DXP-xMAP General List-Mode Specification

The xMAP processor can support a wide range of timing or mapping operations, including mapping with full MCA spectra, multiple SCA regions, and finally a variety of list-mode variants.

List-mode operation is used to record several properties for a given event, on an event by event basis. The use of list-mode may be advantageous for readout efficiency (if there are very few events per pixel, it takes less space to store the individual event energies rather than to store a complete MCA histogram); the use of list-mode is essential if several data items must be stored for each event (energy, event time, time over threshold, etc). This document focuses on the latter case, where some information other than pixel number must be stored for each event (this general case of course also covers the case where you want to store event energy and pixel number for each event).

In general list-mode, for each event, several values are recorded in the output data stream. A single output format can support a variety of different data combinations; all combinations will include the event energy, expressed as the MCA bin number.

Buffer Specification

For general list-mode, the standard 256-word buffer header is present, but there is no pixel header, just event by event data. The buffer header contains the number of events in the buffer, the definition of the list-mode data (how many words per event, etc), as well as the run statistics for the buffer (live time, real time, etc), so pileup correction can be done on a buffer by buffer basis (no guarantees that the dead time is constant across the buffer, though).

Buffer Header

For all timing applications that use the dual buffers, the buffer header will have a fixed, 256-word length (the word size is 16 bits in this mode). The contents of the header are defined below; please note that general list-mode does not use many of the words in the buffer header. These words were retained for consistency with the other mapping modes.

Word Number	Contents
0	Tag Word 0: 0x55AA
1	Tag Word 1: 0xAA55
2	Buffer Header Size (=256)
3	Mapping Mode: 3: General List-mode

Word Number	Contents
4	Run Number
5 to 6	Sequential Buffer Number (low word first)
7	BufferID (0:A, 1:B)
8	Number of Pixels in buffer – unused in general list-mode (set to zero)
9 to 10	Starting Pixel Number (low word first) – unused in general list-mode (set to zero)
11	Module Serial Number?/Module #
12	Detector Channel 0 (set by host in DSP)
13	Det. Element, Ch0
14	Detector Channel 1 (set by host in DSP)
15	Det. Element, Ch1
16	Detector Channel 2 (set by host in DSP)
17	Det. Element, Ch2
18	Detector Channel 3 (set by host in DSP)
19	Det. Element, Ch3
20	Channel 0 MCA length (number of channels)
21	Channel 1 MCA length (number of channels)
22	Channel 2 MCA length (number of channels)
23	Channel 3 MCA length (number of channels)
24	Buffer errors: Buffer overrun Not used for list mode (set to zero)

Word Number	Contents
25-26	Total number of words in buffer, not including buffer header (list-mode only)
27-31	Reserved (set to 0)
32-63	32 User words (set in USER DSP array)
64	List-mode variant: 0: Energy plus pixel (slow) (3 words per event) 1: Energy plus pixel (fast) (3) 2: Energy plus clock time (3)
65	Words per Event
66 to 67	Total number of events in buffer (all channels but not special records)
68 to 69	Number of Channel 0 events
70 to 71	First Channel 0 Event number
72 to 73	Channel 0 upper time word at beginning of buffer (for time or counter based variants)
74 to 75	Number of Channel 0 input triggers
76 to 77	Channel 0 live time
78 to 79	Channel 0 real time
80 to 81	Number of Channel 1 events
82 to 83	First Channel 1 Event number
84 to 85	Channel 1 upper time word at beginning of buffer (for time or counter based variants)
86 to 87	Number of Channel 1 input triggers
88 to 89	Channel 1 live time
90 to 91	Channel 1 real time

Word Number	Contents
92 to 93	Number of Channel 2 events
94 to 95	First Channel 2 Event number
96 to 97	Channel 2 upper time word at beginning of buffer (for time or counter based variants)
98 to 99	Number of Channel 2 input triggers
100 to 101	Channel 2 live time
102 to 103	Channel 2 real time
104 to 105	Number of Channel 3 events
106 to 107	First Channel 3 Event number
108 to 109	Channel 3 upper time word at beginning of buffer (for time or counter based variants)
110 to 111	Number of Channel 3 input triggers
112 to 113	Channel 3 live time
114 to 115	Channel 3 real time
116 to 117	Number of special record events
118-255	Reserved (set to 0)

Event Data

The event data starts right after the 256-word buffer header. In general, each event record starts with the event energy, expressed as the MCA bin number, with bin numbers ranging up to 8K (8191 maximum), so 13 bits (bits 0 through 12) are required. The channel number (ranging from 0 through 3) is encoded into bits 13 and 14. Bit 15 will be used as a flag to indicate a special event record. One such special record is a record indicating the last record of the buffer (see below). Additional data for each event is stored right after the event energy, as defined separately for each list-mode variant.

Bit 15 (MSB)	Bits 14 – 13	Bits 12 – 0 (LSB)
Special event flag	Channel number (0-3)	Event energy, in MCA bins (0-8K)

List-mode Variants

General list-mode can support any number of variants, where the variants differ by what is recorded for each event. For the initial release, two variamts are offered; more can be added as necessary.

Variant 0: Energy (in MCA Bins) plus GATE Count

In this variant, the pixel number is stored along with the event energy (expressed in MCA bins). For this variant, the counter advances once for each GATE pulse. Two words are used to record the count for each event, so a total of three words are used per event. Rollover records (see below) are used to support count values up to 64 bits.

Variant 1: Energy (MCA Bin) plus SYNC Count

This variant is similar to the previous variant, except the pixel advances once per pre-scaled SYNC pulse (that is, the user specifies the number N of SYNC pulses required to advance a 'pixel', and the count advances once every N SYNC pulses). Once again, two words are used to store the pixel number for each event, so that three words are used per event, and rollover records (see below) are used to support counts values requiring more than 32 bits.

Variant 2: Energy (MCA Bin) plus Clock Time

Once again, this variant is similar to the previous variant, but instead of using the pixel number based upon an external clock, the internal clock is used to generate the event time (down to a minimum of 20 ns per unit using the full speed 50 MHz clock). Once again, three words are recorded per event, and rollover records are used to handle times greater than $2^{32} * 20$ ns (there will be a rollover record for each channel approximately every 86 seconds).

Special Records

Occasionally, it is necessary to inject different data into the buffer than the standard event record; for a special record, a tag word with bit 15 will be written into the first word of an event record (for a normal event record, bit 15 is not needed to record the energy, and will not be set). To remain consistent with the storage of events, three words will be used for these special data records.

End of Buffer Record (0x8000):

To help ensure buffer integrity, a special end of buffer record is used, indicated by the value 0x8000 in the first entry in the record. The remaining two words in the record record the total number of words in the buffer (including the buffer header as well as the end of buffer record).

Rollover Record (0x810x):

For all of the list-mode variants described above, two words are used to store the time or pixel number associated with an event. It is possible that more than two words are needed, especially when using the 50 MHz clock time, where 32 bits would roll over in about 86 seconds. For a rollover record, the lowest nibble in the rollover record tag word (indicated by 'x' above) indicates the board channel number (on the board – 0, 1, 2 or 3); this allows full flexibility for handling different clocks for different channels (and allows for processing events ordered by channel rather than time). The second and third words in this special record give the top two words of the count type in use (with the understanding that a non-zero value of the top word may never be necessary).

Host Control and Readback

List-mode processing uses the same dual-buffer scheme as MCA and MultiSCA mapping, and the same buffer control bits and indicator bits are used here. These controls are described elsewhere.

As there are several possible list-mode variants, the host must specify the desired variant by writing the appropriate value to the global DSP parameter *LISTMODEVARIANT*.

List-mode processing differs a bit from the other mapping applications due to more variability in the length of the buffer. As a result, the number of words written to the buffer can be read out from DSP parameters; these values are available separately for each output buffer. For output buffer A, the total number of words written to the buffer is stored in the parameters *LISTBUFALEN* and *LISTBUFALENA*, where the latter is the high order word. Similarly, for output buffer B, the DSP parameters *LISTBUFBLEN* and *LISTBUFBLENA* are used. Note that these values are updated even while the buffers are being filled, and can be compared to the maximum number of words that can fit into one buffer to measure the progress of filling the buffer. The buffers have enough memory to store 1 Mword (2^{10} words); in general, the system will automatically switch buffers once the upper word in the buffer length (*LISTBUFALENA* for example) exceeds 15 (at which point the buffer is 15/16 full). It is also possible to switch buffers on command from the host.