Event Code Sequence User Manual

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1 Introduction

The Event Generator (EVG), the head of the LCLS timing system, sends event codes to Event Receivers (EVRs) at 360 Hz, in sync with the machine's 360 Hz fiducial. EVRs are configured to create interrupts to attached computers and/or output hardware triggers upon receipt of specified event codes.

Sequences of event codes are be used by experimenters to trigger hardware and software in desired patterns.

2 Event Generator and Event Codes

Each event code is assigned a single, unique, and constant delay value in the EVG Input Output Controller (IOC). These values define when event codes will be transmitted from EVG in 8.4 ns ticks relative to the machine's 360 Hz fiducial.

Event codes and their delay values are written to an EVG sequence RAM when they are to be transmitted. After receiving a fiducial trigger, the EVG walks through the sequence RAM and transmits event codes once their delays expire.

Since event code delay values are unique and constant, active event codes are transmitted from the EVG and are received by EVRs with constant delays from the 360 Hz fiducial. Figure 2.1 shows the event code delay configuration user interface.

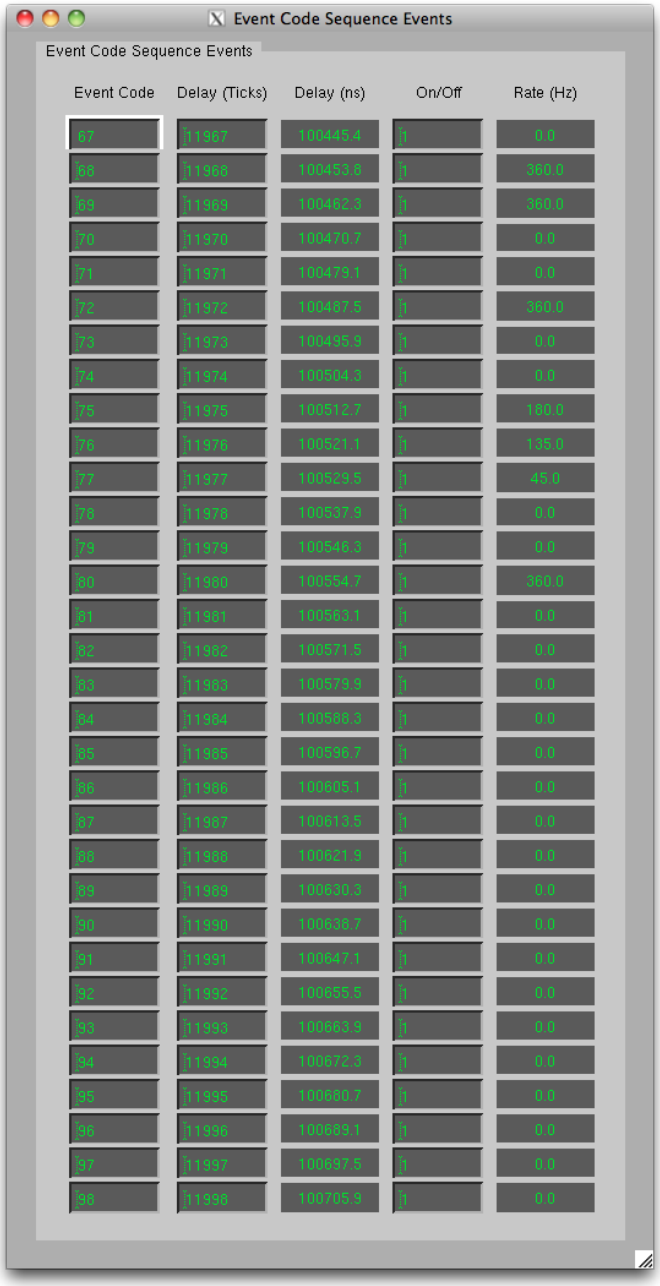

Figure 2.1. LCLS Event Code Configuration

3 Experiment Event Codes

Thirty-two event codes, event codes 67 to 98, are reserved for experiments. The event codes' delay values increase by one tick, 8.4 ns, per event code, creating a contiguous block of event codes in the EVG sequence RAM.

3.1 Grouping and Terminators

Experiment event codes are partitioned into one to four groups of two or more event codes. The largest event code of each group is used as the group's terminator. Terminators are transmitted whenever event codes from their groups are transmitted.

Event code 140, an event code transmitted on LCLS timeslots at 120 Hz, is used as a start marker for experiment software and appears before experiment event codes in the EVG sequence RAM — that is, all experiment event codes have delay values greater than event code 140. Users can use the start marker and group terminators to verify which event codes were sent on each LCLS timeslot.

4 Event Code Sequences

Up to four variable length sequences can be simultaneously active. Sequences can be 1–2048 steps in length with each step consisting of an event code to transmit after an adjustable delay relative to the previous step.

Sequences are not synchronized with other timing events and can be started and stopped at any time. They can also be configured to repeat any number of times, including indefinitely.

Delays are specified in the positive number of beam shots and 360 Hz fiducials from the previous shots. Event codes with zeroed delay times will be transmitted along with the previous step in order of increasing event code, a restriction imposed by the EVG (see Chapter 2). Sequences first steps must be assigned a non-zero delay. This restriction ensures that users explicitly choose delay times between the last and first steps of repeating sequences.

Beam delays are counted down at the machine's current beam rate. If the machine's rate drops to 0 Hz, sequences waiting on beam delays will pause.

Fiducial delays are counted down at the machine's fiducial rate of 360 Hz, giving a 2.78 ms delay for each fiducial tick. The fiducial rate is not affected by beam rate.

If a step is assigned both a beam and fiducial delay, the beam delay is counted down before beginning the fiducial delay. That is, if a step is assigned a beam delay of three and a fiducial delay of two, the step's event code will be transmitted 5.56 ms after the third beam pulse since the previous step.

The EVG will continue playing sequences in the event beam is lost in the machine unknown to the EVG. Timestamps are provided to inform users of the last time each sequence has started and stopped.

4.1 Example Sequence 1

Table 4.1 contains an example sequence. The sequence's timing is shown in Figure 4.1 with green lines representing event code 72, the sequence's terminator. The blue line marks the moment the sequence is activated.

This example assumes:

- a constant beam rate of 120 Hz,

- the sequence is started between less than 2.78 ms after a beam pulse, and
- the sequence is configured to repeat forever.

Table 4.1. Example Sequence

Step	Event Code	Beam Delay	Fiducial Delay
1	67	0	1
2	68	1	0
3	70	0	2
4	69	0	0
5	71	2	1

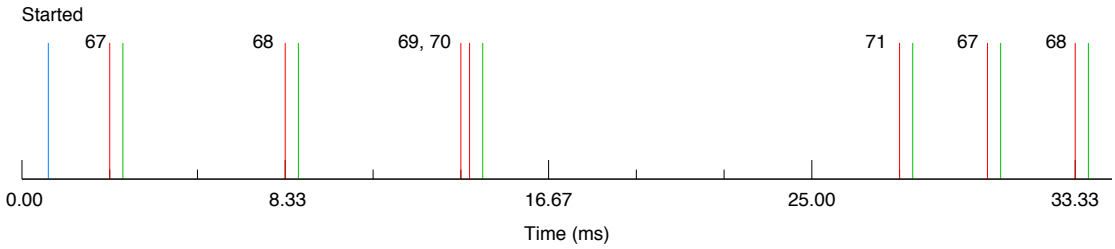

Figure 4.1. Example Sequence's Timing

The sequence begins with event code 67 being output on the fiducial following the start of the sequence. The delay from starting the sequence to the event code being transmitted is less than or equal to 2.78 ms. Note that because only a fiducial delay is specified, this event could be transmitted on any timeslot. A beam delay would ensure the step is output on an LCLS timeslot, with beam.

Since an event code from this sequence is transmitted, the sequence's terminator is also sent out. The terminator (72) is five event codes greater than the step's event code (67), and will therefore arrive at the EVR in five 8.4 ns ticks (42 ns) following event code 67.

Step two has a beam delay of one, and will output on the next beam pulse. Assuming a constant beam rate of 120 Hz, the step's event code and terminator will be transmitted 5.56 ms after the first step.

The third step is delayed two fiducials from the previous step and will be transmitted 5.56 ms after step two. The fourth step is not delayed and will be transmitted along with step three. However, step four's event code will arrive at the EVR before step three's since its event code is a lesser value.

Again, assuming a constant beam rate of 120 Hz, there will be beam on the fiducial following step four. On the following beam pulse, step five's beam delays will be exhausted and the fiducial delays begin. Step five's event code and terminator are transmitted on the fiducial following the second beam pulse after step four.

Because the sequence is configured to repeat and has not reached its repeat limit, the sequence begins again from step one. Here the usefulness of the first step's delay value becomes more clear; The first step's fiducial delay of one guarantees there will be one fiducial (2.78 ms) delay following the last step of the sequence.

Note that due to the fiducial-only delay of step one and the beam delay of step two, the delay time between the sequence's first and second steps has changed on the second play of the sequence, even though the beam rate has remained constant.

4.2 Example Sequence 2

Figure 4.2 shows timing of another example event code sequence.

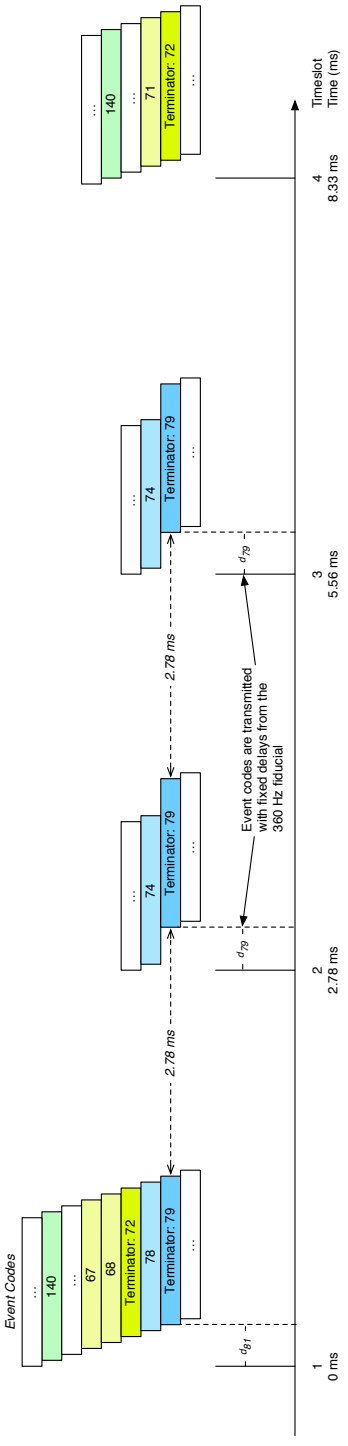

Figure 4.2. Event Code Sequence Timing

5 User Interface

All control and status Process Variables (PVs) are available to be written to from both the electron and photon control systems.

Potential event code partitioning and sequence control user interfaces are found in Figure 5.1 and Figure 5.2 respectively.

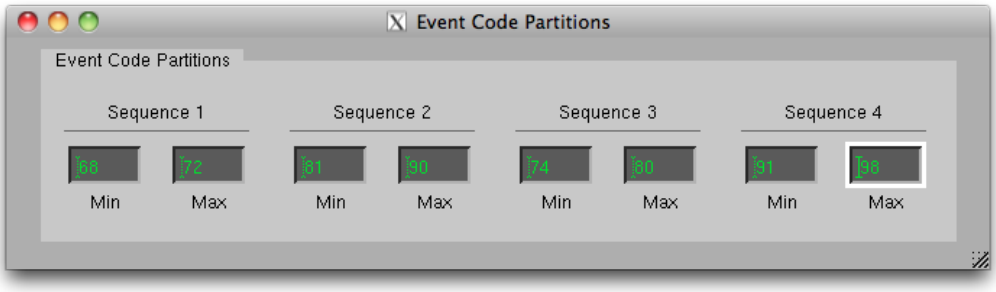

Figure 5.1. Event Code Partition User Interface

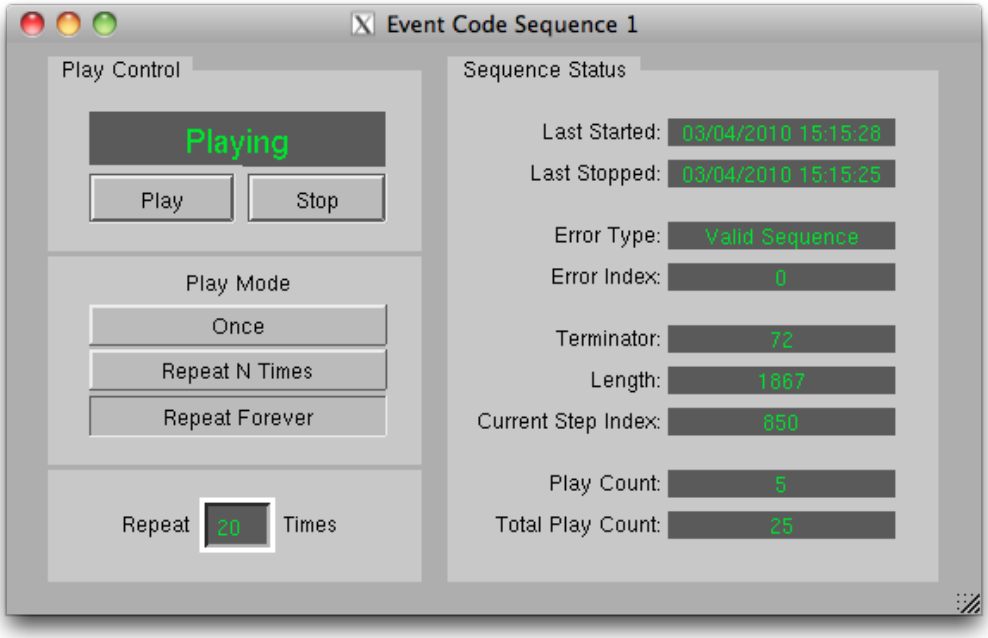

Figure 5.2. Sequence Control User Interface

6 Sequencing Experience

Between Jan. 2010 and Dec. 2010 we have accumulated some running experience with the event sequencing. It has been critical for running LCLS experiments. It has become clear, however, that 4 changes are necessary. These are described in the following 4 paragraphs.

Having 8 event codes per group is not sufficient. The RSXS experiment in SXR needs 9, and as more complicated experiments are performed in the future we would predict more would be necessary. We believe 4 groups of 16 would be sufficient for the foreseeable future. The 4 sets are useful because 2 experiments run at the same time (day shift and night shift) while 2 other experiments are setting up for the next run (typically the following week).

It is also important for the sequences to have a programmable "start phase" settable via an EPICS variable. This will allow the sequence to start on any of the common LCLS phases: 360 Hz, 120 Hz, 60 Hz, 30 Hz, 10 Hz, 5 Hz, 1 Hz, 0.5 Hz. The 360 Hz option will have lowest latency in the startup of the sequence (2.8 ms), while the 0.5 Hz option will have up to a 2 second startup latency.

The per-group terminator eventcode idea should be eliminated. We will use eventcode 1 as the terminator (this arrives at the beginning of the next fiducial). This is being done to decrease the complexity, at the cost of 2.8ms of PCDS DAQ EVR multicast packet delivery latency and 360 Hz CPU interrupts in the PCDS DAQ master crate. Users were frequently making errors not setting the correct terminator, and often non-sequencing eventcodes users were interested in recording in the DAQ system were coming after the terminator.

We will start to run most of the time with only fiducial delays, and beam delays will be set to zero. This is because we need to run sequences at times when event code 140 is not available (e.g. MD/ROD days).

Appendices

A List of Acronyms

EVG Event Generator

EVR Event Receiver

IOC Input Output Controller

PV Process Variable