Power Converter Surveillance during the TI8 tests

M. Jonker

Introduction

The power supply surveillance plays an important role in the extraction interlock system.

- The surveillance system will be explained here in detail to provide a better understanding of its capabilities.

  Discussions following the beam incident revealed that the functioning of the system was not fully understood.

- Future extensions and improvements will be discussed as well.

Basic principle

- At time t, validate that the actual magnet currents are within tolerance.
  - Time t
    - How is it signalled,
    - how close can it be to the actual extraction,
    - how large is the sampling interval.
  - What tolerances do we need, what can we achieve
- The system should be reliable
  - Timing errors
  - Correct reference values

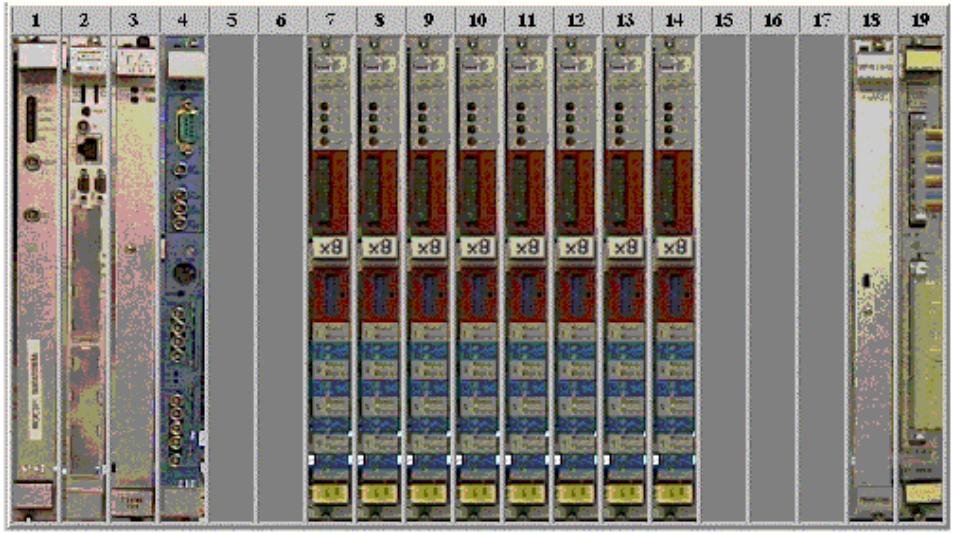
Implemented as part of the ROCS system

The ROCS system

What makes up a rocs/mugef system

VME crate with:

(FEI components in red)

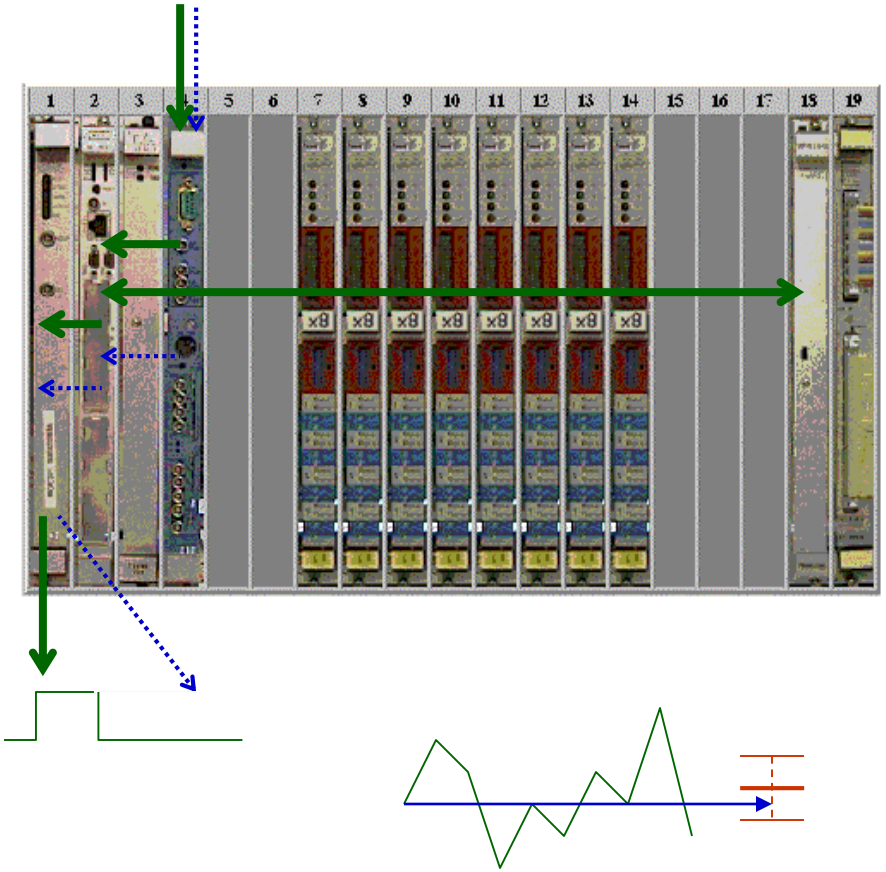


- SAC with **FEI output circuit**
- **PPC** (lynxos 2.5.1 / 4.0)
- themis 206, battery backed-up memory board
- **TG8**
- 1-8 ramp cards (up to 64 channels)
- **1-4 adc cards** (up to 64*2 channels (ref, dcct)
- statophone controler (to control hw status)

Fast Extraction Interlock

Process Implementation:

- Timing interrupt, wakeup PPC
- Retrieve current measurement
  - 1 .. N ms-samples from continuous measurements
- Average and compare if within tolerance with reference value
- Generation of extraction permit



Since 2004:

- Removal of extraction permit automatically after 1… 255 ms (was set to 20 ms)

Failures Causes

- False negatives

  system is ok, but not reported as such (inefficient)

  - The system is late
  - The system has the wrong or missing timing interrupt
  - The system is sensitive to large noise fluctuations

- False Positives

  system is not ok, but not reported as such (dangerous!)

  - The system is not operational and left in an ok state (2003)
  - The hardware signal gets stuck in an ok state.
  - A large measurement error masks a magnet current out of tolerance.
  - The system has wrong settings and wrong corresponding references (bad setting management).
  - System is triggered by wrong timing signals
    (>2006 with multi cycling + mixed fast and slow extractions)

Improvements in 2004

BIC, level sensitive, not time sensitive

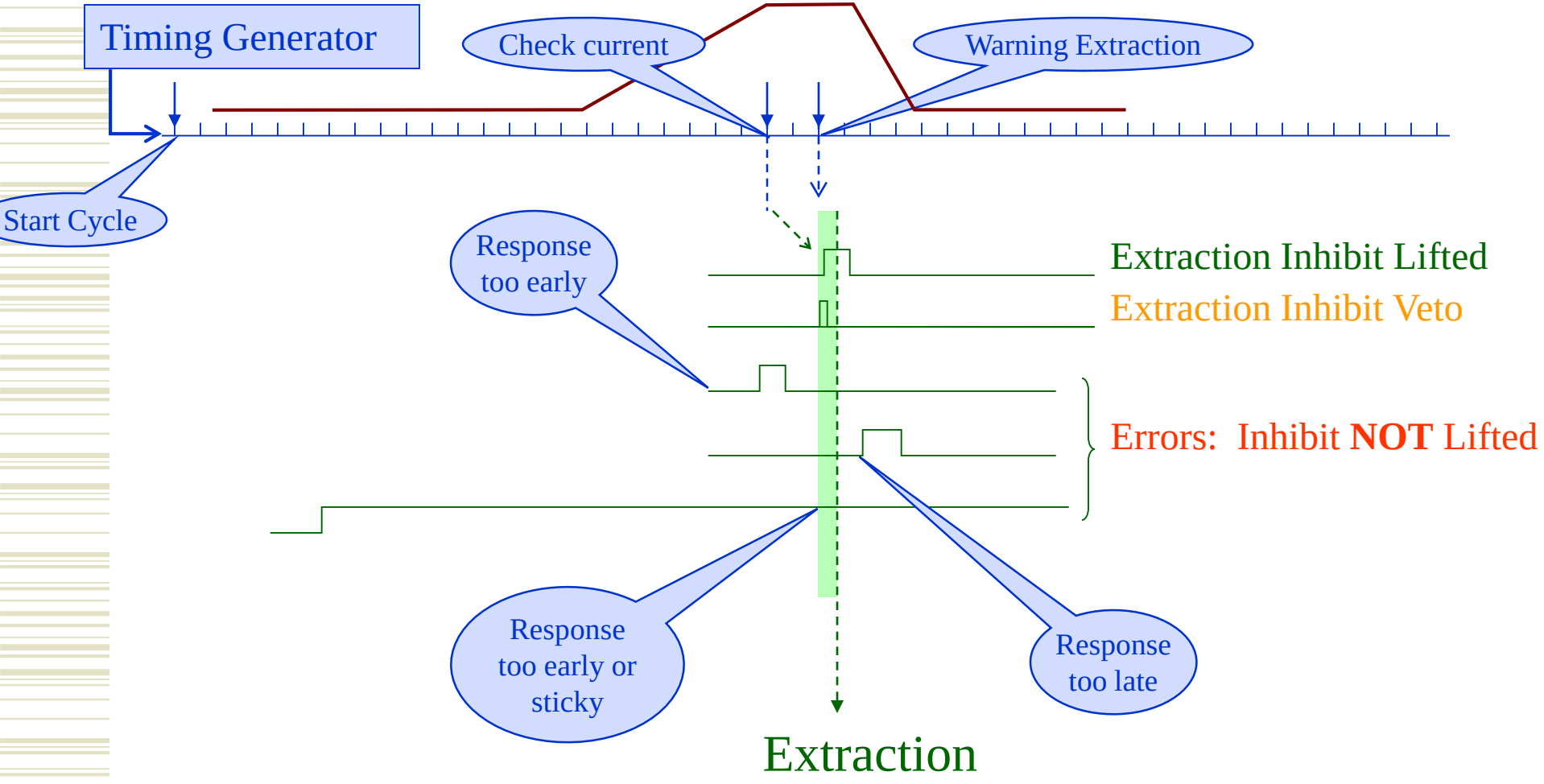
origin: Disagreement of BIC functional spec in 2003

- Modified hardware, to reduce false positives due to software failures.
  - The software sets the pulse duration for the extraction permit output.

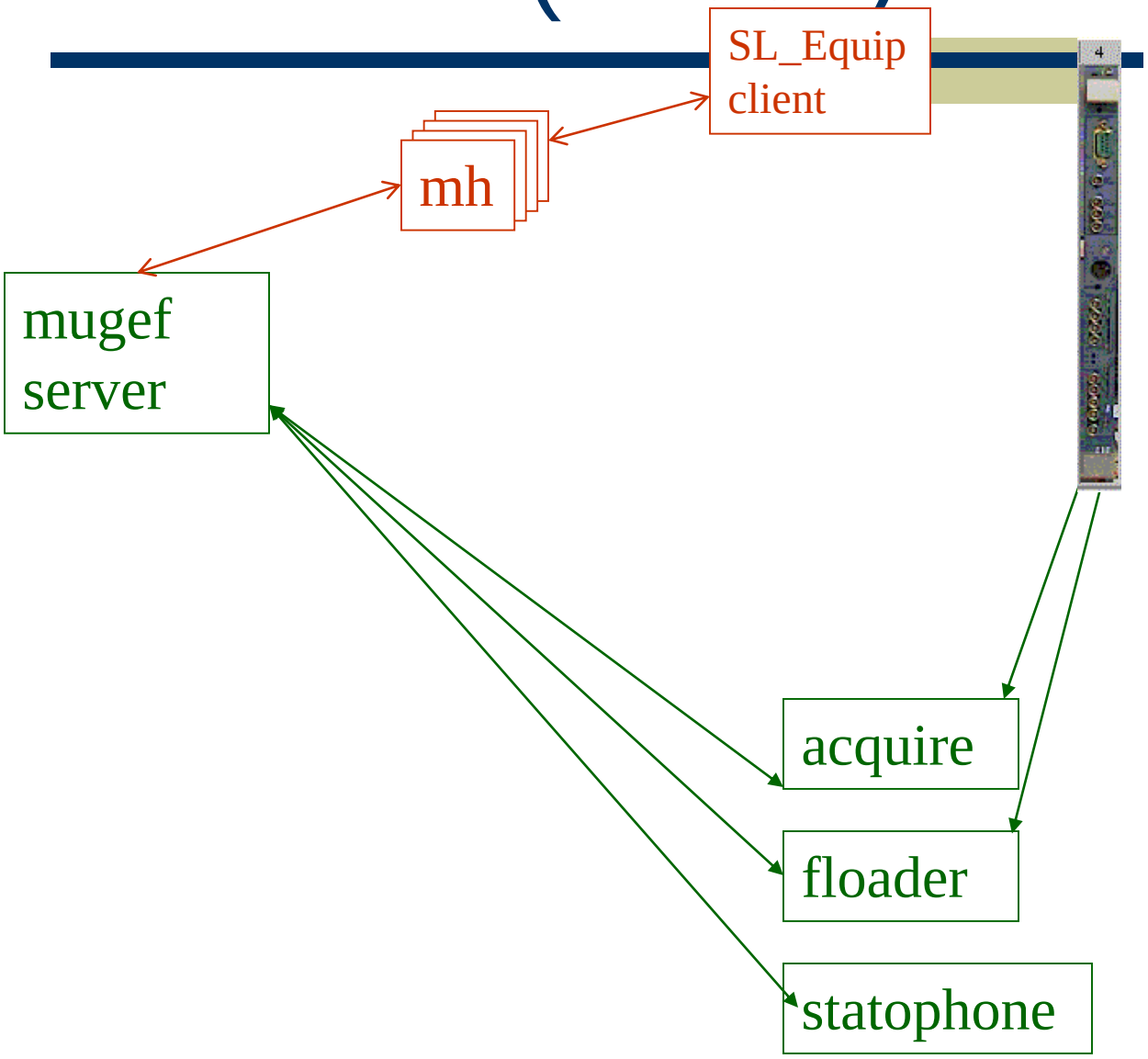
  Output returns to unsafe independent of software.
- Simplification of the ROCS processes (including the FEI).
  - Reduce logical path for interrupt processing
    - Elimination of three context switches and one thread creation.
    - FEI runs a dedicated high priority thread

  Faster system response time (Also due to faster processors)

Transition Sensitive BIC
a robust solution…



Architecture (>2004)



The beam incident

What happened

- Timing interrupt was set to 7 ms before effective extraction.
- Surveillance was based on average over 10 samples.
- We were hit right at the vulnerable place.
- (See slide of)

We new that the timing and number of samples were not optimal.

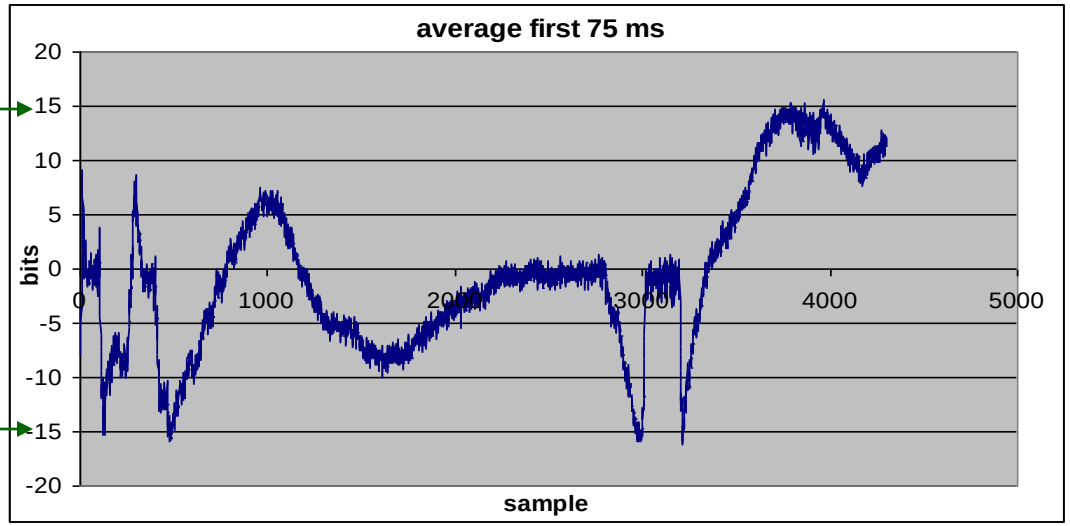
We underestimated the incidence rate of the interlocks and the correlation of interlocks with the extraction time.

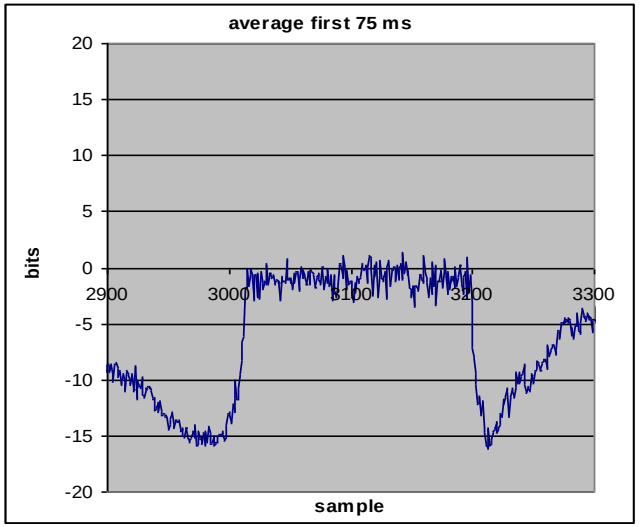
Preparation of next extraction test

- Test of MSE current stability and noise
  See next slides
- Based surveillance on a single ms sample
- Moved timing event forward as far as possible.
- Verification new operational modes
  (This confirmed some concerns I had)
  - And still it left one rocs system, that was not formally tested, in a non functioning state until the Monday of the extraction tests.

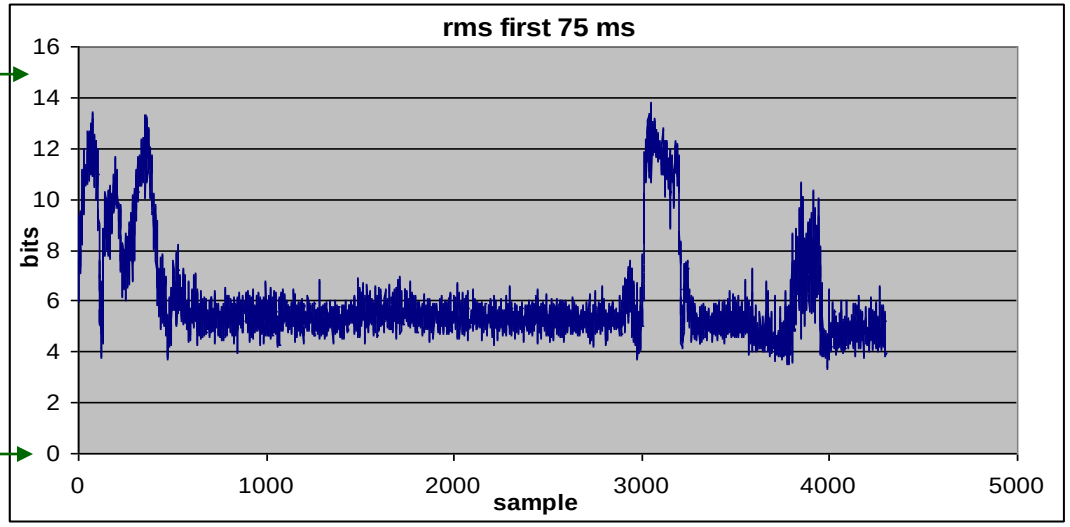
MSE stability and noise (20 hrs)

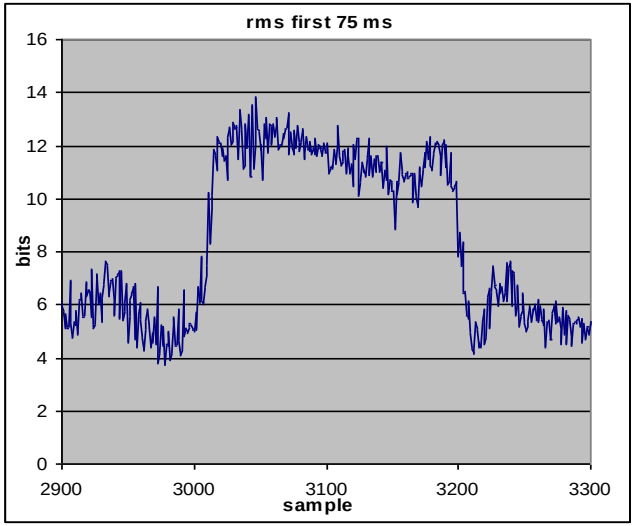
± 0.5 ppm





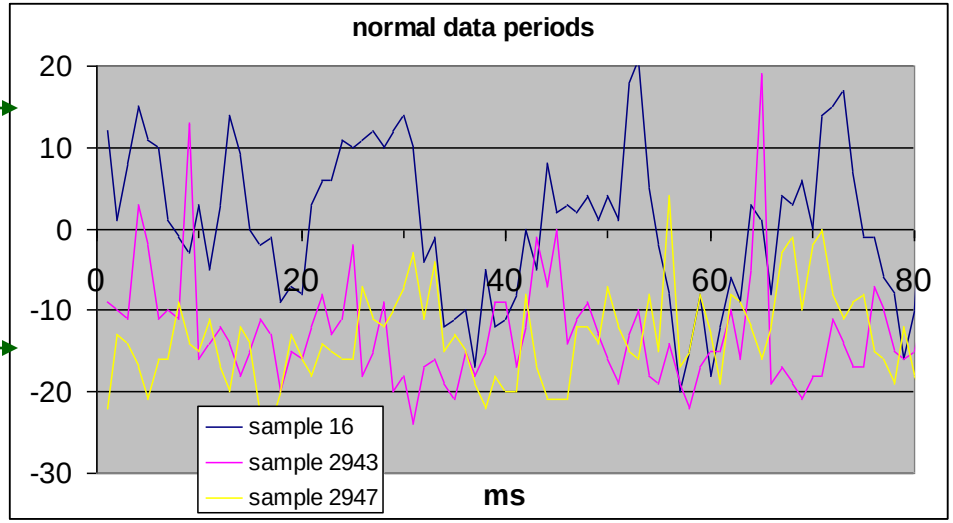
0.5 ppm



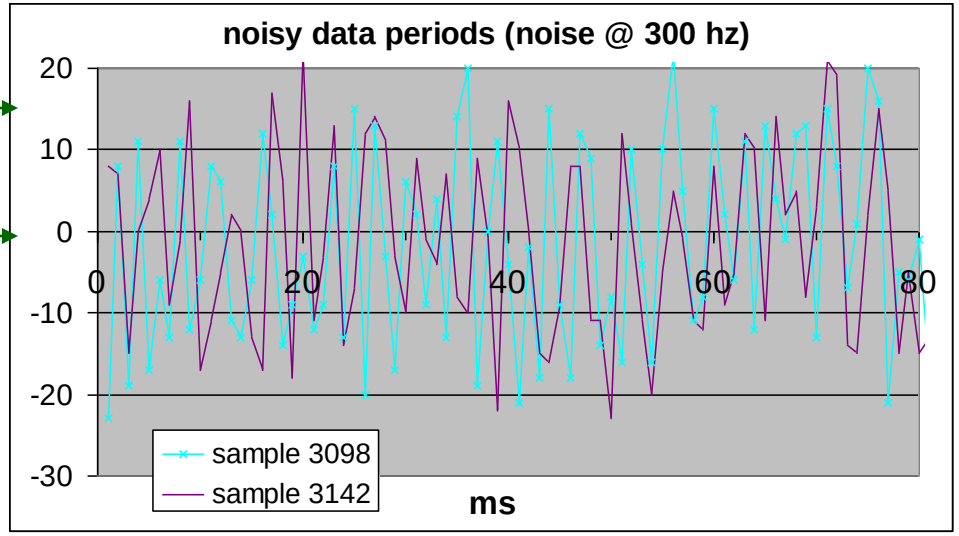


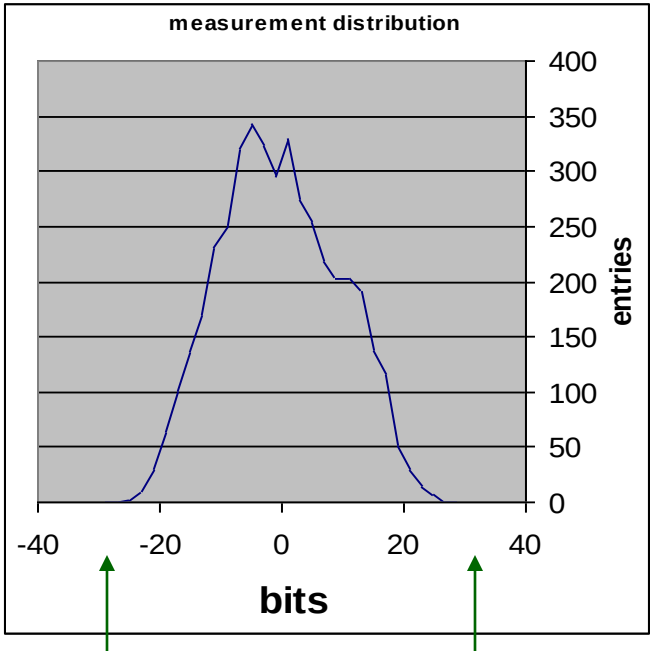
MSE stability and noise (20 hrs)

± 0.5 ppm



0.5 ppm

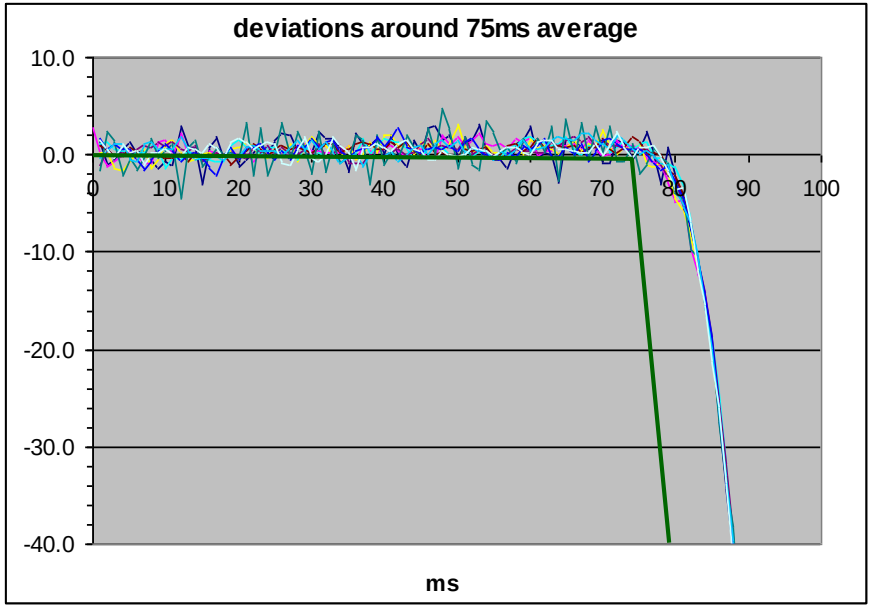


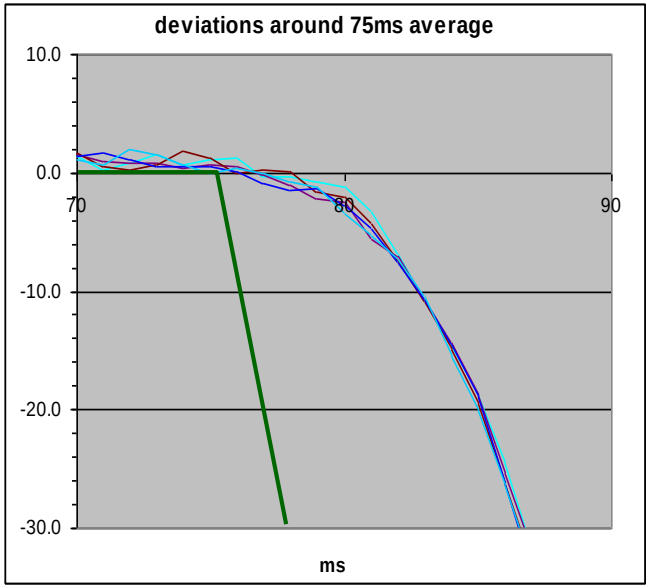


Based on a single sample

All values (drifts + noise) over the 20 hrs period fall within a window of ±1 ppm.

MSE Current Delay





MSE Power Converter delay of output current with respect to the reference (due to filters).

It takes of the order of 10 ms before the current drops below 1 ppm.

The first 5 ms the drop is negligible.

Formal Testing

- There was some serious doubts that in the new configuration, the system would work properly.
  - Speed up of processing with respect to 2003
  - Single sample, but is data already available in the memory of the acq cards?
- A formal test confirmed the worries, the system did responded 2 super cycles after a converter “trip”.
  - The system was too fast so data was not available yet, but 2 supercycles old.
- The problem was fixed, the rocs were restarted, the formal test was repeated on 2 out of 3 systems.
  - The system that was used for SPS power supplies was left out.
- Before the extraction started I discovered that the later system was not running the correct version.
  - I.e. it did not pick up the latest version when it was restarted.

Evolution

Future modifications of the system

- Beam Dump on unhandled interrupts.

  A function start signal that is not properly dealt with by the Rocs software is detected and can be used to dump trigger the beam dump.

- Slow extraction surveillance

  The FEI system can be used also for slow extraction. The system is retriggered every 20 ms to validate the magnet currents.

- Move functionality into hardware.

  A new version of the acq boards could contain onboard out of bound checking, providing a continuous monitoring.

Issues

- Hardware failures, i.e. sticky output, or random pulses on the output are not detected.
  - Needs modification of BIC, or of BIC surveillance.
    (Modified BIC: block extraction in case of state transitions at wrong time)
- Multi cycling, and if the same magnet surveillance channel is used for both fast and slow extraction, we are subject to timing errors (pulsing of the fast extraction kickers during the slow extraction is unprotected)
  - Do not use same BIC or BIC channels for dual purposes. (Or modified BIC behaviour as above)
- Setting of reference values
  - Reference values are maintained independently of setting values. The operator has an option to reset the reference values to the average of the last n extractions.
  - How can we make this option safer and avoid accidental abuse of this option.
- Build-in Formal Testing
  - After each change of the system, the system should be formally tested.
  - How can we enforce this? (i.e. after a change of software or FEI option, could one ask for an automatic test procedure?)

Conclusions

- The mixed Hardware / Software surveillance system provides an acceptable test for the fast extraction interlocks.
- The noise levels and drifts of (all) the current measurements needs to be understood and possibly improved.
- Surveillance of hw-malfunctioning needs to be added (either by modification of BIC, or by added BIC surveillance).
- Surveillance can be extended to a) slow extractions b) system integrity.
- Certain surveillance tasks can be integrated closer into the hardware.
- Formal test procedures are important
  - The ROCS surveillance is part of a more complex system.
  - A good understanding of the overall system is needed, in order to
  - Define test procedures that effectively tests week points in the interlock system.
  - Tests must be repeated each time the system is restarted. Independently of the system experts.