor methods for several types. If the initial value
    is given as string , optionally a type can be specified, which
    has to be one of:

      ngcbPARAM_CHAR   - logical ('T' or 'F' or 0 or 1)
      ngcbPARAM_INT    - 32-bit signed integer
      ngcbPARAM_FLOAT  - 32-bit floating point
      ngcbPARAM_DOUBLE - 64-bit floating point
      ngcbPARAM_STRING - string
                         (max. length: ngcbPARAM_MAX_STRING = 256)

ngcbPARAM(const char *paramName);
    Constructor for parameter with undefined type.

virtual ~ngcbPARAM();
    Destructor method.

void Alias(const char *a);
    Set an alternative alias name for this parameter.

int Type();
    Get parameter type.

void Type(int newType);
    Set a new parameter type. See above for valid types.

int Changed();
    Returns 1 in case the parameter value has changed since the last
    call of this method. Otherwise 0 is returned.

int Comp(ngcbPARAM p)
    Returns 1 in case the parameter value is equal to the value
    of parameter <p>. Otherwise 0 is returned.

void Store();
    Store parameter value to a temporary buffer.

void Restore();
    Restore parameter value from a temporary buffer.

char *Get();
    Get parameter value converted to string format.
```

```
int Set(const char *newValue);
    Convert value from string format to Type() and set this as
    new value.

int Set(char newValue);
    Convert value from logical format to Type() and set this as
    new value.

int Set(int newValue);
    Convert value from 32-bit signed integer format to Type()
    and set this as new value.

int Set(float newValue);
    Convert value from 32-bit floating point format to Type()
    and set this as new value.

int Set(double newValue);
    Convert value from 64-bit floating point format to Type()
    and set this as new value.

char ValChar();
    Get parameter value converted to logical format.

int ValInt();
    Get parameter value converted to 32-bit integer format.

float ValFloat();
    Get parameter value converted to 32-bit floating point format.

double ValDouble();
    Get parameter value converted to 64-bit floating point format.

char *ValString();
    Get parameter value converted to string format - same as Get().

ngcbPARAM_LIST class:

ngcbPARAM_LIST();
    Constructor method.

virtual ~ngcbPARAM_LIST();
    Destructor method.

ngcbPARAM *Add(ngcbPARAM *newParam, int noDelete = 1);
    Add a new parameter object to the list. If a parameter object
    with the same name does already exist a pointer to the existing
    object is returned. Otherwise the same object is returned.
    If noDelete is set to zero, the parameter object will be deleted
    when the parameter is removed from the list, otherwise not (default).

ngcbPARAM *Add(const char *paramName, char initVal);
ngcbPARAM *Add(const char *paramName, int initVal);
ngcbPARAM *Add(const char *paramName, float initVal);
ngcbPARAM *Add(const char *paramName, double initVal);
ngcbPARAM *Add(const char *paramName, const char *initVal);
ngcbPARAM *Add(const char *paramName, const char *initVal, int type);
    Add a parameter to the list. If the initial value
    is given as string , optionally a type can be specified, which
    has to be one of:

      ngcbPARAM_CHAR   - logical ('T' or 'F' or 0 or 1)
      ngcbPARAM_INT    - 32-bit signed integer
      ngcbPARAM_FLOAT  - 32-bit floating point
      ngcbPARAM_DOUBLE - 64-bit floating point
      ngcbPARAM_STRING - string
                         (max. length: ngcbPARAM_MAX_STRING = 256)

    A pointer to the new parameter object is returned. In case the
    parameter already exists, a pointer to the existing parameter
```

```
    object is returned. No check for NULL-pointer return value required.

ngcbPARAM *Add(const char *name);
    Add a parameter of undefined type to the list.

void Clear();
    Remove all parameters.

void Remove(ngcbPARAM *param);
    Remove parameter object from list - resolve by object.

void Remove(const char *paramName);
    Remove parameter object from list - resolve by parameter name.

ngcbPARAM *Get(const char *paramName);
    Searches the list for a parameter object with the given name
    and returns a pointer to the object. If the parameter is not in
    the list, a NULL pointer is returned.

ngcbPARAM_LIST *First();
    Returns the list entry point for "walking" through the list
    (see example below).

int Set(const char *paramName, char paramValue);
int Set(const char *paramName, int paramValue);
int Set(const char *paramName, float paramValue);
int Set(const char *paramName, double paramValue);
int Set(const char *paramName, const char *paramValue);
    Convenience functions to set a parameter value in the list.

int ValChar(const char *paramName, char *paramValue);
int ValInt(const char *paramName, int *paramValue);
int ValFloat(const char *paramName, float *paramValue);
int ValDouble(const char *paramName, double *paramValue);
int ValString(const char *paramName, char *paramValue);
    Convenience functions to get a parameter value from the list.

oid ClrCtrlList(int instance);
    Remove a controller (=sequencer) instance defined by its
    (sequential) instance number from all parameters inside the list.

oid ClrAcqList(int instance);
    Remove an acquisition process defined by its sequential instance
    number from all parameters inside the list.
```

PUBLIC DATA MEMBERS

```
ngcbPARAM class:

  char name[64];       - parameter name

  char alias[64];      - parameter alias name

  char format[16];     - format for output of the Get(),ValString()
                         methods. The default depends on the type:

                           ngcbPARAM_CHAR: "%c"
                           ngcbPARAM_INT: "%d"
                           ngcbPARAM_FLOAT/DOUBLE: "%6G"
                           ngcbPARAM_STRING: not applicable

  int fits;             - flag to put the parameter into the
                          FITS-header

  char comment[28];     - optional comment for FITS-header

  char unit[4];         - optional unit
```

```
    int flag;            - storage space for application specifc flags
                           (initial value is 0)

    int ctrlList;        - controller modules (sequencer), where the
                           parameter is used. This is a bit-list
                           maintaining up to 32 controller modules
                           (bit 0 for 1st. module, bit 1 for 2nd. module
                           and so on).

    int acqList;         - acquisition -processes, where the parameter
                           is  used. This is a bit-list maintaining up
                           to 32 acquisition processes (bit 0 for
                           1st. module, bit 1 for 2nd. module and so on).

  ngcbPARAM_LIST class:

    ngcbPARAM *param;    - pointer to parameter object

    ngcbPARAM_LIST *next; - pointer to next list element
```

RETURN VALUES

```
  If not specified differently, all functions return ngcbSUCCESS
  in case of success. Otherwise ngcbFAILURE is returned and the
  ErrMsg() method will return a detailed error message.
```

EXAMPLES

```
  Example for "walking" through a parameter list:

      ngcbPARAM_LIST list;
      ngcbPARAM_LIST *l;
      ngcbPARAM *p;

      // Add some parameters to the list...
      list.Add("Parameter1", "value");
      list.Add("Parameter2", (char)1);
      list.Add("Parameter3", (int)5);
      list.Add("Parameter4", (float)0.1);
      list.Add("Parameter5", (double)0.2);
      list.Add("Parameter6", "1.1", ngcbPARAM_FLOAT);

      p = list.Get("Parameter3");
      if (p != (ngcbPARAM *)NULL)
        {
        strcpy(p->format, "0x%08x");
        }

      // Now just print the whole list
      for (l=list.First();l!=(ngcbPARAM_LIST *)NULL;l=l->next)
        {
        p = l->param;
        printf("%s = %s\n", p->name, p->Get());
        }
```

1.10 ngcbIFC Class

NAME

ngcbIFC - NGC interface class

SYNOPSIS

```
#include <ngcbIFC.h>

ngcbIFC interface();
```

DESCRIPTION

This class defines the general basic interface functions
(Open, Close, Read, Write, etc.) to the NGC front end.
It is functional for a locally installed standard NGC interface
board. In case the board is installed on another computer a
driver interface process has to be started on that computer.
Apart from the process startup which should happen via the
overloaded ExecServer()/KillServer() methods, the functionality
of the interface should be transparent to the application.
Most public functions can be overloaded to provide the appropriate
client part of an interprocess communication.

PUBLIC METHODS

```
ngcbIFC();
    Constructor method.

ngcbIFC(const char *name);
    Constructor method with default interface name.

virtual ~ngcbIFC();
    Destructor method. This will in any case call the Close() method.

virtual int Open();
virtual int Open(const char *name);
    Opens an interface device. If <name> is not specified
    the default device name from the constructor is taken.
    If a driver interface process is used, the name will
    contain the information which interface process to
    start on which host in an application specific format.

virtual int Close();
    Closes an interface device.

virtual int ExecServer()
    Start driver interface process. The information which
    process to start on which host should be retrieved from
    the Name() method.

virtual int KillServer()
    Exit/Kill the driver interface interface process.

virtual int Connect();
    Only for driver interface interfaces: connect through to device
    (i.e. send a command to the driver interface process to
    open the device).

virtual int Disconnect();
    Only for driver interface interfaces: disconnect from the device
    (i.e. send a command to the driver interface process to
    close the device).

virtual int Fd();
    Returns the (remote-) interface file descriptor.

virtual int Pid();
    Returns the process id of the driver interface process or zero
    in case no driver interface process is used.
```

```
virtual const char *Host();
    Returns the host name of the driver interface process or a NULL
    pointer in case no driver interface process is used.

virtual int Reset();
    Resets/intializes an interface device.

virtual int Read(int *buffer, int size);
    Read <size> words from device. The function returns the status
    word of the operation (see below for further details).

virtual int Write(int *buffer, int size);
    Write <size> words to device. The function returns the status
    word of the operation (see below for further details).

virtual int ReadAddr(ngcb_route_t route,
                     int addr, int *buffer, int size, int *result);
    Reads size words from <addr> into buffer. <result> returns
    a status word for the operation (see below for further details).
    The operation implements a 4-byte-swap in case the calling
    computer has a big-endian architecture. The ngcb_route_t
    structure contains the following elements:

      int numHdr;             - number of headers to target including
                                the terminating <0x2>
      int hdr[ngcbMAX_MOD];   - array of headers including the
                                terminating <0x2>

virtual int WriteAddr(ngcb_route_t route,
                      int addr, int *buffer, int size, int *result);
    Writes size words from buffer to <addr>. <result> returns
    a status word for the operation (see below for further details).
    The operation implements a 4-byte-swap in case the calling
    computer has a big-endian architecture.

int ReadAddr(ngcb_route_t route, int addr, int *buffer, int size);
int WriteAddr(ngcb_route_t route, int addr, int *buffer, int size);
    Same as above but these interfaces hide the result code in case it
    is not needed. These methods call the virtual ReadAddr()/WriteAddr()
    method described above and need not to be overloaded by specific
    interface implementations.

virtual int Status()
    Returns the status of the interface board.

virtual int Timeout(int seconds);
    Sets a new timeout for read/write operations (in seconds).

virtual int Timeout();
    Returns the current timeout (in seconds);

virtual int Running();
    Returns 1 in case the driver interface process is running.
    Otherwise the function returns zero. This method is
    fully application specific.

virtual int Connected();
    Returns 1 in case the driver interface process is connected
    to the device (i.e. device is open). Otherwise the function
    returns zero.

virtual void Verbose(const char *format, ...);
    Verbose method. A message is passed to the verbose output depending
    on the current verbose level. If the verbose level is zero,
    the message is ignored.

virtual void Log(const char *format, ...);
    Log method.
```

```
virtual int Sim(int flag)
    Switch to simulation mode.

int WriteBuffer(int *buffer, int size, int *result)
    Writes a formatted buffer to the device. The format is:
    <hdr1 hdr2 ... hdrN address data1 data2 ...>
    <result> returns the status word for the operation. An error
    message can be retrieved via the Result2Err() method.
    The operation implements a 4-byte-swap in case the calling
    computer has a big-endian architecture. This method calls
    the virtual WriteAddr() method and needs not to be
    overloaded by specific interface implementations.

char *Name();
    Returns the current interface(-device) name, as specified in
    the constructor or in the last Open() call. Can also be used
    to set a new (default-) name.

char *Type();
    Returns a pointer to the interface type identifier string.

char *Arg();
    Returns a pointer to the interface argument string. The
    argument string is intended to be passed to a driver interface
    process as command line.

void Instance(int instance);
    Sets an interface instance number. This ist just intended
    to store an outside reference index, to be given back
    via the Instance() method. The instance number is not
    used or changed inside this base interface class.

int Instance();
    Returns the interface instance number.

int Standby();
    Bring interface device to standby state. The driver interface process
    (if required) is alive, but the physical device is disconnected
    (i.e. closed).

int Online();
    Bring interface device to on-line state. The driver interface
    process (if required) is alive and the physical device is
    connected (i.e. opened). If the device was disconnected before
    (i.e. was in standby- or off-state), a hardware reset is performed.

int Off();
    Bring interface device to off-state. The physical devices is
    disconnected and the driver interface process is not alive.

char *ErrMsg();
    Returns the current error message in case of failure.

int BigEndian();
    Returns 1 in case the computer architecture is big-endian.
    Otherwise the function returns zero.

void Result2Err(char *errStr, int resultCode)
    Fills <errStr> with an error string matching the result code.
```

PUBLIC DATA MEMBERS

```
int ioError;       - Indicates that the preceeding transaction caused
                     an i/o error (generally the connection should be
                     reset in that case).

int local;         - If set to 1 the interface device is local. Otherwise
                     it is installed on on a different computer and
                     communication is done via a driver interface process.
```

```
int sim;           - Interface simulation level (0 = normal mode).

int xterm;         - Start driver interface process in new terminal.

int verboseLevel;  - Verbose level

int logLevel;      - Log level

char thisHost[64]; - Host where this instance is launched

ngcb_vb_t verboseHandler;
    External verbose handler to be used instead of the built-in
    one:

      void myHandler(int flag, const char *format, ...)

    The usage is the as printf plus an additional flag which can
    be one of:

      ngcbVB_PRINT     - pass message to verbose output
      ngcbVB_LOG       - log message

ngcb_es_t errStateHandler;
    External error-state handler of type:

      void myHandler(char *erms, ngcbIFC *module)
```

RETURN VALUES

```
If not specified differently, all functions return ngcbSUCCESS in case
of success. Otherwise ngcbFAILURE is returned and ErrMsg() will contain a
detailed error message.

The status word for device i/o (resultCode) may have the following
values:

    ngcbRES_SUCCESS (0)   - successful operation

    Bit 0..7 - operation status byte (ngcbRES_ERR_IO is not set):

    ngcbRES_OP_INVALID    - invalid address or function
    ngcbRES_OP_FAILURE    - operation failed
    ngcbRES_ERR_HDR       - wrong header
    ngcbRES_ERR_ADDR      - wrong address
    ngcbRES_ERR_DATA      - wrong data
    ngcbRES_ERR_XSIZE     - wrong transfer size
    ngcbRES_ERR_NOT_OPEN  - device is not open

    Bit 8..16 - combination of error bits (ngcbRES_ERR_IO is set):

    ngcbRES_ERR_IO        - i/o error
    ngcbRES_ERR_INTR      - i/o interrupted
    ngcbRES_ERR_OPEN      - error opening device
    ngcbRES_ERR_RESET     - error resetting device
    ngcbRES_ERR_TIMEOUT   - i/o timeout
    ngcbRES_ERR_LINK_DOWN - link channel down
    ngcbRES_ERR_LINK_HARD - link channel hard error
    ngcbRES_ERR_LINK_SOFT - link channel soft error
    ngcbRES_ERR_LINK_FRAM - link channel framing error

    An error string can be retrieved via the Result2Err() method.
    Usually the error message is also in ErrMsg(), but it might
    be required to have the real error code to react on individual
    error conditions without doing ambiguous string parsing again.
```

SEE ALSO

```
ngcbDrvCom(3)
```

1.11 ngcbIFC_MSG Class

NAME

ngcbIFC_MSG - CCS message system interface class

SYNOPSIS

```
#include "ngcbIFC_MSG.h"

ngcbIFC_MSG connection()
```

PARENT CLASS

ngcbIFC_MSG: public ngcbIF

DESCRIPTION

CCS message system interface class. The parent class ngcbIF is overloaded with the appropriate client functions - see man-page for ngcbIFC(4). Interface type is "ccs". The name consists of the tuple "environment,serverName" or only "environment" (in that case the default driver interface process <ngcb2Drv> would be started).

PUBLIC METHODS

```
ngcbIFC_MSG(eccsERROR *s);
    Constructor method.

ngcbIFC_MSG(const char *name, eccsERROR *s);
    Constructor method with default name.

ngcbIFC_MSG(const char *instance, const char *name, eccsERROR *s);
    Constructor methods with instance and default name.

virtual ~ngcbIFC_MSG();
    Destructor method.
```

RETURN VALUES

If not specified differently, all functions return ngcbSUCCESS in case of success. Otherwise ngcbFAILURE is returned, an error is added to the error-stack and the ErrMsg() method will return a detailed error message.

SEE ALSO

ngcbIFC(4), msgMESSAGE(4)

1.12 ngcbSIM Class

NAME

ngcbSIM - NGC front-end module simulator class

SYNOPSIS

```
#include <ngcbSIM.h>

ngcbSIM module();
```

DESCRIPTION

NGC front-end module simulator class. The simulator configures itself dynamically via the system headers sent with the write() system call. A new simulator object is created recursively for every NGC hardware module defined via the link configuration register. It provides all NGC hardware registers including sequencer pattern- and program-RAM. The voltage setting is sloped to the telemetry values via the DAC - ADC conversion function. The message packets are routed to the right destination instance using the information in the routing headers. The result is automatically passed back recursively to the main entry point (first ngcbSIM instance). Timeouts and errors can be simulated by accessing unused addresses at any module instance:

```
  ngcbTESTERR_NO_ACK (0x100)    - no acknowledge
  ngcbTESTERR_IVLD (0x101)      - invalid address
  ngcbTESTERR_SEQ_EMPTY (0x200) - sequencer FIFO becomes empty
  ngcbTESTERR_SEQ_IDLE (0x201)  - sequencer goes to idle state
```

PUBLIC METHODS

```
ngcbSIM();
    Constructor method.

virtual ~ngcbSIM();
    Destructor method.

int Status();

void Timeout(int seconds);
    Set timeout in seconds. This will implement an appropriate
    delay for the ngcbTESTERR_NO_ACK error simulation or in
    case the required up-stream channels had not been enabled.

void Reset();
    Reinitialize all register values.

int Write(int *buffer, int size);
    Handle the write system call on the main entry point
    (first instance).

int Execute(int *fifoBuf, int *buffer, int size, int length);
    Extract next header element from <buffer> and either execute
    a (private) read-from-address/write-to-address function on this
    instance or cut the header element from the route and pass
    the buffer to one of the next connected simulator objects
    as described in the header part of the buffer. The <fifoBuf>
    represents the RX-FIFO on the hardware interface device.
    All results are stored in that buffer and can finally
    be read-out via the Read() method. The handshake signals are
    set properly by the responding simulator instance.

void Read(int *buffer, int size);
    Handle the read system call on the main entry point
    (first instance).

virtual void Verbose(const char *format, ...);
    Verbose method. A message is passed to the verbose output depending
    on the current verbose level. If the verbose level is zero,
    the message is ignored.
```

```
virtual void Log(const char *format, ...);
    Log method.

int *Fifo();
    Returns a pointer to the FIFO buffer, where to store the
    the actual data. Methods overloading the ReadCB() callback
    must always store the result into here.

void Sync();
    Handle the sychnronous start signal;

virtual void ResetCB()
    Callback to initialize additional stuff.

virtual int WriteCB(int addr, int *buffer, int size);
    Callback to install additional functionality to the
    write-to-address function accessing this instance.

virtual int ReadCB(int addr, int size);
    Callback to install additional functionality to the
    read-from-address function accessing this instance.
```

PUBLIC DATA MEMBERS

```
ngcbSIM *mod[ngcbNUM_LINK]; - Next connected modules

ngcbSIM *mod0;              - First module (entry point)

int verboseLevel;           - Verbose level

int logLevel;               - Log level

ngcb_vb_t verboseHandler;
    External verbose handler to be used instead of the built-in
    one:

      void myHandler(int flag, const char *format, ...)

    The usage is the as printf plus an additional flag which can
    be one of:

      ngcbVB_PRINT - Pass message to verbose output
      ngcbVB_LOG   - Log message
```

PRIVATE METHODS

```
int WriteAddr_(int addr, int *buffer, int size);
  Write-To-Address function to be handled by this simulated
  module instance. The function will call the WriteCB() callback
  in case the address could not be resolved.

int ReadAddr_(int addr, int size);
  Read-From-Address function to be handled by this simulated
  module instance. This will store the result into the
  global RX-FIFO buffer. he function will call the ReadCB() callback
  in case the address could not be resolved.
```

RETURN VALUES

```
The Write() method returns the number of data words written.
A zero value indicates an error and the status should be checked
via the Status() method.

The Fifo() method returns a pointer to the FIFO buffer, where to
store the the actual data for read-from-address operations.

The Status() method returns the content of the interface status
register.
```

```
The Execute() and the ReadCB()/WriteCB() callbacks return a result
code for the executed operation. The result code consists of the
following or'ed bit values:

  ngcbIFC_STAT_ACK      - acknowledge received
  ngcbIFC_STAT_VALID    - address was valid
  ngcbSIM_UPDATE_STATUS - status invariant operation (all header 0x8
                          functions accessing the local configuration
                          register)
```

SEE ALSO

```
ngcbIFC(4), ngcbMOD(4)
```

1.13 ngcbNET Class

NAME

ngcbNET, ngcbBOARD - NGC network structure classes

SYNOPSIS

```
#include <ngcbNET.h>

ngcbBOARD board();

ngcbNET network();
```

DESCRIPTION

NGC network structure classes. These classes describe a module network connected to the physical interface. The network may have a chain- or a tree-structure. The ngcbBOARD class describes one physical board in the network. The ngcbNET class describes the overall network. The boards need to be enabled after reset. An appropriate Enable() method provides this functionality for each board.

PUBLIC METHODS

ngcbBOARD class:

```
ngcbBOARD();
    Constructor method.

virtual ~ngcbBOARD;
    Destructor method deleting all boards on the downlinks.

int Enable(ngcbIFC *dev, char *erms);
    Enables this board and all connected boards on the
    downlinks.

int BoardInfo()
    Update board information. This retrieves the product codes and
    the actual board temperature from the NGC hardware.

void Dump(char *s);
void Dump(FILE *s);
    Dump board information to a string or to an output stream.
```

ngcbNET class:

```
ngcbNET();
    Constructor method.

ngcbNET(ngcbIFC *interface);
    Constructor method defining the interface device to access
    the NGC network.

int Add(ngcb_route_t route, char *erms);
    Add a route to a module to the network. This will automatically
    create not yet existing boards on the route.  The ngcb_route_t
    structure contains the following elements:

      int numHdr;             - number of headers to target including
                                the terminating <0x2>
      int hdr[ngcbMAX_MOD];   - array of headers including the
                                terminating <0x2>

int Enable(char *erms);
    Enable the whole network.

void Dump(char *s);
void Dump(FILE *s);
    Dump network information to a string or to an output stream.
```

PUBLIC DATA MEMBERS

```
       ngcbBOARD class:

         ngcbIFC *dev;                    - interface device (passed through)

         ngcb_route_t route;              - route to board

         int numLink;                     - number of downlinks to activate

         int boardId;                     - unique board id

         int productCode;                 - Product code

         int revision;                    - Revision number

         int serialNumber;                - Derial number

         int temperature;                 - Board temperature

         ngcbBOARD *board[ngcbNUM_LINK]; - boards on downlinks

       ngcbNET class:

         ngcbBOARD mainBoard;  - first board in network

         ngcbIFC *dev;          - interface device to access the NGC network
```

RETURN VALUES

```
       If not specified differently, all functions return ngcbSUCCESS
       in case of success. Otherwise ngcbFAILURE is returned and the
       <erms> will return a detailed error message.
```

SEE ALSO

```
       ngcbIFC(4)
```

1.14 ngcbOBJ Class

NAME

ngcbOBJ - general NGC object class

SYNOPSIS

```
#include <ngcbOBJ.h>

ngcbOBJ object();
```

DESCRIPTION

General NGC object class. This is the parent class of both the NGC hardware modules and the acquisition process interface.

PUBLIC METHODS

```
ngcbOBJ();
    Constructor method.

void Instance(int n);
int Instance();
    Functions to trace an instance number for this object.
    If not set, the instance is zero.

int LogErr(char *pos)
    Logs the actual code position and then calls the Failure()
    call-back. Generally intended to be be called with the
    argument macro NGCB_CODE_POS.

virtual char *ErrMsg();
    Returns the current error message in case of failure.

virtual void Verbose(const char *format, ...);
virtual void Verbose(int level, const char *format, ...);
    Verbose method. A message is passed to the verbose output depending
    on the current verbose level. If the verbose level is zero,
    the message is ignored. The second version only prints the message
    if the verbose level exeeeds the given <level>.

virtual void Log(const char *format, ...);
virtual void Log(int level, const char *format, ...);
    Log method. If the verbose level is zero, the message is ignored.
    The second version only logs the message if the log level
    exeeeds the given <level>.

virtual int Success();
virtual int Failure();
    Callbacks for SUCCESS and FAILURE return. These are defined
    by default to return ngcbSUCCESS/ngcbFAILURE. Further error
    handling/logging can be added here. Applications may also
    use the return(ngcbMOD_ERR) macro, which will additionally
    log the current code-position before executing the Failure()
    callback.
```

PUBLIC DATA MEMBERS

```
int xterm;         - Start sub-processes in new terminal.

int verboseLevel;  - Verbose level

int logLevel;      - Log level

ngcb_vb_t verboseHandler;
    External verbose handler to be used instead of the built-in
    one:

      void myHandler(int flag, const char *format, ...)
```

```
The usage is the as printf plus an additional flag which can
be one of:

  ngcbVB_PRINT  - pass message to verbose output
  ngcbVB_LOG    - log message
```

RETURN VALUES

```
If not specified differently, all functions return ngcbSUCCESS
in case of success. Otherwise ngcbFAILURE is returned and the
ErrMsg() method will return a detailed error message.
The Success()/Failure() callbacks can be used to overload the
return values and to add some individual error handling/logging.
```

1.15 ngcbMOD_CLASS

NAME

ngcbMOD - general NGC front-end module class

SYNOPSIS

```
#include <ngcbMOD.h>

ngcbMOD module();
```

PARENT CLASS

ngcbMOD: public ngcbOBJ

DESCRIPTION

General NGC front-end module class. This is the parent class of all NGC front-end modules (sequencer, CLDC, ADC).

PUBLIC METHODS

```
ngcbMOD(ngcb_route_t);
    Constructor method specifying the local route to the
    module inside the front-end (header).

ngcbMOD(ngcbIFC *dev, ngcb_route_t);
    Constructor method specifying the interface device and
    the local route to the module inside the front-end (header).

virtual ~ngcbMOD();
    Destructor method.

ngcb_route_t *Route();
    Returns the local route to the module inside the
    front-end (header).

ngcbIFC *Dev();
    Returns the interface device.

void Dev(ngcbIFC *dev);
    Assings a new device to the module.

int Initialize();
    Initialize module (e.g. read product information).

int ReadAddr(int addr, int *buffer, int size);
    Reads size words from <addr> into buffer.

int WriteAddr(int addr, int *buffer, int size);
    Writes size words from buffer to <addr>.

int Temperature(int *t);
    Read temperature of the board, where this module resides.

virtual void Reset();
    Call-back function to align soft-states after reset.

virtual int Online();
    Call-back function executed when going to ONLINE-state.

virtual int Standby();
    Call-back function executed when going to STANDBY-state.
```

PUBLIC DATA MEMBERS

```
char name[64];       - Optional name for this module

ngcbIFC *dev;        - Interface device assosiacted with this module
```

```
ngcb_route_t route;  - Local route to the module inside the
                       front-end (header)

int productCode;     - Product code

int revision;        - Revision number

int serialNumber;    - Serial number
```

RETURN VALUES

If not specified differently, all functions return ngcbSUCCESS in case of success. Otherwise ngcbFAILURE is returned and the ErrMsg() method will return a detailed error message. The Success()/Failure() callbacks from the ngcbOBJ class can be used to overload the return values and to add some individual error handling/logging.

SEE ALSO

ngcbOBJ(4), ngcbIFC(4)

1.16 ngcdcsCLDC_CLASS

NAME

ngcdcsCLDC_CLASS - NGC clock- and bias-driver class

SYNOPSIS

```
#include <ngcdcsMOD_CLASS.h>

ngcdcsCLDC_CLASS cldc();
```

PARENT CLASS

ngcdcsCLDC_CLASS: public eccsERROR_CLASS, public ngcbMOD

DESCRIPTION

NGC clock- and bias-driver class.

PUBLIC METHODS

```
ngcdcsCLDC_CLASS(ngcb_route_t route);
    Constructor method specifying the local route to the
    module inside the front-end (header).

ngcdcsCLDC_CLASS(ngcbIFC *dev, ngcb_route_t route);
    Constructor method specifying the interface device and
    the local route to the module inside the front-end (header).

virtual ~ngcdcsCLDC_CLASS();
    Destructor method.

void Reset();
    Align soft-states after reset;

ccsCOMPL_STAT Online(int check=1)
    Hook method, which is executed when going online. If the
    <check> flag is set, then the telemetry values are checked
    against the current voltage setup before going on-line.

ccsCOMPL_STAT Standby();
    Hook method, which is executed when going standby.

ccsCOMPL_STAT Calibrate();
    Calibrate (offset compensation). This will disable the
    CLDC output first.

void ClearCalibration();
    Clears the calibration.

ccsCOMPL_STAT Check();
    Check the telemetry against the current setup. An error is
    returned, when the deviation of one of the telemetry values
    exceeds the margin given in the public data member <margin>.

ccsCOMPL_STAT Selftest();
    Perform a selftest. The output is disabled before the test
    starts.  The voltage setup has to be re-loaded afterwards.

ccsCOMPL_STAT OffsetClk(double volt);
    Set the offset for the clock voltages.

ccsCOMPL_STAT OffsetDC(double volt);
    Set the offset for the bias voltages.

double OffsetClk();
    Returns the offset for the clock voltages.

double OffsetDC();
    Returns the offset for the bias voltages.
```

```
ccsCOMPL_STAT DacChan(int chan, double volt)
    Set voltage on a specific DAC channel.

ccsCOMPL_STAT VoltageDC(int num, double volt, int rangeCheck=1);
    Set bias voltage.

ccsCOMPL_STAT VoltageClk(int num, int l, double volt, int rangeCheck=1);
    Set voltage for clock level <l>.

ccsCOMPL_STAT VoltageClk(int num, ngcdcs_clkv_t cv, int rangeCheck=1);
    Set voltage for clock (all levels).

ccsCOMPL_STAT Setup();
    Apply the voltage setup as specified in the public clock and
    DC-voltage arrays.

ccsCOMPL_STAT TelChan(int chan);
    Set telemetry channel.

ccsCOMPL_STAT TelData(double *volt);
    Read current telemetry data.

ccsCOMPL_STAT TelDC(int num, double *volt);
    Telemetry for bias voltage.

ccsCOMPL_STAT TelClk(int num, int l, double *volt);
    Telemetry for clock voltage level <l>.

ccsCOMPL_STAT TelClk(int num, ngcdcs_clkv_t *cv);
    Telemetry for clock voltage (all levels).

int Enabled();
    Returns 1 in case the CLDC output is enabled.

ccsCOMPL_STAT Enable();
    Enable CLDC output.

ccsCOMPL_STAT Disable();
    Disable CLDC output.

const char *StatusString();
    Return a string matching the CLDC status (enabled or disabled).

ccsCOMPL_STAT Zero();
    Set all CLDC voltages and all offsets to zero volts.

ccsCOMPL_STAT Monitor(int num, int chan);
    Set clock channel number for clock monitor. <num> specifies
    the clock monitor number (1 or 2).

virtual double ConvertTel(int value);
    Convert digital value of telemetry ADC to a voltage.

virtual int Volt2Reg(double *volt, int chan, double corr=1.0);
    Convert voltage for DAC channel <chan> to a digital value.
    <corr> specifies a correction factor to be applied.

virtual double Reg2Volt(int regVal, int chan, double corr=1.0);
    Convert register value of DAC channel <chan> to a voltage.
    <corr> specifies a correction factor to be applied.

virtual ccsCOMPL_STAT LoadCfgFile(const char *fileName=NULL);
    Load voltage configuration file. This is supposed to fill
    the public clock- and DC-voltage setup arrays. A setup is done
    afterwards.
```

```
virtual ccsCOMPL_STAT SaveCfgFile(const char *fileName);
    Save current setup to a voltage configuration file.
```

PUBLIC DATA MEMBERS

```
int status;              - Soft status:

    ngcbCLDC_STAT_ENABLED   - enabled
    ngcbCLDC_STAT_DISABLED  - disabled

int autoEnable;          - Enable voltage outputs when going on-line.
                           Default is 0.

char cfgFile[256];       - Current voltage file

ngcdcs_clk_t *clk;       - Array of clock voltages

ngcdcs_clkv_t *clkTel;   - Array of saved clock voltages telemetry values

int numClk;              - Number of clock voltages

double offsetClk;        - Offset for clock voltages (default is 0.0)

ngcdcs_dc_t *dc;         - Array of bias voltages

double telemetryGain;    - Gain factor for telemetry (default is 1.5,
                           which corresponds to a range of +-15 V).

double *dcTel;           - Array of saved bias voltages telemetry values

int telFlag;             - Flag to update telemetry. This is always set
                           to one, in case a voltage has changed. It
                           cane be used to trace the voltage setting.
                           Must be reset by the instantiating application.

int numDc;               - Number of bias voltages

double offsetDC;         - Offset for bias voltages (default is 0.0)

int clkMon1;             - Clock on monitor 1

int clkMon2;             - Clock on monitor 2

double margin;           - Margin for telemetry check (in volts).
                           The default value is 0.0 volts (telemetry
                           disabled).

The ngcdcs_clk_t object contains the following members:

    ngcdcs_dc_t level[ngcdcsCLDC_DCLK]; - setup for all levels

The ngcdcs_dc_t object contains the following members:

  double volt;           - Setup value
  double range[2];       - Range
  double dacCorr;        - DAC correction factor
  double telCorr;        - Telemetry correction factor
  int dacChan;           - DAC channel
  int telChan;           - ADC channel for telemetry
  char name[64];         - Name of the voltage

The ngcdcs_clkv_t object contains the members:

  double volt[ngcdcsCLDC_DCLK]; - Voltage values for all levels
```

RETURN VALUES

```
       If not specified differently, all functions return SUCCESS
       in case of success. Otherwise FAILURE is returned and an
       error is added to the error-stack.
```

CAUTIONS

```
       All channel numbers (clock, bias, DAC, telemetry, clock-monitor),
       which are given as argument to the above member functions,
       start with zero!
```

SEE ALSO

```
       ngcbIFC(4), ngcbMOD(4)
```

1.17 ngcdcsSEQ_CLASS

NAME

ngcdcsSEQ_CLASS - NGC sequencer class

SYNOPSIS

```
#include <ngcdcsMOD_CLASS.h>

ngcdcsSEQ_CLASS seq();
```

PARENT CLASS

ngcdcsSEQ_CLASS: public eccsERROR_CLASS, public ngcdcsMOD

DESCRIPTION

NGC sequencer class.

PUBLIC METHODS

```
ngcdcsSEQ_CLASS(ngcb_route_t route);
    Constructor method specifying the local route to the
    module inside the front-end (header).

ngcdcsSEQ_CLASS(ngcbIFC *dev, ngcb_route_t route);
    Constructor method specifying the interface device and
    the local route to the module inside the front-end (header).

ngcdcsSEQ_CLASS(ngcb_route_t route, ngcbPARAM_LIST *p);
    Constructor method specifying the local route to the
    module inside the front-end and a pointer to a dynamic
    parameter list.

ngcdcsSEQ_CLASS(ngcbIFC *dev, ngcb_route_t route, ngcbPARAM_LIST *p);
    Constructor method specifying the interface device and
    the local route to the module inside the front-end and
    a pointer to a dynamic parameter list.

virtual ~ngcdcsSEQ();
    Destructor method.

void Reset();
    Align soft-states after reset;

ccsCOMPL_STAT Online();
    Hook method, which is executed when going online.

ccsCOMPL_STAT Standby();
    Hook method, which is executed when going standby.

ccsCOMPL_STAT Selftest();
    Perform a selftest.

ccsCOMPL_STAT TriggerMode(int flag);
    Enable (flag = 1) or disable (flag = 0) the trigger mode. When the
    trigger mode is disable the sequencer does never wait for the
    external trigger.

ccsCOMPL_STAT RunCtrl(int flag);
    Enable (flag = 1) or disable (flag = 0) external run-control
    for this instance. When run-control is disabled this sequencer
    instance will not be started automatically via the run-signal
    line on the backplane.

ccsCOMPL_STAT Start(int sync);
    Start sequencer. If the <sync>-flag is set to 1, then the run-signal
    on the backplane is also raised to start further sequencer
    instances on the same backplane.
```

```
ccsCOMPL_STAT Step(int sync);
    Start sequencer and run till next break-point. If the <sync>-flag
    is set to 1, then the run-signal on the backplane is also raised
    to start further sequencer instances on the same backplane.

ccsCOMPL_STAT Stop(int force=0);
    Stop sequencer immediately. If the force-flag is set to 1 the
    command will be sent regardless of the actual sequencer state.
    Otherwise it will only be sent when not in idle state.

ccsCOMPL_STAT Break();
    Let sequencer stop at next breakpoint.

ccsCOMPL_STAT Break(int timeout, int interval=100);
    Let sequencer stop at next breakpoint and wait with timeout
    (in seconds) for sequencer program termination. A polling interval
    in milliseconds can be given (default is 100).

 ccsCOMPL_STAT Wait(int event, int timeout, int interval=100);
    Wait with timeout (in seconds) for sequencer program event.
    A negative value will set an infinite timeout. A polling interval
    in milliseconds can be given (default is 100). The routine returns
    immediately with an error, in case the sequencer goes to failure
    state. The event can be one of the following:

      ngcbSEQ_STAT_WAITING - sequencer is waiting for trigger

      ngcbSEQ_STAT_PRGEND  - program end bit is set or sequence
                             has terminted

      ngcbSEQ_STAT_BREAK   - break-point has been reached or
                             sequence has terminated

int BreakTimeout(double *timeout);
    Returns a timeout (in seconds) to be used for the break-command.
    This is the maximum time which may pass until a break-point is
    reached. If none of the patterns executed by the current program
    contains a break-point, or if the program contains infinite loops
    without any break-point, the routine will return -1 (= infinite)
    and the calling application should use the Stop() command rather
    than the Break() command. If no valid clock pattern setup or no
    valid program is currently loaded, an error is returned.

ccsCOMPL_STAT Trigger();
    Send a trigger command.

ccsCOMPL_STAT Status(int *hwStatus);
    Get sequencer hardware status.

void NewStatus(int newStatus);
    Set a new status (soft-status only).

const char *StatusString();
    Returns a string matching the sequencer soft state
    (idle, running, failure).

int RunningState();
    Returns 1 if the sequencer is in running state. Otherwise
    zero is returned.

int FailureState();
    Returns 1 if the sequencer is in failure state. Otherwise
    zero is returned.

ccsCOMPL_STAT PatTime(ngcdcs_pat_t pat, int apply=1);
    Compute execution time of pattern <pat>.

int PatNumStates(ngcdcs_pat_t pat);
    Compute number of states in pattern <pat>.
```

```
void DumpPat(char *reply, ngcdcs_pat_t pat);
    Dump pattern <pat> to a string.

void StorePatSetup();
    Store all global patterns to private copy.

ccsCOMPL_STAT RestorePatSetup();
    Restore all global patterns from private copy.

ccsCOMPL_STAT SetupPat();
    Download all defined global patterns.

ccsCOMPL_STAT SetPat(int idx, ngcdcs_pat_t pat);
    Set clock pattern. This will also apply the global dwell time
    factor/add if applicable. If the operation was successful,
    the pattern is copie to the global pattern structure at the
    given index <idx>.

ccsCOMPL_STAT GetPat(ngcdcs_pat_t *pat);
    Retrieve a pattern defined by the address (pat.addr) from the
    sequencer pattern ram.

ccsCOMPL_STAT GetPat(int idx, ngcdcs_pat_t *pat);
    Retrieve a pattern by index from the sequencer pattern ram
    (idx = pattern number).

ccsCOMPL_STAT SetPatClk(int idx, int clkNum, const char *s)
    Set a specific clock timing in a pattern.

ccsCOMPL_STAT DwellTime(int factor, int add);
    Set global dwell time factor+add.

ccsCOMPL_STAT TimeFactor(int factor);
    Set global dwell time factor.

ccsCOMPL_STAT TimeAdd(int add);
    Set global dwell time add.

ccsCOMPL_STAT CleanLoop(int *code, int *codeLength);
    Check loop structures in <code> and remove zero loops.

int ExecTime(double *execTime)
    Compute execution time of whole sequencer program. A negative value
    indicates an infinite loop.

ccsCOMPL_STAT ExecTime(double *execTime, int *code, int length)
    Compute execution time in seconds for a piece of sequencer program
    code (i.e. subroutine).

ccsCOMPL_STAT ResolveSubRt(ngcdcs_seqp_t *prg);
    Resolve subroutines addresses defined in sequencer program
    main code of <prg>. This will fill the all subroutine structures
    including <name> and <time> (see below for structure details).

ccsCOMPL_STAT CheckPrg(ngcdcs_seqp_t *prg);
    Check the sequencer program and cleanup the loop-structures
    in main code and in all resolved sub-routines.

ccsCOMPL_STAT SetupPrg();
    Download current global sequencer program structure.

ccsCOMPL_STAT SetPrg(ngcdcs_seqp_t prg);
    Write the sequencer program <prg> to the controller RAM and
    (if this was successful) copy it to global sequencer program
    structure.

ccsCOMPL_STAT GetPrg(ngcdcs_seqp_t *prg);
    Read sequencer program from controller RAM. The subroutines
```

```
        within <prg> will be resolved automatically.

    void DumpPrg(char *, ngcdcs_seqp_t prg, int n = -1);
        Dump sequencer program <prg> to string:

            n < 0  - whole program
            n = 0  - main program
            n > 0  - subroutine <n>

    void DumpCode(char *reply, ngcdcs_seqp_t prg, int offset, int length);
        Dump piece of sequencer program code to string.

    ccsCOMPL_STAT MinPulse(double *min, int clkNum)
        Compute the minumum distance between two rising edges
        for the given clock number. The <min> value is returned in
        nanoseconds. A negative value indicates that the signal-line
        is not toggling.

    ccsCOMPL_STAT PulseCnt(int *rising, int *falling, int clkNum);
        Compute number of rising/falling edges on the given clock within
        sequencer program. Infinite loops are executed once.

    ccsCOMPL_STAT Parameters(const char *fileName, char *list)
        Appends to the <list> string all parameter names (separated by
        new-line character) which are used by the sequencer program file
        given by <fileName>. The function recursively scans all included
        files.

    ccsCOMPL_STAT LoadClkFile(const char *fileName);
        Load clock pattern file.

    ccsCOMPL_STAT SaveClkFile(const char *fileName);
        Save clock pattern file.

    ccsCOMPL_STAT LoadPrgFile(const char *fileName);
        Load sequencer program file. Two formats (ASCII and BIN) are
        supported by default. Other formats can be added by overloading
        the PrgFile() callback.

    ccsCOMPL_STAT ClearPrgFile();
        Clear sequencer program file. This should be done before loading
        a complete new setup, in order to avoid automatic re-loading of
        the last program upon various parameter setups.

    virtual ccsCOMPL_STAT LoadClk(const char *fileName);
        Callback to load sequencer clock pattern file in application
        specific format.

    virtual ccsCOMPL_STAT SaveClk(const char *fileName);
        Callback to load sequencer clock pattern file in application
        specific format.

    virtual ccsCOMPL_STAT PrgFile(const char *fileName);
        Callback to load sequencer program file in application
        specific format.

    virtual int LookupCB(const char *name, char *value);
        Callback for parameter lookup. The function must return
        non-zero in case the parameter given by its <name> has
        been resolved and the value had been properly set. Otherwise
        zero must be returned.
```

PUBLIC DATA MEMBERS

```
    double clock;      - Sequencer clock (default: 10 ns)

    int status;        - Soft status:

        ngcdcsSEQ_STAT_IDLE     -  idle
        ngcdcsSEQ_STAT_RUNNING  -  running
```

```
    ngcdcsSEQ_STAT_FAILURE  -  failure

int runCtrl;       - External run-control enabled (default is 1).

int continuous;    - Continuous mode flag (default is 0). This would
                     issue a restart at each exposure.

int triggerMode;   - Triggered mode flag (default is 0). This would
                     enable the wait-for-trigger state. If not set,
                     the wait-for-trigger state is ignored. The value
                     only becomes valid at next start. Use the
                     TriggerMode() function to enable/disable the
                     trigger mode at run-time.

int timeFactor;    - Global dwell time factor (default is 1)

int timeAdd;       - Global value to be added to dwell time (default is 0)

int updateFlag;    - Flag to update the sequencer program

char clkFile[256]; - Clock pattern file name

char prgFile[256]; - Sequencer program file name

ngcb_lookup_t paramLookup;        - External handler for parameter lookup

int acqList[ngcdcsACQ_MAX_PROC];  - List of associated acquisition
                                    processes

ngcdcs_win_t win;  - Read-out window structure:

    int sx;   - Start pixel in x-direction (fast)
    int sy;   - Start pixel in y-direction (slow)
    int nx;   - Dimension in x-direction
    int ny;   - Dimension in y-direction

ngcdcs_pat_t *pattern;   - Clock pattern setup

ngcdcs_seqp_t program;   - Sequencer program

The ngcdcs_pat_t object contains the following members:

  int addr;                   - Address (relative to RAM base)
  ngcdcs_pat_st_t state[ngcbSEQ_MAX_STATES];  - States
  int numStates;              - Number of states in this pattern
  int time;                   - Clock pattern execution time in ticks
  char name[128];             - Pattern name

The ngcdcs_pat_st object contains the following members:

  int low;                    - Pattern low
  int high;                   - Pattern high
  int time;                   - Pattern dwell time (in ticks)
  int mod;                    - Allow global dewll time modification

The ngcdcs_seqp_t object contains the following members:

  int code[ngcbSEQ_RAM_SIZE]; - Sequencer program code
  int length;                 - Program code length
  ngcdcs_subrt_t subRt[ngcdcsSEQ_MAX_SUBRT]; - Subroutines
  int numSubRt;               - Number of subroutines
  int stored;                 - Program stored in controller

The ngcdcs_subrt_t object contains the following members:

  int addr;                   - Start address (relative to RAM base)
  int index;                  - Reference index
```

```
  int length;                - Subroutine code length
  double time;               - Execution time in seconds
  char name[128];            - Subroutine name (optional)
```

RETURN VALUES

If not specified differently, all functions return SUCCESS in case of success. Otherwise FAILURE is returned and an error is added to the error-stack.

SEE ALSO

ngcbIFC(4), ngcbMOD(4), ngcbPARAM(4)

1.18 ngcdcsADC_CLASS

NAME

ngcdcsADC_CLASS - NGC ADC class

SYNOPSIS

```
#include <ngcdcsMOD_CLASS.h>

ngcdcsADC_CLASS adc();
```

PARENT CLASS

ngcdcsADC_CLASS: public eccsERROR_CLASS, public ngcdcsMOD

DESCRIPTION

NGC ADC class.

PUBLIC METHODS

```
ngcdcsADC_CLASS(ngcb_route_t route);
    Constructor method specifying the local route to the
    module inside the front-end (header).

ngcdcsADC_CLASS(ngcbIFC *dev, ngcb_route_t route);
    Constructor method specifying the interface device and
    the local route to the module inside the front-end (header).

ngcdcsADC_CLASS(ngcb_route_t route, int n, int b);
    Constructor method specifying the local route to the
    module inside the front-end (header) and the number
    of ADC units + bits per pixel on this module.

ngcdcsADC_CLASS(ngcbIFC *dev, ngcb_route_t route, int n, int b);
    Constructor method specifying the interface device and
    the local route to the module inside the front-end
    and the number of ADC units + bits per pixel on this module.

virtual ~ngcdcsADC_CLASS();
    Destructor method.

void Reset();
    Align soft-states after reset;

ccsCOMPL_STAT Online();
    Hook method, which is executed when going online.
    This will write the actual configuration to the hardware.

ccsCOMPL_STAT Standby();
    Hook method, which is executed when going standby.

ccsCOMPL_STAT Selftest();
    Perform a selftest.

void Preset(int size, int n);
    Configuration preset with a given packet size and <n> enabled
    ADC units. The <size> and <n> will be adjustet to the nearest
    possible value. This will not yet transfer the configuration
    to the hardware. The latter is done by the Online() hook.

ccsCOMPL_STAT Disable();
    Disable all ADC units on this module.

ccsCOMPL_STAT Enable(int n);
    Enable first n ADC units on this module.

ccsCOMPL_STAT Enable();
    Enable all ADC units on this module.
```

```
ccsCOMPL_STAT First(int flag);
    Set "first-in-chain"-flag.

ccsCOMPL_STAT Convert(int cvt1, int cvt2);
    Enable/disable conversion on conversion strobe 1 and/or 2.

ccsCOMPL_STAT PacketSize(int size);
    Set transfer packet size. A value of zero lets the system
    choose a proper size.

ccsCOMPL_STAT PacketCnt(int size);
    Set packet routing length. This is the number of packets to
    be received from the down-link(s) before the own data is
    transferred.

ccsCOMPL_STAT OpMode(int newMode);
    Set operation mode. Valid values are:

      ngcbADC_MODE_NORMAL (0)
      ngcbADC_MODE_SIM    (1)

ccsCOMPL_STAT SimMode(int newMode)
    Set simulation mode. Valid values are:

      ngcbADC_SIM_NUMBERS (0)
      ngcbADC_SIM_CNT     (1)

ccsCOMPL_STAT Delay(int ticks);
    Set conversion strobe delay in ticks.

ccsCOMPL_STAT Offset(int chan, double offset);
    Set ADC offset (in Volts) on the given offset channel.

ccsCOMPL_STAT Monitor(int num, int chan);
    Set channel number for the monitor. <num> specifies the monitor
    number.

int PixPerWord();
    Returns the number of pixels per 32-bit word (1 or 2).
```

PUBLIC DATA MEMBERS

```
int numAdc;            - Number of ADC units on this module

int enable;            - Number of enabled ADC units on this module

int packetSize;        - Packet size

int packetCnt;         - Packet routing length (number of packets from
                         down-link).

int convert1;          - Enable conversion on convert pulse 1

int convert2;          - Enable conversion on convert pulse 2

int firstInChain;      - First in chain

int opMode;            - Operation mode (0=normal, 1=simulation)

int simMode;           - Simulation mode (0=numbers, 1=counter)

int delay;             - Conversion strobe delay (in ticks)

double offset[32];     - Offset per group

int monitor1;          - Monitor 1
```

```
int monitor2;          - Monitor 2
```

RETURN VALUES

If not specified differently, all functions return SUCCESS in case of success. Otherwise FAILURE is returned and an error is added to the error-stack.

CAUTIONS

The channel number, which is given as argument to the Monitor() member function, starts with zero!

SEE ALSO

ngcbIFC(4), ngcbMOD(4)

1.19 ngcdcsACQ_DATA_CLASS

NAME

ngcdcsACQ_DATA_CLASS - NGC acquisition process data interface class

SYNOPSIS

```
#include <ngcdcsMOD_CLASS.h>

ngcdcsACQ_DATA_CLASS data();
```

PARENT CLASS

ngcdcsACQ_DATA_CLASS: public eccsERROR_CLASS, public ngcdcsOBJ

DESCRIPTION

NGC acquisition process data interface class.

PUBLIC METHODS

```
ngcdcsACQ_DATA_CLASS();
    Constructor method.

ngcdcsACQ_DATA_CLASS(ngcdcs_acq_cfg_t cfg);
    Constructor method with configuration object (see below).

virtual ~ngcdcsACQ_DATA_CLASS();
    Destructor method.

void Configure(ngcdcs_acq_cfg_t cfg)
    Configure system. The configuration object has the following
    members:

      int dataPort;       - Data server port
      int transferMode;   - Data transfer mode
      char host[64];      - Acquisition process host

    The transfer mode must be one of ngcppTMODE_SCIENCE or
    ngcppTMODE_VIDEO. The default value is ngcppTMODE_SCIENCE.
    In science mode the oldest available, but not yet transferred
    frame, which matches the frame-type in the request structure is
    transferred (FIFO). In video-mode for each frame-type matching
    the request, the latest not yet transferred frame is selected (LIFO).
    From this selection the oldest frame is transferred. In both cases
    'not yet transferred' means, that the frame has not yet been
    transferred to the requesting client.

    The configuration becomes active with the next call of the
    Open() - member function.

ngcdcs_acq_cfg_t *Cfg();
    Get pointer to configuration.

ccsCOMPL_STAT Open();
    Open data connection;

ccsCOMPL_STAT Close();
    Close data connection.

int Fd();
    Returns the file descriptor for data connection to acquisition
    process.

int BitPix(int dataType);
    Convert data type to bitpix-value as requiered by the
    FITS-specification.

ccsCOMPL_STAT FrameDef(ngcdcs_framedef_t *frameDef);
    Get currently defined frame types.
```

```
int AvailableFrames();
    Returns currently available frame types.

int FrameType(const char *name);
    Get frame type by frame name.

void FrameName(char *name, int type);
    Get frame name by frame type.

void FrameParam(char *paramName, int type);
     Get frame enable/disable parameter name by type.

void FrameParam(char *paramName, const char *name);
     Get frame enable/disable parameter name by frame name.

int FrameIdx(int type);
     Returns the index for a given frame type.

void SetRequest(int type);
    Setup data request by specifying a new type.

void SetRequest(int sx, int sy, int nx, int ny);
    Setup data request by specifying a new window.

void SetRequest(int type, int sx, int sy, int nx, int ny);
    Setup data request by specifying a new type and a new window.

ccsCOMPL_STAT Request();
    Send data request as defined by the SetRequest() methods.

ccsCOMPL_STAT Request(int type);
    Send data request (new type).

ccsCOMPL_STAT Request(int sx, int sy, int nx, int  ny);
    Send data request (new window).

ccsCOMPL_STAT Request(int type, int sx, int sy, int nx, int ny);
    Send data request (new type and new window).

ccsCOMPL_STAT Retransmit();
    Retransmit frame. Retransmission can only be done in video-
    transfer mode (ngcppTMODE_VIDEO).

ccsCOMPL_STAT Retransmit(int sx, int sy, int nx, int ny);
    Retransmit frame (new window). Retransmission can only be done
    in video-transfer mode (ngcppTMODE_VIDEO).

ccsCOMPL_STAT Cancel();
    Cancel pending data request.

ccsCOMPL_STAT Wait();
    Wait for data event.

ccsCOMPL_STAT Skip();
    Skip data frame

ccsCOMPL_STAT GetFrame(ngcpp_frame_t *frame, int chipId=0);
ccsCOMPL_STAT GetFrame(void *buffer, int chipId=0);
    Get frame (as is). <chipId> specifies a chip in a mosaic.
    If the <chipId> is zero, the data for all chips in a mosaic is
    received.

ccsCOMPL_STAT GetFrame(ngcpp_frame_t *frame,
                       int sx, int sy, int nx, int ny,
                       int chipId=0);
ccsCOMPL_STAT GetFrame(void *buffer,
                       int sx, int sy, int nx, int ny,
                       int chipId=0);
```

```
    Get frame (new window). <chipId> specifies a chip in a mosaic.
    If the <chipId> is zero, the data for all chips in a mosaic is
    received.

ccsCOMPL_STAT Accept();
    Accept data frame (as is). This does not yet receive any data.

ccsCOMPL_STAT Accept(int sx, int sy, int nx, int ny);
    Accept data frame (new window). This does not yet receive any data.

ccsCOMPL_STAT Receive(void *buffer, int offset, int size);
    Receive <size> bytes of frame data and put them into <buffer>
    at <offset>. The offset is given in bytes.

ccsCOMPL_STAT Receive(ngcpp_frame_t *frame, int offset, int size);
    Receive <size> bytes of frame data and put them into the buffer
    of the <frame> structure at <offset>. The offset is given in bytes.

void Scale(ngcpp_frame_t *frame);
    Apply scale factor as defined in the frame header. The data type
    in the header will be updated accordingly.

void Scale(void *buffer, int nx, int ny, int *dataTpye, int *scaleFactor);
    Apply scale factor. The <dataType> may change.

void Scale(void *buffer, ngcdcs_finfo_t *f);
    Apply scale factor as defined in the frame info structure <f>.
    The ngcdcs_finfo_t structure contains the following members:

      int type;         - Unique frame type
      char name[64];    - Unique frame name
      int fcnt;         - Frame counter
      int scaleFactor;  - Scaling factor to be applied in order
                          to normalize
      double expFactor; - Factor for EXPTIME
      int bitPix;       - Bits per pixel (as defined in the
                          FITS-standard)
      int nx;           - Dimension in x-direction
      int ny;           - Dimension in y-direction
      double crpix1;    - Reference pixel in x-direction
      double crpix2;    - Reference pixel in y-direction
      int detIdx;       - Detector index (for mosaics)
      int expCnt;       - Exposure counter
      char utc[64];     - Time when frame was ready in the
                          pre-processor
      ngcdcsCUBE *cube; - Data cube object to be used for storing
                          to a cube

    The value of bitPix may change, when aplying the scaleFactor.

void Scale(void *buffer);
    Apply scale factor as defined in the last received header.
    The data type in the last received header will be updated
    accordingly.

Information on current frame:

int Valid();
     Returns 1 in case a valid frame was received. Otherwise
     zero is returned.

int FrameType();
     Returns the type of the current frame.

int FrameIdx();
     Returns the index for current frame type.

void FrameName(char *name);
     Get current frame name.
```

```
int DataType();
     Return data type of current frame.

int ScaleFactor();
     Return scaling factor for current frame.

double ExpFactor();
     Return EXPTIME factor for current frame.

int FrameCounter();
     Return frame counter for current frame.

int SetupId();
     Return setup-id of the current frame.

int StartX();
     Return start pixel in x-direction for current frame.

int StartY();
     Return start pixel in y-direction for current frame.

int NX();
     Return x-dimension of current frame.

int NY();
     Return y-dimension of current frame.

int FrameSize();
     Return frame size in bytes of current frame.

int DatumSize();
     Return pixel datum size in bytes of current frame.

int BitPix();
     Return bitpix-value of data type of current frame (as requiered
     by the FITS-specification).
```

PUBLIC DATA MEMBERS

```
int numDet;    - Number of detectors in mosaic

int ioError;   - Flag indication that an i/o-error has occured
```

RETURN VALUES

If not specified differently, all functions return SUCCESS in case of success. Otherwise FAILURE is returned and an error is added to the error-stack.

SEE ALSO

ngcdcsOBJ(4), ngcdcsACQ(4)

1.20 ngcdcsACQ_CLASS

NAME

ngcdcsACQ_CLASS - NGC acquisition process interface class

SYNOPSIS

```
#include <ngcdcsMOD_CLASS.h>

ngcdcsACQ_CLASS acq();
```

PARENT CLASS

```
ngcdcsACQ_CLASS: public eccsERROR_CLASS, public ngcdcsOBJ,
                 public ngcbTHREAD
```

DESCRIPTION

NGC acquisition process interface class.

PUBLIC METHODS

```
ngcdcsACQ_CLASS();
    Constructor method.

ngcdcsACQ_CLASS(ngcbPARAM_LIST *p);
    Constructor method with parameter list.

ngcdcsACQ_CLASS(ngcdcs_acq_cfg_t cfg, ngcbPARAM_LIST *p);
    Constructor method with configuration object (see below) and
    parameter list.

virtual ~ngcdcsACQ_CLASS();
    Destructor method.

void Configure(ngcdcs_acq_cfg_t newConf)
    Configure system. The configuration object has the following
    members:

      int cmdPort;        - Command server port
      int dataPort;       - Data server port
      int errPort;        - Error-stack server port
      int numDataClient;  - Number of data clients
      int transferMode;   - Data transfer mode
      char host[64];      - Acquisition process host
      char dev[128];      - Acquisition process DMA device name

    The port numbers may be set to zero to let the system choose an
    approporiate one. The actual number are stored in the public
    data members cmdPort and dataPort. The configuration becomes
    active with the next call of the Exec() - member function.

void GetCfg(ngcdcs_acq_cfg_t *currentConf);
    Returns the current configuration, as given via the Configure()
    method.

ccsCOMPL_STAT Alloc(int size);
    Allocate new frame buffer of the given size. A zero size
    will free the buffer. A negative value will allocate a default
    size.

ccsCOMPL_STAT Alloc();
    Same as Alloc(int size) but uses the preset value of the public
    data member <allocSize> (see below).

void Dictionary(ngcdcsDIC *dictionary);
    Attach to a dictionary.

void Exposure(ngcdcsEXP *exposure);
    Attach to an exposure setup.
```

```
ngcdcsEXP *Exposure();
    Returns the current exposure setup.

void ErrState(int id, const char *erms);
    Set this module instance to error state. An external error state
    handler will be called with an internal <id>, <erms> and a pointer
    to this object as argmuents.

void SimError(int error);
    Trigger an error simulation. Possible values for <error> are:

        ngcdcsACQ_TESTERR_DATA_IO - Data i/o failed
        ngcdcsACQ_TESTERR_STORE   - Failed to store data to disk

void Sim(int flag);
    Switch to simulation mode if <flag> is not equal to zero.

char *Host();
    Returns acquisition process host name.

char *Dev();
    Returns acquisition process device name.

int Pid();
    Returns process id of current acquisition process or zero, if
    no process is launched.

ccsCOMPL_STAT Reset();
    Internal cleanup. If no acquisition process is launched,
    the function will have no further effect.

ccsCOMPL_STAT Exec();
ccsCOMPL_STAT Exec(const char *newProcess);
    Launch new acquisition process specified by process name. The
    previously running process will automatically be aborted before.
    If no name is given, the previous process will be (re-)launched.
    If name is NULL or an empty string, the previously launched process is
    aborted and the saved process name is deleted, so no re-launch will
    happen when calling Exec() until a new name is given. In
    burst-mode (i.e. burst > 0) the process given in the global
    burstProcess name will be used instead of <newProcess>.

ccsCOMPL_STAT Abort();
    Abort current acquisition process.

virtual ccsCOMPL_STAT DataConnect();
    Establish a (local) connection to the data server. A local
    connection would require an asynchronous data transfer
    implementation. If this is not desired or possible,
    the DataConnect() method has to be overloaded with a "no operation"
    function. Then the host name returned by the Host() member function
    and the data port number stored in the public data member dataPort
    can be used to implement an exernal data transfer task.

int FdCmd();
    Returns file descriptor for connection to command server thread.

int FdErr();
    Returns error-stack file descriptor.

ccsCOMPL_STAT HandleFdCmdEvt();
    Handle input on command server file-descriptor. This is an
    i/o error case.

ccsCOMPL_STAT HandleFdErrEvt();
    Handle input on run-time error-stack file descriptor.

const char *StatusString();
    Returns a string matching the acquisition module status
```

```
    (idle, running, failure);

ccsCOMPL_STAT Burst(int num);
    Set number of bursts. If burst is greater than zero, the
    burst-process definded in the public data member <burstProcess>
    is launched instead of the defined acquisition process. If
    burst is a negative number, its absolute value is used as number
    for the internal burst buffers.

ccsCOMPL_STAT BurstSkip(int num);
    Set number of frames to skip before starting burst.

ccsCOMPL_STAT Start();
    Send start command to acquisition process.

ccsCOMPL_STAT Restart();
    If acquisition process was not in ready state, a stop command
    is issued before starting.

ccsCOMPL_STAT Stop();
    Send stop command to acquisition process.

ccsCOMPL_STAT NewSetup();
    Mark next setup. Should be called before each new
    exposure.

ccsCOMPL_STAT ResetCnt();
    Set flag to reset acquisition process counters

ccsCOMPL_STAT End();
    Set flag to end processing as soon as possible by computing
    an intermediate result.

ccsCOMPL_STAT Cmd(const char *cmd, char *reply);
    Send user-defined ASCII command to acquisition process. The
    reply will be stored in <reply>.

ccsCOMPL_STAT Upload(int id, const char *path);
    Upload a FITS-file to the acquisition process. The data
    has to be marked with an integer <id> to be resolved by the
    acquisition process.

ccsCOMPL_STAT Upload(int id, char *buffer, int size);
    Upload a raw data buffer to the acquisition process. The data
    has to be marked with an integer <id> to be resolved by the
    acquisition process.

ccsCOMPL_STAT Clear(int id);
    Clear uploaded data region. This will mark the data region
    given by its <id> as invalid.

ccsCOMPL_STAT SyncParam(int timeout=20);
    Synchronize parameter setup with the given timeout.

ccsCOMPL_STAT SetParam(const char *paramName,
                       const char *paramValue,
                       int sync=1);
    Set an acquisition process parameter. If <sync> is set to 1, the
    SyncParam() method is called after uploading the parameter.

ccsCOMPL_STAT GetParam(const char *paramName, char *paramValue);
    Retrieve a parameter from acquisition process.

ccsCOMPL_STAT ApplyParamList(ngcbPARAM_LIST *list, int sync=1);
    Upload all parameters which are defined in both the given
    <list> and in the acquisition process. If <sync> is set to 1, the
    SyncParam() method is called after uplaoding the parameters.
```

```
ccsCOMPL_STAT ApplyParamList(int sync);
    Apply the global parameter list.

ccsCOMPL_STAT HwWin(int sx, int sy, int nx, int ny)
    Set HW read-out window.

ccsCOMPL_STAT SimTime(int ms);
    Set simulation interval for acquisition process (in milliseconds).

float Perf();
    Returns current CPU load in percent.

void Statistics(ngcdcs_acqperf_t statistics);
    Retrieve data transfer statistics of last exposure. The
    ngcdcs_acqperf_t structure contains the following members:

      double net;   - Network overhead in seconds
      double disk;  - Disk overhead in seconds
      double file;  - File creation overhead in seconds
      double fits;  - FITS-header overhead in seconds
      double proc;  - Post-processing overhead in seconds
      double size;  - Reference size for rate in bytes

int TransferEnable();
    Enable sustained transfer. This will also start the data
    transfer if not yet done.

void TransferDisable();
    Disable sustained transfer.

ccsCOMPL_STAT StartTransferring();
    Start data transfer.

void StopTransferring();
    Stop data transfer.

ccsCOMPL_STAT StartExposure();
    Start exposure. This will also start the data transfer if not
    yet done.

void StopExposure();
    Stop exposure.

int Transferring();
    Check protected transferring flag. Returns 1 in case the
    transfer is still in progress.

int LastTransfer();
    Returns 1 in case the last data transfer of an exposure has been
    started. The flag is reset to zero, when a new exposure is
    started.

ccsCOMPL_STAT FrameDef(ngcdcs_framedef_t *frameDef);
    Get currently defined frame types.

ngcdcs_framedef_t *ngcdcsACQ::Frame(const char *name);
    Get status info for a frame specified via its <name>.

ccsCOMPL_STAT FrameGen(const char *frameName, int gen);
    Switch generation for frame with the given name on/off (gen = 1/0).

void ExpStartTime(struct timeval timeVal);
    Set exposure start time.

const char *ExpStartTime();
    Get exposure start time.
```

```
double ExpStartTimeMJD();
    Get exposure start time (MJD).

int ExpSeqNo();
    Get current exposure sequence number.

int ExpActive();
    Returns 1 in case an exposure is currently active on this
    acquisition module.

virtual ccsCOMPL_STAT Store(char *buffer, ngcdcs_finfo_t finfo,
                            char *where);
    Overloadable function to store a frame to disk. The data buffer
    is passed in <buffer>. The string <where> returns the full path,
    where the data has actually been stored. This depends on the naming
    scheme, the file format etc. given in the exposure configuration
    object, which can be retrieved via the Exposure() method.

    The ngcdcs_finfo_t structure contains the following members:

      int type;          - Unique frame type
      char name[64];     - Unique frame name
      int fcnt;          - Frame counter
      int scaleFactor;   - Scaling factor to be applied in order
                           to normalize
      double expFactor;  - Factor for EXPTIME
      int bitPix;        - Bits per pixel (as defined in the
                           FITS-standard)
      int sx;            - Lower left corner (x-direction)
      int sy;            - Lower left corner (y-direction)
      int nx;            - Dimension in x-direction
      int ny;            - Dimension in y-direction
      double crpix1;     - Reference pixel in x-direction
      double crpix2;     - Reference pixel in y-direction
      int detIdx;        - Detector index (for mosaics)
      int expCnt;        - Exposure counter
      char utc[64];      - Time when frame was ready in the
                           pre-processor
      ngcdcsCUBE *cube;  - Data cube object to be used for storing
                           to a cube

    The ngcdcsCUBE object contains the following members:

      FILE *fd;            - File descriptor
      int naxis1;          - Dimension in x-direction for all images
                             in the cube
      int naxis2;          - Dimension in y-driection for all images
                             in the cube
      int naxis3;          - Number of images
      int bitPix;          - Bits per pixel for all images in the cube
                             (as defined in the FITS-standard)
      int sx;              - Lower left corner (x-direction)
      int sy;              - Lower left corner (y-direction)
      char fileName[256]; - Actual filename (full path)
      char frameName[64]; - Frame type name for all images in the cube
      int Size();          - Returns actual size of the cube data in bytes
      int Open(const char *path, const char *name); - create cube file
      void Close();        - Close the cube file (empty cubes will be
                             removed)

      The naxis1,2,3, the bitPix and the frameName of the individual
      frames to be added have to be checked for consistency with the
      overall value in the ngcdcsCUBE object before storing!
```

PUBLIC DATA MEMBERS

```
int ioError;                - Flag indication that an i/o-error has
                              occured

ngcdcs_es_t errStateHandler; - External error state handler of type:
```

```
  void myHandler(char *erms, ngcdcsACQ *module)

ngcdcs_acq_dcf_t detCfg      - Detector configuration:

    int numDet;     - Number of detectors in mosaic
    int addIdx;     - Flag to add detector index to filename
    int det0;       - First detector in this instance
    int sx;         - Lower left x (for HW-window)
    int sy;         - Lower left y (for HW-window)
    int nx;         - Detector x-dimension
    int ny;         - Detector y-dimension
    int splitX;     - Split to FITS extensions
    int splitY;     - Split to FITS extensions

int allocSize;               - Frame buffer size preset (in bytes)

ngcdcsACQ_DATA data;         - Data interface

int updateFrames;            - Flag indicating that frame configuration
                               has changed

int burstNum;                - Number of bursts (zero = burst disabled).
                               Default value is 0.

int burstSkip;               - Frames to skip before starting burst.
                               Default value is 0.

int continuous;              - Continuous mode flag. If the flag is set,
                               the counter reset function is disabled.
                               Default value is 0.

int transfer;                - Transfer flag (sustained data connection)

char burtsProcess[256];      - Burst process to start in burst mode.
                               Default is <ngcppBurst>.

int status;                  - Soft status:

  ngcdcsACQ_STAT_IDLE    -  idle
  ngcdcsACQ_STAT_READY   -  acq.process has been launched and is ready
                            to receive commands
  ngcdcsACQ_STAT_RUNNING -  running
  ngcdcsACQ_STAT_FAILURE -  failure (run-time error)

int cmdPort;                 - Actual command server port

int dataPort;                - Actual data server port
```

RETURN VALUES

If not specified differently, all functions return SUCCESS in case of success. Otherwise FAILURE is returned and an error is added to the error-stack.

SEE ALSO

ngcdcsACQ_DATA(4), ngcdcsOBJ(4)

1.21 ngcdcsCTRL_CLASS

NAME

ngcdcsCTRL_CLASS - NGC controller class

SYNOPSIS

```
#include <ngcdcsMOD_CLASS.h>

ngcdcsCTRL_CLASS controller();
```

PARENT CLASS

ngcdcsCTRL_CLASS: public eccsERROR_CLASS, public ngcbOBJ

DESCRIPTION

NGC controller class. This is an interface class handling
a number of interface devices and their associated NGC-networks
containing the sequencer-, CLDC- and ADC-modules.

PUBLIC METHODS

```
ngcdcsCTRL_CLASS();
    Constructor method.

virtual ~ngcdcsCTRL_CLASS();
    Destructor method.

ccsCOMPL_STAT Sim(int flag);
    Set all defined devices to simulation mode.

ccsCOMPL_STAT AttachMod(ngcbMOD *);
    Attach an additional module to global controller handling.
    The Reset(),Standby(),Online() hooks will be called and the
    links leading to the module will be configured automatically.
    The module will be deleted at shutdown and has to be attached
    again if applicable. This requires that the module has been
    created with the <new> operator. The method will also
    associate externally defined handlers for verbose/log output
    with this module.

ccsCOMPL_STAT Initialize();
    Internal intialization after configuring. This will associate
    externally defined handlers for verbose/log output and error
    state and associate an appropriate network structure for
    the defined devices and modules.

ccsCOMPL_STAT Shutdown();
    This first aborts (standby state) and then deletes all
    controller modules. The Initialize() method needs to be called
    to bring the controller up again.

ccsCOMPL_STAT Abort();
    Abort all defined modules. This will stop the sequencer(s)
    and disable the CLDC-module(s).

ccsCOMPL_STAT Reset();
    Overall reset. This will reset all controller device and align
    the soft states for the sequencer-, CLDC- and ADC-modules.

ccsCOMPL_STAT Refresh(int id=0);
    Refresh internal telemetry of the CLDC module given by its <id>.
    If the <id> is zero, all modules are refreshed. Module numbers
    start with 1.

ccsCOMPL_STAT Standby();
    Bring interface devices to standby state. Driver interface processes
    are alive, but the physical devices are disconnected (i.e. closed).

ccsCOMPL_STAT Online();
    Bring interface devices to on-line state. This will also align
```

```
    the soft states for the sequencer-, CLDC- and ADC-modules and
    call the appropriate on-line hooks. The driver interface
    processes are alive and all physical devices are connected
    (i.e. opened). If a device was disconnected before (i.e. was
    in standby- or off-state), a hardware reset is performed on
    this device and the NGC- network is (re-)enabled afterwards.
    If the <check> flag is set, then system integrity checks are
    performed before going on-line.

ccsCOMPL_STAT Off();
    Bring interface devices to off-state. All physical devices are
    disconnected and driver interface processes are not alive.

void Shutdown();
    Shutdown all controller modules. This will delete all created
    objects for the sequencer-, CLDC- and ADC-modules.

ngcbNET *Network(int instance);
    Return pointer to the NGC network structure associated with
    a device specified by its instance number. If no network
    is associated to the given interface instance, a NULL pointer
    is returned.

ccsCOMPL_STAT Enable();
    Enable all networks associated with the defined interface devices.

ccsCOMPL_STAT ReadAddr(ngcbIFC *dev, ngcb_route_t route, int address,
                       int *buffer, int size);
    Reads size words from the given device address into buffer.
    The ngcb_route_t structure contains the following elements:

      int numHdr;             - Number of headers to target including
                                the terminating <0x2>
      int hdr[ngcbMAX_MOD];   - Array of headers including the
                                terminating <0x2>

ccsCOMPL_STAT WriteAddr(ngcbIFC *dev, ngcb_route_t route, int address,
                        int *buffer, int size);
    Writes size words from buffer to the given device address.
    The ngcb_route_t structure contains the following elements:

      int numHdr;             - Number of headers to target including
                                the terminating <0x2>
      int hdr[ngcbMAX_MOD];   - Array of headers including the
                                terminating <0x2>

ccsCOMPL_STAT WriteBuffer(ngcbIFC *dev, int *buffer, int size);
    Writes a formatted buffer to the given interface device.
    The format of the buffer is:
    <hdr1 hdr2 ... hdrN address data1 data2 ...>
```

PUBLIC DATA MEMBERS

```
ngcb_es_t errStateHandler; - External error-state handler of type:

    void myHandler(char *erms, ngcbIFC *module)

int ioError;              - Indicates that the preceeding transaction
                            caused an i/o error on one of the interface
                            devices(generally the connection should be
                            reset in that case).

ngcbIFC *dev[ngcdcsCTRL_MAX_DEV];            - Controller interface devices
int numDev;                                  - Number of interface devices

ngcdcsCLDC_CLASS *cldc[ngcdcsCTRL_MAX_CLDC]; - CLDC modules
int numCldcMod;                              - Number of CLDC modules
int cldcRef;                                 - CLDC reference module

ngcdcsSEQ_CLASS *seq[ngcdcsCTRL_MAX_SEQ];    - Sequencer modules
int numSeqMod;                               - Number of sequencer modules
```

```
int seqRef;                                     - Sequencer reference module

ngcdcsADC_CLASS *adc[ngcdcsCTRL_MAX_ADCMOD]; - ADC modules
int numAdcMod;                                  - Number of ADC modules
int adcRef;                                     - ADC reference module
```

RETURN VALUES

If not specified differently, all functions return SUCCESS in case of success. Otherwise FAILURE is returned and an error is added to the error-stack.

SEE ALSO

ngcbOBJ(4), ngcbIFC(4), ngcbNET(4), ngcbMOD(4), ngcdcsCLDC_CLASS(4), ngcdcsSEQ_CLASS(4), ngcdcsADC_CLASS(4)