# PSD EM User Manual

**Version 1.1 (5/4/2000)**

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# 1. SCOPE OF THE DOCUMENT

The purpose of this document is to provide a user manual for the PSD EM subassembly. This manual should introduce the user in the general functionality of the system, and should provide a reference document that allows for a proper configuration and usage of the system.

# 2. REFERENCE DOCUMENTS

RD1 EM software version 228 / V1.07

RD2 PSD Software description (TBD)

RD3 SPI INTERFACES SPECIFICATION, SPI-SI-0-1324-CNES, TBD

# 3. GENERAL FUNCTIONALITY

The scope of this paragraph is the presentation of the general functionality of the PSD subassembly in order to clarify the meaning of the PSD parameters.

## 3.1. Multiplexing

The PSD subassembly is equipped with 19 input channels (also called *mux channels*), each connected to one of the 19 fast detector output channels. Each of the 19 channels can be enabled or disabled individually in order to activate or to suppress pulse-shape discrimination for individual detectors. On the EM, only channels 0-6 (7 channels) are implemented. These channels correspond to connectors J14 - J20.

Pulse Shape Discrimination for background reduction is only meaningful for events that are contained within one germanium detector. Therefore it has been decided to have only one PSD system that treats all 19 detectors with an input multiplexing. If signals occur on several PSD inputs within TBD, the event is considered as a multi-detector event and is not treated by the PSD subassembly.

## 3.2. Triggering

After multiplexing, there is a hardware triggering system that is common to all detector channels. The hardware trigger (or front-end trigger) is characterised by three quantities: the **FRONT END TRIGGER LEVEL (FET)**, the **LOWER LEVEL DISCRIMINATOR (LLD)**, and the **TIME WINDOW (TW)**. All three quantities are configurable by telecommand. The major aim of the hardware threshold is to trigger the PSD system on detector pulses and to separate real event triggers from noise triggers. Consequently, the optimum trigger parameters will depend on the noise in the system. The 3 front-end trigger parameters are the most critical parameters of the PSD system since noise triggers can easily exceed the expected event rates, leading directly to an exceed in time-tag rates sent to DFEE.

The following logic has been implemented for the 3 front-end trigger parameters:

1. The detector current must first rise above the FET level which aims in discriminating real pulses against noise. The FET threshold should usually be set just above the noise level.
2. After a FET, the detector current must rise above the LLD within a time interval specified by TW.

A forth quantity, the **UPPER LEVEL DISCRIMINATOR (ULD)** is fixed and discriminates events that exceed a given threshold. In the EM, this level roughly corresponds to TBD.

### 3.3. Digitisation

After triggering, the detector current is digitised by 4 interleaved ADCs at a frequency of 25 MHz, leading to a time resolution of 10 ns. The ADCs have a resolution of 10 Bits, but only the 9 most significant Bits are used for the analysis. For the EM, the conversion function is roughly 7 digits / mV. With a typical baseline of 45 digits, this corresponds to a maximum voltage of 67 mV for a maximum ADC value of 511.

### 3.4. Veto

The PSD system may receive a veto signal from the DFEE in order to suppress event processing. In the case that no DFEE cable is connected to the PSD, no veto is active, i.e. all events are processed by the PSD.

The Veto signal is hardwired in the PSD and cannot be influenced by configuration commands.

### 3.5. Gain range

There are two gain ranges available in the PSD. For the EM, these gain ranges correspond to TBD. The gain range is common to all detectors and may be selected by configuration command. The front-end trigger characteristics are not influenced by the gain range selection.

### 3.6. Event identifier emission

The PSD system communicates with the DFEE subassembly by two signals:

1. A time-tag signal that is emitted if a trigger occurred in the PSD system
2. A data bus for identification of valid events (DFEE ID)

If a front-end trigger occurs in the PSD system without a Veto signal active, a time-tag is emitted to the DFEE system. The PSD system is then integrating over the measured pulse shape using a 9 Bit hardware integrator in order to estimate the energy of the event. This energy estimate is then compared to a validity range, specified for each detector individually by the **LOWER ENERGY THRESHOLD (LET)** and the **UPPER ENERGY THRESHOLD (UET)**. The LET and UET are configurable for each detector by configuration commands. If the pulse integral falls within the validity interval, an event identifier is emitted to the DFEE.

The relation between the hardware integrator 9 Bit value and the energy is rather complex since the integral is composed of both the pulse area and the baseline area. The baseline may vary as function of time and event frequency.

### 3.7. HSL

Scientific data is transmitted on the HSL from the PSD subassembly to the DPE subassembly. The scientific data consists of:

1. event data
2. curve data

The number of curves that are transmitted in a HSL data frame, and the frequency of curve data transmission can be configured using configuration commands. The transmission rates may differ between the operational mode and the calibration or diagnostic mode.

Detector pulses that were accumulated during cycle n of the 8 Hz HSL clock are sent to the DPE during cycle n+1. A new cycle begins with the falling edge of the 8 Hz clock. At this moment the PSD subassembly prepares the data frame in a FIFO buffer. It may happen that at the moment of the 8

Hz falling edge not all events of cycle n are yet processed, hence they would be lost since they are not allowed to be sent in cycle n+2. For this reason, a post processing of 10 events at maximum is allowed after the falling edge of the 8 Hz clock occurs. The FIFO buffer is only prepared after this postprocessing. The maximum number of events to be postprocessed can be set by configuration commands.

### 3.8. Pulse shape discrimination

Pulse shape discrimination is performed by comparing measured detector pulse shapes to a library of pulse templates. As result of the comparison, an event may be flagged as single site event (most significant Bit of the PSD word set to 0) or as multiple site event (most significant Bit of the PSD word set to 1). Event selection statistics are maintained in the housekeeping telemetry.

Library templates can be uploaded using telecommands for each individual detector. The libraries are stored in EEPROM. Two library sets may be uploaded for each detector. The selection of the library set is done via configuration command. Further, the number of time-steps used for the pulse shape analysis and the number of library templates are also configurable.

### 3.9. DSP32 software

The PSD subassembly houses a DSP32C digital signal processor. This processor handles all communications with the environment (LSL, HSL, DFEE) and performs the scientific analysis of the digitised pulses shapes. The software in the PSD is composed of two parts:

1. The functional software (eng.s) that handles all interfaces and the data accumulation and preparation
2. The scientific software (science.s) that analyses the pulse shapes and handles the library management

In the EM, the functional software has version number 228 and the scientific software has version number V1.07.

# 4. COMMANDING THE PSD

The scope of this paragraph is to provide command descriptions which allow the modification of configurable PSD parameters. The command structure is defined in RD3.

## 4.1. Enabling / disabling detector channels

**Aim :**

Enable or disable individual detector channels.

**Command sequence :**

| Configuration command | Action | Affected Bytes in command |
|---|---|---|
| 01 Hex | Enables / Disables individual detectors | 3-5 & 7-9 |

**Verification sequence :**

| Housekeeping command | Action | Affected Bytes in command |
|---|---|---|
| 01 Hex | Read detectors enable / disable status | 3-5 & 7-9 |

**Range :**

Flags : 0 or 1

**Default :**

All detectors are enabled in all scientific modes (all Bits are set to 0).

**Procedure :**

no details

**Notes :**

1. Different set of detector channels can be enabled or disabled for either operational / calibration mode or for diagnostics mode. Operational / calibration mode channel selections are determined by Byte 3-5 of the configuration command. Diagnostics mode channel selections are determined by Byte 7-9 of the configuration command (see RD3 for the detector - Bit correspondence).
2. A Bit set to **0** means **enable**, a Bit set to **1** means **disable** the detector channel.

## 4.2. Specify pulse trigger characteristics

**Aim :**

Define the pulse trigger characteristics to adapt to the actual noise level and detector gain.

**Command sequence :**

| Configuration command | Action | Affected Bytes in command |
|---|---|---|
| 01 Hex | Sets FET, LLD, and TW | 5-6 & 9-10 |

**Verification sequence :**

| Housekeeping command | Action | Affected Bytes in command |
|---|---|---|
| 01 Hex | Reads FET, LLD, and TW | 5-6 & 9-10 |

**Range :**

| Parameter | Minimum | Maximum | Unit | Comment |
|---|---|---|---|---|
| FET | 0 | 7 | Dec | higher FET value means lower FET threshold |
| LLD | 0 | 7 | Dec | lower LLD value means lower LLD threshold |
| TW | 0 | 7 | Dec | time window(ns) = 300 + TW * 160 |

**Default :**

| Parameter | Value | Unit | Comment |
|---|---|---|---|
| FET | 2 | Dec | |
| LLD | 4 | Dec | corresponds roughly to 630 keV |
| TW | 1 | Dec | corresponds to 460 ns |

**Conversion function / table :**

**FET**: The following conversion function has been established between lower pulse area threshold (pulse area at half maximum) and FET (the pulse area is the net integral over the digitised pulse, baseline subtracted; this is the most precise measure of the event energy that is avaliable to the PSD subassembly):

| channel | conversion function |
|---|---|
| 0 | PA = 900 - 658.6 * FET |
| 1 | TBD |
| 2 | TBD |
| 3 | TBD |
| 4 | TBD |
| 5 | TBD |
| 6 | TBD |

Using the relation between PA and energy as given in section 4.4, the following conversion function result between lower energy threshold (in keV) and FET:

| channel | conversion function |
|---|---|
| 0 | Energy (keV) = 102.37 - 84.82 * FET |
| 1 | TBD |
| 2 | TBD |
| 3 | TBD |
| 4 | TBD |
| 5 | TBD |
| 6 | TBD |

**LLD**: The following conversion function has been established between lower pulse area threshold (pulse area at half maximum) and LLD:

| channel | conversion function |
|---|---|
| 0 | PA = -500 + 500 * LLD |
| 1 | TBD |
| 2 | TBD |
| 3 | TBD |
| 4 | TBD |
| 5 | TBD |
| 6 | TBD |

Using the relation between PA and energy as given in section 4.4, the following conversion function result between lower energy threshold (in keV) and LLD:

| channel | conversion function | Minimum | Maximum |
|---|---|---|---|
| 0 | Energy (keV) = -491 + 212 * LLD | 0 | 993 keV |
| 1 | TBD | TBD | TBD |
| 2 | TBD | TBD | TBD |
| 3 | TBD | TBD | TBD |
| 4 | TBD | TBD | TBD |
| 5 | TBD | TBD | TBD |
| 6 | TBD | TBD | TBD |

Note that there is no strict LLD / FET - energy relation since for a given energy the peak height varies with the shape of the pulse; the above relation should be considered as an average relation.

**Procedure :**

In the following a procedure is described which allows to set the front-end characteristics for various noise conditions:

1. **Initialise:** Set FET=0, LLD=7, TW=1

1. **Determine FET value:** The FET serves to discriminate real pulse triggers against noise triggers. For this reason the FET threshold should lie above the noise level. To determine the critical threshold, set the FET to its minimum (0) which corresponds to the highest FET threshold. Monitor the registered pulse shapes in either configuration or diagnostics mode. Rise the FET (from 0 - 7) until noise triggers occur (visible either by a noisy curve display or an increase in the jitter of the curve start time). Fix the FET to the highest level (= lowest value) where no noise triggers occur (for security one might lower the FET 1-2 digits below this value).

2. **Determine LLD value:** This value mainly sets the lower energy threshold (see above). Lower LLD (from 7 - 0) until the desired energy level was reached. If noise triggers occur, lower FET again until they disappear.

3. **Set TW value:** This value should be set between 0-1. For TW=0 less noise triggers should occur than for TW=1, but scientific data could be biased for TW=0. Thus to reduce noise triggers one could switch from TW=1 to TW=0.

**Notes :**

FET : **Increasing** the FET value **reduces** the FET threshold level (inverse relation)! Or in other words, increasing the FET value makes the PSD more sensitive. If the FET threshold level is too low (i.e. the FET value too high), noise triggers will appear.

LLD : The relation of LLD value to detector current is a linear function with a possible offset.

TW : The minimum time window (TTW=0) corresponds to 300 ns, the maximum (TTW=7) corresponds to 1560 ns. For TTW=7 the time window is ineffective since it exceeds the pulse accumulation time.

### 4.3. Specify gain range

**Aim :**

Switch between normal and extended PSD gain range.

**Command sequence :**

| Configuration command | Action | Affected Bytes in command |
|---|---|---|
| 01 Hex | Set gain flag | 6 & 10 |

**Verification sequence :**

| Housekeeping command | Action | Affected Bytes in command |
|---|---|---|
| 01 Hex | Read gain flag | 6 & 10 |

**Range :**

| Flag | Gain range |
|---|---|
| 0 | 0 - 2 MeV (TBC) |
| 1 | 0 - 6 MeV (TBC) |

**Default :**

Flag = 0 (0-2 MeV gain range) (TBC)

**Procedure :**

no details

**Notes :**

none

## 4.4. Specify energy thresholds

**Aim :**

Specify the energy range for each detector channel for which a event ID will be emitted to the DFEE sub-system and which will be analysed by PSD subassembly.

**Command sequence :**

| Configuration command | Action | Affected Bytes in command |
|---|---|---|
| 02 Hex | Set lower energy thresholds (LET) for detectors 0-8 | 5-22 |
| 03 Hex | Set lower energy thresholds (LET) for detectors 9-18 | 3-22 |
| 04 Hex | Set upper energy thresholds (UET) for detectors 0-8 | 5-22 |
| 05 Hex | Set upper energy thresholds (UET) for detectors 9-18 | 3-22 |

**Verification sequence :**

| Housekeeping command | Action | Affected Bytes in command |
|---|---|---|
| 02 Hex | Read lower energy thresholds (LET) for detectors 0-8 | 5-22 |
| 03 Hex | Read lower energy thresholds (LET) for detectors 9-18 | 3-22 |
| 04 Hex | Read upper energy thresholds (UET) for detectors 0-8 | 5-22 |
| 05 Hex | Read upper energy thresholds (UET) for detectors 9-18 | 3-22 |

**Range :**

| Parameter | Minimum | Maximum | Unit | Comment |
|---|---|---|---|---|
| LET | 0 | 511 | Dec | values > 511 will be interpreted as 511 |
| UET | 0 | 511 | Dec | values > 511 will be interpreted as 511 |

**Default :**

| Parameter | Value | Unit | Comment |
|---|---|---|---|
| LET | 10 | Dec | 0 keV for EM |
| UET | 511 | Dec | ~ 8 MeV for EM |

## Conversion function / table :

The following conversion functions have been determined between the pulse area (PA) and the LET and UET parameters for the different EM channels:

| channel | conversion function |
|---|---|
| 0 | PA = -4969.5 + 49.231 * LET (UET) |
| 1 | TBD |
| 2 | TBD |
| 3 | TBD |
| 4 | TBD |
| 5 | TBD |
| 6 | TBD |

The following conversion functions have been determined between the pulse area (PA) and the photon energy in keV for the different EM channels:

| channel | conversion function |
|---|---|
| 0 | PA = 658.6 + 2.358 * Energy (keV) |
| 1 | PA = 601.6 + 2.362 * Energy (keV) |
| 2 | PA = 597.6 + 2.304 * Energy (keV) |
| 3 | TBD |
| 4 | TBD |
| 5 | TBD |
| 6 | TBD |

The typical energy resolution for the pulse area (PA) is between 2-3 % (1 sigma). The conversion function is based on the analysis of calibration data taken with a germanium detector and $^{60}$Co and $^{228}$Th sources. For the calibration only multiple site events were used since they provide a better signal to noise ratio for gamma-ray lines. Note that for a given energy, the pulse area slightly increases with increasing TTP while the scatter of the pulse area decreases (see Fig. 1). Note that for a narrow TTP range the pulse area energy resolution is between 1-2 % (1 sigma).

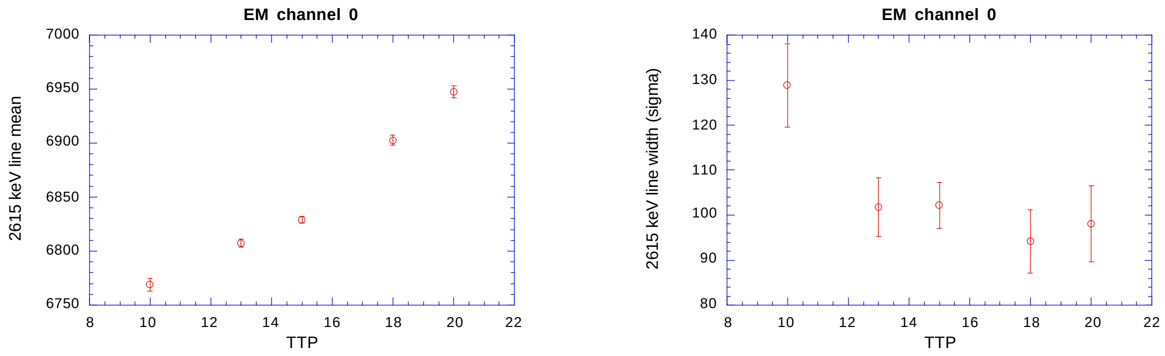


*Fig. 1: Mean (left) and standard deviation (right) of the pulse area for 2615 keV photons. The pulse area increases with increasing TTP while the scatter of the pulse area diminishes with increasing TTP.*

Based on the above relations the following conversion functions have been determined between the LET and UET parameters and the photon energy in keV for the different EM channels:

| channel | conversion function | LET = 10 | UET = 511 |
|---|---|---|---|
| 0 | LET (UET) = 114.32+ 0.0479 * Energy (keV) | 0 keV | 8281 keV |
| 1 | TBD | | |
| 2 | TBD | | |
| 3 | TBD | | |
| 4 | TBD | | |
| 5 | TBD | | |
| 6 | TBD | | |

The actual conversion functions on the SPI EM may deviate from this due to gain and pulse baseline differences. In the ideal case, the conversion function should be redetermined using the following procedure.

**Procedure :**

In order to determine the threshold conversion function, the following procedure has been applied at CESR:

1. Connect the germanium detector fast output to one of the activated PSD channels
2. Collect ~2000 HSL frames (~5 minutes) of $^{228}$Th source data with the LET/UET set to narrow intervals (110-112, 120-122, 140-142, 180-182, 220-222, 240-242, 260-262, 280-282).
3. Determine the mean pulse area for all files and derive a (linear) relation between pulse area and LET/UET value.
4. Collect ~10000 HSL frames (~20 minutes) of $^{228}$Th / $^{60}$Co source data ($^{228}$Th source very close to detector to dominate over room background, $^{60}$Co at 1.5 m). The $^{228}$Th source has 2 well separated strong gamma-ray lines at 583 keV and 2615 keV. The 583 keV is blended with the 511 keV line and is of limited use. The $^{60}$Co source has to nearby gamma-ray lines ray 1173 keV and 1333 keV.
5. Determine the pulse area spectrum for single and multiple events. Gamma-ray lines should be dominant in the multiple event spectrum.
6. Fit the 1173 keV, the 1333 keV and the 2615 keV lines in the multiple spectra and determine the linear calibration relation between pulse area and gamma-ray photon energy.

Eventually, the 2.6 MeV $^{228}$Th line may fall out of the PSD energy range for different gain adjustments. If this happens than another source like $^{60}$Co may be used in conjunction with $^{228}$Th.

**Notes :**

none

### 4.5. Specify 8 Hz post-processing

**Aim :**

Specify the number of events that are postprocessed after 8 Hz falling edge and before HSL FIFO buffer preparation.

**Command sequence :**

| Configuration command | Action | Affected Bytes in command |
|---|---|---|
| 02 Hex | Set number of events for 8 Hz post processing | 3 |

**Verification sequence :**

| Housekeeping command | Action | Affected Bytes in command |
|---|---|---|
| 02 Hex | Read number of events for 8 Hz post processing | 3 |

**Range :**

| Parameter | Minimum | Maximum | Unit | Comment |
|---|---|---|---|---|
| postprocessed events | 0 | 10 | Dec | 0 means no post processing |

**Default :**

| Parameter | Value | Unit | Comment |
|---|---|---|---|
| postprocessed events | 1 | Dec | 1 event is postprocessed |

**Procedure :**

no details

**Notes :**

Note that this parameter has an impact on the HSL timing. Each post processed event may add up to 1.25 ms processing time.

## 4.6. Define curve transmission rates

**Aim :**

Specify the curve transmission rates in the different scientific modes.

**Command sequence :**

| Configuration command | Action | Affected Bytes in command |
|---|---|---|
| 0A Hex | Set curve transmission rates | 3-6 |

**Verification sequence :**

| Housekeeping command | Action | Affected Bytes in command |
|---|---|---|
| 0A Hex | Read curve transmission rates | 3-6 |

**Range :**

| Parameter | Minimum | Maximum | Unit | Comment |
|---|---|---|---|---|
| 8 Hz rate | 0 | 255 | Dec | period in units of 125 ms |
| subrates | 0 | 5 | Dec | number of shapes |

**Default :**

| Parameter | Value | Unit | Comment |
|---|---|---|---|
| OP mode 8 Hz rate | 32 | Dec | 1 shape every 4 seconds (1 per 32 8 Hz clck) |
| OP mode subrate | 0 | Dec | not relevant |
| CALIB & DIAG mode 8 Hz rate | 0 | Dec | use subrate information |
| CALIB & DIAG mode subrate | 5 | Dec | 5 shapes per 8 Hz clock |

**Procedure :**

no details

**Notes :**

8 Hz rate has priority with respect to subrate information. The 8 Hz rate specifies the rate at which 1 pulse shape is sent in the HSL data (i.e. 32 means send 1 pulse shape every 32 cycles = 4 seconds). Only if the 8 Hz rate is set to 0, subrate information is used. The subrate specifies how many shapes are sent in the HSL data (i.e. 5 means send 5 pulse shapes per HSL frame).

# 5. DISCRIMINATION CONTROL

## 5.1. A/D offset control settings

**Aim :**

Adjust the software gain and offset correction for the 4 interleaved ADCs. This adjustment is needed to optimise the scientific analysis of the pulse shapes.

**Command sequence :**

| Configuration command | Action | Affected Bytes in command |
|---|---|---|
| 06 Hex | Set gain and offset adjustments | 3-10 |

**Verification sequence :**

| Housekeeping command | Action | Affected Bytes in command |
|---|---|---|
| 06 Hex | Read gain and offset adjustments | 3-10 |

**Range :**

| Parameter | Minimum | Maximum | Unit | Comment |
|---|---|---|---|---|
| gain adjustment | -128 | 127 | Dec | signed 8 Bit integer |
| offset adjustment | -128 | 127 | Dec | signed 8 Bit integer |

**Default :**

| Parameter | Value | Unit | Comment |
|---|---|---|---|
| gain adjustment | 0 | Dec | |
| offset adjustment | 0 | Dec | |

**Conversion function / table :**

The pulse shape is corrected in software using the formula

$$pcorrect_i = pulse * gain + offset$$

where

$$gain = 1.0 + (gain\ adjustment\ value) * 0.0005$$

and

$$offset = (offset\ adjustment\ value) * 0.05$$

**Procedure :**

no details

**Notes :**

none

## 5.2. Library selection and control

**Aim :**

Specify the library set, the number of time, and the number of library templates used for pulse shape discrimination.

**Command sequence :**

| Configuration command | Action | Affected Bytes in command |
|---|---|---|
| 07 Hex | Set library selection and control for detectors 0-6 | 3-28 |
| 08 Hex | Set library selection and control for detectors 6-12 | 3-28 |
| 09 Hex | Set library selection and control for detectors 13-18 | 3-26 |

**Verification sequence :**

| Configuration command | Action | Affected Bytes in command |
|---|---|---|
| 07 Hex | Read library selection and control for detectors 0-6 | 3-28 |
| 08 Hex | Read library selection and control for detectors 6-12 | 3-28 |
| 09 Hex | Read library selection and control for detectors 13-18 | 3-26 |

**Range :**

| Parameter | Minimum | Maximum | Unit | Comment |
|---|---|---|---|---|
| Library set | 0 | 1 | Dec | only two sets (0,1) fit into memory |
| Number of time steps | 6 | 64 | Dec | |
| Number of templates | 0 | 38 | Dec | |

**Default :**

| Parameter | Value | Unit | Comment |
|---|---|---|---|
| Library set | 0 | Dec | only one library set is loaded in EEPROMs |
| Number of time steps | 64 | Dec | |
| Number of templates | 26 | Dec | |

**Procedure :**

no details

**Notes :**

The number of time steps is required to reconstruct the information that is compressed into the 16 Bits of the PSD information word.

### 5.3. Library upload

**Aim :**

Library templates may be uploaded into the PSD system and stored in EEPROM after calibration of the system. Each detector has at maximum 2 attributed sets of library templates.

**Command sequence :**

| Upload command | Action | Affected Bytes in command |
|---|---|---|
| 0B Hex | Send library template definition and data items 0-3 | 3-20 |
| 0C Hex | Send data items 4-13 | 3-32 |
| 0D Hex | Send data items 14-23 | 3-32 |
| 0E Hex | Send data items 24-33 | 3-32 |
| 0F Hex | Send data items 34-43 | 3-32 |
| 10 Hex | Send data items 44-53 | 3-32 |
| 11 Hex | Send data items 54-63 | 3-32 |

**Verification sequence :**

Read HK0 (status) and make sure that no CRC error occurred.

**Range :**

Bytes 3-6 specify the reference of the library template.

| Parameter | Minimum | Maximum | Unit | Comment |
|---|---|---|---|---|
| Detector selection | 0 | 18 | Dec | |
| Curve selection | 0 | 37 | Dec | special value 255 loads library parameter block |
| Set number | 0 | 1 | Dec | |
| Data items | 1 | 64 | Dec | usually 64 |

**Default :**

not applicable

**Procedure :**

no details

**Notes :**

Normally, the curve selection parameter is comprised between 0 and 37. However, if a curve selection parameter of 255 is specified, the data items are interpreted as library parameter information and not as a library template. Library parameter information is needed for fine tuning of the scientific PSD software and for setting the discrimination characteristics.

**Library template building using the EM as standalone system :**

The following recipes may be applied to build single site interaction pulse shape template libraries using the EM without having access to the energy information. For the calibration a 228Th source is used which leads to a double-escape gamma-ray line at 1560 keV.

1. Set LLD=7 in order to suppress the low energy gamma-ray tail in the spectrum (see calibration relations of section 4.2).
2. Set LET-UET around the 1560 keV energy range. For example: for EM channel 0 a window around 190 may be used, i.e. LET=185 and UET=195 (see calibration relations of section 4.4).
3. Accumulate data placing a $^{228}$Th source as close as possible to the germanium detector.
4. During data analysis, select only those event with pulse areas close to 1560 keV. For example: for EM channel 0 select only pulses with PA= [4300,4380] (see section 4.4). One may further select only those pulses that were flagged by the PSD as single site interaction, which, however, introduces a bias with respect to the actual active library. To improve the signal to noise ratio one could establish a more refined relation between pulse area and energy as function of TTP value, an select only those events which are around the double escape line.

# 6. SOFTWARE MAINTENANCE

The PSD system is equipped with a DSP32C digital signal processing unit. In the EM, the DSP32C software resides in EEPROM which can be reprogrammed via an IDE interface (the EM PSD box has to be opened for this reprogramming). On start-up, the EEPROM code is copied into RAM and executed there.

The software is designed as modules which are connected via jump or call vectors. Software can be maintained either by replacing code directly in RAM or by adding software modules and redirection of the jump or call vectors. For this purpose a specific software maintenance mode is foreseen which can be accessed when the system is set to configuration mode. The DSP32C code for software maintenance resides in EEPROM and consists of a reduced command interpreter. When in software maintenance mode, the only commands allowed are memory upload, memory dump, and status HK0 (TBC).

# 7. Monitoring the PSD

## 7.1. Technical housekeeping data

### 7.1.1. Voltage control

**Aim :**

Collect information about the PSD subassembly voltages.

**Command sequence :**

| Housekeeping command | Action | Affected Bytes in command |
|---|---|---|
| 12 Hex | Read voltages | 3-10 |

**Conversion function / table :**

TBW

**Notes :**

none

### 7.1.2. Temperature control

**Aim :**

Collect information about the temperatures in the PSD subassembly.

**Command sequence :**

| Housekeeping command | Action | Affected Bytes in command |
|---|---|---|
| 12 Hex | Read temperatures | 11-18 |

**Conversion function / table :**

TBW

**Notes :**

none

### 7.1.3. Software control

**Aim :**

Collect information about actual software performance and status. Mainly used for debugging. Also used for the reconstruction of the rate time information.

**Command sequence :**

| Housekeeping command | Action | Affected Bytes in command |
|---|---|---|
| 12 Hex | Command count, last received command code and identifier, last DFEE ID sent, 8 Hz counter | 19-26 |
| 13 Hex | Events and curves in buffers, error count since last power-on, last error type | 3-8 |
| 1C Hex | RAM checking, analogue control | 17-22 |

**Conversion function / table :**

The *command count* is a roll-over counter of the number of commands received by the PSD EM, including the housekeeping commands.

The *last received command code* Byte contains the last command code that was received by the PSD EM, excluding housekeeping commands. The following table summarises possible return values:

| **Value** | **Meaning** |
|---|---|
| 43 Hex (C) | Configuration command |
| 44 Hex (D) | Memory dump command |
| 49 Hex (I) | Library upload command |
| 4C Hex (L) | Memory upload command |
| 4D Hex (M) | PSD mode command |
| 50 Hex (P) | Parameter command |
| 52 Hex (R) | Software maintenance command |

The *last received command identifier* Byte contains the last command identifier that was received by the PSD EM, excluding housekeeping commands. The possible return values depend on the command code :

| **Command code** | **Possible command identifiers** |
|---|---|
| 43 Hex (C) | 01 - 0A Hex (command identifier) |
| 44 Hex (D) | Most significant Byte of start address |
| 49 Hex (I) | 0B - 11 Hex (library upload identifier) |
| 4C Hex (L) | Most significant Byte of start address |
| 4D Hex (M) | 53 (S), 58 (X), 43 (C), 59 (Y), 44 (D) (all hex) |
| 50 Hex (P) | parameter identifier |
| 52 Hex (R) | 4D (M), 52 (R) |

The *last HSL identifier sent to DFEE* contains the last 16 Bit identifier that was sent to the DFEE.

The *8Hz counter* contains the actual value of the PSD internal 8 Hz roll-over counter. The least 3 significant Bits (Bits 5,6,7) of this counter are always 0 on the EM.

**Notes :**

RAM checking is not implemented on the EM. The corresponding Bytes should always be 0.

## 7.2. Scientific housekeeping data

### 7.2.1. Channel rates

**Aim :**

Collect information about the detector channel rates, i.e. the event rates that are passed to the analysis software (TBC).

**Command sequence :**

| Housekeeping command | Action | Affected Bytes in command |
|---|---|---|
| 13 Hex | Compressed channel rates for detectors 0-17 | 9-26 |
| 14 Hex | Compressed channel rate for detector 18 | 3 |

**Conversion function / table :**

The channel rates for each detector are compressed into 8 Bits using the following scheme:

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| exponent | | | mantisse | | | | |

Decompression leads to a 16 Bit value given by

value = mantisse * 2 ^ (exponent + 4)

Units for the decompressed value are events per 64 seconds.

**Notes :**

none

### 7.2.2. Selection statistics

**Aim :**

Collect information about the scientific selection statistics, i.e. the number of events that have been identified as single interaction events or multiple interaction events per detector.

**Command sequence :**

| Housekeeping command | Action | Affected Bytes in command |
|---|---|---|
| 14 Hex | Compressed selection statistics for detectors 0-10 | 5-26 |
| 15 Hex | Compressed selection statistics for detectors 11-18 | 3-18 |

**Conversion function / table :**

The selection statistics for each detector are compressed into 8 Bits using the scheme described in section 7.2.1. Decompression leads to a 16 Bit value. Units for the decompressed value are events per 64 seconds.

**Notes :**

none

### 7.2.3. Rate history

**Aim :**

Track the history of global front-end LLD and ULD rates (no breakdown per detector). The LLD rates are the number of pulses within 2 seconds that led to a front-end trigger (i.e. pulses that exceeded the LLD within TW after a FET trigger). The ULD rates are the number of pulses within two seconds that exceeded the ULD. These parameters may be useful for deadtime estimation.

**Command sequence :**

| Housekeeping command | Action | Affected Bytes in command |
|---|---|---|
| 15 Hex | Rate history for 2 second intervals 1-2 | 19-26 |
| 16 Hex | Rate history for 2 second intervals 3-8 | 3-26 |
| 17 Hex | Rate history for 2 second intervals 9-14 | 3-26 |
| 18 Hex | Rate history for 2 second intervals 15-20 | 3-26 |
| 19 Hex | Rate history for 2 second intervals 21-26 | 3-26 |
| 1A Hex | Rate history for 2 second intervals 27-32 | 3-26 |

**Conversion function / table :**

Uncompressed 16 Bit values. Units are triggers per 2 seconds.

**Notes :**

none

### 7.2.4. Library status

**Aim :**

Collect information about pulse baseline and noise running averages.

**Command sequence :**

| Housekeeping command | Action | Affected Bytes in command |
|---|---|---|
| 1B Hex | Read running averages | 3-26 |
| 1C Hex | Read running averages | 3-16 |

**Conversion function / table :**

The running average is given by

$$ravg = 0.25 * (\text{running average value})$$

where 'running average value' is the unsigned 8 Bit integer value as read from housekeeping.

**Notes :**

Noise running averages are not implemented on the EM. The content of all Bytes should be 0.