Temperature monitor for the calorimeter

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Next steps

- More accurate calibration with a climatic chamber
  - in a few weeks, both for single crystal and 3x3 crystal module
- Improving the parameterization of R(T)
- Design of the readout card
- Production & test of the readout card
- Integration with DAQ
  - preliminary idea discussed with Mauro Villa

done with Lorenzo S. but no details today

today's report

to be developed

Outline

- Design of the temperature readout system
- Validation of the readout cards (CTR and CTR-aux)
- Outlook

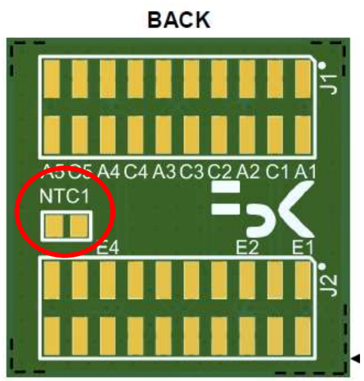
NTC sensors

- Main features of the Negative Temperature Coefficient sensors:

mounted on each SiPM tile

Part number:	**B57471V2103J062**
Form factor	**SMD size 0805**
B coefficient (25-100 °C)	**4480 K ±3 %**
$\mathbf{R_R}$ tolerance	**±5 %**
Cooling time constant	**10 s**
Heat capacity	**35 mJ/K**

syst. Error 1.2 °C
at 15 °C:
calibration needed!



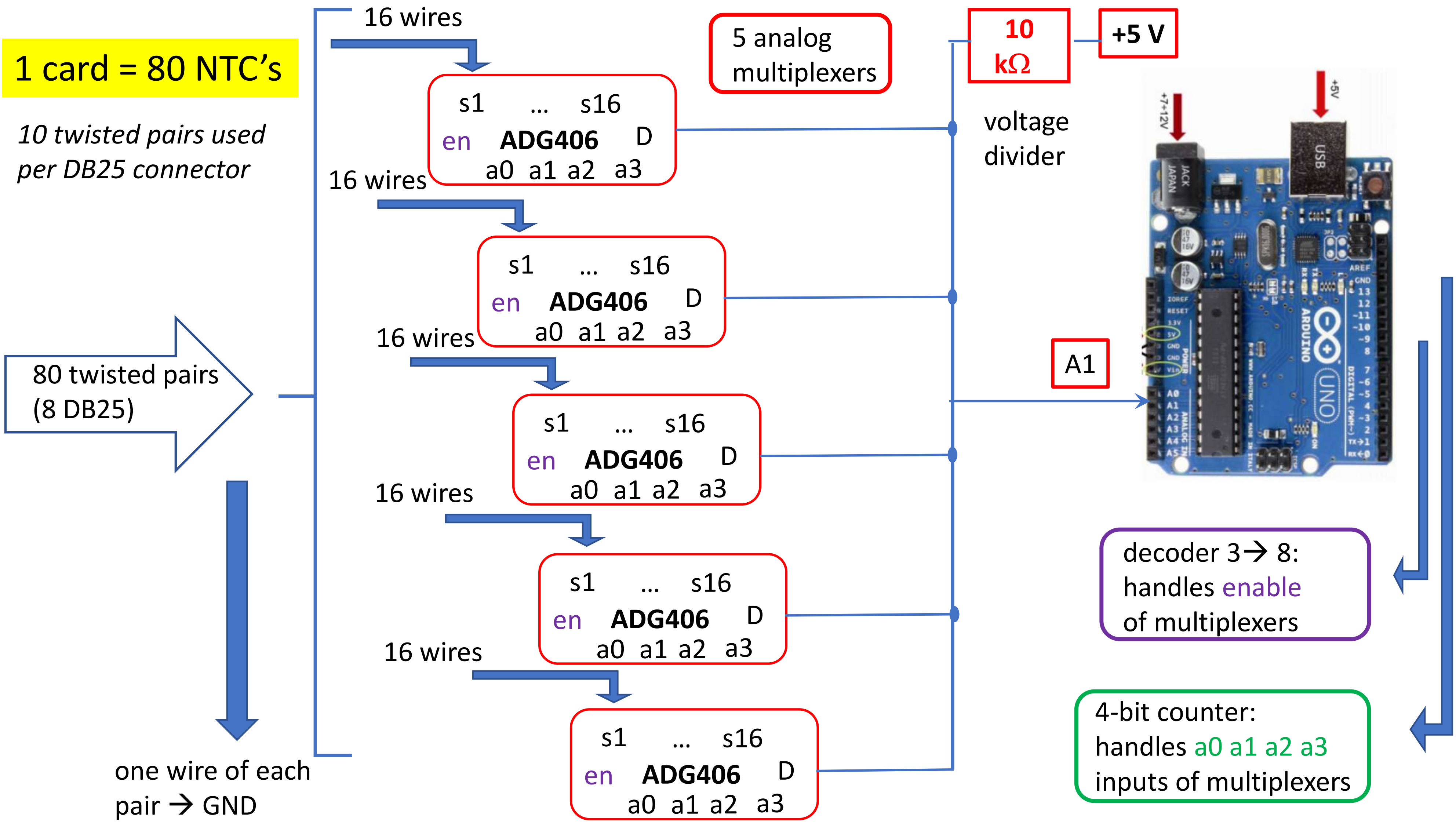
Reference value: $\mathbf{R_R}$ **= 10 kΩ** @ T_R = 25 °C (298.15 K)

$$R_T = R_R e^{B\left(\frac{1}{T}-\frac{1}{T_R}\right)}$$

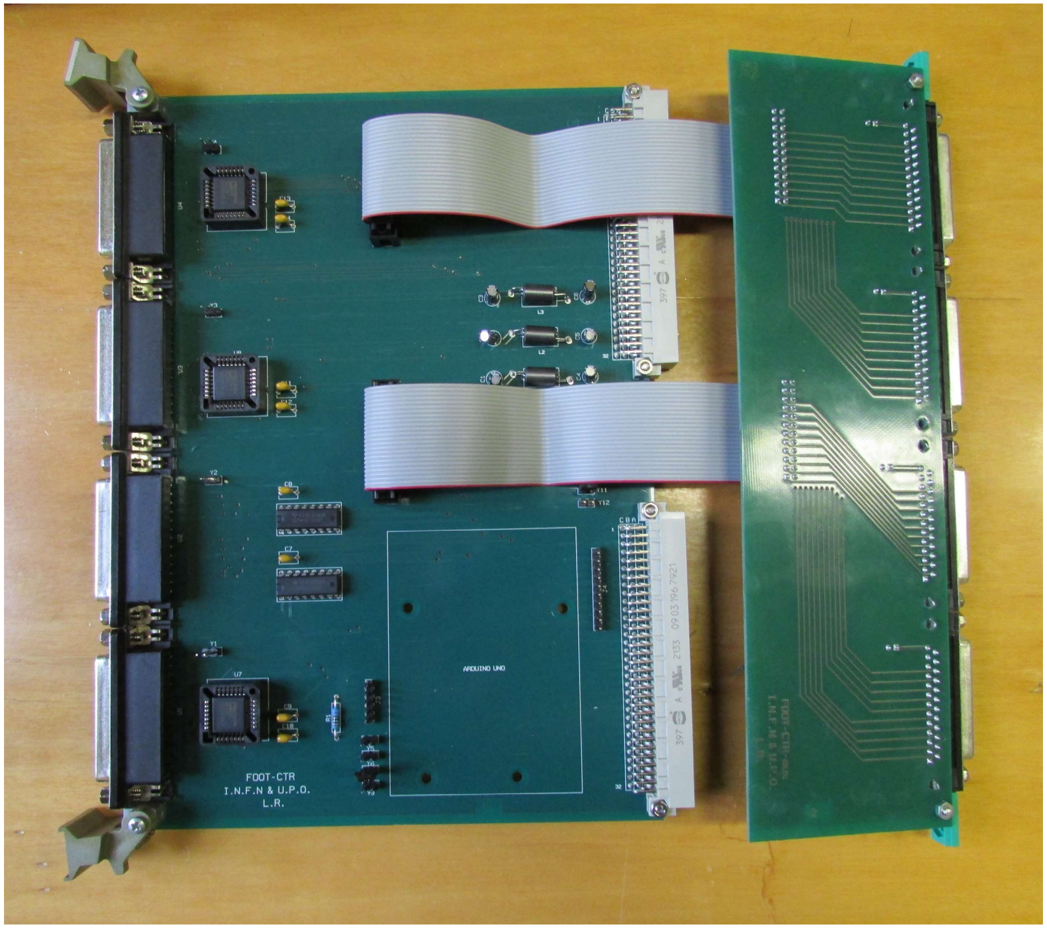
approximate two-parameter (B, R_R) formula for R(T)

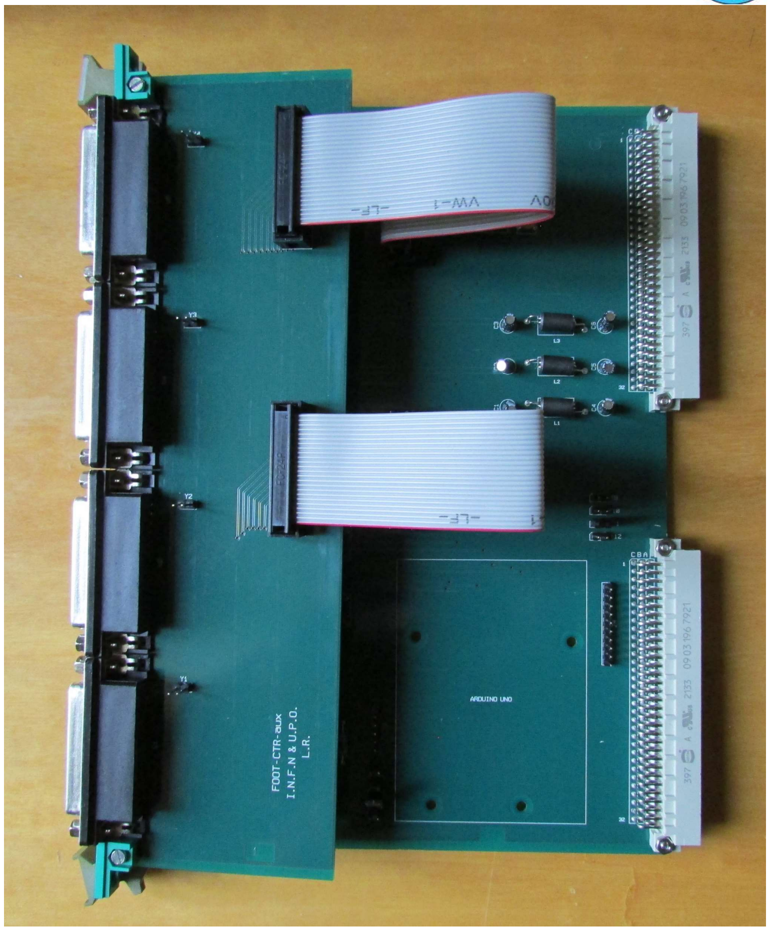
System overview

- Four main cards + four auxiliary cards to handle 320 channels
  - 8 slots needed on a VME (6U) crate
  - 5 m twisted pair cables coming from boards near che calorimeter
- Arduino UNO mounted on the «master» card
  - Signals distributed to the other cards via J2 connectors on VME backplane
- Arduino «sketch» reads in turn all 320 channels
  - Raw ADC values sent periodically to a receiving PC (via 4.5 m USB cable)
  - Conversion to temperature - including calibration constants - done on the *PC (may also be done by Arduino, using its EEPROM: to be tested)*
  - Monitoring cycle: 25 seconds at present *(may be shortened)*

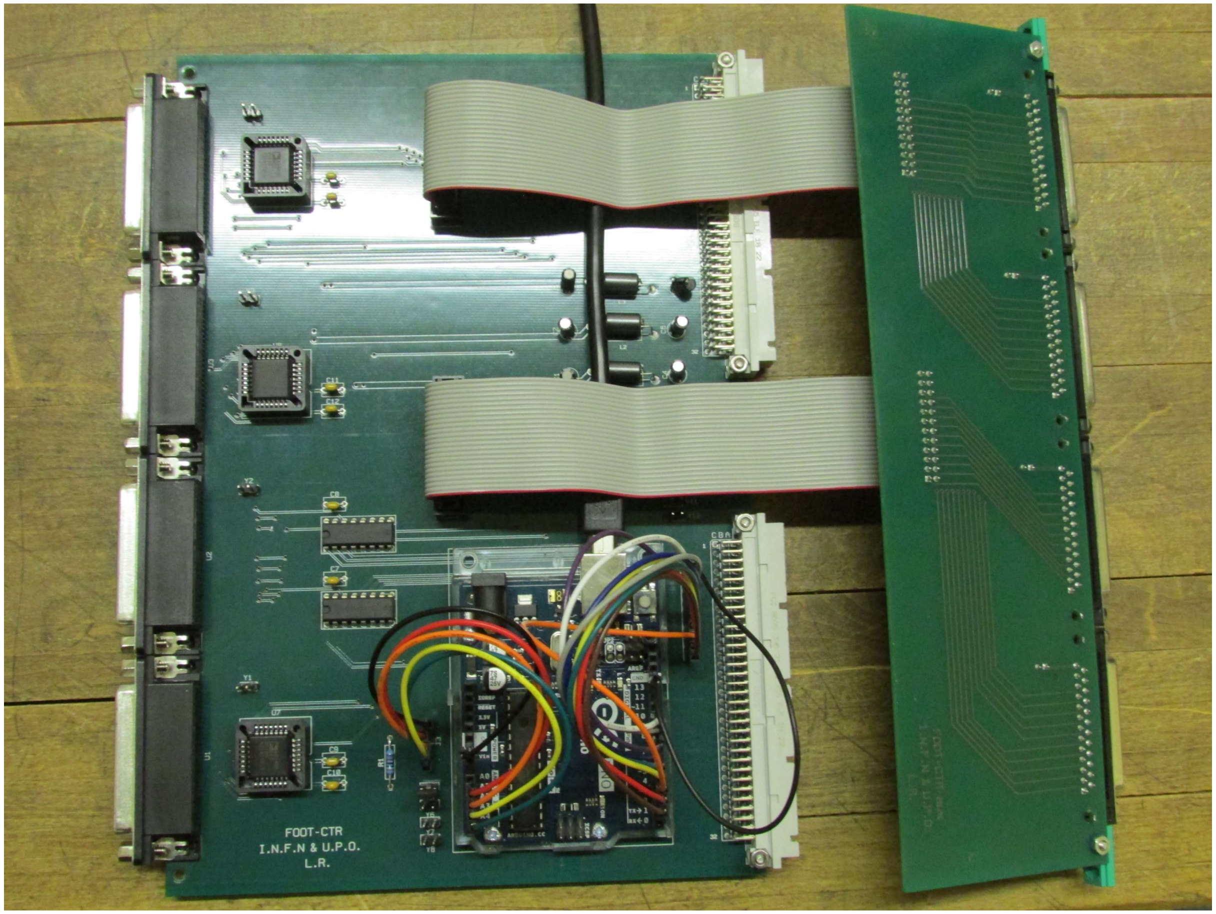

1 card = 80 NTC's
10 twisted pairs used per DB25 connector
80 twisted pairs (8 DB25)
one wire of each pair → GND
16 wires
16 wires
16 wires
16 wires
16 wires
s1 ... s16
en ADG406 D
a0 a1 a2 a3
s1 ... s16
en ADG406 D
a0 a1 a2 a3
s1 ... s16
en ADG406 D
a0 a1 a2 a3
s1 ... s16
en ADG406 D
a0 a1 a2 a3
s1 ... s16
en ADG406 D
a0 a1 a2 a3
5 analog multiplexers
10 kΩ
+5 V
voltage divider
A1
decoder 3→ 8: handles enable of multiplexers
4-bit counter: handles a0 a1 a2 a3 inputs of multiplexers

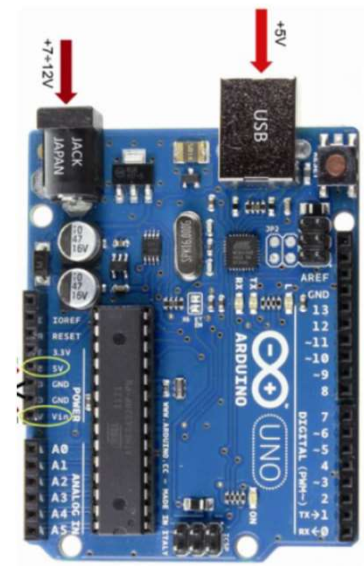
Main board (without Arduino) & auxiliary board





Master board with Arduino

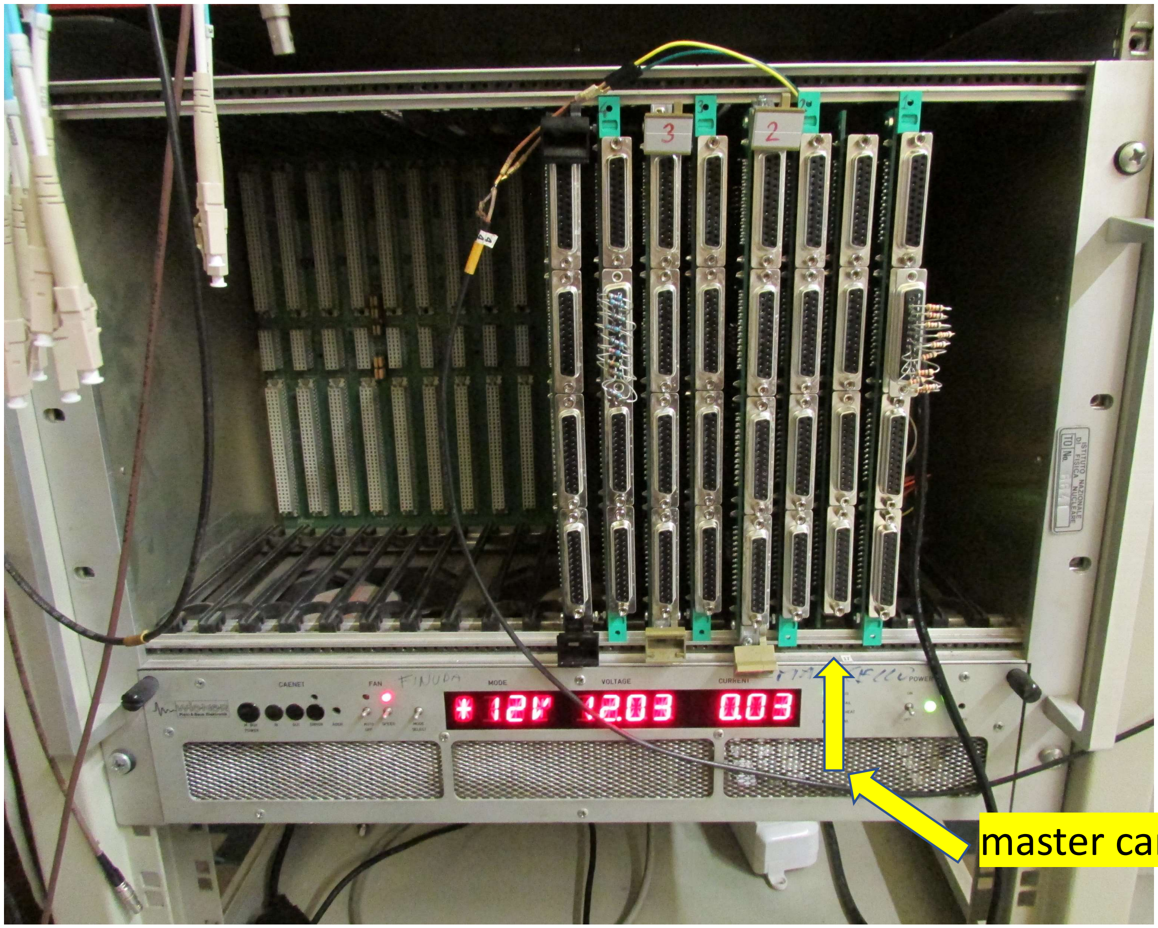




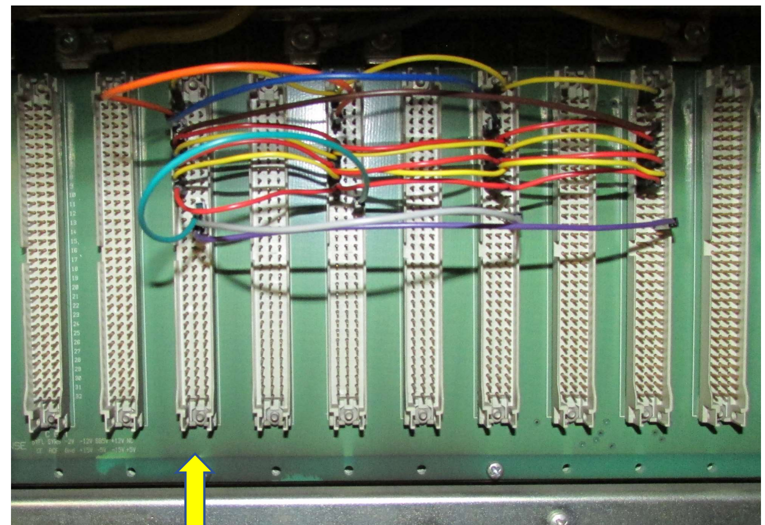
ADC inputs

digital outputs

System under test - hardware

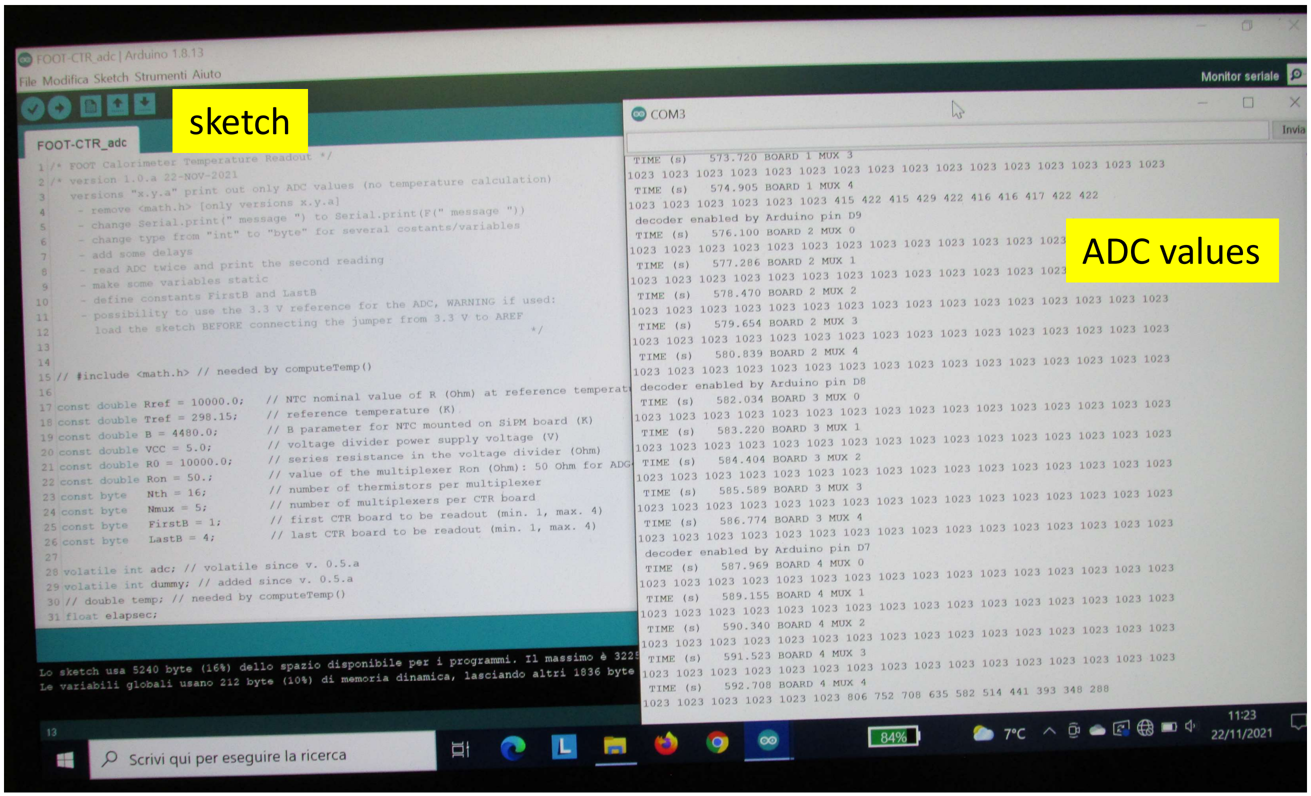


jumpers between four J2 connectors on the VME backplane



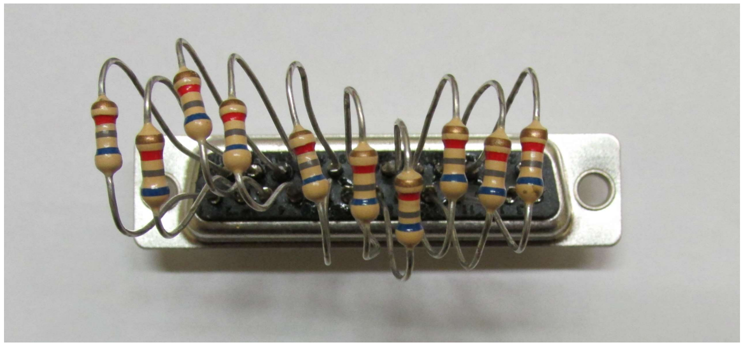
master card

System under test - software



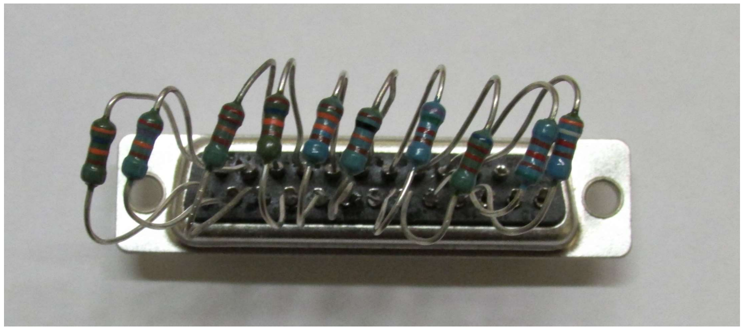
ADC value	R (Ω)	approx. T (°C)
1023	∞	---
630	16000	15
578	13000	20
512	10000	25
438	7500	30
392	6200	35

Test plugs with resistors



10 resistors: 6800 Ω $\pm$5% (nominal)

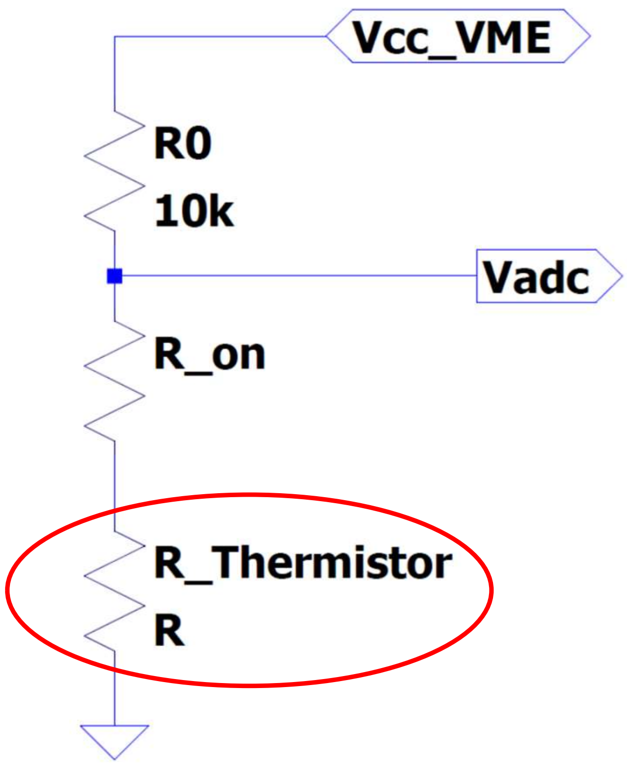
measured: $\langle R \rangle$ = **6850** Ω, σ_R = 120 Ω (1.7%)
with R_{min} = 6730 Ω, R_{max} = 7100 Ω
-1% +4.4%



10 different resistors: 3900 - 36000 Ω $\pm$1% (nominal)

measured deviations from nominal R:
from -0.15% to -1.03%

Voltage divider



$$V_{adc} = \frac{V_{CC}}{adc\_fs} \times adc$$

V_{CC} from Arduino board

$$R = \frac{V_{adc}}{V_{CC}^{VME} - V_{adc}} \times R_0 - R_{on}$$

adc_fs = 1023
adc = value read from Arduino ADC

Possible systematics from V_{CC}, Vcc_VME, R_0, $\mathbf{R_{on}}$

Multiplexer specifications:

Ron (typ.) = 45 - 60 Ω at 25 °C, $V_{DD(SS)}$ = +(-) 12 V

Ron (MAX.) = 80 Ω $V_{DD(SS)}$ = +(-) 13.5 V

Results with ten 6.8 kΩ resistors

- Assuming V_{CC} (Arduino) = 5.0 V
- Assuming $V_{CC(VME)}$ = either 5.0 V or 5.04 V (measured)
- Assuming R_0 = 10 kΩ (may depend on board)
- Assuming R_{on} = 50 Ω (may depend on mux)

Board n. 1, mux n. 4	$V_{CC(VME)}$ = 5.0 V	$V_{CC(VME)}$ = 5.04 V
Vadc (average)	2.050 V	2.050 V
R (average)	6900 Ω	6807 Ω
R – R_{meas} (average)	+49 Ω	-44 Ω
R / R_{meas} (average)	1.0072	0.9936
T derived* from R	32.79 °C	33.08 °C
	-0.15 °C	+0.14 °C

average *adc* = 419.5

«true» T = 32.94 °C

* using 3-parameter formula with nominal R(T) characteristic of NTC's

Results with 10 different resistors

- Assuming V_{CC} (Arduino) = 5.0 V, $V_{CC(VME)}$ = 5.04 V (meas.), R_0 = 10 kΩ, R_{on} = 50 Ω

adc	Vadc	R	$\Delta R/R_{true}$	T_{true}	$T - T_{true}$
805.5	3.937	35641	-0.6%		
750.75	3.669	26721	-0.4%		
707.25	3.457	21783	-0.4%		
633	3.094	15847	-0.4%	15.70 °C	+0.08 °C
582.5	2.847	12932	-0.4%		
513.25	2.509	9860	-0.7%	25.14 °C	+0.15 °C
441.5	2.158	7437	-0.6%		
392.5	1.918	6095	-0.9%	35.27 °C	+0.20 °C
347.25	1.697	5027	-0.8%		
289	1.413	3844	-0.4%		

Summary

- CTR & CTR-aux cards designed (spring 2021) and produced (summer 2021)
- CTR cards tested individually with on-board Arduino UNO
  - Routing of NTC wires via the 5 multiplexers tested
- Distribution of signals via J2 connectors implemented
- Whole system tested successfully
  - Routing of voltage divider voltages to different Arduino ADC channels verified
- Systematic errors from the system $\leq$ 0.2 °C
  - to keep the needed precision, each NTC sensor needs to be calibrated

Outlook

- Some systematic error sources to be further investigated (R_{on}, V_{CC})
- Calibration schedule for Calorimeter modules to be defined (climatic chamber?)
- Calibration constants storage to be implemented (Arduino vs. PC)
- Communication with central DAQ to be defined and implemented