A PLC distributed layout: the case of the Instrument Control Electronics of ESPRESSO

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Introduction

ESPRESSO, the Echelle SPectrograph for Rocky Exoplanet and Stable Spectroscopic Observations of the European Southern Observatory (ESO) is passing the integration phase in Geneva before being shipped to Chile and installed at the Very Large Telescope (VLT) site on the Cerro Paranal.
It is going to be one of the first permanent instruments of VLT with a distributed control electronics based on Beckhoff PLCs.
About 40 motorized stages, more than 90 sensors and several calibration lamps are controlled by the Instrument Control Electronics (ICE) and Software (ICS).
All the ESPRESSO functionalities are managed by two main CPUs that share the workload.
The Beckhoff EtherCAT decentralization modules ensure the EtherCAT continuity among the several PLC electronics subracks placed in different cabinets, allowing optimal distributed architecture.
Furthermore, one of the two CPUs is equipped with an IEEE 1588 protocol interface, used for the time synchronization of distributed clocks in the networks.

ESPRESSO electronics distribution

ESPRESSO control electronics is made of 9 electronics cabinets that host all the electrical devices including the control system. The control system employs a distributed architecture based on Beckhoff PLC [1]. Figure 1 shows the main electronic cabinets. ICE duties are to provide the network and the power supply to each cabinet. Moreover, the EtherCAT link allows the communication between the CPUs, configured and programmed by ICE, and the decentralized Beckhoff modules placed in the different cabinets.
Figure 2 depicts the ESO-VLT Combined Coudé Laboratory (CCL): ICE main cabinet (IMC), Thermal Cabinet (THE), Calibration Unit cabinet (CAL), and Vacuum Control System (VCS) cabinet positions are marked in green, NGC/shutter interface cabinet position is maked in yellow and Front End Unit (FEU) cabinets in blue. Red oval highlights the Service Connection Points (SCP) from which the power is provided to the whole instrument.

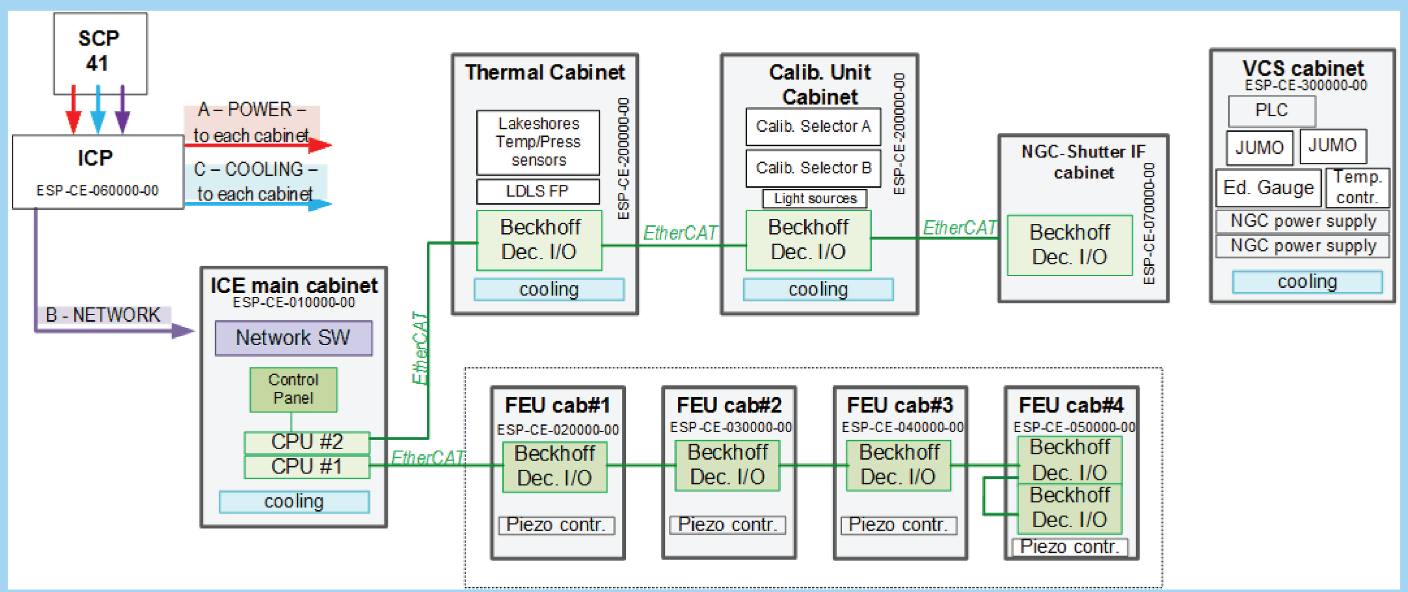

Figure 1 ESPRESSO electronics cabinets

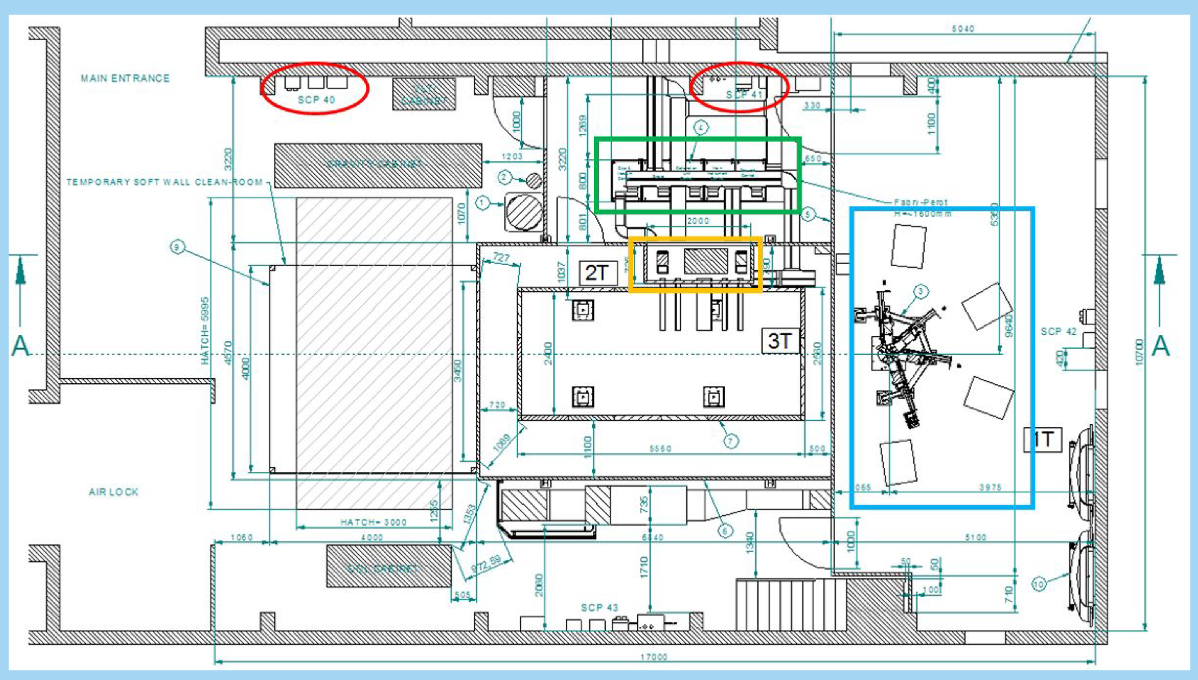

Figure 2 VLT CCL and electronic cabinet position

ICE main core: the Beckhoff CPUs

More than 90 sensors, about 40 motors and several calibration lamps are controlled by the core of the control system: the CPU.
Two CPUs share the workload and are installed in 19 inches subracks placed in the main ICE cabinet (see Figure 3).
The CPU series chosen is the CX2030, based on Intel processor 1,5 GHz dual core. Figure 4 shows the CPU main features.

Figure 3 CPU 1 subrack

Technical data	CX2030
Processor	Intel® Core™ i7 2610UE 1.5 GHz, 2 cores (TC3: 60)
Flash memory	4 or 8 GB CFast flash card (optionally expandable)
Internal main memory	2 GB DDR3 RAM
Persistent memory	128 KB NOVRAM integrated
Interfaces	2 x RJ45, 10/100/1000 Mbit/s, DVI-I, 4 x USB 2.0, 1 x optional interface
Diagnostics LED	1 x power, 1 x TC status, 1 x flash access, 2 x bus status
Clock	internal battery-backed clock for time and date (battery exchangeable)
Operating system	Microsoft Windows Embedded Compact 7 or Microsoft Windows Embedded Standard 7 P
Control software	TwinCAT 2 PLC runtime, NC PTP runtime, NC I runtime
I/O connection	via power supply module (E-bus or K-bus, automatic recognition)
Power supply	24 V DC (-15 %/+20 %)
Max. power loss	20 W (including the system interfaces)
Dimensions (W x H x D)	144 mm x 100 mm x 91 mm
Weight	approx. 1165 g
Operating/storage temperature	-25…+60 °C/-40…+85 °C
Relative humidity	95 %, no condensation
Vibration/shock resistance	conforms to EN 60068-2-6/EN 60068-2-27
EMC immunity/emission	conforms to EN 61000-6-2/EN 61000-6-4
Protection class	IP 20

Figure 4 The main features of the Beckhoff CPU CX-2030

The instrument main cabinet

Figure 5 ESPRESSO instrument main cabinet

Besides the PLC subracks, the ICE main cabinet hosts:
- the instrument alarm system
- the ESO 1HE cabinet cooling controller
- 3 shutters drivers
- the network switch
- a control panel for maintenance purposes

The cabinet, as the VCS, THE and CAL cabinets, is a Schroff Varistar LHX3 type, IP55 compliant.

Functions distribution between the CPUs

Figure 6 shows more in detail the ESPRESSO functions distribution between the two Beckhoff CPUs. The CPU#1 controls all the motors and sensors placed in the FEU area (blue rectangle of Figure 2), while CPU#2 controls all the other devices. The EK1100 modules installed at the beginning of the decentralized modules rows allow the EtherCAT communication among the Beckhoff hardware.
For example, the topology of the CPU#1 linked network is shown in Figure 7.
The communication between the PLC and the higher level Instrument Control Software (ICS) is done via OPC-UA server, installed on the PLCs [2].

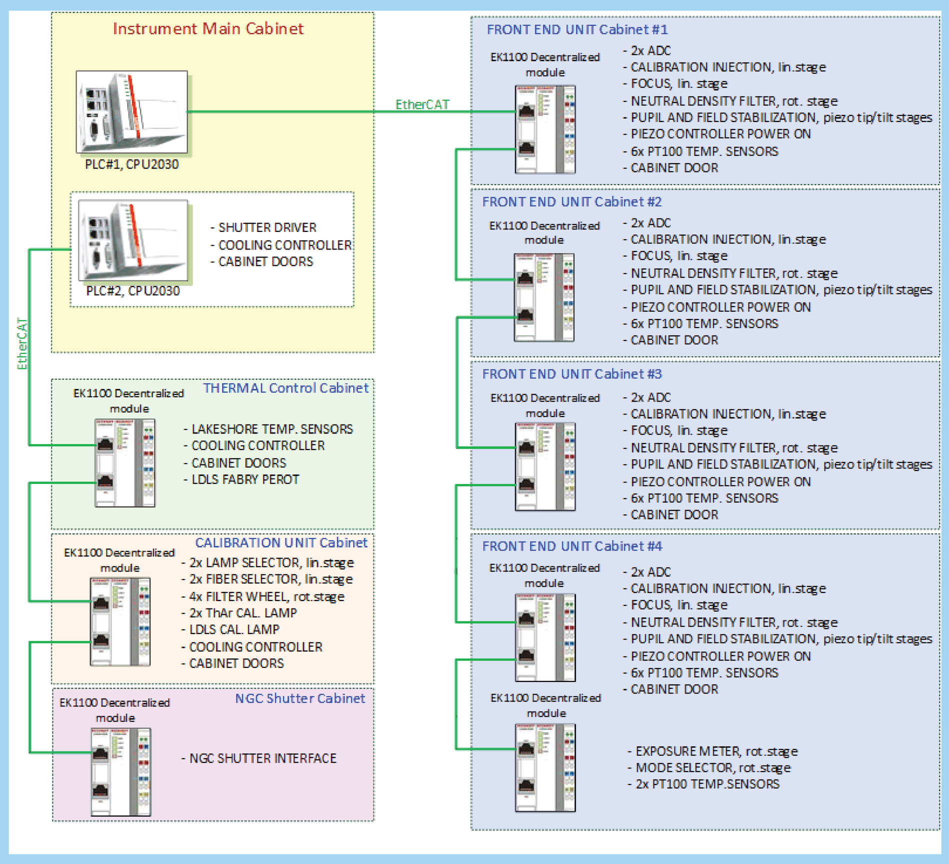

Figure 6 ESPRESSO functions distribution between the two main PLC CPUs

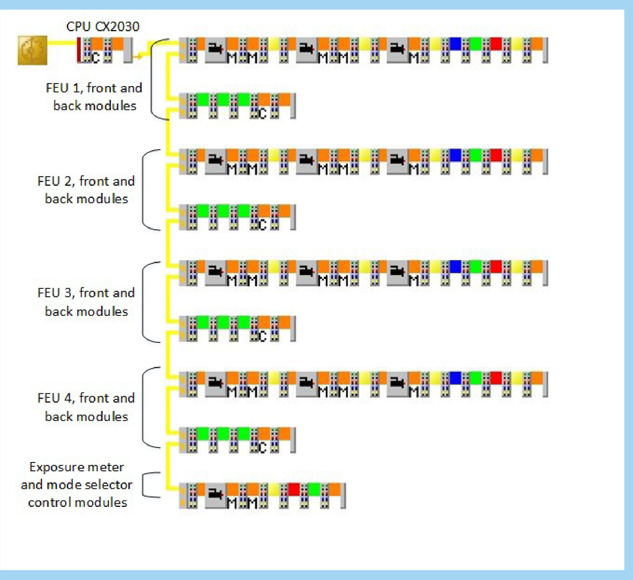

Figure 7 Example of Beckhoff network topology for CPU#1.

FEU functions control: the CPU#1 workload

Figure 8 shows in detail the functions of one of the FEU arms that is controlled by ICE CPU#1. CPU#1 performs the PID control of two linear stage, one filter wheel and two ADCs for each of the four FEU arms. Real time computations are performed for the eight ADC tracking motors, whose PID control loop is corrected at every PLC cycle time. The workload of CPU#1 is, in this way, around 40%, against less than 20% of CPU#2 that does not need to perform real time corrections on the motors controlled.
The FEU cabinets, containing the Beckhoff subracks for the control of each FEU arm and the piezo controller, are depicted in Figure 9, during the Europe installation in Geneva.

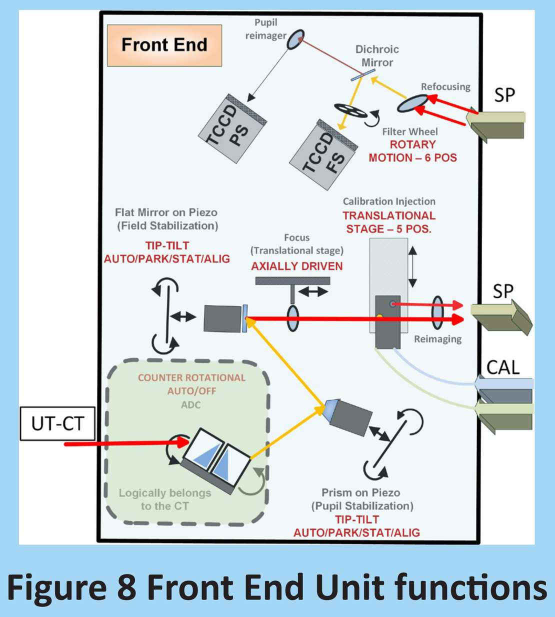

Figure 8 Front End Unit functions

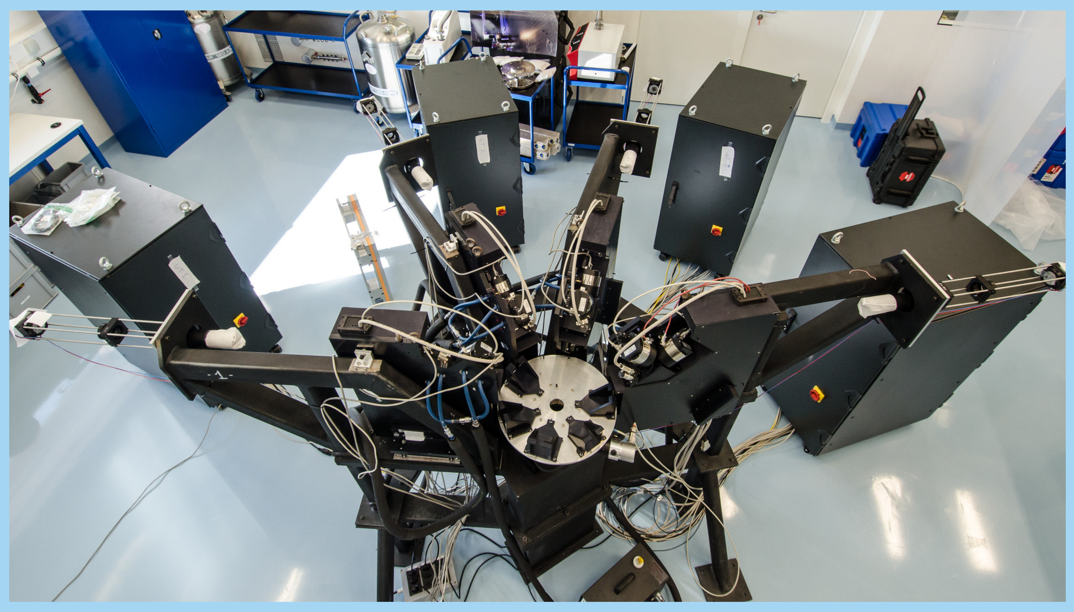

Figure 9 Overview of the FEU cabinets placed near each FEU arm

Bibliography

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[2] R. Cirami, et al., "An OPC-UA based architecture for the control of the ESPRESSO spectrograph @ VLT", San Francisco, USA, ICALEPCS2013, ISBN 978-3-95450-139-7.

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