Interface between CTS-CRU and CTS-Detector Front Ends
Trigger Notes for Developers

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Contents

1 Introduction

Central Trigger System (CTS) consists of the Central Ttrigger Processor (CTP) and the Local Trigger Unit (LTU) boards. The CTP distributes clock, Heart Beat (HB) and triggers. The LTU is transparent in the global mode and emulates CTP in standalone mode.

2 One level trigger

2.1 TTC-PON and GBT (ACO,FIT,MCH,MID,TOF,TPC,ZDC)

2.1.1 Introduction

This section describes the data protocol between

- the CTS and the Common Readout Unit (CRU),
- the CTS and the GBT Front End (FE), i.e. ITS and MFT.

It also includes a description of data transmitted for the above cases. The trigger system and protocol is generally described in [1] and [2]. The protocol is again summarised here in section 2.1.2 followed by details of data formats in subsequent sections.

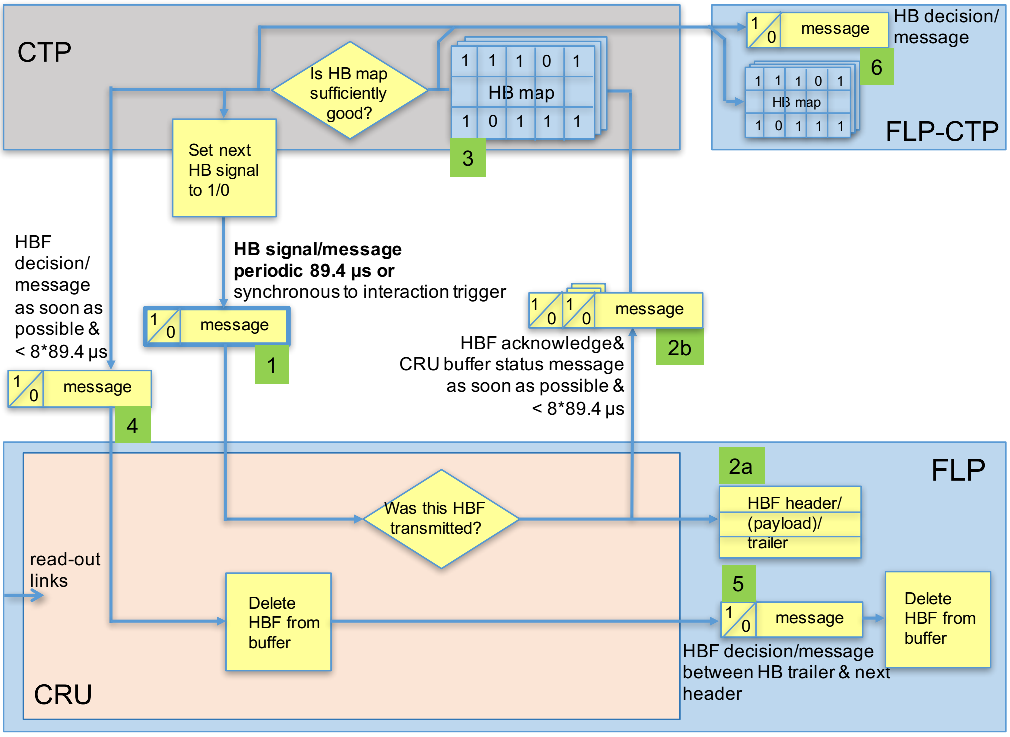

Figure 1: Signal and message flow (from [2]).

2.1.2 CTP-CRU protocol in continuous and triggered modes

The CTP-CRU protocol is identical in the case of continuous and triggered modes. The scenario is described in Figure 1.

- the CTP transmits a TTC-PON message of 77 bits every Bunch Crossing (BC), action 1 in Figure 1.
- For the messages marked as Heart Beat (HB), the CRU responds with an HB acknowledge message (HBAm) [2] acknowledging that data have been successfully collected from the FE and transferred to the FLP, action 2b in Figure 1. A timeout for receiving HBAm on the CTP side is a programmable parameter of order T_{HBAm} $8 * 89.4\mu s$.
- After a time T_{HBAm} the CTP evaluates the HB decision (HBd) for a given HB frame. The decision is based on a predefined function of HBAm messages from all CRUs, action 3 in Figure 1.
- The CTP modifies the HBaccept/HBreject flag in the trigger type in the TTC-PON messages. For full details on strategies for HBR flag modification see section 3.3 in [2].
- The CTP collects all HBd for a given Time Frame (TF) creating the Heart Beat Map of the Time Frame (HBMTF) and transmits them asynchronously to the CRU [3],[4], action 4 in Figure 1 .

2.1.3 CTP-FE protocol in continuous and triggered modes

In the case of CTP-FE communication (see scenario II in fig 2 of [2], direct connection without PON) the CTP transmits every BC a GBT message of 77 bits with a payload identical to the TTC-PON message. No upstream communication from the FE to the CTP is expected. Actually, it is not technically possible because of the passive optical splitting of the GBT links. Note that these detectors (ITS, MFT) also communicate with the CRU, as described in sections 2.1.2 and 2.1.7.

Table 1: Trigger Types

Bit	Name	Comment
0	ORBIT	ORBIT
1	HB	Heart Beat flag
2	HBr	Heart Beat reject flag
3	HC	Health Check
4	PhT	Physics Trigger
5	PP	Pre Pulse for calibration
6	Cal	Calibration trigger
7	SOT	Start of Triggered Data
8	EOT	End of Triggered Data
9	SOC	Start of Continuous Data
10	EOC	End of Continuous Data
11	TF	Time Frame delimiter
...	...	Spare
29	TPCsync	TPC synchronisation
30	TPCrst	TPC reset
31	TOF	TOF special trigger

2.1.4 Trigger Message

The trigger message (data) transmitted to the CRUs and the detector Front Ends (FE) consists of 77 bits arranged as follows: trigger type TTYPE (32 bits), event identification (44 bits), trigger type data valid bit (TTValid). The event identification consist of an LHC orbit counter ORBIT (32 bits) and Bunch Cross (BC) counter BCID (12 bits) [1], [2].

Trigger Type Valid bit :

- TTValid = '1' indicates that the other 3 fields (ORBIT, BCID, TTYPE) are valid.
- TTValid = '0' indicates that the bits occupied by the 3 fields can be used for other communication purposes, e.g. slow control.

The bit HB = '1' indicates that the message is of Heart Beat (HB) type (it can be simultaneously of other types as listed in Table 1) and the corresponding ORBIT and BCID are the identification of the HB. The HB frequency is defined to be equal to LHC orbit frequency [3], i.e. only one HB per ORBIT. It is also synchronised with the LHC orbit, i.e. BC = 0 in trigger messages with HB = '1'.

Trigger Types are described in section 2.1.5. The data format for PON is described in sections 2.1.6 and 2.1.7 and Table 3 includes the payload corresponding to the list of HBd decisions for the given TF. The GBT data are described in section 2.1.8 and Table 4. The GBT format presented is valid for both LTU-CRU and CRU-FE connections. The numbering convention is that the bit/byte counts start with 0, corresponding to the Least Significant Bit (LSB) on the right side. For example <7:0> means 8 least significant bits.

2.1.5 Trigger Types

The LSB bits <11:0> are used for general purposes, while the most significant bits <31:29> are detector dependent. Other bits are not used so far. Aside from the specifically described sequence of operations between CTP-CRU and CTP-FE, no acknowledge messages are required by the CRU to each bit. SOT/EOT,SOC/EOC and TF are synchronised with the HB, i.e. they are always sent in coincidence with the HB flag.

The trigger types are introduced in [1].

HB = '1', HBr = '0' is interpreted as HB accept.

HB = '1', HBr = '1' is interpreted as HB reject.

Health check bit <3> is introduced in [5].

Start/End of data bits <10:7> are introduced in [2], [5].

Time Frame delimiter <11> is introduced in [2], [5].

TPC bits <30:29> are described in [6].

TOF bit <31> is described in [7].

Table 2: HB acknowledge message (HBam) payload

Data	PON byte	Payload	Content
<7:0>	0	<7:0>	HBid (Orbit)
<7:0>	1	<15:8>	HBid (Orbit)
<7:0>	2	<23:16>	HBid (Orbit)
<7:0>	3	<31:24>	HBid (Orbit)
<7:0>	4	<7:0>	CRU id
<1:0>	5	<9:8>	CRU id
<7:2>	5	<7:2>	spare
<0:0>	6	<0:0>	CRU acknowledge
<2:1>	6	<1:0>	CRU buffer status
<7:3>	6	<4:0>	spare

2.1.6 HB acknowledge message (HBam)

The HBam is sent upstream from the CRU to the LTU carrying information about the CRU status. It is natural to assign it the full TTC-PON upstream payload of 56 bits corresponding to one bunch crossing. The HBam was introduced in [2] in Table 7. The version proposed here contains all information proposed originally in [2] updated with the current system status.

2.1.7 Trigger Message through PON

The TTC 10G-PON protocol sends 30 8-bit words per clock cycle (bunch crossing) of which five words are for PON internal use, leaving 25 user words or 200 bits available per bunch crossing [8]. The data format is as follows.

The PON data are divided into two groups. The first 15 bytes carry Trigger Type and event id (BCID and ORBIT). Not all 15 bytes are used, see Table 3. They are sent synchronously with the LHC clock from the CTP to the CRUs. Their TTC PON payload is identical to the GBT message.

The last 10 bytes includes the global Heart Beat Map of the Time Frame (HBMTF). Not all 10 bytes are used, see the following description and Table 3. It was decided that the Time frame should contain a maximum of 256 HB frames [3]. The HBMTF is sent asynchronously from the CTP to the CRUs in 32 bit words, with a header that contains the word count. The HBMTF payload starts with the first header and the first ORBIT of the TF for TF identification:

- HBM header (8 bits),
- ORBIT of the TF (ORBIT1TF) for TF identification (32 bits),

followed by 8 messages of the HBMTF

- HBM header (8 bits),
- HBMFT (32 bits).

The HBMTF payload in each TTC-PON message is validated by

- HB Map Valid bit (HBMValid).

Comment: this format is suggested by O2 in [4]. It implies HBMTF latency of $\approx (256+8)*89.4\mu s = 23.6$ms. It is still to be discussed with the CRU and FE developers.

2.1.8 Trigger Message through GBT

The specified bit allocation is valid for the GBT links directly connected from the LTUs to the FEs (ITS and MFT) and from the CRUs to the FEs. The data format is described in Table 4. In the GBT representation the Valid bit maps to isData (a.k.a. Frame type) bit, see page 15 of [9].

Table 3: PON data format Trigger Message

Data	PON byte	Payload	Content
<7:0>	0	<7:0>	Trigger Type
<7:0>	1	<15:8>	Trigger Type
<7:0>	2	<23:16>	Trigger Type
<7:0>	3	<31:24>	Trigger Type
<7:0>	4	<7:0>	BCID
<3:0>	5	<11:8>	BCID
<7:0>	6	<7:0>	ORBIT
<7:0>	7	<15:8>	ORBIT
<7:0>	8	<23:16>	ORBIT
<7:0>	9	<31:24>	ORBIT
<7:7>	14	<0:0>	TTValid
<7:0>	15	<7:0>	HBM header
<7:0>	16	<7:0>	1st ORBIT of TF/HBMTF
<7:0>	17	<15:8>	1st ORBIT of TF/HBMTF
<7:0>	18	<23:16>	1st ORBIT of TF/HBMTF
<7:0>	19	<31:24>	1st ORBIT of TF/HBMTF
<7:7>	24	<0:0>	HBMValid

Table 4: GBT data format Trigger Message

Data	GBT word	Payload	Content
<15:0>	G0	<15:0>	Trigger Type
<15:0>	G1	<31:16>	Trigger Type
<11:0>	G2	<11:0>	BCID
<15:12>	G2	<>	spare (or level)
<15:0>	G3	<15:0>	ORBIT
<15:0>	G4	<31:16>	ORBIT

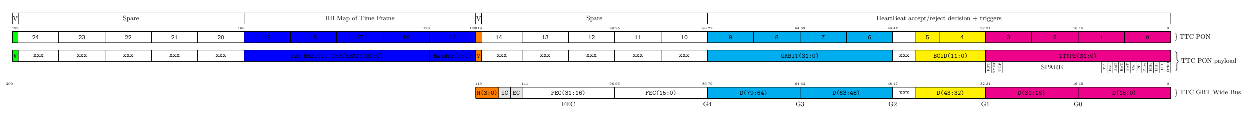

Figure 2: CTP format corresponding to Tables 3 and 4.

2.2 TTC-PON and TTC(old) (TRD)

The trigger distribution for the TRD is special. LM triggers are sent from the LTU to the FE over the TTC system. In parallel they are also transmitted from the LTU to the CRU via the PON, message content is described in Table 3.

The trigger protocol is one level trigger at LM latency realised by a pulse in the TTC A channel. The TRD also requires special calibration triggers every 1000 LM physics triggers (programmable). For the calibration trigger, the LM pulse in A channel is followed by another single pulse with fixed programmable latency with respect to the LM pulse (within the protected interval as defined below). No information is required in the TTC B channel in either case. The calibration triggers have both the physics and calibration type of trigger bits active in the PON trigger message. After each trigger the TRD is protected by the CTP for a programmable time interval of order of a couple of microseconds until TRD BUSY arrives. The TRD needs to communicate its BUSY status to the CTP in a few microseconds in order to optimise the data taking efficiency. To achieve this, the BUSY should be fan-in from all CRUs in the control room (e.g. using additional CRU) and transmitted to thr CTP/LTU electrically or optically. In addition, the CRUs transmit a standard HBT acknowledge message to the CTP.

3 Two level trigger

3.1 TTC(old) and GBT (CPV,EMC,HMP,PHS)

3.1.1 Introduction

This section describes the data protocol between the CTS and the CPV,EMC,HMP and PHS detectors. All these detectors use two level trigger protocol almost identical to the L0 and L1 trigger protocol in Run2 [1]. The specific implementation of the general protocol, i.e. the protocol between

- the CTS and the TTC Front End (FE),i.e. EMC,HMP,PHS,
- the CTS and the GBT FE, i.e. CPV

is described in 3.1.3 and 3.1.4

3.1.2 Two level trigger protocol a la L0/L1 in Run2

There are two trigger levels ,i.e. LL0 and LL1 with adjustable latency (e.g. LM, L0, L1 latencies in Table 8.4 of [1]). Note that the trigger level acronyms are changed with respect to Run2 terminology in order to distinguish between trigger levels (LL0,LL1) and trigger latencies (LM,L0,L1). The LL0 trigger is followed by the LL1 trigger after an adjustable LL0-LL1 time. No additional LL0 triggers are allowed inside the LL0-LL1 time window. The missing LL1 is interpreted as an LL1 reject. After receiving the LL0 trigger, the detector may raise its BUSY signal which is propagated to the CTP signaling that the detector is not ready to accept more triggers.

3.1.3 Trigger message through TTC(old)

The trigger protocol is implemented in the same way as in Run2. The first level trigger LL0 can be sent over cable or as a synchronous one BC wide signal in the TTC A channel. The second level trigger LL1 is sent as a two BC wide synchronous signal in the TTC A channel. The second level trigger is followed by an asynchronous message described in table 5. The Orbit and prepulse PP are transmitted as short messages (broadcast) in the TTC B channel.

3.1.4 Trigger message through GBT (CPV)

The first level trigger LL0 can be sent over cable or via GBT. The second level trigger LL1 is sent after the LL0-LL1 time over the GBT. For both LL0 and LL1 triggers, the data format is described in Table 4. The level bits coding is described in Table 6. The BUSY signal from the detector to the CTP can be transmitted by the LVDS cable as in Run2 or over the GBT if no passive splitting is used. As the CPV uses the standard CRU-FE connection for the read-out, the standard TTC-PON message 3 is sent at LL1 level.

Table 5: TTC data format Trigger Message (EMC,HMP,PHS)

Data	TTC word	Payload	Content
<15:12>	0	<3:0>	LL1 header
<11:0>	0	<31:20>	TType
<15:12>	1	<3:0>	LL1 data
<11:0>	1	<19:8>	TType
<15:12>	2	<3:0>	LL1 data
<11:4>	2	<7:0>	TType
<3:0>	2	<>	spare
<15:12>	3	<3:0>	LL1 data
<11:0>	3	<11:0>	BCID
<15:12>	4	<3:0>	LL1 data
<11:0>	4	<31:20>	ORBIT
<15:12>	5	<3:0>	LL1 data
<11:0>	5	<19:8>	ORBIT
<15:12>	6	<3:0>	LL1 data
<11:4>	6	<7:0>	ORBIT
<3:0>	6	<>	spare

Table 6: Two level trigger coding over GBT

Data	GBT word	Payload	Content
<15:12>	G2	0000	LL0
<15:12>	G2	0001	LL1 accept
<15:12>	G2	0011	LL1 reject

The other option is that the GBT is not used for trigger distribution at all. The LL0 trigger (and BUSY) goes over the LVDS cable and the LL1 trigger goes over the TTC-PON.

Acknowledgement

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References

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