INSTITUTE OF PLASMA PHYSICS OF THE CZECH ACADEMY OF SCIENCES

DATA ACQUISITION WITH REAL-TIME NUMERICAL INTEGRATION FOR COMPASS-U MAGNETIC DIAGNOSTICS

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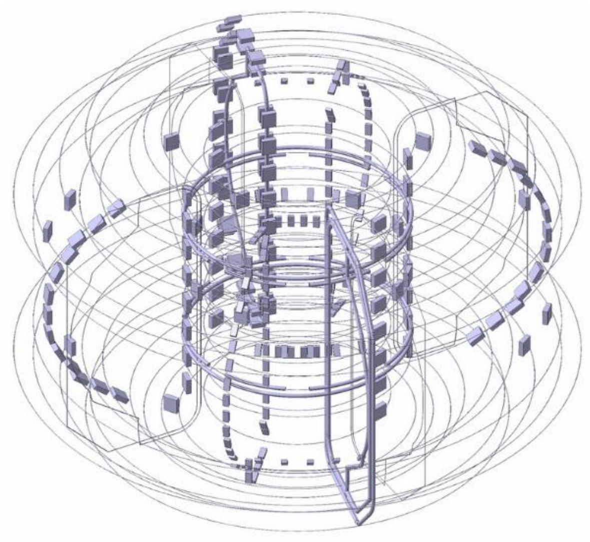
- Prototypes of digital integrator modules developed in retro-compatibility with existing hardware
- Design with 2 channels per module allows for different modes of operation – increased flexibility
- Digital integration tested at COMPASS and newly developed prototypes tested at ISTTOK
- Good first results, fulfilling the COMPASS-U 5 μV drift requirement, imposed by equilibrium reconstruction simulations

COMPASS-U DIAGNOSTICS AND MAGNETICS

Two other contributions provide an **overview of COMPASS-U diagnostics** and the **magnetic diagnostic** in particular.

Status of development of the diagnostic tools for the COMPASS-U tokamak and diagnostic plans for the first plasma
V. Weinzettl, P. Bilkova, I. Duran, et al.

Performance analysis of plasma current and vessel currents diagnostics planned for COMPASS-U
E. Matveeva, et al.

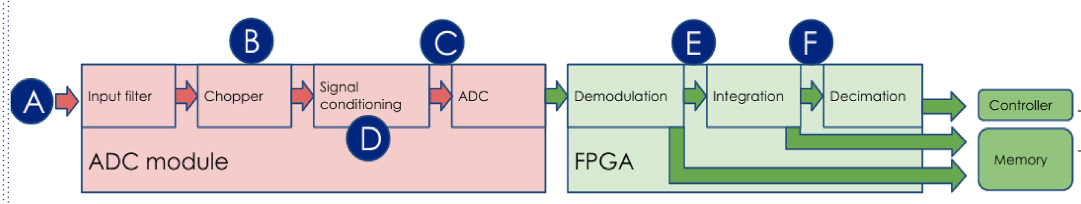

Distribution of key magnetic sensors in COMPASS-U

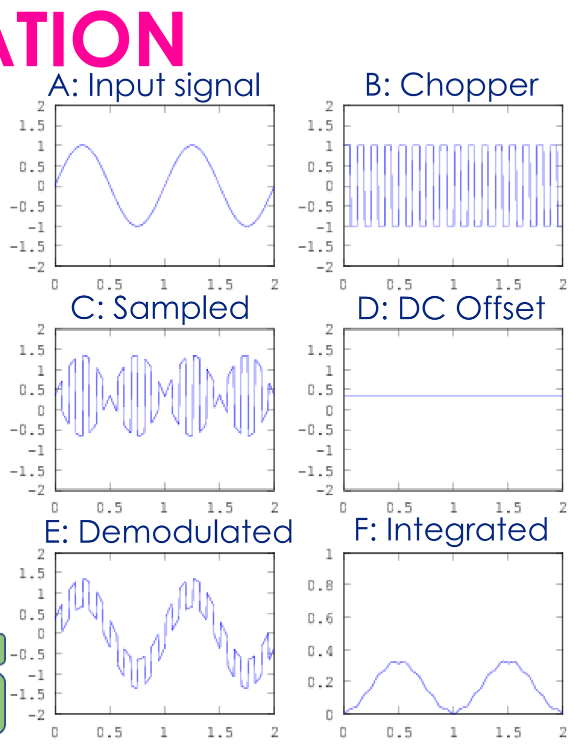
PHASE MODULATED INTEGRATION

- Dynamic range (ADC limits) defined by the input range (dB/dt) not the integrated output (B) as in analogue integrators
- Periodically change polarity of the coil signal before sampling
- Elimination of drift inducing DC offsets added in the electronics chain
- Initially proposed for long pulse integration at W7-X [1], adopted by ITER [2], in use at ISTTOK

Animated

[1] A. Werner, Rev. Sci. Instrum. 77 (2006)
[2] A. J. N. Batista, et al., Fusion Eng. Des. 123 (2017)





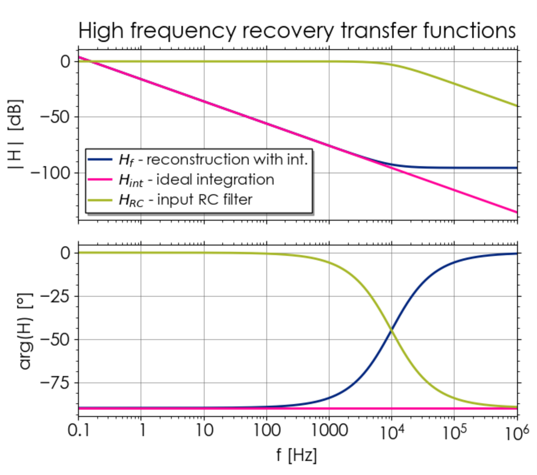
RECOVERY OF HIGH FREQUENCY COMPONENTS

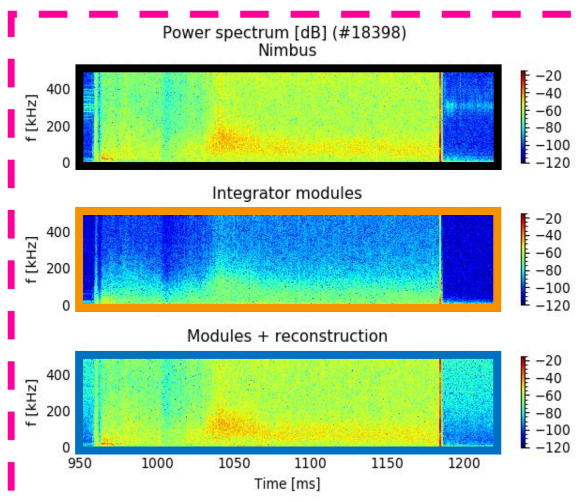
Digital integration with phase modulation was tested on COMPASS with ISTTOK integration modules.

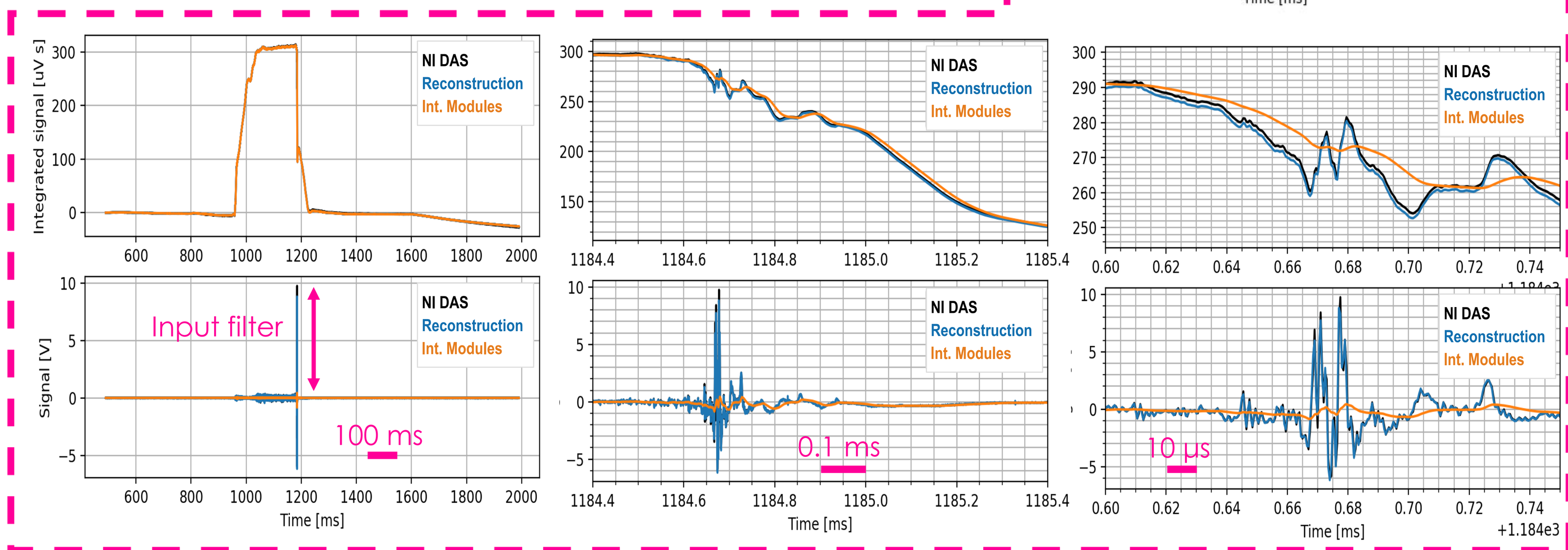
This hardware is compatible with the 'hybrid integrator' method described in [3].

This method relies on, and complements, the integration done by the first order input filter: fc = 8.8 kHz ⇒ τ = 18 μs

It is real-time compatible, however comes with the drawback of added noise.





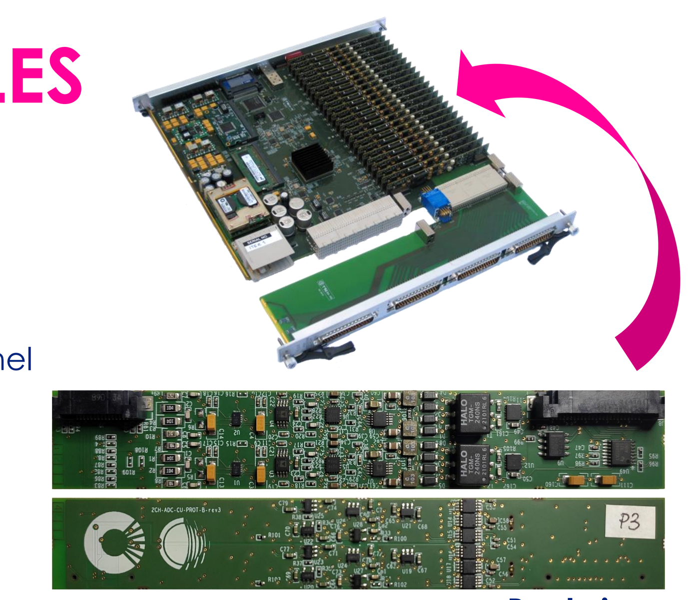


[3] E. J. Strait, et. al, Rev. Sci. Instrum. 68 (1), 1997

PROTOTYPE DAQ MODULES

- Galvanic insulation
- Based on AD4003 18 bit ADC (2 MSPS)
- DC-DC converter working at Nyquist frequency
- Compact size and low power consumption
- Configurable input first order filter
- Separate power circuits and grounding for each channel
- Backwards compatible with IPFN ATCA-IO-Processor [4]

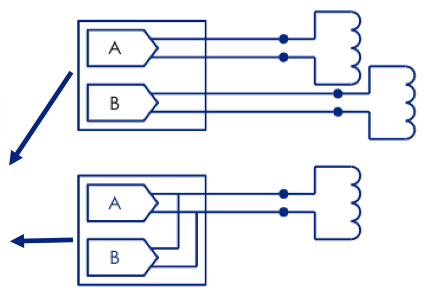
[4] B. Gonçalves, et. al, Fusion Eng. Des. 87 (2012)


Real-size

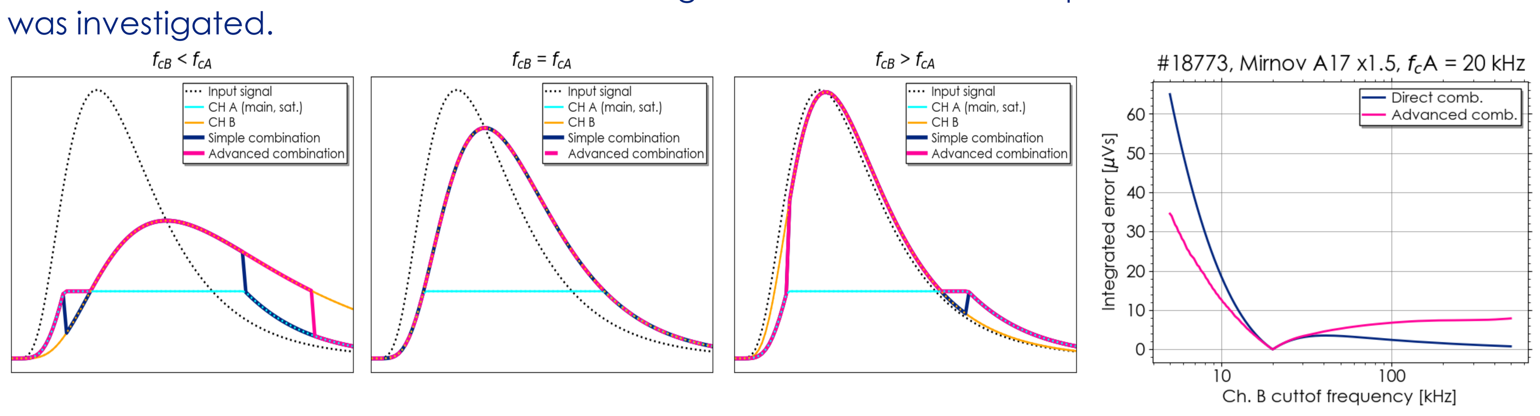
2-CHANNEL SOLUTION

Twin-channel architecture allows for operation in 3 regimes:

Mode	Resolution (A-B)	Bandwidth	Acquires
High density	High – High	Low – Low	2 sensors
High/Low resolution	High – Low	Low – High	1 sensor
Extended dynamic range	High – Low	Low – Low/High	1 sensor



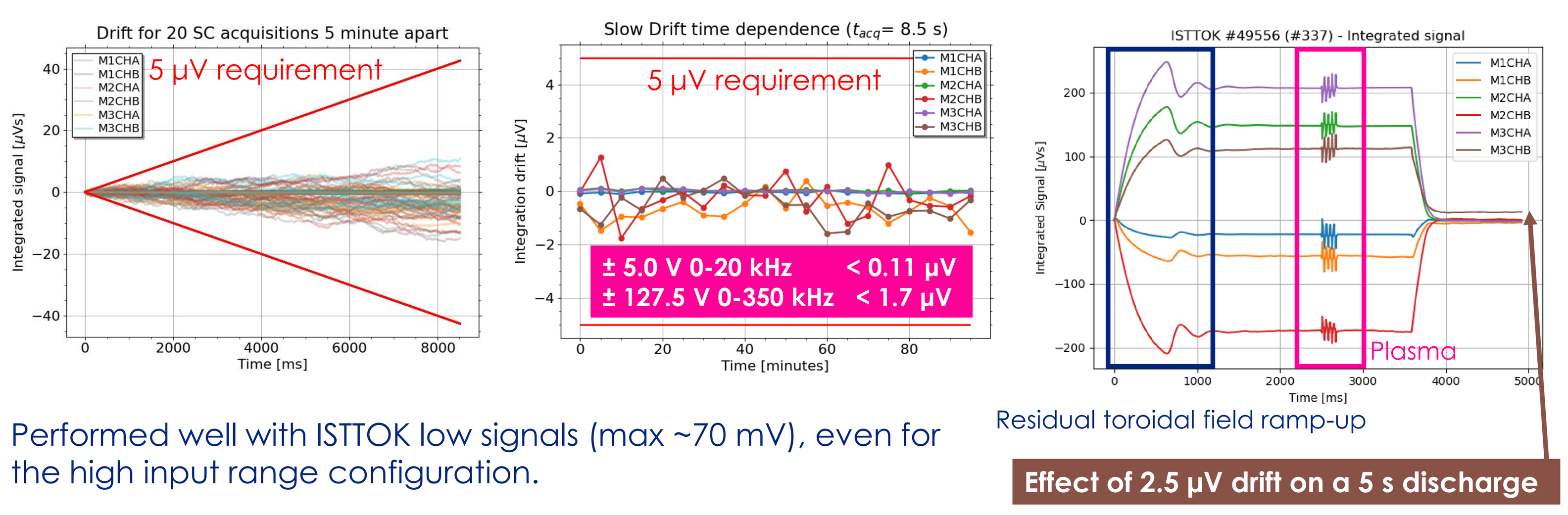
Reconstruction of a signal from two sources introduces error if the bandwidths of the channels are different. Knowing that in magnetic signals saturation will occur in isolated peaks, an advanced method for real-time reconstruction of the signal from two channels upon saturation of one of them was investigated.



Simulation with COMPASS magnetics data with artificially saturation showed that this technique minimizes integral error if the cutoff frequency of the high input range channel is lower than the high resolution one.

DRIFT MEASUREMENTS AND ISTTOK DATA

The requirement on integrator drift for COMPASS-U was established as **<5 μV**, given the estimated pulse length below **10 s**. First results are encouraging with a measured drift one order of magnitude below for high sensitivity configuration and compliance even for high input range configurations. (Presented measurements carried out with short-circuited inputs.)



Performed well with ISTTOK low signals (max ~70 mV), even for the high input range configuration.

Residual toroidal field ramp-up

Effect of 2.5 μV drift on a 5 s discharge

FUTURE WORK

- Complete the evaluation of the final configuration (input range, bandwidth), adjusted to the expected signals for COMPASS-U magnetics
- Development of new ATCA carrier board for 24 modules ongoing at IPFN
- Commissioning of the system with up to 12 boards, 288 modules for a full ATCA crate.

ACKNOWLEDGEMENTS

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