100 Hz DATA ACQUISITION IN THE TANGO CONTROL SYSTEM AT THE MAX IV LINAC

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Abstract

The MAX IV synchrotron radiation facility is currently being constructed in Lund, Sweden. A linear accelerator serves as the injector for the two storage rings and also as the source of short X ray pulses, in which mode it will operate with a 100 Hz repetition rate. The controls system, based on TANGO, is required to collect and archive data from several different types of hardware at up to this 100 Hz frequency. These data are used for example in offline beam diagnostics, for which they must be associated to a unique electron bunch number. To meet these requirements, the timing performance of the hardware components have been studied, and a TANGO Fast Archiver device created. The system is currently in the deployment phase and will play an important role in allowing the linac and Short Pulse Facility reach their 100 Hz design goal.

INTRODUCTION

The accelerator complex at the MAX IV laboratory consists of a 3 GeV, 250 m long full energy linac, two storage rings of 1.5 GeV and 3 GeV and a Short Pulse Facility (SPF). The repetition rate of the linac is a maximum of 10 Hz when serving as the injector for the rings and 100 Hz when providing pulses for the SPF.

The control system has a three-tier architecture, with specific hardware handling the real-time tasks and TANGO [1] representing the middle tier as the primary control system. Most equipment is interfaced directly to TANGO via TCP/IP. For the client layer, physicists and operators can interact with TANGO via its Python and MATLAB bindings or through the SARDANA [2] layer, which brings a macro server and standardised Graphical User Interfaces based on TAURUS [3].

In the operation of the linac it is necessary to be able to archive data through the TANGO system at the repetition rate or bunch frequency of the electrons. For example, oscilloscope devices connected to Current Transformers at various locations along the length of the linac are used to record the distribution in time of the charge of the passing electron bunches. These waveform data will be used, for example, in the offline diagnosis of any beam loss. The capturing of information from the control system at high frequency is referred to as Fast Archiving, since it must perform at up to 100 Hz to record every electron bunch when the linac is operating in SPF mode. The same system will also be used to read data from the linac and the storage rings at 10 Hz, where it will be used, for example, in the Slow Orbit Feedback system.

The work that is reported here has so far focused on the integration of TANGO devices for controlling oscilloscopes into the Fast Archiver, though the inclusion of other equipment such as power supplies is foreseen in the future. The first section of the report documents how the performance of the many devices that will participate in the Fast Archiving is being systematically measured. The second section then describes the design and functioning of the Fast Archiver and how the oscilloscope devices have been adapted for inclusion in the system.

TIMING PERFORMANCE STUDIES

Timing performance studies are being performed on the TANGO devices that will take part in the Fast Archiving. The performance studies first check that the hardware itself is capable of sending or receiving commands at a sufficiently high frequency. An example is shown in Fig. 1 for a certain type of power supply used at Max IV.

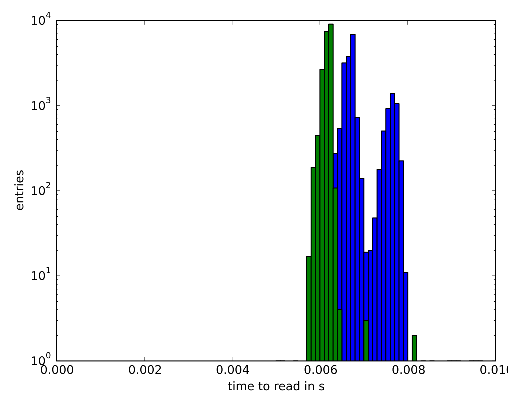

Figure 1: Distribution of time taken to read the current from a power supply over a direct raw socket connection (green) and via the “Current” attribute in its TANGO device integrated to the control system (blue).

A script is used that repeatedly reads, for example, the value of the current from the power supply hardware and plots the distribution of the time needed to receive a reply. In this example the distribution (in green) in well within the 10 ms envelope needed for 100 Hz operation. The performance of the TANGO device is then checked by measuring the distribution of the time needed to read the attribute “Current” once the device has been interfaced to the TANGO control system. The difference between the two distributions gives an indication of the overhead of the control system, including the network performance. In this case, the distribution (in blue) remains within the 10 ms envelope though adds a few ms to the “raw” performance of the hardware over a direct TCP/IP connection. It can be concluded that this hardware should be suitable for 100 Hz operation.

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At the present time we are using these simple tests to identify which devices will need improvements in their communication speed if they are to participate in the Fast Archiving in the future.

THE FAST ARCHIVER

Oscilloscope Device Adaptation

Similar studies to those described above have been performed on the Rohde and Schwarz RTO oscilloscopes [4] that are used in the linac to measure the charge-time distributions of the passing electron bunches. For these devices, the attribute of interest is the "Waveform" which is a spectrum attribute with length of up to 10,000 corresponding to the captured data from the Current Transformer hardware. This attribute can be read from all channels of the oscilloscope simultaneously in around 3 ms as shown in Fig. 2, so the hardware performance is proven to be acceptable.

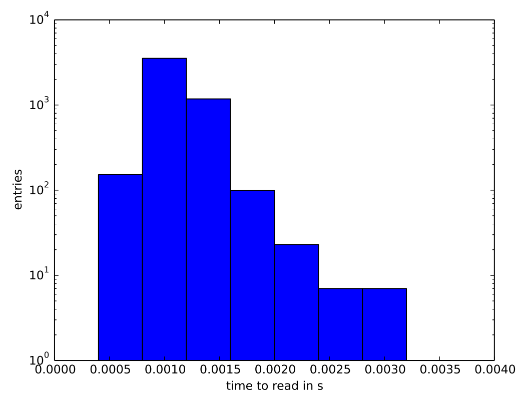

Figure 2: Distribution of time taken to read the "Waveform" attribute from the Rohde and Schwarz oscilloscope TANGO device. The device reads all four channels in the same request.

The oscilloscopes receive an external trigger synchronised with the repetition rate of the linac. Libera timing modules [5] make this trigger signal available in the TANGO system, with the Libera TANGO devices sending TANGO events as the trigger counter increments. The event system in TANGO is known to perform many times faster than 100 Hz. In the first attempt to synchronise the reading of the waveforms to the trigger counter, the oscilloscopes were configured to continually capture waveforms on the external trigger, while the TANGO device subscribed to events from the Libera. The reception of an event from the Libera prompted the request of the the waveform data, which at that moment should correspond to the previous trigger. However, to guarantee that the waveform read out corresponds to the one just captured by the hardware, this mechanism relies on the event jitter being less than around 7 ms (given the 3 ms needed to read out the waveform data) which could not be assured. A method that did not rely on the timing performance of the TANGO event system was therefore sought. The oscilloscopes are now configured to wait for the external trigger and block until a new waveform is captured. This ensures that any waveform read out after the block is released is guaranteed to correspond to the previous trigger. The TANGO device implements a thread which repeatedly runs these single acquisitions. Each time a new acquisition is made, the device sends an event containing the waveform data (and its timestamp). In this way the oscilloscopes respond to their external triggers but do not rely on any further software triggering of the readout of the waveform data; rather, the oscilloscope TANGO device is responsible for pushing events as the oscilloscope receives external triggers.

Fast Archiver Design

The purpose of the Fast Archiver is to associate data collected from any participating TANGO device to a unique electron bunch number in the linac. The bunch number (or trigger counter) comes from the Libera timing modules; as described above the Libera TANGO devices are configured to send TANGO events containing the trigger number each time it increments, and these events also contain the timestamp of the trigger. The only requirement on the TANGO devices participating in the Fast Archiving is that they send events containing the data to be archived with a timestamp, as explained above for the case of the oscilloscope device. Given these constraints, the design of the Fast Archiver system is then shown in Fig. 4.

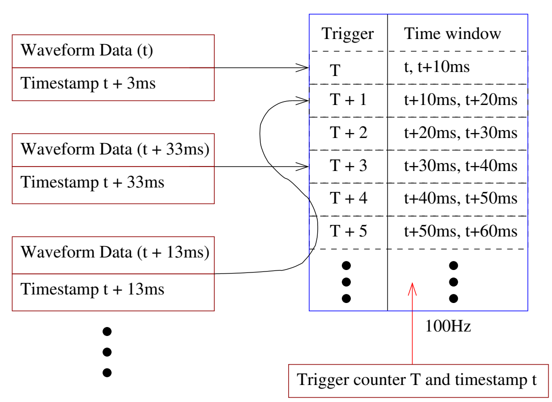

Figure 3: The Synchroniser device receives events containing the trigger counter, T, and timestamp, t, from the Libera device and events containing the data to be archived and corresponding timestamps from one or more other devices. Irrespective of the order in which the events arrive, the data to be archived can be associated with the correct trigger number by comparing timestamps. In this example, waveform data will typically arrive 3 ms after the event from the Libera.

The system comprises one or more Synchroniser devices (Fig. 3) which receive events from the Libera and also from one or more devices that are pushing data to be archived. The Synchroniser devices make the association of the data with the correct trigger number by comparing the timestamp

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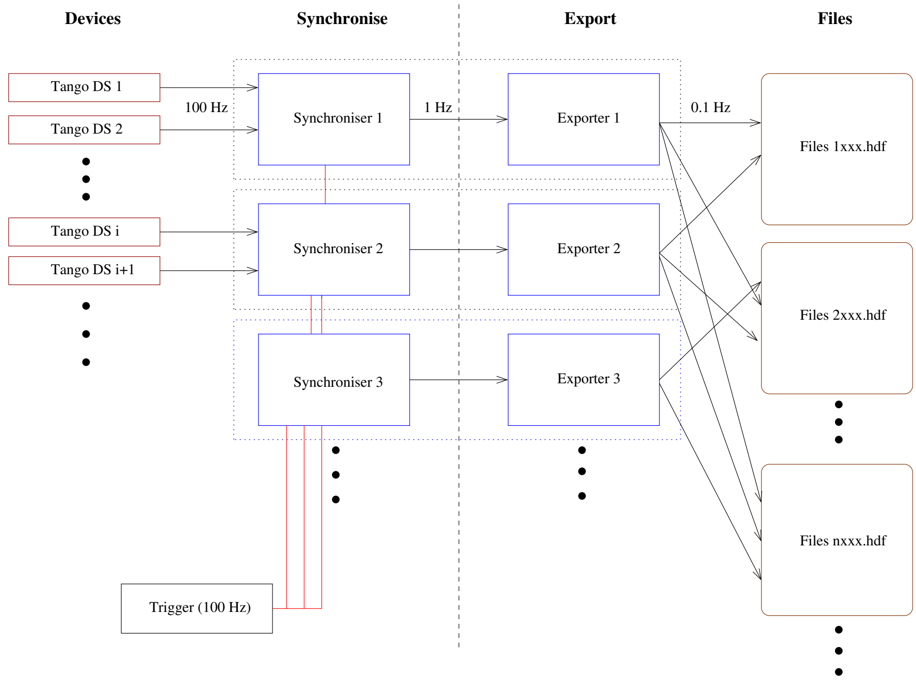

Figure 4: Design and operation of the Fast Archiver in 100 Hz scenario. Multiple Synchroniser devices subscribe to events from the participating hardware, arriving at 100 Hz. An Exporter process buffers these at 1Hz in association with the correct trigger number (see Fig. 3). Every 10 s the data, now with an associated trigger number, is written to files.

of the Libera events to the timestamps that come with the data to be archived. In this way the data from the hardware participating in the Fast Archiving becomes correctly associated with the unique bunch number, irrespective of the order in which the events arrive at the Synchroniser. A validity flag is used to handle any ambiguities in the association of the trigger number, for example if two data events arrive with timestamps that may both be matched to the same trigger.

The Synchroniser devices each implement an Exporter process, which takes the data buffered with the corresponding trigger counter and writes them to an hdf5 file. A single file is created to hold a certain number of events, and is written to by all Synchroniser devices. As such, the data from all participating hardware for a given range of trigger numbers ends up in the same file.

CONCLUSIONS

A system has been designed to allow the archiving of data from the TANGO control system at up to 100 Hz, assuming that the data orginates from devices that are capable of addressing their hardware within a 10 ms time interval and can push the data together with their timestamps as TANGO events. A single Fast Archiver device taking the data from a single oscilloscope device has been successfully tested in the laboratory at 100 Hz. For the MAX IV linac a Fast Archiver comprising 18 Synchroniser devices has been deployed. These are currently archiving 152 waveform attributes from 38 oscilloscope devices, though the maximum repetition rate of the linac has so far been 0.50 Hz.

ACKNOWLEDGMENT

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[2] SARDANA software website: `http://www.sardana-controls.org`

[3] TAURUS website: `http://www.taurus-scada.org`

[4] Rohde and Schwarz RT0 1024 Digital Oscilloscope on the R&S website: `https://www.scope-of-the-art.com/en/rto/0`

[5] Libera Single Pass E, Electron beam position processor for single pass machine: `http://www.i-tech.si/accelerators-instrumentation/single-pass-e/`

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