10.2 BCD Proposal: Timing System

Overview

Precision timing is needed throughout the machine to control RF phase and time-sampling beam instrumentation. The Timing System is envisaged to emulate the architecture of the control system with a centrally located dual redundant source phase-locked to a satellite reference, distributing redundant fiber signals to all machine sector nodes for further local distribution. Timing is phase locked to the RF system and stability at the point of RF measurement and control has to be ~10 picoseconds, and for the bunch compressor short-term stable to ~100 femtoseconds. The system will be designed to auto-failover in the event of a link failure between main control and a remote node. The fibers are temperature compensated to achieve phase stability by use of a shorter series section of fiber in a temperature controlled environment. The system builds on prior investigations done at NLC and uses commercial off-the-shelf components.

1. Baseline Configuration

1.1 Functions

Global timing provides

a. Master oscillator distribution (1.3 GHz)
b. 5 Hz timing fiducial distribution
c. Programmable triggers for field hardware
d. Mechanism to synchronize software processing to timing events
e. Time fiducials for synchronized timestamps for software and hardware events.

1.2 Key parameters that influence Timing

Bunch Compressor Phase Tolerance	0.03 to 0.1 degrees at 1.3 GHz
Inter-linac timing tolerance	100 femto-seconds

1.3 Description

The timing system will be fully redundant. The master oscillator and 5Hz timing fiducial will be distributed in a star configuration to sectors via redundant active phase stabilized fibers. Required timing triggers and other frequencies will be developed locally at sector locations. Figure 1 is a block diagram of the central timing distribution system.

10.2 BCD Proposal: Timing System

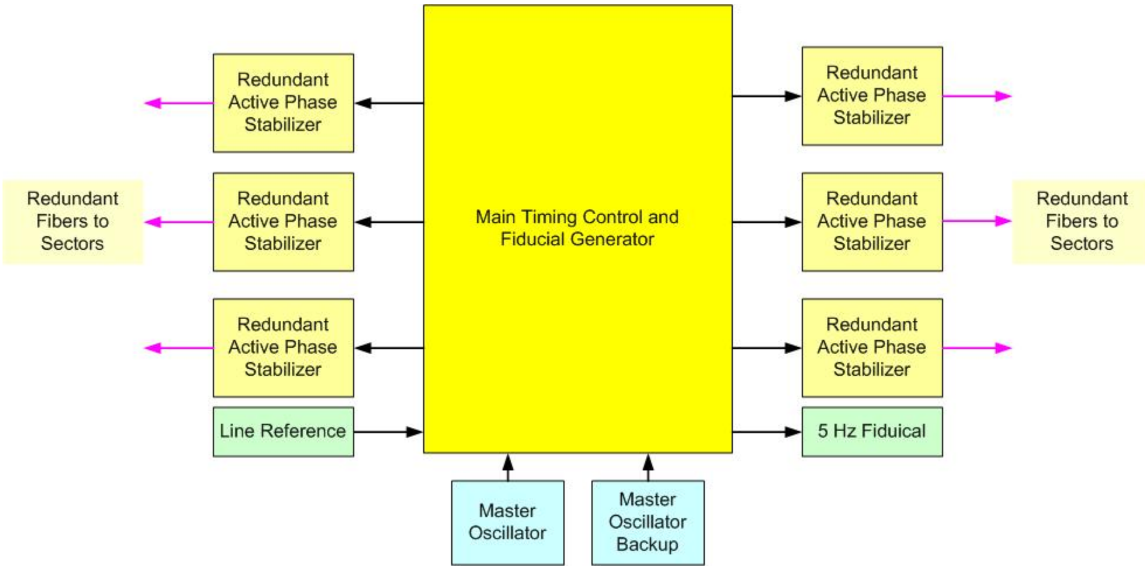

Figure 1. Block diagram of main timing showing star distribution of master oscillator and 5 Hz fiducial.

Figure 2 shows distribution of timing references to local controllers and the LLRF system.

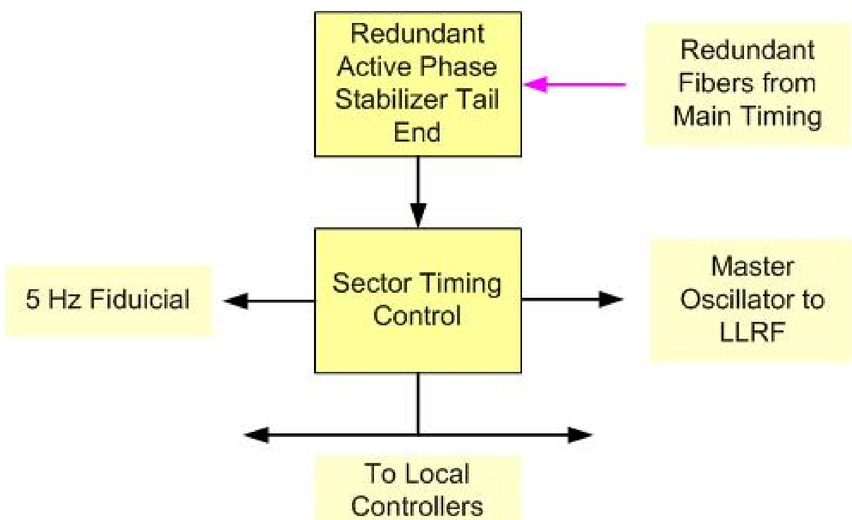

Figure2. Sector Timing Distribution

10.2 BCD Proposal: Timing System

2. Features Summary

2.1 Master 0scillator/ 5 Hz timing fiducial distribution

The master oscillator will be distributed via dual redundant fiber optic links in a star configuration to each sector. Each link will use a phase stabilization scheme similar to that described in reference 2. The 5Hz timing fiducial will be encoded within the master oscillator waveform by a momentary phase shift.

2.2 Programmable triggers for field hardware

The master oscillator and 5 Hz fiducial will be processed by a local module to produce programmable triggers for field device. Individual triggers will be produced by counting down the master oscillator or a lower derived frequency where appropriate to produce required triggers. Additional programmable delays will be provided where necessary. A graded approach to triggers will be used depending on the particular requirements;i.e., high precision (pico-second) timing will be provided for devices such as kickers, medium precision (nano-second) for devices such as septa and low precision (microsecond) for non time critical applications.

Additional frequencies (3MHz for injector, damping Ring RF (TBD), damping ring revolution clock (TBD), 54 MHz (lasers)) will be generated where needed by synchronous digital dividers operating off the received master oscillator. These additional frequencies will be phased to the 5 Hz fiducial.

2.3 Synchronizing software processing to timing events

A means of synchronizing software processing to timing events will be provided. This may be done by encoding events on the master oscillator distribution but this may affect overall received master oscillator stability. A separate event link may be used as is done at APS and SLS. Event system modules are commercially available. The event system rate could be synchronous to a subharmonic of the master oscillator if desired. A third method is to use a local module to count down a subharmonic of the master oscillator to generate interrupts at desired times.

2.4 Synchronized time stamps for software and hardware events.

It is desirable for all remote processors, whether embedded or not to have the same concept of time; i.e., have their time-of-day clocks synchronized to a common source. This feature has been provided in the past by the timing event system. A similar capability is needed for the ILC. The time-of-day clock in conjunction with special timing hardware at each remote processor can provide synchronized time stamps to the microsecond or better resolution.

A pulse ID number will be developed that identifies pulses within the 1 millisecond pulse train. This ID number will accompany data relating to individual pulses.

The timing system also provides timing references to the MPS system to time stamp hardware events to aid in unraveling cascades of trips.

10.2 BCD Proposal: Timing System

2.5 Other

It is anticipated that global timing will be line-locked.

2.6 Present State of the art

Reference 2 gives results of a fiber stabilization scheme that reported short term stabilities of +/- 750 femtoseconds and jitter of 250 femtoseconds RMS in a band of 10 seconds to 10 kHz. Reference 3 describes a scheme for delivering phase stable rf reference to antennas located as far as 15 km from the source. The frequencies involved are considerably higher (27 – 142 GHz) and the integrated phase noise measured at 81 GHz is 0.018 radians from 1kHz to 10 MHz offset.

Timing event system hardware modeled on the APS system is commercially available from reference 4.

2.7 Path to Specification

The following items need to be resolved

a. Required timing tolerances, both drift and jitter, for each of the field devices.
b. Required master oscillator stability (drift and jitter) for each RF device.
c. The location and number of master oscillator receiver nodes.
d. Interfaces between timing RF and Detectors need to be defined.

2.8 Required R&D

a. The phase stabilization scheme described in reference 1 will be prototyped using newer high performance components.
b. The bunch compressor (and perhaps devices at the interaction region) require a higher level of phase stability then the Linac RF modules. Methods to deliver such higher stability need to be studied.
c. Evaluate cost/performance of different methods of synchronizing software processing to timing events.

2.9 References:

1. Larsen, R.S. , Technical Systems Configurations -Electrical Subsystem: Instrumentation – Timing, Rev.1, March 23, 2001 http://docdb.fnal.gov/ILC-public/DocDB/ShowDocument?docid=107
2. Frisch, J., Bernstein, D., Brown, D., Cisneros, E. “A High Stability, Low Noise RF Distribution System”, Proceedings of PAC2001, pp 816-818. http://docdb.fnal.gov/ILC/DocDB/0000/000035/001/PhaseAndTiming.pdf
3. Shillue, B. “High Frequency Local Oscillator Transmission for the Atacama Large Millimeter Array (ALMA)”.

4. Micro-Research Finland Oy, http://www.mrf.fi

10.2 BCD Proposal: Timing System

3. Cost Model

The cost model will be developed from re-modeling of the previous bench prototype that was successfully tested for the NLC [Ref. 2]. A complete system design needs to be modeled with the machine sector model, numbers of distribution points from each node per sector, fibers and cables, and temperature – phase compensation. A bottom-up system cost model will be produced following cost estimating rules of the GDE.

4. Alternate Configuration

No alternates under active consideration at this time.