The CLS Beam Monitor System

CLS DETAIL DESIGN NOTE – 8.2.38.4 Rev. 4

Date: 2005-10-26

Canadian Light Source
101 Perimeter Road
University of Saskatchewan
Saskatoon, Saskatchewan Canada

	Signature	Date
	Original on File – Signed by:	
Author	(J.M. Vogt)	2005-10-26
Reviewer #1	(L.O. Dallin)	
Reviewer #2	(R.M. Silzer)	
Approver	(E. Matias)	

REVISION HISTORY

Revision	*Date*	*Description*	*Author*
A	2001-06-05	Conceptual design - draft	J.M. Vogt
B	2001-06-08	Incorporated N.G. Johnson's comments	J.M. Vogt
0	2001-06-15	Conceptual design – issued for use	J.M. Vogt
C	2001-07-26	Preliminary design - draft	J.M. Vogt
1	2001-08-30	Preliminary design – issued for use	J.M. Vogt
2	2001-10-16	Revised Room Numbers	J.M. Vogt
3	2002-05-02	Revised wiring for SR BPMs	J.M. Vogt
3A	2005-10-14	Detail design, implementing ECOs 062, 063, 072, 103, 228, 229, 243 – issued for review	J.M. Vogt
4	2005-10-26	Detail design, issued for use	J.M. Vogt

1. Purpose and Scope

This document describes the CLS Beam Monitoring System, which consists of two types of Beam Loss Monitors (CBLM and BBLM), two types of Beam Position Monitors (BPM and SLM), and three types of Current Transformers (ICT, FCT, PCT). Transition Radiation Monitors are not within the scope of this document, since their data acquisition system is independent of all other monitors. Also, the instrumentation of the Booster SLMs (Tracking Generator, RF-amplifier, spectrum Analyser) is not within the scope of this document.

For the purpose of data acquisition, LTB is an extension of the LINAC, since there are no trigger signals that trigger any actions in LTB independent of the LINAC. LINAC and LTB are therefore grouped together in this document.

2. Definitions and Abbreviations

BLM: Beam Loss Monitor

CBLM: Cerenkov BLM

BBLM: Bergoz BLM

BPM: Button Beam Position Monitor

LR-BPM: Log-ratio BPM

SLM: Stripline Beam Position Monitor

ICT: Integrating Current Transformer

FCT: Fast Current Transformer

PCT: Parametric Current Transformer

DAQ: Data Acquisition Station

3. References

[1] CLS document 8.2.38.3 “Beam Loss Monitors”

[2] CLS document 2.2.38.4 / 4.2.38.1 “Beam Charge Monitors for the Transfer Lines”

[3] CLS document 7.2.39.20 “The “Fast” Machine Protection System for the Storage Ring”

[4] CLS document 7.2.38.5 “BPM Test Report”

4. Architecture and Locations

Drawing BLDG/ME/MON/0050910 shows the locations of the 8 data acquisition stations (DAQs) used for the CLS beam monitor system. All stations except DAQ2405-01 are based on a VME crate (see Appendix B for specifications), which is a WIENER VME6021/613, consisting of a 6U UEN6021 PLENUM bin, a UEL6020/3 fan tray, and a UEP6021 power supply with 5V/230A, ±12V/11.5A. Each VME has a SIS1100/SIS3100 fibre optic link to the data acquisition computer (see Fig. 1). NIM crates are WIENER UEN03/UEP22.

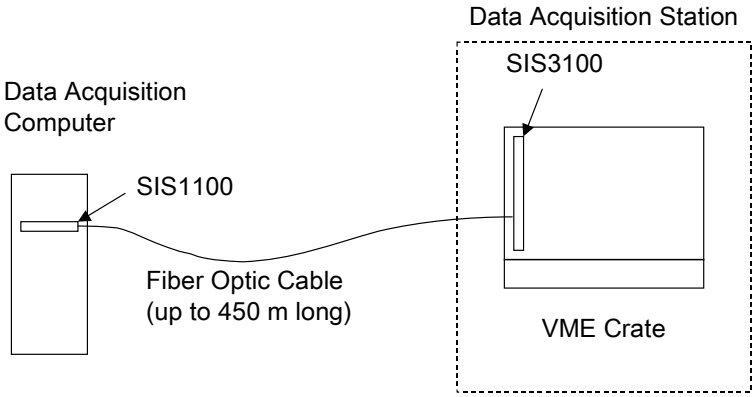

Fig. 1: Data acquisition architecture.

5. Beam Loss Monitors

The Beam Loss Monitors are described in Ref. [1]. There are two different kinds:

- Cerenkov BLMs, which are used to detect sudden beam loss.
- Bergoz BLMs, which are used to detect gradual beam loss.

5.1 Cerenkov BLMs

To avoid ground loops, the HV supplies for the CBLMs are located in the data acquisition stations. Care has to be taken to avoid grounding the detectors or the cables in any other place. The HV supplies are C.A.E.N. SY2527 with C.A.E.N. A1733N cards.

The nominal locations of the CBLMs are shown in drawing BLDG/ME/MON/0050900. Table 1 in Appendix A correlates the CBLMs with the data acquisition stations. However, the detectors are portable and can be moved in order to locate trouble spots during debugging.

5.1.1 LINAC and LTB

There are no CBLMs permanently installed in the LINAC or in LTB. However, there are 6 locations in the LINAC and 12 in LTB, where CBLMs can be placed. They are connected to 2 charge-integrating ADCs (C.A.E.N. V792N) in DAQ0006-01. The ADC gate is derived from the gun trigger. The wiring is shown in drawing ACCL/EE/MON/WIR/0068600.

5.1.2 Booster

There are no CBLMs in the Booster

5.1.3 BTS

There are 4 CBLMs in BTS, which are connected to the oscilloscope switches in DAQ2403-01. The wiring is shown in CDAC/EE/MON/WIR/0068403.

5.1.4 Storage Ring

There are 8 CBLMs in the Storage Ring. Feeds from DAQ2403-01 are terminated on two enclosed panels within the tunnel. One panel supporting 4 CBLMs is located in room 1401, the other in room 1407. The detectors are normally stored near the panels. When the CBLMs are used, temporary cables will be run between the panels and the locations where the CBLMs are placed. The signal outputs of the CBLMs are connected to the oscilloscope switches in DAQ2403-01. The wiring is shown in CDAC/EE/MON/WIR/0068403.

5.2 Bergoz BLMs

There are 4 BBLMs in the Booster and 36 in the Storage Ring. The nominal locations of the BBLMs are shown in drawing BLDG/ME/MON/0050900. However, the detectors are portable and can be moved in order to locate trouble spots during debugging. The wiring diagram of the BBLMs is shown in CDAC/EE/MON/WIR/0068610. Table 2 in Appendix A correlates the BBLMs with the data acquisition stations.

The BBLM detectors consist of Bergoz BLM cards (TTL outputs) and TTL-to-fibre converters (ACCL/EE/MON/0052470) integrated into the same enclosure.

The fibre-to-ECL converters were designed at CLS (ACCL/EE/MON/0052480), and the scalers are C.A.E.N. V820AC.

6. Beam Position Monitors

A BPM consists of a set of 4 buttons, and an SLM consists of a set of 4 striplines. Bergoz BPM Modules are used to acquire position information in the Booster and in the Storage Ring.

Drawing BLDG/ME/MON/0050910 shows the locations of all Beam Position Monitors.

6.1 LTB

There are 6 SLMs in LTB, which will not be instrumented until the beam can be chopped.

6.2 Booster

6.2.1 BPMs

There are 28 BPMs in the Booster. Their sensitivity is 4.938 %/mm in both X and Y. During commissioning, all of them were instrumented with Bergoz BPM modules. 8 BPM modules were supplied by Danfysik and remain in the Booster as permanent instrumentation. Their gain is 0.125 V/% in both X and Y, resulting in an overall system gain of 0.617 V/mm (1.62 mm/V) in

both X and Y. In addition, 5 spare “standard” Storage Ring BPM modules (see 7.4.1) are used in the booster after commissioning unless they are needed elsewhere.

Readout of the Bergoz-BPM modules is via 24-bit sampling VME ADCs (ICS-110BL) made by Interactive Circuits and Systems Ltd., modified for a ±10V input range (see manual in Appendix C, specifications in Appendix B). Drawings BR1/EE/MON/WIR/0068700 – 0068703 show the wiring from the BPMs to the ADCs. The ADCs are clocked internally, but the readout trigger is provided by the Timing System (see CDAC/EE/TMNG/WIR/0068400).

6.2.2 SLMs

There are 2 SLMs in the Booster, which are used for tune measurements. The wiring diagrams are expected to be included in the Danfysik as-built drawing package. However, at present they cannot be retrieved.

6.3 BTS

There are 2 SLMs in BTS. The decision about their ultimate instrumentation has been deferred. For now they can be monitored with an oscilloscope, see BTS1/EE/WIR/0070957.

6.4 Storage Ring

All 72 BPMs in the storage ring have the same cable arrangement in common:

- Semi-rigid cable (RG402/U, in most cases 46 cm long) from the BPM to a small panel near the beam pipe, SMA male at the BPM, N female bulkhead at the panel.
- ¼” Heliax cable from the panel to the data acquisition station,
  either male N connector screwed onto the panel and male SMA connector at the Bergoz crate
  or male N connector screwed onto the panel and N female bulkhead mounted on an insulated panel at the other end of the cable.

6.4.1 Sensitivities of the BPMs and Gains of the BPM Modules

The 48 BPMs in the Storage Ring cells are considered to be the “standard” BPMs. Their sensitivity is 6.757 %/mm in X and 7.102 %/mm in Y in the centre of the vacuum pipe. These numbers were first calculated and later confirmed experimentally using the BPM test station [4]. The “standard” BPMs are connected to the “standard” Storage Ring BPM modules, which have a gain of 0.187 V/% in X and 0.162 V/% in Y, resulting in an overall system gain of 1.261 V/mm in X and 1.152 V/mm in Y. These modules are labelled “SR” on the front panel. BPM1402-01, BPM1402-02, BPM1402-03, BPM1402-04, BPM1402-05, and BPM1402-06 are also “standard” BPMs, but they are not connected to BPM modules.

BPM1410-01 and BPM1411-01 have a sensitivity of 31.7 %/mm in X and 23.6 %/mm in Y (these numbers were calculated). They are connected to modified BPM modules with a gain of 0.1 V/% in X and 0.11 V/% in Y, resulting in an overall system gain of 3.17 V/mm in X and 2.6 V/mm in Y. These modules are labelled “ID” on the front panel. BPM1410-06 and BPM1411-06 have the same sensitivity, but they are not connected to BPM modules.

BPM1408-01 has a sensitivity of 14.36 %/mm in X and 10.63 %/mm in Y (these numbers were calculated). It is connected to a “standard” Storage Ring BPM module, resulting in an overall system gain of 2.685 V/mm in X and 1.722 V/mm in Y. BPM1408-06 has the same sensitivity, but it is not connected to a BPM module.

6.4.2 Orbit Correction System

There are 55 BPMs for the orbit correction system.

Locations: 4 in each of the 12 cells, 1 each in straights 03, 04, 05, 07, 08, 09, 10.

Readout: Table 3 in Appendix A shows the assignment of BPMs to the data acquisition stations. The BPMs are connected to Bergoz BPM modules in Bergoz BPM-RFC crates. Readout of the Bergoz-BPM modules is via ICS-110BL sampling VME ADCs made by Interactive Circuits and Systems Ltd., modified for a ±10V input range (see manual in Appendix C, specifications in Appendix B). They are connected to the XOUT and YOUT signals in the rear of the BPM crates. The ADCs are free running, using their internal clock. The wiring is shown in SR1/EE/MON/WIR/0068704, 0068706, 0068708, and 0068710.

A second copy of the XOUT and YOUT signals is available at the front panel of each BPM module. Active buffers/ splitters (SR1/EE/MON/0062740) are used to make these XOUT and YOUT signals available for monitoring with an oscilloscope and for various other applications, including the “fast” machine protection system.

6.4.3 “Fast” Machine Protection System

The following BPMs are used in the fast machine protection system: The 48 BPMs in the cells, BPM1408-01, BPM1410-01, BPM1411-01. The fast machine protection system is described in [3].

6.4.4 Transverse Feedback System

2 BPMs are reserved for the transverse feedback system (BPM1411-06 and BPM1406-01).

Locations: Straight 11 and straight 6 (wiggler straight)

Readout: Deferred

Kickers: The transverse feedback kickers (both x and y) will be located in straight 02 (diagnostic straight). These kickers will also function as the tune kickers for the tune measurements.

6.4.5 Tune Measurements

BPM1402-01 (diagnostic straight) will be used for tune measurements.

Readout: Cables to insulated panel in DAQ2405-01, see SR1/EE/MON/WIR/0090703.

Kickers: See 7.4.2.

6.4.6 Misc. Testing

BPM1402-02 (diagnostic straight) is reserved for misc. testing.

Readout: Cables to insulated panel in DAQ2405-01, see SR1/EE/MON/WIR/0090703.

6.4.7 Facility Diagnostic Beamline

BPM1402-03 (diagnostic straight) is for the OSR beamline.

Readout: Insulated panel in OSR hutch (room 1602.1), see SR1/EE/MON/WIR/0090703.

6.4.8 Reserved for Users

BPM1402-04 (diagnostic straight) is reserved for the users.

Readout: Deferred

6.4.9 Turn-by-turn Position Measurements

There are 2 BPMs for turn-by-turn position measurements (BPM1402-05 and BPM1406-06).

Locations: 1 in straight 02 (diagnostic straight), 1 in straight 06 (wiggler straight).

Readout: 1406-06 deferred. 1402-05 has LR-BPM Module in DAQ2404-01.

6.4.10 Virtual FCT and ICT

BPM1402-06 (diagnostic straight) is connected to the 4 button sum panel shown in CDAC/EE/MON/WIR/0068630. The 4 button sum results in a fast (bunch by bunch) signal that is almost independent of the beam position (virtual FCT). The signal can be used as is, or can be attenuated by 20 dB or amplified by 23 dB. It is connected to the oscilloscope switch of OSC2403.1-02.

Mounted on the 4 button sum panel is an envelope detector (SR1/EE/MON/0090890), which generates a signal that follows the envelope of a bunch train (virtual ICT). This signal is also monitored by OSC2403.1-02. The amplitude of the signal is affected by the gain / attenuation selection for the virtual FCT signal.

6.4.11 Reserved for Future Use

7 BPMs are reserved for future use: BPM1403-06, BPM1404-06, BPM1405-06, BPM1407-02, BPM1408-06, BPM1409-06, BPM1410-06. BPM1410-06 is wired to P2408.2-02.

Readout: Deferred.

7. Current Transformers

7.1 Integrating Current Transformers

ICTs are used to measure the charge in a pulse train [2]. They are either connected to a charge integrating ADC, or the signal is displayed on an oscilloscope. Drawing BLDG/ME/MON/0050910 shows the locations of the ICTs.

7.1.1 LTB

There are 3 ICTs in LTB. Two of them (ICT0003-01 and ICT0004-01) are connected to a charge integrating ADC in DAQ0006-01. ICT1300-01 is wired to P1021.1-28 in the control room and is looked at using an oscilloscope. The wiring is shown in ACCL/EE/MON/WIR/0068600.

7.1.2 BTS

There are 2 ICTs in BTS, connected to one of the oscilloscope switches in DAQ2403-01. The wiring is shown in BTS1/EE/WIR/0070957.

7.2 Fast Current Transformers

FCTs are used to measure the profile of the 500 MHz bunch train [2]. The output signals of the FCTs run through 46 cm (18") of semi-rigid cable (RG402/U) from the FCT to a small, insulated panel near the beam pipe (SMA male at the FCT, N female bulkhead at the panel).

Drawing BLDG/ME/MON/0050910 shows the locations of the FCTs.

There are:

- 1 FCT in LTB – the wiring diagram can no longer be found.
- 1 FCT in the Booster – the wiring diagram is shown in BTS1/EE/WIR/0070957.
- 1 FCT in BTS – the wiring diagram is shown in BTS1/EE/WIR/0070957.

7.3 Parametric Current Transformers

PCTs are used in the Booster and in the Storage Ring to measure the average current. High precision (1 μA or up to 10^{-6}) is required in the Storage Ring in order to determine the decay time of the beam. Drawing BLDG/ME/MON/0050910 shows the locations of the PCTs.

7.3.1 Booster

There is 1 PCT in the Booster, which is connected to OSC2403.1-01, and to an ADC. The ADC is an ICS-110BL sampling VME ADC made by Interactive Circuits and Systems Ltd., modified for a ±10V input range (see manual in Appendix C, specifications in Appendix B). The wiring is shown in BR1/EE/MON/WIR/0069800.

7.3.2 Storage Ring

There is 1 PCT in the Storage Ring. The Bergoz PCT front-end electronics are located in the storage ring tunnel near the PCT toroid. The PCT output chassis is located in DAQ2405-01, and is connected to the front-end via a 25m cable (Bergoz PCT Option 005-025m). A Keithley 2000 multimeter (6½ digits) is used for readout. The wiring diagram is shown in SR1/EE/MON/WIR/0069805.

Appendix A

Data Acquisition Station	CBLM
DAQ0006-01	CBLM0001-01, CBLM0001-02, CBLM0001-03, CBLM0001-04, CBLM0001-05, CBLM0001-06, CBLM0001-07, CBLM0003-01, CBLM0003-02, CBLM0003-03, CBLM0003-04, CBLM0003-05, CBLM0004-01, CBLM0108-01, CBLM0108-02, CBLM0108-03, CBLM0108-04, CBLM1300-01
DAQ2403-01	CBLM1305-01, CBLM1400-01, CBLM1400-02, CBLM1400-03, CBLM1401-01, CBLM1401-02, CBLM1401-03, CBLM1401-04, CBLM1407-01, CBLM1407-02, CBLM1407-03, CBLM1407-04

Table 1: Assignment of the CBLMs to the data acquisition stations.

Data Acquisition Station	BBLM
DAQ2401-01	BBLM1302-01, BBLM1302-02, BBLM1403-01, BBLM1403-02, BBLM1403-03, BBLM1404-01, BBLM1404-02, BBLM1404-03, BBLM1405-01, BBLM1405-02, BBLM1405-03, BBLM1406-01, BBLM1406-02, BBLM1406-03, BBLM1407-01, BBLM1407-02, BBLM1407-03, BBLM1408-01, BBLM1408-02, BBLM1408-03
DAQ2403-01	BBLM1303-01, BBLM1304-01, BBLM1409-01, BBLM1409-02, BBLM1409-03, BBLM1410-01, BBLM1410-02, BBLM1410-03, BBLM1411-01, BBLM1411-02, BBLM1411-03, BBLM1412-01, BBLM1412-02, BBLM1412-03, BBLM1401-01, BBLM1401-02, BBLM1401-03, BBLM1402-01, BBLM1402-02, BBLM1402-03

Table 2: Assignment of the BBLMs to the data acquisition stations.

Data Acquisition Station	BPM
DAQ2404-01	BPM1411-01[(1)], BPM1411-02, BPM1411-03, BPM1411-04, BPM1411-05, BPM1412-02, BPM1412-03, BPM1412-04, BPM1412-05, BPM1401-01, BPM1401-02, BPM1401-03, BPM1401-04
DAQ2406-01	BPM1402-10, BPM1402-07, BPM1402-08, BPM1402-09, BPM1403-01, BPM1403-02, BPM1403-03, BPM1403-04, BPM1403-05, BPM1404-01, BPM1404-02, BPM1404-03, BPM1404-04, BPM1404-05
DAQ2406-02	BPM1405-01, BPM1405-02, BPM1405-03, BPM1405-04, BPM1405-05, BPM1407-01, BPM1406-02, BPM1406-03, BPM1406-04, BPM1406-05, BPM1407-03, BPM1407-04, BPM1407-05, BPM1407-06
DAQ2408-01	BPM1408-01, BPM1408-02, BPM1408-03, BPM1408-04, BPM1408-05, BPM1409-01, BPM1409-02, BPM1409-03, BPM1409-04, BPM1409-05, BPM1410-01, BPM1410-02, BPM1410-03, BPM1410-04, BPM1410-05

Table 3: Assignment of the BPMs to the data acquisition stations.

[(1)] Not used in orbit correction system.

Appendix B

Specifications for VME Crates

- 21 Slot 6U/160mm VME crate.
- IEEE 1014 / IEC 821 backplane.
- Modular design with removable power supply and fan tray.
- MTBF > 60000 hours, MTTR < 5 minutes, no tools required (both fan and power supply).
- Monitoring of individual fans. Failure of any fan shall shut off power supply.
- Hot-swappable fan tray.
- Sensor for module temperature. Over-temperature shall shut off power supply.
- Available power supply current:

  5V: > 200A

  ±12V: > 10A
- Noise and ripple: < 10 mV_{pp} (0-20 MHz).
- Remote monitoring of crate status.
- Optional upgrade of the VME crates to VME64x.

Specifications for VME Sampling ADCs

- 6U module compatible with IEEE 1014 / IEC 821 backplane.
- Resolution of 22 bits or more.
- Simultaneous sampling rate of 80 kHz or more.
- Input signal bandwidth: DC to >20 kHz.
- External clock and programmable internal clock.
- Differential inputs for noise reduction:
  - Differential input voltage range of ±10V (full scale).
  - One side of the differential inputs will be kept near ground.
- Minimum on-board storage of 2 Kword per channel.

Appendix C

- Multiplexed Beam Position Monitor User's Manual
- Integrating Current Transformer User's Manual
- Fast Current Transformer User's Manual
- Parametric Current Transformer User's Manual
- ICS-110BL Operating Manual