Temperature measurements during Module Test

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Module Test Meeting

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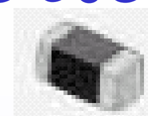
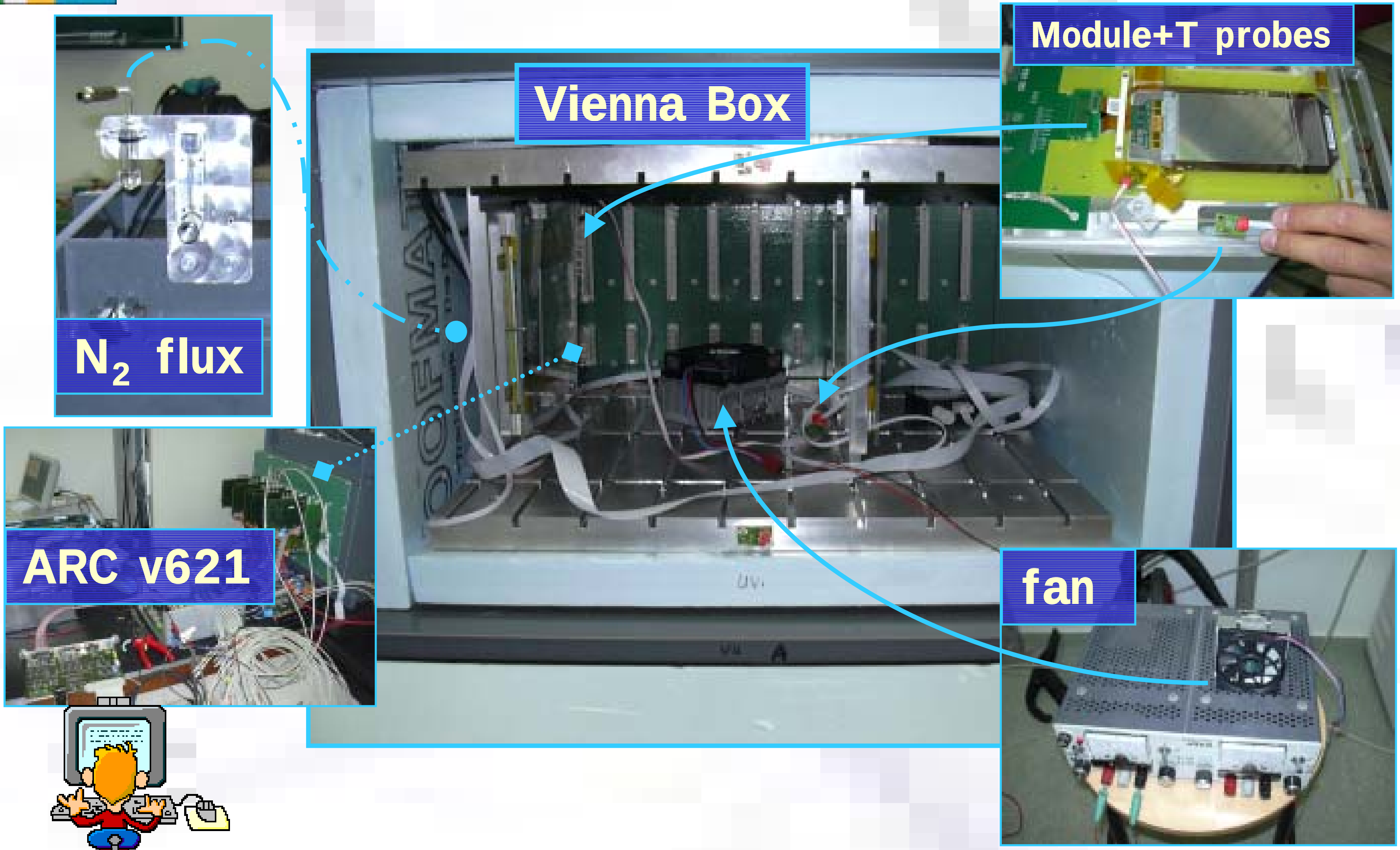
Outline

- Measurement of Sensor and Hybrid temperatures using DCU ADC
  - two Negative Temperature Coefficient (NTC) high precision thermistors 
    - one glued onto Silicon sensor backside
    - one next to the DCU on the Hybrid

- Measurement of internal temperature of the DCU
  - for the moment not working with ARC (SW bug?)

Experimental Setup



Some clarifications

- Why ARC system only and not LT software?
  - both systems can read temperatures
  - our FEC was not working properly (HW failure)
  - our backup solution for measurement in cold box: ARC readout

- Measurement of room temperature
  - Vienna Box T probe
  - Independent measurement of sensor temperature T^{ref} (if thermalized)
  - in all the measurements the Relative Humidity was kept under 15% level

NTC Basic characteristics

- Resistance of the thermistor: $R=R_0e^{B(1/T-1/To)}$
  - R: resistance at temperature T[K]
  - R_0: resistance at temperature T_0[K]
  - B: B-constant of the thermistor
- muRata NTH5G16P33B103F07TH
  - T_0=298.1 K (=25°C)
  - R_0=10 kΩ (±1.1%)
  - B=3380 K (±1%) tight tolerance type

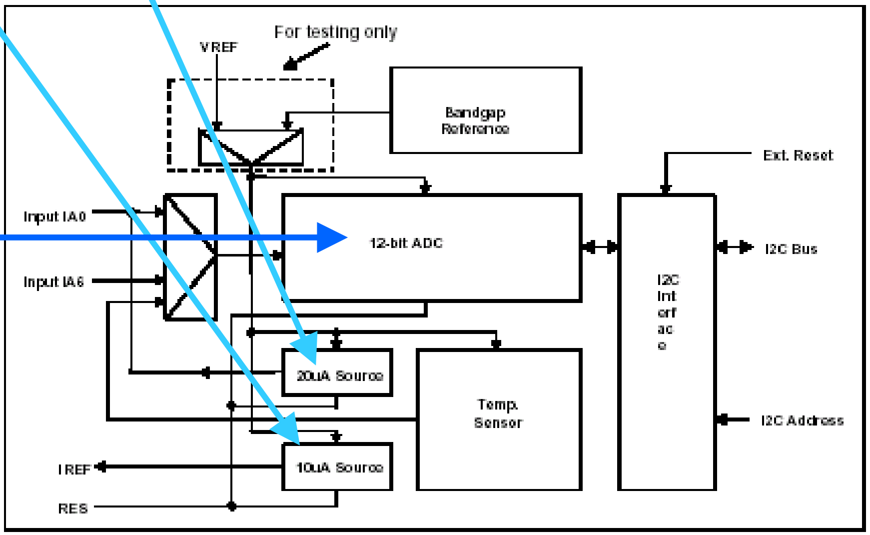
NTH5G Series

DCU output

Guido Magazzù's private communications – preliminary data

- Voltage drop over the thermistors
  - two constant current sources in the DCU
    - $\langle I_{20} \rangle = 19.23 \pm 0.37\ \mu A$ (Sensor NTC) *
    - $\langle I_{10} \rangle = 9.63 \pm 0.04\ \mu A$ (Hybrid NTC) *
  - 12-bit ADC
    - $ADC^{out} = ADC^{offset} + ADC^{gain} \times V_{in}$
    - $ADC^{gain} = 2.22$ ch/mV (±1%) *
    - $ADC^{offset} = (-1.5 \pm 0.5)$ ch *
    - good linearity
      - <1 ch if 20 mV<V_{in}<1.25 V *
      - <2 ch if 1.25 V<V_{in}<1.5 V *
    - saturated at 1.8 V *

DCU Architecture



*Guido Magazzù's private communications – preliminary data

ARC v621 readout

- Readout of the DCU with ARC system
  - version 6.2.1
  - directory Environment of the Root output file
    - output of the DCU 12-bit ADC from:
      - Sensor thermistor read through the DCU: **TempSenNtc1DCU**
      - Hybrid thermistor read by DCU only: **TempHybNtc**
        - (for the moment stored with the name **TempHybDCU**, to be fixed)

ARC

- conversion $ADC^{out} \rightarrow V_{in} \rightarrow R_x = V_{in}/\langle I \rangle \rightarrow T_x = T(R_x)$
  - measurement of Sensor and Hybrid Temperatures with DCU NTC thermistors
  - error propagation

Sensor Temperature

ADC^{out} [ch]	$T_x^{Sen} \pm \Delta T_x^{Sen}$ [°C]	T^{ref} [°C]	$T_x^{Sen} - T^{ref}$ [°C]
445	23.8±0.6	24.6	-0.8
568	17.6±0.6	18.6	-1.0
845	8.0±0.6	9.1	-1.1
1107	1.9±0.6	3.5	-1.6
1552	-5.5±0.6	-5.0	-0.5
2026 (V_{in}=0.9 V)	-11.0±0.6	-10.9	-0.4
2802 (V_{in}=1.3 V)	-17.4±0.6	-17.8	+0.4

Good agreement between the two measurements:

1. DCU NTC (T_x^{Sen})
2. Vienna Box T probes (T^{ref})

- ARC system turned on for only 1 minute
  - to minimize effects on Sensor Temperature

Hybrid Temperature

ADC^{out} [ch]	Hyb: $T_x^{Hyb} \pm \Delta T_x^{Hyb}$ [°C]	Sen: $T_x^{Sen} \pm \Delta T_x^{Sen}$ [°C]	$T_x^{Hyb} - T_x^{Sens}$ [°C]
197	27.0±0.4	23.8±0.6	+3.2
250	20.8±0.4	17.6±0.6	+3.2
368	11.3±0.4	8.0±0.6	+3.3
454	6.4±0.4	1.9±0.6	+4.5
659	-2.0±0.4	-5.5±0.6	+3.5
867	-7.8±0.4	-11.0±0.6	+3.2
1209	-14.5±0.5	-17.4±0.6	+2.9

V_{in}=0.5 V

- the Hybrid is around 3°C warmer than the Sensor
  - after 1 minute of ARC system running

Cooling Cycle

- Special "cooling cycle" test
  - Vienna box is set to -20°C
  - TIB module biased with HV=400 V
  - ARC system on
- start: T^{ref}=-20.1°C
- after 1 hour: T^{ref}=-17.0°C T_x^{Sen}=-14.1°C
  - » reached in less than half an hour
- after 2 hours: nothing has changed
- after 3 hours: " " " "

A simple example...

- From "Preliminary Procedures For Module Testing Using ARC Systems" (Version 1.2 October 10, 2003):
  - "The measurement of the IV of the sensor(s) in the sensor database needs to be retrieved in order to compare to the module measurements." (Ernesto Migliore's Formula):
    - $I(T)=I(T_0)\cdot(T/T_0)^2\cdot e^{-7100\cdot(1/T-1/T_0)}$
  - IV Test: "A module is graded C if any of the following conditions are met:
    - […]
    - **$I(450\ V)_{measured} > 1.5xI(450\ V)_{database}$ (1 sensor modules)**
    - […]"

...A simple example

- $I_{database}(450\ V)=I(T_0)$ taken at $T_0=22°C=295\ K$
- Perform IV Test (10 minutes) in our clean room at $T=23°C=296\ K$ (air temperature)
- Rescale $I(T)=1.1xI(T_0)$
- The module is rejected if $I(450\ V)_{measured}>1.5xI(T)=1.5x1.1xI(T_0)=1.6xI(T_0)$
- The module temperature is measured $T_x^{Sen}=25°C=298\ K$
- Rescale $I(T)=1.3xI(T_0)$
- The module is rejected if $I(450\ V)_{measured}>1.5xI(T)=1.5x1.3xI(T_0)=1.9xI(T_0)$

Conclusion

- Using ARC system and DCU NTC+ADC Temperature measurements on Hybrid and Sensors are made with 0.5°C uncertainty
  - we can better compensate the Silicon current changes with a more accurate rescaling of I(T)