

# Integrated Gigasample Processor

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# Outline

- 1 System overview
  - Introduction
  - Operating experience
- 2 Features
  - Specification highlights
  - Architecture
  - Important features
  - Front and Back End
- 3 User Interface
  - Controls
  - Diagnostics
- 4 Measurement Examples
  - Photon Factory
  - DAΦNE

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# iGp Highlights



- A 500+ MHz processing channel.
- Finite Impulse Response (FIR) bunch-by-bunch filtering for feedback.
- Control and diagnostics via EPICS soft IOC on Linux.
- External triggers, fiducial synchronization, low-speed ADCs/DACs, general-purpose digital I/O.

# What's Inside



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# Installed Units and Tests

- iGp is installed or has been tested in the following machines:
  - DAFNE: four systems, transverse feedback;
  - Advanced Light Source: one system, longitudinal feedback;
  - Photon Factory (KEK): one system, longitudinal feedback.
- Gproto tests:
  - PEP-II transverse feedback;
  - KEKB transverse feedback;
  - ATF damping ring longitudinal feedback;
  - DAFNE transverse feedback;
  - PEP-II bunch-by-bunch luminosity monitor.

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# iGp Specifications

- Design goals:
  - Reliability;
  - Maintainability;
  - Ease of use;
  - Diagnostics.
- FPGA based processing:
  - Flexible;
  - Field upgradable.

## Specifications

Bunch spacing  $\geq 1.9$  ns

Harmonic number 64–5120

ADC resolution 8 bits

DAC resolution 12 bits

Feedback filter 16-tap FIR

Downsampling 1-32

DAQ memory 8 MB

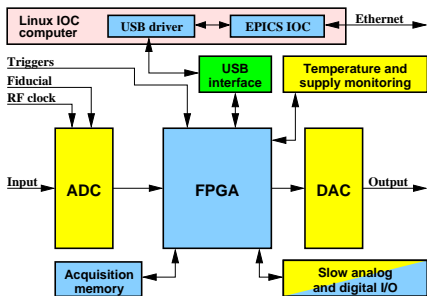
Digital GPIO 32 channels

Slow analog I/O 8 channels

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# System Block Diagram



- Real-time processing in the FPGA.
- Low-rate ( $\leq 10$  Hz) diagnostics via USB.
- 8 MB memory:
  - Data acquisition in normal operation;
  - Can be used for grow/damps, other diagnostics;
  - Internal or external data acquisition triggers.



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# Important Features

- ADC and DAC timing adjustment with 10 ps step size.
  - Eliminates the need for mechanical delay lines.
- High bandwidth
  - 1.26 GHz input bandwidth;
  - 200-300 ps output rise and fall times.
- Self-test program for verifying system health.
  - Generated report can be compared to factory results using "diff".
- User-friendly IOC setup program
  - With a series of windows leads the user through network setup, date/time setting, and IOC name.
- DAC test pattern generator.

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# Front/Back-end Unit

- 2U 19" rackmount chassis, just like the iGp.
- 1.5 GHz front-end detection frequency.
- 2-cycle comb generator.
- 1 GHz back-end frequency.
- Integrated control via iGp GPIO:
  - Front and back-end LO phase shifters;
  - Front and back-end attenuators.



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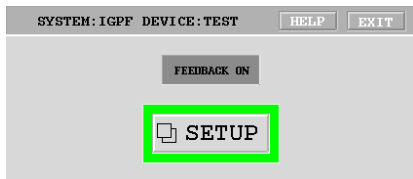
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# Top-Level Panel



- Top-level panel is kept very simple on purpose.
- One control: feedback on/off.
- Error summary:
  - Green - no errors;
  - Yellow - warning (saturation);
  - Red - error.

# Control Panel

SYSTEM: IGPF DEVICE:TEST      HELP      EXIT

**TIMING CONTROL**

DCM RESET      OFF

DCM PHASE      256

FIDUCIAL DELAY      0

-----

COEFFICIENT SET      Set 0

SHIFT GAIN      0

DOWNSAMPLING      1

OUTPUT DELAY      120

-----

GROW/DAMP ENABLE      OFF

REC. DOWNSAMPLE      1

RECORD LENGTH      131072

GROW LENGTH      85536

HOLD-OFF      0

**TRIGGER**

S       INT

R       EXT

C

Acquire

OFF

Arm

OFF

Auto re-arm

OFF

RESET

**MEMORY**

read

**ACQ MEMORY**

BLOCK

SRAM

**DAC TEST**

Enable

OFF

Value

2047

Ramp

Square

DC

Custom

**STATUS**

Clock missing

● 0

DCM1 unlocked

● 0

DCM2 unlocked

● 0

FIR saturation

● 0

Fiducial error

● 4

Interval (sec)

4

COUNT

**Buttons:** Coefficients, Waveforms, Environment, Devices, Config S/R

- Controls:

- Timing;
- Feedback;
- Data acquisition;

- Status:

- RF clock;
- FPGA DCMs (digital clock managers);
- Saturation;
- Fiducial.

# Control Panel

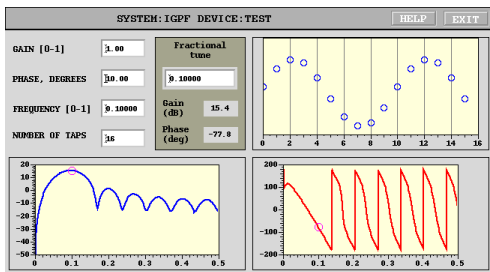
SYSTEM: IGPF DEVICE: TEST    HELP    EXIT

<b>TIMING CONTROL</b>	<b>TRIGGER</b>	<input type="checkbox"/> Coefficients
DCM RESET    OFF	S <input checked="" type="checkbox"/> INT	<input type="checkbox"/> Waveforms
DCM PHASE    256	R <input type="checkbox"/> EXT	<input type="checkbox"/> Environment
FIDUCIAL DELAY    0	Acquire	<input type="checkbox"/> Devices
-----	OFF	<input type="checkbox"/> Config S/R
COEFFICIENT SET    Set 0	Arm	
SHIFT GAIN    0	OFF	<b>MEMORY</b>
-----	Auto re-arm	<input type="checkbox"/> read
DCM UNLOCKED    0	OFF	
DCM PHASE    256	RESET	
DCM DELAY    0		<b>ACQ MEMORY</b>
DCM GAIN    1		<input checked="" type="checkbox"/> BLOCK
DCM OUTPUT DELAY    120		<input type="checkbox"/> SRAM
-----		<b>STATUS</b>
DCM GROW/DAMP ENABLE    OFF	<b>DAC TEST</b>	Clock missing
REC. DOWNSAMPLE    1	Enable	<input type="checkbox"/> 0
RECORD LENGTH    131072	OFF	DCM1 unlocked
GROW LENGTH    85536	Value	<input type="checkbox"/> 0
HOLD-OFF    0	2047	DCM2 unlocked
	<input checked="" type="checkbox"/> Ramp	<input type="checkbox"/> 0
	<input type="checkbox"/> Square	FIR saturation
	<input type="checkbox"/> DC	<input type="checkbox"/> 0
	<input type="checkbox"/> Custom	Fiducial error
		<input type="checkbox"/> 4
		Interval (sec)
		<input type="checkbox"/> 4
		COUNT

- Controls:
  - Timing;
  - Feedback;
  - Data acquisition;
- Status:
  - RF clock;
  - FPGA DCMs (digital clock managers);
  - Saturation;
  - Fiducial.



# Coefficient Generator

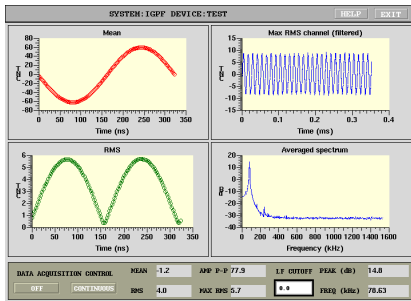


- Integrated filter generator and analyzer.
- Computes frequency response.
- Gain and phase readout at the tune frequency.
- Filter tuning made easy.

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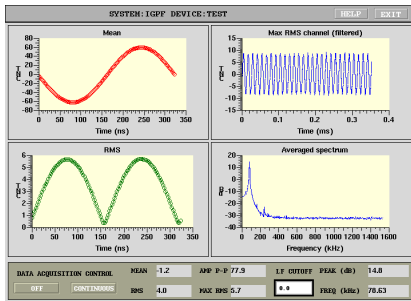
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# Waveform Display



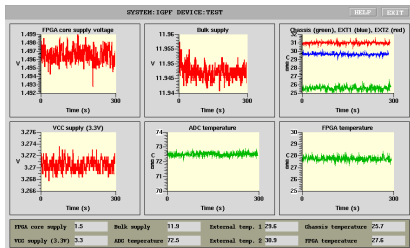
- From bunch data matrix to vectors:
  - Bunch-by-bunch mean and RMS;
  - Time record of the most unstable bunch;
  - Averaged spectrum.
- From vectors to scalars for stripcharting:
  - Mean;
  - Overall and maximum RMS;
  - Peak-to-peak amplitude;
  - Spectral peak frequency and magnitude.

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# System Health



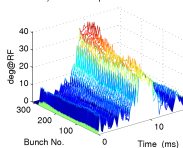
- Built-in monitoring of supply voltages and system temperatures.
- Voltages:
  - FPGA core;
  - Global 3.3 V;
  - Bulk supply (12 V).
- Temperatures:
  - ADC;
  - FPGA;
  - Board temperature;
  - ECL clock delays.

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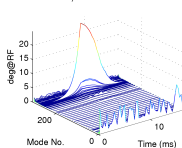
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# Photon Factory Longitudinal Grow/Damp

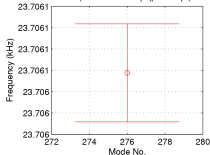
a) Osc. Envelopes in Time Domain



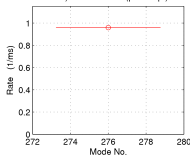
b) Evolution of Modes



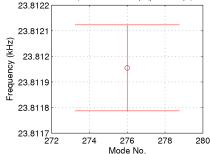
c) Oscillation freqs (pre-brkpt)



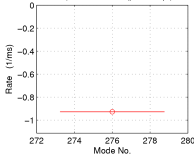
d) Growth Rates (pre-brkpt)



e) Oscillation freqs (post-brkpt)



f) Growth Rates (post-brkpt)



- A test as a longitudinal feedback.
- 500.1 MHz RF, 312 bunches.
- Growth and damping rates of  $1 \text{ ms}^{-1}$ .

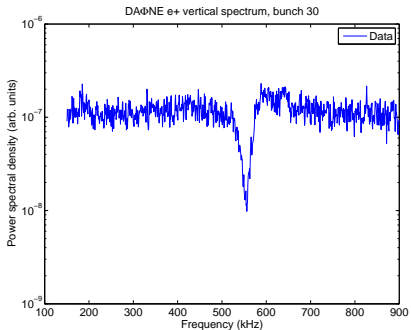
PF-jun3007/215154: Io=200mA, Dsamp=1, ShfGain=0, Nbun=312,  
At Fs: G1=0.10338, G2=0.1723, Ph1=65.515, Ph2=65.5215, Brkpt=20000, Calib=1.

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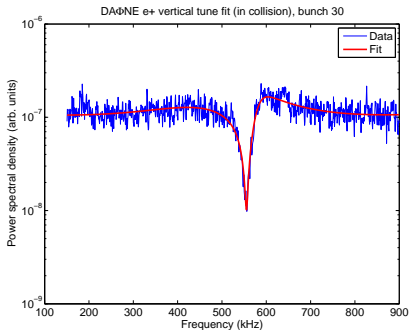


# DAΦNE Steady-state Recording



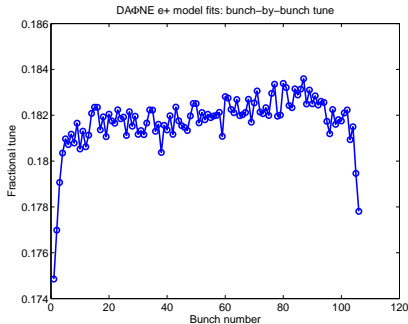
- Vertical feedback in the positron ring.
- 368 MHz, 120 bunches.
- Bunch spectrum shows a notch due to feedback action.
- Fit the spectrum using the feedback/beam model.
- Extract bunch-by-bunch tunes.
- **Completely parasitic!**

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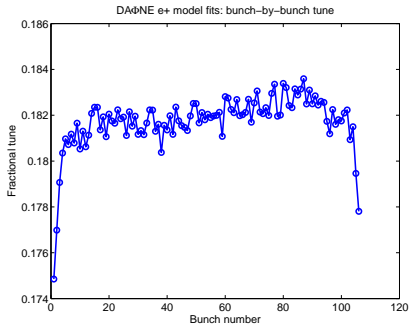
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- iGp is a proven bunch-by-bunch feedback and diagnostic platform.
- Integrated tools make for extremely simple system configuration and maintenance.
- Powerful diagnostics provide real-time stability and performance tracking.
- Direct interface to sophisticated Matlab analysis tools for machine studies.

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