Title: **HEPI Requirements**

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Issue 1	09.01.1997	all	typos
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		7	HBR I/F HEPI–DPE
		7	LBR I/F DPE–HEPI
		8	Time synchronisation between the detectors
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1 Introduction

1.1 Scope

This report documents the current requirements for HEPI (Hardware Event Pre-processor of IBIS) board within the DPE (Data Processing electronics) of the IBIS instrument

1.2 Applicable and reference documents

EID-A (latest version)
EID-B (latest version)
IN-IB-SAP-RP-031
IN-IM-TES-RP-0018
IN-IM-TES-TN-0012
IN-IM-TES-TN-0013
IN-IM-TES-TN-0017
IN-IM-TUB-RP-002
IN-IM-TUB-RP-003
IN-IM-TUB-RP-004
IN-IM-TUB-TN/EL-005
IN-IM-TUB-TN/EL-007
IN-IM-TUB-TN/EL-008

2 Description

2.1 Overview

HEPI is the interface between the detector plane and the DPE. The events are generated at the CdTe layer (ISGRI) and the CsI layer (PICSIT). Each detector layer is divided into eight modules. A FIFO Data Manager (FDM) collects the digital output data of these modules and sorts them by time. HEPI gets the data via an unidirectional High Bit Rate Serial Interface (HBR I/F) from each detector. The control of these HBR I/F is done by the HEPI. On HEPI the data are pre-processed and some of them are accumulated in histograms Then the DPE reads out the data via two different HBR I/F's. These interfaces are controlled by the DPE. Controlling and exchange of HK data and look up table data are intended via a serial, bi-directional Low Bit Rate Interface (LBR I/F). The DPE further processes the data and hands them over to the On Board Data Handling system (OBDH).

3 General

3.1 Input and output lines

⇒ Each input and output interface is realized as a differential RS 422 line.

3.2 Changing of parameters and LUT

⇒ All parameters and look up tables (LUT) may be loaded and modified by the DPE.

4 Serial interfaces

4.1 HBR I/F from detectors to HEPI

4.1.1

⇒ Each detector is connected via an unidirectional High Bit Rate Interface (HBR I/F) with HEPI. This interface is under control of HEPI.

4.1.2

⇒ Each interface connection requires four control lines (Data, Sample, FIFO_not_empty, clock).

4.1.3

⇒ Two additional lines clear the output FIFO's of the detectors

4.2 Data Format

Following data formats are used:

4.2.1

⇒ The data word of 64 bit consists of four 16 bit words.

1st word: Time in units of 238.4 ns (most significant 16 bit of 24 bit time word)
2nd word: 8 bit Time (least significant 8 bit of 24 bit time word) plus
8 bit Rise Time (only applicable for CdTe)
3rd word: Amplitude (CdTe 11 bit, CsI 10 bit) plus 1 bit flag for CdTe Calibration or plus 2 bit flags for CsI calibration and multiple event, plus 2 bit for number of multiple events
4th word: Pixel Address (CdTe 14 bits, CsI 12 bits)

1st word

MSB															
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
time 1st byte (MSB)								time 2nd byte							

2nd word

16	17	18	19	20	21	22	23	24	25	260	271	282	29	30	31
time 3rd byte (LSB)								rise time (only CdTe)							

3rd word

32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
cal. flag					amplitude (CdTe)										
cal. flag	mp	nmp				amplitude (CsI)									

4th word

															LSB
48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63
		address (CdTe)													
				address (CsI)											

Table 1: Data format of the transmission between detectors and HEPI

4.2.2

⇒ The data are right justified, i.e. LSB of information is LSB of 16 bit word.

4.2.3

⇒ The transmitted sequence of 16 bit words should be 1,2,3,4.

4.2.4

⇒ MSB should be transmitted first.

4.2.5

⇒ The pixel address of the individual pixel is: Y value (6 bit for CsI or 7 bit for CdTe) and Z value (6 bit for CsI or 7 bit for CdTe).

Y_6	Y_5	Y_4	Y_3	Y_2	Y_1	Y_0	Z_6	Z_5	Z_4	Z_3	Z_2	Z_1	Z_0
0	0	0	0	1	0	0	1	0	0	1	1	1	0

Figure 1: Bit representation of the address of a CdTe pixel

The individual pixel is therefore represented with a 12 bit value for the CsI and a 14 bit value for the CdTe detector. The Y value represents the column number and the Z value represents the row number of the detector layer. Figure 1 shows an example of the address format of a CdTe pixel. This pixel is located at the 5th column and the 79th row of the detector if the numbering of the (columns, rows) starts at (1, 1).

4.3 HBR I/F from HEPI to DPE

4.3.1

⇒ The HEPI is connected via two unidirectional High Bit Rate Interfaces with the DPE.

One interface is used for events with time information, the other for reading out histogram memory and rate meters.

4.3.2

⇒ These interfaces are under control of the DPE.

4.3.3

⇒ The connection requires three lines (Data, Enable, Clock).

4.3.4

⇒ The DPE detects a request with two dedicated FIFO status lines

4.4 LBR I/F from HEPI to DPE

4.4.1

⇒ Controlling of the HEPI (receiving of commands and parameters) and transmitting of HK data is performed via a bi-directional Low Bit Rate I/F (LBR I/F).

4.4.2

⇒ The Low Bit Rate Interface (LBR I/F) consists of seven lines (Clock, Forward, Data, Return Data and four address lines)

4.4.3

⇒ The LBR I/F is under control of DPE

4.4.4

⇒ The data rate is 64 kbit/sec

4.4.5

⇒ A synchronous data link protocol (SDLC) is applied for communication.

5 HEPI functions

The following data processing tasks are performed by HEPI.

5.1 Event type generation

⇒ HEPI receives 64 bits for each event from each layer and generates individual event types.

5.2 Detection of time coincidence between of CdTe and CsI events

⇒ Since the time jitter is TBD µsec for CdTe events and TBD µsec for CsI events a variable time window with a programmable width are applied to compare the time information of the events.

5.3 Adding of timing information

⇒ The original timing information of the detector layers (238 nsec within 2 sec) are transformed to 61 µsec within 72 h.

5.4 Synchronising of time information between the CsI and CdTe layers

5.4.1

⇒ HEPI controls the time synchronisation of both detector layers

It should be possible to clear the output FIFOs of the detector layers at the beginning of each observation. HEPI looks for the zerocrossing of the time information to control that both layers are working synchronously. The zerocrossing occurs if the following event gets a smaller time information than the previous one, because the synchronisation pulse resets the time counter of the layer between these events.
HEPI reads only events from the same synchronisation cycle (the time between adjacent synchronisation pulses) out of the different FIFOs.

5.4.2

⇒ The synchronisation pulse are generated each 125 msec by DPE and then received by HEPI.

5.4.3

⇒ The time synchronisation pulse from DPE are divided by eight by HEPI and then distributed to PICSIT and ISGRI.

5.4.4

⇒ The pulse are delayed individually for each layer.
So it is possible to synchronise the time information of both layers.

5.4.5

⇒ The delay time of the synchronisation pulse is changeable for each layer.

5.4.6

⇒ The zerocrossings of each layer are counted and may be read out as house keeping data.

5.5 Amplitude correction

⇒ An amplitude correction should be applied to each CsI event.

This task applies to all CsI events. The sensitivity of individual pixels is not equal. For a given gamma-ray line energy the pixel amplitude is proportional to the gamma-ray line energy but different for each pixel.
Therefore an amplitude correction is intended. For this correction a linear regression algorithm
$A_{out}(i) = a_i + b_i(A_{in}(i))$
with i = pixel address are used. The precision of the constants a_i is 6 bit and of the gain b_i is be 10 bit.

5.6 Incident pixel reconstruction

5.6.1

⇒ HEPI should reconstruct the incident pixel ($P_{incident}$) for multiple events using a threshold energy for the single energy deposits and the total energy by summing them.

Following reconstruction schemes should be applied to the events:

double:	if ($E_{tot} > E_{thres.}$)	$P_{incident}$ corresponds to max. (E_1, E_2)
triple:	if ($E_{tot} < E_{thres.1}$)	$P_{incident}$ corresponds to min (E_1, E_2, E_3)
	if ($E_{thres.1} < E_{tot} < E_{thres.2}$)	$P_{incident}$ corresponds to mid (E_1, E_2, E_3)
	if ($E_{tot} > E_{thres.2}$)	$P_{incident}$ corresponds to max. (E_1, E_2, E_3)

This results in the following energy ranges and resolutions:

	number of bit	energy range	resolution (1 bit)
single:	10	0 - 5 MeV	5 keV
double:			
A(i)[10 bit] + A(i+1) [10 bit] = $A_{mult.}$ [11 bit]	11	0 - 10 MeV	5 keV
cut-off of LSB	10	0 - 10 MeV	10 keV
triple			
A(i)[10 bit] + A(i+1) [10 bit] + A(i+1) [10 bit]			
= $A_{mult.}$ [12 bit]	12	0 -15 MeV	5 keV
cut-off of LSB and MSB	10	0 - 10 MeV	10 keV

This reconstruction requires that each element of one multiple event of the CsI layer is flagged and adjacent in the output FIFO of the detector. Also the multiplicity of each multiple event is required.

5.6.2

⇒ Multiple events with a calibration flag are rejected.

5.6.3

⇒ Triple events with an energy sum larger than 10 MeV are only counted and then discarded.

5.6.4

⇒ For the polarimetry mode HEPI reconstructs the incident pixel of CsI double events using the same algorithm as described above.

5.6.5

⇒ For the polarimetry mode HEPI reconstructs the scattering angle of CsI double events.

5.7 CsI histogram tasks

These functions apply to all CsI events.

5.7.1

⇒ The width of each energy bin is selectable.

The number of energy channels depends on the data mode.
The histogram tasks require a total amount of 2.262 Mbyte mass memory.

5.7.2

Single events histogramming

⇒ Accumulation of single CsI events. The number of energy channels is 256. This requires a mass memory of 1 Mbyte.

5.7.3

Multiple events histogramming

⇒ Accumulation of the position of the incident pixel and the total energy of the multiple CsI events. The number of energy channels is 256. This requires 1 Mbyte mass memory.

5.7.4

Calibration histogramming

⇒ This task accumulates CsI calibration events. The number of energy channels is 32 for each line (511 keV and 1175 keV). This requires 262 kbyte mass memory (8 bit counter)

5.7.5

Polarimetry histogramming

⇒ This function accumulates the incident pixel, the total energy and the scattering angle of double CsI events. This task performs alternatively between the two histogram tasks 5.7.2 and 5.7.3. The number of energy channels is 64 and the resolution of the angle is 3 bit (1 of 8 adjacent pixel). This requires a total amount of 2 Mbyte mass memory.

5.8 Toggle buffer

⇒ HEPI uses one buffer for histogramming and a toggle buffer to read out the histograms of the previous observation.

5.9 CdTe and CsI Photon by Photon mode

The main task for the Photon by Photon mode is done by the DPE.

5.9.1

⇒ HEPI only provides the individual CdTe and CsI events with the correct timing information.

5.9.2

⇒ An additional amplitude selection is applied to the individual events of the CsI detector.

5.10 Spectral timing

⇒ HEPI collects the CsI single and multiple events in histograms with 8 energy channels within a variable short time period. This time period is programmable from 0.976 msec up to 500 msec. The energy values of the events should are within 8 programmable energy ranges. The position information of the events are discarded.

5.11 Burst photon by photon recording

5.11.1

Pre-burst recording

⇒ HEPI keeps the CsI single and multiple events in photon by photon mode with no position information in a cyclic organized memory. After a burst detection, the pre-burst-recording stops and the data are transmitted after the burst data. The size of the buffer is 524 kbyte. For 95 % of BATSE 1B bursts a pre-burst recording of 10 sec is sufficient. A buffer of 450 kbyte is required if the data are stored in 24 bit words and the recording time is 10 sec.

Following data format is used:

	Number of bit
type	1
energy	8 (cut-off LSB)
time	15 (cut-off LSB, 61 μsec within 2 sec)
total	**24**

5.11.2

Burst detection

⇒ HEPI uses both detector layers for a GRB burst alert. This leads to a coarse information of the direction of the GRB. For each detector the event rates are counted on different time scales (62.5 ms, 250 ms and 1000 ms) but for the whole energy ranges. At the end of each time scale the contents of the counter is read out and the difference to the previous value is compared with a threshold (principle of gradient threshold of the count rate). If the threshold is exceeded in both detectors for one or more time scales the burst alert is set and handed over to the DPE via a status line.

5.11.3

Burst recording

⇒ In case of a burst alert HEPI records all CsI and CdTe events, except for calibration events. The time and energy resolution are listed in Table 2. Since the number of bursts is very small (about one per month), this mode is alternative to all other tasks. So all available memory on HEPI except of the pre-burst buffer is used (4.72 Mbyte).

5.11.4

⇒ The burst recording starts under control of the DPE or automatically. This mode is programmable.

5.11.5

⇒ HEPI records the data in the following data format

	Event type		allocated number of bit
1	CdTe single type	type	2
		position	14
		amplitude	11
		rise time	8
		spare	5
		total	**40**
2	CsI single	type	2
		energy (cut-off of the LSB)	8
		arrival time	13
		spare	1
		total	**24**
3	CsI multiple	type	2
		energy (cut-off of the LSB)	8
		arrival time	13
		spare	1
		total	**24**
4	CsI and CdTe single in time coincidence	type	2
		position CdTe	14
		energy CdTe	11
		rise time CdTe	8
		CsI type (single/multiple)	1
		position CsI	12
		energy CsI (cut-off of the LSB)	8
		total	**56**

Table 2: Event type and bit allocation of the burst mode

5.12 Event Counter

5.12.1

⇒ An event counter for each layer (TBD) is intended to control the rate of the incoming and outgoing events. These count rates could be compared on ground with the number of received events.

5.12.2

⇒ The event counters are read out TBD times (e.g. after each integration) via the LBR I/F (TBD) as HK data.

5.13 Rate meters

⇒ For the CsI detector rate meters of each pixel are intended. Each rate meter counts the number of events and may be read out via the HBR I/F B to the DPE.

5.14 Test mode

⇒ For test purposes HEPI is able to directly transmit the raw event data (without pre-processing) from the CsI or CdTe detectors to the DPE.

6 Loadable parameters

⇒ To get a high flexibility of HEPI all thresholds and LUTs of the different data processes are programmable by the DPE.

7 House keeping data

⇒ HEPI delivers all relevant information (parameters, thresholds, LUT, rate meters) as HK data.