BEAM SYNCHRONIZATION FOR TRISTAN AR

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ABSTRACT

The single bunched electron beam from the 2.5 GeV linac has been injected successfully into the accumulating ring and accumulated for a long time. The pulse width of the bunch is less than 2 nano sec, and the repeat injections into one of 640 RF buckets have done well. It is possible to select freely any one of the 640 RF buckets. The revolution frequency of the accumulating ring can be generated where it is required.

INTRODUCTION

The accumulating ring (AR) of TRISTAN accumulates and accelerates single bunched beams which are injected from the electron and positron linac (Linac). The positron linac is under construction. Revolution frequency of the AR (f_{REV}) is 795 KHz; Harmonic number is 640; RF frequency (f_{AR}) is 508.58 MHz. As repetition frequency of the Linac operation has no relation with the RF frequency of the AR, the synchrnization between the Linac beam and the RF bucket of the AR is required. The AR orbit has 640 RF buckets at intervals of about 2 nano sec. So the beam pulse width of the injected beam must be less than 2 nano sec. Timing accuracy of the synchronization must be less than $\sim$ 200 pico sec, and it is necessary to be able to select freely any one of the 640 RF buckets and to repeat the injection into the same bunch until it is filled enough.

In the case of collision of the accumulated electron and positron on the AR or beam transfer from the AR to the MR (main ring), the bucket selection mentioned above is one of the important functions.

Distribution and transmission of the AR revolution frequency signal are required for the beam monitor and the main ring injection. Its rise-time must be kept less than $\sim$ 2 nano sec in the transmission of about 600 m. For this purpose, the signal; f_{REV} is generated by a frequency divider dividing the 508 MHz RF frequency where it is required.

As the Linac beam is also used for the Photon Factory (PF) 2.5 GeV storage ring dedicated to the synchrotron radiation research, it must be considered carefully that the cahnge of the operation modes goes on smoothly[1]. The operation of the PF ring is different from the AR. The revolution frequency and the RF frequency of the PF ring are 1.6 MHz and 500.105 MHz respectively.

SCHEME OF SYNCHRONIZATION

A schematic diagram and a time chart of the synchronization are shown in Fig. 1 and Fig. 2 respectively. The AR RF frequency is divided by 640 and we get the AR revolution clock which is the reference signal of the synchronization. In the synchronizer the repetition frequency of the Linac is synchronized with the f_{REV}, that is, the phase of the Linac repetition frequency signal is shifted to coincide with that of the f_{REV} (Fig. 2). At first, the synchronizer generates a pre-trigger pulse for the Linac klystrons and the AR kickers about 100 μsec in advance of the gun trigger. And then, it generates the gun trigger pulse at several integer times the revolution period after the pretrigger. After all, we find that both of the pretrigger and the gun trigger are synchronized with the AR revolution frequency.

In order to generate the AR revolution frequency at the Linac control area, the f_{AR} is tranmitted there from the AR west hall through the temperature compensated coaxial cables of about 900 meters length and amplifiers. By means of the frequency dividier, the RF frequency is divided by 640 and we get the revolution clock which gives one of the 640 RF buckets on the AR. We call it the bucket address "#0". A symmetrical bucket of "#0" is the bucket address "#320" (Fig. 3).

In an "alternate mode", the address #0 or #320 is selected alternately every time the beams are injected.

The 508 MHz digital delay is used to select an arbitary address. It is necessary for the e^+/e^- col-
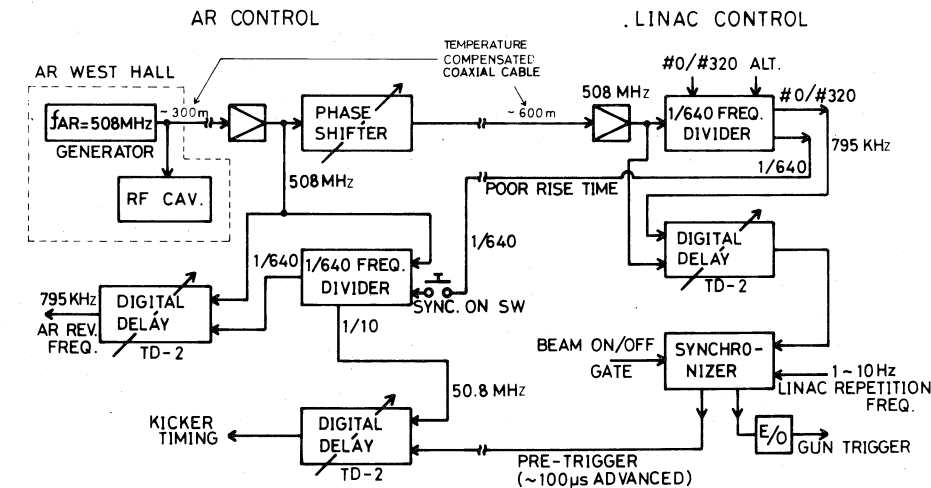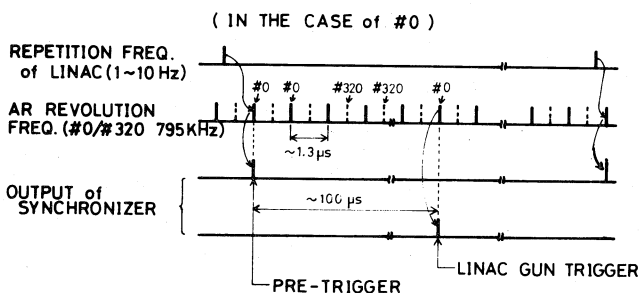
Fig. 2 Time chart of the synchronization.
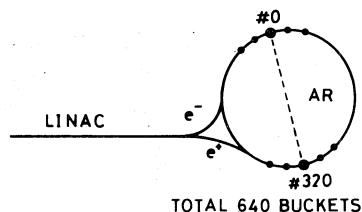
Fig. 1 Scheme of the synchronization.

Fig. 3 Bucket address on the AR orbit.

lision at a specified point on the AR and for the injection into the main ring. The RF phase angle to the injected beams is adjusted by a phase shifter which is located between the RF generator and the frequency divider.

The AR revolution clock is used in the AR area for diagnostic measurement of the accumulated beam and for beam-transfer into the MR. It is, however, difficult to transmit the revolution clock from the Linac area to the AR area keeping good rise-time ($\sim$ 1 nano sec). So we generate the revolution clock by using another frequency divider which is synchronized instantaneously with the poor rise-time revolution clock transmitted from the Linac area. Though there is a slight phase difference between the synchronized revolution clock and the true one in the Linac area, the stability of the phase is assured, and the fast rise-time pulse signal of the revolution clock is available in the AR area.

All the functions mentioned above are controlled remotely from the console at the control room through the computers and the CAMAC system.

When the two single bunched beams (#0, #320) accumulated by the AR are transfered to the MR, the frequency difference ($\sim$ 1 KHz) between the f_{AR} and the f_{MR} (RF frequency of the MR) is required to move the #320 bunch beam position by shifting the RF phase. Because the MR circumference is eight times as long as the AR. Therefore, after one (#0) of the two single bunched beams is transfered to the MR, another (#320) can not be transfered to the colliding point on the MR, if the f_{MR} is equal to the f_{AR}. In order to detect the phase coincidence between the AR's f_{REV} and the MR's f_{REV}, a high resolution coincidence circuit is being developed for the MR injection.
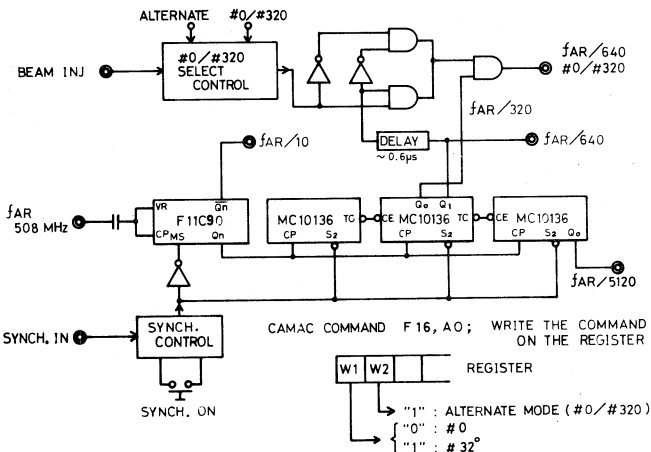

Fig. 6 The 508 MHz digital delay.
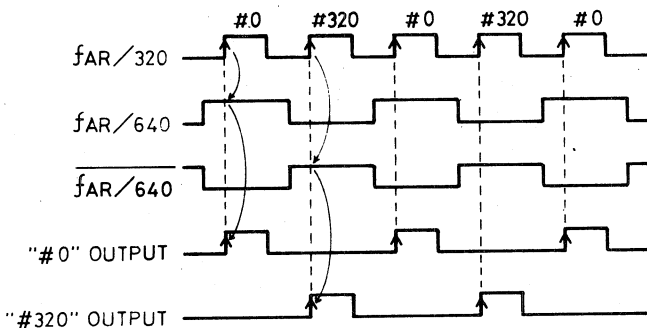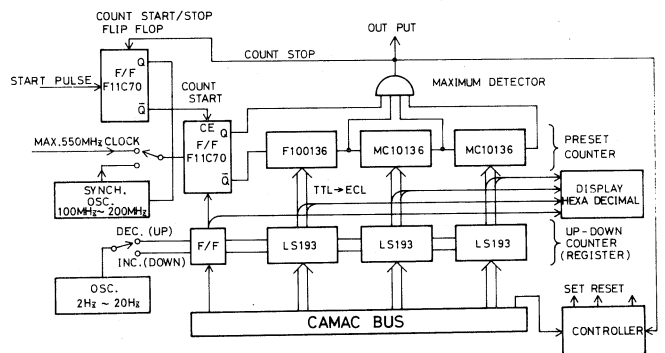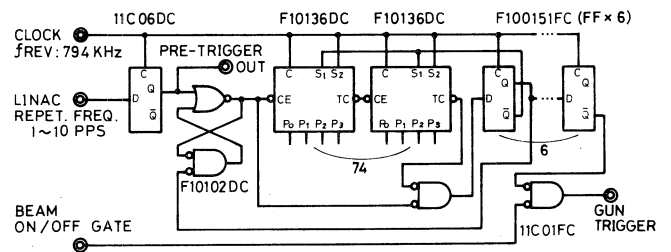

Fig. 7 The synchronizer.

ELECTRONICS FOR SYNCHRONIZATION

Frequency divider

Fig. 4 shows the schematic diagram of the frequency divider (CAMAC module) which is composed of high speed integrated ECL circuits containing a 508 MHz pre-scalar (F11C90) and counters (MC10136). As shown in the time chart (Fig. 5) an output signal of 508 MHz/320 is gated by that of 508 MHz/640. The gate signal (508 MHz/640) of normal or inverted phase gives the address "#0" or "#320" of the RF buckets respectively. When the "alternate mode" is selected, the output signal of the address #0 and #320 goes out alternately every time the Linac beam is injected into the AR. It is possible for the frequency divider to start to work synchronized with an external signal by pushing a synch. switch button.

508 MHz digital delay module[2]

This module is used to delay a pulse signal synchronized with the f_{AR}: 508 MHz. As it has a 508 MHz preset counter, the minimum step of delay time is about 2 nano sec (Fig. 6).

It is a single width CAMAC module which has high speed integrated ECL circuits and a multiplayer circuit board (five layers). As the preset counter is a 13 bit binary one, the maximum preset number is 8191 and the maximum delay time is about 16.38 μsec in 2 nano sec step.

Synchronizer

It generates a pre-trigger pulse and a gun trigger pulse synchronized with the AR revolution frequency as shown in Fig. 7 and Fig. 2. The down counter F10136DC's and the flip-flop F100151FC are preset the number 74 and 6 respectively. After the pre-trigger goes out, it counts the revolution clock by 80 counts in total and the gun trigger goes out. The time difference between the pre-trigger and the gun trigger is about 100 μsec. The jitter of the output trigger pulse to the revolution clock is less than 100 pico sec.

RESULTS

It is necessary to compare the output trigger pulses of the synchronizer with the phase of the AR
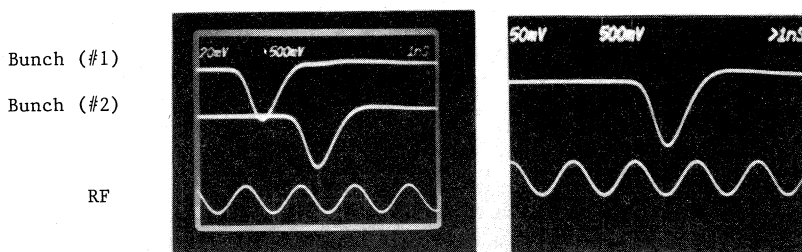

Fig. 4 The frequency divider.

Fig. 5 Time chart of the frequency divider.

Bunch (#1)

Bunch (#2)

RF

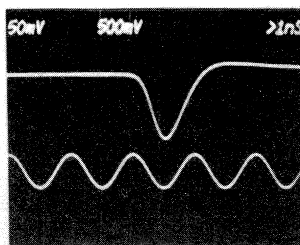Fig. 8 Bunched waveforms
and RF waveform.

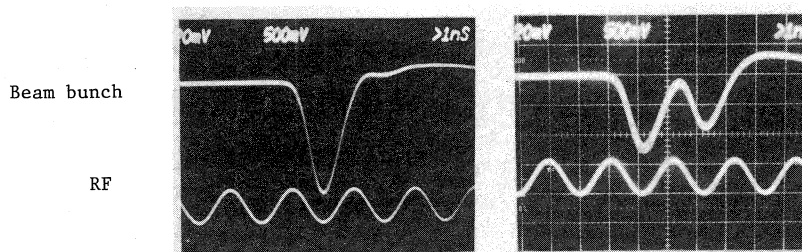Fig. 9-A At 60° phase shift.

Beam bunch

RF

Fig. 9-B At 120° phase shift.   Fig. 9-c At 180° phase shift.
Fig. 9   Bunch waveforms in the case of the RF phase shift.
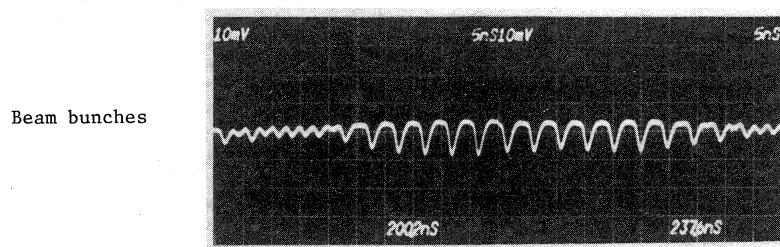
Beam bunches

Fig. 10 Effect of 20 degree RF phase shift.
(0° ∿ 360° in 20° step, 12 pulses/bunch).

master generator for measurement of jitter and drift between them. However, it is difficult because the distance between the master generator and the synchronizer is farther than 900 m. So we can see these only by ovbserving the injected beam into the AR.

Single bunch waveforms of the fast current monitor are illustrated in Fig. 8. More than 20 pulses of the Linac beam are injected into the same bucket. The observed signal shows sufficiently a single bunch shape together with the RF waveform. A middle waveform in Fig. 8 is the single bunch beam shifted by one bucket address using the digital delay. While the beams are injected into a same bucket for three days, we can not find double bunch beams caused by the phase drift of the injected beam.

When the phase of the f_{AR} is shifted by 180° using the phase shifter, the injected beams are separated into double bunches as shown in Fig. 9-C. At 60° shift of the RF phase, a beam bunch doesn't appear at the next bucket (Fig. 9-A). As the injected beams out of the RF bucket are not captured and spilled out, we can not estimate the phase stability of the synchronization by the fact mentioned above. At 120° shift of the RF phase, a little beam bunch appears at the next bucket (Fig. 9-B). So it is certain that the drift and jitter of the phase are less than ± 120°.

Fig. 10 shows the beam bunch waveform that is formed by twelve times injections per bunch from the Linac, shifting the RF phase from 0° to 360° in 20° step successively, and simultaneously increasing the address number by two. We find that the phase shift of 20 degrees affects the injected beam intensity if the Linac beam intensity is constant during the injection. So it can be estimated that the beam pulse width from the Linac is nearly 2 nano sec.

In the case of the positron injection from the Linac to the AR, it is expected that the pulse width of the injected positron bunch is as short as possible to prevent the beam loss on the AR. Because the positron intensity from the Linac will be very low compared with the electron.

REFERENCES

1) Photon Factory Activity Report 1982/83 National Laboratory for High Energy Physics, KEK.
2) Digital delay CAMAC module with 550 MHz preset counter (TD-2), K. Ishii, KEK-83-14, September 1983 A/I.