Petra 3 Fast Orbit Feedback

ARIES Workshop on Electron and Hadron Synchrotrons

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Petra 3 Fast Orbit Feedback

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DESY, Hamburg, Germany

- until 2009 in operation
- Energy 6 GeV
- Circumference 2304 m
- RF 499,564 MHZ
- Revolution Time 7.685 µsec
- Revolution Frequency 130,1 kHz
- Up to 24 Beam lines / Unduators
- RF 499.564 MHZ
- Harmonic Number 3840
- 8ns, 16ns, 192ns typ Bunchspaching
- Tunes fs 6kHz, fx 19khz, fz 38khz
- 250 BPMs Libera Brilliance Type
- 100 fast correctors
- top up injection

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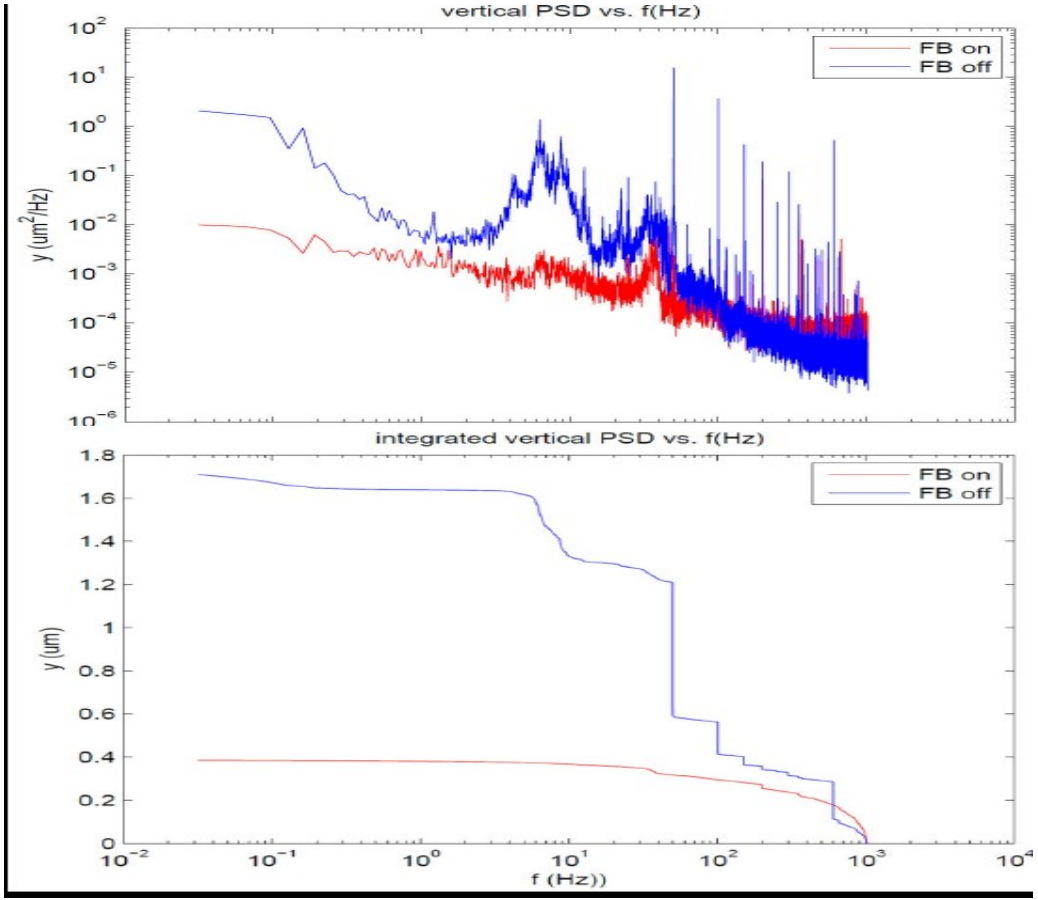
Requirements



Task:

- orbit stability of ±0.5 um in the vertical plane over 24 h
- Damping DC to 200Hz
- Compensation of 50Hz and harmonics
- Feed forward during Injection
- Interaction with slow orbit control and Beam line via control system

Restrictions

- total Delay (Cable, Electronic, …)
- Bandwidth (Correctors Magnets)
- Noise (BPM)

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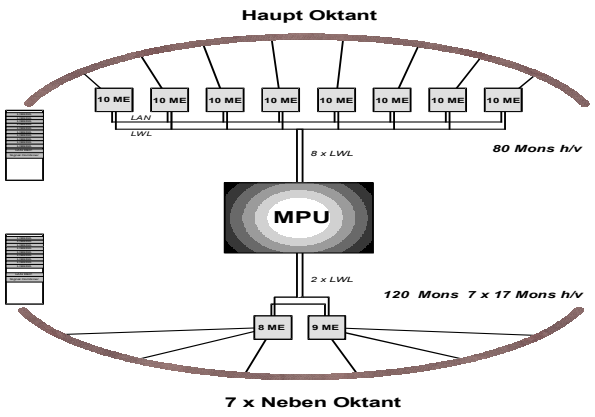
approach



- star topologies
- Turn by Turn Data Processing from BPMs to Power supply
- custom made TbT Data output of Libera BPMs
- air coils over stainless steel camper
- current source power supplies (full digital)
- no frequency gap
- reference Orbit of FOFB control by slow orbit correction and user requirements
- DC current of fast Corrector removed by slow corrector

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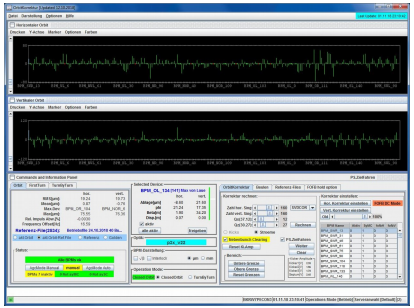
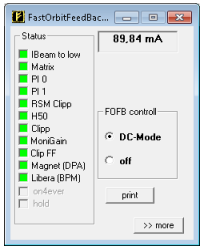
Operation Example (Control System View)

USO (orbit fine correction and DC current reduction)
Undulator Section Control



slow orbit Corretion



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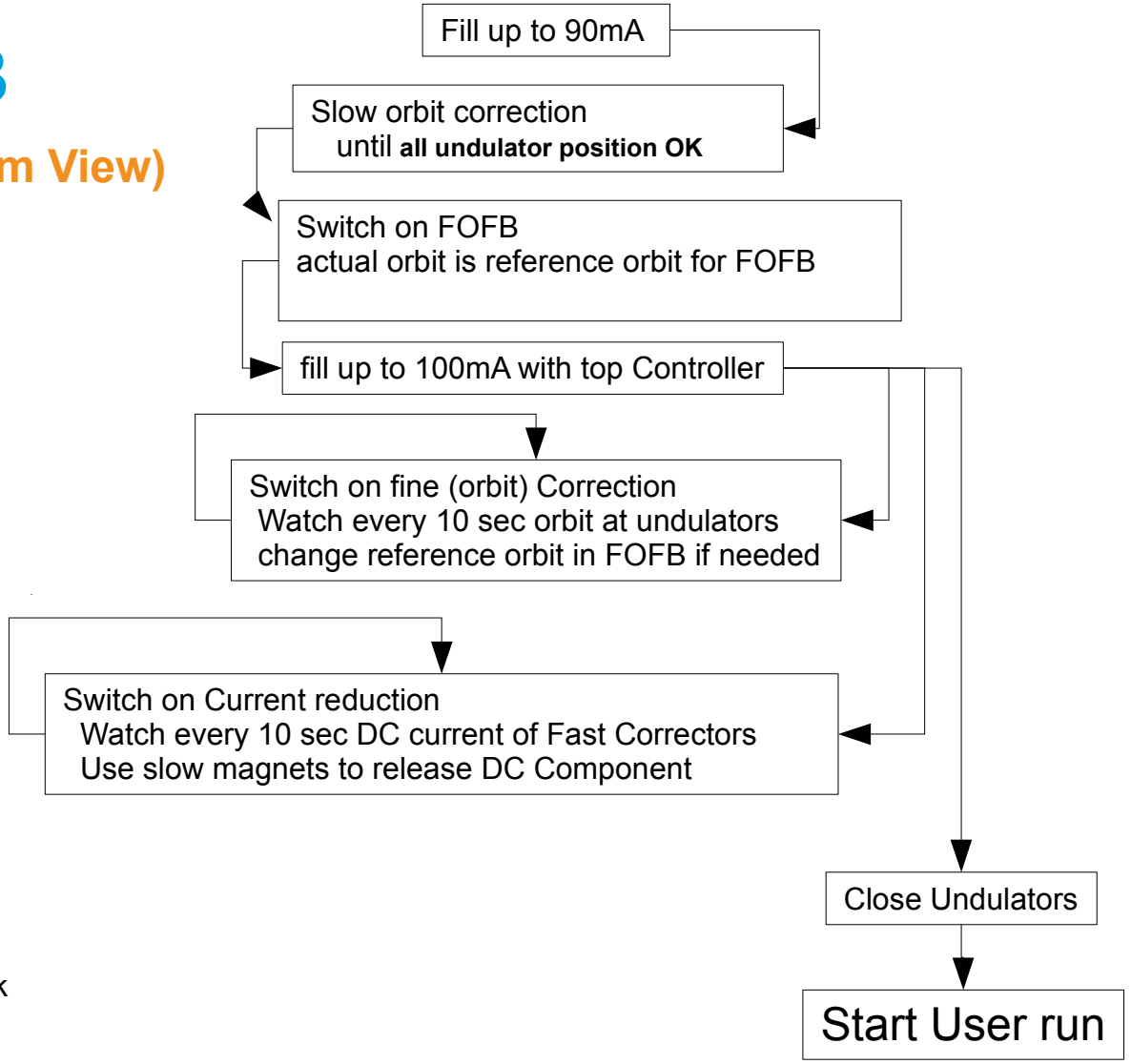

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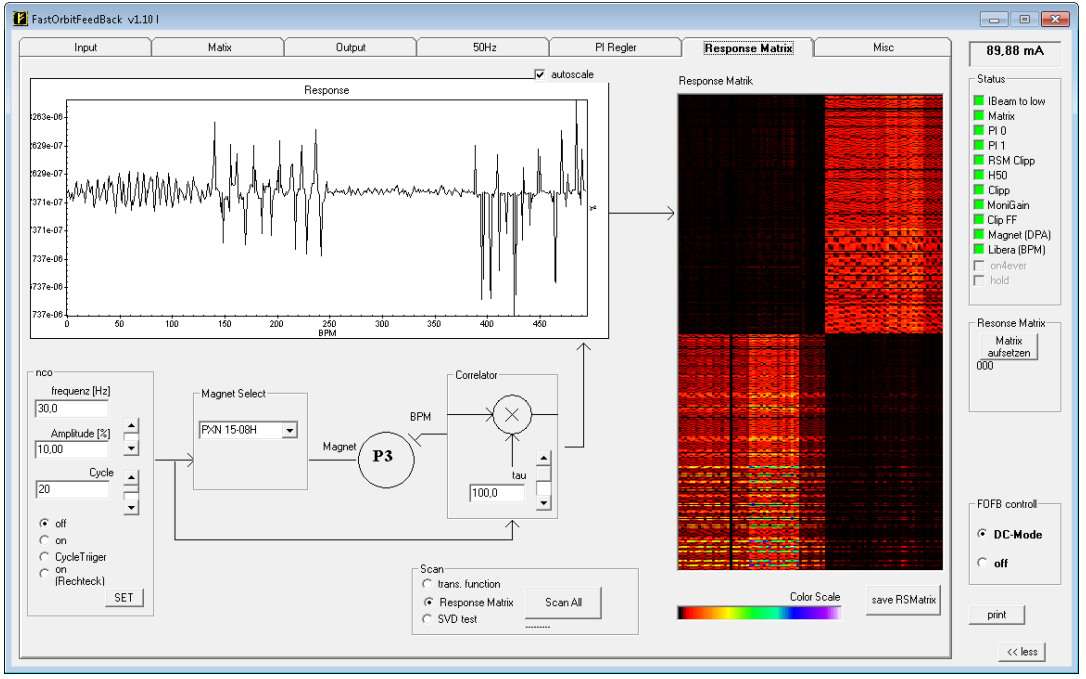
Measure Orbit Response Matrix *M*



- Response measurement with frequency correlation of one corrector and all BPM simultaneous
- Exaltation with frequency (typ 30Hz)
- Time for measurement 3 Minutes

$$\Delta x_i = M_{ij} \Delta \theta_j$$

change of beam position at BPM i

change of the kick angle of the corrector j

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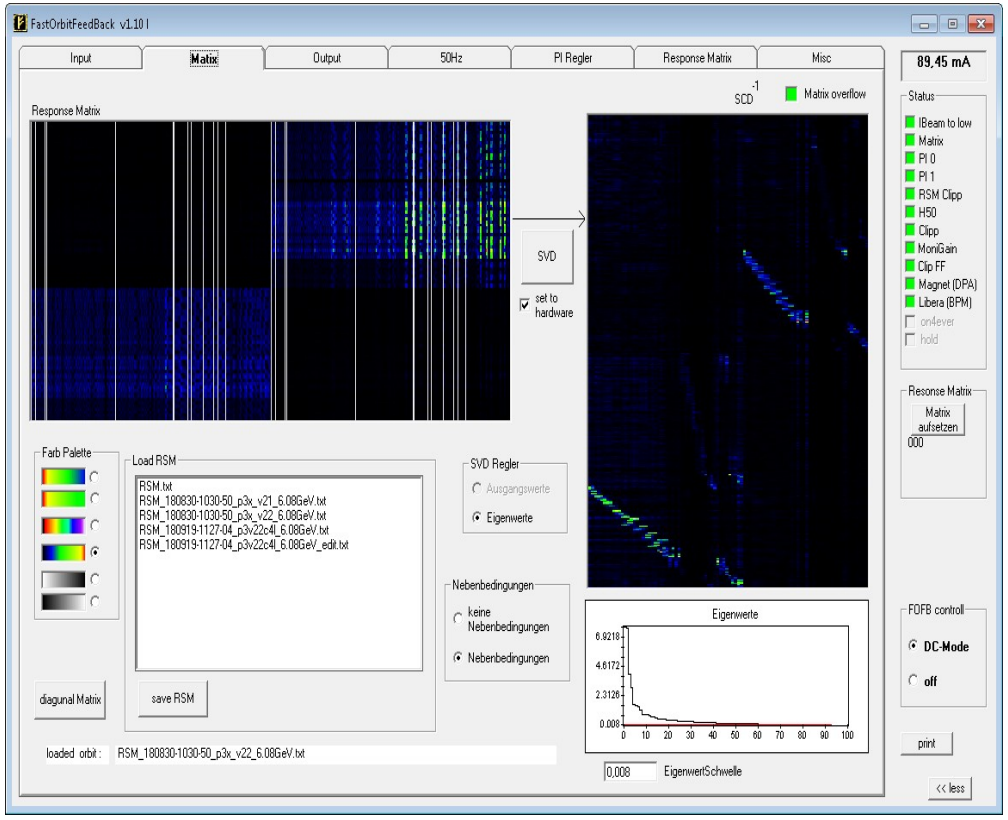
SVD



$$\underset{n\,x\,d}{A} = \underset{n\,x\,r}{U} * \underset{r\,x\,r}{D} * \underset{r\,x\,d}{V^T}$$

- BPM n **(250)**
- corrector j **(100)**
- Singular values r **(90-100)**

- Offline calculation of SVD
- Add Eigenvalue cut manually
- Add constrains for BPMs
- load SVD Matrix to FPGA

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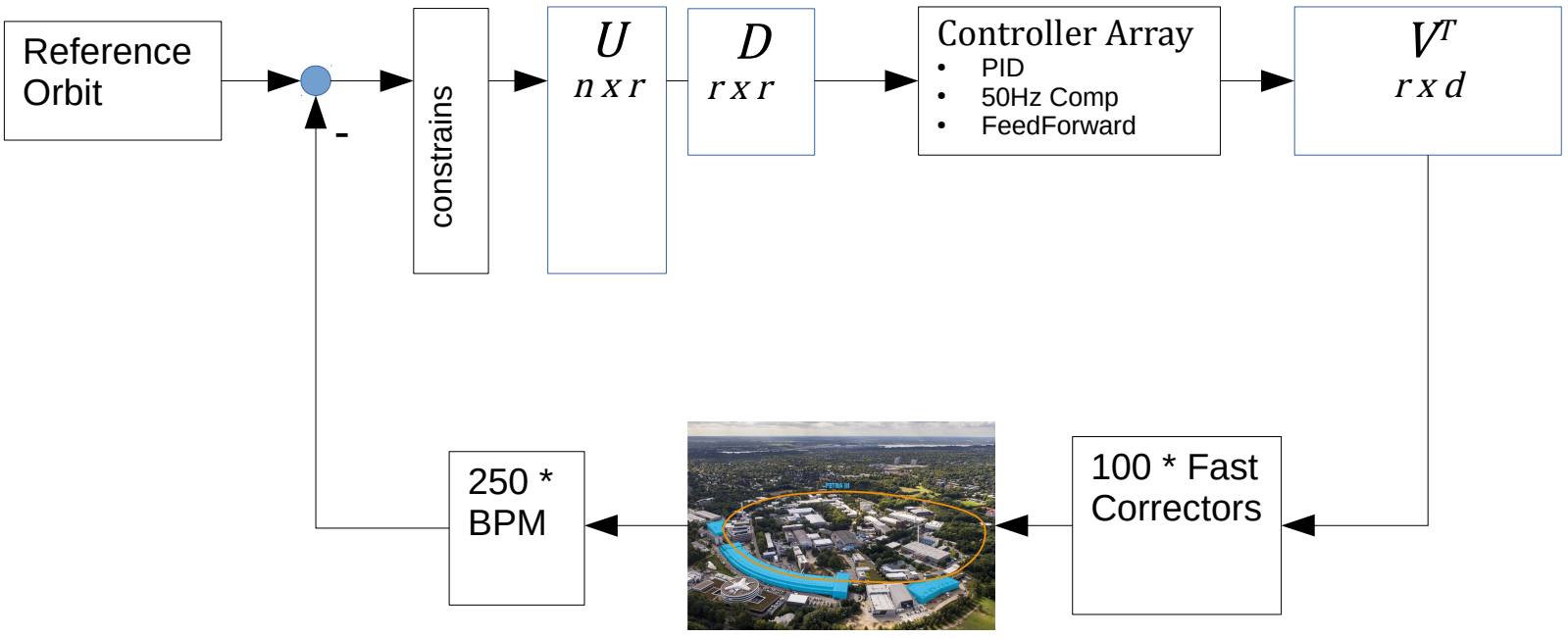
Controller overview



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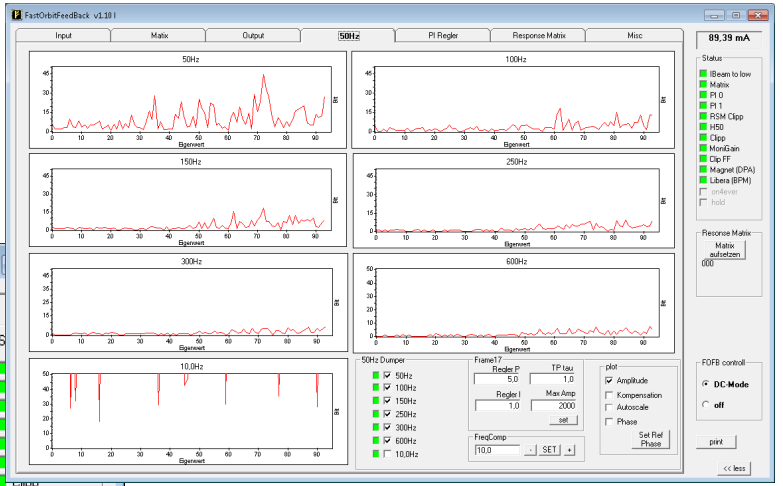
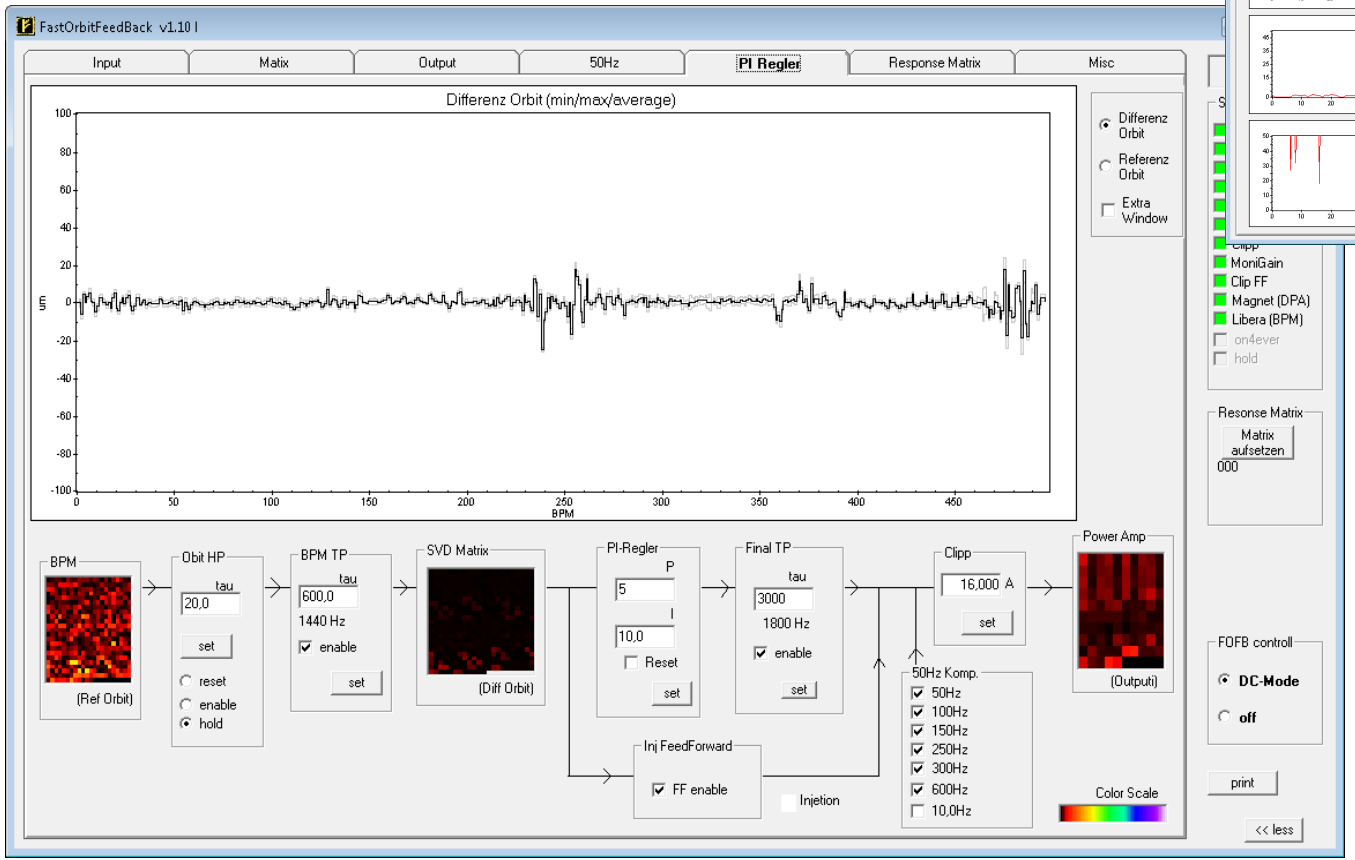
Controller





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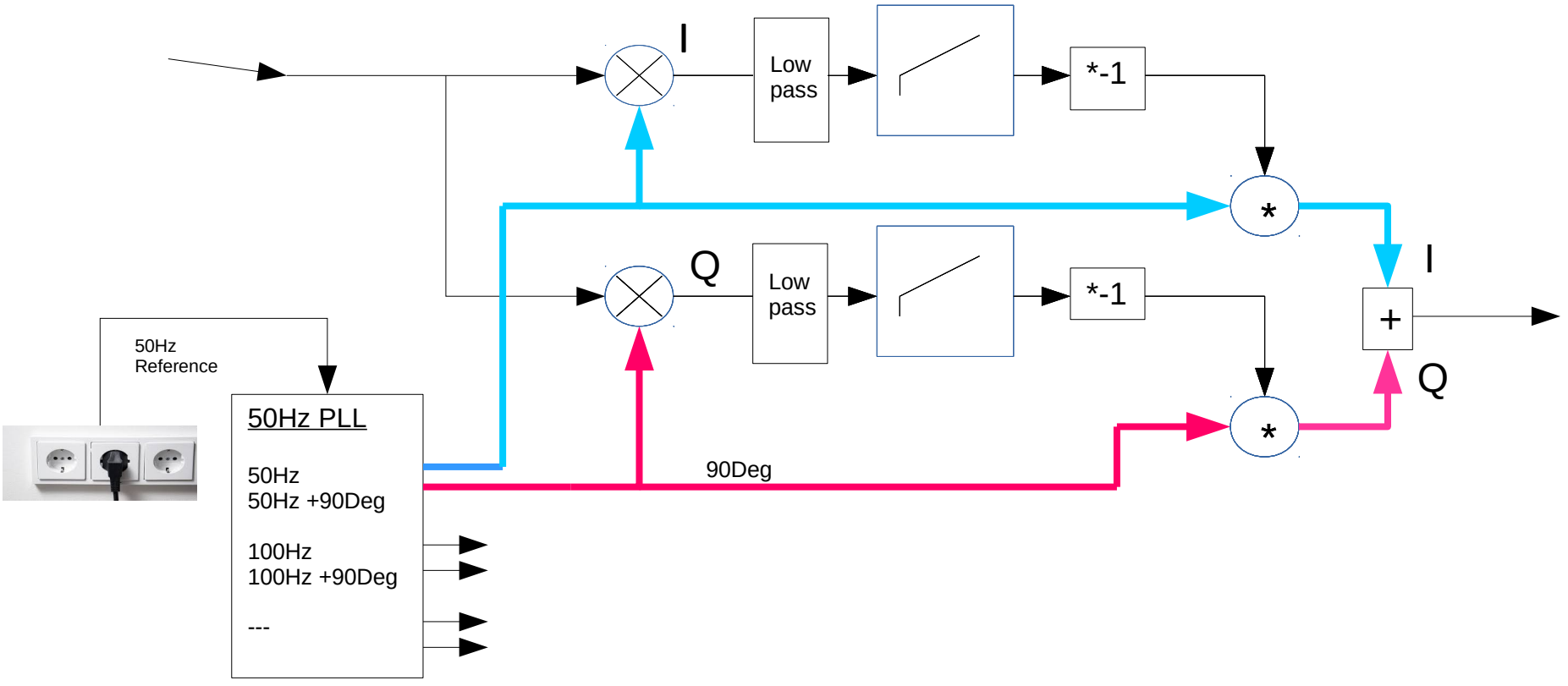
50 Hz Harmonic Compensation



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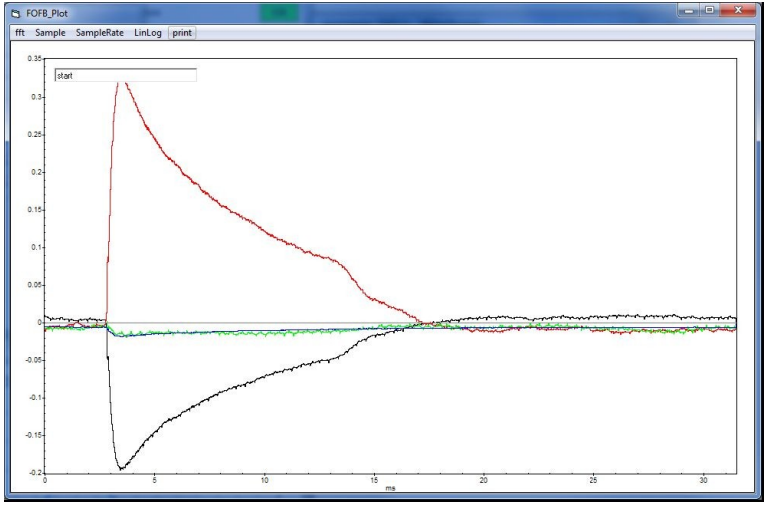
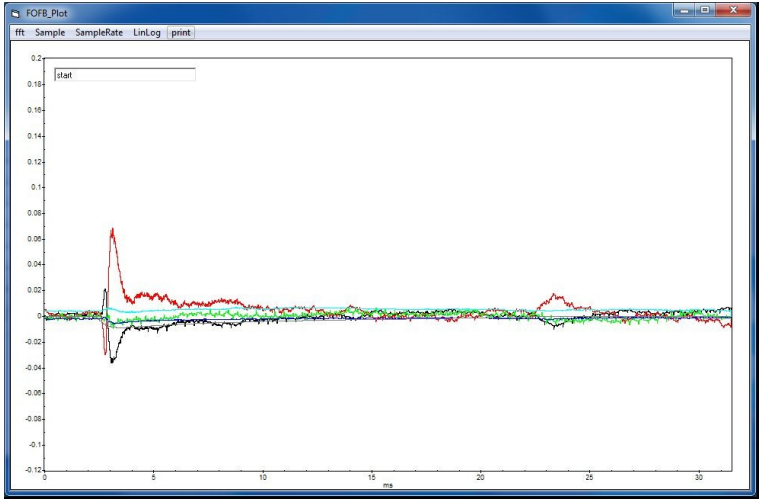
Injection FeedForward



Injection FeedForward off



Injection FeedForward on

- During topup Injection FastOrbitFB
  Is in hold state (15ms).
- Kicker an Septum Bump compensate
  with adaptive FeedForward
- Limitation of 1kHz Magnet / Amplifier Bandwidth

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BPMs and Signal Distribution

Up to 15 Libera BPM connect to a DataCombiner in one Crate

- Custom made TbT Data Output combined to one optical link
- Optical Link to central Data processor
- 26 Crates for 250 BPMs installed

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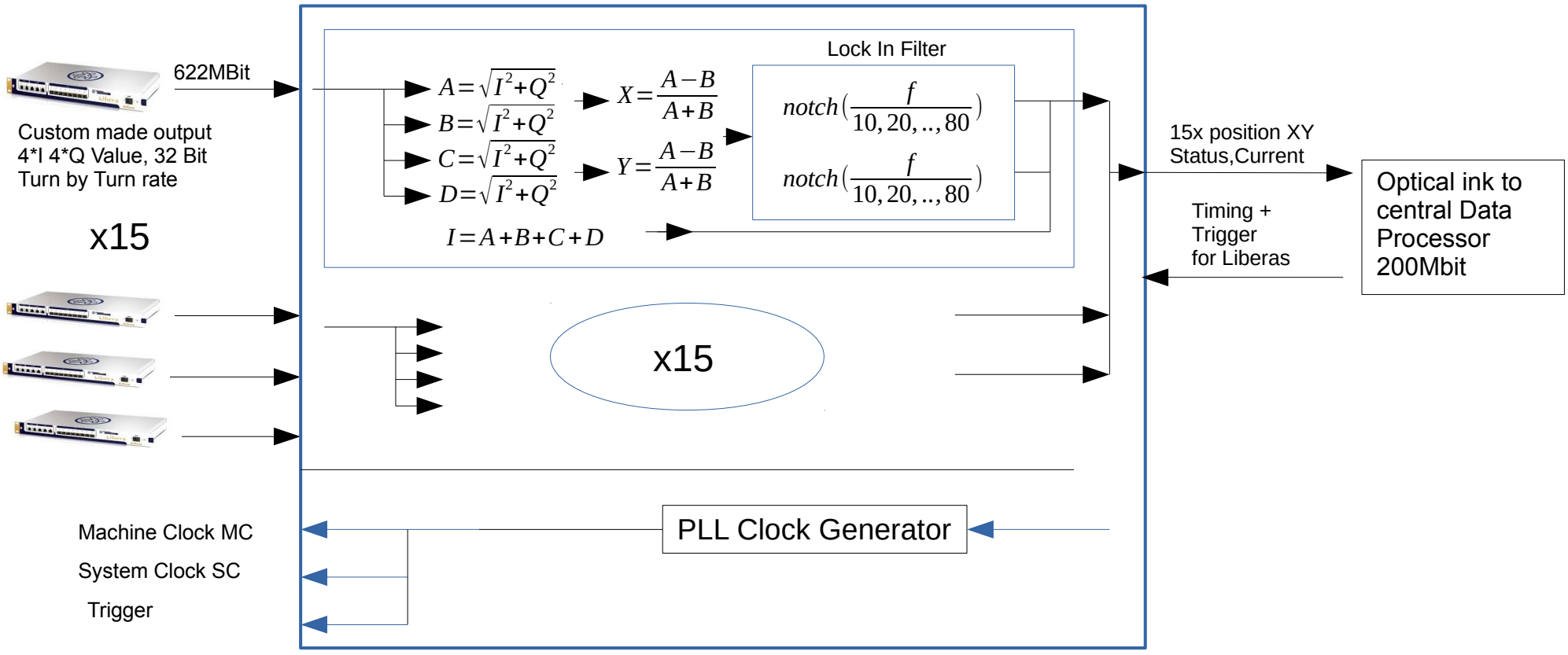
BPM TbT Signal processing and Combing to one link



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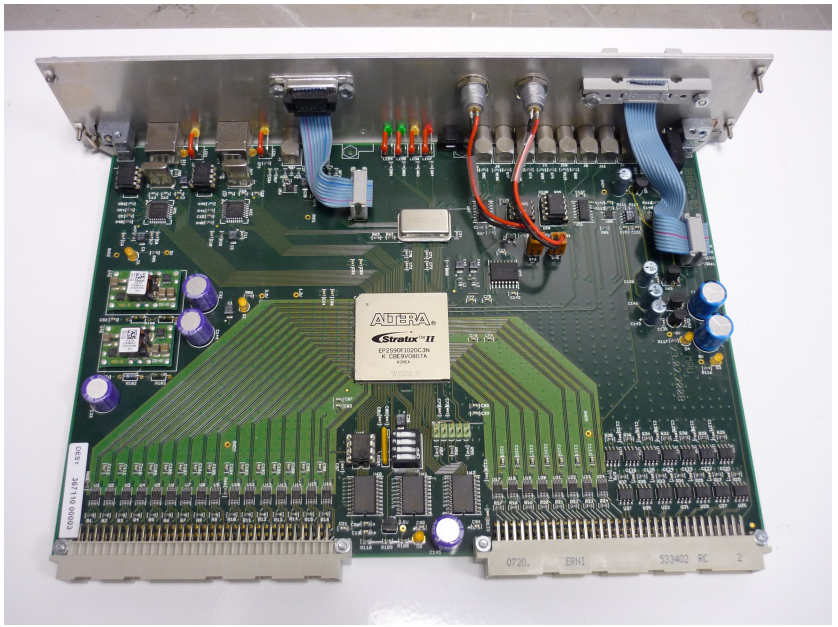
Central Data Processor (MPU)



Central Data Processor

- Altera Stratix3 FPGA
- Windows7 Server
  connect via USB2.0
- USV powered

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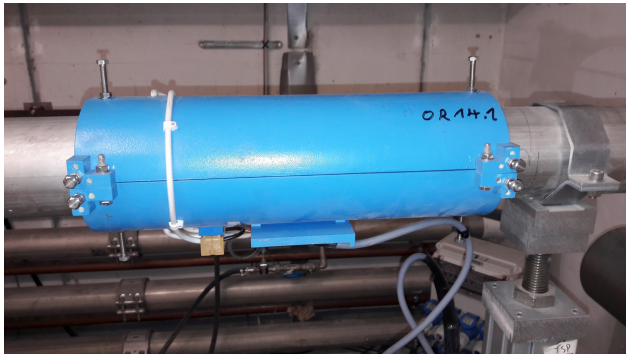
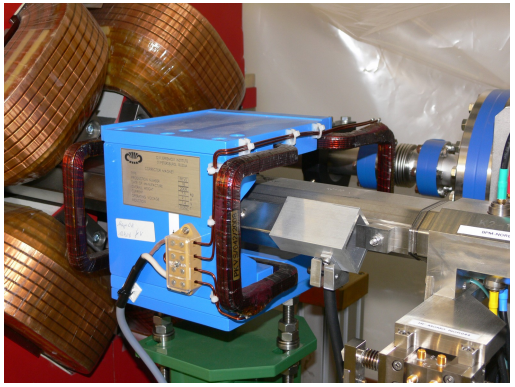
Corrector Magnets





Air Coil

- typ 2x20 Windings
  over stainless steal camber
- typ 200µH inductance
- Max 20A

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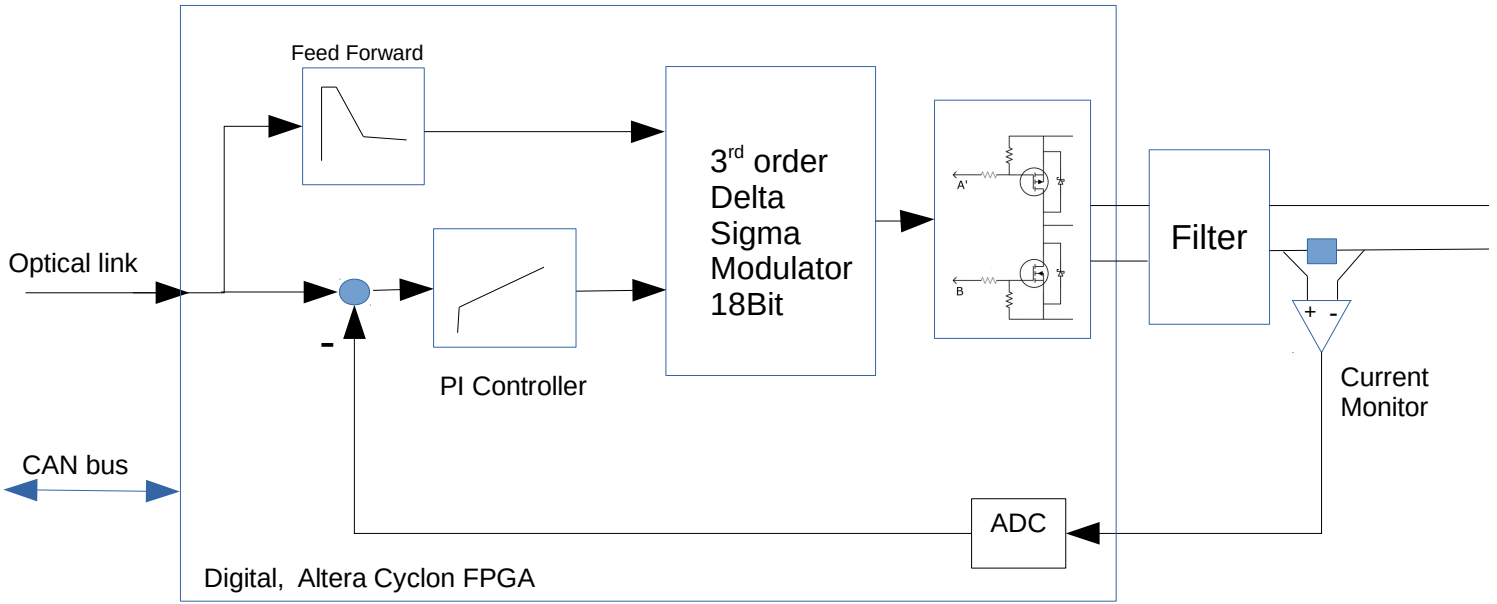
Digital Magnet Powersupply



Full Digital Power Supply

- 18Bit Resolution
- 260Khz Switching frequency synchron to Machine clock
- 48V 18Amp Output
- Digital Input

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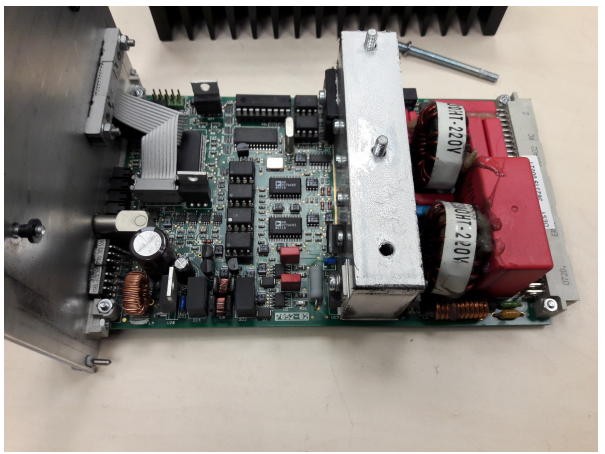
Digital Magnet Power supply



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Delay budget

From Pickup to BPM output	3 Turns	21 µS
Cable BPM Central Processor		10 µS
Processing	10 Turns	76 µS
Cable Processor Amplifrer		10µS
Digital Powersupply	3 Turn	21µS
Magnets 1kHz BW	90 Deg	250µS*

		645µS

* same effect as 250uS delay in the FB loop

- 645µS Delay *4 → 390Hz FB 3dB Frequency
- FB Bandwidth limited with Filters to 150-200Hz for better noise Performance
- higher Frequency are processed with 50Hz Compensation and adaptive injection FeedForward

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FAQs

star architecture ?
- global approach
- easy to implement (regulator in eigenvalue domain)
- all in one FPGA
- additional hardware and optical links

TbT dataprocessing needed ?
- avid aliasing effects
- reduce total delay
- reduce effect of Data package synchronisation
- need for adaptive Feedforward

minimise total delay ?
- lower bandwidth
- better performance for lower frequency (10Hz)

reason for fine correction by Control system every 10sek?
- SVD algorithm corrects an group of BPM not only the position at the undulator

Advance of DC remove of fast correctors ?
- Avoid saturation of powersupplys
- after beamloss FOFB is switch off and all obit corretions of the FOFB are lost.
- quick refill after beam loss is possible without closed Undulator and without orbitkorretion.

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FAQs

special cables for the correctors ?
- cable have length of max 60 meters, crosstalk would be a problem
- use of special coaxial power cables

How to disable an broken BPM during userrun ?
- disable it in the reference orbit so that it has no orbit displacement
- hope the other BPMs around did the job and the FB is stable

How to disable an broken corrector during run ?
- Beam almost lost if an corrector fails
- better repair it
- or measure a new RSM without this corrector

why Window7, PC und USB2.0 based Hardware ?
- tradition of HERA and Petra 2
- good experience

Experience/problems of 9 Years operation ?
- power supply failure
- mechanical problem with power FETs → solved
- hard to detect bad Response matrix and Eigenvalue cut → remove redundant correlators
- detect ill BPMs → Filter in Signal combiner shows switching artefact of Libera
- software bugs, effects update of controll system
- server overload → planed : better use not a usb2.0 conection

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future plans Petra 4 outlock

near future

- update to Windows 10
- new Hardware and better FPGAs
- Linux based servers

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- expect 700 BPM and 250Correctors
- UTCA.4 hardware
- redundant power supply
- new control system (good by TINE ?)
- new BPM System (single bunch, first turn)

Thank you