Stanford Linear Accelerator Center
Stanford Synchrotron Radiation Laboratory

LCLS Specification # 1.1 - 305	**LCLS Timing System Requirements - DRAFT**

LCLS Physics Requirements Document # 1.1 - 305	**Controls**	**Revision 0**

LCLS Timing System Requirements

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Brief Summary: This specification describes the role of the timing system in the LCLS and its performance requirements. The timing system is inherently associated with the low level RF system and control system of the existing SLAC accelerators. Compatibility with multiple beam programs at SLAC requires that the LCLS precision timing also communicate with existing systems.

Keywords: Timing, controls, trigger, diagnostics, beam code.

Key WBS#'s:

The role of the timing system in the LCLS is to provide synchronization between a number of processes:

- The injection of the electron bunch into the accelerator.
- Energizing pulsed devices like klystrons and pulsed magnets.
- Data acquisition from diagnostic devices such as BPMs to coincide with the passage of the beam pulse.

The LCLS will operate in conjunction with other beam programs at SLAC which will continue to use the existing SLC control system. The LCLS timing controls therefore need to retain compatibility with the existing timing system.

The timing is to be synchronized with both the SLAC 476 MHz reference RF signal and the 360 Hz power line frequency. This is implemented at SLAC through the generation of 360 Hz timing fiducials on a 476 MHz carrier broadcast on the Main Drive Line (MDL) running the entire length of the accelerator. This signal can be tapped and detected at each of the 30 sectors along the accelerator. This is shown in a simplified schematic diagram in figure 1.

Synchronization is also required with the digital control system through the SLAC PNET data line. In order for LCLS to operate side-by-side with the multi-functioning main linac and associated beam lines and storage rings, the LCLS control system must receive the beam code information from the SLC system. The beam codes allow the accelerator pulsed power devices and data acquisition system to be triggered according to the rate requirements of the beams to different users. The SLC control system distributes this beam code information via a Master Pattern Generator (MPG) which broadcasts a 128-bit word at a rate of 360 Hz over a dedicated network, PNET. The LCLS control system is therefore required to incorporate a PNET receiver to interpret SLC beam codes for the EPICS timing distribution. The EPICS timing distribution is able to synchronize operations between different IOCs and control the sequencing of various processes.

The fiducial generator also provides a 119 MHz phase-locked clock signal which is the 4th subharmonic of 476 MHz. The 119 MHz clock cycles can be counted so that the coarse timing can be stepped in units of the clock cycle, 8.4 ns. The 119 MHz is an ordinal frequency for the accelerator system. The RF Photoinjector uses a gun laser with an oscillator frequency of 119 MHz. The timing system with its 119 MHz step resolution is therefore able to select any of the 119 MHz light pulses from the oscillator.

In some cases a finer control of the timing step size is required. The laser pulse selected from the 119 MHz train is injected into an S-band 2856 MHz bucket of the linac RF system. These frequencies are in the ratio 24:1 so the timing must also provide a means of selecting which S-band bucket contains the electron bunch. In the injector the S-band bucket number is determined by the fixed phase relationship between the 119 MHz laser oscillator and the 2856 MHz RF signal. However, diagnostic instrumentation such as oscilloscopes used to simultaneously observe the laser pulse amplitude and a BPM signal need to be triggered on a predetermined S-band bucket, whose spacing is 350 ps. Since the electron bunch length at the injector is 10 ps we are requiring a fine timing step resolution of <20 ps with a maximum of 2 ps rms jitter. Triggers from the timing vernier will also be required for pump-probe measurements of the electron bunch at the end of the accelerator and the x-ray pulse at the end of the undulator. In this case the downstream 119 MHz laser oscillator can lock to an arbitrary S-band bucket. The vernier timing system will allow the user to reproducibly find and lock to the same 2856 MHz RF bucket occupied by the electron bunch.

The maximum trigger rate is specified as 360 Hz even though the maximum beam rate for LCLS is only 120 Hz. This is to allow operational flexibility in choosing the “time slot” in which the LCLS beam is injected. Triggers are synchronized to the 360 Hz AC mains frequency which can be divided up into 6 timeslots of 60 Hz. In order to avoid conflicts with other users in the accelerator the LCLS will operate on different time slots than, for example, PEPII operation. The types of conflicts we avoid this way are transient power loading and transient disturbances to the 476 MHz MDL frequency during PEPII injection cycles. This means that some LCLS pulses could be separated from other user pulses by as little as 1/360th second. The 360 Hz trigger rate also makes available “interstitial” triggers between beam pulses that can be used, for example, by the BPM processor module for calibration cycles when the beam is not present.

Table 1: Timing system parameters

Maximum trigger rate	360 Hz
Clock frequency	119 MHz
Clock precision	20 ps
Coarse step size	8.4 ns ± 20 ps
Delay range	>1 sec
Fine step size	20 ps
Maximum timing jitter w.r.t. clock	2 ps rms
Differential error, location to location	8 ns
Long term stability	20 ps

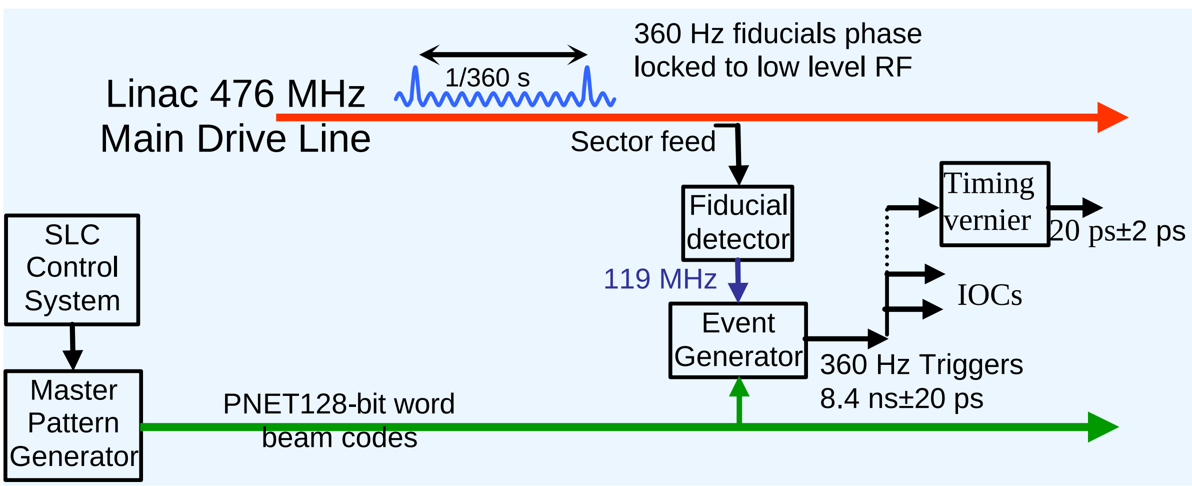

Figure 1: Simplified schematic relationship between components of the timing system