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CMS Level-1 Global Calorimeter Trigger to Global Trigger and Global Muon Trigger Interfaces

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Abstract

The interfaces between the CMS Level 1 Global Calorimeter Trigger electronics crate and the Global Trigger and Global Muon Trigger are specified. Cabling, data format, and timing are described.

1 Introduction

The three central components of the CMS Level-1 trigger logic are the Global Calorimeter Trigger, Global Muon Trigger and Global Trigger. Detailed descriptions of these systems can be found elsewhere [1]. The Global Calorimeter Trigger receives trigger objects and energy information from the 18 crates of the Regional Calorimeter Trigger, and passes to the Global Trigger the highest Et objects along with total and missing energy information. The Global Muon Trigger also receives trigger objects (muon candidates) from the trackfinding processors for the different muon chamber systems, sorts and filters these objects and passes the best muon candidates to the Global Trigger. In addition to muon tracks, activity information is sent from the calorimeter regions to the Global Muon Trigger to assist in the classification of muon candidates. This activity information is routed through the Global Calorimeter Trigger.

This note describes the content and format of the data sent from the Global Calorimeter Trigger to the Global Trigger, and to the Global Muon Trigger.

The Global Muon Trigger (GMT) and the Global Trigger (GT) are housed together in a single crate in the underground counting room USC55. The Global Calorimeter Trigger (GCT) comprises three crates of electronics in an adjacent rack. Data are sent from the GCT to the GT and GMT on serial links. The serialiser/deserialiser devices transform between 16-bit parallel data clocked at 80 MHz and a 1.44 Gbit/s serial stream. The serial data is carried on cable assemblies comprising two pairs of conductors, so that each assembly has a capacity of 64 bits per LHC beam-crossing interval (bx). A total of seven such cables are used to transfer data to the GT, and a further twelve to the GMT. We give the details of the data content and format in Sections 2 and 3, and the physical implementation of the data links in Section 4.

2 Calorimeter data to the Global Trigger

Table 1: Summary of GCT-to-GT input cables

Cable	Content
1	Isolated electron/photon objects
2	Non-isolated electron/photon objects
3	Central jet objects
4	Forward jet objects
5	Tau-flagged jet objects
6	Energy summary information
7	Jet counts

The data sent to the Global Trigger comprise five types of trigger object, energy information and jet counts as listed in Table 1. The data format for all five object types is identical. Descriptions of the data follow.

2.1 Object data

The calorimeter trigger processing identifies and sorts electron/photon and jet candidates. The four highest-ranked candidates in each category are passed to the GT for each event. For each selected candidate, the GCT sends rank and position information encoded in fifteen bits: six bits rank, four bits pseudorapidity (η) position, five bits azimuth angle (ϕ) position. The rank information generally represents a coding of the object Et, with the definition of the rank assignments programmable within the calorimeter trigger logic. The objects are sorted by rank within the GCT, so that object 1 is the highest ranked object, object 2 the second highest ranked, and so on. The ϕ position ranges from 0 to 17 and defines a 20° sector. The η position is coded as three bits value plus a sign bit. For objects other than forward jets, the η regions are of size $\Delta\eta\approx0.35$ with regions 0-3 in the barrel part of CMS, 4-6 in the endcap. For forward jets, the η value ranges from 0-3. The size of the η regions is $\Delta\eta=0.5$ and the range covered is $3<|\eta|<5$. The details of the bit mapping on cables are shown in Table 2 in the Appendix.

2.2 Energy summary information

The energy sum information consists of the three quantities total Et, total calibrated Et in jets (Ht) and missing Et. Both Et and Ht are sent as 12-bit value plus an overflow bit on a programmable, linear energy scale. Missing Et is sent as a 2-vector with both magnitude and azimuthal direction. The magnitude is again encoded in 12 bits plus an overflow bit; the direction is a 6-bit value between 0-35. The zero and sense of rotation of the azimuth angle are the same as for the object data, with two bins of EtMiss_phi corresponding to one bin of Object_phi. The details of the bit mapping on cables are shown in Table 3 in the Appendix

2.3 Jet counts

Twelve jet counts are sent, encoded in five bits per count. The code jet count=31 is used to indicate an overflow condition. The details of the bit mapping on cables are shown in Table 4 in the Appendix

3 Calorimeter data to the Global Muon Trigger

The calorimeter sends two bits of information to the GMT for each of the 18×14=252 (ϕ,η) regions of the barrel and endcap calorimeters. The two bits for each region are labelled MIP, for a small but significant energy deposit compatible with the passage of a minimum ionising particle, and Q, for a quiet region with no significant energy. These bits are passed to the GMT on 12 cables; the mapping of cables to regions of the calorimeter is illustrated in Figure 1. The details of the bit mapping on cables are shown in Table 5 to Table 8 in the Appendix.

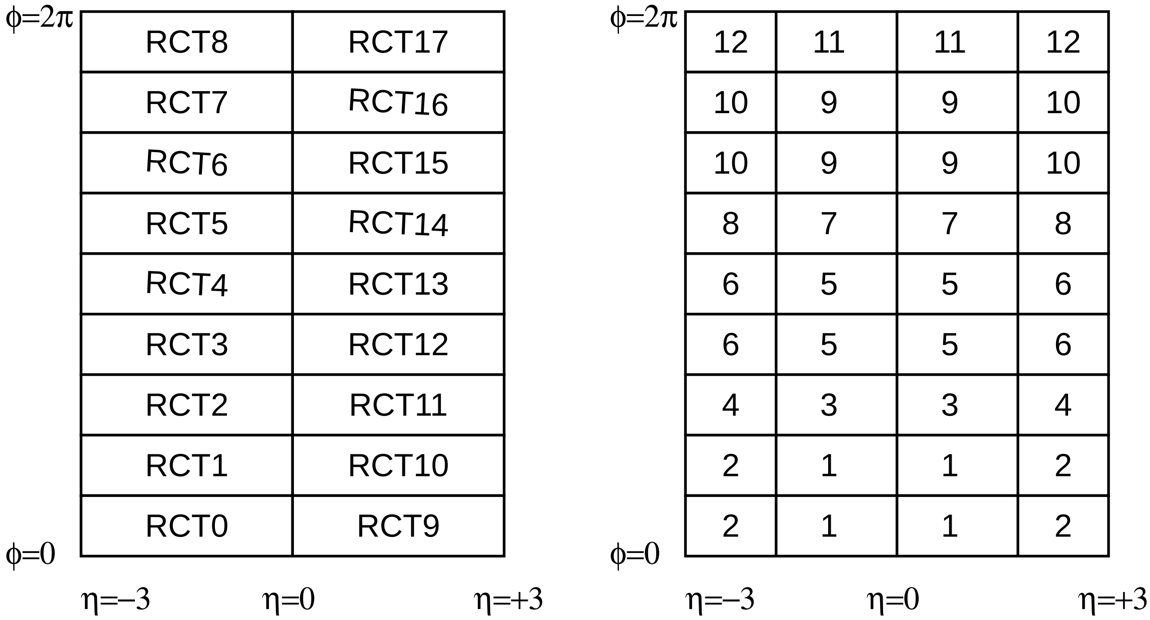

Figure 1: Mapping of the barrel and endcap calorimeters to Regional Calorimeter Trigger crates (left) and GCT-to-GMT cables (right)

4 Hardware details

4.1 Serial links

The links to the Global Trigger and GMT will use the National Semiconductor DS92LV16 25–80 MHz serialiser/deserialier (serdes) device [2]. The devices will be clocked at 80.16 MHz in this application. The serialiser circuit accepts 16 bits of LVTTL parallel data per clock cycle and encodes them onto 18 bits serial in differential LVDS. The serial data rate is 1.44 Gbit/s although, since only 16 of the 18 bits contain trigger data, the effective transfer rate of one link is 1.28 Gbit/s. At the destination this bit stream is received by a deserialiser, which recovers the 80 MHz parallel data. These devices require a precise, low-jitter clock at the transmit (GCT) end. Control of the devices is performed by FPGAs.

4.2 Cables and connectors

For transmission of the serial data we will use Infiniband connectors and halogen-free SkewClear cable from Amphenol. The 1X Infiniband connectors accommodate two differential pairs, and are available from Tyco/AMP [3]. The part number for the board-mounting connector is 1364532-1; this is a seven-pin connector with pins 1,4,7 ground pins. The +/− differential signals for pair 0 are received on pins 2/3, and those for pair 1 on pins 5/6.

The cables will be 3 metres in length, with each cable carrying two pairs of 28 AWG wire and passive equalisation circuits to 100Ω impedance. Completed cable assemblies using PVC-jacketed SkewClear are currently available from Amphenol [4] in a comprehensive range of lengths and wire gauges. It is probable that halogen-free versions will become available through industry in the near future; however as a fallback solution the 19 assemblies required can be made up in-house. The cables will be routed from the front of the GCT crates, through unused slots in the GCT processor crate and through a dedicated hole into the GT rack, arriving at the rear of the GT/GMT crate.

4.3 Timing and synchronisation

The 80ps RMS precision required for the operation of the serialisers is provided by the clock distribution system in the GCT, which is described elsewhere [5]. The clock jitter requirements at the GT/GMT end are much less demanding. Most of the data uses only bits 15:1 of each 16-bit link, so that bit 16 is used to distinguish between the two 80 MHz clock cycles in one bx, and to flag and check BC0 synchronisation.

All data for a given bunch crossing will arrive at the same time at the GT input. The latency from the data input to the RCT to the GT input will be 33 crossings. The data to the GMT will arrive 17 crossings earlier.

4.4 Error detection

There will be no error detection bits. However, offline and online running of test pattern generation, transmission, and decoding will be used. Provisions for fast and efficient offline (but synchronised) testing should be made in all trigger subsystems. During timing setup, test patterns will be sent from the GCT to GT and GMT in lieu of normal trigger data.

5 References

[1] CMS collaboration, “The Trigger and Data Acquisition Project, Volume 1: The Level-1 Trigger”, CERN LHCC 2000-038.

[2] http://www.national.com/pf/DS/DS92LV16.html

[3] http://catalog.tycoelectronics.com/TE/docs/pdf/9/75/222579.pdf

[4] http://www.amphenol-aipc.com/infinib.htm

[5] http://www.phy.bris.ac.uk/research/pppages/CMS_trigger/timing2.pdf

Appendix: Definitions of bit assignments on cables

Table 2: Bit assignments on GT input cables 1-5 (object data)

Bit no.	Pair 0; Cycle 0	Pair 0; Cycle 1	Pair 1; Cycle 0	Pair 1; Cycle 1
1	Object 1 rank#0	Object 3 rank#0	Object 2 rank#0	Object 4 rank#0
2	Object 1 rank#1	Object 3 rank#1	Object 2 rank#1	Object 4 rank#1
3	Object 1 rank#2	Object 3 rank#2	Object 2 rank#2	Object 4 rank#2
4	Object 1 rank#3	Object 3 rank#3	Object 2 rank#3	Object 4 rank#3
5	Object 1 rank#4	Object 3 rank#4	Object 2 rank#4	Object 4 rank#4
6	Object 1 rank#5	Object 3 rank#5	Object 2 rank#5	Object 4 rank#5
7	Object 1 eta#0	Object 3 eta#0	Object 2 eta#0	Object 4 eta#0
8	Object 1 eta#1	Object 3 eta#1	Object 2 eta#1	Object 4 eta#1
9	Object 1 eta#2	Object 3 eta#2	Object 2 eta#2	Object 4 eta#2
10	Object 1 eta_sign	Object 3 eta_sign	Object 2 eta_sign	Object 4 eta_sign
11	Object 1 phi#0	Object 3 phi#0	Object 2 phi#0	Object 4 phi#0
12	Object 1 phi #1	Object 3 phi #1	Object 2 phi #1	Object 4 phi #1
13	Object 1 phi #2	Object 3 phi #2	Object 2 phi #2	Object 4 phi #2
14	Object 1 phi #3	Object 3 phi #3	Object 2 phi #3	Object 4 phi #3
15	Object 1 phi #4	Object 3 phi #4	Object 2 phi #4	Object 4 phi #4
16	Always ‘1’	‘1’=BC0 else ‘0’	Always ‘1’	‘1’=BC0 else ‘0’

Table 3: Bit assignments on GT input cable 6 (energy summary)

Bit no.	Pair 0; Cycle 0	Pair 0; Cycle 1	Pair 1; Cycle 0	Pair 1; Cycle 1
1	Total_Et #0	Ht #0	EtMiss_mag #0	EtMiss_phi #0
2	Total_Et #1	Ht #1	EtMiss_mag #1	EtMiss_phi #1
3	Total_Et #2	Ht #2	EtMiss_mag #2	EtMiss_phi #2
4	Total_Et #3	Ht #3	EtMiss_mag #3	EtMiss_phi #3
5	Total_Et #4	Ht #4	EtMiss_mag #4	EtMiss_phi #4
6	Total_Et #5	Ht #5	EtMiss_mag #5	EtMiss_phi #5
7	Total_Et #6	Ht #6	EtMiss_mag #6	Always ‘0’
8	Total_Et #7	Ht #7	EtMiss_mag #7	Always ‘0’
9	Total_Et #8	Ht #8	EtMiss_mag #8	Always ‘0’
10	Total_Et #9	Ht #9	EtMiss_mag #9	Always ‘0’
11	Total_Et #10	Ht #10	EtMiss_mag #10	Always ‘0’
12	Total_Et #11	Ht #11	EtMiss_mag #11	Always ‘0’
13	Total_Et_OV	Ht _OV	EtMiss_mag _OV	Always ‘0’
14	Always ‘0’	Always ‘0’	Always ‘0’	Always ‘0’
15	Always ‘0’	Always ‘0’	Always ‘0’	Always ‘0’
16	Always ‘1’	‘1’=BC0 else ‘0’	Always ‘1’	‘1’=BC0 else ‘0’

Table 4: Bit assignments on GT input cable 7 (jet counts)

Bit no.	Pair 0; Cycle 0	Pair 0; Cycle 1	Pair 1; Cycle 0	Pair 1; Cycle 1
1	JC0 #0	JC3 #0	JC6 #0	JC9 #0
2	JC0 #1	JC3 #1	JC6 #1	JC9 #1
3	JC0 #2	JC3 #2	JC6 #2	JC9 #2
4	JC0 #3	JC3 #3	JC6 #3	JC9 #3
5	JC0 #4	JC3 #4	JC6 #4	JC9 #4
6	JC1 #0	JC4 #0	JC7 #0	JC10 #0
7	JC1 #1	JC4 #1	JC7 #1	JC10 #1
8	JC1 #2	JC4 #2	JC7 #2	JC10 #2
9	JC1 #3	JC4 #3	JC7 #3	JC10 #3
10	JC1 #4	JC4 #4	JC7 #4	JC10 #4
11	JC2 #0	JC5 #0	JC8 #0	JC11 #0
12	JC2 #1	JC5 #1	JC8 #1	JC11 #1
13	JC2 #2	JC5 #2	JC8 #2	JC11 #2
14	JC2 #3	JC5 #3	JC8 #3	JC11 #3
15	JC2 #4	JC5 #4	JC8 #4	JC11 #4
16	Always ‘1’	‘1’=BC0 else ‘0’	Always ‘1’	‘1’=BC0 else ‘0’

Table 5: Bit assignments on GMT input cables 1/5/9. The numbering of barrel/endcap pseudorapidity regions corresponds to that used for calorimeter trigger objects. Phi0 for the three cables is ϕ=0/6/12; Phi1 is ϕ=1/7/13; Phi2 is ϕ=2/8/14; Phi3 is ϕ=3/9/15.

Bit no.	Pair 0; Cycle 0	Pair 0; Cycle 1	Pair 1; Cycle 0	Pair 1; Cycle 1
1	Eta-0_Phi0_MIP	Eta-0_Phi0_Q	Eta-2_Phi0_MIP	Eta-2_Phi0_Q
2	Eta-1_Phi0_MIP	Eta-1_Phi0_Q	Eta-3_Phi0_MIP	Eta-3_Phi0_Q
3	Eta-0_Phi1_MIP	Eta-0_Phi1_Q	Eta-2_Phi1_MIP	Eta-2_Phi1_Q
4	Eta-1_Phi1_MIP	Eta-1_Phi1_Q	Eta-3_Phi1_MIP	Eta-3_Phi1_Q
5	Eta+0_Phi0_MIP	Eta+0_Phi0_Q	Eta+2_Phi0_MIP	Eta+2_Phi0_Q
6	Eta+1_Phi0_MIP	Eta+1_Phi0_Q	Eta+3_Phi0_MIP	Eta+3_Phi0_Q
7	Eta+0_Phi1_MIP	Eta+0_Phi1_Q	Eta+2_Phi1_MIP	Eta+2_Phi1_Q
8	Eta+1_Phi1_MIP	Eta+1_Phi1_Q	Eta+3_Phi1_MIP	Eta+3_Phi1_Q
9	Eta-0_Phi2_MIP	Eta-0_Phi2_Q	Eta-2_Phi2_MIP	Eta-2_Phi2_Q
10	Eta-1_Phi2_MIP	Eta-1_Phi2_Q	Eta-3_Phi2_MIP	Eta-3_Phi2_Q
11	Eta-0_Phi3_MIP	Eta-0_Phi3_Q	Eta-2_Phi3_MIP	Eta-2_Phi3_Q
12	Eta-1_Phi3_MIP	Eta-1_Phi3_Q	Eta-3_Phi3_MIP	Eta-3_Phi3_Q
13	Unused	Unused	Unused	Unused
14	Unused	Unused	Unused	Unused
15	Unused	Unused	Unused	Unused
16	Always ‘1’	‘1’=BC0 else ‘0’	Always ‘1’	‘1’=BC0 else ‘0’

Table 6: Bit assignments on GMT input cables 2/6/10. The numbering of barrel/endcap pseudorapidity regions corresponds to that used for calorimeter trigger objects. Phi4 for the three cables is ϕ=4/10/16; Phi5 is ϕ=5/11/17.

Bit no.	Pair 0; Cycle 0	Pair 0; Cycle 1	Pair 1; Cycle 0	Pair 1; Cycle 1
1	Eta+0_Phi2_MIP	Eta+0_Phi2_Q	Eta+2_Phi2_MIP	Eta+2_Phi2_Q
2	Eta+1_Phi2_MIP	Eta+1_Phi2_Q	Eta+3_Phi2_MIP	Eta+3_Phi2_Q
3	Eta+0_Phi3_MIP	Eta+0_Phi3_Q	Eta+2_Phi3_MIP	Eta+2_Phi3_Q
4	Eta+1_Phi3_MIP	Eta+1_Phi3_Q	Eta+3_Phi3_MIP	Eta+3_Phi3_Q
5	Eta-0_Phi4_MIP	Eta-0_Phi4_Q	Eta-2_Phi4_MIP	Eta-2_Phi4_Q
6	Eta-1_Phi4_MIP	Eta-1_Phi4_Q	Eta-3_Phi4_MIP	Eta-3_Phi4_Q
7	Eta-0_Phi5_MIP	Eta-0_Phi5_Q	Eta-2_Phi5_MIP	Eta-2_Phi5_Q
8	Eta-1_Phi5_MIP	Eta-1_Phi5_Q	Eta-3_Phi5_MIP	Eta-3_Phi5_Q
9	Eta+0_Phi4_MIP	Eta+0_Phi4_Q	Eta+2_Phi4_MIP	Eta+2_Phi4_Q
10	Eta+1_Phi4_MIP	Eta+1_Phi4_Q	Eta+3_Phi4_MIP	Eta+3_Phi4_Q
11	Eta+0_Phi5_MIP	Eta+0_Phi5_Q	Eta+2_Phi5_MIP	Eta+2_Phi5_Q
12	Eta+1_Phi5_MIP	Eta+1_Phi5_Q	Eta+3_Phi5_MIP	Eta+3_Phi5_Q
13	Unused	Unused	Unused	Unused
14	Unused	Unused	Unused	Unused
15	Unused	Unused	Unused	Unused
16	Always ‘1’	‘1’=BC0 else ‘0’	Always ‘1’	‘1’=BC0 else ‘0’

Table 7: Bit assignments on GMT input cables 3/7/11. The numbering of barrel/endcap pseudorapidity regions corresponds to that used for calorimeter trigger objects. Phi0 for the three cables is ϕ=0/6/12; Phi1 is ϕ=1/7/13; Phi2 is ϕ=2/8/14; Phi3 is ϕ=3/9/15.

Bit no.	Pair 0; Cycle 0	Pair 0; Cycle 1	Pair 1; Cycle 0	Pair 1; Cycle 1
1	Eta-4_Phi0_MIP	Eta-4_Phi0_Q	Eta-6_Phi0_MIP	Eta-6_Phi0_Q
2	Eta-5_Phi0_MIP	Eta-5_Phi0_Q	Eta-6_Phi1_MIP	Eta-6_Phi1_Q
3	Eta-4_Phi1_MIP	Eta-4_Phi1_Q	Unused	Unused
4	Eta-5_Phi1_MIP	Eta-5_Phi1_Q	Unused	Unused
5	Eta+4_Phi0_MIP	Eta+4_Phi0_Q	Eta+6_Phi0_MIP	Eta+6_Phi0_Q
6	Eta+5_Phi0_MIP	Eta+5_Phi0_Q	Eta+6_Phi1_MIP	Eta+6_Phi1_Q
7	Eta+4_Phi1_MIP	Eta+4_Phi1_Q	Unused	Unused
8	Eta+5_Phi1_MIP	Eta+5_Phi1_Q	Unused	Unused
9	Eta-4_Phi2_MIP	Eta-4_Phi2_Q	Eta-6_Phi2_MIP	Eta-6_Phi2_Q
10	Eta-5_Phi2_MIP	Eta-5_Phi2_Q	Eta-6_Phi3_MIP	Eta-6_Phi3_Q
11	Eta-4_Phi3_MIP	Eta-4_Phi3_Q	Unused	Unused
12	Eta-5_Phi3_MIP	Eta-5_Phi3_Q	Unused	Unused
13	Unused	Unused	Unused	Unused
14	Unused	Unused	Unused	Unused
15	Unused	Unused	Unused	Unused
16	Always ‘1’	‘1’=BC0 else ‘0’	Always ‘1’	‘1’=BC0 else ‘0’

Table 8: Bit assignments on GMT input cables 4/8/12. The numbering of barrel/endcap pseudorapidity regions corresponds to that used for calorimeter trigger objects. Phi4 for the three cables is ϕ=4/10/16; Phi5 is ϕ=5/11/17.

Bit no.	Pair 0; Cycle 0	Pair 0; Cycle 1	Pair 1; Cycle 0	Pair 1; Cycle 1
1	Eta+4_Phi2_MIP	Eta+4_Phi2_Q	Eta+6_Phi2_MIP	Eta+6_Phi2_Q
2	Eta+5_Phi2_MIP	Eta+5_Phi2_Q	Eta+6_Phi3_MIP	Eta+6_Phi3_Q
3	Eta+4_Phi3_MIP	Eta+4_Phi3_Q	Unused	Unused
4	Eta+5_Phi3_MIP	Eta+5_Phi3_Q	Unused	Unused
5	Eta-4_Phi4_MIP	Eta-4_Phi4_Q	Eta-6_Phi4_MIP	Eta-6_Phi4_Q
6	Eta-5_Phi4_MIP	Eta-5_Phi4_Q	Eta-6_Phi5_MIP	Eta-6_Phi5_Q
7	Eta-4_Phi5_MIP	Eta-4_Phi5_Q	Unused	Unused
8	Eta-5_Phi5_MIP	Eta-5_Phi5_Q	Unused	Unused
9	Eta+4_Phi4_MIP	Eta+4_Phi4_Q	Eta+6_Phi4_MIP	Eta+6_Phi4_Q
10	Eta+5_Phi4_MIP	Eta+5_Phi4_Q	Eta+6_Phi5_MIP	Eta+6_Phi5_Q
11	Eta+4_Phi5_MIP	Eta+4_Phi5_Q	Unused	Unused
12	Eta+5_Phi5_MIP	Eta+5_Phi5_Q	Unused	Unused
13	Unused	Unused	Unused	Unused
14	Unused	Unused	Unused	Unused
15	Unused	Unused	Unused	Unused
16	Always ‘1’	‘1’=BC0 else ‘0’	Always ‘1’	‘1’=BC0 else ‘0’