Performance of the Reference and Timing Systems at SPring-8

Yuji Ohashi
SPring-8

Outline

1. Introduction
2. Tools
3. Performances
4. New synchronization scheme between 508 and 2856 MHz
5. Summary

Y.Kawashima
T. Asaka
H.Ego
M.Hara
T.Ohshima
T.Takashima
H.Yonehara
1. Introduction

1) **SPring-8 accelerator configuration**

2) Beam operation mode (over 40 beam filling patterns)
   - single-bunch filling
   - partially continuous filling
   - hybrid

3) History
   - 1991~1993 : R&D
   - 1994~1996 : Construction
   - 1997~ : Commissioning/Beam to users
2. Tools

1) **508 MHz Synchronous Universal Counter (SUC)**
   - Direct counting of 508 MHz *(MC10E136, E016)*
   - Frequency division: “1/N”
   - Timing delay: 30 or 16 bits
   - non-stop / single action (revolution counting / injection interval)
   - Time jitters: $\pm 2$ ps

2) **Reference signal distribution**
   - PSOF + E/O + O/E + PLL feedback (♦)
   - Phase stability: $1^\circ$

3) **Timing signal distribution**
   - PSOF + E/O + O/E
   - SUC + reference signal: $\sim \pm 2$ ps (relative to reference signal)

(♦) Phase Stabilized Optic Fiber, Electric-to-Optic Transmitter, Optic-to-Electric Receiver, and Phase-lock-loop
3. Performances

1) **Relative timing measurement between picosec laser pulse and synchrotron light**
   - Streak camera: $\sim \pm 2$ ps

2) Single-bunch beam operation
   - RF knockout system in SY
   - Impurity $< 10^{-9}$ ($\frac{\text{# of } e^- \text{ outside of main bunch}}{\text{# of } e^- \text{ in main bunch}}$; in SR)
   - Beam refills during user time

3) **Beam energy correction / earth tide effect**
   - Daily circumference change: $\sim 70$ $\mu$m at max.
   - Correction step: 0.1 Hz (0.28 $\mu$m)
4. New Synchronization Scheme between 508 and 2856 MHz

[ 250 ps grid pulse / acceleration of 1 RF bucket in Linac ]

- A common sub-harmonic oscillator: 2 CW RF generation

- Linac operation: pulse mode (usually)

- Pulse generation of 2856 MHz
- Start 2856 MHz generation by 508 MHz RF timing
- “508 MHz SUC + Arbitrary waveform generator + Bandpass filter + Frequency multiplier”

- 2855.981281 MHz (duration: ~290 μs)
5. Summary

1) R & D
   • 508 MHz Synchronous Universal Counter
   • Reference signal distribution by “PSOF+E/O+O/E+PLL”: 1°
   • Timing signal distribution with 508 MHz synchronization: ~ ± 2 ps

2) Providing precision timing for beam injection, beam monitoring, and experiments: ~ ± 2 ps

3) Synchronization between 508 and 2856 MHz RF’s (arbitrary)
   • A beam in one RF bucket is injected into SY from Linac
   • Require only one master synthesizer of 508 MHz

Ref.)
Electronics setup

new 2856 MHz system

Linac e-gun trigger

optic signal to e-gun
Configuration of SPring-8 Accelerators

Storage Ring (SR)
508.58 MHz
(harmonic #:2436)

Linac
2856 MHz
60 Hz
Grid pulser:
250 ps
1 ns
40 ns

Booster Synchrotron (SY)
508.58 MHz
(harmonic #:672)
1 Hz

Harmonic number ratio= 29 : 8
508 MHz Synchronous Universal Counter

DI to set “M” externally

Display

set address (“M”, “N”)

RF in

External

Reset/Start

“1/N” out

“M” out

Standard NIM package

30 (or 16) bit model

N=“harmonic number - 1”,  M=0, 1, ………, N-1, N

Frequency range: 480 ~ 520 MHz (adjustable below 480 MHz)
Time Jitter Measurement

- Offset = 0.000 Volts
- Delay = 16.2230 ns
- Window 2 = -937.50 uVolts
- Lower = 17.12 %
- Stop = 16.2676 ns
- Sigma = 2.4 ps

Trigger on External at Neg. Edge at -150.0 mVolts
Phase-Stabilized Optic Fiber

Ref.) J. Urakawa, Particle Accelerators, 1990, Vol.29, pp.251-256
Reference Signal Distribution

in SR

(air-conditioned: 25±1 °C)

Optic directional coupler

Storage ring 1.44 km

PSOF (~1700m)
+ E/O & O/E
+ PLL

508.58 MHz

E-station

PLL

E/O

O/E

B-station

A-station

C-station

D-station

O/E
Reference Signal Distribution to SY

Timing Signal Distribution

NIM level pulse 20 ns width
Level converter
E/O (ORTEL 3510 A)
Optic fiber (DTS-M02: 500 meters long)
O/E (ORTEL 4511A)
CFD (ORTEC 935)
NIM level pulse 20 ns width

Side A

as a Pulse generator
508 MHz SUC
PLL system
(KO) → Circulator
Optic fiber
Received RF
O/E

(1) Transmission of reference RF
RF
(2) Transmission of pulse signal
Pulse signal

Side B

RF source
508 MHz SUC
O/E
CFD

Output pulse signal with low time jitter

w/o synchronization

w/ synchronization
Time jitter measurement at electron gun

\[ \sigma = 7.4 \text{ ps} \]
Relative timing between pulsed laser and synchrotron light
Single-bunch beam

main bucket
masked by optical shutter
Single-bunch beam (3 buckets)

main bucket ( x 750= ~1.5x10^9 )

oise from optic system

side bucket
Beam energy correction / earth tide effect

14 µm
1 day

machine study
Beam energy correction -2

Frequency correction by GPS-based frequency counter
GPS-based frequency counter

long term stability: $\sim 10^{-10}$

Diagram:

- Satellite (GPS)
- Reference clock
- Antenna
- Receiver HP58503A
- Reference frequency 10 MHz
- Frequency counter HP53132A
- Synthesizer Rohde & Schwarz or HPE4433B
Effect of earth tide

Variation of Circumference of the SPring-8 Storage Ring

Circumference [m]

1435.951
1435.950
1435.949
1435.948
1435.947

1997/01  1998/01  1999/01  2000/01  2001/01  2002/01

LSS  HHLV  Hybrid
Block diagram of 2856 MHz generation

508.58 MHz RF

Bandpass filter

508 MHz SUC

Gun trigger signal

Repetition rate of 60 Hz

Start signal

Arbitrary waveform generator
(SONY-Teltronix: AWG2041)

(508.58 MHz × 63 / 359)

Bandpass filter: ±3 kHz

Frequency multiplier: (× 32)

Bandpass filter

Mechanical phase shifter

2855.981281 MHz
Spectra of 2856 MHz RF

- **(a)** AWG + BPF + Frequency multiplier
- **(b)** HP8664A
ICALEPCS 2001

New Linac RF system
Modules

- Jitter reduction of pulse signal
  EG&G ORTEC: # 935
  “Quad 200-MHz Constant-Fraction Discriminator”

- Phillips Scientific
  Logic Unit: #754, 755, … (up to 300 MHz)
  Discriminator: #704, 708, … (up to 300 MHz)
  Amplifier: #774, 775 (0.1 MHz ~ 1.8/1.5 GHz)

- Level Translator
- Gate and Delay Generator
  (60 Hz Synchronizer, Fast Level Converter, …)
New 2856 MHz system

Arbitrary Waveform Generator

Frequency multiplier (x32)
AWG

SONY-Tektronix : AWG2041
Ortel Co.
E/O: 3510A
O/E: 4511A

patch pannel
Electron gun trigger system
MC10E136

6-Bit Universal Up/Down Counter

The MC10E100E136 is a 6-bit synchronous, presettable, cascadeable universal counter. The device generates a look-ahead-carry output and accepts a look-ahead-carry input. These two features allow for the cascading of multiple E136's for wider bit width counters that operate at very nearly the same frequency as the stand alone counter.

- 550 MHz Count Frequency
- Fully Synchronous Up and Down Counting
- Internal 75 kΩ Input Pulldown Resistors
- Look-Ahead-Carry Input and Output
- Asynchronous Master Reset
- Extended 100E VEE Range of -4.2 V to -5.46 V

The CLOUT output will pulse LOW for one clock cycle one count before the E136 reaches terminal count. The COUT output will pulse LOW for one clock cycle when the counter reaches terminal count. For more information on utilizing the look-ahead-carry features of the device please refer to the applications section of this data sheet. The differential COUT output facilitates the E136's use in programmable divider and self-stopping counter applications.

Unlike the H136 and other similar universal counter designs the E136 carry out and look-ahead-carry out signals are registered on chip. This design alleviates the glitch problem seen on many counters where the carry out signals are merely gated. Because of this architecture there are some minor functional differences between the E136 and H136 counters. The user, regardless of familiarity with the H136, should read this data sheet carefully. Note specifically (see logic diagram) the operation of the carry out outputs and the look-ahead-carry in input when utilizing the master reset.

When left open all of the input pins will be pulled LOW via an input pulldown resistor. The master reset is an asynchronous signal which when asserted will force the Q outputs LOW.

The Q outputs need not be terminated for the E136 to function properly, in fact if these outputs will not be used in a system it is recommended to save power and minimize noise that they be left open. This practice will minimize switching noise which can reduce the maximum count frequency of the device or significantly reduce margins against other noise in the system.
Note that this diagram is provided for understanding of logic operation only. It should not be used for propagation delays as many gate functions are achieved internally without incurring a full gate delay.
Underground temperature

Variation of Underground Temperature at the SPring-8 Storage Ring

- d = -0.5 m
- d = -3.0 m
- d = -5.0 m
- d = -10.0 m

Temperature [deg]

Year
1997/01 1998/01 1999/01 2000/01 2001/01 2002/01