May 19, 2011

Development of Pulse Detection IC for LIDAR on planetary lander

Takahide Mizuno, Kousuke Kawahara, Hirokazu Ikeda

ISAS/JAXA, Japan

Contents

Background ~ Hayabusa Project ~

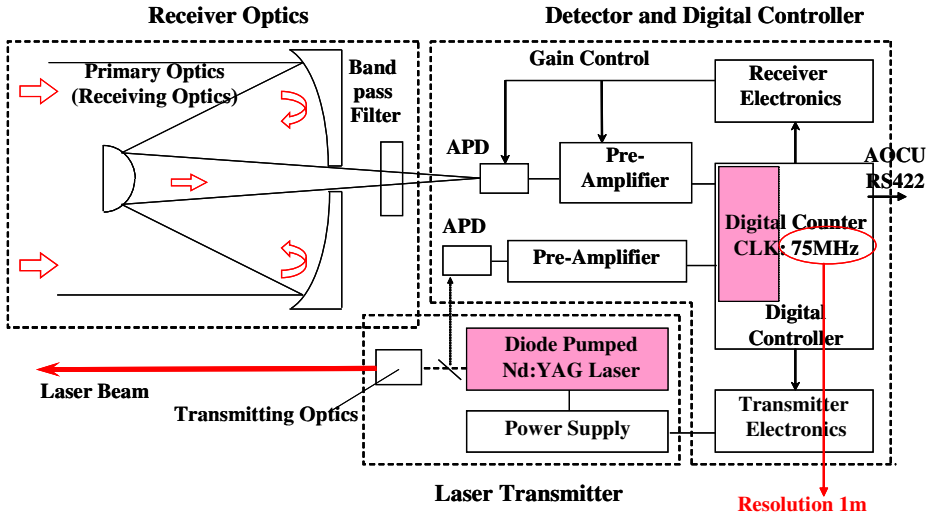


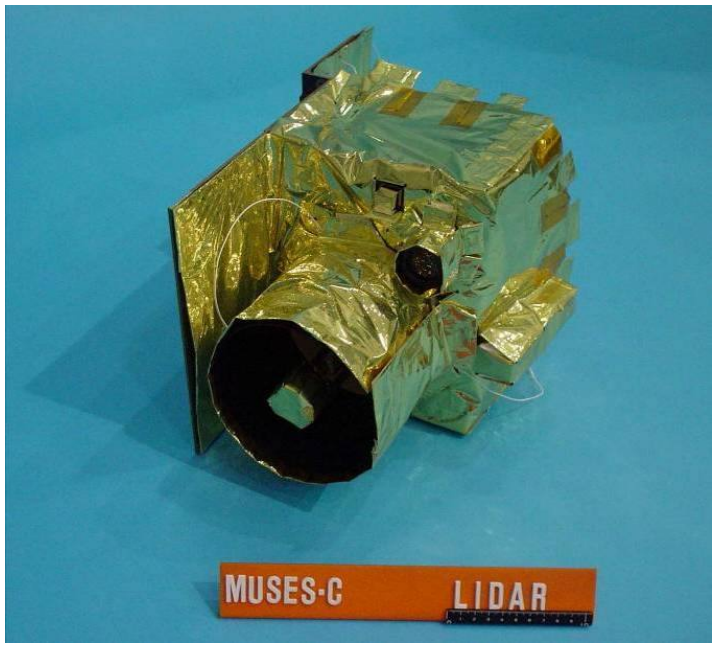



Technical demonstration spacecraft
- **Operation of Ion Engines**
- **Earth Gravity Assist with Ion Engines**
- **Rendezvous with Itokawa with Autonomous Navigation**
- **Scientific Observation of Itokawa**
- **Touch-down and Sample Collection**
- **Return and Recovery of Capsule**

- **Launch date : May 9, 2003**
- **Touchdown date: November 19, 2005**
- **Re-entry date: June 13, 2010**

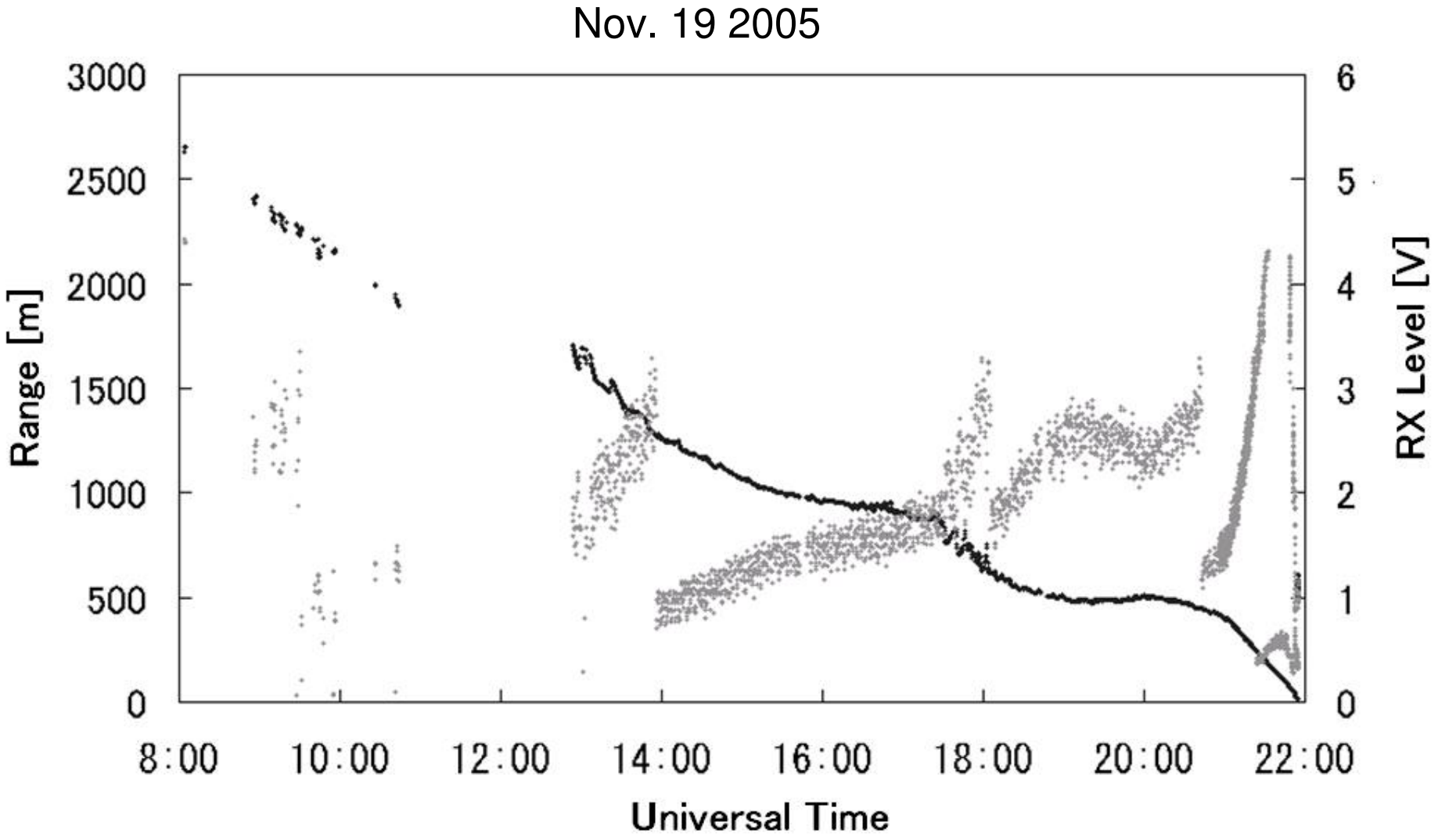
Background ~ Hayabusa's LIDAR ~





Items	Specification
Range	50m～50km
Accuracy	±1m(@50m)
Repetition Rate	1Hz
Laser	Q-SW, Nd:Cr:YAG
Wave length	1064 nm
Output Power	8 mJ
Pulse Width	14 nsec
TX Beam Width	ϕ 1.7 mrad （1/e^2）
RX FOV	ϕ 1 mrad
RX Optics	Casegren ϕ 126 mm、SiC
Weight	3.7kg Include: DC/DC, Radiator
Power	17.0W (+LD Heater max5W)
Size	240mm×228mm×250mm Radiator: 240mm×300mm

Ranging result in touchdown sequence



Background ~ required dynamic range ~

- Dynamic range : more than 60 dB
  - In the case of a non-cooperative target, a receiving circuit is required a large dynamic range. If the required coverage is 50 km ~ 50 m, the received electrical charges is 0.002 pC ~ 2000 pC.
  - In addition to a large total dynamic range, every gain stage also needs to have about 10 dB dynamic range. Because, the receiving power of every shot will vary widely due to the fluctuations of a back scattering factor and irradiated spots.

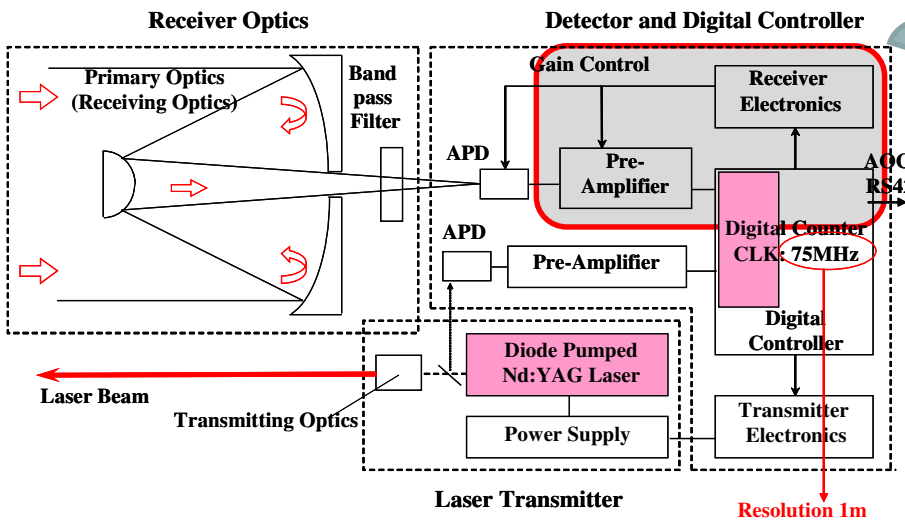
$$P_r = P_t \frac{\pi \rho D^2}{32 R^2} \eta$$

P_t (Transmitting signal power) : 5 mJ
D (Diameter of receiving-antenna) : 100 mm
η (System efficiency) : 70 %
ρ (Reflectance of a target) : 5 %
YAG laser wave length : 1.064 um
Transmitting pulse width : 10 ns
The multiplication of APD : 100
The efficiency of APD : 40 %

Contents

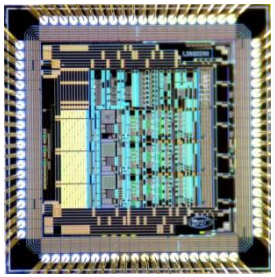
Purpose of device development

discrete parts



SOC

System On Chip



- Reduction of circuit area
- Reduction of size and weight
- Reduction of development period
- Reduction of digital clock frequency

  => Lower power consumption

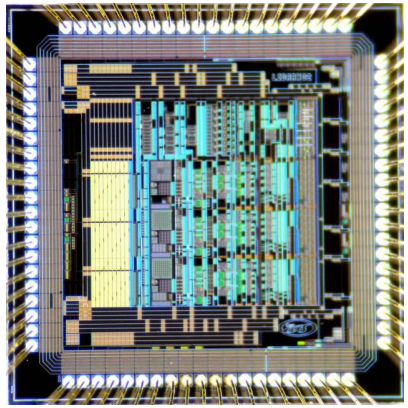
Contents

1. Background (Experience of Hayabusa)
2. Purpose of device development
3. **Device outline**
4. Results of evaluation
5. Summary

Specifications

Main function of LIDARX03

- Gain adjustment (for 60dB dynamic range)
- Timing detection (for counter trigger)
- TAC (for Low digital frequency)



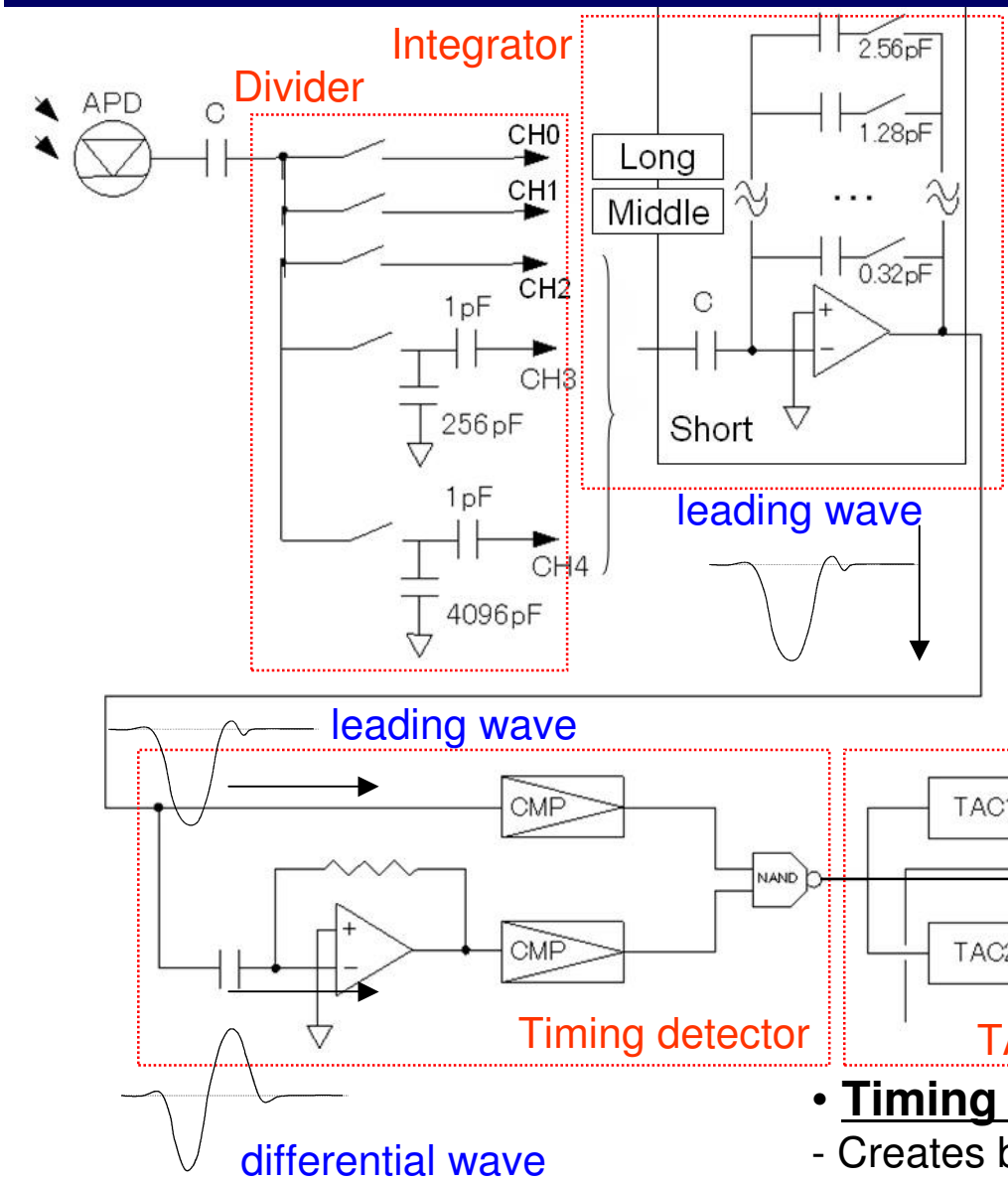
Features of LIDARX03

Dynamic range	0.002pC ~ 2000 p C (60dB)
Gain control	Digital
Range resolution / time resolution	~ 10 cm / ~ nanoseconds
Quality	SPACE CLASS2 (2012)

Process and package

Process	CMOS 0.35μm TSMC
Bare chip size	3 mm x 3 mm
Package	Ceramic QFP (80 pins) 14 mm x 14 mm

Circuit structure



- **Divider (coarse gain ADJ)**
  - Selects integrator channnels or
  - Split the electrical charges by capacitor
  - Coarse adjustment of gain.

- **Integrator (fine gain ADJ)**
  - Adjusts its gain by means of changing feedback capacity.
  - The gain can be controlled by 4 bit-command.
  - Fine gain adjustment
  - Create a symmetry wave (leading wave).

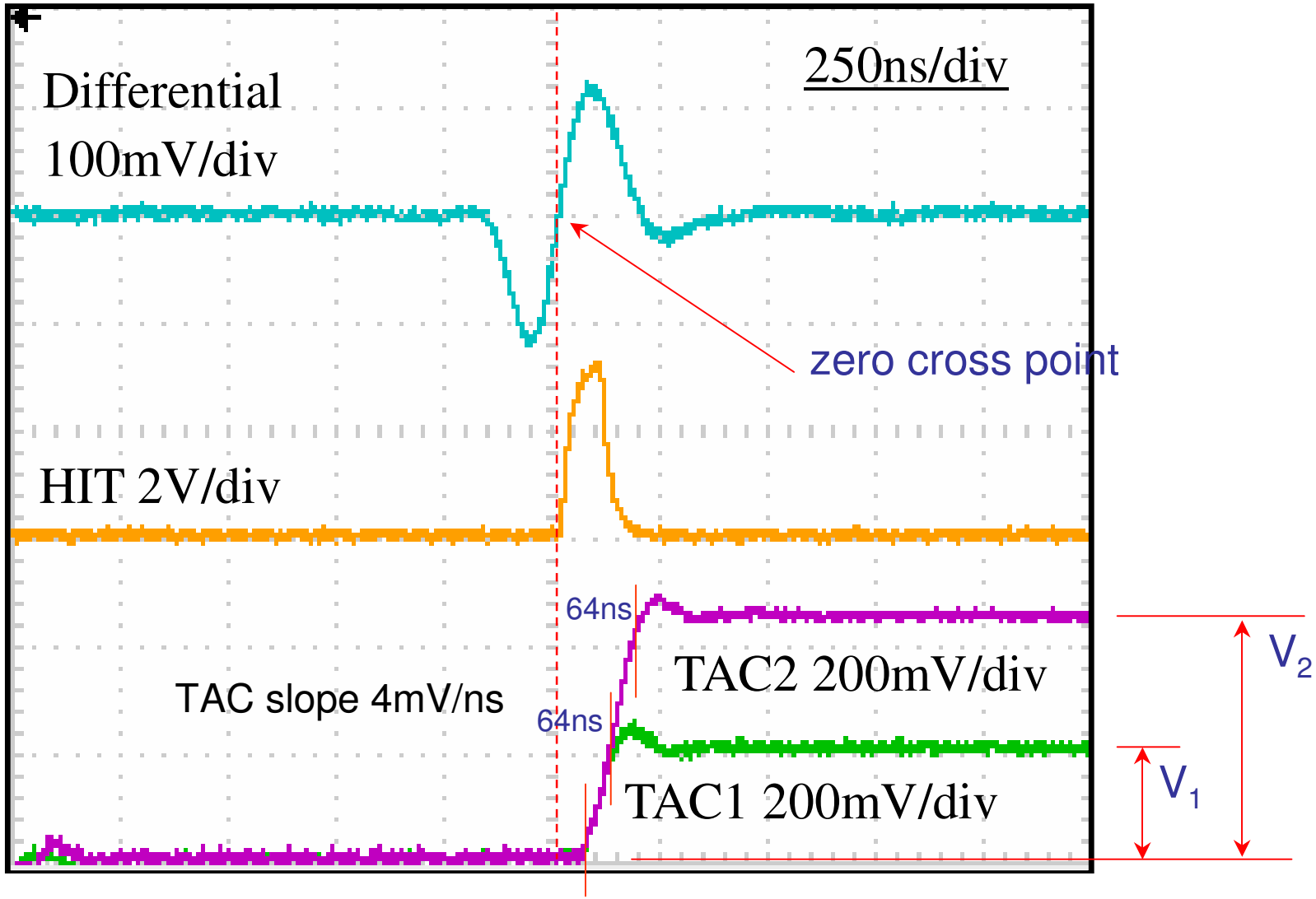
Hit Pulse (Detection timing)

- **TAC**
  - Generates analog level for interpolation

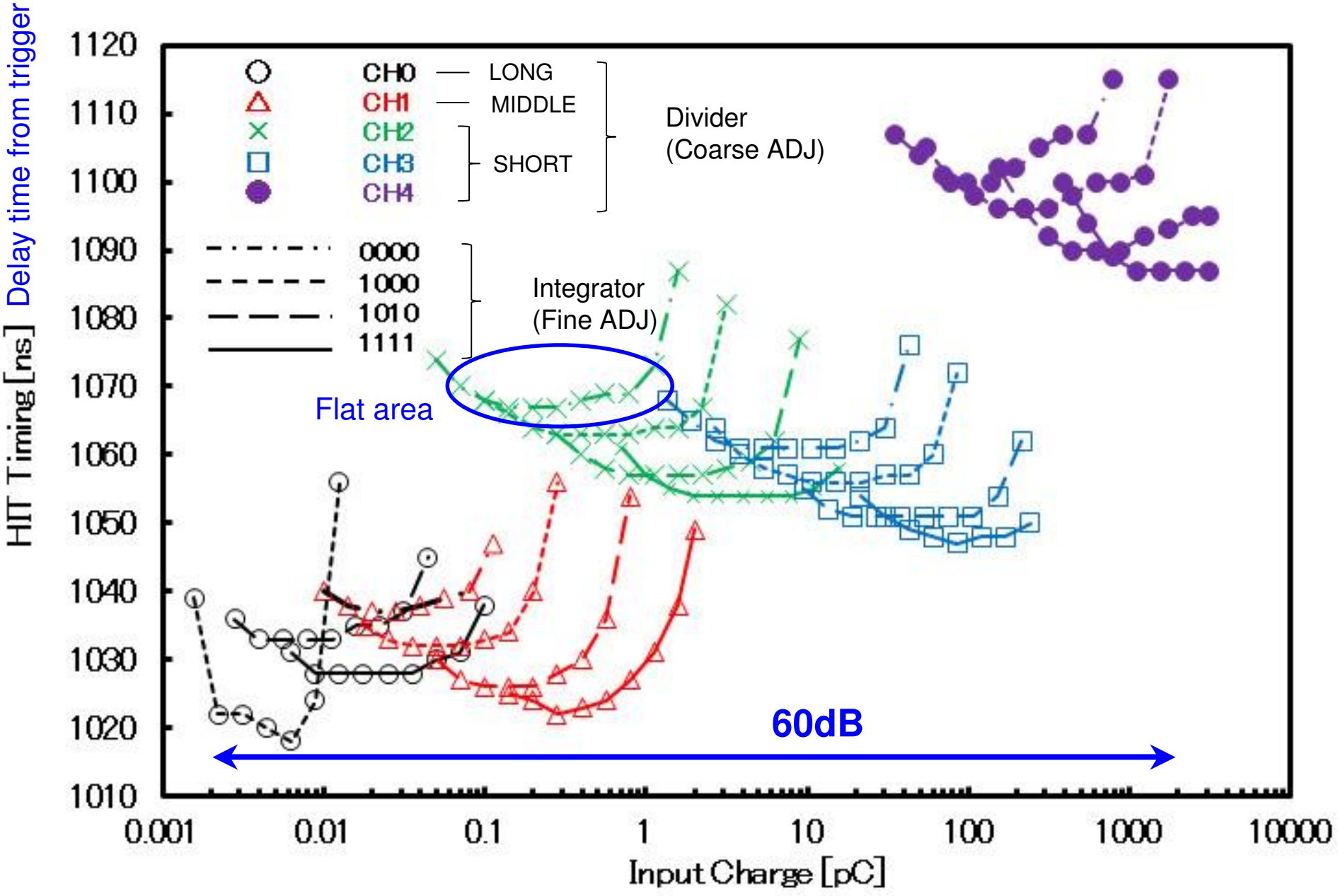
- **Timing detector**
  - Creates bipolar wave by differential circuit.
  - Detect zero cross timing of a differential wave
  - Sends a HIT Pulse as a timing of signal detection.

Contents

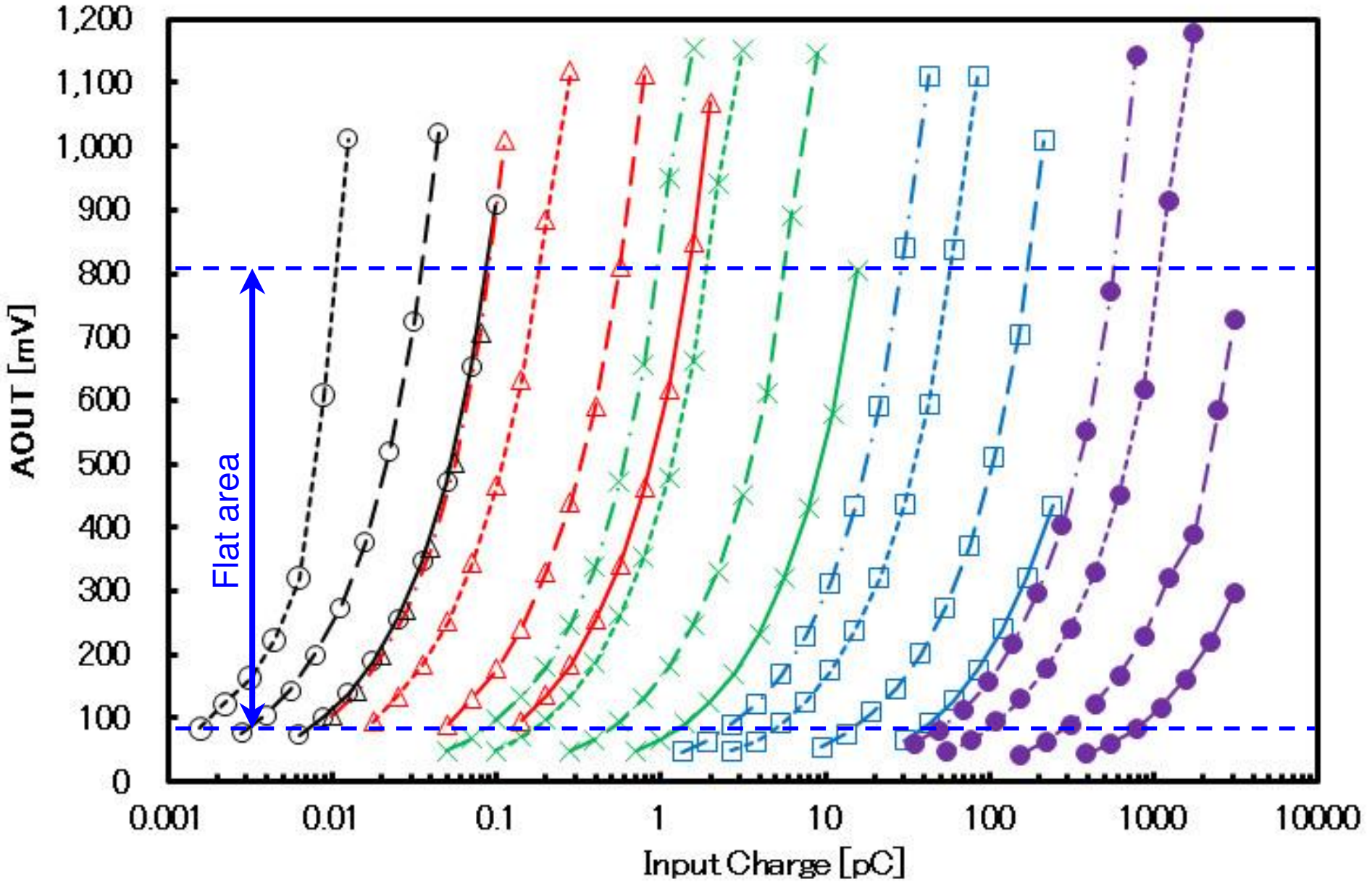
Results ~ Typical output waveforms ~



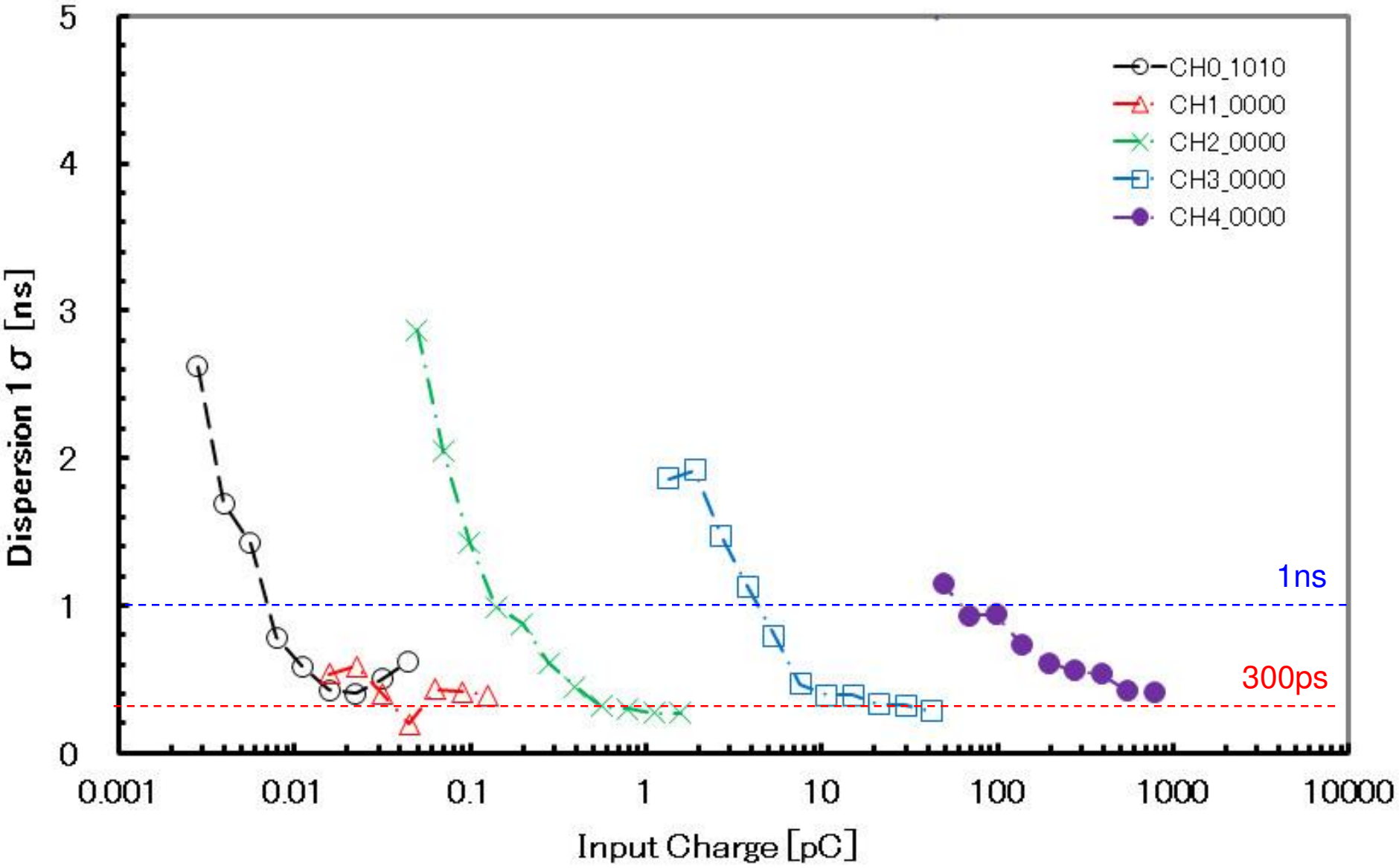
Input charge dependence of HIT timing



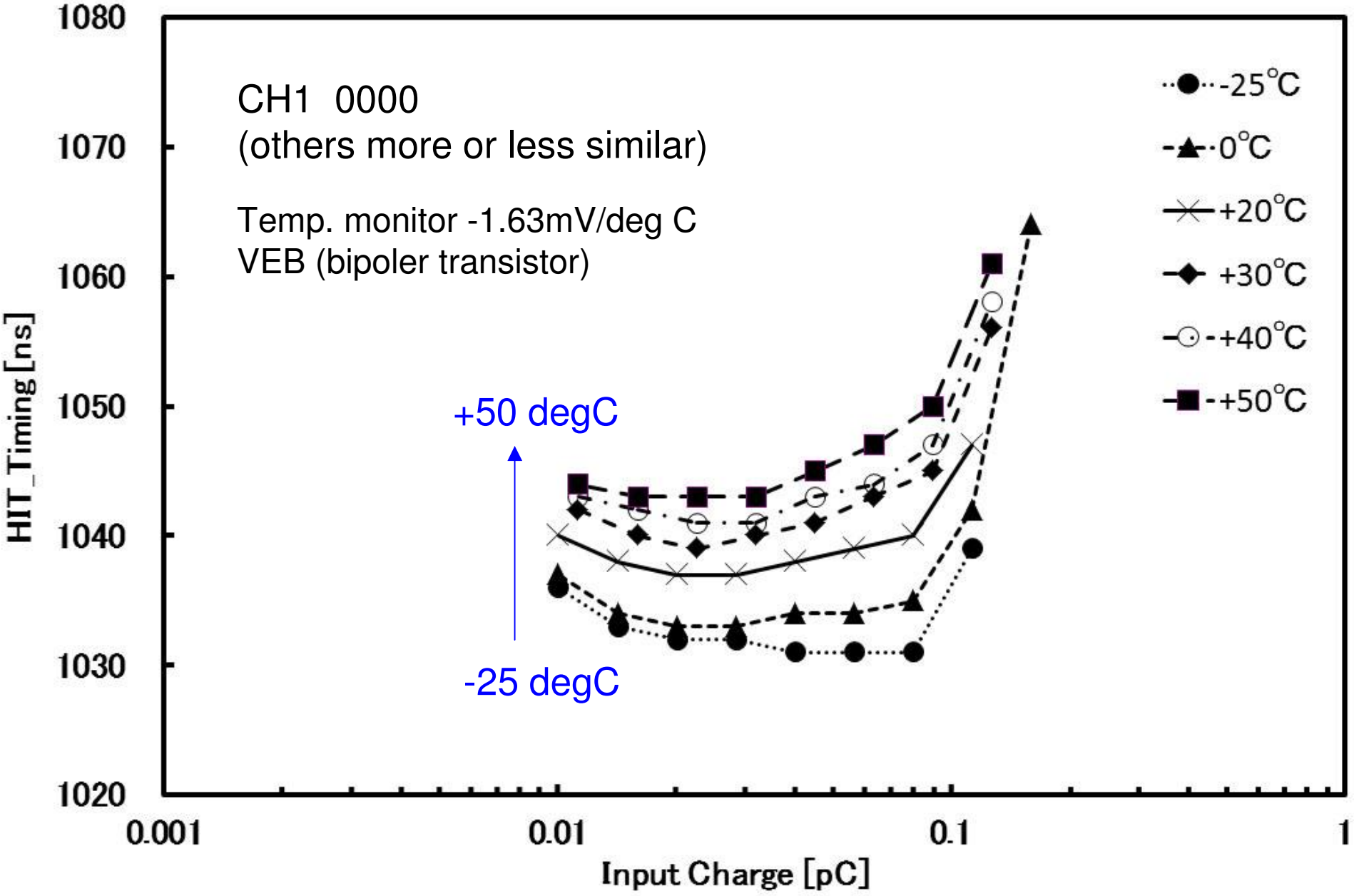
Input charge dependence of signal level



Input charge dependence of timing dispersion (1σ)

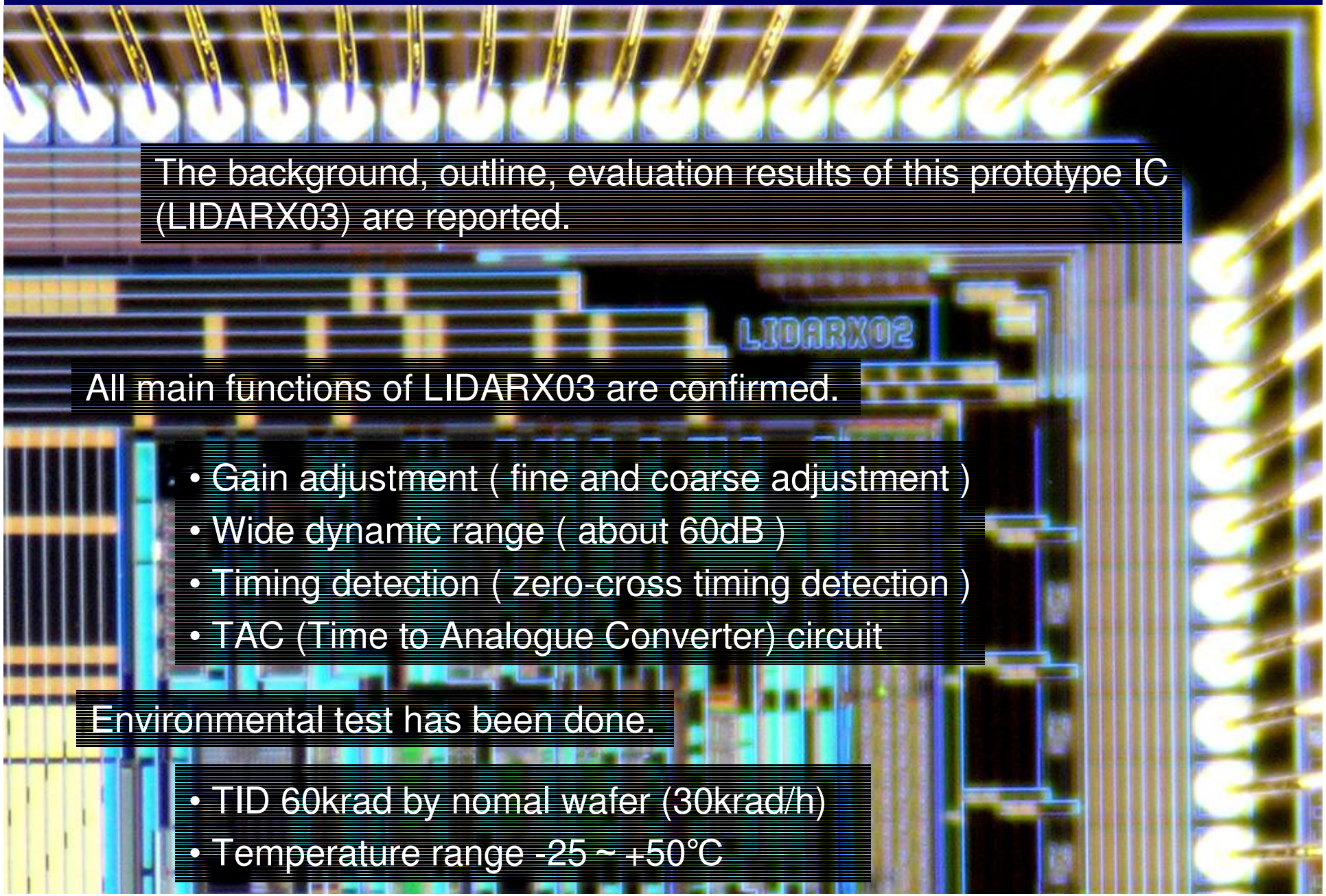


Temperature dependence of detection timing



Contents

Summary



The background, outline, evaluation results of this prototype IC (LIDARX03) are reported.

All main functions of LIDARX03 are confirmed.

- Gain adjustment (fine and coarse adjustment)
- Wide dynamic range (about 60dB)
- Timing detection (zero-cross timing detection)
- TAC (Time to Analogue Converter) circuit

Environmental test has been done.

- TID 60krad by nomal wafer (30krad/h)
- Temperature range -25 ~ +50℃