Magnet Power Supply System

T. Kawamoto
T. Sueno
N. Tokuda
T. Oki

Contents

- Existing KEKB power supplies.
- New power supplies to be developed for SuperKEKB.
- R&D and the preliminary test results.

Existing KEKB Power supplies

We have ~ 2300 power supplies:

Class	# of power supplies	Typical load
Small-class (< 10 A, 0.5 kW)	1885	Steering magnet etc
Medium-class (< 500 A, 100 kW)	368	Local Quads
Large-class (< 500 A, 500 kW)	14	Quad families
Megawatt-class (< 1250 A, 1 MW)	6	Bending magnets
To be reused after appropriate maintenance and overhaul : in progress.		
To be reused. Current setting resolution will be improved by 20-bit DAC.		
Rubbished and replaced by newly developed PSs: in progress.		

Typical spec.

Stability	< 20 ppm / day
Ripple	< 10 ppm
Setting resolution	< ± 50 ppm (16-bit DAC)

First new megawatt-class power supply

Other 9 power supplies for bending and wigglers
will be delivered by end of March.

New Power supplies to be developed for SuperKEKB

*:developed in FY2011; †: in FY2012; ():spec./# has not been fixed.

Power	# of power supplies	Typical load
0.95 MW	2*	LER / HER Bends.
0.4~1 MW	8* / 1†	LER / HER Wiggs.
< 100 kW	(~ 50)	Local Q
~ 10 kW (1000 A)	(~ 10)	QCS main
~ 0.5 kW (± 50 A)	(~ 50)	QCS correction
< 70 kW	23*	Damping Ring (Q, B …)
< 630 kW	2†	Damping Ring (Bends.)
< 36 kW	(Many)	Damping Ring (Others)

Target spec. of power supply for Bends and Wiggs.

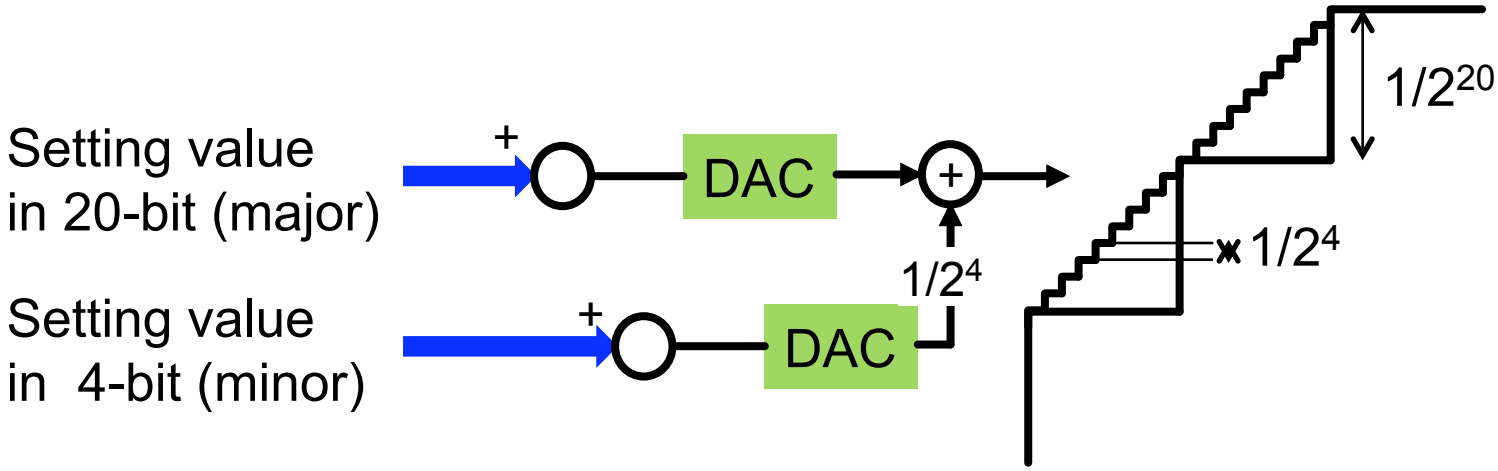
Stability	< 2 ppm / day
Ripple	< 1 ppm
Setting resolution	< ± 0.1 ppm (~23-bit)

R&D 1: higher current-setting resolution

For more precise setting of the current,
increasing the DAC bits from present 16 to 20 or more is necessary.

Step 1. Try new commercial use 20-bit DAC.
(AD5791: released in 2010/March/11th by Analog Devices)

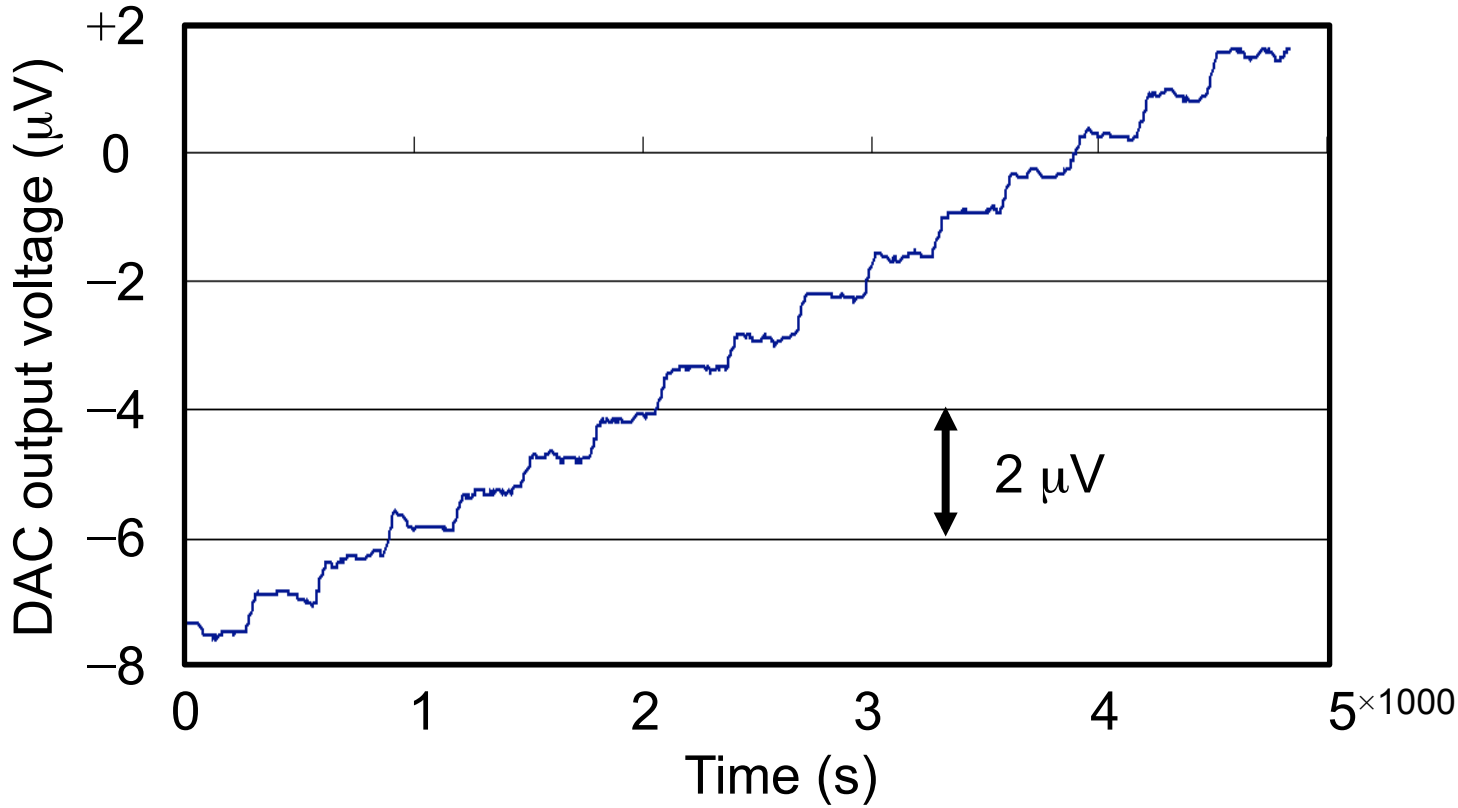
Step 2. Two 20-bit DAC's are combined for 24-bit resolution.



Step 3. For 24-bit resolution, another scheme has been tried:
summing the output of sixteen (= 2^4) 20-bit DAC's.

Preliminary test result: two 20-bit DAC's 24-bit system

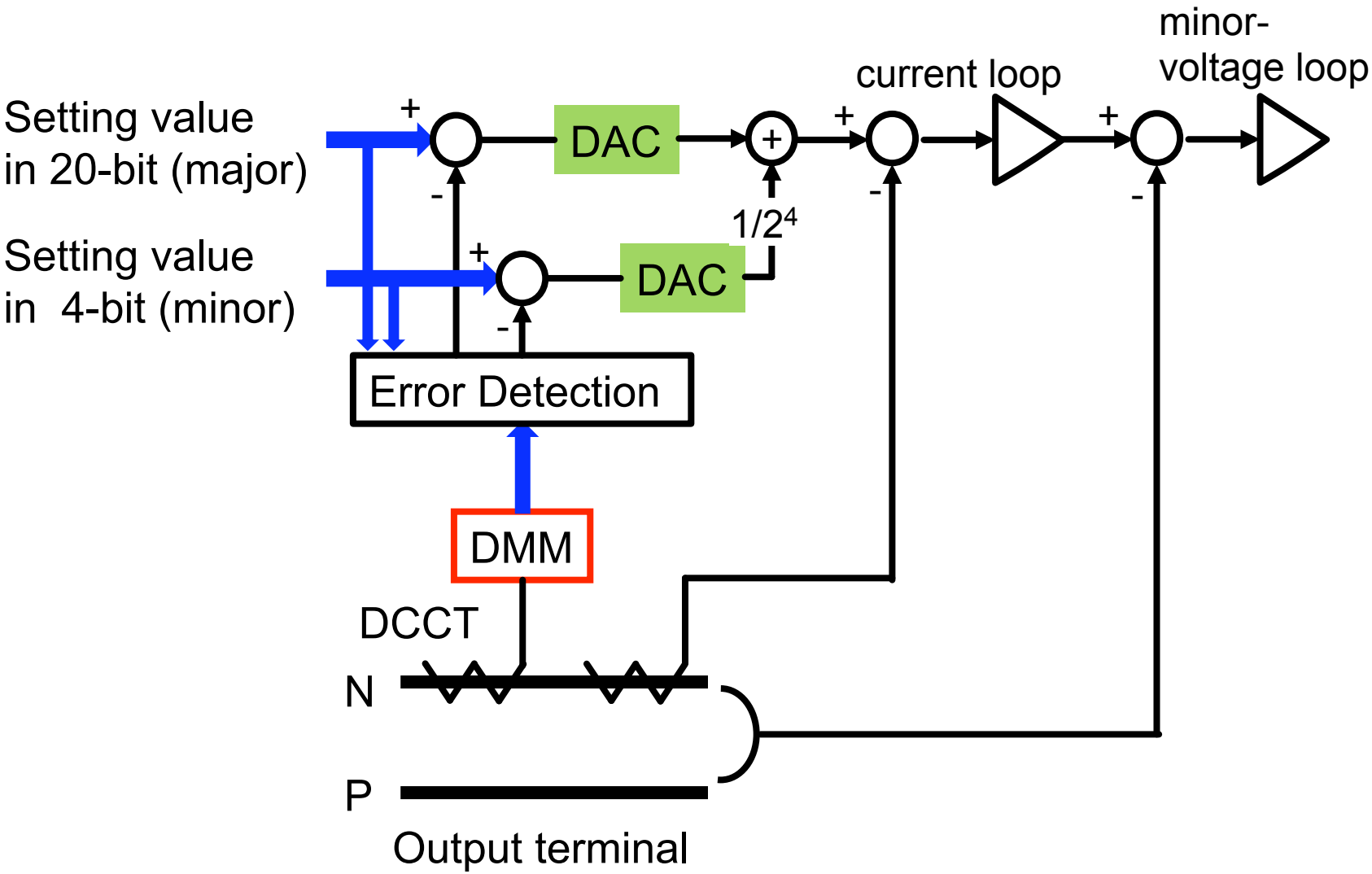
Increasing DAC input digital value by 1 least significant bit (LSB),
DAC output voltage is measured by DMM KEITHLEY 2002.
(range: 2 V, integrate time in Power Line Cycles (PLC): 50, 10 moving digital filter)



1 LSB (0.6 μV) response can be seen.

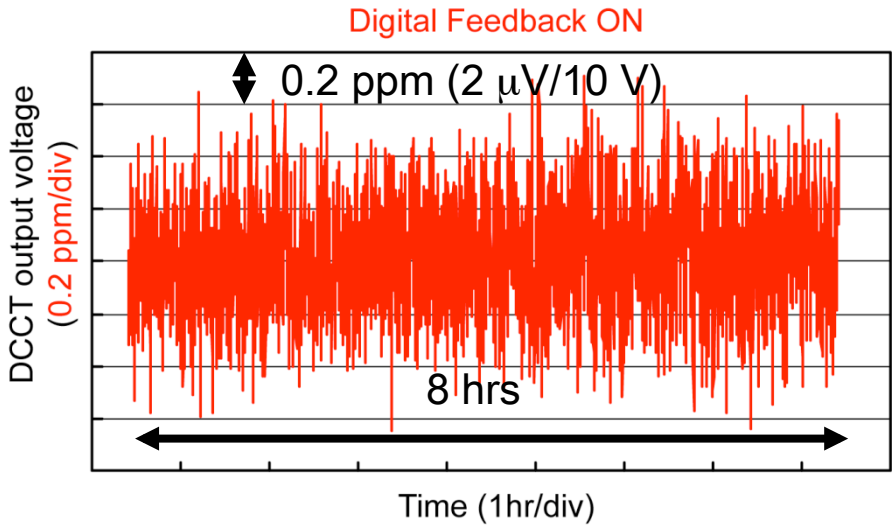
R&D 2: current-stability improvement

Digital feed back control for long-term stability improvement.



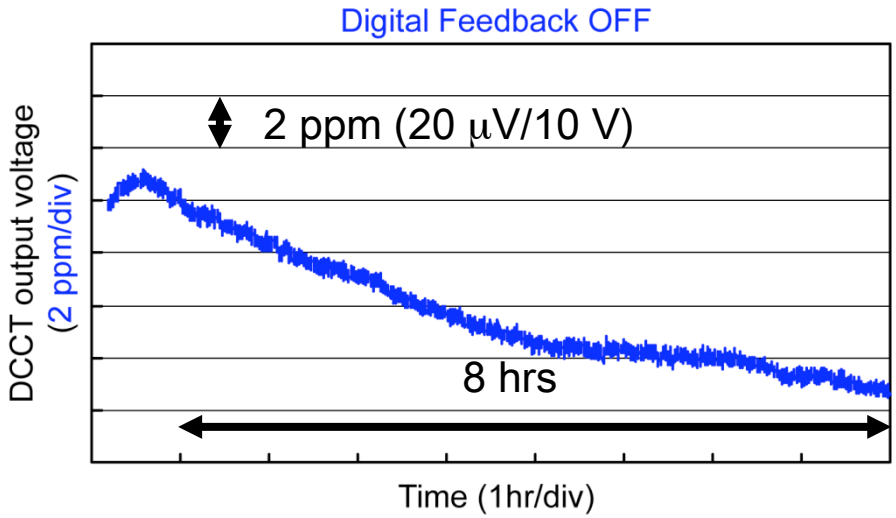
Preliminary test result: digital feedback system

Long-term stability test was performed by using
a medium-class power supply (15 V, 500 A).



measured by DMM (20 V range, 10 PLC, 10 moving Filt)

1.4 ppm / 8 hrs
(peak-to-peak fluctuation included)



7.5 ppm / 8 hrs

Summary

- Small/medium-class power supplies:
  Overhaul is in progress.

- Large-class power supplies for the Quad families:
  Improvement is planned for more precise setting resolution,
  increasing the DAC bits from present 16 (LER)/18 (HER) to 20.
  And overhaul is planned.

- Megawatt-class power supplies:
  Old PSs were rubbished,
  and have been replaced by newly developed PSs: in progress.

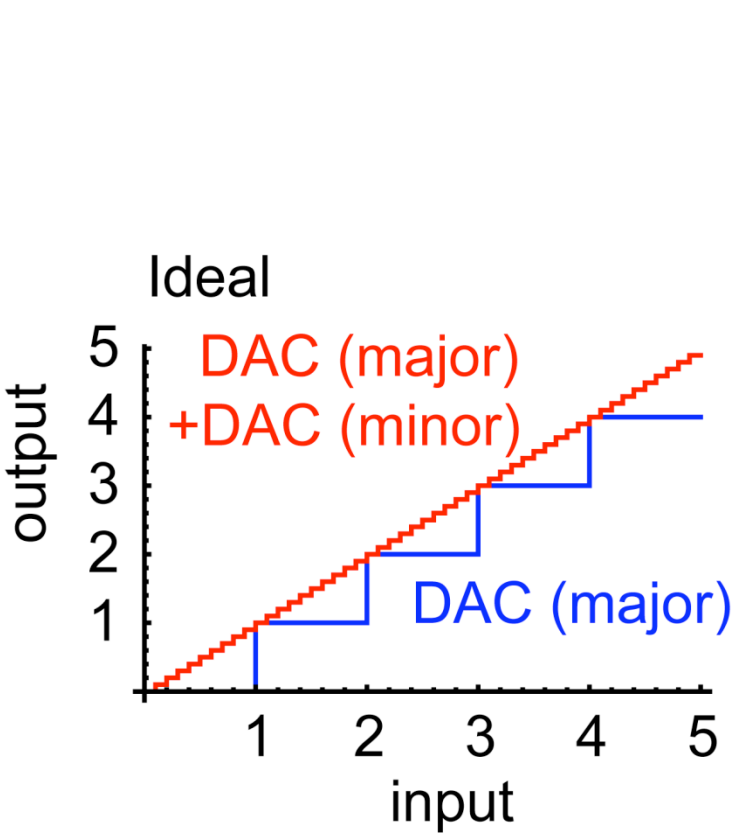
- New 10 megawatt-class power supplies for the main ring and
  23 medium-class power supplies for the damping ring
  are to be delivered by end of March 2011.

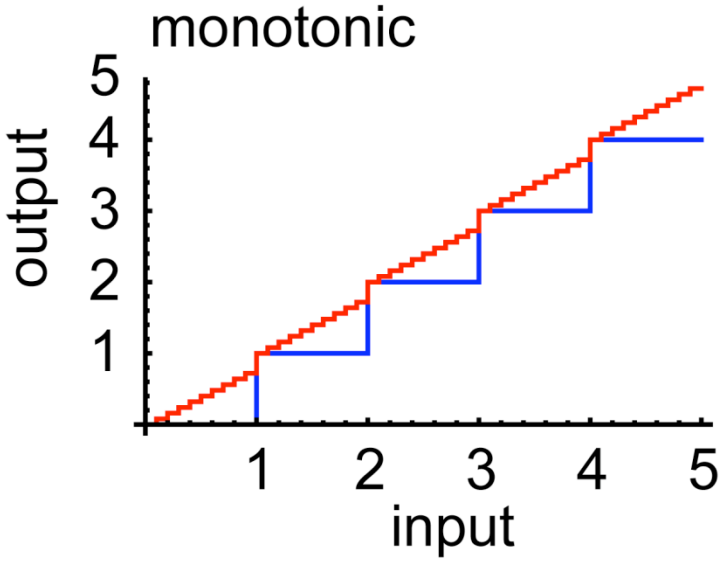
- R&D has been performed, and the preliminary results are satisfactory.
  24-bit setting resolution and digital feedback system
  have been applied to the new 10 megawatt-class power supplies.

Back-up slide

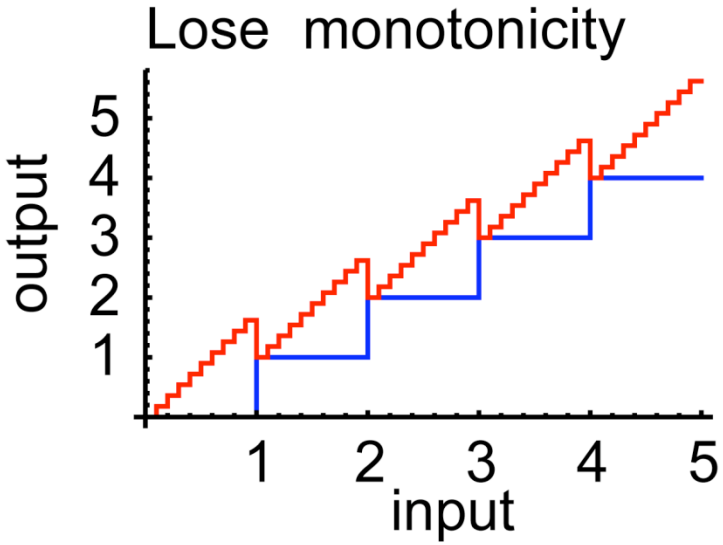
Why sixteen DAC's 24-bit system?

Care must be taken to the monotonicity of two DAC’s 24-bit system





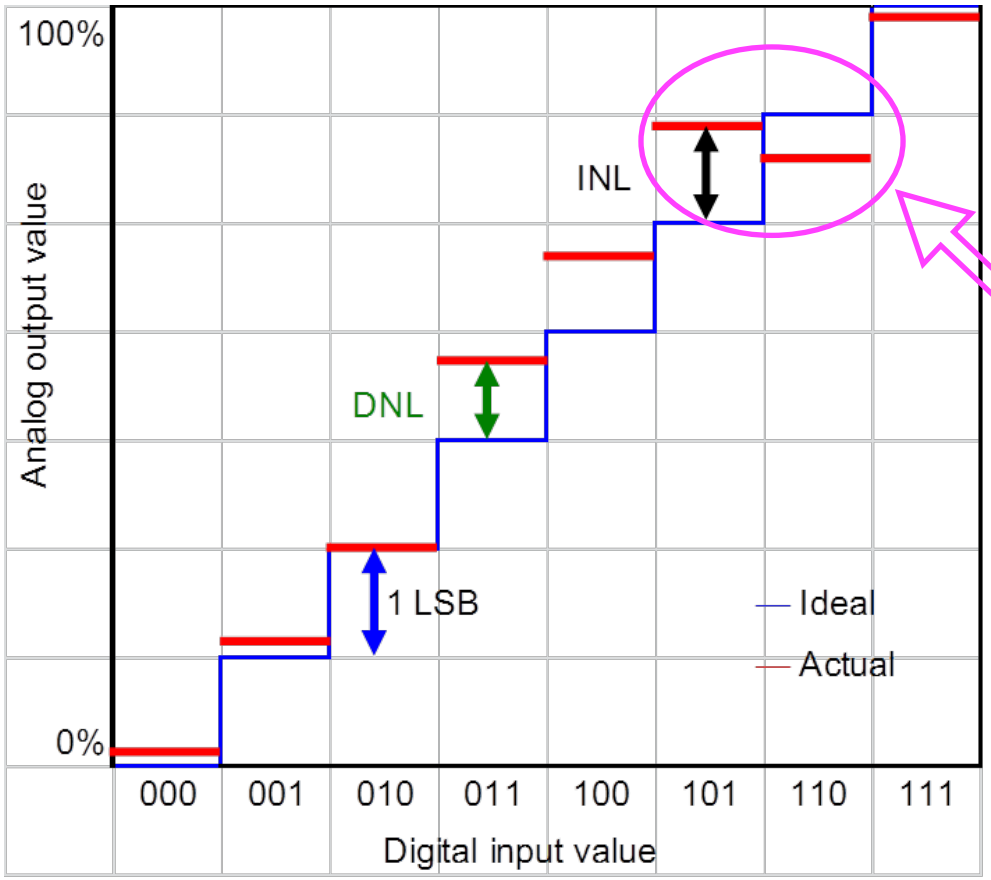
Not so bad



Bad

Non linearity and monotonicity

LSB: least significant bit
DNL: differential non linearity
INL: integral non linearity



Lose monotonicity

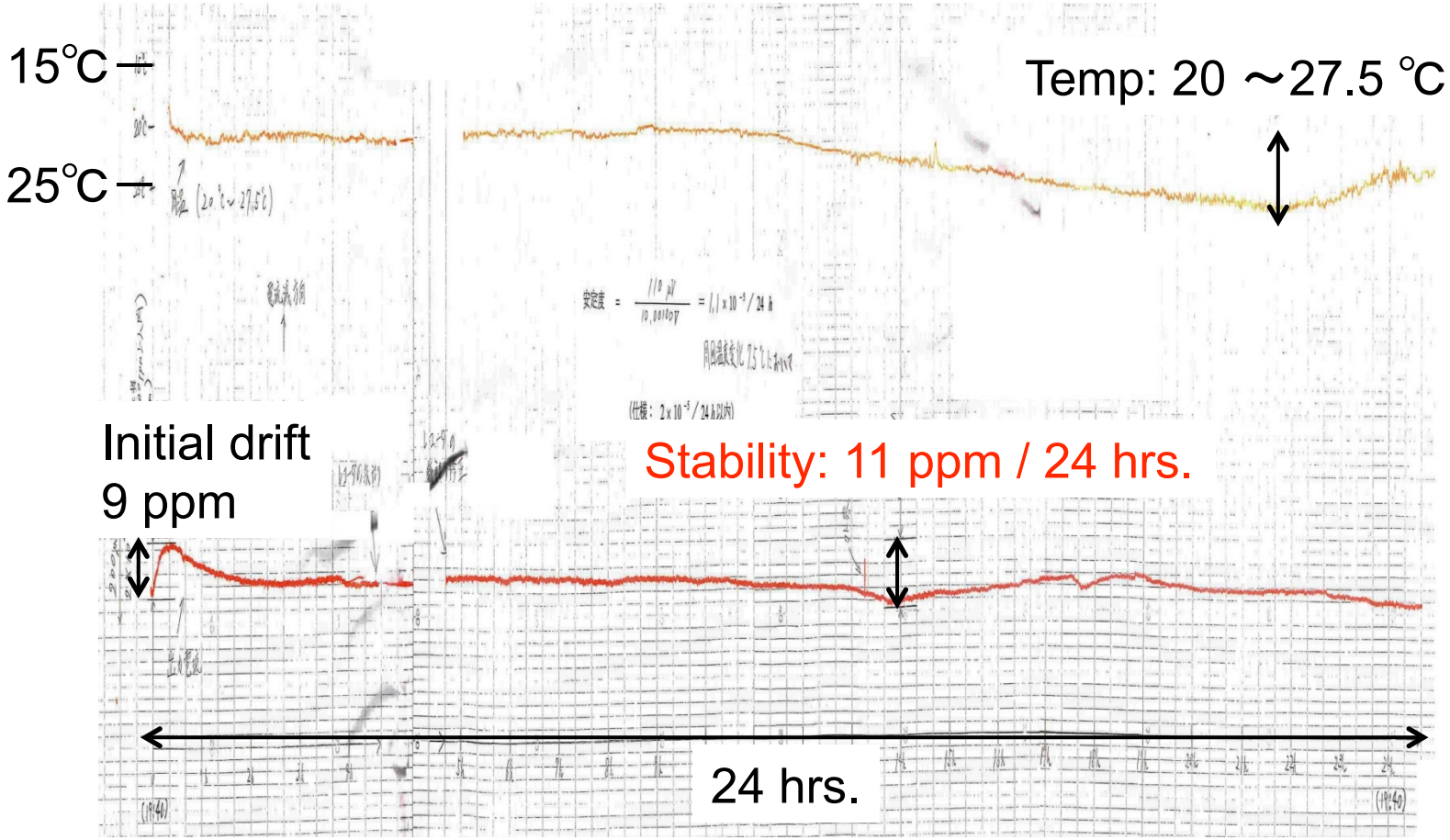
AD7846K (16-bit): DNL ±0.5 LSB max
INL ±2 LSB
AD5791B (20-bit): DNL ±0.75 LSB typ. (test result: <±0.1 LSB)
INL ±0.5 LSB typ. (test result: -0.2 ~ +0.6 LSB)

Typical long-term stability

Prototype power supply for QCS main coil

Power supply: Transistor-dropper type (1000 A-30 V).

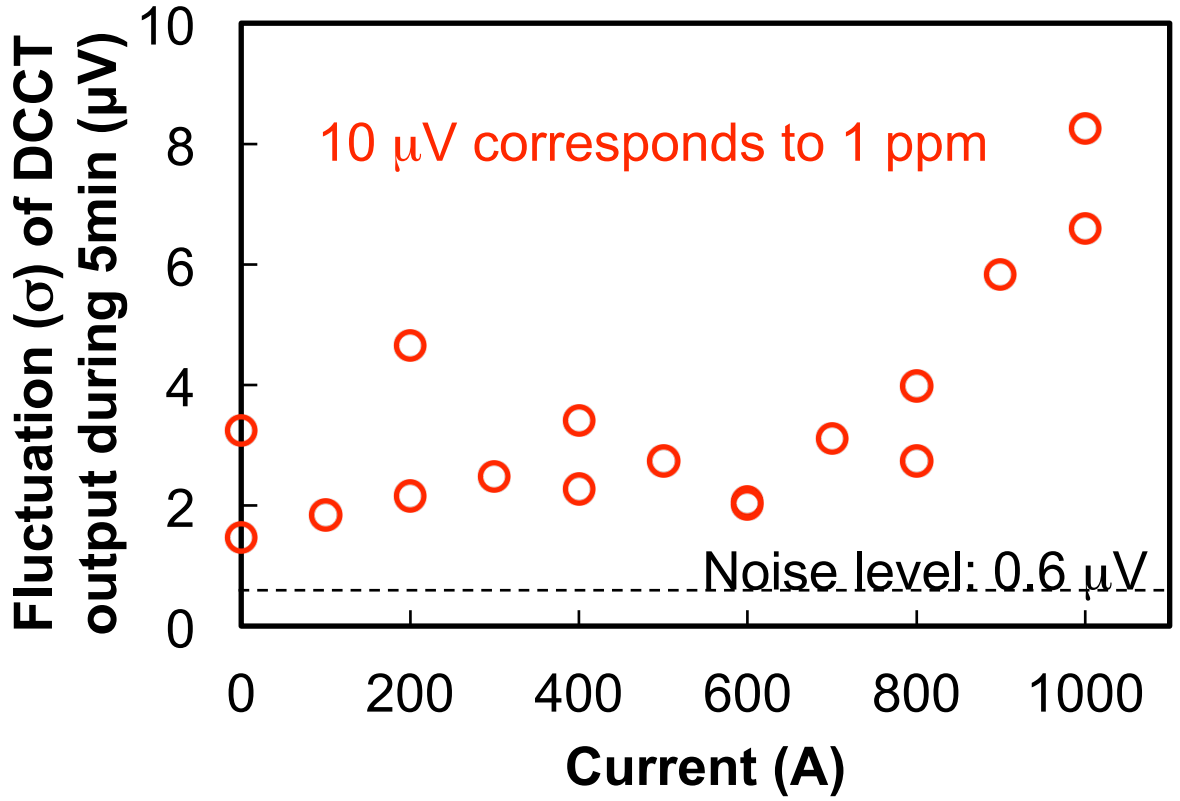
Test Load: 1.2 mΩ resistor



How much jitter on the measured current

For precious control, lower jitter is necessary on the current monitoring.
Current is measured by a DCCT and a DMM.

Power supply: Transistor-dropper type (1000 A-30 V).
DCCT: 1000 A / 10 V output
DMM: KEITHLEY 2002 (10 PLC, 20 V range)



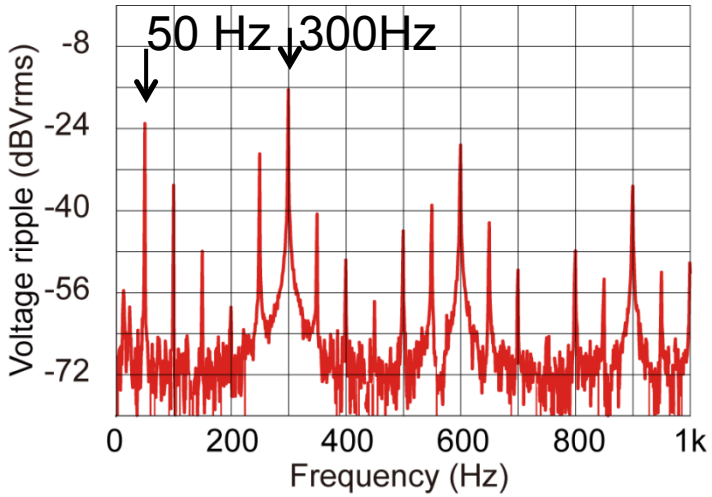
Typical ripple

QF4E magnet system

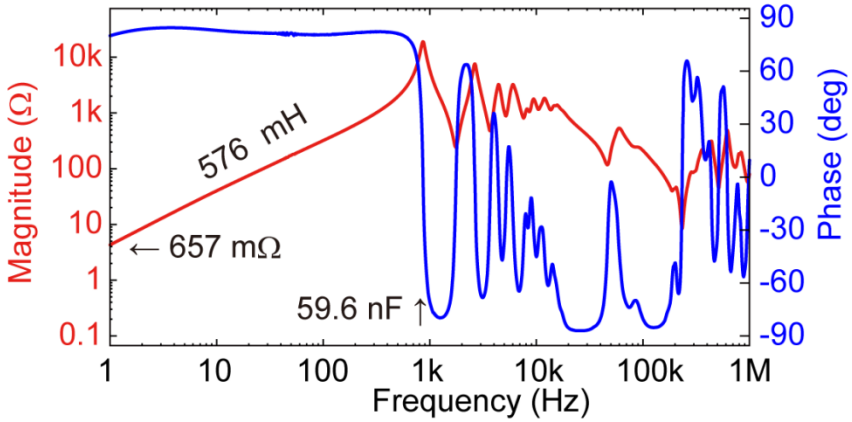
Power supply: Transistor-dropper type (500 A-380 V).

Load: 40 Quads connected in series around KEKB ring.

Measured voltage ripple



Measured load impedance



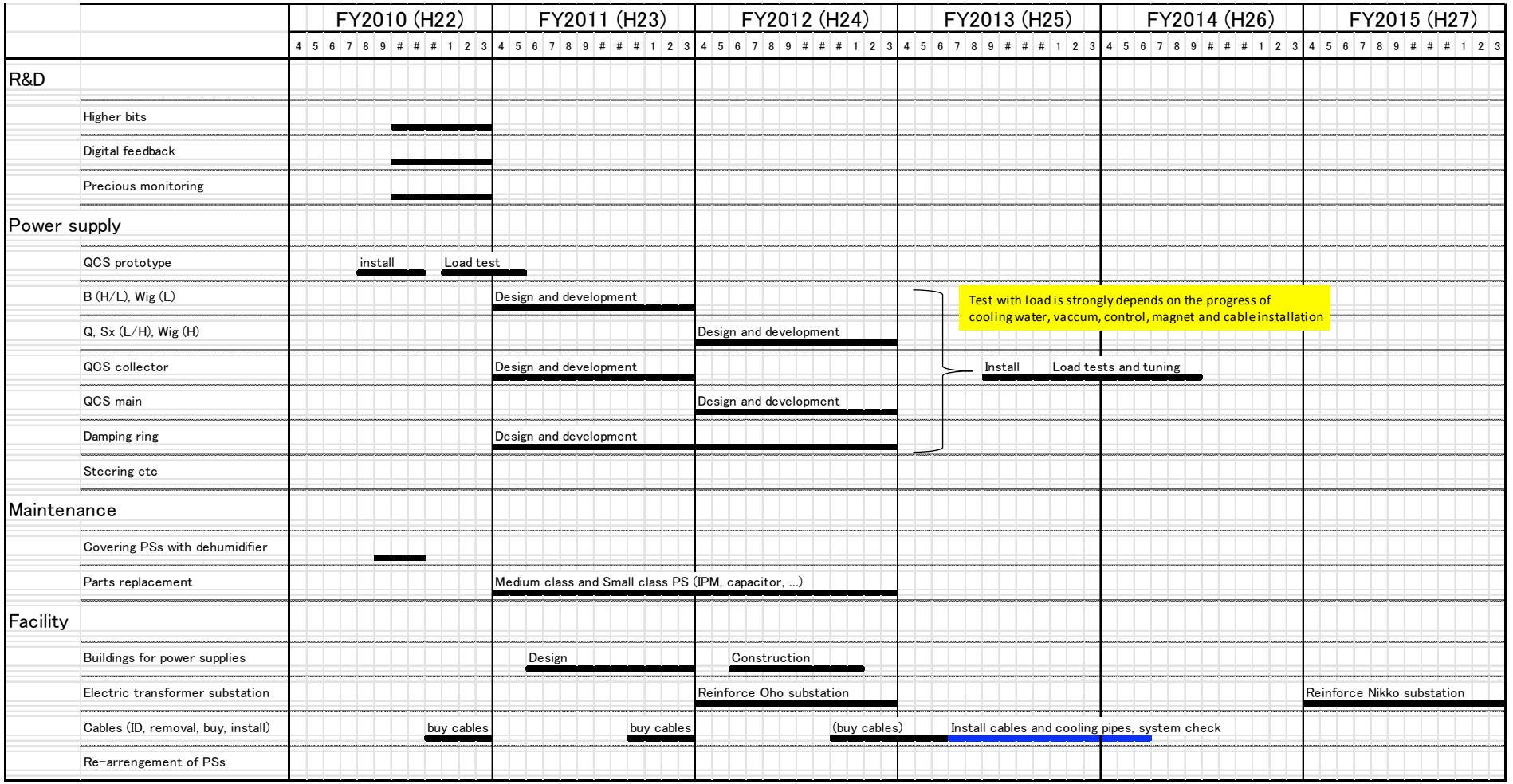
$Z \sim 0.66\ \Omega + 0.58\ H\ (f < 1kH)$

$$\text{Current ripple} = \frac{\text{Voltage ripple}}{\text{Load impedance}}$$

50 Hz: 0.7 ppm

300Hz: 0.3 ppm

Schedule


FY2010 (H22)
FY2011 (H23)
FY2012 (H24)
FY2013 (H25)
FY2014 (H26)
FY2015 (H27)
4 5 6 7 8 9 # # # 1 2 3
R&D
Higher bits
Digital feedback
Precious monitoring
Power supply
QCS prototype
install
Load test
B (H/L), Wig (L)
Design and development
Q, Sx (L/H), Wig (H)
Design and development
QCS collector
Design and development
Install
Load tests and tuning
QCS main
Design and development
Damping ring
Design and development
Steering etc
Test with load is strongly depends on the progress of cooling water, vaccum, control, magnet and cable installation
Maintenance
Covering PSs with dehumidifier
Parts replacement
Medium class and Small class PS (IPM, capacitor, ...)
Facility
Buildings for power supplies
Design
Construction
Electric transformer substation
Reinforce Oho substation
Reinforce Nikko substation
Cables (ID, removal, buy, install)
buy cables
buy cables
(buy cables)
Install cables and cooling pipes, system check
Re-arrengement of PSs