Measurement and Control of the Beam Intensity for the SPIRAL2 Accelerator

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IBIC 2013 International Beam Instrumentation Conference

The phase 1 of the SPIRAL2 facility is under construction at the national heavy ion accelerator (GANIL, Caen, France). The accelerator including an RFQ and a superconducting LINAC will produce deuteron, proton and heavy ion beams in a wide range of intensities and energies (beam power range: a few 100W to 200kW). The measurements of the beam intensities are ensured by means of several AC and DC Current Transformers (ACCT/DCCT).

These measurements are required for the accelerator tuning and the beam controls for safety requests during the daily operation. The uncertainty has to be taken into account to determine the threshold value. This paper presents the measuring chain description of ACCT/DCCT, the signal processing by integration and the uncertainty studies.

ACCELERATOR CHARACTERISTICS

SPIRAL2 will produce different beams (protons, deuterons and heavy ions) at very high intensity.

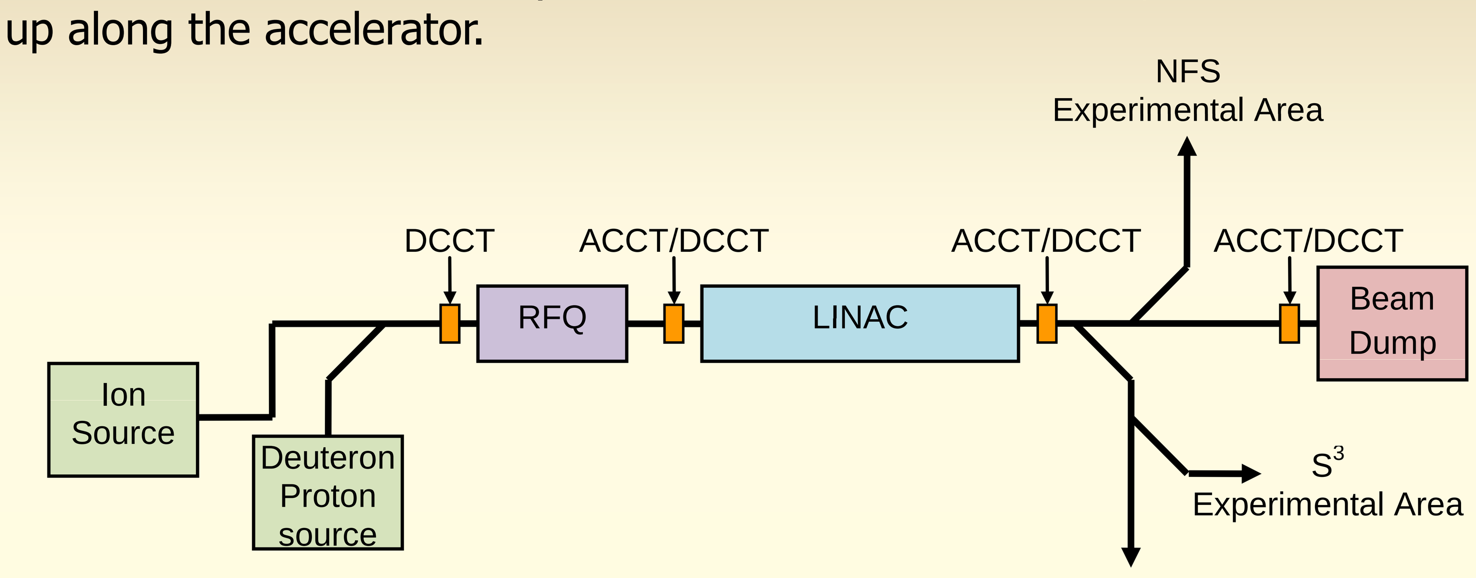
Beam	P	D+	Ions
Max. Intensity	5mA	5mA	1mA
Max. Energy	33MeV	20MeV/A	14.5MeV/A
Max. Power	165kW	200kW	48kW

The beam will be chopped so as to reduce the mean intensity while keeping the same peak current. The chopper is necessary in the tuning phases of accelerator in order to increase the beam power progressively.
The duty cycle of the slow chopper ranges are:

- from 1/10000 to 1/2000 at 1Hz
- from 1/2000 to 1/1 at 5Hz

NON DESTRUCTIVE BEAM INTENSITY MEASUREMENTS

In order to control continuously the intensities and the losses, ACCT and DCCT are set up along the accelerator.



DCCTs : Bergoz NPCT-175-C030-HR
ACCTs : Homemade

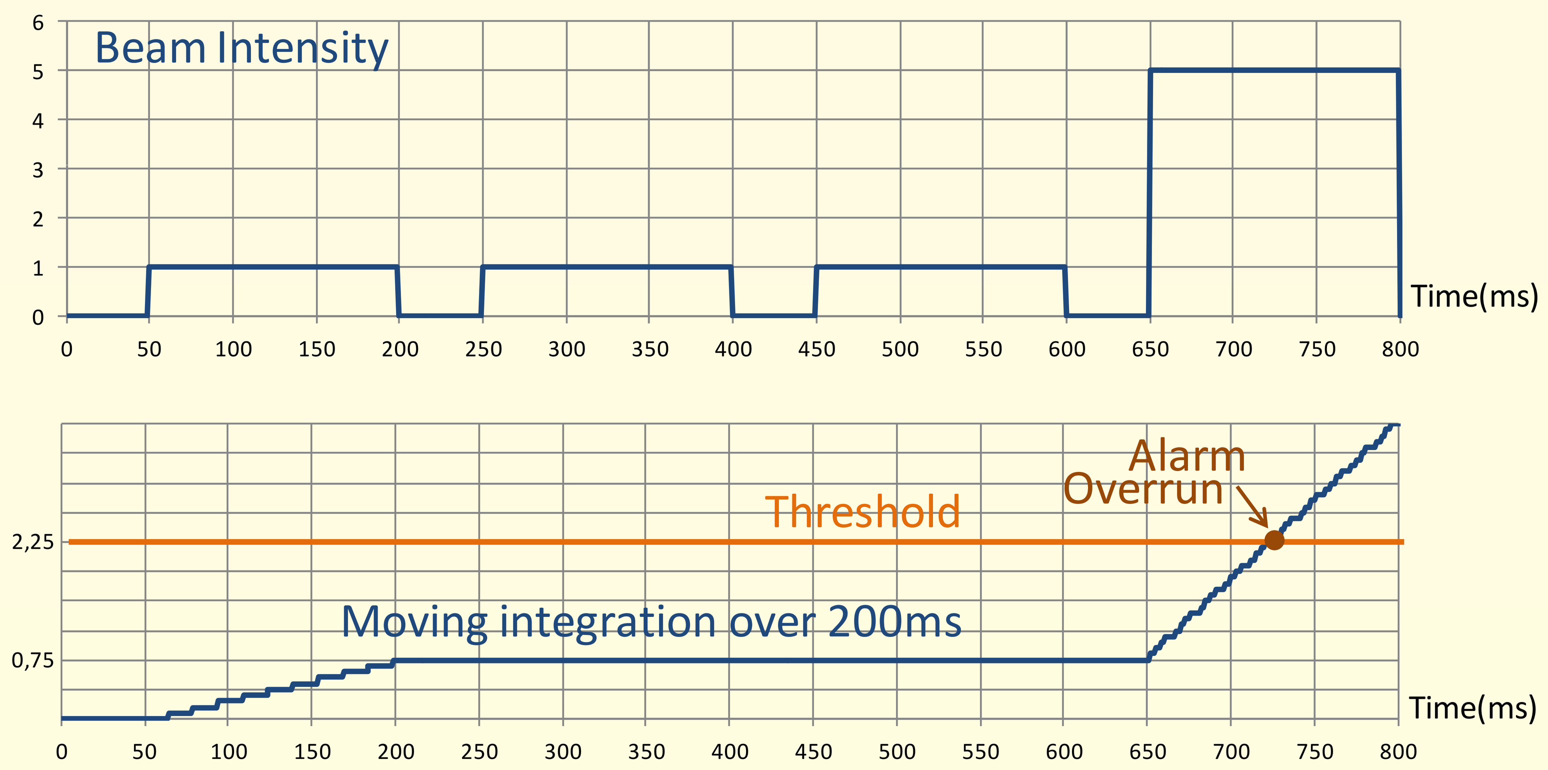
The measurements of intensities and transmissions are required for the accelerator tuning and the beam controls for safety.

BEAM INTENSITY CONTROL

The mean intensities and transmissions are compared to maximum allowed intensities. Each overrun have to send an alarm to the Machine Protection System.

The slow chopper periods (1s or 200ms) and the required response time (<1s) do not enable to use a simple filter to extract the mean intensity.
To control the mean intensities, a digital moving integration over 1s or 200ms allows:

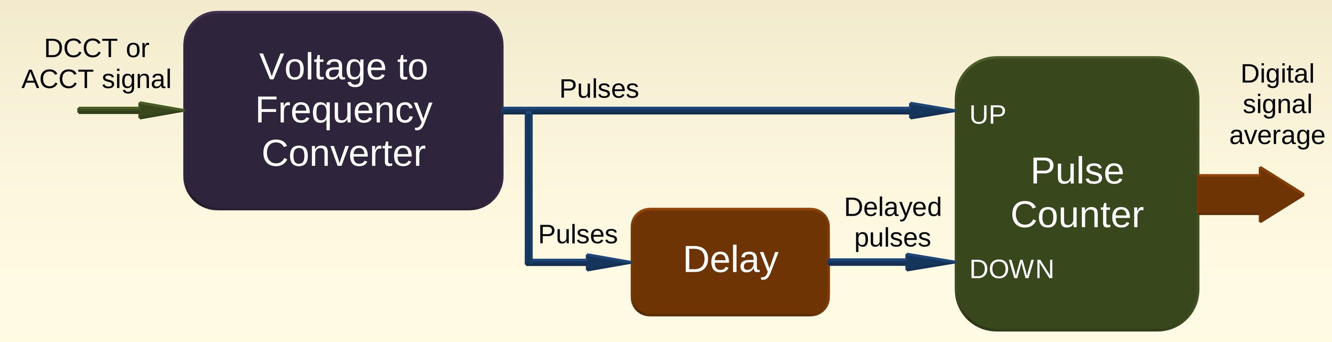
- response times lower than slow chopper period
- response times depending on intensity level excess



Threshold monitoring by moving integration

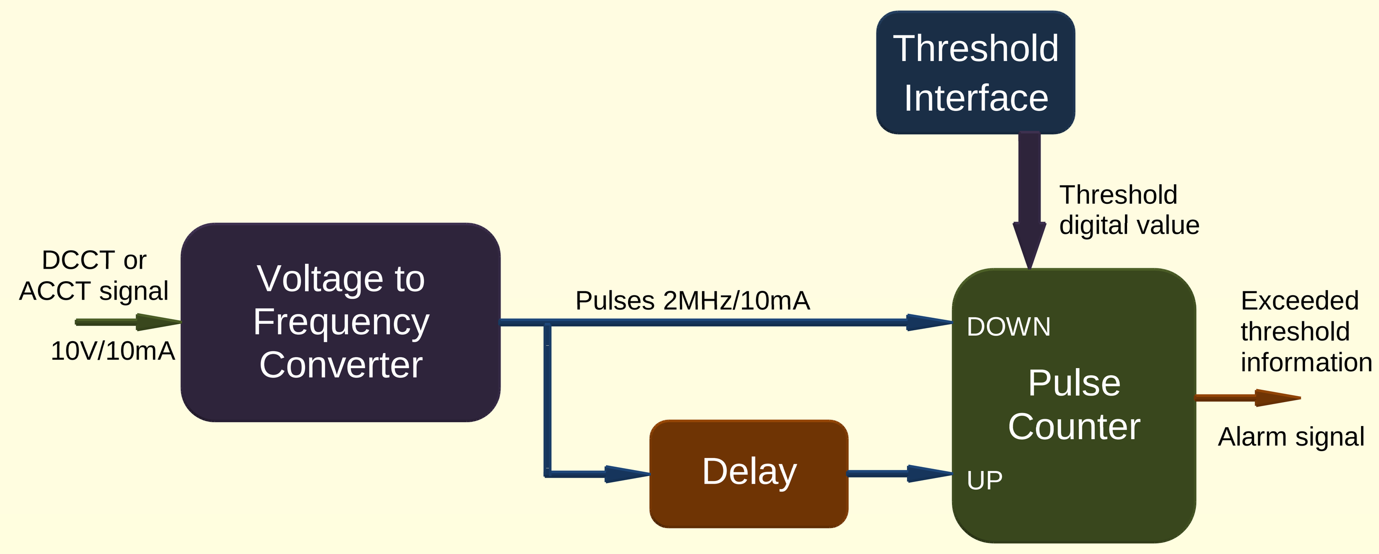
INTEGRATOR PRINCIPLE

The ACCT or DCCT signal is converted into a pulse frequency. Continually, a counter adds up the pulses and removes the delayed pulses. The delay corresponds to the time interval of integration. This time is equal to a multiple of the chopper period, the counter value is then representative of the input average signal.



Integrator principle

To generate the alarm signal, the counter starts at the threshold value and its inputs are inverted. Therefore, the counter value is equal to the threshold value minus the integrator value.
A negative value of counter is equivalent to the exceeded threshold.



Synoptic of threshold monitoring

UNCERTAINTIES IN MEASUREMENT

The threshold values must take into account the measurement uncertainty.

Sources of uncertainty	ACCT	DCCT
Linearity*	0.1%	0.6%
Offset vs. Temperature*	-	In progress
Integrator Offset	0.5µA	0.5µA
External magnetic field max.	5µA	-
Noise	3nA/√Hz	200nA/√Hz
Low drop	2%/s	-
Slew rate	5µs	50µs

*measured by the Ganil test bench

The minimum intensity that can be measured:

- DCCT : few 10µA
- ACCT : less than 10µA

Optimization of ACCT Low Drop
The low drop is the gradual fall of the ACCT signal during a constant pulse beam. A new electronic was developed to reduce the ACCT low frequency up to few 10mHz.
A clamp function is implemented to generate the DC of the ACCT signal. The negative component corresponding to the beam off is set to zero at each chopper period by the digital clamp. The low drop effect is minimized when the clamp is trigged in the middle of the time off.

Optimization of DCCT Offset
The DCCT offset arises mainly from the temperature of transformers.
A study is in progress to stabilize the temperature of the ACCT/DCCT blocs.

Optimization of external electromagnetic field
Three shielding layers (Armco, Mu-metal and copper) protect the sensors from external electromagnetic fields.
A vertical shield plate between AC and DC sensors is installed to minimize the disturbance produced by the DCCT magnetic modulator on the ACCT.

CONCLUSION

The ACCT/DCCT blocs are made and qualified. The Ganil electronics are in the prototype step. The monitoring threshold system and the DCCT temperature stabilization are being characterized.
The next step consists to measure the uncertainties of the global chain (diagnostic, electronic and integrator) with the Test Bench.

Another step is to improve the system after the Failure Mode and Effect Analysis (FMEA).
The last step will be the manufacturing of the final version of the electronic cards and the re-characterization.