CENTRE NATIONAL D'ÉTUDES SPATIALES

Some CNES electronic activities using Microcontrollers

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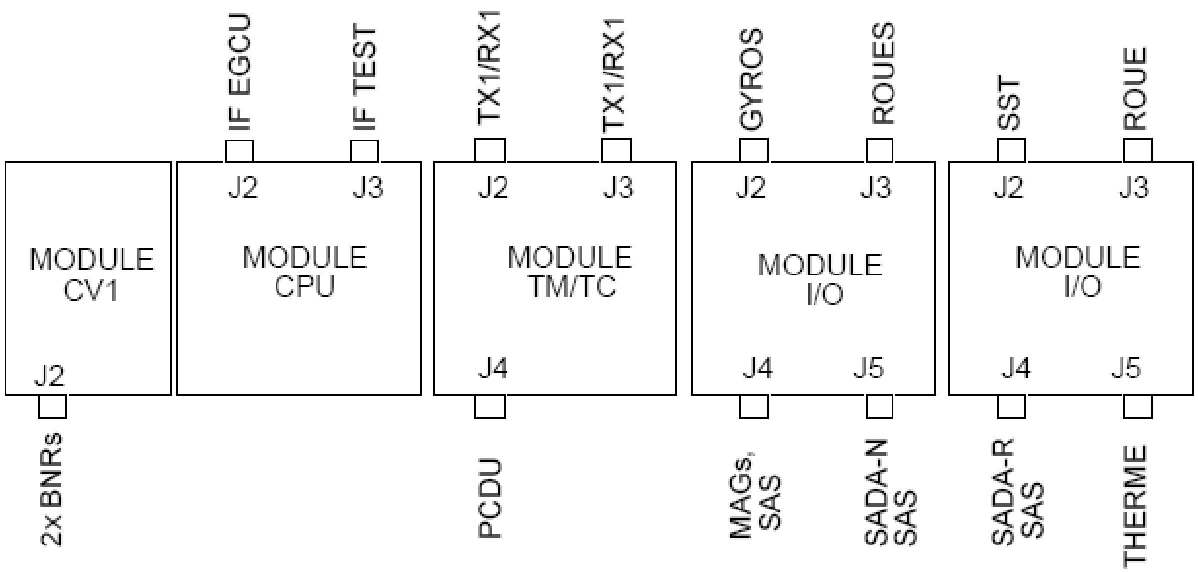
Summary

- MYRIADE Heritage on Microcontrollers
- Space Evaluation on Microcontrollers
- Thermal Control and Servitude Bus (TCSBUS)
- Li-Ion Battery Balancing Electronic (LIBBE)

MYRIADE Heritage

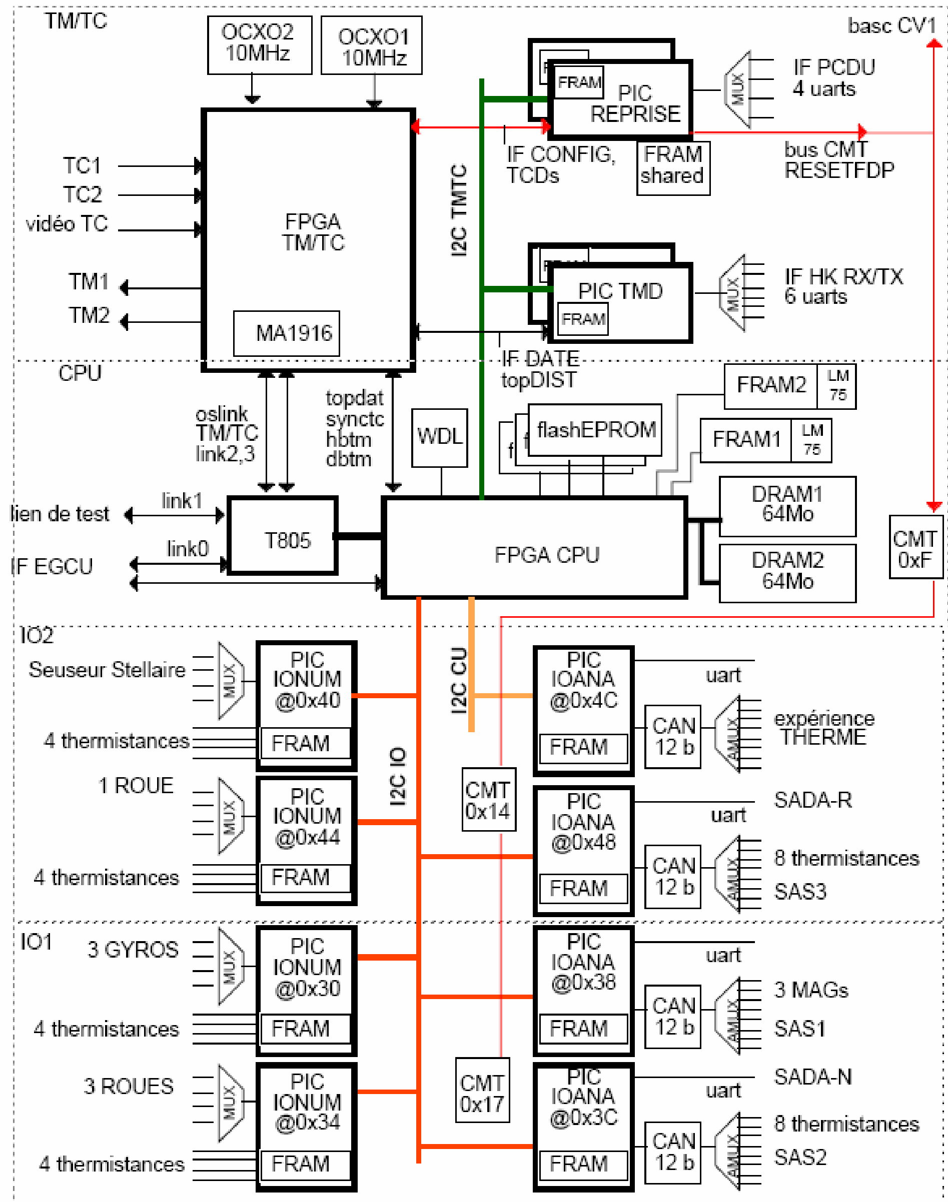
MYRIADE OBC



IF EGCU
IF TEST
TX1/RX1
TX1/RX1
GYROS
ROUES
SST
ROUE
MODULE CV1
J2
MODULE CPU
J2
J3
MODULE TM/TC
J2
J3
J4
MODULE I/O
J2
J3
J4
J5
MODULE I/O
J2
J3
J4
J5
2x BNRs
PCDU
MAGs, SAS
SADA-N SAS
SADA-R SAS
THERME

MYRIADE OBC

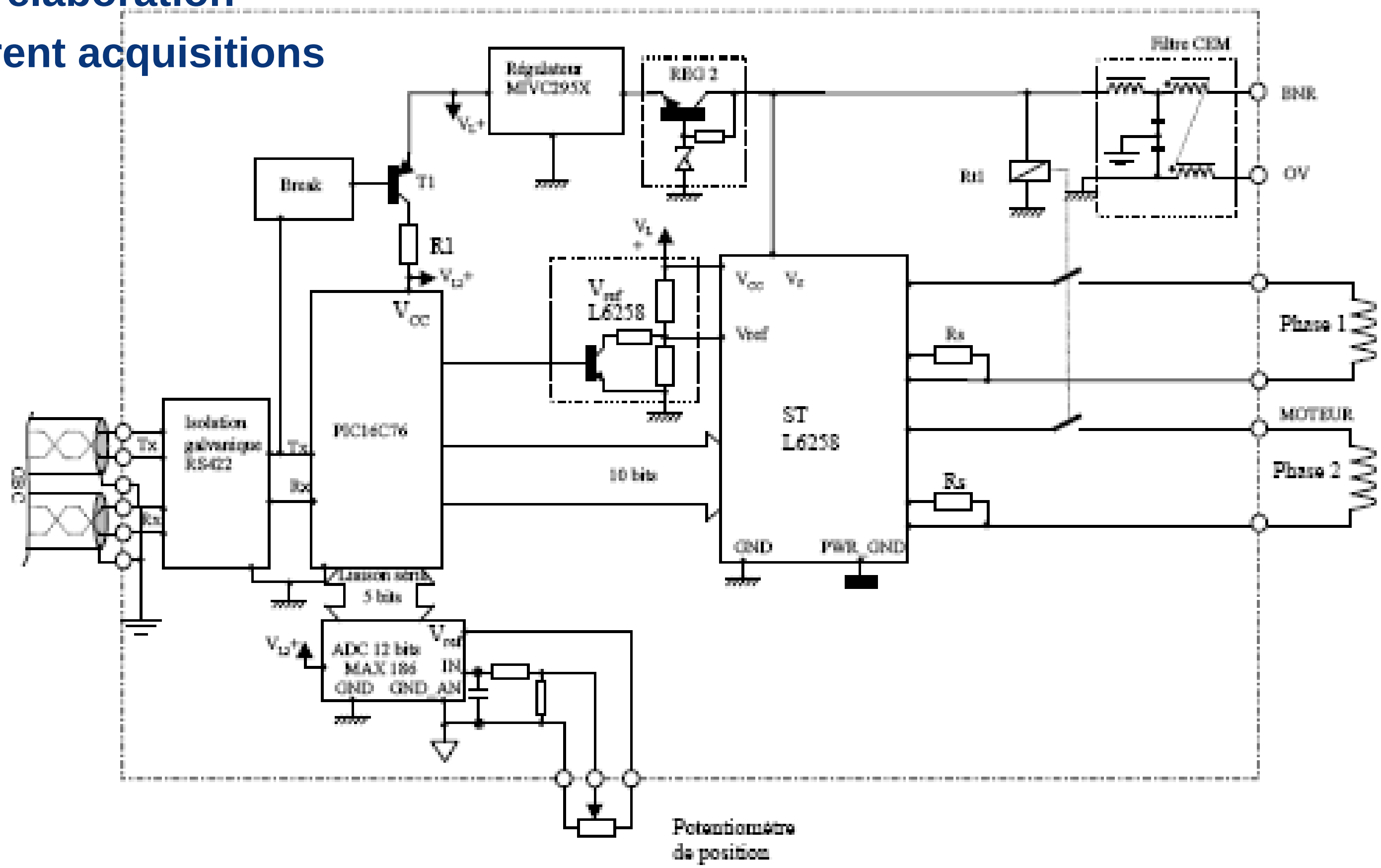
- **OBC architectures :**
  - PIC16C76 from MICROCHIP
  - PIC16C76 tested in radiation and evaluated for space.
  - Protections :
    - PIC supply current limited (Latch-up)
    - De-latch circuit
    - External particular watchdog
  - I/O modules :
    - PIC between internal I2C bus and external I/F
    - Digital I/O
    - Analog I/O
  - TM/TC module :
    - Redounded PICs I/F with PCDU
    - Redounded PICs I/F with RX/TX



MYRIADE SADM

■ SADM MYRIADE :

- PIC16C76
- Electronic command of the drive mechanism
- Interface dialog with OBC
- Motor Phase references elaboration
- Motor position and current acquisitions



MYRIADE

- Excellent behavior in flight
- 8 satellites in orbit :
  - DEMETER, PARASOL, 4 ESSAIM (2004)
  - SPIRAL (2007)
  - PICARD (2010)
- No anomaly on Microcontrollers

WAY FORWARD

- **NEW generation of MYRIADE products :**
  - **Obsolescence of PIC16C76**
  - **Find a new PIC reference for MYRIADE line of product (OBC, SADM, others…)**
- **Space evaluation :**
  - **CNES R&T will start on space evaluation of Microcontrollers**
- **New applications :**
  - **Decentralized I/F units**
    - Sensor network
    - Discrete standards interfaces
    - Active Thermal control
  - **Battery management**

Space Evaluation

Space Evaluation

- **Preliminary trade-off on microcontrollers :**
  - **CNES internal preliminary evaluation on Microcontroller needs**
  - **Replacement of the Microchip PIC16C76 used by MYRIADE**
  - **First references chosen : Microchip PIC18LF2620, PIC18LF2820, PIC18LF4620, PIC18LF4820**
    - Pin compatible for MYRIADE OBC (PIC18LF2620, PIC18LF2820)
    - Same supply voltage
    - Identification of the main performance needed for new applications
    - Limit the complexity compared of the new PIC available by MICROCHIP (PIC32)
    - Similar technologies with 16C family (radiation aspects)
  - **Application : Low cost missions which accept commercial components.**

Space Evaluation

■ R&T Studies on space evaluation :

- **Strengthening of the Microcontroller**
  - Protection against Latch-up
  - Memories protection against SEU
  - Recovery after transients
  - Re programming
  - Design of all these protection functions around the Microcontroller
  - Packaging
- **Radiation tests :**
  - Breadboard including all the protections and recovery circuits
  - Microcontroller operating with an adequate software
  - Test of the maximum internal functions of the Microcontroller (RAM, EEPROM, I/O, ADC, UART, clock, I2C Bus, CAN Bus…)
- **Planning : 2011-2012**
- **Outputs :**
  - PIC reference available for space application
  - Design of protection mechanisms
  - User manual for space application

TCSBUS

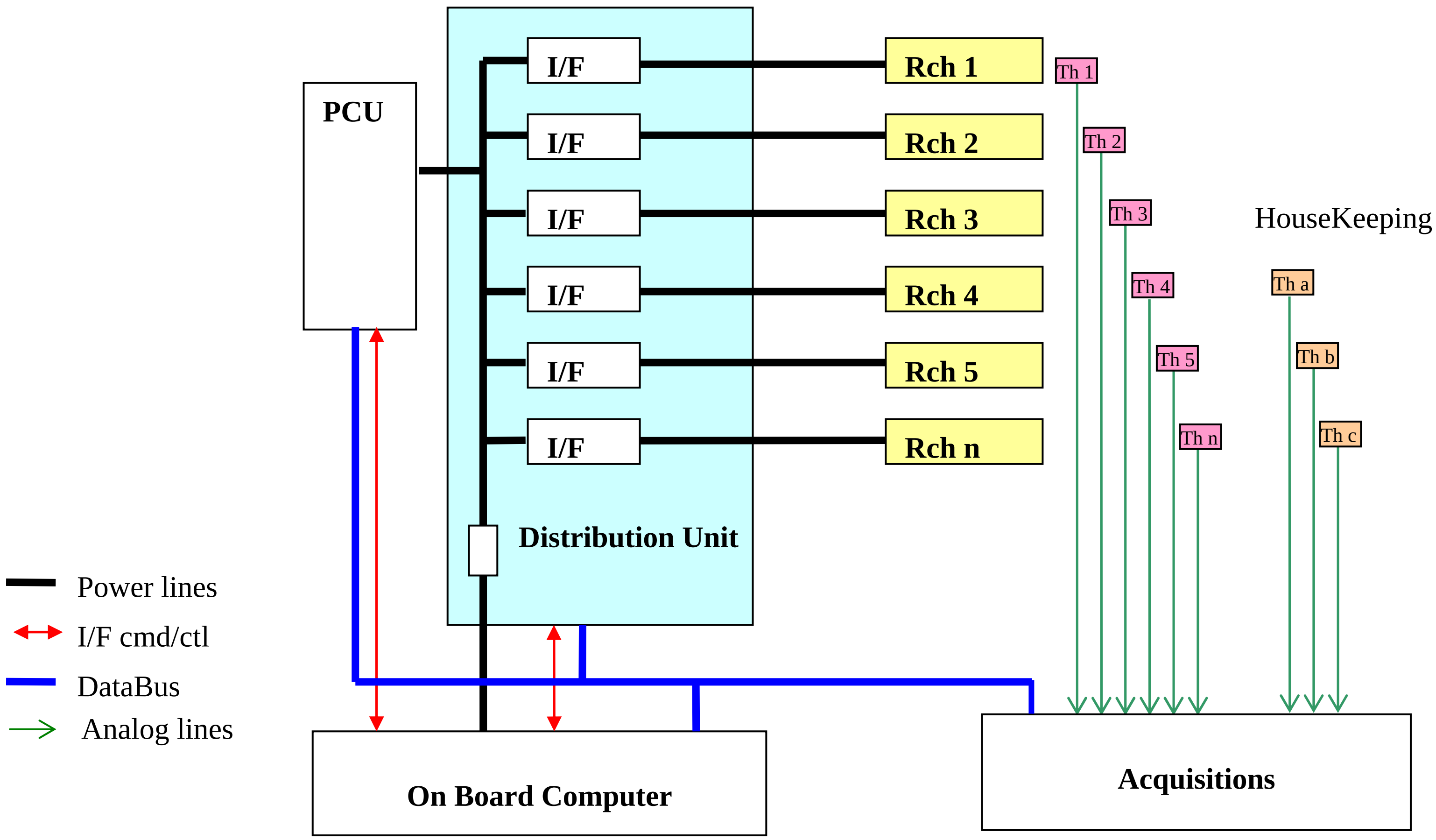
- **TCSBUS : Thermal Control and Servitude BUS**

TCSBUS : Context

- **Harness reduction :**
  - **R&T 2007 CNES ASTRIUM : “harness reduction”**
  - **From classical centralized architecture to decentralized**
  - **Reduction by 3 of the harness**
  - **Need decentralized interface box or terminals**
  - **Good candidate for harness reduction : active thermal control**
- **R&T TCSBUS:**
  - **R&T 2009 studies between CNES and SOPRA/DELTA TECHNOLOGIES**
  - **Decentralized architecture of an active thermal control and servitude based on low baud rate data bus**
  - **Planning :**
    - 06/2010 : Architecture trade-OFF
    - 12/2010 : Detailed Design and realization of elegant bread-board
    - 06/2011 : Tests revue

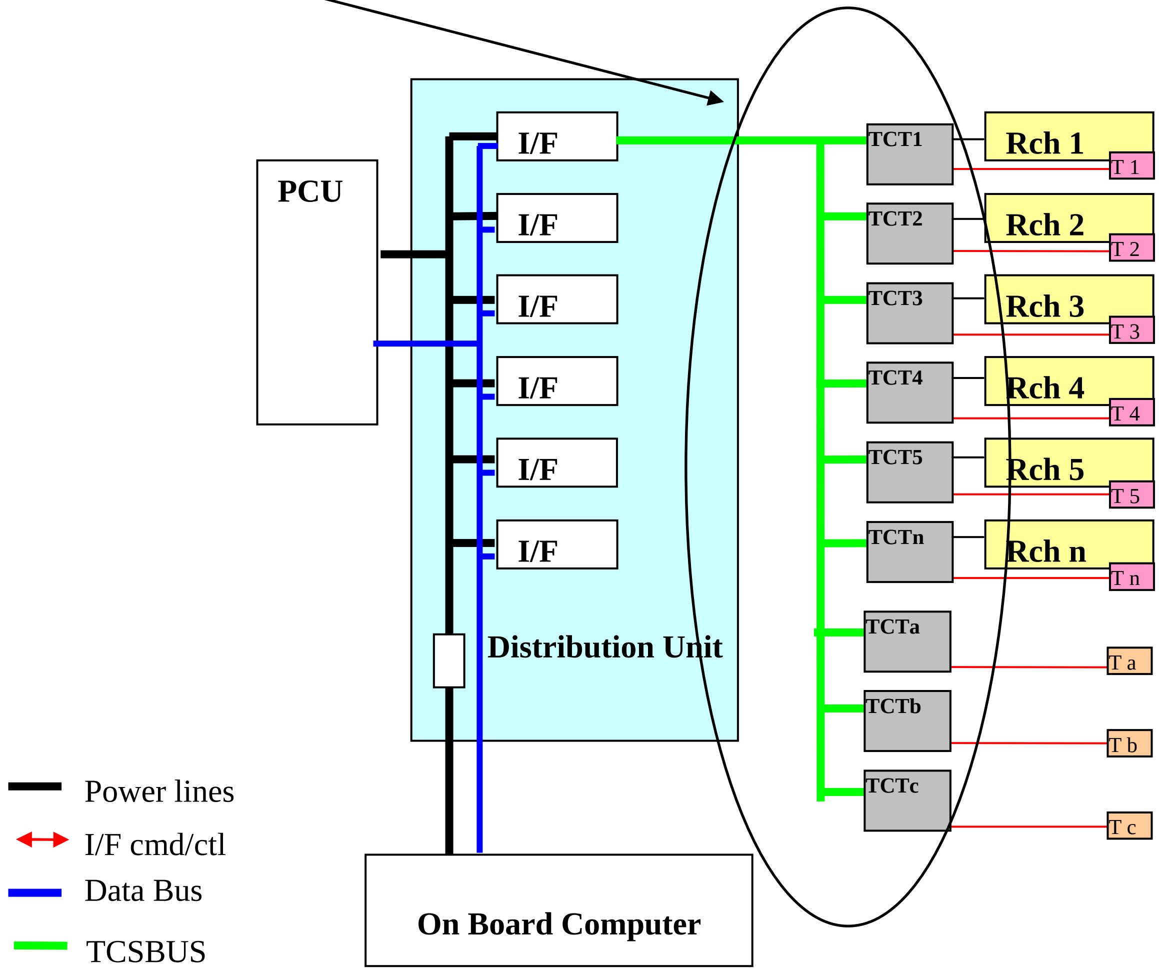
TCSBUS : Architecture

- **Example of active thermal control with basic centralized architecture :**



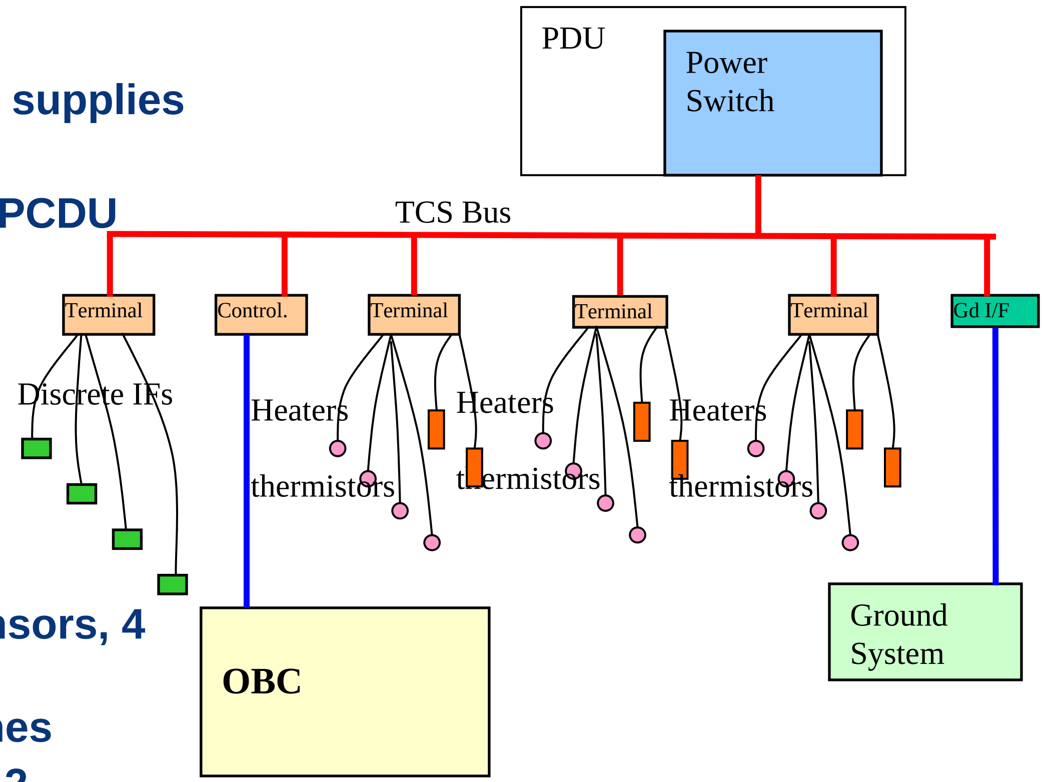
TCSBUS : Architecture

- **Example of active thermal control with decentralized architecture :**
  - **TCSBUS studied**



TCSBUS : Architecture

- **Architecture of the TCSBUS :**
- **TCS Bus :**
  - 2 wires for Databus RS485,
  - 2 wires for 5V supply,
  - 2 wires for power distribution and heater supplies
  - up to 16 terminals connected
  - Direct interface with MYRIADE OBC and PCDU
- **Bus controller :**
  - I/F with OBC,
  - Master
  - DCDC converter
- **Terminals :**
  - I/F with users
  - Thermal Control Terminal : 8 thermal sensors, 4 heaters
  - Power Distribution Terminal : 4 power lines
  - Discrete Standard Interfaces Terminal : 12 discrete I/O
- **Ground I/F**
  - Specific Terminal like a Bus controller



TCSBUS : Smart Component

- **High integration**
  - **Terminal and Bus Controllers lower than 60x60x20mm (not optimized)**
  - **Connector on the Bus (µCOMP SOURIAU connectors)**
- **Generic internal smart component :**
  - **Interface and Communication between BC and Terminals through the DATABUS (RS485) : UART**
  - **Analog and Digital acquisitions from users interfaces : ADC 10bits**
  - **Low discrete signal command to users**
  - **Power switch commands for thermal control heaters or equipments**
  - **Data processing**
  - **Data storage**
  - **Calibration curves**
- **Microcontrollers**
  - **Heritage on MYRIADE OBC using MicrochipPIC16C76**
  - **Microchip PIC18F family for TCSBUS**

TCSBUS : Smart Component

- **Main required functions of terminals :**

Required by terminals							
	Program memory FLASH (bytes)	RAM (bytes)	EEPROM (bytes)	ADC	I/O	Peripherals	Voltage
Bus Controller	30k	1500	256	5	19	2 UART	2V to 5.5V
Thermal Control Terminal	25k	1850	256	7	35	1 UART	2V to 5.5V
Discrete Interfaces Terminal			256	9	36	1 UART	2V to 5.5V
Power Distribution Terminal			256	10	27	1 UART	2V to 5.5V

TCSBUS : Microcontrollers

- **Generic Microcontroller characteristics :**
  - 4 Preselected references
  - CNES internal preliminary trade-off
  - PIC18LF4620 QFN44

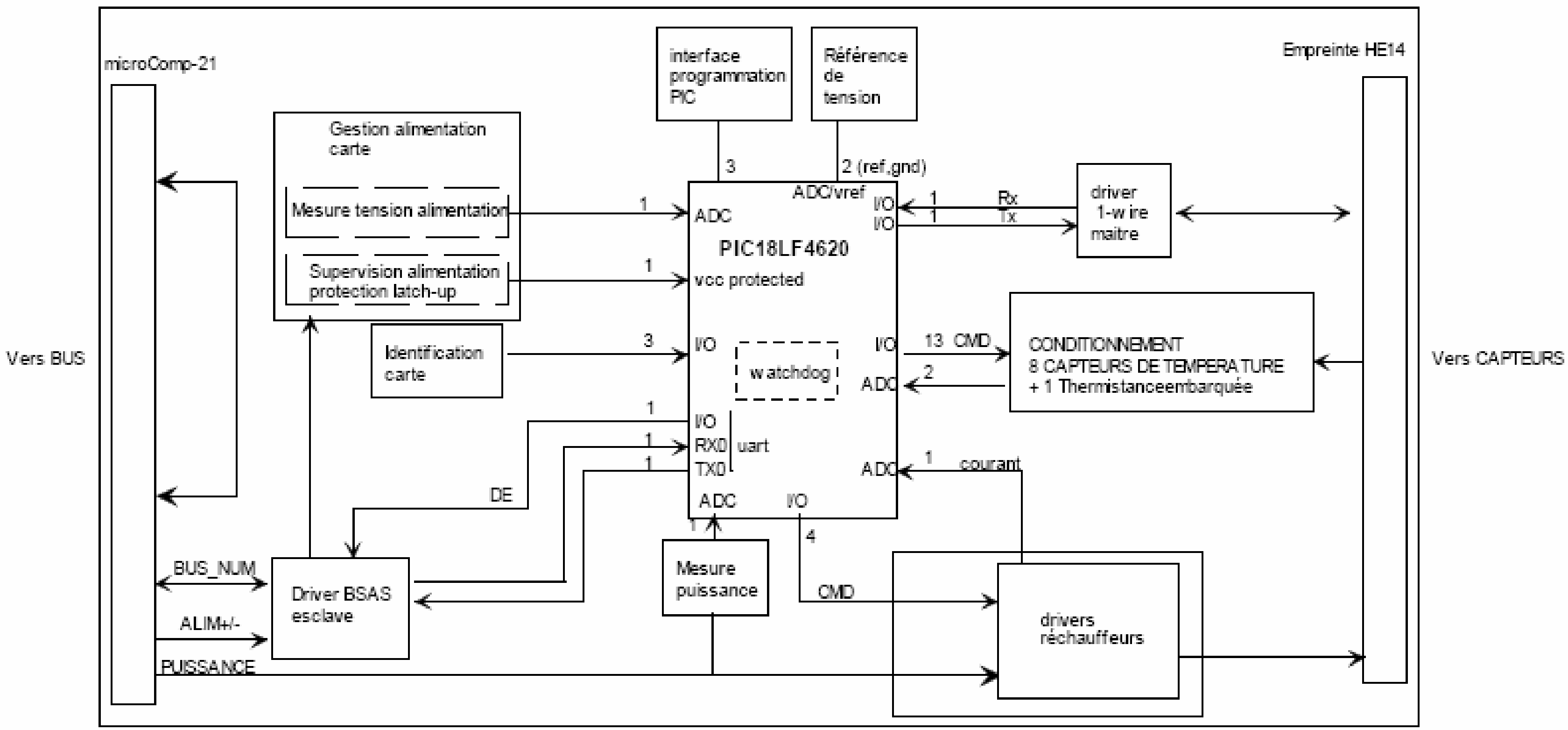
	Program memory Flash (KB)	RAM Bytes	EEPROM (bytes)	Timer	ADC	Pin count	Périphériques	Voltage
PIC18LF2620 in production [Maquette Contrôleur de bus]	64	3.968	1024	1 x 8bits 3x16bits	10CH, 10 bit	28 SPDIP, SOIC	1-A/E/USART, 1-MSSP(SPI/I2C)	2 à 5.5V
PIC18LF6722 in production [Maquette CTS]	128	3.936	1024	2 x 8bits 3x16bits	12CH, 10-bit	64 TQFP	2-A/E/USART, 2-MSSP(SPI/I2C)	2 à 5.5V
PIC18LF2520 in production	32	1.536	256	1 x 8bits 3x16bits	9CH, 10 bits	28 SPDIP, SOIC 28 QFN	1-A/E/USART, 1-MSSP(SPI/I2C)	2 à 5.5V
PIC18LF4620 in production	64	3.968	1024	1 x 8bits 3x16bits	13CH, 10 bits	40-Pin PDIP 44-Pin TQFP 44-Pin QFN	1-A/E/USART, 1-MSSP(SPI/I2C)	2 à 5.5V
PIC18LF4680 in production	64	3328	1024	1 x 8bits 3x16bits	11CH, 10 bits	40-Pin PDIP 44-Pin TQFP 44-Pin QFN	1-A/E/USART, 1-MSSP(SPI/I2C)	2 à 5.5V

TCSBUS : Microcontrollers

- **Microcontroller protections :**
  - Latch-up protection : A current limitation on the power supply is implemented in order to limit the dissipation inside the Microcontroller and then the destruction.
  - De-latch circuit in order to re-initialize de Microcontroller after a latch up or an SEE : An external circuit cut OFF the Microcontroller supply during few milliseconds.
  - Discrete external watchdog : One task of the µC is to generate a periodic signal on one I/O port. In case of no activity inside the PIC this signal is not refreshed then the discrete external circuit initializes the Microcontroller by switching OFF and ON its supply.

TCSBUS : Thermal Control Terminal

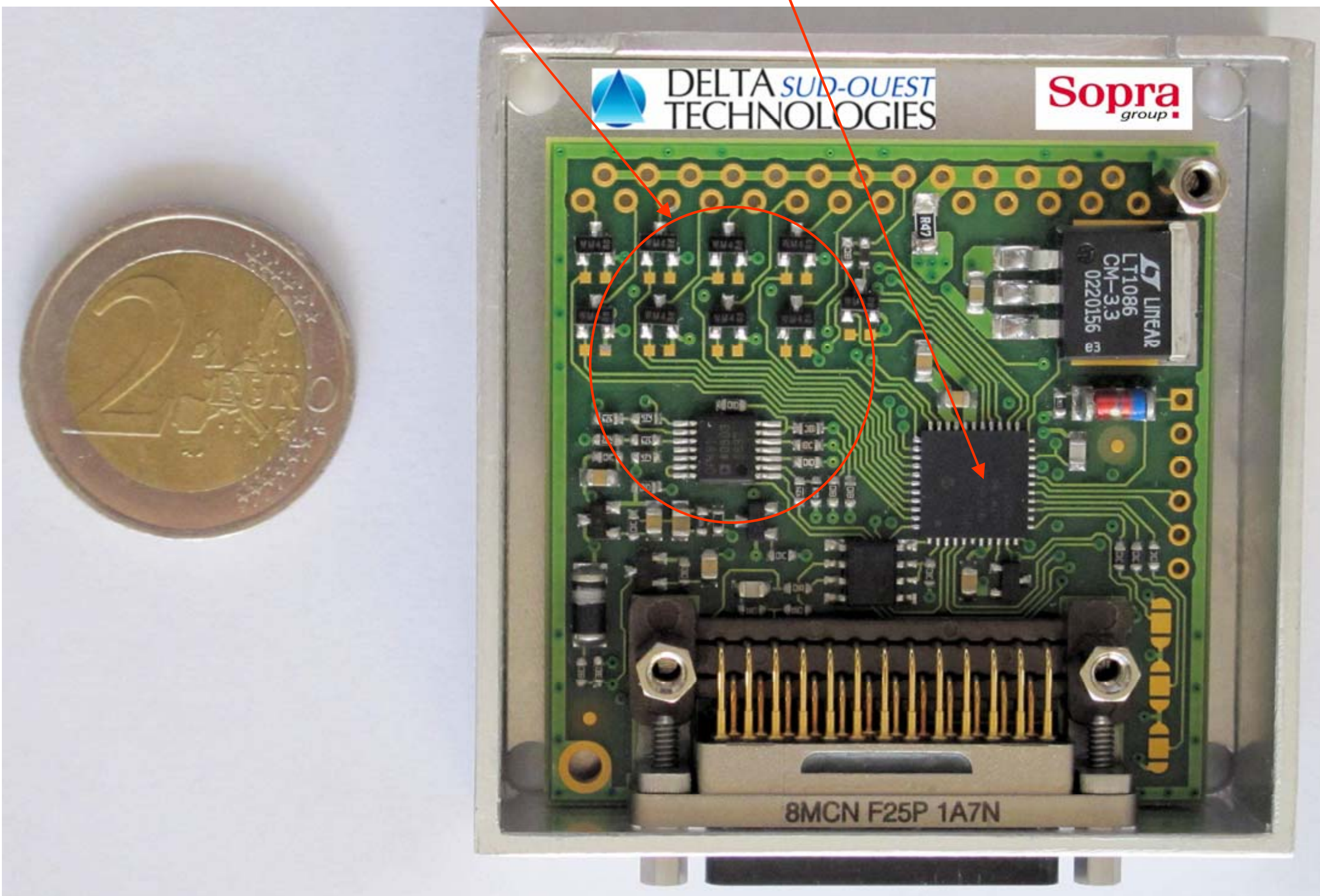
- **Thermal Control Terminal internal architecture :**
  - **8 thermal sensor input acquisitions**
  - **4 power switched lines for heaters**
  - **Other acquisitions : internal temperature, supply voltage, power voltage, heater currents**
  - **1-WIRE bus output (possibility to connect 1-Wire digital thermal sensor network)**



TCSBUS : Thermal Control Terminal

- **Thermal control terminal**:

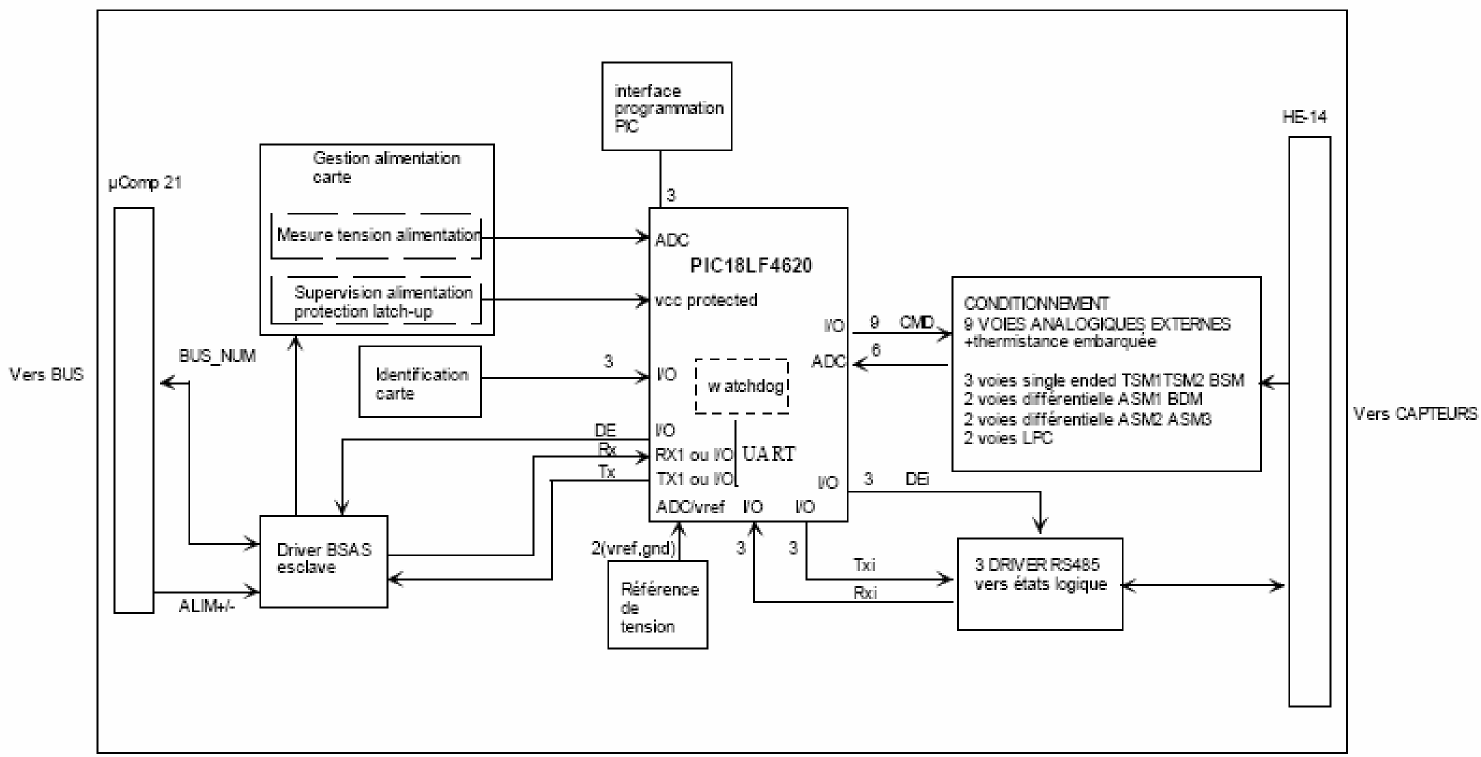
Thermal acquisition µC



Top view

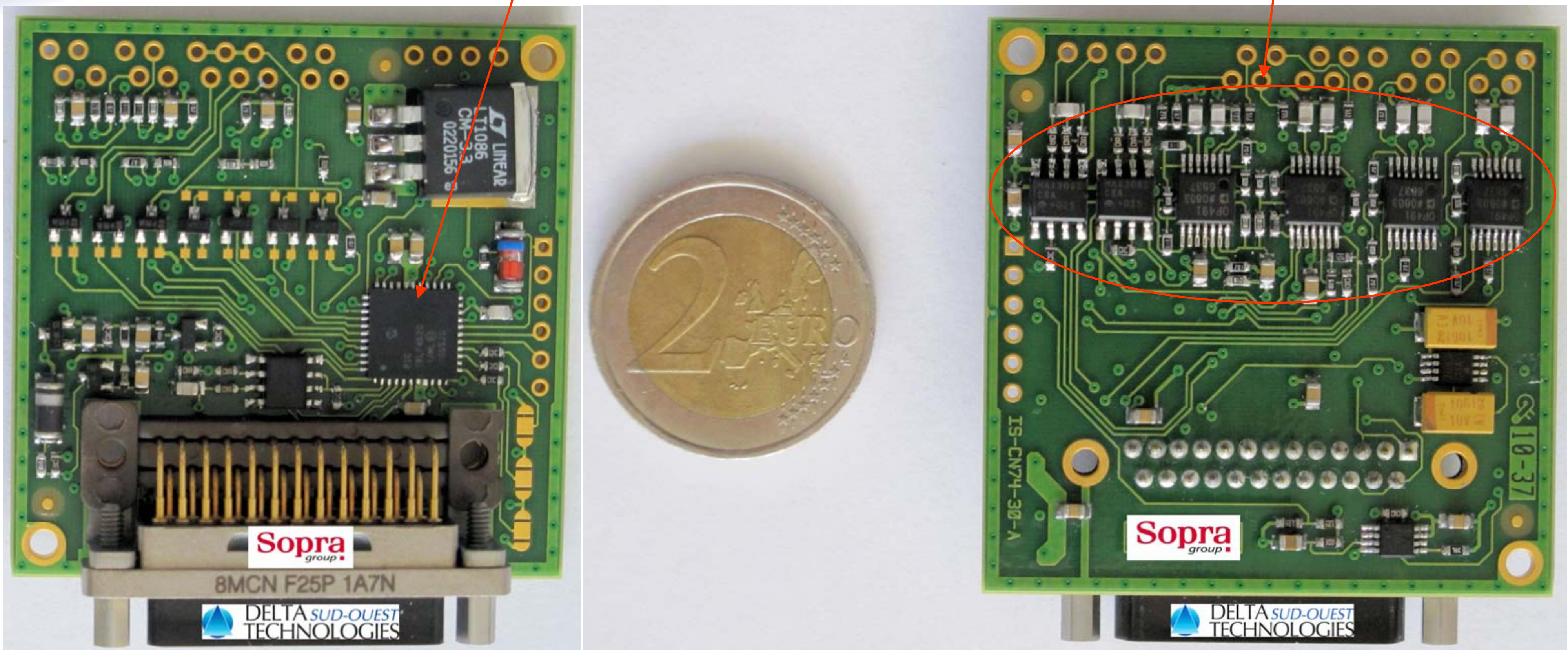
TCSBUS : Discrete Interfaces Terminal

- **Discrete Interfaces terminal internal architecture :**
  - **11 external I/O :**
    - 2 SBDL configurable input or output
    - 3 analog acq. configurable TSM1 (thermal sensor type 1), TSM2 or BSM (switch status)
    - 2 analog acq. configurable ASM1 (0/+ 5V) or BDM (single digital)
    - 2 analog acq. configurable ASM2 (+/-5V) or ASM3 (+/-10V)
    - 2 LLC (low level command)



TCSBUS : Discrete Interfaces terminal

- **Discrete Interface terminal**:

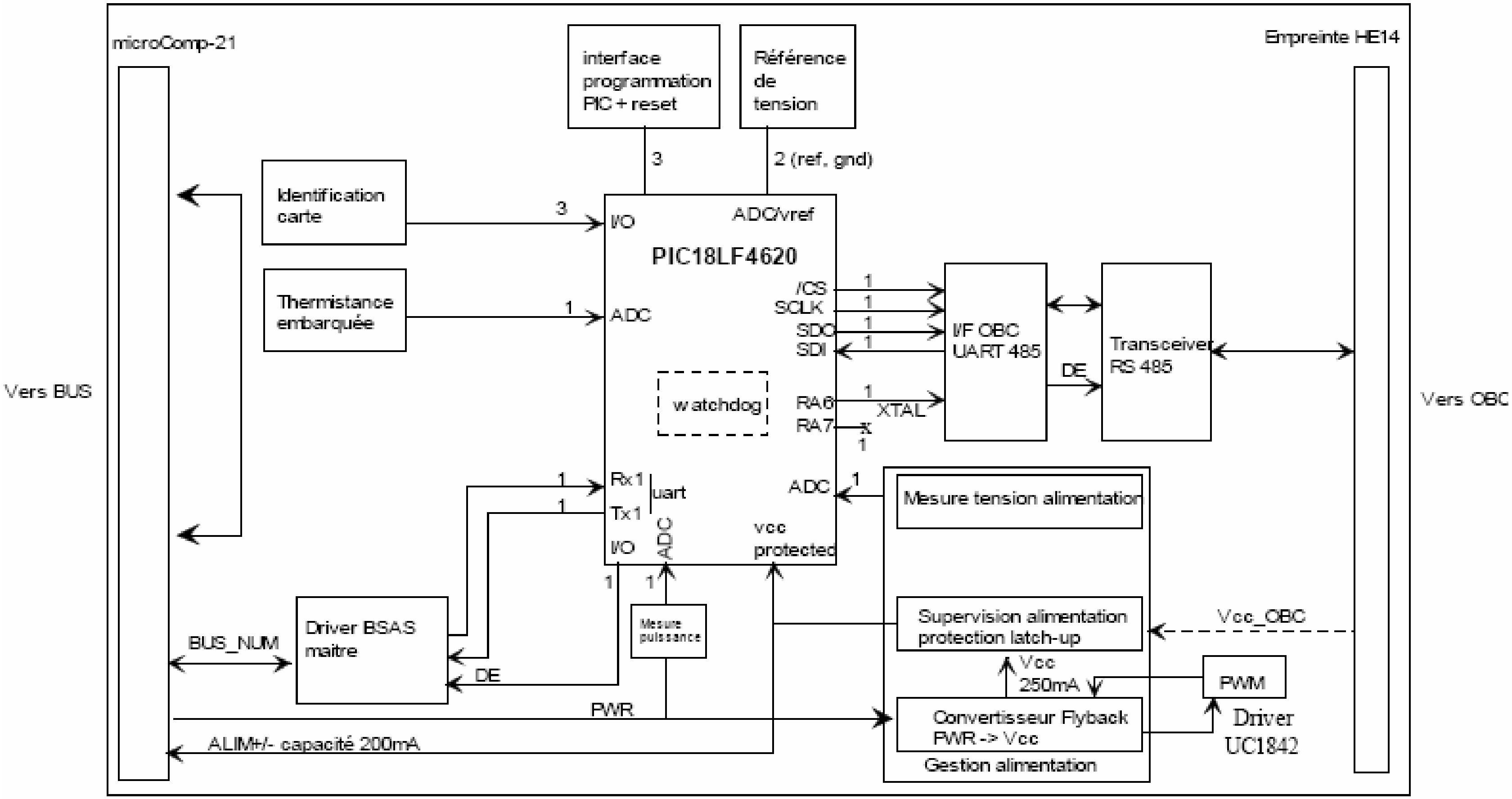


Top view

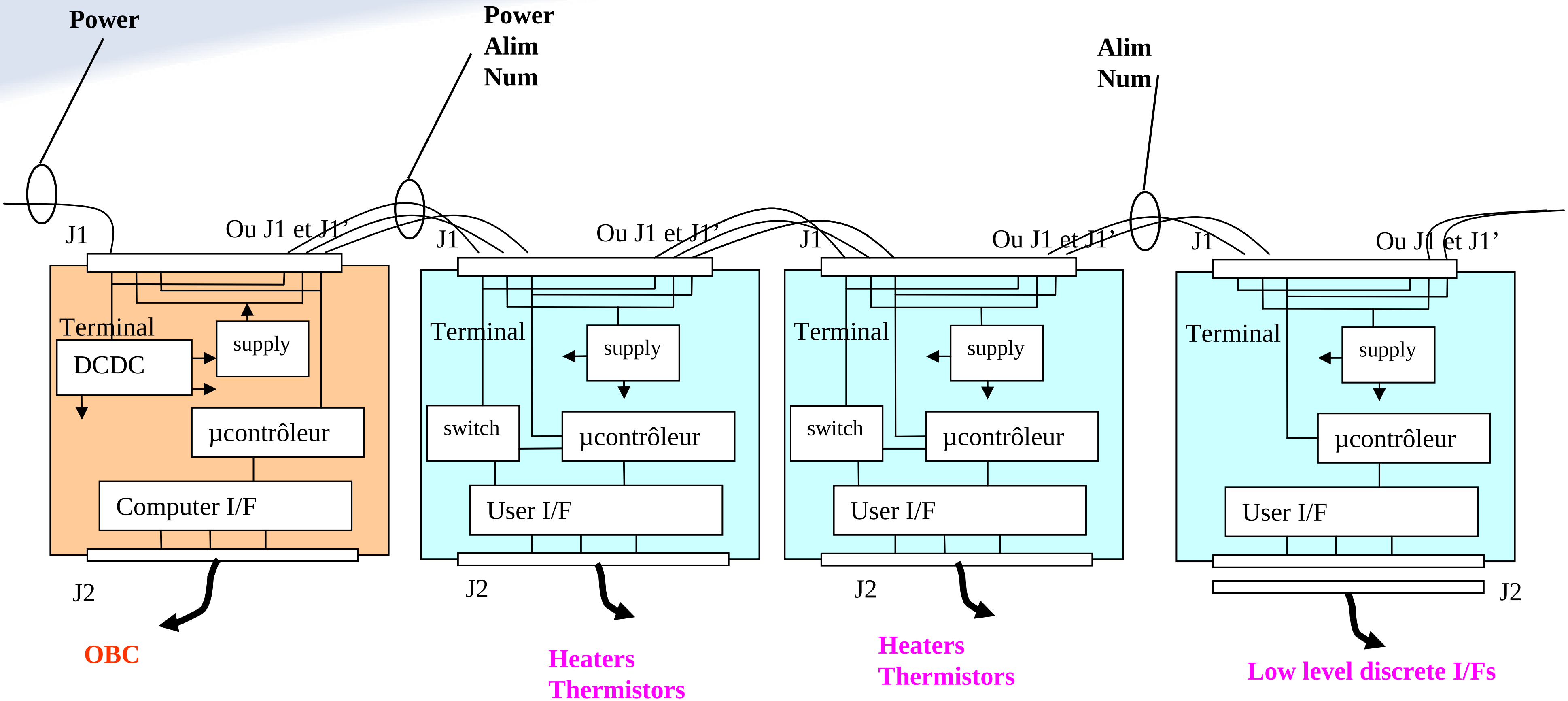
Bottom view

TCSBUS : Bus Controller

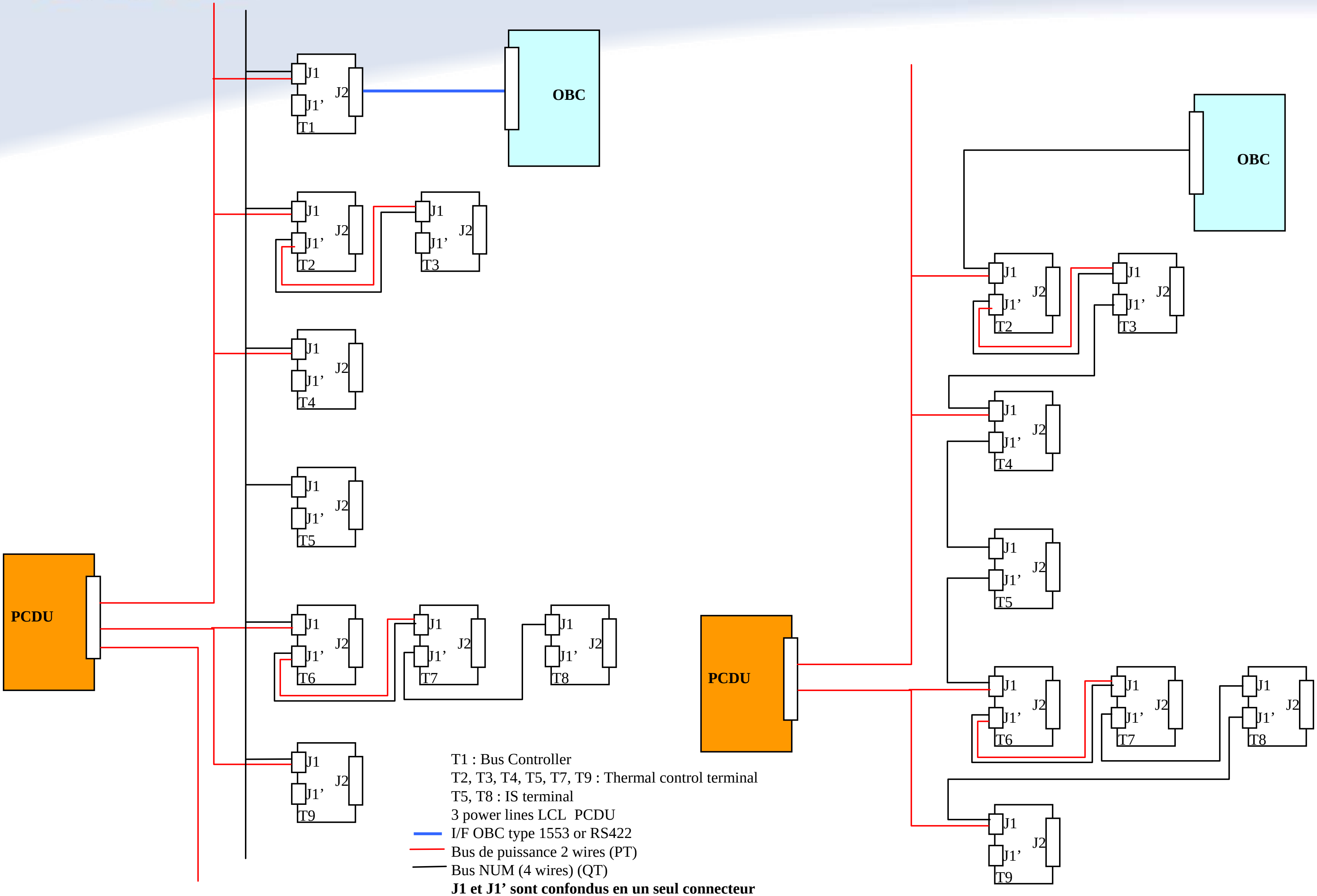
- **Bus Controller internal architecture :**
  - Internal DCDC converter : power supply all the terminals
  - Internal UART for OBC interface
  - 1553 I/F evaluated (but not bread-boarded)



TCSBUS : Network



TCSBUS : Network



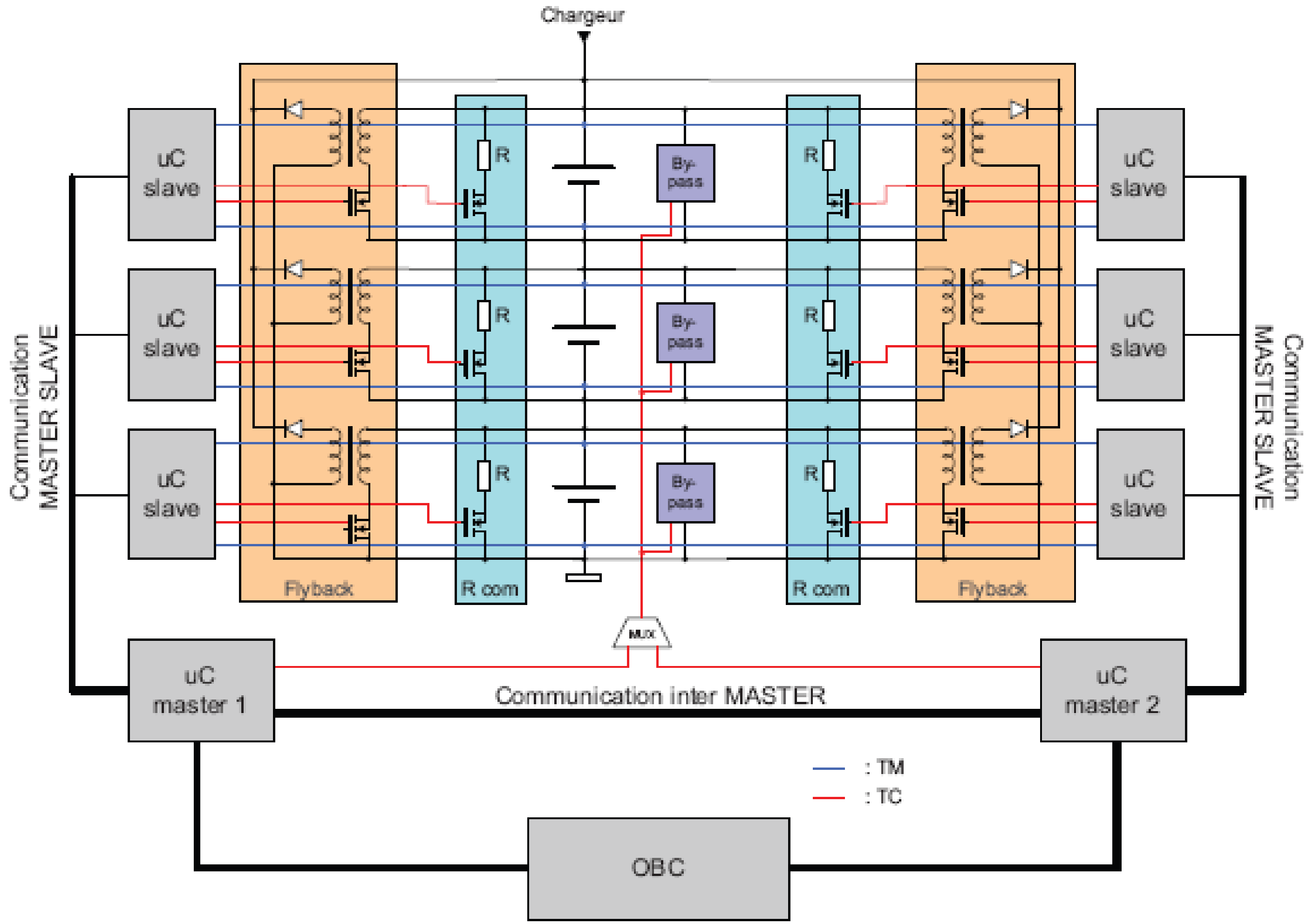
LIBBE

- **LIBBE : Lithium-ion Battery Balancing Electronic**

LIBBE

LIBBE architecture :

- Redounded architecture
- Master microcontroller
- Slave microcontrollers (one per Li-Ion cell)
- Evaluation of two methods of cell balancing : switched resistor or Flyback
- By-Pass commands
- Communication busses



LIBBE

Advantage of Microcontroller for LIBBE :

- Microcontroller allows to reduce electronic circuit with smart functions on each battery cell
- Data bus communication between battery cells using internal microcontroller UART
- Need to adapt DC cell voltages on the data bus by capacitor coupling
- Possibilities to adapt balancing algorithms for a large type of Li-Ion batteries
- Microcontroller supply compatible with Li-ion cell voltage range
- Microcontroller with low consumption available

LIBBE

- **Master microcontroller main functions:**
  - UART : interface RS485 Manchester bi-phase with capacitor coupling on master/slave communication bus
  - SPI : Interfaces between the 2 redundant master microcontrollers
  - I/O : OBC interface via RS422 links
  - I/O : By-Pass commands
  - ADC : battery voltage monitoring, temperature, internal voltages
- **Microcontroller reference :**
  - PIC18LF2520 : breadboard
  - PIC18LF2620 compatible (see MYRIADE OBC, TCSBUS, Space studies)

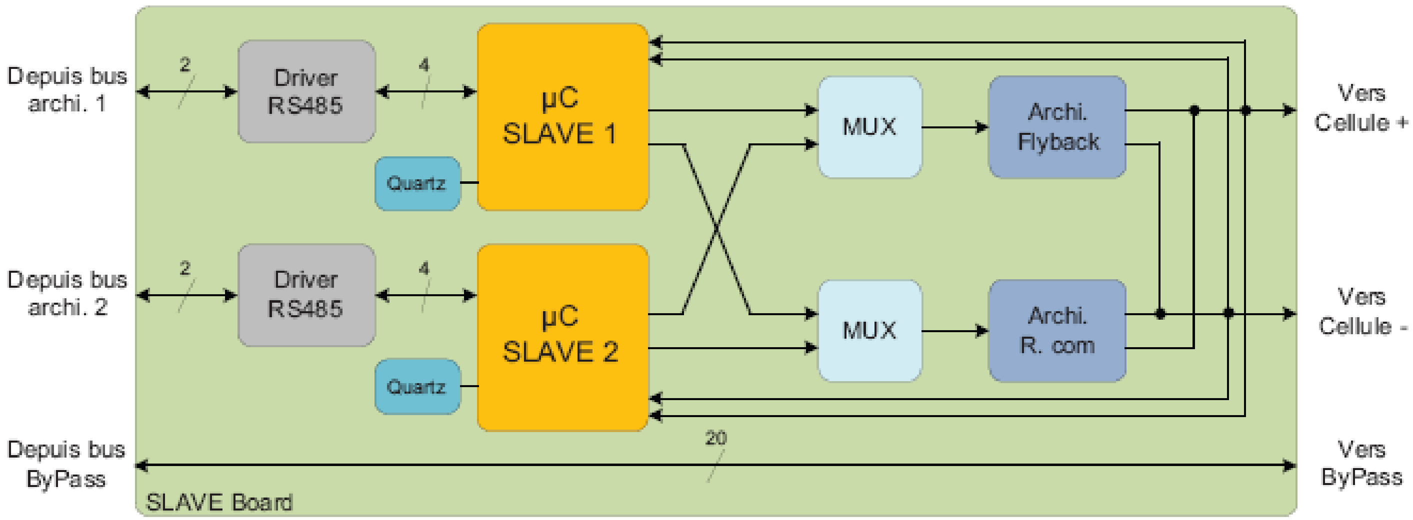
LIBBE

■ Slave microcontroller main functions :

- UART : interface RS485 Manchester biphase with capacitor coupling on master/slave communication bus
- PWM I/O : switch command of the balancing system
- ADC : cell voltage monitoring, reference voltage

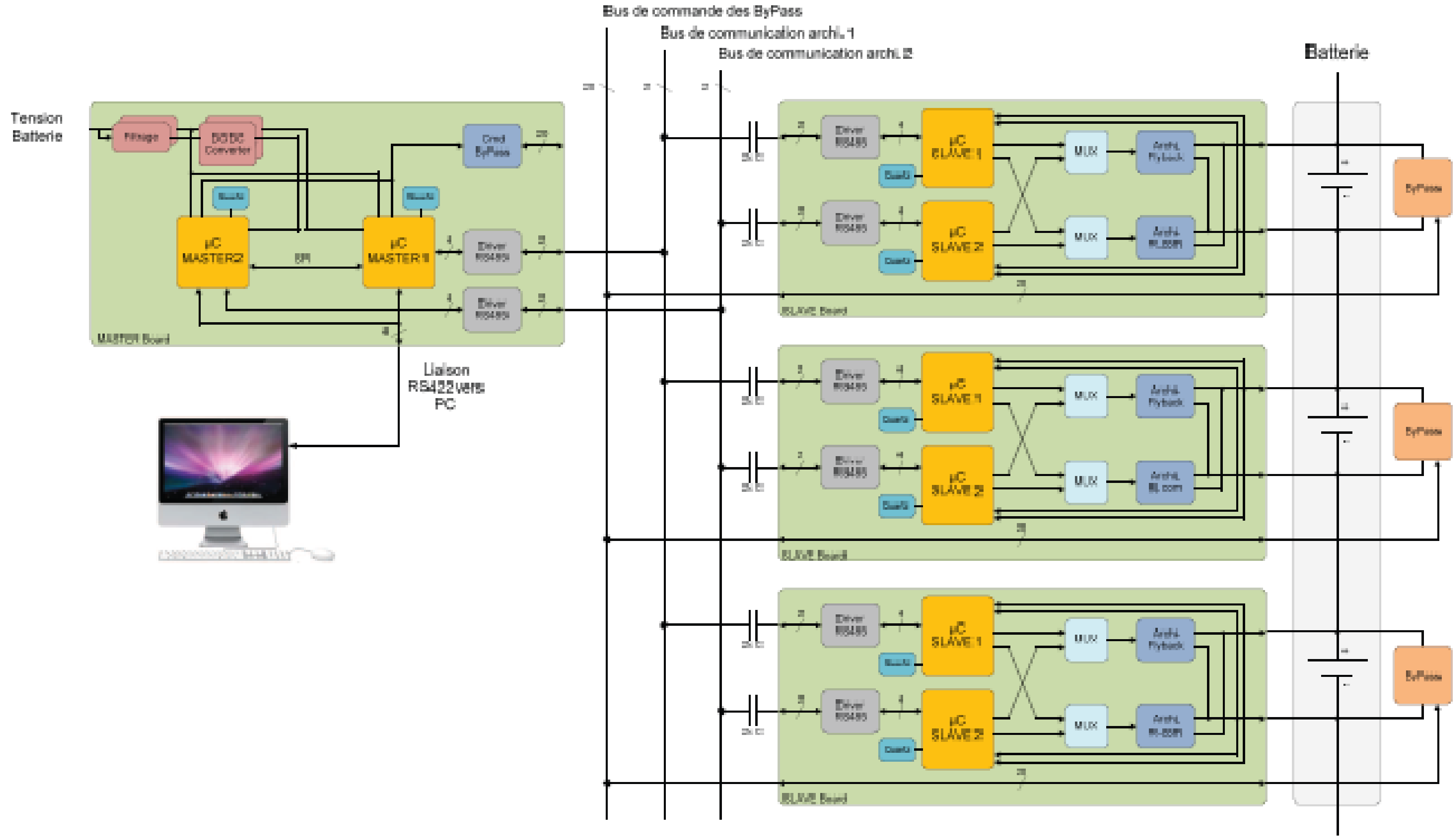
■ Microcontroller reference :

- PIC18LF2520 : breadboard
- PIC18LF2620 compatible (see MYRIADE OBC, TCSBUS, Space studies)
- Power management function : leakage current minimization on the Li-Ion cell (0.5µA in sleep mode)
- Supply voltage from 2V to 5.5V : version LF



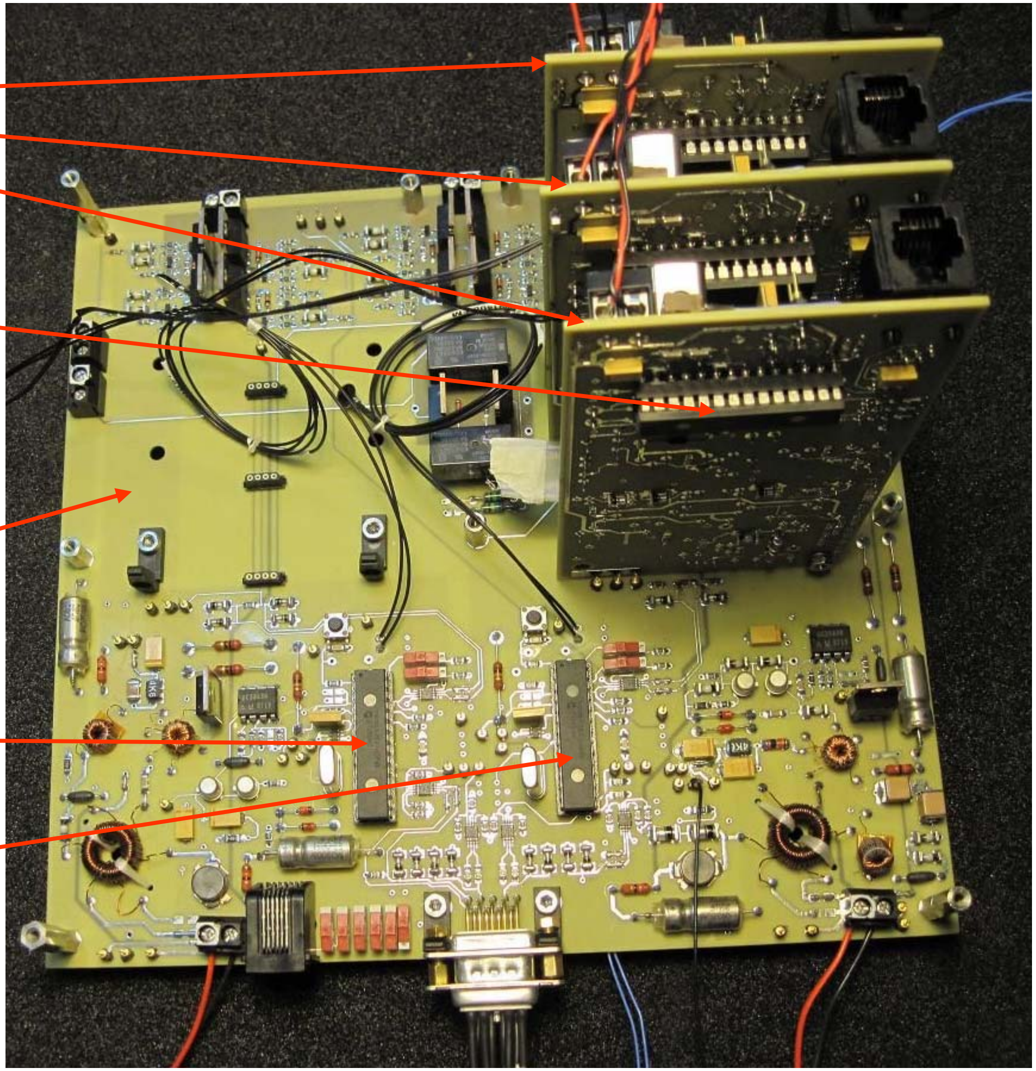
LIBBE

- **General implementation of the breadboard :**
  - **Test on going**



LIBBE

■ **General implementation of the breadboard** :



Conclusions

- **Advantages of Microcontrollers :**
  - **Very high integration and small electronics**
  - **Easy to develop**
  - **Smart functions near utilization (acquisition,filtering, regulation, timing,…)**
  - **No expensive**
- **Drawbacks :**
  - **Radiation tolerance to be tested**
  - **Need to be protected against SEE, latch-up**
- **Application :**
  - **Low cost projects : MYRIADE…**
  - **COTS**