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- LIGO -
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# Calculating the Trend Data

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# 1 Summary

LIGO trend frames are calculated at one-second and one-minute intervals. The one-second trend is stored in one minute long frame files, whereas the one-minute trend is stored in one hour long frame files. Trend channels are denoted by their corresponding channel name extended by a suffix describing the statistical quantity they represent. For each recorded channel the trend data consists of the number of points (".n"), the mean value (".mean"), the root-mean-square value (".rms"), the minimum value (".min") and the maximum value (".max"). Additionally, the standard deviation (".stddev") can be calculated from the above values as needed.

# 2 One-Second Trend

Only valid data points are included into calculating the one-second trend. If no valid data points exist within the one second boundary, the one-second trend is invalid for this interval.

## 2.1 Conventions

The following conventions were chosen (quantities marked by an 'x' are stored in the frame file, quantities marked by '+' are calculated on-the-fly):

| | | |
|---|---|---|
| Number of points | $N_s$ | x |
| Data index | $i = 1, 2, 3, \ldots N_s$ | |
| Data points | $x_i$ | |
| Mean | $\overline{x}_s$ | x |
| Maximum | $x_s^{\max}$ | x |
| Minimum | $x_s^{\min}$ | x |
| RMS | $x_s^{\mathrm{rms}}$ | x |
| Standard deviation | $\sigma_s$ | + |

The number of data points within one second interval is equal to the sample rate of the corresponding channel.

## 2.2 Formulae

The one-minute trend is calculated as follows:

$$\overline{x_s} = \frac{1}{N_s}\sum_{i=1}^{N_s} x_i$$

$$x_s^{\max} = \max_i \{x_i\}$$

$$x_s^{\min} = \min_i \{x_i\}$$

$$x_s^{\mathrm{rms}} = \sqrt{\frac{1}{N_s}\sum_{i=1}^{N_s} x_i^2}$$

$$\sigma_s = \sqrt{\frac{N_s}{N_s-1}\left\{(x_s^{\mathrm{rms}})^2 - (\overline{x_s})^2\right\}}$$

# 3 One-Minute Trend

Only valid one-second trend points are included into calculating the one-minute trend. If no valid one-second trend points exist within the one minute boundary, the one-minute trend is invalid for this interval.

## 3.1 Conventions

The following conventions were chosen (quantities marked by an ‘x’ are stored in the frame file, quantities marked by ‘+’ are calculated on-the-fly):

| | | |
|---|---|---|
| Number of points | $N_m$ | x |
| Number of one-second points | $n_m$ | |
| Data index | $i = 1, 2, 3, \ldots n_m$ | |
| One-second data points | $(x_s)_i$ | |
| Mean | $\overline{x_m}$ | x |
| Maximum | $x_m^{\max}$ | x |

| | | |
|---|---|---|
| Minimum | $x_m^{\min}$ | x |
| RMS | $x_m^{\mathrm{rms}}$ | x |
| Standard deviation | $\sigma_m$ | + |

## 3.2 Formulae

The one-minute trend is calculated as follows:

$$N_m = \sum_{i=1}^{n_m} (N_s)_i$$

$$\overline{x_m} = \frac{1}{N_m} \sum_{i=1}^{n_m} (N_s)_i (\overline{x_s})_i$$

$$x_m^{\max} = \max_i \{(x_s)_i\}$$

$$x_m^{\min} = \min_i \{(x_s)_i\}$$

$$x_m^{\mathrm{rms}} = \sqrt{\frac{1}{N_m} \sum_{i=1}^{n_m} (N_s)_i \, (x_s^{\mathrm{rms}})_i^2}$$

$$\sigma_m = \sqrt{\frac{N_m}{N_m - 1} \left\{ (x_m^{\mathrm{rms}})^2 - (\overline{x_m})^2 \right\}}$$

Since the minute trend is calculated from the one-second trend, it avoids floating point round-off errors when adding a large number of terms.

# 4 Trend over Other Intervals

A trend which averages over multiple one-second or one-minute points can be calculated ‘on-demand’ using the one-second or the one-minute trend, respectively. For example, a ten-minute trend would average over 10 one-minute trend data points.

## 4.1 Conventions

The following conventions were chosen (quantities marked by an 'x' are stored in the frame file, quantities marked by '+' are calculated on-the-fly):

| | | |
|---|---|---|
| index denoting new binning | $h$ | |
| Number of points | $N_h$ | + |
| Number of one-minute points/<br>Number of one-second points | $n_h$ | |
| Data index | $i = 1, 2, 3, \ldots n_h$ | |
| One-minute data points | $(x_h)_i$ | |
| Mean | $\overline{x_h}$ | + |
| Maximum | $x_h^{\max}$ | + |
| Minimum | $x_h^{\min}$ | + |
| RMS | $x_h^{\mathrm{rms}}$ | + |
| Standard deviation | $\sigma_h$ | + |

## 4.2 Formulae

The arbitrary binned trend is calculated as follows:

$$N_h = \sum_{i=1}^{n_h} (N_m)_i$$

$$\overline{x_h} = \frac{1}{N_h} \sum_{i=1}^{n_h} (N_m)_i (\overline{x_m})_i$$

$$x_h^{\max} = \max_i \{(x_m)_i\}$$

$$x_h^{\min} = \min_i \{(x_m)_i\}$$

$$x_h^{\text{rms}} = \sqrt{\frac{1}{N_h}\sum_{i=1}^{n_h}(N_m)_i\,(x_m^{\text{rms}})_i^2}$$

$$\sigma_h = \sqrt{\frac{N_h}{N_h-1}\left\{(x_h^{\text{rms}})^2-(\overline{x_h})^2\right\}}$$