Epoch Definition Guide

Version 0.1

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1: Introduction
Markers are special events that occur during a measurement and can be used to align unsynchronized data. This document seeks to standardize the definition of a marker and lays out an Excel based table format for unambiguously describing markers and how they relate to epochs. The objective is to allow clear communication of markers, and automated epoch extraction through the LeidenBioDataToolbox.

When conducting E-Prime experiments and recording data with AcqKnowledge, two different types of markers can be saved:

1. Signal markers
2. Label markers

**Signal markers** are markers sent by E-Prime via the printer port (LPT) to the Biopac data acquisition unit, and recorded in AcqKnowledge as a signal.

**Label markers** are markers defined directly in AcqKnowledge and saved as labels.

2: Signal Markers (E-Prime)
Markers can be sent from E-Prime to BIOPAC via the printer port (LPT). Two type of markers can be sent:

1. Pulses
2. Slide Onset/Offset markers

2.1: Pulses
When sending a pulse, a value is temporarily written to the LPT. This generally occurs inside an inline object:

```
'Send Pulse Marker:
writeport g_PortAddress, 10
sleep 20
writeport g_PortAddress, 0
```

When the code above is run, the LPT with the address defined in `g_PortAddress` is set to the value 10. E-Prime subsequently halts execution for 20 ms, then continues with the next writeport statement, which sets the LPT back to zero. A sleep of between 20 and 100 ms usually used, depending on the sampling frequency. It is advisable to keep the at its value for at least 10 samples; e.g., for a sampling rate of 1000 Hz the sleep needs to be at least \(10*\frac{1}{1kHz} = 10\) milliseconds (20 or 50 ms will also do).
Figure 1: A pulse marker with value 10 sent at 1 minute.

The time when the LPT assumes a value of 10 will be referred to as the On Event, and the time when the LPT releases that value, in this case by assuming a value of 0, will be referred to as the Off Event. In Figure 1 the On event occurs at 60 seconds, and the Off event occurs 20 milliseconds after, which is the duration of the ‘sleep’ command in E-Prime.

An Off event can also occur when the LPT changes to a different value that is not 0. Note that when running an E-Prime experiment the Off event occurs closer to the slide subsequent to the inline object compared to the On event. However, there is still a delay between the marker’s off event and the subsequent slide’s onset. This delay consists of: (1) the time E-Prime needs to finish processing the inline object(s); (2) the time needed to load the subsequent slide; and (3) the wait caused by E-Prime syncing the slide onset with the monitor’s refresh cycle.

A ‘marker’ is the whole duration in which the LPT assumed the marker value, in this case 10; i.e. a marker spans from its On event to its Off event.

### 2.2: Slide Onset/Offset markers

An alternative method for sending markers with E-Prime is with a onset/offset command:

```plaintext
'Set onset/offset markers:
EpochSlide.OnsetSignalEnabled = True
EpochSlide.OnsetSignalPort = g_PortAddress
EpochSlide.OnsetSignalData = 13
EpochSlide.OffsetSignalEnabled = True
EpochSlide.OffsetSignalPort = g_PortAddress
EpochSlide.OffsetSignalData = 0
```

When an inline object with the code above is executed, no markers are actually sent. Instead, the code instructs E-Prime to send the specified marker at the onset of the object EpochSlide; i.e., when the EpochSlide object is written to the screen, the LPT is set to 13. Subsequently, when E-Prime
has finished executing the EpochSlide object, the LPT is set to 0. The LPT address is specified in PortAddress.

![Multiple LPT markers](image)

**Figure 2:** A Onset/Offset marker with value 13. The slide onset, and hence its on event, is at 150 seconds; and the slide end, and hence its off event, is at 250 seconds.

In a similar manner as with pulse markers, the On event of a Onset/Offset marker is when the LPT assumes the marker value, and the Off event is when it releases it.

Note that the On event of a Onset/Offset marker is truer to the actual onset of the slide object, compared to the On or even Off event of a preceding pulse. Also note that the offset marker is sent when the slide object is done executing; however, the slide will remain visible until overwritten by a subsequent slide.

### 3: Label Markers (AcqKnowledge)
Markers can be saved directly in AcqKnowledge as ‘labels’. These labels can be entered live either by manually typing a label (not recommended) or via a preprogrammed hotkey. Labels can also be entered post-hoc.

Labels are purely discrete; i.e. they contain a single location in time. Therefore, labels do not have on or off events.

### 4: Marker Occurrence
When defining markers, one needs to specify which occurrence of the marker is being referred to. Marker occurrence is defined as the sequence index of the desired marker within all markers with its value, in that specific channel. The figure below shows 4 pulse markers in the same channel. The first
marker (from left to right) is the first marker with value 10; as such, its occurrence is 1. The second marker is the first marker with value 11, its occurrence is therefore also 1. The third marker is the second marker with value 10, its occurrence is 2.

The fourth marker has occurrence three, when counting markers with a value of ten. However, it is also possible to count markers regardless of value. In this case, the first marker has occurrence 1, the second occurrence 2, the third occurrence 3, etc. Stating ‘overall’ occurrences, which disregards marker value, is necessary when searching for markers with any value (elaborated in a following section).

![Multiple LPT markers](image)

**Figure 3:** Four pulse markers. The marker at 60 seconds is the marker pictured in figure 1. The pulse shape cannot be seen due to the zoom level.

### 5: Defining Epochs in MATLAB via Excel

The Leiden BioData Toolbox v0.1 contains a function that allows user to define epochs based on markers. Epochs are defined by describing the start and end times per epoch, relative to the markers.

The following picture shows a typical signal marker channel, featuring 6 markers: 4 pulse markers with values 10, 11, 10 and 10 respectively; a onset/offset marker with value 13, and a final pulse marker with value 14. Additionally, three label markers have been plotted alongside the signal marker; a ‘start video’ label at 170 seconds; a ‘Probe 1’ label at 200 seconds; and, an ‘end video’ marker at 220 seconds.
The markers in the Leiden BioData Toolbox template file. The blue line is the signal marker channel containing 5 pulse markers, and one onset/offset marker. The three red dots illustrate the locations of the label markers in the template data.

The above pictured markers will be used as an example for defining epoch using the Leiden BioData Toolbox v0.1. First, an Excel sheet that specifies the epoch defining rules must be created. It is advisable to make this marker overview before, or during, the programming of the E-Prime script. A sample Excel Epoch definition table is given on the next page.
Figure 5: Epoch Definition Excel File. The sheet consists of 13 rows, and columns A through N. The Excel print-screen has been split into two sections for better viewing. The columns A through L, in the top figure are required for defining an epoch. Additional metadata columns can be added as desired. These columns will appear in the final analysis output and can be used to factorize, sort, subset or reorder the data.

<table>
<thead>
<tr>
<th>L</th>
<th>M</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>EpochName</td>
<td>EpochDescription</td>
<td>EpochDescription2</td>
</tr>
<tr>
<td>Epoch 1</td>
<td>Section between the first pulses with values 10 and 11</td>
<td>You can add as many extra metadata columns as you want.</td>
</tr>
<tr>
<td>Window 1</td>
<td>Section between the second and fourth markers, regardless of value</td>
<td>This section will also be split into 10 second windows.</td>
</tr>
<tr>
<td>Window 2</td>
<td>2 minute section centered around the first marker with value 14</td>
<td>This epoch ends after the signal ends and will be rejected.</td>
</tr>
<tr>
<td>Window 3</td>
<td>20 second section centered around the first marker with value 14</td>
<td>This epoch will be sliced into just one window.</td>
</tr>
<tr>
<td>Epoch 2</td>
<td>Section between the second and third markers of value 10</td>
<td></td>
</tr>
<tr>
<td>Epoch 3</td>
<td>Period while the marker is at 13</td>
<td></td>
</tr>
<tr>
<td>Epoch 4</td>
<td>First 30 seconds of period while the marker is at 13</td>
<td></td>
</tr>
<tr>
<td>Epoch 5</td>
<td>Epoch with non-existing start marker</td>
<td>This epoch will not be identified since its start marker does not exist.</td>
</tr>
<tr>
<td>Film</td>
<td>Section between the manual start and end labels</td>
<td></td>
</tr>
<tr>
<td>End film to 14</td>
<td>Section between the label 'end video' and the marker with value 14</td>
<td>This epoch shows that you can combine labels and markers.</td>
</tr>
<tr>
<td>Section</td>
<td>Section between the third marker with value 10 and the 9th overall marker</td>
<td></td>
</tr>
<tr>
<td>Sections</td>
<td>The &quot;Section&quot; epoch split into 20 second windows.</td>
<td>This section will also be split into 20 second windows.</td>
</tr>
</tbody>
</table>
The Epoch definition table must consist of the columns with the following headers in the first row:

A. StartChannel  
B. StartValue  
C. StartDelay  
D. StartAt  
E. StartOccurrence  
F. EndChannel  
G. EndValue  
H. EndDelay  
I. EndAt  
J. EndOccurrence  
K. EpochSlide  
L. EpochName  
M. Optional: extra metadata column  
N. Optional: extra metadata column

5.1: Channel  
The StartChannel and EndChannel parameters indicate the channel in which the signal markers are found. To use label markers, fill in ‘label’ as the channel (e.g. row 10 in Figure 5; note that the row number is the Excel sheet row number). Since the start and end locations of the epoch are independently determined, you can combine labels and channels to define an epoch (e.g. row 11 in Figure 5). Note that the channel must be the channel number inside MATLAB, which is not necessarily the same channel number as inside AcqKnowledge.

5.2: Value  
The StartValue and EndValue parameters are the values of the markers which indicate the start and end of that epoch, respectively. When using signal markers, the value parameters must be a non-zero positive integer. Alternatively, fill in ‘any’ when the markers should only be identified based on its overall occurrence, regardless of value (e.g. rows 3, 12 and 13 in Figure 5). Any can also be used when using labels; however, be sure to take into account that AcqKnowledge automatically adds a default starting label called ‘Segment 1’. As such, when referring to the first manually entered label of any value, it may be necessary to set the occurrence at 2 (‘Segment 1’ will be the first label of any value, and the desired label will be the second).

5.3: Delay  
The StartDelay and EndDelay parameters signify the period between the marker events, and the actual start of stop of the event, in seconds. Use negative values to indicate a pre-period (e.g., the epoch defined on row 5 in Figure 5 starts 10 seconds before the off event of the first occurrence of marker 14, in channel 7).

5.4: At  
The StartAt and EndAt parameters must be set to either on or off, and signify whether the on or off event of the given marker is to be used. See section 2 for explanation of On and Off events. Note that since labels are discrete markers, without starts or ends, they do not require specifying the At (any StartAt or EndAt will be ignored when using labels).
5.5: Occurrence
The StartOccur and EndOccur parameters indicate the occurrence of the marker that should be used to define the epoch start and end, respectively. See section 4: Marker Occurrence. StartOccur and EndOccur must be positive non-zero integers.

5.6: EpochSlice
The EpochSlice parameter signifies if that epoch needs to be sliced into smaller epochs, i.e. slices. If the EpochSlice value is set to zero, the epoch is not sliced; otherwise, the epoch is sliced into windows with a duration equal to the EpochSlice value, in seconds. For example, the epoch defined on row 2 in the Excel epoch definition table will not be sliced, whereas the epoch defined on row 3 will—into 10 second windows. The slicing algorithm will split epochs into windows starting at the start of the epoch, if the epoch cannot be split into full windows, the last window will contain the remainder. Epochs shorter than the windows they have to be sliced into—its non-zero EpochSlice value—will be sliced into a single slice.

5.7: Name
The EpochName field indicates the name of that epoch. It can be a string of characters, and can feature letters, numbers, spaces and special characters. All epoch names must be unique; i.e., no two epoch names should be equal to any other.

5.8: Extra Metadata Columns
Any amount of extra columns can be added to the epoch definition table. The top rows of the extra columns must be unique and valid variable names: they may contain letters, numbers and underscores, but must start with a letter. The header may not be one of the following reserved words: epochDur, epochStartime, epochEndTime, epochStartIndx, epochEndIndx, epochName, epochType, sliceType or epochSource. The fields below the headers can contain any type of information. These columns will appear in the final analysis output and can be used to factorize, sort, subset or reorder the data.

5.9: Epoch Definition Rule
The following rule can be used to understand the epoch definition algorithm:

An epoch with the name [EpochName] starts at [StartDelay] seconds after the [StartOccurrence]-th occurrence of marker with value [StartValue] in channel [StartChannel] turns [StartAt], and ends at [EndDelay] seconds after the [EndOccurrence]-th occurrence of marker with value [EndValue] in channel [EndChannel] turns [EndAt]. Optionally, the epoch will be sliced into windows of [EpochSlice] seconds.

5.10: Epoch Existential Requirements
Epochs that do not meet the following requirements will be rejected:

- Epochs must start before they end.
- Epoch must start after the measurement starts.
- Epochs must end before the measurement ends.
- Epochs must be at least two samples long.
5.11: Reading the Epoch definition file in MATLAB

The Excel file with the epoch definitions can be read into MATLAB using the `epochsFromExcel(filename)` method. Subsequently, the epochs generated from the Excel file can be loaded into the object using the `loadTiming(epochDataset)` method:

```matlab
% Generate Epoch Dataset from epoch definition file:
epochData = BiopacObject.epochsFromExcel('EpochPrototype');

% Load the epochs into the object:
BiopacObject.loadTiming(epochData);
```

**NOTE:** The first (leftmost) sheet in the Excel file will be read by MATLAB, regardless of its name.

The Toolbox will automatically process the Excel file and reject any epochs that do not meet their respective requirements:

```matlab
> Generating epochs from Excel file TemplateDetail.acq.
Could not find the start of the epoch defined in row 3 (Epoch 3), reason: The specified occurrence of the specified marker is missing.
Done generating epochs (11 of 12 were found).
Slicing epoch "Window 1" into 5 slice(s).
Slicing epoch "Window 2" into 1 slice(s).
Slicing epoch "Sections" into 7 slice(s).
Done slicing epochs. Total epochs now 21.

> Checking and loading epochs into object.
The following epoch(s) rejected because they were out of bounds:
  Window 2
Epochs from file TemplateDetail.acq loaded into object (20 of 21 were OK).
```

The epochs as found by the above mentioned script is plotted on the next page.
Figure 6: Epochs from the Excel file. The red dots represent the label markers entered in AcqKnowledge, and the blue line is the signal marker measured using BIOPAC. The markers LTR are: ‘start video’, ‘Probe 1’ and ‘end video’.