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HARPS

Control Electronics Design Report

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Chapter 1: Introduction

1.1 Scope

The purpose of this document is to describe the instrument functions-electronics and the mechanical parts controlled by it.
The control is based on ESO standard VLT components except peripherals like remote temperature controllers, sensors and transducers that were chosen from third party suppliers for this application.
This document has been prepared for the final design review so that some issues with the TBC or TBD comments are dependent of the decisions taken during the review.

1.2 Documents

1.2.1 Applicable Document

AD-1	HARPS Calibration, Operation and Maintenance Plan	3M6-PLA-HAR-33100-0005	1.0	4/12/2000
AD-2	DFS Software User Requirements and Design Report	3M6-TRE-HAR-33110-0001	1.1	17/1/2000

1.2.2 Reference Document

RD-1	HARPS CCD Detector Final Design, Analysis and Performance Report	3M6-TRE-HAR-33104-0002	1.0	28/02/2001
RD-2	HARPS ICD between Detector Unit and Spectrograph	3M6-TRE-HAR-33100-0010	1.0	
RD-3	HARPS Temperature-Control System of the Spectrograph	3M6-TRE-HAR-33102-0005	1.0	28/02/2001
RD-4	LN2 Level Sensor, Technical Manual	VLT-MAN-ESO-17130-2017	1.0	14/01/2000

1.3 Acronyms

AD	Applicable Document
CCD	Charge-Coupled Device
HCFA	HARPS Cassegrain Fiber Adapter
HW	Hardware
CCD	Charge-Coupled Device
CFC	Continuous-Flow Cryostat
DFS	Data-Flow system
ESO	European Southern Observatory
ICS	Instrument Control Software
IWS	Instrument Work Station
LAN	Local Area Network
LCU	Local Control Unit
LN_2	Liquid Nitrogen
PMT	Photomultiplier Tube
RD	Reference Document
SW	Software
TBC	To Be Confirmed
TBD	To Be Defined
TCS	Telescope Control System
UTP	Unshielded Twisted Pair

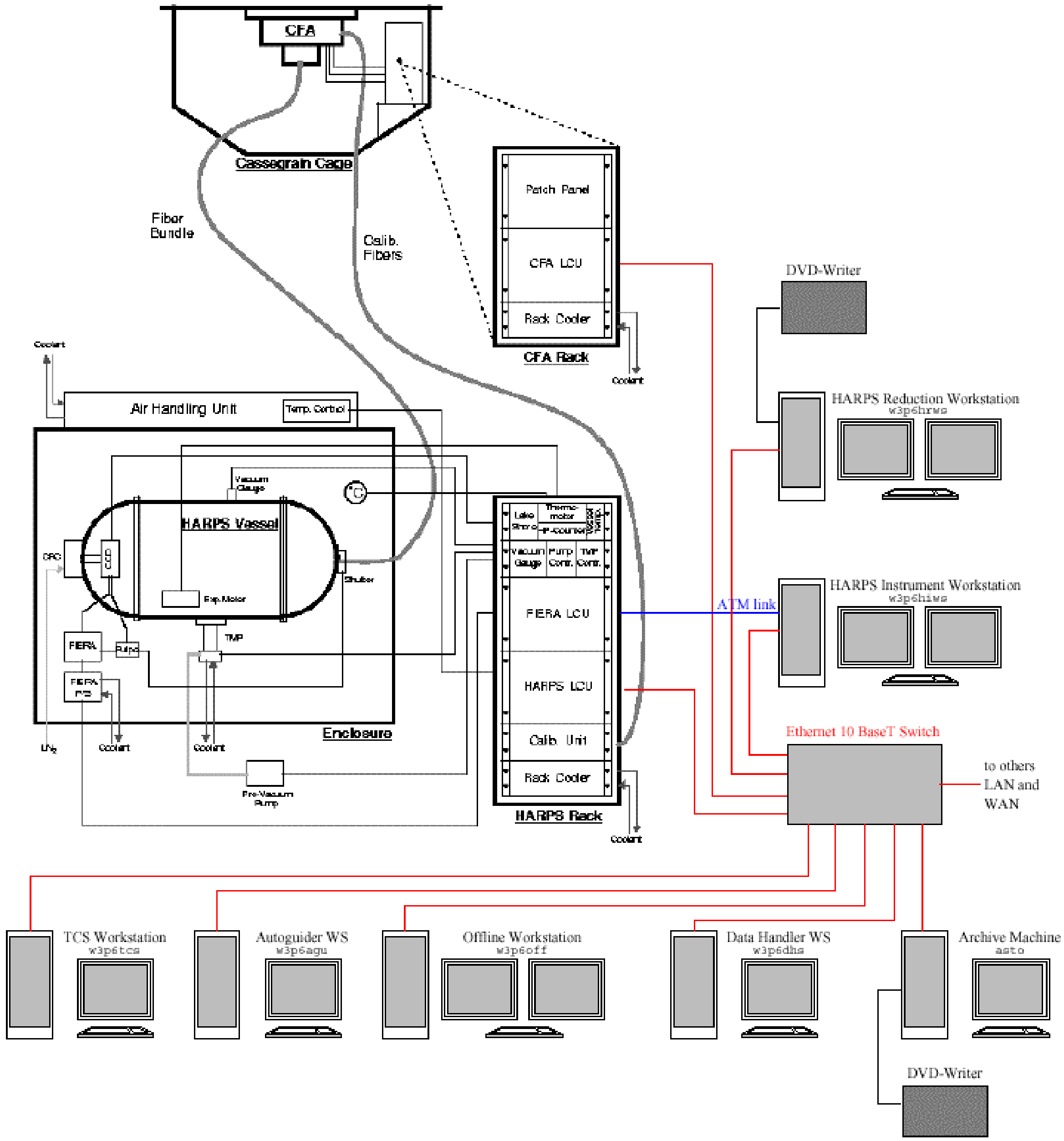
Chapter 2: General Design Description

2.1 Architecture Overview

The instrument control, e.g., work stations and terminals will be located at (TBD), linked to the La Silla LAN. The HCFA from the electronic-control point of view for an easy mounting/dismounting to the Telescope is connected to the electronics control by two industrial robust connectors.
The HCFA control rack size fits it in the Cassegrain without problems, for the location and fixation since it will replace other Telescope systems we will try to use the same fixation.

Regarding the network, the 3p6 Telescope is internally wired with UTP cables for 100 Mb/s and linked by an optic-fiber to the La Silla LAN. Based on it, the FIERA, HCFA and HARPS LCU's being in a network segment isolated by the respective switch, may reach a throughput of 100 Mb/s.

Figure 1: Overview of the HARPS HW



2.2 Instrument Functions Overview

- Calibration Unit
  - Calibration Lamps control
  - Calibration Lamp Selection
- ND-Wheel Control Electronics
- ADC
  - Rotation Control Electronics
  - In/Out Function
- Calibration Mirror Positioning
- Iodine Cell
  - Temperature Control
  - In/Out Function
- Fiber Head Protection Slide
- Fiber-Head Selection
- Flat Field

All the mechanical components that are part of the instrument functions are usual for the Observatory environment, which is a guarantee for maintainability. According the design requirements isn't a mayor problem to achieve the required positioning resolutions.

2.3 Interlocks Overview

- Photon counter (TBD)
  - Photomultiplier protection
- Vessel vacuum
- Temperatures

Usually the interlocks may be grouped in software and hardware interlocks, depending on the application, a warning zone is established in which the user is informed for take the respective actions.
Local interlocks are already incorporated in the individual subsystems, e.g., the instrument function limits for carriages with linear motion, control boards maximum ratings, etc.
Since the electronics have the control over the instrument functions, defined the interlock conditions based on the normal operation, they may be easily implemented in the hardware control.

Chapter 3: The Instrument LCU's

3.1 HARPS LCU

The HARPS Local Control Unit (LCU) will be installed in a rack (Fig. 1) located in the Coudé room outside of the HARPS enclosure. It consists of a VME chassis with VLT standard components:

- 1 CPU Motorola MVME2604-4331
- 1 Transition Module MVME712M
- 1 Motor controller MACCON MAC4-INC
- 1 Servo Amplifier ESO VME-4-SA
- 1 Digital I/O board ACROMAG AVME-9481
- 1 Triple Voltage power supply KNIEL 358-006-02
- 2 Single Voltage power supply KNIEL 311-053-02
- ISER – Serial ports interface

Motor functions configuration:

Function	MACCON # -Channel	Amplif. VME-4-SA #	Mode
Calibration lamp 'A'	I-1	I-1	Linear
Calibration lamp 'B'	I-2	I-2	Linear

Digital signals:

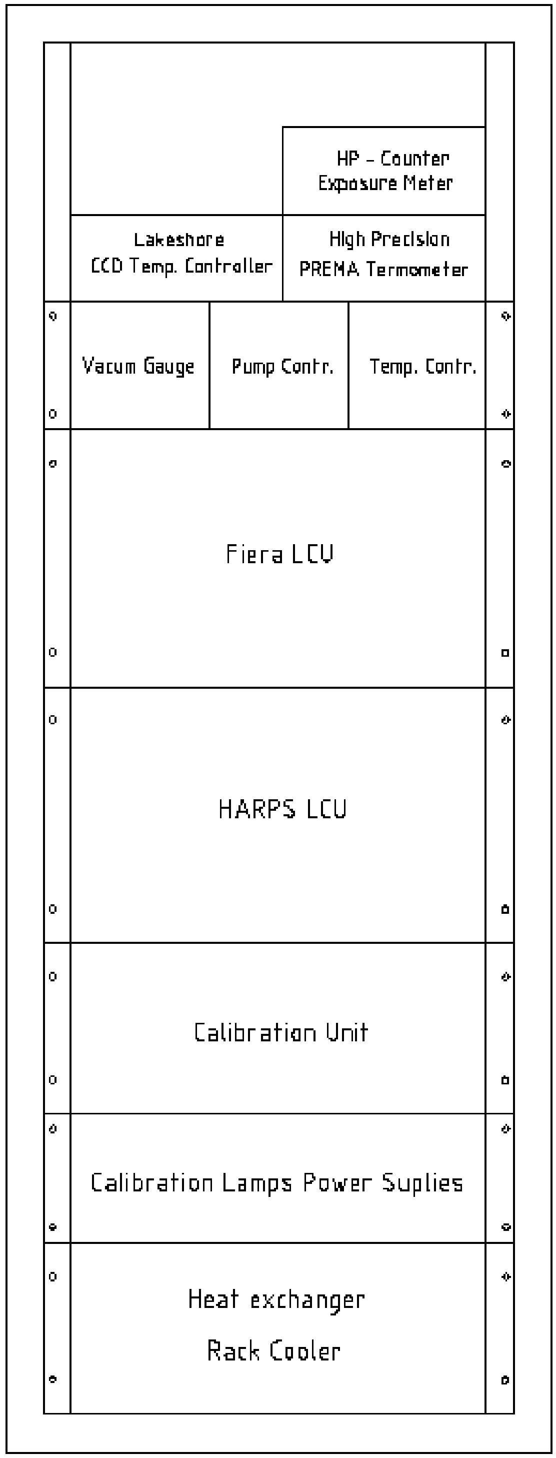
Signal	Digital board # bit	Comments
Calibration lamp control	I - 1..5	on-off for 5 lamps
Calibration lamp status	I - 6..11	Status for 5 lamps
Vacuum pump status	I - 12	
Interlock	I - 13	
Flat Field led	I - 14	Led on/off

HARPS Rack Remote links:

Function	Controller	Link Type	Comments
Pulse counter CCD Temp. control	Agilent 53132 A Lakeshore 331S	RS232 RS232	Controlled by ISER Controlled by ISER
Temp. sensors	Prema 3040	RS232	Controlled by ISER
Room temperature	ADAM 5000	RS485	Controlled by ISER
Vessel temperature	ADAM 5000	RS485	Controlled by ISER

3.1.1 HARPS Rack Layout

Figure 2: HARPS Rack



3.2 HCFA LCU

The HCFA LCU is located in a rack (Fig. 2) located in inside the Cassegrain cage. It consists of a VME chassis with VLT standard components:

- 1 CPU Motorola MVME2604-4331
- 1 Transition Module MVME712M
- 2 Motor controller MACCON MAC4-INC
- 2 Servo Amplifier ESO VME-4-SA
- 1 Digital I/O board ACROMAG AVME-9481
- 1 Triple Voltage power supply KNIEL 358-006-02
- 2 Single Voltage power supply KNIEL 311-053-02
- ISER – Serial ports interface

Additionally to the slot required by the calibration unit, close to it is required a space for mount the lamps power supplies.

Motor functions configuration:

Function	MACCON # -Channel	Amplif. VME-4-SA #	Mode
ADC in-out	II-1	II-1	Linear
ADC rotation ADC diff. rotat.	II-2 II-3	II-2 II-3	Circular Circular
Calibration mirror	II-4	II-4	Linear
I_2 Cell in/out	III-1	III-1	Linear
Fiber heads	III-2	III-2	Linear
ND-Wheel	III-3	III-3	Circular
Fiber Heads Protec.	Not used	III-4	Linear

Digital signals:

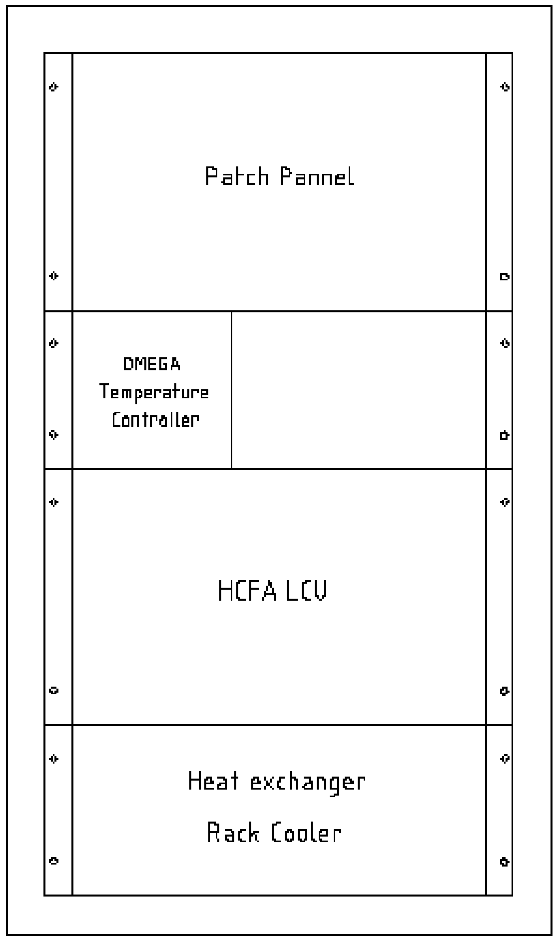
Signal	Digital board # bit	Comments
Iodine cell-fan on/off	I-1	

HCFA Rack Remote links:

Function	Controller	Link Type	Comments
I_2 Cell temperature	OMEGA CN77000	RS232	Controlled by ISER
HCFA temperatures	ADAM 5000	RS485	Controlled by ISER

3.2.1 HCFA Rack Layout

Figure 3: HCFA Rack



Chapter 4: Components and Control systems

4.1 Calibration Unit

The calibration unit consists of a twin fiber-carriages, each of them may be positioned independently to any of the five lamp target-slots, so that every lamp may be used either with anyone of the fibers, or intermediate positions options that have to be equivalent to 'dark' exposures.

4.1.1 Calibration Lamps

To avoid the light brightness variation due to the lamp 'cold start', it was foreseen to leave the lamps-on during the observations. A light sensor inside the lamp housing will indicate each lamp-on status. The interface electronics for the digital I/O (ACROMAG board) for read the sensor status, will be mounted on a PCB in standard Weidmueller DIN module.
The power supplies for the calibration lamps will sit in a dedicated chassis under the calibration lamps-slot.

Having lamps simultaneously on, the total amount of light that falls into a fiber when is alone in front of one lamp, shouldn't be interfered by the reflection of adjacent lamps that falls trough the free fiber-head space of the second unit.

4.1.2 Calibration Lamp Selection

Both carriage motors will be driven by a servo position control that is located in the HARPS-LCU (MACCON / VME-4-SA).
Incremental encoders of 1000 steps/rev. allow the servo to positioning the head-carriages within 0.02mm.

4.2 ND-Wheel Control Electronics

According the detector sensitivity, the calibration lamp light intensity may be attenuated by a neutral density (ND) filter wheel. .

The ND-Wheel position is controlled by a MACCON servo system located in the HARPS-LCU. The resolution, dependent of the wheel diameter, is given by a Heidenhain incremental encoder which is coupled directly to the wheel.

4.3 ADC

The Atmospheric Dispersion Corrector unit has three functions, two angular position controls for the prisms and one linear which moves both prisms in/out of the field.

4.3.1 Rotation Control Electronics

Both prisms control will be configured as a 360 circular function, so that the encoders that are directly coupled to the prism-axis will give for each prism a reference angle to a zero position.

By using a 3600 encoder pulses with a interpolation factor=4, the angular resolution for the prisms positioning is 1.5’, the smallest position window for the servo control is 1 bit on the MACCON encoder counter. That means that when the target position is reached, the control will react on the adjacent bits, it gives in worse case a positioning precision better than 4.5’.

4.3.2 In/Out Function

The in/out function carries both prisms, being a linear function, once initialized it permits to position the prisms with a precision better than 0.01mm. The end of range in both directions is limited by micro switches that disable the motion in the limit direction.

4.4 Calibration Mirror Positioning

As well as all the linear functions, the calibration mirror consist of a incremental encoder directly coupled to the spindle. The spindle pitch/encoder-pulses ratio gives a resolution of 0.002mm that may be increased 4 times by interpolation in the MACCON controller, those values guarantee widely to re-positioning the unit within 0.01mm.
The working range is protected by limit switches that when it is on the limit, disable the unit motion in the limit direction. One of the limits is used for initialize the incremental encoder.

4.5 Iodine Cell

The cell is mounted in a carriage that permits the in/out position, Since the unit is heated, for prevent to contaminate the Cassegrain beam, two ventilators will extract the air from inside the CFA.
All electrical connections will pass trough switch-able terminal strips that permits either test-points access or disconnection of the whole unit for troubleshooting.

4.5.1 Temperature Control

For the iodine cell heating, the OMEGA CN77000 controller was suggested. The unit controls two channels with PT100 sensors via RS485, the manufacturer specifies an accuracy of ±0.5ºC with a resolution of 0.1ºC. Assuming that the accuracy is bounded to long term offsets and discarding temperature environment variations, the relative measurements should match the required 0.1ºC stability.

4.5.2 In/Out Function

The servo control is similar to the other linear functions, e.g., limit switches, encoder, motor-tacho controlled by MACCON with a theoretical resolution better than 0.002mm. as result it permits a servo positioning accuracy within 0.01mm.

4.6 Fiber Head Protection Slide

The unit mechanical-function is equal to the other linear systems with the exception that there is no encoder. The control, since hasn't position reference, works in 'current mode', driving the motor from limit to limit, e.g., controlled directly by the power amplifier VME-4-SA.

4.7 Fiber-Head Selection

A motor-tacho encoder unit moves via a spindle one block were the fiber heads are fixed. This system, depending on the encoder resolution, permits a positioning accuracy of 1.5 microns with a 1000 pulses/rev. encoder.

4.8 Flat Field

A led of the commercial 480nm type controlled by the HARPS-LCU will be installed inside the spectrograph for that purpose. It will be directly controlled by one bit of the ACROMAG board.

4.9 Exposure Meter

A solution identical to the exposure meter for the UVES spectrograph has been chosen. *Two* photon-counting heads will collect a part of the polychromatic light (not yet dispersed by the echelle grating) entering the spectrograph. The first will serve to monitor the flux on the object fiber (fiber A). This will allow to determine precisely the mean time of the exposure. The second performs the measurement of the flux on the reference fiber (fiber B) with the main purpose of checking the flux of the calibration lamps.

Mechanically, the exposure meter will be mounted on the vacuum vessel on a dedicated vacuum flange (TBD). The light is passed by a small optical system through the vacuum window and focused on the photosensitive area of the PMT photocathode.

The exposure meter will use un-cooled photonmultiplier tubes with low dark count rate which will be in the order of few tens of counts at 20°C. These tubes are equipped with a complete photon-counting circuit with TTL output. A standard pulse counter will measure the count rate of the two channels simultaneously.

4.9.1 Photon-Counting Head

The selected photon-counting head is a Hamamatsu H6240 type. The photonmultiplier tube is mounted side on. It is specially designed for low light-level conditions. The photon-counting head has an internal high-voltage power supply, an integrated photon-counting circuit, and a TTL output. The head is completely pre-adjusted and ready-to-use. It requires only a +5Vdc source.

As a result of the compromise between spectral range and dark counts we have chosen the H6240-01 head. The technical data of this head are shown in Table 1.

Table 1: Technical data of the Hamamatsu H6240-01 photon-counting head

Description	Value	Units
Supply voltage	4.5 to 5.5, max. 6	Vdc
Input current at 2.5 Mcps output	max. 90	mA
Operating temperature	+5 to +40	°C
Storage temperature	-20 to +50	°C
Effective photosensitive area	4 x 20	mm x mm
Spectral range	185 to 850	nm
Spectral response @ 400 nm @ 500 nm @ 600 nm @ 700 nm @ 800 nm	 320'000 330'000 230'000 75'000 13'000	cps/pW
Dark counts at 20 °C	typ. 20	cps
Counting linearity (10% deviation) true rate: n=n'/(1-n't) n = true , n' = measured, t = pulse-pair resolution	2.5	Mcps
Maximum count rate	30	Mcps
Pulse pair resolution	35	ns
Output pulse width Ouput Logic Pulse width Termination	30 TTL, positive 30 50	ns ns Ohm
Connections (3 wires) Vcc (+5V) GND SIGNAL OUT	 AWG22 (red) AWG22 (black) RG-174/U	

Important notes:

1. When supply voltage turned on the PMT might be damaged by high light intensity causing high anode current. This shall be avoided by interlocking the supply voltage with the pulse counter. Supply voltage is turned off when the count rate exceeds the maximum allowed count rate.
2. Power supply must always be turned off when connecting/disconnecting the photon-counting head.
3. The photon-counting head should always be kept in darkness to avoid increase of dark current.

4.9.2 Pulse Counter

The TTL output pulses produced by the photon-counting head are collected by the digital pulse counter Agilent 53132 A (former HP). The two input channels allow to connect *two* photon-counting heads at the same time. The Agilent 53132 A is a GP-IB programmable stand-alone counter with 10 digits front panel display and control keyboard. It is equipped with an IEEE-4888 interface. The general characteristics of the Agilent 53132 A are shown in Table 2. The pulse counter will be located on the HARPS rack in the Coudé-west room.

Table 2: General characteristics of the Agilent 53132 A pulse counter

Description	Value	Units
Supply Voltage	115/230 ±10%, 50/60	V, Hz
Power consumption	typ. 30, max. 170	W
Operating Temperature	0 to 55	°C
Storage Temperature	-40 to 71	°C
Dimesions WxHxD	88.5 x 212.6 x 348.3	mm x mm x mm
Weight	3.5	kg
Security	IEC-1010, UL-3111-1, CAN 1010.1	
EMC	CISPR-11, EN 50 082, IEC 801-2,-3,-4	
Interface	IEEE-488	

Table 3: Performances of the Agilent 53132 A pulse counter

Number of input channels	2	
Coupling impedance	1M or 50	Ohm
Pulse resolution	4.5	ns
Sensitivity	0.1 to 10	V p-p
Trigger level Range Accuracy Resolution	 ± 5.125 ± (15 + 1% of trigger level) 5	 V mV mV
Damage level @ 50 Ω	5	Vrms
Measurements	Frequency, Period, Freqeuncy ratio, Time Intervall, Rise/Fall Time, Pulse Width, Totalize, etc.	

4.9.3 Power Supply for the Photon-Counting Head

A 5Vdc power supply of the type KNIEL CP5.4 will be used for both photon-counting heads. The power supply will be located at the CFA Rack.

4.9.4 Interfaces

Between the different link options that the manufacturers offer for access its instruments, one option is to use the transmission via RS232 or RS485 depending on the unit. By this way the instrumentation will be linked to the ISER-8 controller (VLT standard) that supports both serial protocols.

4.9.5 Cables and Connectors

The connections from the HAMAMATSU H6240 photon counting head will go to a terminal strip close to it, from there, the signal output will be connected by a BNC and the VCC power supply with a separate LEMO connector.

4.10 CCD Temperature Control

Since high control stability is required, the CCD temperature will be controlled by an external Lakeshore controller instead of PULPO. PULPO will be kept fully operational for all others of its functions (including shutter control and read out of two additional PT100 temperature sensors on the CCD cold plate), but it will not be used to control the CCD heater current. This solution allows to keep the standard HW configuration for FIERA and SW configuration for the DCS.
Two silicon diodes are mounted on the CCD cold plate. One of them serves as input for the control loop of the Lakeshore controller. A heating wire on the CCD cold plate is directly connected to the Lakeshore output.

4.10.1 Sensors

Two silicon diodes model DT-470 are mounted on the CCD cold plate. One will be used as control loop input, the other is used only for measurement but could also replace the first sensor in case of failure. Silicon diodes have been preferred against PT-100 because of their high repeatability of better than 0.01 K at cryogenic temperatures.

4.10.2 Controller

A Lakeshore 331S autotuning temperature controller (see Table 4 and Table 5) will perform precise control of the CCD temperature. The Lakeshore controller possesses a fully programmable PID control loop, but it is also capable of complete and reliable autotuning as well as many other functions. In this configuration and using the silicon diodes, the Lakeshore 331S is able to deliver a CCD temperature stability in the order of 0.01°C.
For sufficient redundance the control system foresees two temperature sensors and two heating wires mounted in the detector head and wired to the electrical connectors. In case of failure the system is easily repaired without opening the vacuum vessel or the detector dewar. In addition, it will also be possible to use PULPO to control the heating wire.

Table 4: Lakeshore 331S controller characteristics

Description	Value	Units
Supply Voltage	115/230 ±5%, 50/60	V, Hz
Power consumption	120	W
Operating Temperature for rated accuracy	15 to 35	°C
Operating Temperature at reduced accuracy	10 to 40	°C
Dimesions WxHxD	217 x 90 x 317	mm x mm x mm
Weight	4.77	kg
Serial interface Connector	RS232C, 9600 BAUD DE-9	
Additional interfaces	IEEE-488	
Input connector	6 pin DIN	
Heater connector	Dual banana	

Table 5: Performances of the Lakeshore 331S controller

Number of sensor inputs	2	
Sensor type used	Silicon diode DT-470	
Useful range	1.4 to 475	K
Absolute accuracy	± 0.120	K
A/D converter resolution	24 bit	
Measurement resolution	0.005	K
Update rate	10	readings/s
Control	Digital, three-term PID with autotuning, 2 control loops	
Control stability	± 0.01	K
Heater output type	Variable DC current source	
Heater isolation	Optical isolation to other circuits	
Heater output resolution	18 bit	
Heater power/current	max. 50/1	W/A
Heater load for full power	25 or 50	Ohm
Heater load for HARPS	TBD	Ohm

4.10.3 Interfaces

The Lakeshore temperature controller is linked via a serial RS232 interface to ISER interface board of the HARPS LCU. It will be controlled by the ICS instead of the DCS. Via the ICS the set temperature as well as all control parameters can be set and read out. It will also deliver the exact temperature of the silicon diodes.

The controller will be located on a dedicated rack inside the HARPS room.

4.10.4 Cables and Connectors

Cables and connectors are described in the CCD Detector Design Report (RD-1). The electrical vacuum feed-through is described in RD-2.

4.11 Vacuum Vessel Temperature Control

The temperature control of the Vacuum Vessel is described in RD-3. The control loop is identical to that of the CCD temperature control. It uses also a Lakeshore 331S controller described in Section 4.10.2. This offers the advantage of providing only one spare controller for both systems.

4.11.1 Sensors

Two DT-470 silicon diodes will be used to control the HARPS Enclosure Box temperature. One of them will be used as control loop input. The performances of the temperature measurement at room temperature by means of the Lakeshore 331S and the silicon diodes is shown in Table 6.

Table 6: Accuracy of the temperature measurement of the HARPS enclosure by means of a DT-470 sensor and a Lakeshore controller

Description	Value	Units
Temperature (ambient)	20	°C
Absolute accuracy	± 0.105	K
Measurement resolution	0.004	K
Control stability	± 0.01	K

4.11.2 Controller and Interfaces

See Sections 4.10.2 and 0.
The controller will be located in the HARPS-RACK.

4.11.3 Heater

The heater is described in detail in RD-3. It consists of a heat-exchange body with a 50 Ohm heating wire delivering a maximum heating power of 50 W. A second heating wire will be installed but not connected. It will only serve in case of the necessity of supplying a constant heat-power term to the control system.

4.11.4 Cables and Connectors

A two-wire cable for 2 A current (min.) connects the heater to the Lakeshore controller. The connections between the Lakeshore 331S and the two sensors are included into the controller package. It foresees two four-leads cables (standard Lakeshore) directly connected to the Lakeshore 331S.

Chapter 5: Environment Monitoring

5.1 Environment Sensors

5.1.1 Overview of the Various Sensors Locations

HCFA	This is the HARPS Cassegrain Fiber Adapter which forms the interface to the telescope. It is mounted at the Cassegrain Focus of the 3.6-m telescope and is therefore exposed to varying environmental conditions. It contains nearly all moving parts of the HARPS instrument as well as the iodine cell for self-calibration.
Coudé Room	This is the Coudé-West room of the 3.6-m telescope building at the ESO La Silla Observatory. The attained temperature stability over a full year is of about ±1°C.
Calibration Unit	This Unit is mounted in an electronic rack inside the Coudé Room. It contains all calibration sources.
HARPS Room	The HARPS Room (also called HARPS Enclosure) is a separate room inside the Coudé Room. This room is air conditioned and stabilized in temperature with an accuracy of about 0.3°C.
HARPS Enclosure	An isolation box inside the HARPS room which surrounds the Vacuum Vessel. The air temperature inside this box is controlled to better than ±0.05 C.
Vacuum Vessel	The Vacuum Vessel contains the entire HARPS spectrograph which is operated in vacuum. It is about 3 meters long and 1 meter in diameter.
Optical Bench	This is the optical bench of the spectrograph which supports all optical elements. Its dimensions are about 2500x700x200 mm.

5.1.2 Specific HARPS Sensors for Monitoring of the Environment

The list of HARPS-specific environment sensors is given in Table 12 in the Appendix. Only the sensors within ICS are shown. Standard sensors recorded by the TCS or DCS are not listed therein.

5.1.3 Generic Environment Sensors

As mentioned in AD-2 additional environmental parameters arising from other systems shall be recorded and inserted into the FITS header. See examples in Table 7.

Table 7: Generic environment sensors

Parameter	System to deliver
seeing	TCS (or seeing monitor)
relative humidity	meteo monitor
wind speed	meteo monitor
atmospheric pressure	meteo monitor
etc.	

5.1.4 Inclusion into FITS Headers

As a general rule all available sensors are included into the FITS headers in order to allow the observer to have an overview of the general environmental conditions at the moment of the observation. The FITS header will contain the mean value of the sensors during the exposures, but also the first derivative, and the RMS issued from linear regression if sufficient data points available (TBC, TBD). These values will be used also for maintenance purposes as described in AD-1.

5.2 Controllers and Sensors

5.2.1 Temperature Measurement

5.2.1.1 Sensors

The goals of the temperature measurement are mainly two:

a) Monitor the general HARPS environment, for example for safety reasons. For this application no accuracy and repeatability had been specified since this is not critical. For these cases Type E thermocouple have been chosen which allow to monitor the temperature over a large range with good accuracy, and at low costs. The typical repeatability is of few tenths of degree and is largely sufficient for this application. These sensors are available on adhesive foils or screw-mountable stainless-steel holders.

b) Monitor precisely the temperature of the spectrograph and its components for performance tracking of the instrument which has to provide 1 m/s RV accuracy. These measurements will allow to verify that the spectrograph environment remains stable. Since the spectrograph temperature is designed to remain stable at better than ±0.05°C the sensors and the controller must perform temperature measurements with short and long-term stability of the same accuracy level or better. The ceramic mounted PT100 sensors has a guaranteed stability of 0.05°C over one year and for a wide temperature range and variations. It has therefore been chosen for this specific application. These sensors are available on adhesive foils or screw-mountable stainless-steel holders.

c) Sensors used with the control loops of the vacuum vessel and CCD temperature are Silicon diodes. Very good long-term stability is expected using this type of sensors.

5.2.1.2 The Prema 3040 Multi-Channel Thermometer

For the precise temperature measurement inside the HARPS room we have chosen to employ two Prema 3040 multi-channel thermometer. This model allows to read out up to 18 PT100 or 34 thermocouples with a resolution of 0.001°C over a very wide temperature range. The delivered resolution is consistent with the long-term stability of the measurement which is of the order of few m°C. The characteristics of this instrument are given in Table 8 while the measurement performance for a PT100 and a Type E thermocouple are shown in Table 8.
The standard Prema 3040 model will be controlled via an RS 232 interface. The unit will be installed on the HARPS rack and will be linked to the ISER interface board on the HARPS LCU.

Table 8: Characteristics of the PREMA 3040 multichannel thermometer

Description	Value	Units
Supply Voltage	115/230 ±10%, 50/60	V, Hz
Power consumption	typ. 20, max. 50	W
Heat-up time for full accuracy	3	hours
Operating Temperature	10 to 45	°C
Storage Temperature	-25 to 60	°C
Relative humidity	< 75 %	
Dimensions WxHxD	94 (2 HE) x 225 (19") x 375	mm x mm x mm
Weight	3.4	kg
Security	EN 61 010, CE compliant	
EMC Interfaces	EN 50 081, EN 50 082, EN 55 011, CE compliant RS232 or IEEE488	
# of channels max.	18 PT 100 or 34 thermocouples	

Table 9: Measurement performances of the PREMA 3040 multichannel thermometer

	PT 100	Type E thermocouple
Integration time	100 ms to 100 s	100 ms to 100 s
Max. resolution	0.001°C	0.001°C
Temperature range	-200 to 850 °C	-270 to 1000 °C
Accuracy @ 20°C (24h)	0.004 °C (operated @ 1 mA)	0.009 °C
Accuracy @ 20°C (1 year)	0.011 °C (operated @ 1 mA)	0.009 °C

5.2.1.3 Absolute and Relative Accuracy

Absolute accuracy is not required for our application. Nevertheless we foresee to cross-calibrated all the sensors including the spares during the initial phase of the instrument integration.
Relative accuracy over 10 years will be limited by the long-term stability of the PT 100 sensors. Considered the high repeatability of the PT100 sensors and the very stable environmental conditions of their application we foresee long-term stability in the order of 0.05°C in compliance with the required 0.1°C stability of the spectrograph.

5.2.1.4 The Adam Temperature Controller

For all temperature sensors dislocated from the HARPS room, e.g., at the HCFA, and which do not require highest accuracy, small and low-cost ADAM-5013 modules capable to read three PT100 sensors may be equipped in a ADAM-5000-485 controller frame up to a maximum of four. Or in case more than twelve PT100 sensors have to be read, the ADAM-5000E may be equipped with a maximum of eight ADAM-5013 units allowing to read 24 PT100 sensors.

ADAM modules integrate a signal transducer, that according specifications, guarantee a accuracy of 0.2% which is within the 0.1°C for ambient temperature range with typically 0.01°C resolution.
The ADAM-5000, carrier of the ADAM-5013 modules, is linked via an RS-485 bus to the ISER interface board of the HCFA LCU.

5.2.2 Pressure Measurement

The pressure of the detector dewar will be monitored permanently by PULPO/FIERA and the DCS. Only the pressure inside the vacuum vessel of the spectrograph will be recorded by the ICS. The measured pressure ranges from ambient pressure to low-vacuum condition of 10^{-3} mbar. A standard Pirani-Piezo gauge can be used for this purpose. The chosen solution consists of a RPT 100 Pfeiffer gauge controlled by the Pfeiffer DPG 109 controller. The DPG 109 allows to connect up to 9 Pfeiffer gauges through a RS 485 bus. Thus, additional Pfeiffer pressure gauges of different type can be added later. The controller itself is linked to the HARPS LCU via a RS232 interface. Technical data of the gauge and its controller are given in Table 10 and Table 11, respectively.

Table 10: Technical data of the Pfeiffer RPT 100 gauge head

Description	Value	Units
Principle of measurement	Piezo/Pirani	
Measurement range	10^{-4} to 1200	mbar
Accuracy Reaction time	@ 5 - 1200 mbar: 0.5% F.S. @ < 5mbar: 10% of measured value < 200	 ms
Cycle time	20	ms
Supply voltage	24	V
Supply current	55	mA
Interface Electrical connection	RS232 or RS485 Sub d connection 9 pins	
Protection class	IP 40	
Weight	0.2	kg
Vacuum connection	DN 16 KF	
Operating temperature	5 to 50	°C
Storage temperature	-40 to 60	°C
Max. degassing temperature	70	°C

Table 11: Technical data of the Pfeiffer DPG 109 controller

Description	Value	Units
Channels	Up to 9 gauge heads (different types)	
Supply voltage	90-260, 50/60	V AC, Hz
Power consumption	max. 48	W
Operating temperature	5 to 50	°C
Storage temperature	-20 to 60	°C
Outputs		
Relay contacts	8	
Set points	adjustable	
Reaction time	< 50	ms
Lifetime of relay contacts	> 100000	cycles
Rating of the relay contacts	AC 50/3 DC 30/3	V/A V/A
Digital Interface		
Type	RS232	
Connector	TBD	
Weight	1	kg

5.2.3 Measurement of the LN_2 Level

The liquid Nitrogen level in the storage dewar will be measured with an instrument based on a commercial sensor from ‘Cryo Diffusion’ which is described in the document ‘VLT-MAN-ESO-1730-2017’ (RD-4).
The original sensor only displays the LN2 level on an analog scale, when a push-button is being pressed. The battery-powered unit will be modified in such a way that:

1. the level is permanently displayed
2. the unit is externally powered
3. the analog output signal (0-10 V) is available for a transducer connected to an RS232

Chapter 6: EMC Considerations

All the electronic control boards and component used are standard VLT components that match Electromagnetic Compatibility and Power Quality specifications ([1]). Electronics design, interconnections and installations will be carried out according ESO internal Electronic Design Specifications ([2]).

([1]) VLT-SPE-ESO-10000-0002
([1]) VLT-SPE-ESO-10000-0003
([2]) VLT-SPE-ESO-10000-0015

Chapter 7: Appendix

7.1 List of HARPS-Specific Environment Sensors

The list of HARPS-specific environment sensors are given in Table 12. Only the sensors control via the ICS are shown. Standard sensors recorded by the TCS or DCS are not listed herein.

Table 12: List of HARPS -specific sensors

DID name	Sensor description and location	Sensor type	Controller & Interface	LCU	Value range	Format & Unit	Resolution
	Temperature of HCFA body	PT-100	ADAM-4000 RS485	HCFA	-100 to 100 °C	±nnn.nn °C	0.01 °C
	Temperature of iodine cell	PT-100	OMEGA RS232	HCFA	TBD	TBD °C	TBD °C
	Temperature of HCFA Environment Spare #1	Type E thermocouple	ADAM-4000 RS485	HCFA	-100 to 100 °C	±nnn.nn °C	0.01 °C
	Temperature of HCFA Environment Spare #2	Type E thermocouple	ADAM-4000 RS485	HCFA	-100 to 100 °C	±nnn.nn °C	0.01 °C
	Temperature of Calibration Unit	Type E thermocouple	PREMA 3040 RS232	HARPS	-100 to 100 °C	±nnn.nn °C	0.01 °C
	Temperature of Coudé Room	Type E thermocouple	PREMA 3040 RS232	HARPS	-100 to 100 °C	±nnn.nn °C	0.01 °C
TBC	Temperature 1 of HARPS Room (control reference)	TBD	TBD	HARPS	TBD	TBD	TBD
	Temperature 2 of HARPS Room	Type E thermocouple	PREMA 3040 RS232	HARPS	-100 to 100 °C	±nnn.nn °C	0.01 °C
	Temperature 3 of HARPS Room	Type E thermocouple	PREMA 3040 RS232	HARPS	-100 to 100 °C	±nnn.nn °C	0.01 °C
	Temperature of Air-Handling Unit Cooling Water	Type E thermocouple	PREMA 3040 RS232	HARPS	-100 to 100 °C	±nnn.nn °C	0.01 °C
	Temperature 1 of HARPS Enclosure Box (reference)	Silicon diode DT-470	Lakeshore 331S RS232	HARPS	0 to 50 °C	nn.nnn °C	0.001 °C
	Temperature 2 of HARPS Enclosure Box	Silicon diode DT-470	Lakeshore 331S RS232	HARPS	0 to 50 °C	nn.nnn °C	0.001 °C
	Temperature 3 of HARPS Enclosure Box	PT-100	PREMA 3040 RS232	HARPS	0 to 50 °C	nn.nnn °C	0.001 °C
	Temperature of HARPS Environment Spare #1	PT-100	PREMA 3040 RS232	HARPS	-100 to 100 °C	±nn.nn °C	0.01 °C
	Temperature of HARPS Environment Spare #2	PT-100	PREMA 3040 RS232	HARPS	-100 to 100 °C	±nn.nn °C	0.01 °C
	Temperature of HARPS Environment Spare #3	PT-100	PREMA 3040 RS232	HARPS	-100 to 100 °C	±nn.nn °C	0.01 °C

	Temperature of Vacuum Vessel detector side	PT-100	PREMA 3040 RS232	HARPS	0 to 50 °C	nn.nnn °C	0.001 °C
	Temperature of Vacuum Vessel collimator side	PT-100	PREMA 3040 RS232	HARPS	0 to 50 °C	nn.nnn °C	0.001 °C
	Temperature of Vacuum Vessel top	PT-100	PREMA 3040 RS232	HARPS	0 to 50 °C	nn.nnn °C	0.001 °C
	Temperature of Vacuum Vessel bottom	PT-100	PREMA 3040 RS232	HARPS	0 to 50 °C	nn.nnn °C	0.001 °C
	Temperature of Vacuum Vessel east	PT-100	PREMA 3040 RS232	HARPS	0 to 50 °C	nn.nnn °C	0.001 °C
	Temperature of Vacuum Vessel west	PT-100	PREMA 3040 RS232	HARPS	0 to 50 °C	nn.nnn °C	0.001 °C
	Temperature of Vacuum Vessel Spare #1	PT-100	PREMA 3040 RS232	HARPS	0 to 50 °C	nn.nnn °C	0.001 °C
	Temperature of Vacuum Vessel Spare #2	PT-100	PREMA 3040 RS232	HARPS	0 to 50 °C	nn.nnn °C	0.001 °C
	Temperature of Vacuum Vessel Spare #3	PT-100	PREMA 3040 RS232	HARPS	0 to 50 °C	nn.nnn °C	0.001 °C
	Temperature of CFC vessel outside	PT-100	PREMA 3040 RS232	HARPS	0 to 100 °C	nn.nn °C	0.01 °C
	Temperature of the Image Scrambler	PT-100	PREMA 3040 RS232	HARPS	0 to 50 °C	nn.nnn °C	0.001 °C
	Temperature of Optical Bench detector side Temperature of Optical Bench collimator side Temperature of Optical Bench top	PT-100 PT-100 PT-100	PREMA 3040 RS232 PREMA 3040 RS232 PREMA 3040 RS232	HARPS HARPS HARPS	0 to 50 °C 0 to 50 °C 0 to 50 °C	nn.nnn °C nn.nnn °C nn.nnn °C	0.001 °C 0.001 °C 0.001 °C
	Temperature of Optical Bench bottom	PT-100	PREMA 3040 RS232	HARPS	0 to 50 °C	nn.nnn °C	0.001 °C
	Temperature of Optical Bench east	PT-100	PREMA 3040 RS232	HARPS	0 to 50 °C	nn.nnn °C	0.001 °C
	Temperature of Optical Bench west	PT-100	PREMA 3040 RS232	HARPS	0 to 50 °C	nn.nnn °C	0.001 °C

	Temperature of Fiber Exit	PT-100	PREMA 3040 RS232	HARPS	0 to 50 °C	nn.nnn °C	0.001 °C
	Temperature of Collimator	PT-100	PREMA 3040 RS232	HARPS	0 to 50 °C	nn.nnn °C	0.001 °C
	Temperature of Echelle Grating	PT-100	PREMA 3040 RS232	HARPS	0 to 50 °C	nn.nnn °C	0.001 °C
	Temperature of the Grism	PT-100	PREMA 3040 RS232	HARPS	0 to 50 °C	nn.nnn °C	0.001 °C
	Temperature of Camera Optics detector side	PT-100	PREMA 3040 RS232	HARPS	0 to 50 °C	nn.nnn °C	0.001 °C
	Temperature of Camera Optics collimator side	PT-100	PREMA 3040 RS232	HARPS	0 to 50 °C	nn.nnn °C	0.001 °C
	Temperature of Detector-Head Vessel outside	PT-100	PREMA 3040 RS232	HARPS	0 to 50 °C	nn.nnn °C	0.001 °C
	Temperat ure of Spectrograph Spare #1	PT-100	PREMA 3040 RS232	HARPS	0 to 50 °C	nn.nnn °C	0.001 °C
	Temperature of Spectrograph Spare #2	PT-100	PREMA 3040 RS232	HARPS	0 to 50 °C	nn.nnn °C	0.001 °C
	Temperature of Spectrograph Spare #3	PT-100	PREMA 3040 RS232	HARPS	0 to 50 °C	nn.nnn °C	0.001 °C
	Temperature 1 of CCD (control reference)	Silicon diode DT-470	Lakeshore 331S RS232	HARPS	0 to 350 K	nnn.nnn K	0.001 K
	Temperature 2 of CCD	Silicon diode DT-470	Lakeshore 331S RS232	HARPS	0 to 350 K	nnn.nnn K	0.001 K
	Pressure inside Vacuum Vessel	Pfeiffer RPT 100	Pfeiffer DPG 109 RS 232 or 485	HARPS	1.2 x 10^3 to 1 x 10^{-4} mbar	n.nnn $E^{\pm x}$ mbar	four digits
DCS	Pressure inside Detector Dewar	Balzers PKR 250 (TBC)	PULPO	FIERA	1000 to 1 x 10^{-9} mbar		
	Pressure Spare #1	TBD	Pfeiffer DPG 109 RS 232 or 485	HARPS	1.2 x 10^3 to 1 x 10^{-9} mbar	n.nnn $E^{\pm x}$ mbar	four digits
	Accelerometer Optical Bench (TBC)	TBD	TBD	HARPS	TBD	TBD	TBD
	Accelerometer Coudé Floor (TBC)	TBD	TBD	HARPS	TBD	TBD	TBD
	Liquid-Nitrogen Level	Capacitance LN_2-level sensor	AMI Model 185 (TBC) RS232	HARPS	0 to 100 %	nnn.n %	0.1 %

7.2 List of Cable and Connectors

For the ‘La Silla’ project-part, have been chosen according the requirements and considering the maintenance aspects, e.g., spare parts diversification vs. measurements feasibility and friendly use mainly three manufactures: LEMO, WEIDMUELLER and PHOENIX CONTACTS.
Note that this doesn’t comprehend ESO standard boards nor third party suppliers, in each particular case as far as feasible, it will be brought to the above considerations.

A detailed cable and connections listing may drift depending on the final project review decisions. This is an essential part of the technical documentation, which is not only needed for the project, rather is part of the system information for maintenance.

7.3 Technical documentation

A complete system information, e.g., schematics, drawings, components data sheets, instrument manuals, etc. will be stored at (TBD).