A COMPLETE SOLUTION FOR BEAM LOSS MONITORING

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Abstract

In particle accelerator facilities knowing the beam loss is crucial for the machine to be running at optimal efficiency. Beam loss can be monitored on different time scales. Time scale of seconds is used at normal operation to detect any irregularities such as changes in the beta function or vacuum drop. Time scale of 1 ms is used to optimize injection, and 1 us timescale in case of severe problems when the beam does not live for more than a couple of turns. The presented beam loss system (microIOC-BLM) uses Bergoz BLM sensors, Beam loss Signal Conditioner (BSC) for data acquisition and microIOC-CosyIcon as the central processing unit. The system is cost effective, portable and can be expanded with additional measuring points. Selectable counting interval from 100 us to 10 s covers a large part of the required time scales. The minimum and maximum count rates are limited by the sensor between 1/s to 10 M./s. Trigger and gate signals are supported as is summing over a number of measurements.

INTRODUCTION

Knowing the beam loss is crucial for the machine to be running at optimal efficiency. microIOC-BLM is a turnkey solution for monitoring beam loss in synchrotron and particle accelerators. It is suitable for storage rings and boosters, while due to its counting operation is not suitable for transfer lines and LINACs. Readings are obtained in real time, thus making the system ideal for optimizing the machine parameters. Since the system is highly portable, it can be used also to pinpoint loss locations or help with commissioning new devices.

The microIOC-BLM system consists of the following components:

- Bergoz BLM detectors where the signal pulse is generated.
- Beam loss Signal Conditioning (BCS) units used for counting and processing pulses from the BLM detectors. Two BLM detectors can be connected to a single BSC. If the two detectors are positioned on the opposite sides of the vacuum chamber, coincidences can be measured to determine Touschek effect [1, 2].
- microIOC-CosyIcon used as a central unit to control and give power to BCS units and to interface with the control system. The BSC can be connected directly to the microIOC-CosyIcon or can be connected with each other in daisy chain configuration (Figure 1).

Figure 1: BSC modules connected in a daisy chain and connected to a microIOC-CosyIcon as the central processing unit. To each BSC to Bergoz detectors can be connected (not shown).

The BSCs are controlled using a RS485 serial communication. EPICS [3] support is provided to allow direct integration into control system. User interfaces written in EDM [4], WebCA [5] and java using the Caj library [6] exist to allow remote monitoring of the BLM system.

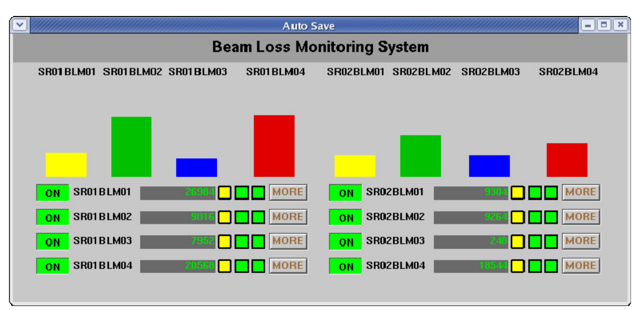

Figure 2: A BLM system overview screen written in EDM

OPERATING MODES

To accommodate all possible applications allowed by the sensor, a flexible data acquisition system is required. By using different modes, the user can select how the counted BLM pulses will be stored in the memory buffer and later used to display relevant data.

Let us define a time-slot count (TSC) as the number of BLM pulses accumulated over certain time slot. The time slot can be defined either by a Gate/Trigger signal or by elapsed time. At the end of time slot the TSC are stored into memory buffer. For any measurement it needs to be selected how and when to capture TSC (TSC capture mode) and how to store TSC into the memory (TSC store mode).

TSC Capture Mode

There are four different ways to capture TSC:

- **Time-based operation** – time-slot for the TSC acquisition is defined by the elapsed time. The time-slots are of equal duration and the advancement to the next time-slot is made after the time of the slot has elapsed.

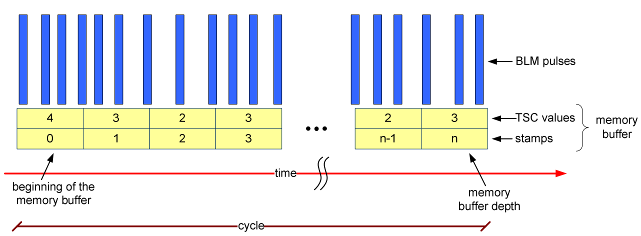

Figure 3: time-based operation

- **Gate-based operation** – time-slot for the TSC acquisition is defined by external gate signal. The time-slot starts at inactive to active gate-signal transition and ends at active to inactive gate-signal transition. The BLM pulses are counted only when the gate signal is active.

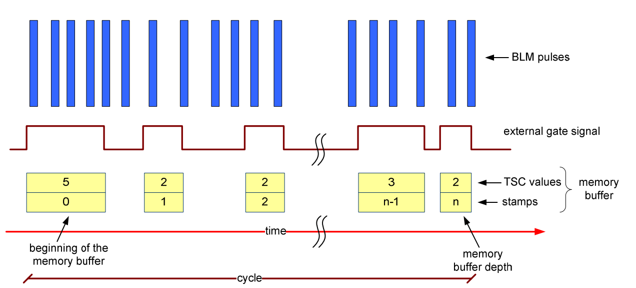

Figure 4: gate-based operation

- **Trigger-based operation** – time-slot for the TSC acquisition is defined by external gate signal. The time-slot starts at inactive to active gate-signal transition and ends when the new time-slot becomes active. Therefore the BLM pulses are always counted.
- **Triggered time-based operation** – the only difference to time-based operation is that an inactive to active gate-signal transition is required to start the measurement.

TSC Store Mode

There are four different ways how to store TSC into the memory:

- **Single-cycle mode** – TSC are being continuously written into memory-buffer one after another until memory-buffer depth is filled.
- **Round-cycle mode** – TSC are being continuously written into memory-buffer one after another. When the end of the memory buffer is reached, writing starts from the beginning, overwriting previously written TSC.
- **Integral SW-cycle mode** – TSC are being continuously written into memory-buffer one after another. When the end of the memory buffer is reached, writing starts from the beginning. In contrast to round-cycle mode, TSC are not overwritten, but added to previous values. The number of cycles must be selected.
- **Integral HW-cycle mode** – like Integral SW-cycle mode, but rising edge of gate-signal transition is required to start writing from the beginning of the buffer. The number of cycles must be selected.

BSC DESIGN

The solution is based on Xilinx CoolRunner II CPLD [7] and ARM microcontroller [8]. CPLD handles signal detection and counting, while microcontroller handles data storage and serial interfacing (Figure 5). BLM detector requires certain power supply (5V, -5V, 24V), provided by BSC, and it outputs pulses varying in width and height (PIN diode recombination process). Pulses exceeding certain threshold and width are acknowledged and count according to active mode of operation.

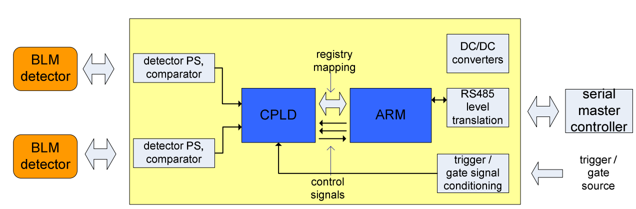

Figure 5: BSC hardware schematic

In CPLD there are two counters, one for each channel, counting pulses accordingly to the current mode of operation. For example, if gate-based operation is chosen, only counts appearing at active gate-signal are acknowledged. These counts are provided as memory mapped registers to the ARM microcontroller. Microcontroller processes readout data and stores it accordingly to memory buffer. The system provides also some diagnostic features like for example measuring of time slot width (e.g. external gate signal), and BLM saturation detection (if pulses from detector are wider than some specific time-value). The entire system is powered through single power supply source, for this multiple DC/DC converters are used, which are all monitored through microcontroller.

APPLICATIONS

Machine Monitoring

This is the most common use of the BLM system and means monitoring of beam loss at different positions around the machine to insure normal operation. In case of vacuum problems or misalignment, the beam loss increases and appropriate actions can be taken. The time scale for this application is 1 second.

For this application time-based operation should be selected and a round-cycle mode (continuous measuring without integration). Since the beam loss is determined as the total sum of values in the buffer, the product of time scale and buffer size should be 1 s. The time-slot should be sufficiently large to reduce statistical fluctuations. The time-slot should not cover the whole 1 s interval to get meaningful values for the standard deviation.

Ramping Losses

Beam ramping lasts in the range 100 ms to 500 ms. Since beam loss can vary significantly in this time interval it is important to have time distribution of beam loss events.

For this application Triggered time-based operation should be selected with hardware trigger indicating the start of injection. To have good time resolution time base of 1 ms should be selected. Since small time-slots are used, Integral HW-cycle mode should be selected to increase statistics by averaging over a large number of injections.

Event Measurements

It is possible to perform beam loss measurements only at special events in the machine. For this application Gate-based operation should be selected. Depending on the application any of the TSC modes can be selected.

CONCLUSIONS

Due to very small size and low unit cost of detectors, and low cost of cabling and other electronics, the microIOC-BLM system is an excellent solution to monitor beam loss over the whole machine.

It is for facilities that want to have one solution to cover all beam loss monitoring applications, whether it is monitoring at fixed places in normal operation, pin-pointing irregular losses, commissioning new devices, optimizing the machine or performing scientific measurements.

It is ideal in cases when the final number of BLM detectors in not known, since additional detectors can be added to the system at any time. Due to possible connection of the BSCs in a daisy chain (Figure 1), additional BSCs can be added without pulling cables from outside of the ring.

REFERENCES

[1] Beam loss monitoring and control, Kay Wittenburg, Proceedings of EPAC 2002, Paris, France

[2] The beam loss monitoring system for HLS storage ring, Li Yuxiong et. al..

[3] http://www.aps.anl.gov/epics/.

[4] http://ics-web1.sns.ornl.gov/edm/.

[5] http://webca.cosylab.com/.

[6] http://caj.cosylab.com/.

[7] Xilinx homepage: www.xilinx.com

[8] Philips ARM family: www.standardics.nxp.com/products/lpc2000/