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OPTICAL INTERFACE SPECIFICATION BETWEEN CMS CALORIMETER TRIGGER PRIMITIVE GENERATORS TO LEVEL 1 REGIONAL TRIGGER AND LAYER 1

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Abstract

This document provides the interface specification between TPG, RCT and Layer 1 with optical connections.

1 INTRODUCTION

This note describes the link protocols and payload information between CMS Calorimeter Trigger Primitive Generators (TPG), L1 Regional Trigger (RCT) and Layer 1. The protocol are packetized, with each single packet containing information relating to a single bunch crossing and constrained to 25 ns.

There are two sets of protocols. One set is used to send trigger primitives from oSLBs to oRMs/CTP7s and from uHTRs to oRMs. The interface is based on the protocol used with copper cables between CMS Calorimeter Trigger Primitive Generator and the Level 1 Regional Trigger [1,2]. The second set of links connects the uHTRs to the CTP7s.

2 oSLB LINK SPECIFICATION

Each packet is composed by 6 words of 16 bits and contains the trigger primitives of 8 individual electron towers (8 bits and 1 isolation bit each), 4 hamming codes (5 bits each) and 4 BC0 flags (1 bit each). Table 1 shows each word and bit order.

-	Word 1	Word 2	Word 3	Word 4	Word 5	Word 6
Byte 1, bit 7	E_T 3 bit 7	E_T 7 bit 7	E_T 4 bit 6	E_T 8 bit 6	BC0 flag	BC0 flag
Byte 1, bit 6	E_T 3 bit 6	E_T 7 bit 6	E_T 4 bit 5	E_T 8 bit 5	Ham 2 bit 4	Ham 4 bit 4
Byte 1, bit 5	E_T 3 bit 5	E_T 7 bit 5	E_T 4 bit 4	E_T 8 bit 4	Ham 2 bit 3	Ham 4 bit 3
Byte 1, bit 4	E_T 3 bit 4	E_T 7 bit 4	E_T 4 bit 3	E_T 8 bit 3	Ham 2 bit 2	Ham 4 bit 2
Byte 1, bit 3	E_T 3 bit 3	E_T 7 bit 3	E_T 4 bit 2	E_T 8 bit 2	Ham 2 bit 1	Ham 4 bit 1
Byte 1, bit 2	E_T 3 bit 2	E_T 7 bit 2	E_T 4 bit 1	E_T 8 bit 1	Ham 2 bit 0	Ham 4 bit 0
Byte 1, bit 1	E_T 3 bit 1	E_T 7 bit 1	E_T 4 bit 0	E_T 8 bit 0	T4 Isol bit	T8 Isol bit
Byte 1, bit 0	E_T 3 bit 0	E_T 7 bit 0	T3 Isol bit	T7 Isol bit	E_T 4 bit 7	E_T 8 bit 7
Byte 0, bit 7	E_T 1 bit 7	E_T 5 bit 7	E_T 2 bit 6	E_T 6 bit 6	BC0 flag	BC0 flag
Byte 0, bit 6	E_T 1 bit 6	E_T 5 bit 6	E_T 2 bit 5	E_T 6 bit 5	Ham 1 bit 4	Ham 3 bit 4
Byte 0, bit 5	E_T 1 bit 5	E_T 5 bit 5	E_T 2 bit 4	E_T 6 bit 4	Ham 1 bit 3	Ham 3 bit 3
Byte 0, bit 4	E_T 1 bit 4	E_T 5 bit 4	E_T 2 bit 3	E_T 6 bit 3	Ham 1 bit 2	Ham 3 bit 2
Byte 0, bit 3	E_T 1 bit 3	E_T 5 bit 3	E_T 2 bit 2	E_T 6 bit 2	Ham 1 bit 1	Ham 3 bit 1
Byte 0, bit 2	E_T 1 bit 2	E_T 5 bit 2	E_T 2 bit 1	E_T 6 bit 1	Ham 1 bit 0	Ham 3 bit 0
Byte 0, bit 1	E_T 1 bit 1	E_T 5 bit 1	E_T 2 bit 0	E_T 6 bit 0	T2 Isol bit	T6 Isol bit
Byte 0, bit 0	E_T 1 bit 0	E_T 5 bit 0	T1 Isol bit	T5 Isol bit	E_T 2 bit 7	E_T 6 bit 7

Table 1 – Packet specification over a bunch crossing.

The 5-bit hamming code generation is defined in CMS IN 2001/016 [3]. The following algorithm is used:

- Hamming bit 0 = NOT(XOR(d0,d1,d3,d4,d6,d8,d10,d11,d13,d15,d17))
- Hamming bit 1 = NOT(XOR(d0,d2,d3,d5,d6,d9,d10, d12,d13,d16,d17))
- Hamming bit 2 = NOT(XOR(d1,d2,d3,d7,d8,d9,d10,d14,d15,d16,d17))
- Hamming bit 3 = NOT(XOR(d4,d5,d6,d7,d8,d9,d10,d18))
- Hamming bit 4 = NOT(XOR(d11,d12,d13,d14,d15,d16,d17,d18))

Each hamming calculation block takes 19 bits and each of the codes shown in Table 1 are:

- Ham 1 = Hamming (BC0 & ET 2 & ET 1)

- Ham 2 = Hamming (BC0 & ET 4 & ET 3)
- Ham 3 = Hamming (BC0 & ET 6 & ET 5)
- Ham 4 = Hamming (BC0 & ET 8 & ET 7)

Alignment characters are sent instead of data when the link is idle, either during gap periods (<K28.7, K28.5>) or when the transmitter is not running (<K28.1, K28.5>). Table 2 illustrates the transitions between idle and data for these two states.

Cycle	Byte 1	Byte 0
…	K28.1	K28.5
Not Running, Cycle k	K28.1	K28.5
Not Running, Cycle k+1	K28.1	K28.5
Packet 1, Word 1	E_T 3 (bits 0 to 7)	E_T 1 (bits 0 to 7)
…	…	…
Packet 1, Word 6	BC0=1 / …	BC0=1 / …
Packet 2, Word 1	E_T 3 (bits 0 to 7)	E_T 1 (bits 0 to 7)
…	…	…
Packet n, Word 6	BC0=0 / …	BC0=0 / …
Gap, Cycle 1	K28.7	K28.5
Gap, Cycle 2	K28.7	K28.5
…	…	…
Gap, Cycle m	K28.7	K28.5
Packet 1, Word 1	E_T 3 (bits 0 to 7)	E_T 1 (bits 0 to 7)
…	…	…
Packet n, Word 6	BC0=0 / …	BC0=0 / …
Not Running, Cycle 1	K28.1	K28.5
Not Running, Cycle 2	K28.1	K28.5
…	K28.1	K28.5

Table 2 – Packet sequence and idle transitions.

2.1 PHYSICAL CONNECTION

- Optical specification: wavelength=850nm, optical encoding=NRZ
- Optical connections: LC-LC
- Fiber type: OM3 or better

2.2 SIGNALING

- Line rate = 4.8G sync
- Symbol encoding = 8b10b
- User Interface = 16bit @ 240 MHz
- Comma Word (when not running) = x”3CBC” with k code bytes = “11”
- Comma Word (during gap) = x”FCBC” with k code bytes = “11”
- Link alignment = Comma Words and BC0 flag

2.3 PROTOCOL AND ALIGNMENT

- The baseline is 1 packet per bunch crossing.
- Words of packets with no data are replaced by alignment sequences.
- Synchronous operation is guaranteed by transmitting every link with the same reference clock and alignment flag (RCT BC0).
- Receiver aligns links by detecting 8b10b K28.5 characters on byte 0 and alignment-to-data transitions.

2.4 ERROR DETECTION

- Four individual 5 bits Hamming code per packet.
- Receivers compute local Hamming code and check data integrity.
- Status signals from the High Speed transceivers used to check invalid 8b10b characters.
- BC0 flags are 1 in the first packet after alignment-to-data transition.

3 oSLB PAYLOAD SPECIFICATION

3.1 PAYLOAD SPECIFICATION

1. Each data packet contains six 16-bit words.
2. Each data packet contains the energy of 8 trigger towers for full data or 4 trigger towers for half data (see 3.2).
3. The energy of each trigger tower is given by 8 bits plus 1 isolation bit.
4. The four BC0 flags are equivalent and mark the first packet.

3.2 HALF DATA

1. Due to the detector architecture, some links carry half data: 4 trigger towers instead of 8.
2. Either trigger towers 1 through 4 or 5 through 8 have valid energy.
3. Bits of trigger towers not used are zeroed by the transmitter logic.
4. Hamming codes and BC0s are always valid independently of full or half data operation.

3.3 COMMANDS TRANSMISSION

During idle operation, control or info commands can be transmitted to the receiver. Commands are 16 bit wide and are packed in 2 words as shown in Table 3.

Cycle	Byte 1	Byte 0
Cycle k	K28.1 / K28.7	K28.5
Cycle k+1	K28.1 / K28.7	K28.5
Command Cycle 1	Command (bits 15 to 0)	K28.5
Command Cycle 2	Command (bits 7 to 0)	CRC (XOR)
Cycle k+4	K28.1 / K28.7	K28.5
Cycle k+5	K28.1 / K28.7	K28.5

Table 3 – Commands integrated into the alignment stream.

Where CRC (XOR) = Command (bits 15 to 8) XOR Command (bits 7 to 0).

The transmitter checks the number of idle words remaining before sending commands.

Table 4 contains the list of reserved commands.

Name	Value	Description
Start	0x0000	Transmission of TPs will begin on next BC0
Stop	0x0001	Transmission of TPs has stopped

Table 4 – Reserved commands.

4 uHTR/CTP7 LINK SPECIFICATION

Each packet is composed by 16 bytes. The first byte of each packet is a K character. For the bunch which contains BC0, the first byte is K28.3 while for all other packets the first byte is K28.5 (Ethernet comma character). The last byte each packet is a CRC on the 14 bytes of packet payload (not including the K character or the CRC byte itself). The internal structure of the payload depends on the portion of the detector under consideration.

4.1 PHYSICAL CONNECTION

- Optical specification: wavelength=850nm, optical encoding=NRZ
- Optical connections: MTP (uHTR) to dual MTP (CTP7) via patch-panel
- Fiber type: OM3 or better

4.2 SIGNALING

- Line rate = 6.4G sync
- Symbol encoding = 8b10b
- User Interface = 16bit @ 320 MHz
- Packet header word (BC0) = x”XX7C” with k code bytes = “01”
- Packet header word (non-BC0) = x”XXBC” with k code bytes = “01”
- Link alignment = Comma Words and BC0 flag

4.3 PROTOCOL AND ALIGNMENT

- The baseline is 1 packet per bunch crossing.
- Words of packets with no data are replaced by alignment sequences.
- Synchronous operation is guaranteed by transmitting every link with the same reference clock and alignment flag (BC0 K character in header).
- Receiver aligns links by detecting 8b10b K28.5 characters on byte 0 of all packets (except BC0 packet).

4.4 ERROR DETECTION

- CRC code per packet (CRC-8-CCITT)
- Status signals from the High Speed transceivers used to check invalid 8b10b characters.

5 uHTR/CTP7 PAYLOAD SPECIFICATION

5.1 PAYLOAD SPECIFICATION FOR HF

1. Each data packet contains a header (K-character), trailer (CRC) and 14 payload bytes.
2. Each packet contains the data for eleven HF towers.
3. The energy for each tower is given by 8 bits and there are two feature bits for each tower.
4. The least-significant feature bit indicates that the tower's long/short fiber ratio is consistent with an electron or photon energy deposit.
5. The most-significant feature bit is not assigned in the current firmware (reserved).

Byte	7	6	5	4	3	2	1	0
0	8b10b K-Character (K28.3 for BC0, K28.5 otherwise)							
1	Tower 30 Energy							
2	Tower 31 Energy							
3	Tower 32 Energy							
4	Tower 33 Energy							
5	Tower 34 Energy							
6	Tower 35 Energy							
7	Tower 36 Energy							
8	Tower 37 Energy							
9	Tower 38 Energy							
10	Tower 39 Energy							

11	Tower 40/41 Energy			
12	Tower 33 FB	Tower 32 FB	Tower 31 FB	Tower 30 FB
13	Tower 37 FB	Tower 36 FB	Tower 35 FB	Tower 34 FB
14	Reserved (0)	Tower 40/41FB	Tower 39 FB	Tower 38 FB
15	CRC-8-CCITT			

Table 5 – Packet Format for uHTR/CTP7 connections in HF

5.2 PAYLOAD SPECIFICATION FOR HB/HE

1. Each data packet contains a header (K-character), trailer (CRC) and 14 payload bytes.
2. Each packet carries the data for eight trigger towers.
3. The energy for each tower is given by 8 bits and there are six “extended information” bits for each tower.
4. The meanings of the extended information bits are not specified at this time, but will likely include information about shower shape and requests for MIP calibration triggers.

Byte	7	6	5	4	3	2	1	0
0	8b10b K-Character (K28.3 for BC0, K28.5 otherwise)							
1	Tower A Energy							
2	Tower B Energy							
3	Tower C Energy							
4	Tower D Energy							
5	Tower E Energy							
6	Tower F Energy							
7	Tower G Energy							
8	Tower H Energy							
9	Tower B EB [1:0]		Tower A Extended Bits [5:0]					
10	Tower C Extended Bits [3:0]				Tower B Extended Bits [5:2]			
11	Tower D Extended Bits [5:0]						Tower C EB [5:4]	
12	Tower F EB [1:0]		Tower E Extended Bits [5:0]					
13	Tower G Extended Bits [3:0]				Tower F Extended Bits [5:2]			
14	Tower H Extended Bits [5:0]						Tower G EB [5:4]	
15	CRC-8-CCITT							

Table 6 – Packet Format for uHTR/CTP7 connections in HB/HE

REFERENCES

[1] 2006 Interface Specification for CMS Level 1 Regional Calorimeter Trigger to Calorimeter Global Trigger, CMS IN 2006/032, 6 October 2006

[2] Revised CMS Calorimeter Trigger Primitive Generator to Level 1 Regional Trigger Interface, CMS IN 2004/008, 23 March 2004

[3] CMS Calorimeter Trigger Primitive Generator to Level 1 Regional Trigger Interface, CMS IN 2001/016