FRS data structure for VME crates

(This documentation was written by Maggy Hellström. Corrections and extension by Karl-Heinz Schmidt, June 27, 2005 and December 2006.)

The migration from CAMAC to VME has led to a completely new data structure for FRS events. Whereas some features of the older system have disappeared (such as the dT 1 MHz scaler), new ones have become standard (e.g. time stamp).

The VME ADCs, TDCs and QDCs can all be operated in zero-suppression and/or overflow suppression mode, and individual input channels can be enabled or disabled by software. This necessitates the "tagging" of each converted value with channel number and slot (also called GEO), as well as the implementation of header and footer blocks clearly demarcating the data originating from individual modules - something that was not needed in the old fixed-length readout used with the CAMAC-based system.

This document aims at introducing the new data format and to suggest way to implement the unpacking of the data.

A typical event

As not all the VME modules deliver their data in "compatible" format, some restraints have been placed on the readout order - and thus on the event structure. In addition, some small modifications to the data structures inherent to the VME modules have been made in the readout function (f_user.c and associated files) - see the relevant documentation!

A typical event could look like this (visualized by the MBS program):

....

The first 4 longwords contain time stamp information. This is followed by 10 longwords from the scaler: 1 header longword + 8 longwords (one per channel) + 1 footer longword. [To be implemented: Then comes 4 longwords from the pattern unit: 1 header longword + 2 data longwords + 1 footer longword]. Then data from each accessed ADC, TDC and QDC module follows, formatted using a standard recipe (per module minimum 1 longword, maximum 34 longwords).

Time stamp

See Notes below for additional information!

Longword 1: (time stamp unit identifier)
bits 0-15: FRS branch = 512 (0x200)
bits 16-31: all zero (0x0)

Longword 2: (time stamp word 1)
bits 0-15: data
bits 16-31: word 1 identifier = 247 (0x00f7)

Longword 3: (time stamp word 2)
bits 0-15: data
bits 16-31: word 1 identifier = 503 (0x01f7)

Longword 4: (time stamp word 3)
bits 0-15: data
bits 16-31: word 1 identifier = 759 (0x02f7)

Scaler

Because the scaler is a 32-bit one, there is no room for channel information to be recorded together with the data. The data is therefore delivered sequentially, starting from channel 0 up to the maximum number of read channels. (This is specified in the f_user.c file.)

Longword 1: (header = scaler identifier)
bits 0-5: number of read channels = chn
bits 6-23: all zero
bits 24-26: header flag = 2 (0x2, 010b)
bits 27-31: scaler GEO = 6 (0x6, 00110b)

Longwords 2 -- chn+1: (scaler data, sequential)
bits 0-31: channel contents

Longword chn+2: (footer = end-of-block)
bits 0-26: all zero
bits 24-26: footer flag = 4 (0x4, 100b)
bits 27-31: scaler GEO = 6 (0x6, 00110b)

Pattern unit

The data returned is fixed-length (4 longwords) and a hardwired GEO address 5.

Longword 1: (header = pattern unit identifier)
bits 0-5: number of data longwords = 2
bits 6-23: all zero
bits 24-26: header flag = 2 (0x2, 010b)
bits 27-31: pattern unit GEO = 5 (0x5, 00101b)

Longword 2: (data 1)
bits 0-15: pattern unit bit register
bits 16-23: data word 0 (0x0, 00000000b)
bits 24-26: data flag = 0 (0x0, 000b)
bits 27-31: pattern unit GEO = 5 (0x5, 00101b)

Longword 3: (data 2)
bits 0-15: pattern unit multiplicity register
bits 16-23: data word 1 (0x1, 00000001b)
bits 24-26: data flag = 0 (0x0, 000b)
bits 27-31: pattern unit GEO = 5 (0x5, 00101b)

Longword 4: (footer = end-of-block)
bits 0-23: all zero
bits 24-26: footer flag = 4 (0x4, 100b)
bits 27-31: pattern unit GEO = 5 (0x5, 00101b)

ADCs, QDCs and TDCs

Two cases can be distinguished: either valid data is present or not. The latter case can e.g. occur if there were no valid input signals, if all channels were disabled, etc., and is distinguished by the presence of a single longword. If at least one valid datum is present, the data structure will have the form header + data + footer.

No valid data

Longword 1: (header)
bits 0-5: number of data longwords = 0

bits 6-23: all zero
bits 24-26: no-valid-data flag = 6 (0x6, 110b)
bits 27-31: unit GEO

Valid data present

Longword 1: (header)
bits 0-5: number of read channels = chn
bits 6-23: all zero
bits 24-26: header flag = 2 (0x2, 010b)
bits 27-31: unit GEO

Longwords 2 -- chn+1: (data)
bits 0-11: channel contents
bit 12: underflow bit
bit 13: overflow bit
bits 14-15: all zero
bits 16-20: channel number
bits 24-26: data flag = 0 (0x0, 000b)
bits 27-31: unit GEO

Longword chn+2: (footer = end-of-block)
bits 0-15: unit event counter
bits 16-26: all zero
bits 24-26: footer flag = 4 (0x4, 100b)
bits 27-31: unit GEO

Note: 1 byte = 8 bits, 1 word = 2 bytes = 16 bits, 1 longword = 2 words = 4 bytes = 32 bits.
Bits are counted from 0 and upward, and written out with the least significant bits (LSBs) to the right.
10010110b (binary notation) = 0x96 (hexadecimal notation) = 150 (decimal notation).

Note 2: MBS writes out data in "swapped" word order, which corresponds to word1, word2 (or byte2, byte1, byte4, byte3) - this can be a bit confusing at first... When you type an event on screen, all data is presented in hexadecimal notation. For instance the 8 words of the time stamp information could look like "200 0 17ff f7 38e1 1f7 563 2f7" where longword 1 = 0x00000200, longword 2 = 0x00f717ff, longword 3 = 0x01f738e1 and longword 4 = 0x02f70563.

Unpacking in SATAN:

SATAN offers tools for a user-friendly unpacking by the macros **SCAN**, **EVENT**, and **GOOREAD**. The following example refers to a data structure similar to that described above. Each VME slot requires one **SCAN** macro referring to the corresponding slot number as well as to the nature and the highest address of the data. (Here the first address is counted as “one”.) The data are transferred to the **DATA** arrays defined by the **DATA** keywords of the **GOOREAD** macro. The connection between the **SCAN** macros and the **GOOREAD** macros is provided by the **GOOREAD** keyword of the **SCAN** macros. The **GOOREAD** keyword refers to the sequence of **GOOREAD** macros appearing in the programme. (Alternatively, the **CONTROL** or the **PROCID** of the corresponding subevent may be used instead of the **GOOREAD** keyword to establish the correlation between the **SCAN** and the **GOOREAD** macros.)

See the following example:

```
SCAN GOOREAD(1) TIMESTAMP(3);
SCAN GOOREAD(1) SCALERS(14) SLOT(6);
SCAN GOOREAD(1) PATTERN(2) SLOT(5);
SCAN GOOREAD(1) ADC(32) SLOT(11);
SCAN GOOREAD(1) ADC(32) SLOT(13);
SCAN GOOREAD(1) TDC(32) SLOT(15);
SCAN GOOREAD(2) QDC(32) SLOT(17);
/* The data length defined in the SCAN macro (e.g. SCALERS(14), ADC(32)) counts the highest address
of 32-bit words (counting starts from 1), when all channels deliver data. Note that the SCAN macros must
appear in the declaration section of the user-supplied analysis programme, before the ANTRY macro! The
sequence of data defined by the SCAN macros can be chosen freely, independent of the structure of the
list-mode input data. The sequence of data defined in the SCAN macros must be identical to the
sequence of the GOOREAD macros and the sequence of DATA keywords in each GOOREAD macro. In
other words: The sequence of the data transferred to the GOOREAD DATA arrays is defined by the
sequence of the SCAN macros. */

ANTRY;

EVENT FORMAT(VMEFRS);
/* The format VMEFRS is a special data format for GOOSY data delivered from VME crates. These data
require that the sources of the input data (slots of the VME crate) are defined by the SCAN macro. */

GOOREAD DATA(TS(6),SC(28),PATT(4),ADC(64),TDC(32)) CONTROL(19);
GOOREAD DATA((QDC(32)) CONTROL(29);
/* The length in the DATA keyword of the GOOREAD macro refers to 16-bit words of pure data */
/* The data are provided by the GOOREAD macro to the user analysis programme in the arrays defined in
the DATA key word in fixed-length format. One element of these arrays contains a 16-bit word. Channels
which do not deliver data, e.g. due to zero suppression, are filled with zeroes. */
/* Note that the length specifications in GOOREAD differ from the one in the SCAN macro by a factor of
two for TIMESTAMP, SCALERS and PATTERN. All 32 bits of TIMESTAMP, SCALERS and PATTERN
are significant, and no zero suppression is performed. E.g. a scaler that delivers 32 bits appears in two 16-
bit words in the DATA keyword of GOOREAD. For ADC, TDC, and QDC data, the length specifications in
GOOREAD and in SCAN are the same, because only the lower 16 bits contain the data, while the upper
16 bits contain the address and other additional information. */
```

SATAN provides the possibility for a detailed check output of the raw data and the unpacking by the command "**INPUT filename / DEBUG EVENT(1)**". This option may be very useful for checking the data unpacking. Also more than one event may be printed, but the output becomes rather long. See the following example:

A section of the analysis programme:

```
 . . .
 SCAN GOOREAD(1) SCALERS(14) SLOT(6);
 SCAN GOOREAD(1) TDC(32) SLOT(8);
 SCAN GOOREAD(1) TDC(32) SLOT(9);
 SCAN GOOREAD(1) QDC(32) SLOT(11);
 SCAN GOOREAD(1) QDC(32) SLOT(13);

 SCAN GOOREAD(2) ADC(32) SLOT(9);
 SCAN GOOREAD(2) ADC(32) SLOT(10);
 SCAN GOOREAD(2) ADC(32) SLOT(11);
 SCAN GOOREAD(2) ADC(32) SLOT(12);

/* ================================================================ */
/* End of Declaration Part                                          */
/* ================================================================ */

ANTRY;

/* ================================================================ */
/* Begin of Analysis Part                                           */
/* ================================================================ */

 /************************************
    Provide list-mode data
 ************************************/

 Event Format(VMEFRS);

 GOOREAD DATA(Scalers(28),TDC(64),QDC(64))
         CONTROL(19);

 GOOREAD DATA(ADC(128))
         CONTROL(29);
. . .
```

The dialog:

```
Enter command:
INPUT f011.lmd / debug ev(1)
<I> Dataset F:\LMD-FILES\RUN136\F011.LMD opened for reading list-mode data.
<I> Reading list-mode data from input file.
    GOOSY data format assumed, as specified in the EVENT macro.
<I> GOOSY Listmode data
<I> Blocksize: 32k Bytes
<I> Dataset information:
    Run ID:
    Experiment:
    Date: 29Jul05,    Time: 1606
    Fileno.: 0,    Volume: RUN136
<I> Analysis is running ...
<H> Enter LHALT command or press BREAK button to stop analysis.

<I>        0 events processed. <H> Enter LHALT to stop analysis. Enter command:
<I> $NXTBLOCK: Block with 16384 bytes, total 32768 bytes read.
<I> $NXTBLOCK: Block with 16384 bytes, total 49152 bytes read
<I> B_BEGIN: 0, B_END: 0
```

```
    I_BUF: 203351, I_EVT: 20
<I> 6700 bytes provided by $NXTBLOCK

*** Message from 1. GOOREAD macro for Event Nr.13272662 (current event 1) ***
    Length of event buffer: 150 2-byte (16-bit) words
--- Properties of subevent Nr. 1 : --------------
  Length of subevent  78 2-byte (16-bit) words
  Subeventtype        10
  Subeventsubtype     1
  Subcrate            0
  Procid              10
  Control             19
  <The subevent fits to the filter parameters of this GOOREAD.>
  Detailed information on the data:
  Original data, 76 values (1 number = 2 byte)
   14 12800 1397 11926 -15265 204 1160 0 28466 <10:> 277
   12978 157 -27118 1 11310 161 -24266 158 -11629 <20:> 42
   -27743 42 641 548 2239 1634 -21979 36 0 <30:> 0
   0 13312 0 17920 7 27136 16459 26624 16493 <40:> 26625
   16486 26626 16502 26627 16481 26628 16481 26629 16497 <50:> 26630
   -30676 27850 10 23040 16442 22528 16471 22529 16514 <60:> 22530
   16457 22531 16563 22532 16497 22533 16448 22534 16456 <70:> 22535
   16613 22536 16484 22537 -16289 23756
  Detailed decoding information for VME data
   Scaler header, GEO = 6, 14 Scalers
   Scaler 1 data 1397 11926
   Scaler 2 data -15265 204
   Scaler 3 data 1160 0
   Scaler 4 data 28466 277
   Scaler 5 data 12978 157
   Scaler 6 data -27118 1
   Scaler 7 data 11310 161
   Scaler 8 data -24266 158
   Scaler 9 data -11629 42
   Scaler 10 data -27743 42
   Scaler 11 data 641 548
   Scaler 12 data 2239 1634
   Scaler 13 data -21979 36
   Scaler 14 data 0 0
   ADC Header, GEO = 8, no valid data
   ADC Header, GEO = 13
   ADC Data of GEO 13, Channel 0 = 16459
   ADC Data of GEO 13, Channel 1 = 16493
   ADC Data of GEO 13, Channel 2 = 16486
   ADC Data of GEO 13, Channel 3 = 16502
   ADC Data of GEO 13, Channel 4 = 16481
   ADC Data of GEO 13, Channel 5 = 16481
   ADC Data of GEO 13, Channel 6 = 16497
   ADC Footer, GEO = 13
   ADC Header, GEO = 11
   ADC Data of GEO 11, Channel 0 = 16442
   ADC Data of GEO 11, Channel 1 = 16471
   ADC Data of GEO 11, Channel 2 = 16514
   ADC Data of GEO 11, Channel 3 = 16457
   ADC Data of GEO 11, Channel 4 = 16563
   ADC Data of GEO 11, Channel 5 = 16497
   ADC Data of GEO 11, Channel 6 = 16448
   ADC Data of GEO 11, Channel 7 = 16456
   ADC Data of GEO 11, Channel 8 = 16613
   ADC Data of GEO 11, Channel 9 = 16484
   ADC Footer, GEO = 11
  Decoded data provided by GOOREAD, first 156 values (1 number = 2 byte)
   1397 11926 -15265 204 1160 0 28466 277 12978 <10:> 157
   -27118 1 11310 161 -24266 158 -11629 42 -27743 <20:> 42
   641 548 2239 1634 -21979 36 0 0 0 <30:> 0
```

```
   0 0 0 0 0 0 0 0 0 <40:> 0
   0 0 0 0 0 0 0 0 0 <50:> 0
   0 0 0 0 0 0 0 0 0 <60:> 0
   0 0 0 0 0 0 0 0 0 <70:> 0
   0 0 0 0 0 0 0 0 0 <80:> 0
   0 0 0 0 0 0 0 0 0 <90:> 0
   0 0 16442 16471 16514 16457 16563 16497 16448 <100:> 16456
   16613 16484 0 0 0 0 0 0 0 <110:> 0
   0 0 0 0 0 0 0 0 0 <120:> 0
   0 0 0 0 16459 16493 16486 16502 16481 <130:> 16481
   16497 0 0 0 0 0 0 0 0 <140:> 0
   0 0 0 0 0 0 0 0 0 <150:> 0
   0 0 0 0 0 0
--- Properties of subevent Nr. 2 : --------------
  Length of subevent  60 2-byte (16-bit) words
  Subeventtype        10
  Subeventsubtype     1
  Subcrate            0
  Procid              20
  Control             29
  <The subevent does not fit the filter parameters of this GOOREAD.>

*** Message from 2. GOOREAD macro for Event Nr.13272662 (current event 1) ***
    Length of event buffer: 150 2-byte (16-bit) words
--- Properties of subevent Nr. 1 : --------------
  Length of subevent  78 2-byte (16-bit) words
  Subeventtype        10
  Subeventsubtype     1
  Subcrate            0
  Procid              10
  Control             19
  <The subevent does not fit the filter parameters of this GOOREAD.>
--- Properties of subevent Nr. 2 : --------------
  Length of subevent  60 2-byte (16-bit) words
  Subeventtype        10
  Subeventsubtype     1
  Subcrate            0
  Procid              20
  Control             29
  <The subevent fits to the filter parameters of this GOOREAD.>
  Detailed information on the data:
  Original data, 58 values (1 number = 2 byte)
   0 19968 0 22016 0 24064 24 25088 16459 <10:> 24576
   16514 24592 16481 24577 16509 24593 16503 24578 16478 <20:> 24594
   16482 24579 16445 24595 16484 24580 16497 24596 16470 <30:> 24581
   16493 24597 16483 24582 16508 24598 16483 24583 16480 <40:> 24599
   16479 24584 16481 24585 16479 24586 16463 24587 16494 <50:> 24588
   16490 24589 16505 24590 16493 24591 -30686 25802
  Detailed decoding information for VME data
   ADC Header, GEO = 9, no valid data
   ADC Header, GEO = 10, no valid data
   ADC Header, GEO = 11, no valid data
   ADC Header, GEO = 12
   ADC Data of GEO 12, Channel 0 = 16459
   ADC Data of GEO 12, Channel 16 = 16514
   ADC Data of GEO 12, Channel 1 = 16481
   ADC Data of GEO 12, Channel 17 = 16509
   ADC Data of GEO 12, Channel 2 = 16503
   ADC Data of GEO 12, Channel 18 = 16478
   ADC Data of GEO 12, Channel 3 = 16482
   ADC Data of GEO 12, Channel 19 = 16445
   ADC Data of GEO 12, Channel 4 = 16484
   ADC Data of GEO 12, Channel 20 = 16497
   ADC Data of GEO 12, Channel 5 = 16470
   ADC Data of GEO 12, Channel 21 = 16493
```

```
   ADC Data of GEO 12, Channel 6 = 16483
   ADC Data of GEO 12, Channel 22 = 16508
   ADC Data of GEO 12, Channel 7 = 16483
   ADC Data of GEO 12, Channel 23 = 16480
   ADC Data of GEO 12, Channel 8 = 16479
   ADC Data of GEO 12, Channel 9 = 16481
   ADC Data of GEO 12, Channel 10 = 16479
   ADC Data of GEO 12, Channel 11 = 16463
   ADC Data of GEO 12, Channel 12 = 16494
   ADC Data of GEO 12, Channel 13 = 16490
   ADC Data of GEO 12, Channel 14 = 16505
   ADC Data of GEO 12, Channel 15 = 16493
   ADC Footer, GEO = 12
  Decoded data provided by GOOREAD, first 128 values (1 number = 2 byte)
   0 0 0 0 0 0 0 0 <10:> 0
   0 0 0 0 0 0 0 0 0 <20:> 0
   0 0 0 0 0 0 0 0 0 <30:> 0
   0 0 0 0 0 0 0 0 0 <40:> 0
   0 0 0 0 0 0 0 0 0 <50:> 0
   0 0 0 0 0 0 0 0 0 <60:> 0
   0 0 0 0 0 0 0 0 0 <70:> 0
   0 0 0 0 0 0 0 0 0 <80:> 0
   0 0 0 0 0 0 0 0 0 <90:> 0
   0 0 0 0 0 0 16459 16481 16503 <100:> 16482
   16484 16470 16483 16483 16479 16481 16479 16463 16494 <110:> 16490
   16505 16493 16514 16509 16478 16445 16497 16493 16508 <120:> 16480
   0 0 0 0 0 0 0 0
*** Message from $ENDEVT: Summarized account of the processed event
| EventType: 10, EventSubType: 1, Eventnr.: 13272662, Trigger: 1 :  2 Subevents
| The 1. Subevent is 1 times read. The parameters are :
| SubEventType: 10, SubEventSubtype: 1, ProcessorID: 10, Subcrate: 0, Control: 19
| The 2. Subevent is 1 times read. The parameters are :
| SubEventType: 10, SubEventSubtype: 1, ProcessorID: 20, Subcrate: 0, Control: 29
*********************************************************************************

<I> Elapsed time: 0.27 seconds.
Enter command:
```