Ring magnet system —Power supplies—

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21th KEKB Accelerator Review Committee

List of Magnet power supplies

- Newly fabricated or old power supplies for Main Ring

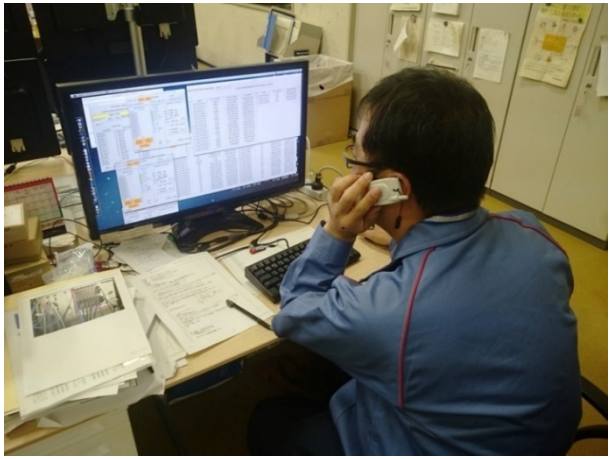
Output power	Newly fabricated PS	Reused PS (#overhauled)	
0.95 MW	2	0	Main dipoles
0.4-1 MW	9	0	Wigglers
0.1-0.5 MW	0	18#	Main quadrupoles
2-105 kW	92	335#	Bend./Quad./Sext.
0.3-2.4 kW	138	1681	Steering magnets/ corrector coils
Total	359	2034	

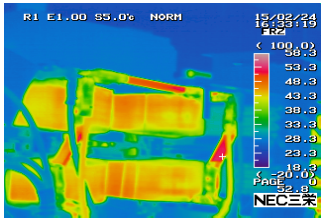
- Newly fabricated or to be fabricated (*) QCS power supplies

2kA, 15V	2+6*	0	QCS Main quads.
<500 A, 20 V	3*	0	QCS Solenoids
±70A, ±10V	45	0	QCS correction coils

Start up: system check and full power load test

- Full-scale start-up tasks such as network test, interlock system test, full power load test, cable connection check to avoid abnormal heating, polarity check, magnet standardization test and so on were completed before Feb.8 beam injection to the MR.



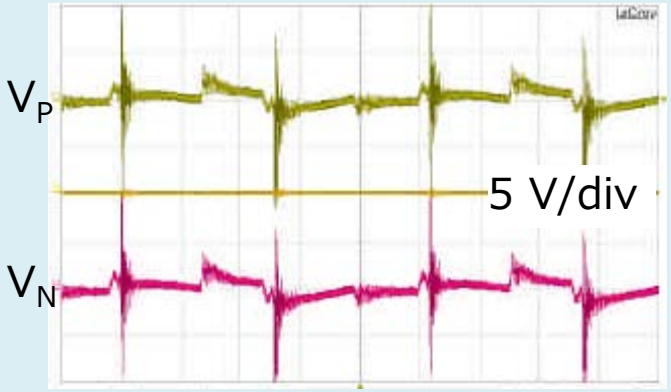


Test example 1/2 —switching noise

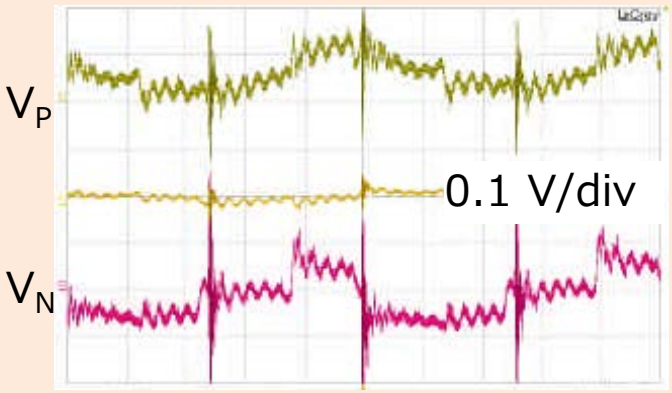
- Old medium-class power supplies were overhauled. Replacement of chemical capacitors, AC-DC converters, circuit breakers and IGBTs was performed.
- In order to reduce switching noise, ceramic capacitors are added at the output terminal. Switching noise is reduced to 1/20.

Ceramic capacitors

W/O capacitor

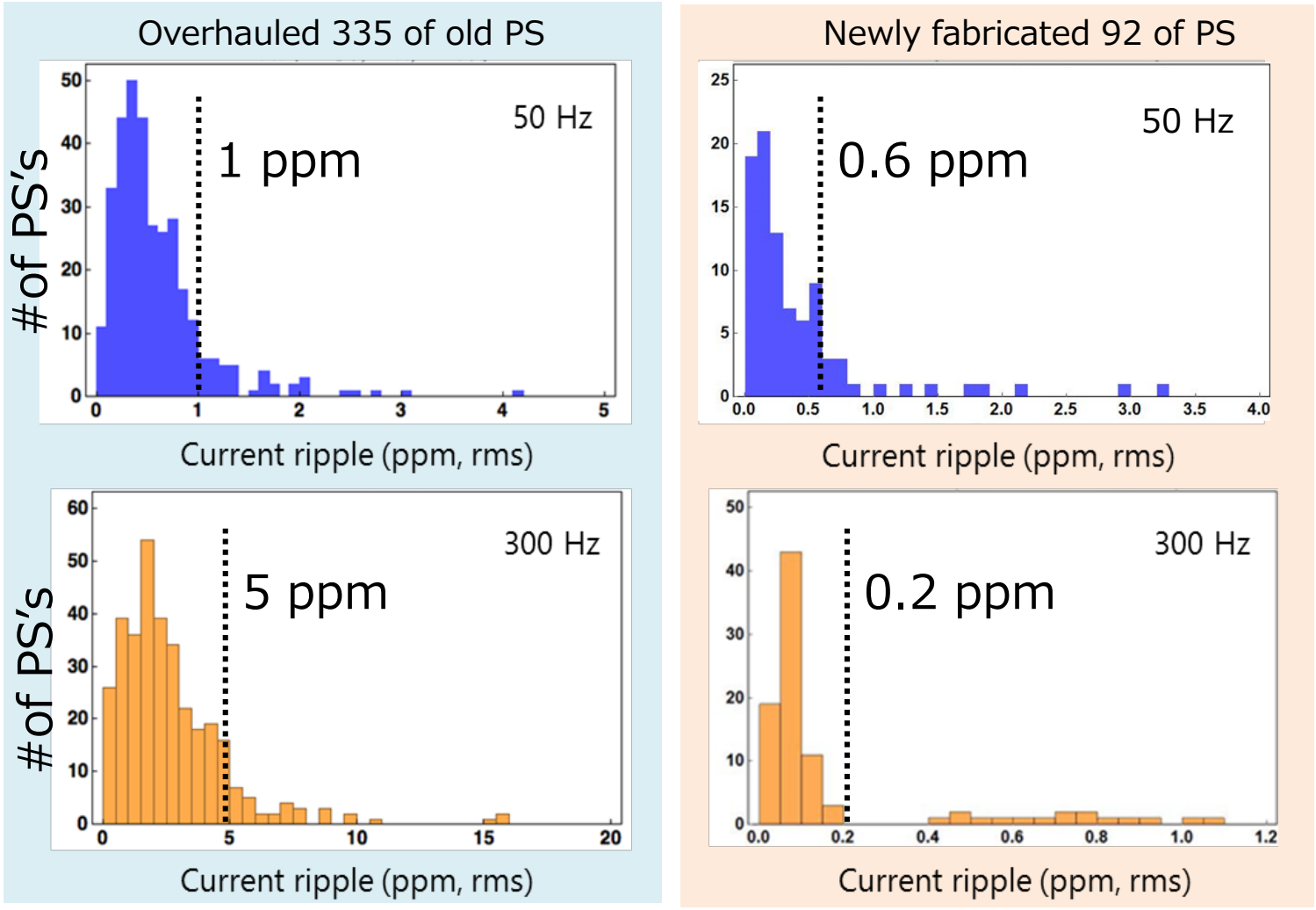


W/ 1 µF capacitor



Test example 2/2 —ripples

- Newly fabricated medium class power supplies were designed to be lower current ripples. Histograms of current ripples are compared with the results of old (overhauled) power supply.



First Commissioning in Phase 1

- Magnet power supply system works well except for following failures occurred up to now.

Failures in Large class PS	# of event	comment
AC input over current	3	AC distortion (RF system crowbar work)
AC input over current	6	AC distortion (VAR system[#] work in line facility)
AC input Stop, CB Fault	2	Earthquake

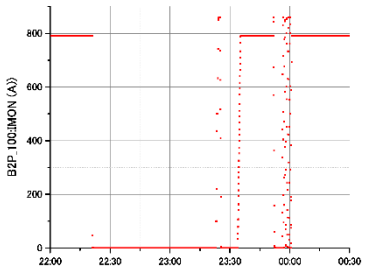
Failures in Medium class PS	# of event	comment
Thermostat	4	Thermal control equipment was repaired.
Over current (IGBT modules)	2	Modules were replaced. Repaired.
Cable GND fault	1	The fault cable was disconnected.
Tracking error	1	Fault in the polarity inversion circuit. Repaired.

Failures in small class PS	# of event	comment
DC-DC board failure Output over voltage etc.	17	Power supplies themselves were replaced.

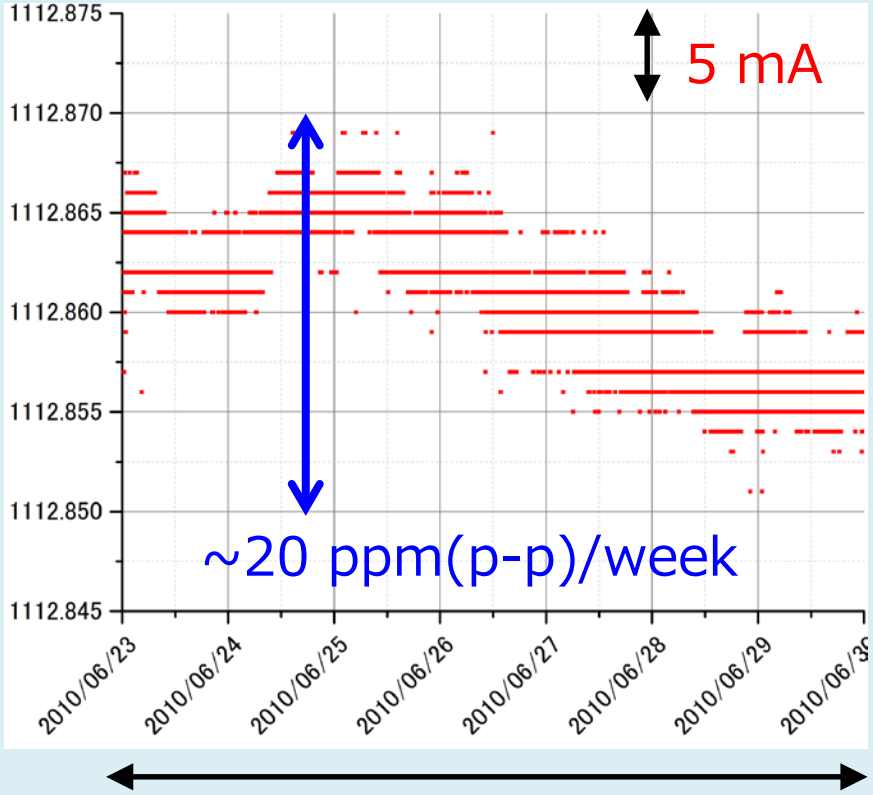
[#]) Compensation system for a reactive power in the AC power distribution facility. AC line phase-advancing capacitor equipment was automatically controlled. However, unexpected operation occurred in early stage of Phase 1. Since capacitors has been manually operated, failures doesn't occur.

First Commissioning in Phase 1-cont.

- How the system works well? Current stability of Main dipole magnet power supply is compared with one of KEKB.

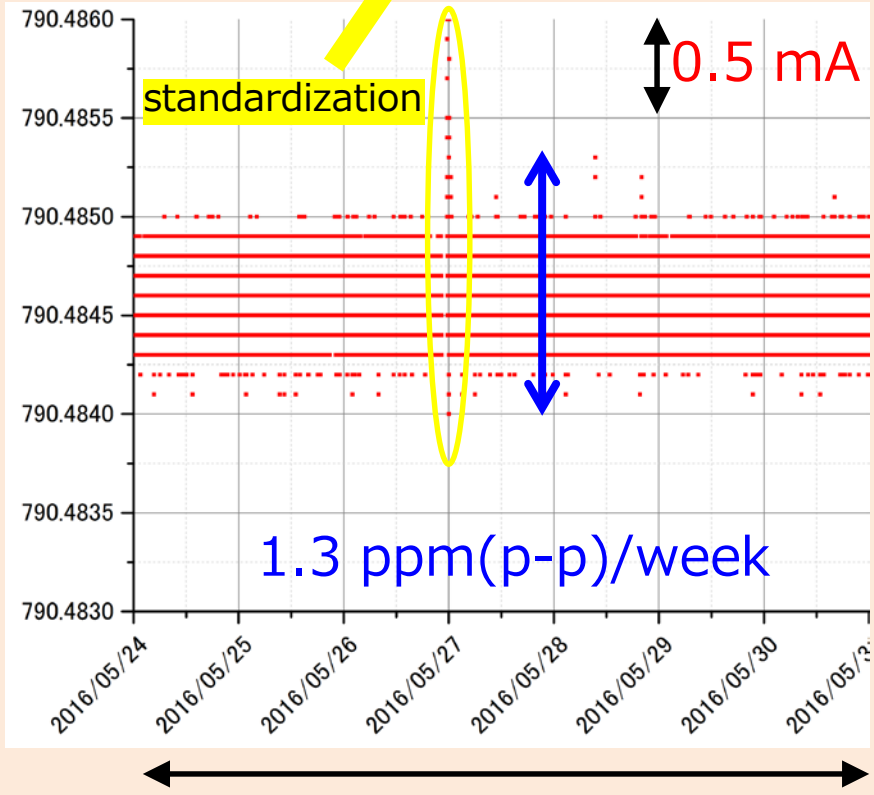


KEKB (1250 A, 770 V)



1 week

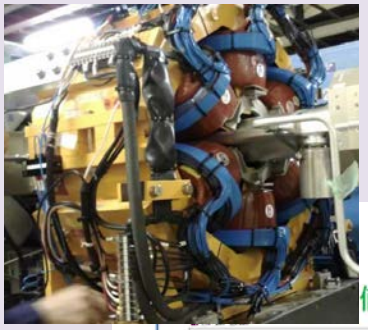
SuperKEKB (860 A, 1100 V)



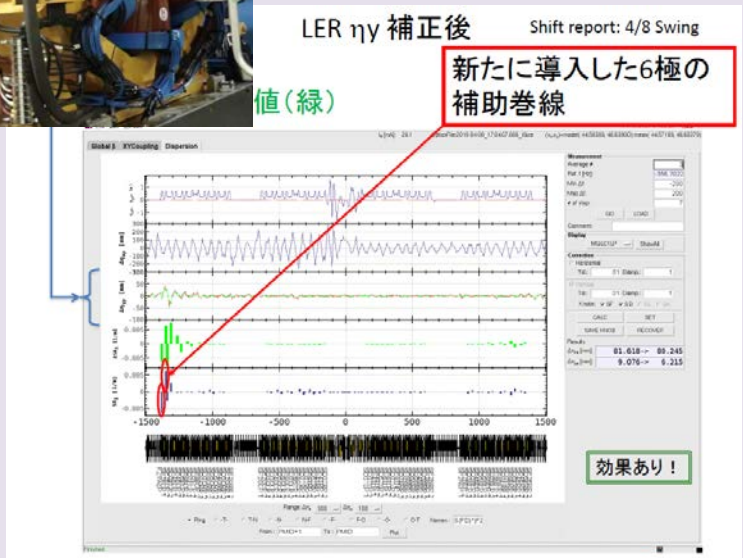
1 week

Two prompt contributions to Phase 1 commissioning

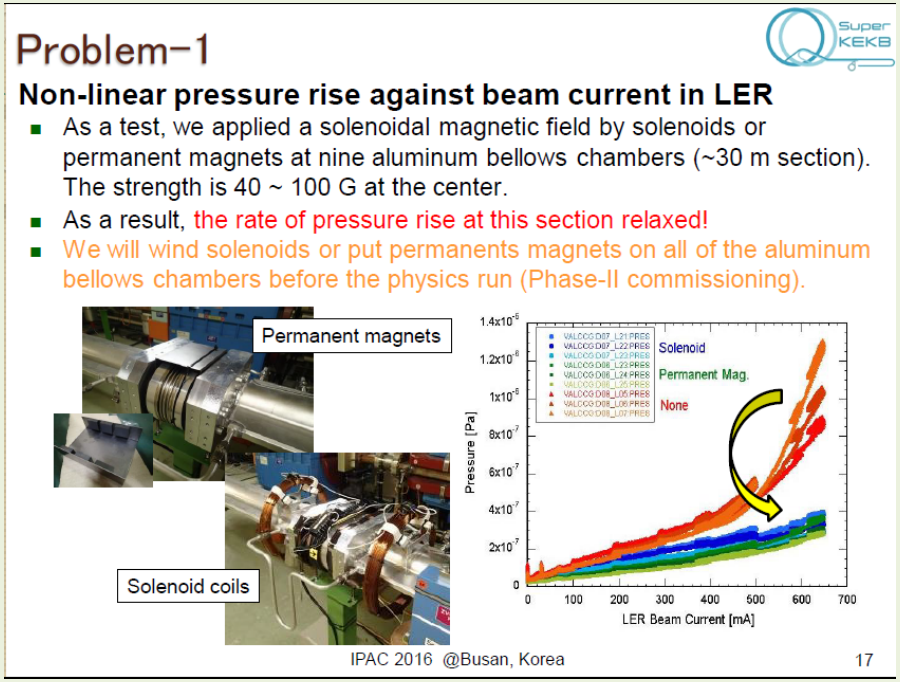
1. As Funakoshi-san and Sugimoto-san reported: in order to compensate a leak field of a lambertson magnet, additional coils of SX and skew Q magnet were wound/ applied for this purpose.
2. As Funakoshi-san and Suetsugu-san reported: Solenoid coils were tentatively wound over LER vacuum chamber by vac. group, and small class power supplies also support to drive it.



Shift report
(April. 8)



Y. Suetsugu (IPAC16)



Preparations for Phase 2: IP collision feedback system

- SLAC Dithering coils for IP horizontal collision feedback system were installed.
- Power supplies were also installed, and cabling for the coils were completed. Magnetic polarity check was done.

Coil installation was performed with U. Wienands, SLAC.

Preparations for Phase 2: QCS power supply system

- Many works are in progress to be ready for the QCS operation, which starts in Nov. 2016 for L-side or Feb. 2017 for R-side.
  - Power supplies

    Prototype power supply for both of main and corrector coils was developed. Mass production and fabrication of anti-solenoid PS's has been carried out.
  - Cabling

    Cable laying work from PS building to IR was completed. Work for the connection of the cables to PS's or QCS is planed in this summer.
  - Facility for power supply

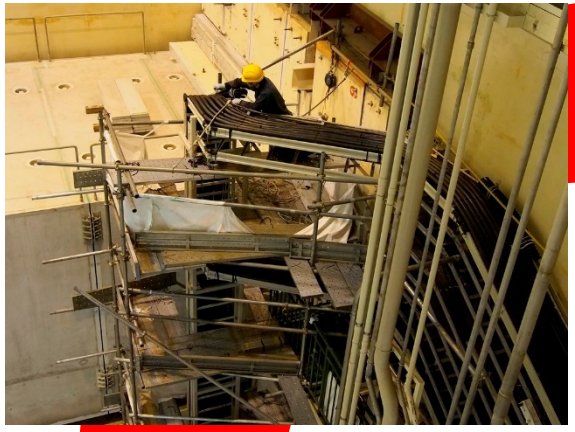
    AC power distribution board and water cooling system has been designed. These will be ready by the end of this Oct.
  - Interlock/monitor system

    PLC system has been fabricated, and will be derived by the end of this July.

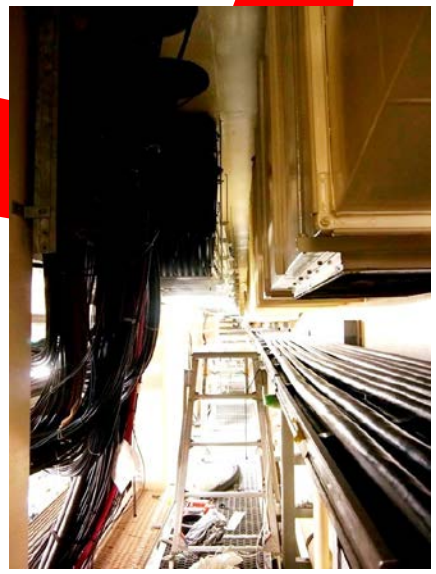
QCS cable laying work

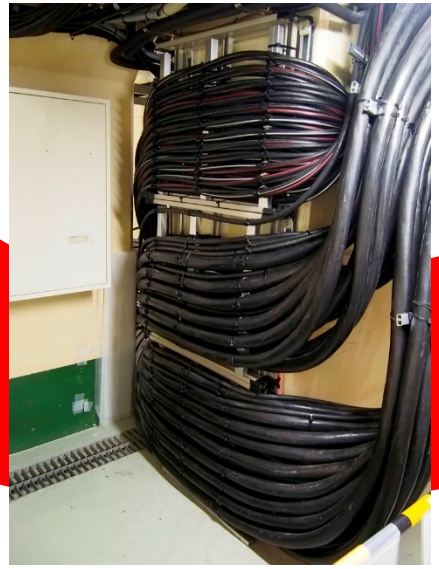
Cables were laid from PS building…

and cable rack to the interaction region…



through vertical shafts…





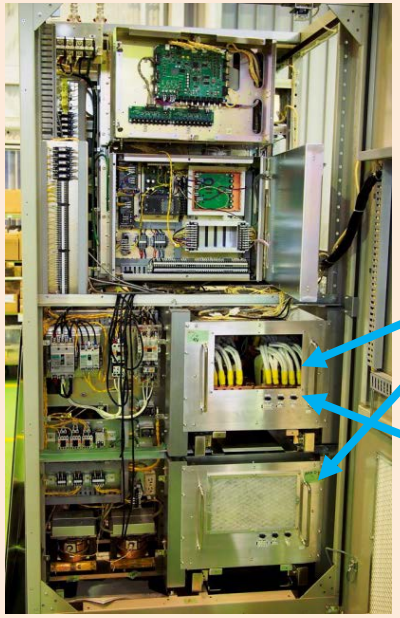
Cables to be connected with QCS magnets

A full-scale prototype of QCS power supply

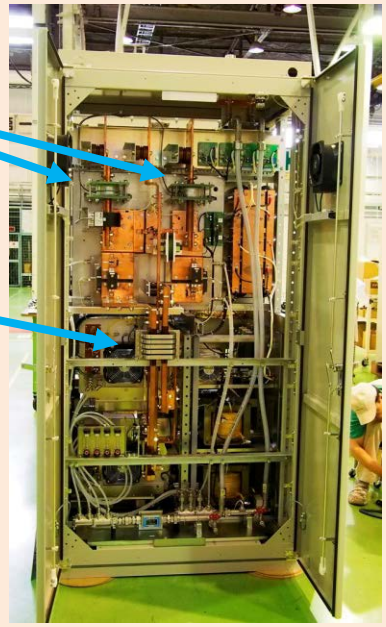
Aiming spec.

Rated output	DC 2 kA, 10 V
Current setting resolution	< 0.1 ppm
Current stability	< 2 ppm/8 hrs.
Current ripple (< 10kHz)	< 1 ppm (rms)
Current noise (> 10kHz)	< 1 ppm (0-peak)

(1) For low ripple and noise: Symmetric structure

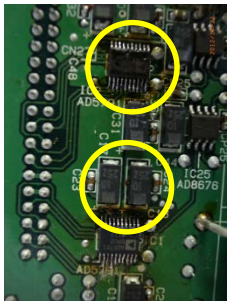


- ✓ DCCTs on both output terminals.
- ✓ Symmetric circuit structure with respect to ground.
- ✓ Shielded high-frequency transformer

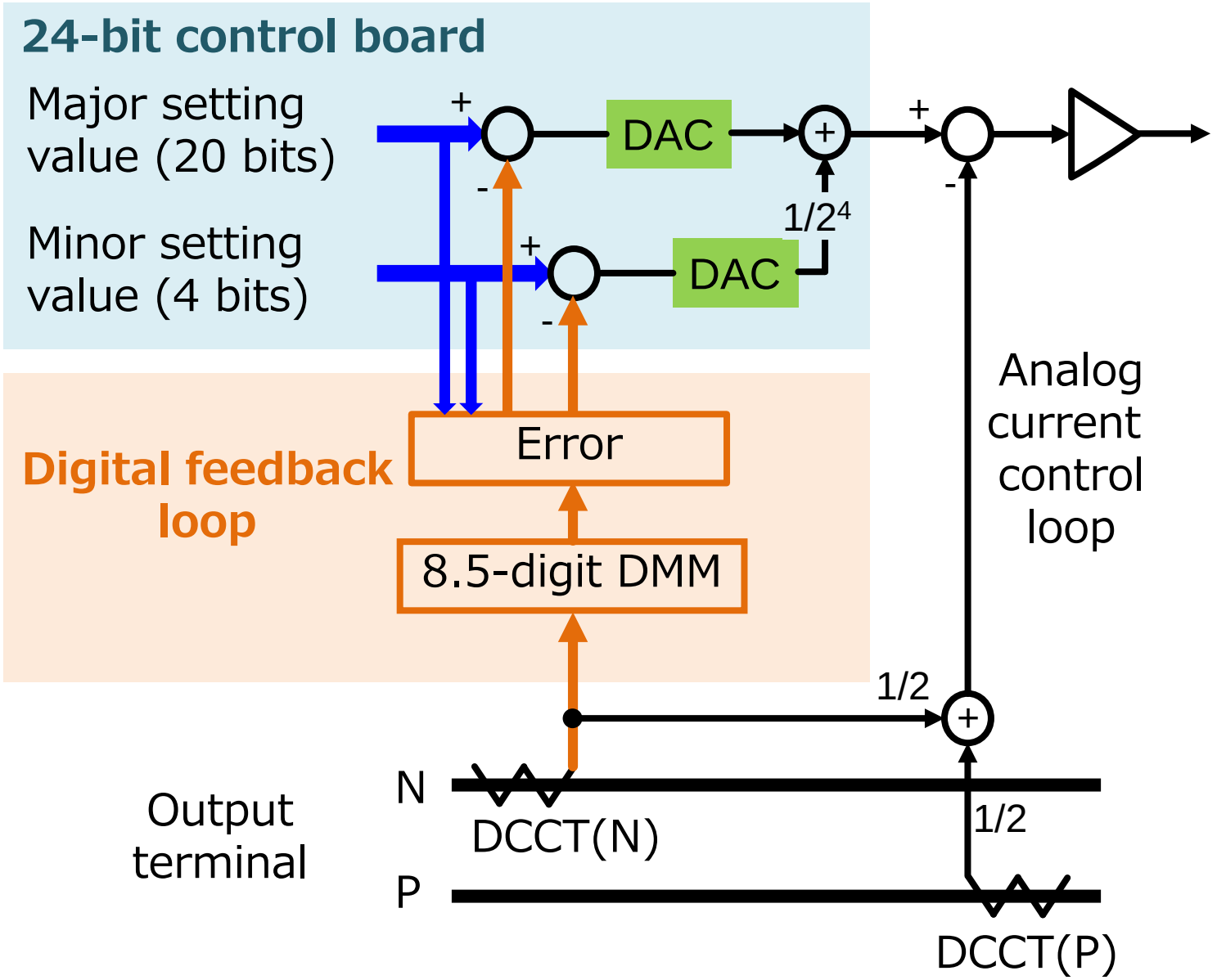


Digital feedback control for QCS power supply

(2) For high stability: Digital feedback with 24-bit control board



Two 20bit DACs (AD5791)



Temp. coefficients of the system

- 0.125 ppm/K (AD5791 DAC with Buffer amps.)
- 0.3 ppm/K (Keithley 2002)
- 1.5 ppm/K (TOPACC) (or 0.5 ppm/K (TOPACC optional))

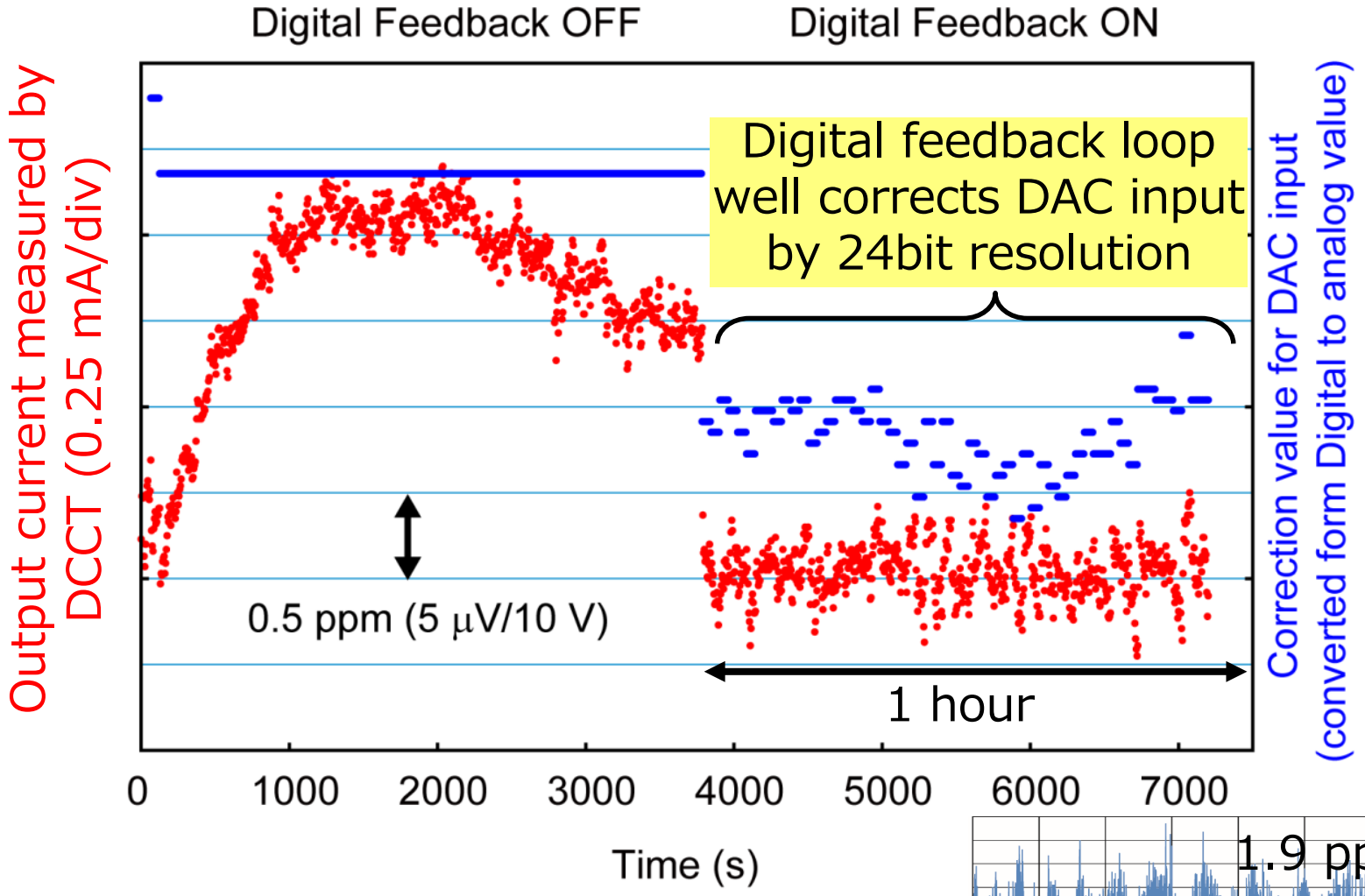
Total: 1.925 ppm/K

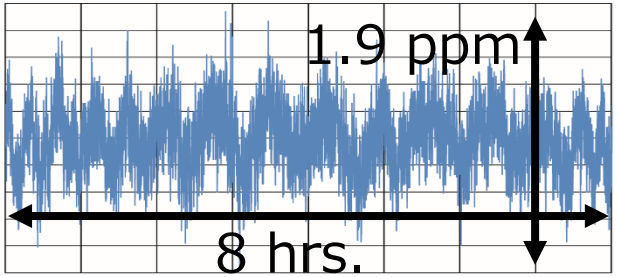
Constant climate chamber keeps temp. within 0.2 deg.

$\rightarrow$ 0.385 ppm for 0.2 deg

Test result of the digital feedback system

- Performed by using a medium-class power supply (15 V, 500 A).





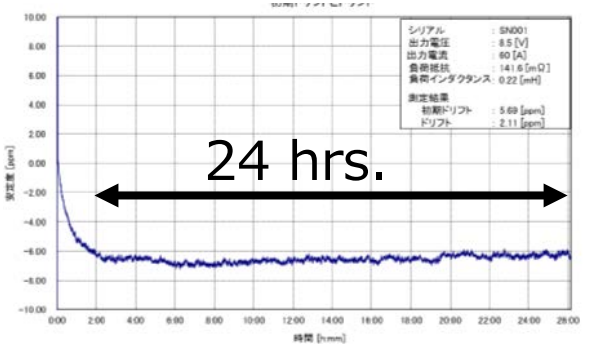
Test result of QCS prototype: 1.9 ppm (p-p)/8 hrs.
Ripple, noise, quench protection test, etc :OK.
→Mass production has been carried out.

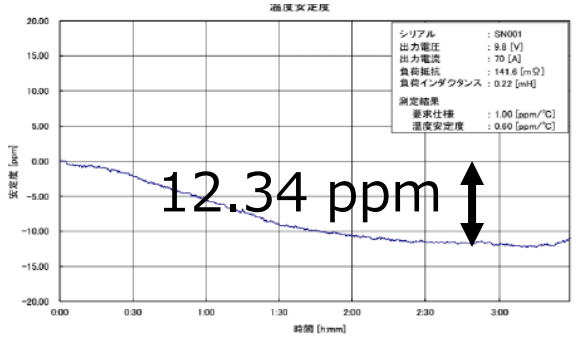
QCS corrector power supply

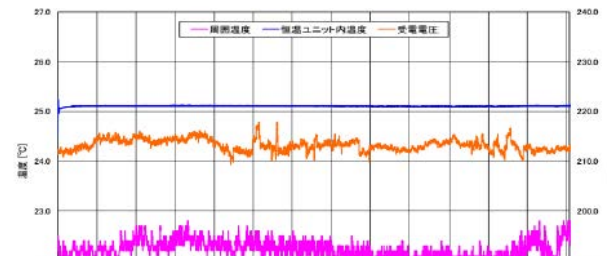
45 of QCS corrector power supplies was fabricated.

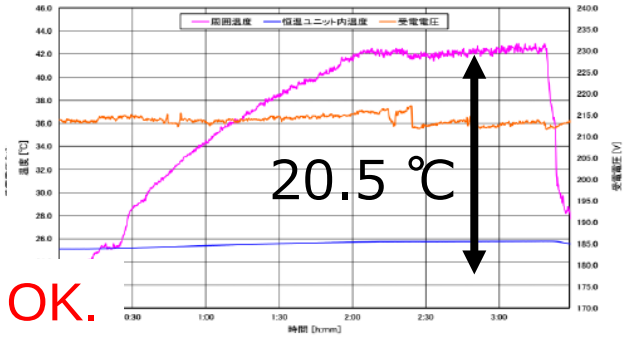
Rated output	DC ± 70 A, 10 V
Current setting resolution	< 1 ppm
Current stability	< 5 ppm/8 hrs.
Current ripple (< 10kHz)	< 5 ppm (rms)
Current noise (> 10kHz)	< 5 ppm (0-peak)

Test results: Stability 2.1 ppm/24 hrs. with temp. coeff. of 0.6 ppm/℃









Ripple, noise, quench protection test and so on: also OK.

Summary

- Magnet power supply system was integrated and finished before Phase 1. Where the full-scale start-up tasks were completed.
- In the full-scale load test, both the old and newly fabricated medium-class power supplies showed low ripple and low noise characteristic, successfully.
- Magnet power supply system has been worked well during Phase 1 commissioning except for several minor failures. The current stability of main dipole power supply should be remarkably mentioned.
- Preparations for Phase 2 have been in progress. Dithering coils for the IP collision feedback system and power supplies have been already installed.
- For the QCS system, many works are in progress to be ready for the QCS operation, which starts in Nov. 2016 for L-side or Feb. 2017 for R-side.