Outer Tracker DAQ Data Format

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Abstract

The format of the Outer Tracker data going from the LEVEL 1 Electronics (TELL1 BOARD) to the HLT Farm is described.

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Prepared by Jacopo Nardulli
NIKHEF, Amsterdam, The Netherlands

Antonio Pellegrino
NIKHEF, Amsterdam, The Netherlands

Dirk Wiedner
Physikalisches Institut, University of Heidelberg, Germany

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1 Introduction

The main aim of this note is to propose a format of the Outer Tracker data, from the LEVEL 1 Electronics (TELL1 Board [1]) to the HLT Farm [2]. Henceforth, we will refer to this data format as "OTDAQ format".

It is important to observe that the OTDAQ format differs from the format of the input data entering the TELL1 BOARD (see Ref. [3]), in that it is a zero-suppressed data format.

The OTDAQ format must at the same time fulfil the LEVEL1 Electronics specifications [4], as well as the needs of the LHCb software [5, 6, 7, 8]. It is implemented in a new software package, called "OTDAQ"; it is included in the LHCb software designed for the production of LHCb data in a format as close as possible to the final HLT Data.

2 Outer Tracker DAQ Data Format

At the moment, it is foreseen that the OT FE data will be distributed to 24 (48)[1] TELL1 BOARD, each one receiving the data of 18 (9) GOL links [9]. In each FE box, the data from the four parallel 8-bit busses of four OTIS TDCs [3] are serialized by one GOL. Each OTIS reads out 32 straws. Therefore, each GOL link serially transmits the complete data of a FE box, i.e. the data from two straw mono-layers. The address scheme used to uniquely identify data from a given FE box (GOL link) is described in detail in Ref. [10] and will be followed throughout this note.

From the software point of view, the data coming from a TELL1 are stored in an object called *"Bank"*; there will be in total 24 (48) banks for the OT. In Table 1, the general structure of the Bank Data Format is shown.

[1]Eventually, the number of TELL1 boards in the OT, 24 or 48, will finally be determined by the maximum allowed output bandwidth toward the LEVEL 1 Farm, should OT data be provided to the LEVEL 1.

<table>
<tr><th>Object</th><th colspan="4">Content</th></tr>
<tr><td>Standard Header</td><td colspan="4">Bank Size [31..0]
Magic Pattern [31..0]
Source ID: Bank ID [31..16] Bank Type: OT [15..0]</td></tr>
<tr><td rowspan="9">OT DATA</td><td rowspan="3">TELL1 HEADER</td><td colspan="3">L1-ID[31..0]</td></tr>
<tr><td colspan="3">R[31..24], L0-ID[23..0]</td></tr>
<tr><td colspan="3">ErrorProgation from TELL1 [31..24]
Trigger-Type[23..20]
Bunch ID [19..8]
Number of GOLs in the Bank [7..0]</td></tr>
<tr><td rowspan="6">TELL1 DATA</td><td rowspan="2">GOL 0</td><td>GOL Header</td><td>GOL 0 Header</td></tr>
<tr><td>GOL 0 Data</td><td>Hit Data 0, Hit Data 1
Hit Data 2, Hit Data 3,
...</td></tr>
<tr><td rowspan="2">GOL 1</td><td>GOL Header</td><td>GOL 1 Header</td></tr>
<tr><td>GOL 1 Data</td><td>Hit Data 0, Hit Data 1
Hit Data 2, Hit Data 3,
...</td></tr>
<tr><td colspan="3">...</td></tr>
<tr><td colspan="3">...</td></tr>
</table>

Table 1: BANK DATA FORMAT - GENERAL STRUCTURE

The bank begins with a *Standard Header* [6, 7, 8], consisting of three 32-bits words: the first word is the Bank Size (total number of words in each bank); the second word is the Magic Pattern (to check the data integrity); the third word contains the Bank Type (identifying this bank as from the OT) and the Source ID, which we propose to be a serial bank number from 0 to 23 (47).

After the standard header, the detector-specific data follows. The OT data begins with a header (TELL1 header) consisting of three 32 bit words. The format of this header is based on that of the HLT Fragment in the TELL1 board [1] and conforms to the L1 requirements [4]. It contains the L1-ID (31..0), the L0-ID (23..0), the Error-Propagation from the TELL1 board (31..24), the L1 Trigger Type (23..20), the Bunch ID (19..8), and the number of GOL chips contributing to the bank (7..0).

After the header, the actual OT data follows. We propose to organize this data as a sequence of GOL data blocks: each GOL DATA block shall consist of a GOL header and the sequence of all hit data. The structure of the GOL header is shown in Table 2: it contains the total number of hits in a given GOL data block, the GOL ID and 3 bits of info for each OTIS. The 10-bits GOL ID uniquely identifies the position of the GOL in the detector according to the address scheme described in Ref. [10].

Bit No	Content	
31	Optical Data Trasmission OK	
29-30	Station	GOL ID
27-28	Layer	
25-26	Quarter	
21-24	Module	
18-20	...	OTIS 3 Header
15-17	...	OTIS 2 Header
14	Buffer Overflow	OTIS 1 Header
13	Self-Test Failed or DLL lost or SEU	
12	Truncation	
11	Buffer Overflow	OTIS 0 Header
10	Self-Test Failed or DLL lost or SEU	
9	Truncation	
0-8	Number of Hits (16 bit each)	

Table 2: GOL HEADER

The Hit-Data structure is shown in Table 3. Two hits per 32-bits word are encoded. Each 16-bits hit word carries a 7-bits straw ID, identifying the OTIS (2 bits) and the channel (5 bits), and an 8-bit drift time, encoded as described in Ref. [3]. As proposed here, each GOL data bank will contain a minimum of one 32-bits words (1 GOL header). Therefore, an "empty" Bank (no hit) will contain 12 bytes of Standard Header, 12 bytes of TELL1 Header, and $18(9) \times 4 = 72(36)$ bytes of GOL headers, i.e. a total of 96 (60) bytes.

The hit data are padded to 32-bits words; the total number of hits in each GOL data block is counted in the GOL header by the "number-of-hits" field. The maximum number of hits N_{hits} in a given GOL data block is determined by the constraint that the maximum Bank size be 4096 bytes. We get 12 bytes (Standard Header) +12 bytes (TELL1 Header) $+18(9)\times 4$ (Gol Header) $+18(9) \times N_{hits} \times 2$ (Hit Data) = 4096 bytes. This gives a maximum number of hits per GOL $N_{hits} = 111(224)$. Since each GOL receives the hit data of 128 straws, this corresponds to an occupancy (in the absence of multiple hits) of about 88% (> 100%). Eventual data truncation will be signalled by the truncation bit.

Bit No	Content structure	Content
31		OTIS ID Check OK
29-30	First Address (8 bit)	OTIS ID
24-28		Channel
16-23	First Data Time (8 bit)	Encoded drift time
15		OTIS ID Check OK
13-14	Next Address (8 bit)	OTIS ID
8-13		Channel
0-7	Next Data Time (8 bit)	Encoded drift time
...		

Table 3: HIT DATA

3 Hit-Only Data

The data format described in Sect. 2, based on the full 8-bits drift time, carries the most complete information one can obtain from the detector. In some cases (trigger applications, dedicated studies etc.) the minimum information, i.e. which detector channels have registered a hit in the valid time window, can already be sufficient. It is therefore of interest to assign a format to this hit data. This can be done either in zero-suppress mode or using a hit mask ("hit pattern").

The zero-suppressed format is analogous to the one described in Sect. 2 but, in contrast to what shown in Tab. 3, only the channel address is needed to identify channels with a hit in the valid time window. This is shown in Tab. 4. The hit data are padded to 32-bits words. The size (in bytes) of a bank of hit-only data is

$$\begin{aligned} 12\,(\text{Standard Header}) &+ 12\,(\text{TELL1 Header}) + 18(9)\times 4\,(\text{Gol Header}) + \\ 18(9) &\times \left\{ int\left(\frac{N_{hits}+4-1}{4}\right)\times 4\right\}\times 1\,(\text{Hit Data}) = \\ 96(60)\,(\text{Headers}) &+ \left\{ int\left(\frac{N_{hits}+3}{4}\right)\times 4\right\}\times 18(9)\,(\text{Data}). \end{aligned}$$

E.g. an occupancy of about 12% gives rise to a bank size of 96(60) (Headers)+ 288(144) (Data) bytes.

Address Bit	Content structure	Content
31 29-30 24-28	Next Address or Pad (8 bits)	1 OTIS ID Channel
23 21-22 16-20	Next Address or Pad (8 bits)	1 OTIS ID Channel
15 13-14 8-12	Next Address or Pad (8 bits)	1 OTIS ID Channel
7 5-6 0-4	First Address (8 bits)	1 OTIS ID Channel
	...	

Table 4: HIT-ONLY GOL DATA

A data format alternative to the one in Tab. 4 is a non-zero suppressed hit pattern, containing bit "1" for each valid hit and bit "0" for each invalid hit. In this format, each GOL contributes a fixed-format four 32-bits words (one per OTIS) to the data bank; no channel address is necessary, since each 32-bits word contains the hit pattern of the 32 OTIS channels, as shown in Tab. 5. The size (in bytes) of a bank of hit-pattern data is

$$\begin{aligned}12\,(\text{Standard Header}) &+ 12\,(\text{TELL1 Header}) + 18(9) \times 4\,(\text{Gol Header}) + \\ 18(9) \times 4 \times 4 &= 96(60)\,(\text{Headers}) + 288(144)\,(\text{Data}).\end{aligned}$$

From the comparison with the zero suppressed format of Tab. 4, it can be deduced that the bank size of the hit-pattern data is smaller than the zero-suppressed one for occupancies above 12%.

Address Bit	Content structure	Content
0-31	OTIS 3 HIT PATTERN	$1 \equiv valid$; $0 \equiv invalid$
0-31	OTIS 2 HIT PATTERN	$1 \equiv valid$; $0 \equiv invalid$
0-31	OTIS 1 HIT PATTERN	$1 \equiv valid$; $0 \equiv invalid$
0-31	OTIS 0 HIT PATTERN	$1 \equiv valid$; $0 \equiv invalid$

Table 5: HIT-PATTERN GOL DATA

4 Special Events

The insertion of special events in the Outer Tracker data stream may be required; e.g.

- Test-pulse events: these can be triggered at regular intervals during data taking. Their net effects shall be to cause response of all the channels in the detector (100% occupancy with no truncation).
- Begin-Of-Run: at the beginning of each run (and perhaps also at regular intervals or on request of the ECS) a special event should be triggered where all settings of the FE Electronics, the OTIS headers etc. are read-back;
- Error conditions detected by the TELL1 board(s) (e.g. event fragment mismatch) might require the usage of special purpose events with debugging information.
- etc.

These types of events and others to be described at a later stage, by their own nature, will not comply to the formats described in the previous sections.

5 Summary-Outlook

The structure of the Data Format presented in this note is to be considered a proposal of the Outer Tracker Group. It has undergone a first round of discussion with the online and offline software group, and supersedes the LHCb note lhcb-2004-033.

References

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