Dune DocDB 11224 v1 **Version 31/October/18**

DUNE Interface Document: Timing

Definition: This document describes the interface between the central timing system and the components of DUNE that it synchronizes. Because the timing system connects to almost all detector systems and has a uniform interface to each of them this document describes all interfaces (rather than being a set of bilateral interface documents). This document describes the necessary interfaces for both timing system and the detector subsystems needed to complete the design, fabrication and installation of their subsystems. This document describes the elements of the scope of each subsystem at the interface between them. Only the single phase and dual phase far detector designs are considered.

Introduction: There is a single central timing system with redundant connections to GPS/GLONASS antennae. The GPS/GLONASS timing information is decoded and allows the DUNE detector to be synchronized to the accelerator time-base at FNAL. Because the single phase and dual phase detectors have widely differing numbers of "end points" that need synchronization, and have different development histories, different protocols are used to communicate with the different detector elements. Single Phase detector elements are synchronized with a development of the ProtoDUNE Timing System (PDTS). Dual Phase detector elements are synchronized with the White Rabbit implementation of the IEEE1588-2008 protocol.

Clock Frequency: The master clock frequency of the DUNE Timing System (DTS) is 125MHz (derived from GPS/GLONASS). For the single phase detectors this is divided down to 62.5MHz

Data Timestamping: All detector components will time-stamp their data using the time-base distributed by the DUNE timing system. The timing system will provide the tools to map between PDTS time-stamps at the end-points, IEEE1588 time-stamps at the end-points and UTC. The round-trip time from the surface to the CUC will be calibrated using fibres in the same bundle as the fibres carrying the GPS signal.

Single Phase Detector:

Protocol: Timing and synchronization messages are distributed encoded using the ProtoDUNE Timing System (PDTS) protocol (DUNE-doc-1651-v3)

Physical Layer: Timing and synchronization messages are distributed on OS2 single mode fibre. The timing system will use 1000Base-BX-20 SFP modules which transmit at 1310nm and receive on 1550nm. The timing end-points on the detector will use matching 1000Base-BX-20 SFP modules which transmit at 1550nm and receive on 1310nm.

Downlink: The timing system will normally transmit continuously. This is to allow end-points to receive a clock even outside of a run. However, the end-points must have the capability of recovering from an interruption in the timing data stream.

Uplink: Each timing end point will implement the parts of the PDTS protocol needed to respond to status requests and delay adjustment commands. If an end point is unable to do this then steps will be taken to ensure that the end point to timing system laser is disabled.

Fault Tolerance: Any hot-swap or other redundancy in the part of the timing system distributing signals to the single phase detectors will be handled within the central timing system.

Dual Phase Detector:

Protocol: The central timing system will communicate with the Dual Phase detector readout sytem using the IEEE1588-2008 protocol

Physical Layer: The IEEE1588 traffic will be transmitted over OS2 single mode fibre. Unless otherwise agreed between the timing system and dual phase detector groups electrical<--> optical conversion will be done by 1000Base-BX modules selected from the list of "compliant" SFP modules given on https://www.ohwr.org/projects/white-rabbit/wiki/SFP

Fault Tolerance: Two independent links, each fed from an independent GPS/GLONASS receiver, will be provided to the dual phase readout system by the timing system. Any fault tolerance mechanisms involving selecting between the two links will be done within the dual phase readout system.

Calibration Systems: Timing and synchronization signals will be provided to the DUNE calibration systems using the PDTS protocol. The physical layer will be the same as for the single phase detector end points. The calibration systems used for dual phase and single phase detectors will use the same timing interface. Low latency synchronous commands, for example to fire laser pulses, will be distributed over the timing system. Fast feedback (for example, the actual time at which the laser fired) will be fed back to the DAQ through the timing system. Prompt asynchronous information from the calibration systems (for example, data from radioactive decays) will also be passed to the DAQ through the timing system. The rate of asynchronous messages should not exceed 100kHz or 100MBit/s per end-point, whichever is greater. The size of each asynchronous message should not exceed 10kBit. Each message should be timestamped.

Time Base Accuracy:

Global Accuracy: The time stamps delivered to the detector endpoints will be accurate to +/- 500ns of UTC.

Within Detector: The time stamps delivered to any two end points within a single phase detector cavern will be synchronized to better than 10ns on average. The accuracy with which detector elements in a dual phase cavern are synchronized is dependent on the White Rabbit network chosen by the dual phase readout system consortium. However, it is anticipated that any two end points in a dual phase cavern will be aligned to better than 10ns on average.

Between Detectors: The time stamps delivered to dual phase and single phase caverns will differ by less than 25ns on average.

Clock Jitter: The clock jitter delivered by the timing system to single phase end points will be less than **TBD** ps RMS integrated over **TBD** Hz to **TBD** Hz.

Power-on initialization and Start of Run setup: The timing system will require initialization and setup on power-on. Before this is done no timing signals (and hence no clock) will be produced. At start of run the timing system will issue a start of run command. Power on initialization will not **require** communication with the DAQ, but will have the **ability** to be controlled by the DAQ.

Monitoring:

Slow Control: The timing system will continuously monitor parameters such as signal strength from the antennae, optical power levels transmitted and received by different parts of the system, temperature and voltage levels at multiple components in the system, etc. The difference between the times received by the two independent GPS/GLONASS receivers fed from the two independent antennae at the head of the Ross and Yates shafts will be continuously monitored. All monitored quantities will be transmitted to the Slow Control system for display and recording. The slow control system will be responsible for producing any error messages, or other user interaction,

Local Monitoring: The timing system may have systems for local control and debugging. Any network or computing infrastructure needed for this is the responsibility of the timing system.

Software: Software in the artdaq framework, together with scripts for testing, will be provided by the timing system.

Integration: Various integration facilities will need small instances of the DUNE timing system, including vertical slice tests stands, cold electronics test stands, DAQ test stands and system integration/assembly sites. For single phase and calibration systems the DAQ consortia will provide timing system software, hardware reference designs, and timing system components (for a list of instances that will be negotiated with the DAQ consortium). For the dual phase this will be unnecessary, since the dual phase readout is able to operate with stand alone timing.

Responsibility for purchase / testing / installation: TBD

Modification history:
Version v1 (31 November 2018): initial document.