SYNCHRONIZED POST MORTEM TRIGGER OF THE PETRA III MPS

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Abstract

PETRA III is a high brilliance synchrotron light source operating at 6 GeV at the DESY site in Hamburg. The Machine Protection System (MPS) of PETRA III determines unsafe situations by a number of different alarms and dumps the beam if necessary. Additionally the MPS measures the beam current with a dedicated DC monitor and creates a post mortem trigger if a beam loss has been detected. This trigger is distributed to each PETRA hall synchronously and is connected to several external systems. These systems store their ring-buffer-data in case of such a post mortem trigger. Especially the beam position monitor system (BPM) benefits from this trigger. This paper describes the creation and distribution of the trigger by the MPS as well as an example of use when interpreting beam losses with collected BPM data.

INTRODUCTION

The modules of the Machine Protection System (MPS) for the synchrotron light source PETRA III are distributed over 9 halls placed alongside the PETRA ring with a circumference of 2.3 km. The MPS captures about 230 alarms from several external systems, e.g. beam position monitors (BPM), temperature alarms, vacuum shutters etc. [1] If an alarm from these system arrives at the MPS the beam is dumped within 400µs. [2] If the MPS detects a beam loss with a dedicated DC current monitor a post mortem trigger for external systems is generated. Figure 1 shows an overview of the MPS and the PETRA III machine.

MOTIVATION

Apart from the protection duty the MPS is also used for diagnostic issues. A beam loss event is created by a dedicated MPS master module if a trip in the beam current has been detected. In this case a post mortem trigger is generated and directly transmitted through the redundant optical loop to all MPS modules. Due to cable trace infrastructure between the MPS modules on the PETRA facility the total length of the optical fibres is about 13km where both loops have the same length. As a result of this the post mortem trigger is active at different times at the MPS modules distributed around the PETRA machine.

For analysis issues the MPS modules need to be synchronized to obtain a unified time scale to compare various datasets sampled by external systems using the post mortem trigger. The accuracy of the post mortem trigger at the output of the MPS modules should therefore be better than one machine turn, which is about 8μs.

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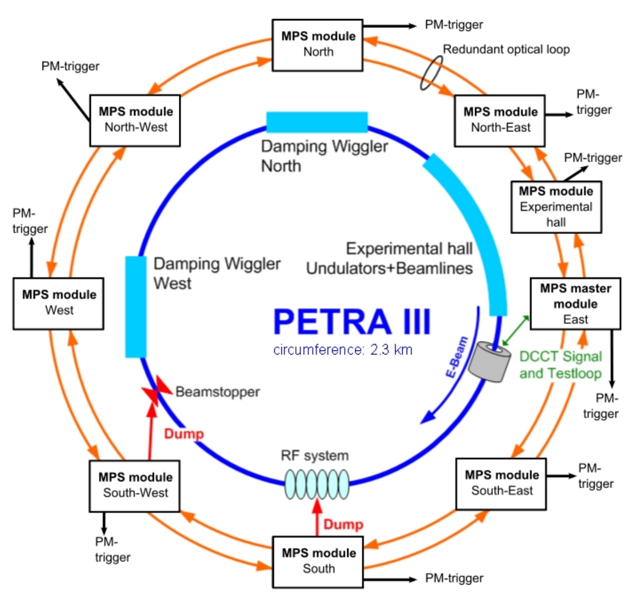

Figure 1: The MPS modules are located around the PETRA machine and are connected through a redundant optical loop. A beam loss is detected in the east hall and transmitted in both directions through the loop. The post mortem trigger is available in each PETRA hall.

SYNCHRONISATION OF THE POST MORTEM TRIGGER

To obtain a synchronized post mortem trigger the MPS modules need to be synchronized first. This is realized using the connection of the modules through the redundant optical loop.

The redundant optical loop

The data transmission inside the MPS is realized through a redundant optical loop and is controlled by one MPS master module which implements an optical frame with a repetition rate of 4μs (see Fig. 2). This frame includes the present beam current, dump information, MPS timing information and, if necessary, a post mortem timestamp. This frame is transmitted with the same content into both loops (clockwise and anticlockwise) outgoing from the MPS master module.

Establishing a synchronized clock in the MPS

To synchronize the distributed MPS modules the MPS master module implements a clock which consists of 32 Bits UNIX time and additional 32 Bits which presents steps down from 1s to less than 1ns. By using such an expanded time format it is possible to create timestamps which are accurate enough to resolve turn by turn events as well as an absolute timestamp. Furthermore, the MPS master module measures the total delay time of one complete optical loop turn (t_{total}). Both the current MPS

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master time and the total loop delay are transmitted to all MPS modules through the optical loops. Each MPS module itself measures the arrival time difference between the optical frames received clockwise and anticlockwise (t_{diff}), calculates its time offset related to the MPS master module (t_{offset}) and sets its own local clock. t_{offset} is calculated as follows:

$$t_{offset} = \frac{t_{total} - |t_{diff}|}{2} \quad (1)$$

Figure 2 shows an example of evaluating t_{total} and t_{diff} for one PETRA hall (N). Only four of nine halls are displayed in this example.

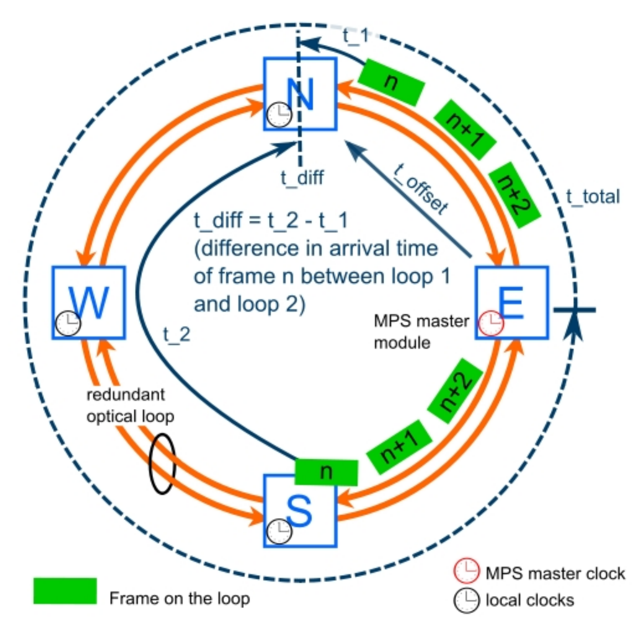

Figure 2: Example for hall N. The MPS master measures the total delay t_{total} and transmits the value to all modules through the optical loops. Each module measures the difference of the arrival time of the frames (t_{diff}) and calculates the offset between the master clock and its local clock (t_{offset}).

To prevent the local clock from skipping when a new MPS master time was received a mechanism has been implemented which tracks the local clock in small steps to the target value. Figure 3 shows the 953ns bits of four local clocks with the resulting jitter due to the tracking algorithm. This measurement was made in the lab where the single modules (1-4) were connected through various fibres with lengths of up to 500m.With the implemented algorithm a jitter of less than 1μs of the local clock could be achieved which is better than the requirement of one machine turn.

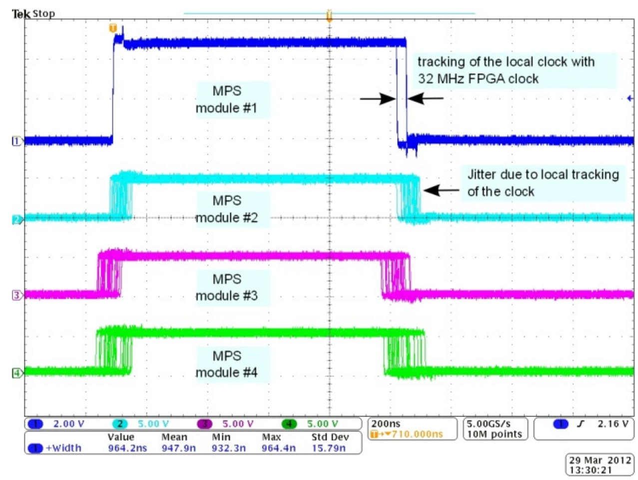

Figure 3: Comparing the 953 ns clock bits of four MPS modules connected through the optical loop with various delays due to optical fibre lengths between the single modules. The jitter of the clock bits is less than 1µs which fulfils the initial requirement. (Trigger on Ch. 1).

All these measurements and data transmissions are running permanently in the MPS hardware modules, which make the system synchronisation independent of the length of the fibre and the number of MPS modules. The protection duty of the MPS remains independent of the synchronisation part of the system.

Creating the Post Mortem trigger at the MPS module output

If a beam loss event was detected by the MPS master module a timestamp for the next post mortem trigger is transmitted through the optical loops. The MPS modules generate the post mortem trigger at their outputs at the same time. Because of to the total loop delay (about 60µs) and some spare time the post mortem trigger is generated with a fixed delay of 154µs (20 turns) after the detection of the beam loss.

USING THE SYNCHRONIZED CLOCKS

Inside the MPS

Besides the usage for the post mortem trigger, the synchronized local clocks are used to create timestamps in several distributed MPS modules when a beam loss was detected or a dump had been created. These timestamps are read out by the MPS device server which then extracts the detailed information of what occurred first. Due to the synchronized MPS modules (local clocks), time relations between dump and beam loss of less than 1µs can be resolved.

Figure 4 gives an overview which timestamps are generated by the MPS (dump and beam loss) and the time when the post mortem trigger for external systems was generated.

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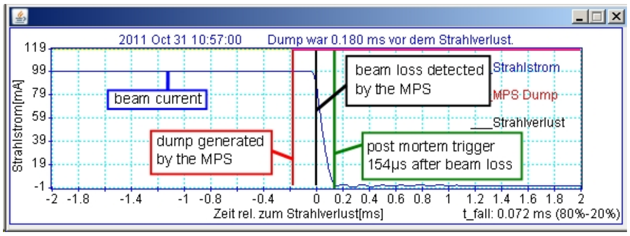

Figure 4: In case of an event the time relations extracted from the timestamps are displayed in the MPS console program. The post mortem trigger is generated 20 turns (154µs) after the beam loss and is not displayed in the console program.

Examples using the Post Mortem trigger with the BPM system

The BPMs are using the post mortem trigger to stop their transient recorders which hold 15k samples before and 1k samples after the trigger each.

Figure 5 shows BPM horizontal orbit data of a very fast beam loss caused by a manually performed dump using a kicker magnet. The orbit deflection of all BPMs is visible within one machine turn (~8µs) which indicates, that the post mortem trigger came at the same time. [3]

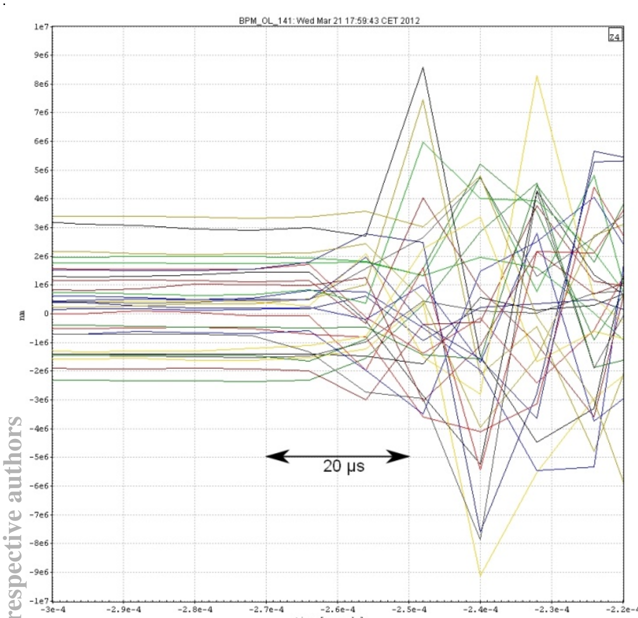

Figure 5: Orbit data of about 30 (of 225) BPMs triggered by a post mortem trigger from the MPS. The orbit deflection of all BPMs begins at the same time with an accuracy of about one machine turn.

Figure 6 shows a typical application. The horizontal orbit data of 30 randomly chosen BPMs across the PETRA machine is shown on a unified timescale. [3]

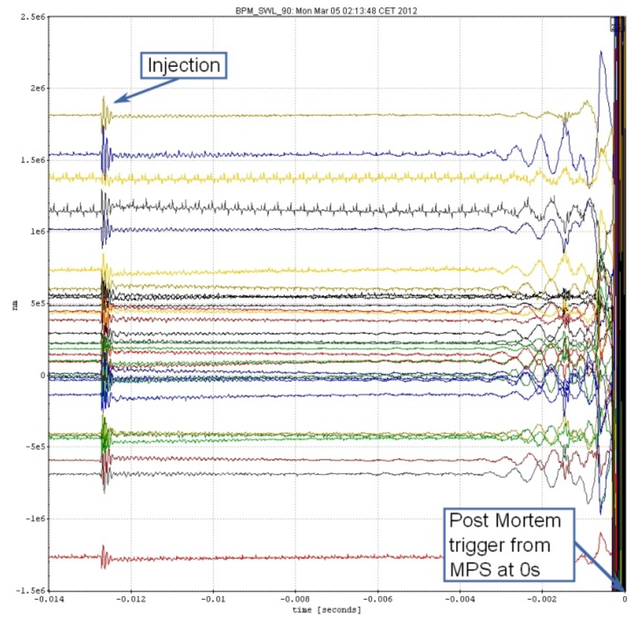

Figure 6: Orbit data of about 30 (of 225) BPMs triggered by a post mortem trigger from the MPS. During the injection (~ -13ms) the beam is stimulated and dumped (~ -250µs; not visible in this picture) by the MPS due to orbit deflections detected by the BPM system. At 0s the post mortem trigger from the MPS arrived.

CONCLUSION

As a central system the MPS collects alarms from several important systems of the PETRA machine.

Apart from the protection duty of a MPS a synchronized post mortem trigger was established by using existing hardware modules and optical fiber links. The MPS post mortem trigger acts independently of any other system and external systems can easily be connected to it so that datasets over various systems can be analyzed on a unified timescale.

During the implementation in the lab it was proven, that the implemented local clocks were working reliably and synchronously (Fig. 3). This was later ensured by evaluating post mortem datasets from the BPM system (Fig. 5).

REFERENCES

[1] T. Lensch, M.Werner, "Machine Protection System for PETRA III", DIPAC09, Basel.
[2] T. Lensch, M.Werner, "Commissioning Results and Improvements of the Machine Protection System for PETRA III", BIW10, Santa Fe.
[3] F. Schmidt-Föhre, DESY, private communication.