A PROGRAMMABLE MULTICHANNEL ANTIALIASING FILTER FOR THE CUORE EXPERIMENT

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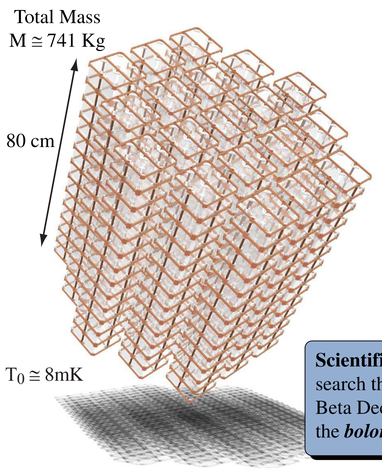
The CUORE experiment

CUORE[1] (*Cryogenic Underground Observatory for Rare Events*) is an experiment under construction at the Laboratori Nazionali del Gran Sasso (*LNGS*).



1) 988 TeO_2 crystals (bolometers) arranged in 19 Towers;

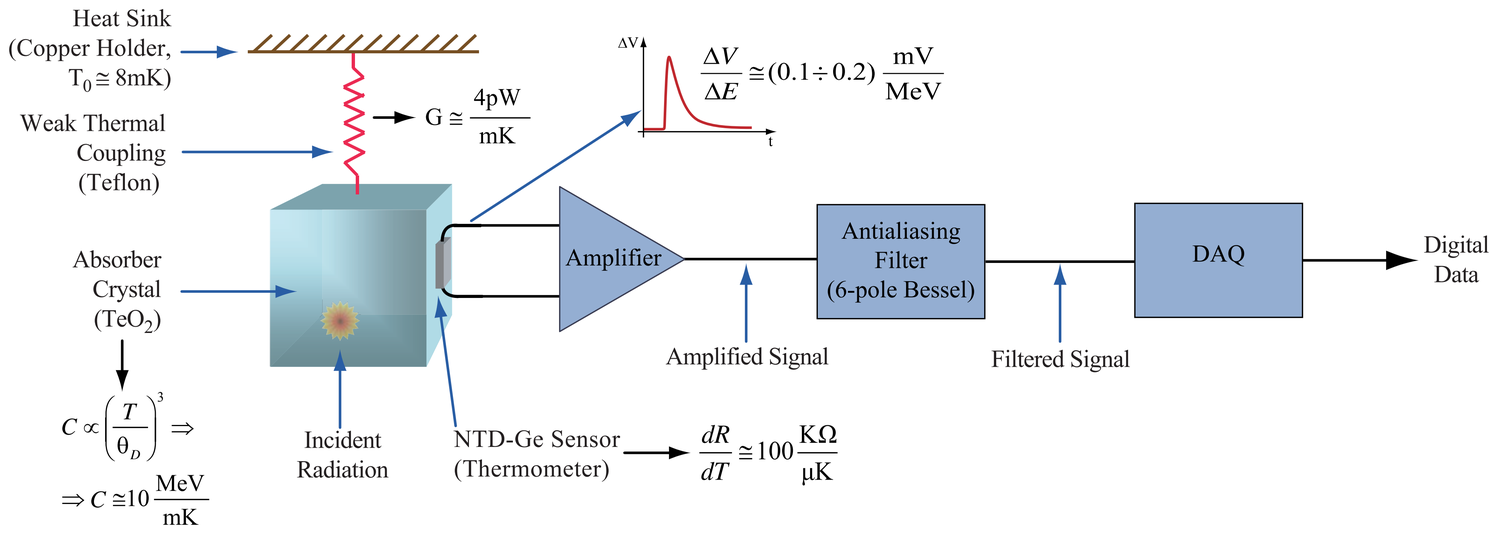
2) Each tower is composed by 4 columns;

3) Each column is composed by 13 crystals;

4) A single bolometer consists of a 5x5x5 cm^3 TeO_2 crystal (750g)

Scientific Goal: search the Neutrinoless Double Beta Decay in ^{130}Te exploiting the ***bolometric tecniques.***

Tellurium Oxide is a dielectric and diamagnetic material. According to the Debye Law, the heat capacity of a single crystal at low temperature is proportional to the ratio $(T/\Theta_D)^3$ where Θ_D is the Debye Temperature of TeO_2. Thus, provided that the temperature is extremely low, a small energy release in the crystal results in to a measurable temperature rise.



The sensitive element is called *bolometer*. A bolometer is composed by a crystal (*absorber*) and a Ge NTD thermistor (*sensor*) glued on it. CUORE bolometers are operated at a temperature of about $(8 \div 10)$ mK inside a $^3He/^4He$ dilution refrigerator. An energy release in the crystal is seen as a voltage drop across the thermistor. The typical amplitude signal variation across the thermistor (at the input preamplifier) is in the order of $\Delta V_{TH} = (100 \div 200)\ \mu V$.

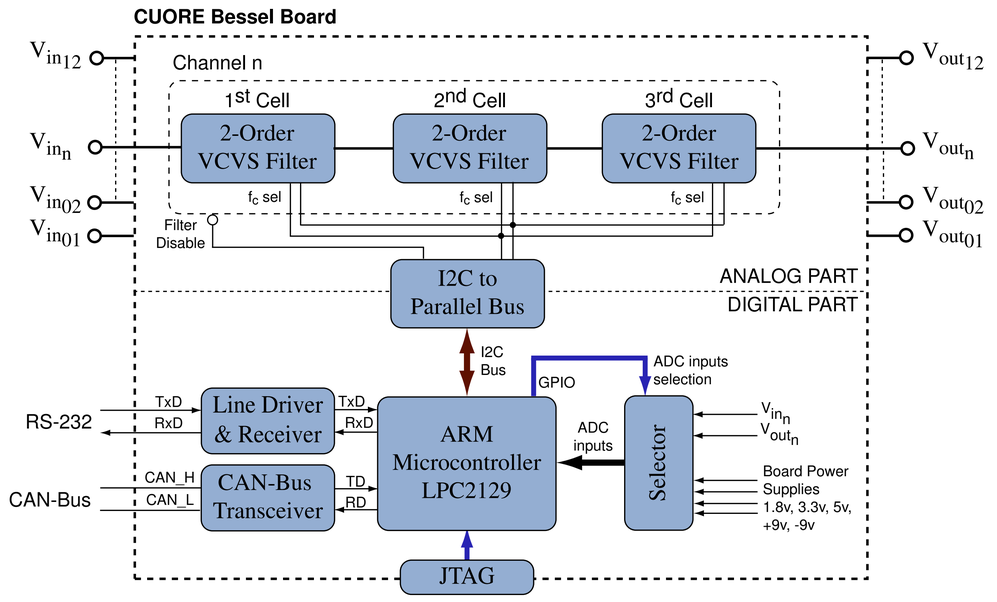
CUORE antialiasing filter

The signal produced by the bolometer is amplified, digitized and analyzed off-line by optimal filtering algorithms in order to maximize the signal to noise ratio. To obtain an adequate frequency response it is needed an *anti-aliasing filter* placed at the downstream of the analog signal processing. The filter type chosen is:

6-pole LP Thomson (or Bessel) Filter ⇒
- maximally linear phase response in the passband
- maximally flat amplitude in the passband

(120 db/decade of roll-off)

These features maximize the shape preservation in passband for the filtered pulse avoiding potential distorsion. Each CUORE antialiasing filter board accommodates 12 channels. The board is equipped with an ARM microcontroller which communicates with the on-board peripherals via I2C and with the remote control via optically coupled CAN-bus. Important features are the **low-cost realization** and the capability to perform **diagnostic routine remotely**.



1) The single filtering channel is composed by a differential input and 3 VCVS cells in cascade;

2) Board totally configurable remotly via CAN-Bus;

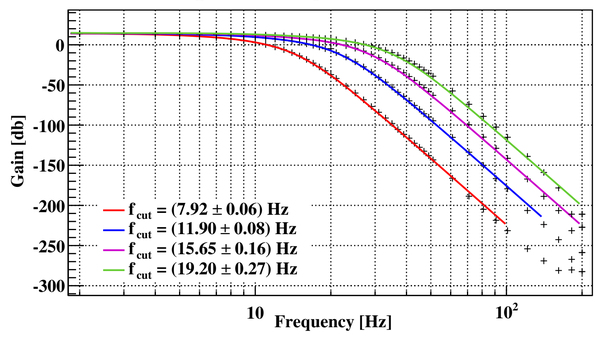
3) Possibilty to select four possible cut frequencies (8, 12, 16 and 20 Hz), in order to adapt the bandwidth to every bolometer;

4) Possibility to notice malfunctioning monitoring the board power supplies voltage, the not filtered signal and the filtered signal through the internal 10-bit ADC of the LCP2129.

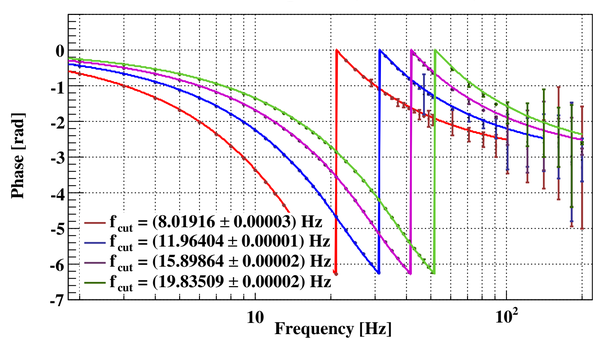
5) Possibility to reprogram and update the ARM firmware through the JTAG interface.

The figure shows the block-diagram of the antialising board. The analog part is composed by twelve identical channels. The cut frequencies are fixed using high-precision resistances (0.1%) and metalized polyester film capacitors (5%). We built 5 prototypes. An automatic set-up was developed to characterize the prototypes that will be used also in the final production. The system is based on a National Instrument® acquisition system and on a Vötsch® enviromental chamber.

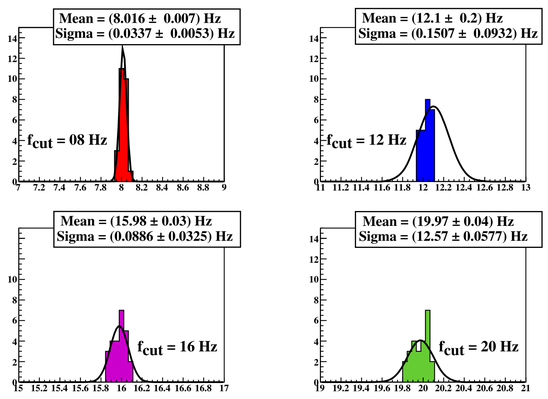
Magnitude Response (Channel 04)



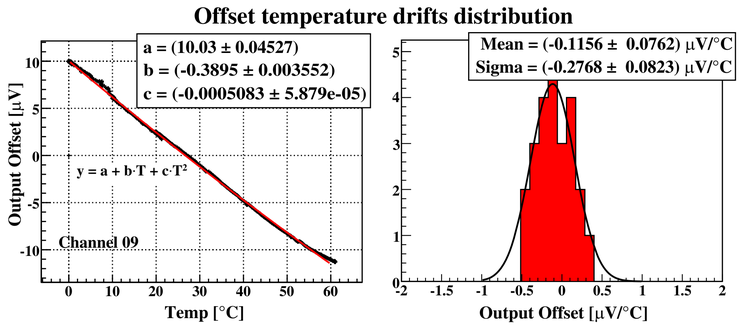
Phase Response (Channel 04)



Cut Frequencies Distribution



Offset temperature drifts distribution



Conclusion

1. We have designed a board that accommodates 12 Bessel six-pole antialiasing filters each one which yields a roll-off of 120 db/decade, a gain in passband of $G \simeq 2$ and four cut frequencies remotely selectable;
2. We have designed an ARM firmware which allow to :
   - communicate with a remote controller via optically coupled CAN-Bus;
   - configure the board through an I2C bus;
   - perform diagnostic routines in order to check the correct operation of the boards.
3. We have characterized the board using an automatic system that will be exploited also for production characterization;
4. The Antialiasing filter boards developed are fully compliant with the specifications of the CUORE experiment and we are going to start the final production.

References

[1] C. Arnaboldi *et al.*, "Cuore: A cryogenic underground observatory for rare events," *Nucl. Instrum. Meth.*, vol. A518, pp. 775–798, 2004.