



pRU Data Format Specification

Ola Grøttvik

April 2018

This document contains technical information regarding the proton CT prototype readout unit (pRU). This is the specification of the data format of which data is offloaded from the pRU.

1 pRU Dataformat v0.2

A pRU word consists of 128 bits, and may be of four types:

1. DATA_WORD
2. TAG_HEADER_WORD
3. TAG_TRAILER_WORD
4. TAG_EMPTY_WORD
5. DELIMITER_WORD

1.1 General format [127:0]

| Name | WORD_TYPE | RU | STAVE | CHIPID | CONTENT |
|--------|-----------|---------|---------|---------|---------|
| Length | 2 | 6 | 4 | 4 | 112 |
| Bits | 127:126 | 125:120 | 119:116 | 115:112 | 111:0 |

WORD_TYPE Determines the type of pRU word.

0x0 DATA_WORD

0x1 TAG_HEADER_WORD

0x2 TAG_TRAILER_WORD

0x3 TAG_EMPTY_WORD or DELIMITER_WORD

RU Identification of which specific readout unit the data originated from.

STAVE Identification of which specific stave the data originated from.

CHIPID Identification of which specific ALPIDE chip the data originated from.

CONTENT Either collection of ALPIDE data or pRU tag data.

1.2 DATA_WORD

The content data field has 14 bytes available. Whenever the WORD_TYPE field is 0x0, each of these 14 bytes can be filled with pure ALPIDE data bytes. The data is filled from the MSB. All fields does not necessarily contain ALPIDE data. If the succeeding pRU word is a TAG_TRAILER_WORD, the FRAME_SIZE field will determine if all fields contain data. If the succeeding pRU word is a DATA_WORD, ALL fields of the specific word contain ALPIDE data. If a field is unused it is padded with 0xFF.

Filtering of redundant ALPIDE data words are on by default, but this may be altered by setting the filter_data_word register. The words that can be filtered out are the following:

- COMMA
- IDLE
- CHIP EMPTY FRAME (Always filtered out but will generate pRU Empty Word.
- BUSY ON
- BUSY OFF
- ALL OTHER WORDS - This includes REGION HEADER, DATA SHORT, DATA LONG and their contents.

| Name | WORD_TYPE | RU | STAVE | CHIPID | DATA |
|--------|-----------|---------|---------|---------|-------|
| Length | 2 | 6 | 4 | 4 | 112 |
| Bits | 127:126 | 125:120 | 119:116 | 115:112 | 111:0 |
| Value | 0x0 | | | | |

1.3 TAG_HEADER_WORD

This tag is transmitted before any ALPIDE data, and is intended to provide required information about time and space, for frame reconstruction in hardware. Any TAG_HEADER_WORD will be followed by any number of DATA_WORD and a closing TAG_TRAILER_WORD.

| Name | WORD_TYPE | RU | STAVE | CHIPID | DATA_FORMAT | UNUSED | BUSY_ON | BUSY_OFF | SPILL_ID | TRIG_SOURCE | MODE | FRAME_ID | ABS_TIME |
|--------|-----------|---------|---------|---------|-------------|--------|---------|----------|----------|-------------|------|----------|---------------|
| Length | 2 | 6 | 4 | 4 | 8 | 19 | 1 | 1 | 16 | 2 | 1 | 32 | 32 |
| Bits | 127:126 | 125:120 | 119:116 | 115:112 | 111:104 | 103:85 | 84 | 83 | 82:67 | 66:65 | 64 | 63:32 | 31:0 |
| Value | 0x1 | | | | 0x1 | 0x0 | | | | | | | 120 MHz Clock |

ABS_TIME The counter of a 120 MHz clock sampled at the moment the ALPIDE_CONTROL module transmits a trigger command to the ALPIDE. If no time information from external triggering exists (e.g. when using the internal sequencer for triggering), this field indicate the counter value from the time the ALPIDE frame header is recognized by the pRU protocol checker.

FRAME_ID The amount of ALPIDE frame headers that have been recognized by the pRU protocol checker (including CHIP EMPTY FRAME).

MODE The readout mode the ALPIDEs are configured in.

- 0x0** TRIGGERED Mode
- 0x1** CONTINUOUS Mode

TRIG_SOURCE The source of the ALPIDE trigger signal

- 0x0** ALPIDE Internal Strobe Sequencer
- 0x1** External pRU Hardware Signal
- 0x2** Software Trigger

BUSY_OFF Indicates that an ALPIDE busy off word was received in the time between last and this frame.

BUSY_ON Indicates that an ALPIDE busy on word was received in the time between last and this frame.

SPILL_ID The current value of the SPILL_ID register.

UNUSED Bits not assigned any specific meaning.

DATA_FORMAT The data format version. Any changes to this data format specification will cause this number to be incremented. Any software written to interpret pRU data can use this field to determine which fields are available.

1.4 TAG_TRAILER_WORD

This tag is transmitted to indicate that a whole ALPIDE frame has been read out, and will also hold information regarding frame size and any errors observed during transmission.

| Name | WORD.TYPE | RU | STAVE | CHIPID | UNUSED | ERROR.FLAGS | FRAME.ID | FRAME.SIZE |
|--------|-----------|---------|---------|---------|--------|-------------|----------|------------|
| Length | 2 | 6 | 4 | 4 | 40 | 8 | 32 | 32 |
| Bits | 127:126 | 125:120 | 119:116 | 115:112 | 111:72 | 71:64 | 63:32 | 31:0 |
| Value | 0x2 | | | | | 0x0 | | |

FRAME_SIZE The amount of ALPIDE data bytes transmitted in the preceding pRU data words.

FRAME_ID The amount of ALPIDE frame headers that have been recognized by the pRU protocol checker (including CHIP EMPTY FRAME). For matching with pRU Header.

ERROR_FLAGS Flags that indicate whether various errors have occurred during transmission of the frame. The following list describes each bit from LSB.

- 0 Decode/Protocol Error** Asserted whenever the 8B10B Decoder has been unable to decode a byte during processing of the frame, but processing may continue. Is also asserted whenever other protocol errors are observed.
- 1 Frame Error** Asserted whenever a fatal error occurred during processing of the frame. This error causes the frame processing to be aborted and instantly produces the trailer.
- 2 Empty Region Error** Asserted when a REGION identifier is detected but no short or long words comes directly after it.
- 3 Double Busy On Error** Asserted when two BUSY ON is detected, without a BUSY OFF in between.
- 4 Double Busy Off Error** Asserten when two BUSY OFF is detected, without a BUSY ON in between.
- 5 Buffer Overflow Error** Asserted whenever a pRU buffer has overflown.
- 6 Max Size Error** Asserted whenever the size of the frame is over 1.048.576 bytes (2 bytes per 1024x512 pixels). Probably caused by error in detecting ALPIDE trailer. Causes cancellation of the frame and forces a trailer word. The maximum size may be edited by setting the proper register on the RU.
- 7 Max Wait Time Error** Asserted whenever the data tagger has been waiting for more than 100 consecutive clock cycles (120MHz) for valid data during the frame. Causes cancellation of the frame and forces a trailer word. The maximum wait time may be edited by setting the proper register on the RU.

UNUSED Bits not assigned any specific meaning.

1.5 TAG_EMPTY_WORD

Special tag for whenever the ALPIDE's contain no pixel hits. The tag is intended to minimize the number of bits transmitted, and can be transmitted without any other pRU word either preceding or succeeding it. The tag contain CHIP identification information as well as time information of both the CHIP and the pRU. In addition to the regular TAG_HEADER_WORD fields, this tag also contain the bunch counter value of the ALPIDE.

The tag also includes compression information, i.e. when enabled in global_regs/empty_frame_compression register, a tag is only transmitted if a certain number of CONSECUTIVE empty frames has been identified. Then, the time and frame ID information is from the first empty frame of the sequence.

| Name | WORD_TYPE | RU | STAVE | CHIPID | RESERVED | UNUSED | NUM_EMPTY | BUNCH_CNT | SPILL_ID | TRIG_SOURCE | MODE | FRAME_ID | ABS_TIME |
|---------------|-----------|---------|---------|---------|----------|---------|-----------|-----------|----------|-------------|------|----------|---------------|
| Length | 2 | 6 | 4 | 4 | 1 | 4 | 16 | 8 | 16 | 2 | 1 | 32 | 32 |
| Bits | 127:126 | 125:120 | 119:116 | 115:112 | 111 | 110:107 | 106:91 | 90:83 | 82:67 | 66:65 | 64 | 63:32 | 31:0 |
| Value | 0x3 | | | | 0x0 | 0x0 | | | | | | | 120 MHz Clock |

NUM_EMPTY The number of consecutive empty frames

FRAME_ID The frame ID for the first empty frame in sequence

BUNCH_CNT The bunch counter value of the ALPIDE in the first empty frame in sequence

RESERVED Must be zero to separate from potential conflict with DELIMITER_WORD.

1.6 DELIMITER_WORD

Special tag for whenever the offload stage needs to be flushed. Does not contain any data.

| Name | WORD_TYPE | DELIMITER |
|---------------|-----------|-----------|
| Length | 2 | 126 |
| Bits | 127:126 | 125:0 |
| Value | 0x3 | ALL ONES |

1.7 Example of Word-Ordering

An ordinary frame will consist of the following:

1. One TAG_HEADER_WORD
2. At least one, and with no upper limit, DATA_WORD
3. One TAG_TRAILER_WORD

The following is an example of an frame where RU=2, Stave=10, CHIPID=3, SPILL_ID=300, TRIG_SOURCE=Software, MODE=TRIGGERED, FRAME_ID=25000, ABS_TIME=500.000.000:

| | | | | | | | | | | |
|--------------|-----------|-----|-------|--------|--------|----------|-------------|------|----------|-------------|
| Name | WORD_TYPE | RU | STAVE | CHIPID | UNUSED | SPILL_ID | TRIG_SOURCE | MODE | FRAME_ID | ABS_TIME |
| Value | 0x1 | 0x2 | 0xA | 0x3 | 0x0 | 0x12C | 0x2 | 0x0 | 0x61A8 | 0x1DCD.6500 |

| | | | | | | | | | | | | | | | | | | |
|--------------|-----------|-----|-------|--------|--------|--------|--------|-------|-------|-------|-------|-------|--------|-------|--------|--------|--------|--------|
| Name | WORD_TYPE | RU | STAVE | CHIPID | DATA0 | DATA1 | DATA2 | DATA3 | DATA4 | DATA5 | DATA6 | DATA7 | DATA8 | DATA9 | DATA10 | DATA11 | DATA12 | DATA13 |
| Value | 0x0 | 0x2 | 0xA | 0x3 | HEADER | HEADER | REGION | SHORT | SHORT | LONG | LONG | LONG | REGION | LONG | LONG | LONG | REGION | SHORT |

| | | | | | | | | | | | | | | | | | | |
|--------------|-----------|-----|-------|--------|-------|--------|-------|-------|--------|-------|-------|--------|-------|-------|--------|---------|--------|--------|
| Name | WORD_TYPE | RU | STAVE | CHIPID | DATA0 | DATA1 | DATA2 | DATA3 | DATA4 | DATA5 | DATA6 | DATA7 | DATA8 | DATA9 | DATA10 | DATA11 | DATA12 | DATA13 |
| Value | 0x0 | 0x2 | 0xA | 0x3 | SHORT | REGION | SHORT | SHORT | REGION | SHORT | SHORT | REGION | LONG | LONG | LONG | TRAILER | 0xFF | 0xFF |

| | | | | | | | |
|--------------|-----------|-----|-------|--------|--------|-------------|------------|
| Name | WORD_TYPE | RU | STAVE | CHIPID | UNUSED | ERROR_FLAGS | FRAME_SIZE |
| Value | 0x2 | 0x2 | 0xA | 0x3 | 0x0 | 0x0 | 0x1A |

Notice that to fields are padded in the second DATA_WORD, and this is reflected in the FRAME_SIZE field, in the trailer.