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Calculating the Trend Data

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1 SUMMARY

The standard trend format is a composite of 5 values: the mean, the minimum, the maximum, the rms and the number of data points which were used to compute the data point. This format is useful to summarize analog channels which are sampled at a much higher rate. It is however inefficient for bit encoded digital values as well as a trend channels which are not derived from a higher sampling rate. We propose to introduce 2 new trend formats:

i) version 2 of the current format which will be used for all analog channels, and
ii) a new digital trend format to store trends of bit encoded values.

1.1 ANALOG TREND CHANNELS

Version 2

The main new feature for version 2 trend files is an optimized storage format. The following changes are incorporated:

i) Trends by default store the standard deviation rather than the root-mean-square. This allows the use of single precision floating point values for all trend values (with the exception of the number of points which is a 32 bit integer),
ii) Trends can omit the minimum, the maximum and the standard deviation, if the number of points is exactly 1, i.e., the channel sampling rate is equal to the trend rate.
iii) Second trend can be omitted if it doesn't provide any useful information. This is mainly the case for monitor processes which have averaging constants longer than a second. However, minute trend must always be provided if a second trend is written.
iv) Trend frames are significantly longer in duration and use compression by default. Second trends are stored in one hour long frames and minute trends are stored in one day long frames. To support the online system trends can still be written as shorter frames (1 minute and 1 hour, respectively), but must be converted to the longer format by an background program whenever enough data has been accumulated.

A trend reader should support the rms by calculating its value on-the-fly.

Version 1

Verison 1 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. The extension can be omitted, if the channel is sampled at the rate of the trend and does not contain minimum, maximum and standard deviation values. In this case it is simply a slow channel.

Trend readers

A general purpose trend reader should support the following features:

i) Reading both version 2 and 1,
ii) Calculating the rms or standard deviation on-the-fly,
iii) Automatically generate trends at lower rates if requested,
iv) Being able to integrate multiple trends generated in parallel by independent sources.

The online trend reader may also support:

i) A proprietary trend format to grant fast access,
ii) The ability to read short and long trends (to facilitate the online writer).

If a trend channels is requested without a specifiaction of an extension, the mean shall be returned.

1.2 Digital Trend Channels

The new format of digital trend channels is optimized to store bit encoded values. A trend is derived from a channel with higher sampling rate by decimation and by by computing a bit mask which marks the bits which were changed. Both the decimated value and the change mask are stored as 32 bit unsigned integers.

For each recorded channel the digital trend data consists of the decimated value (".val") and the change mask (".chg"). If a trend channels is requested without a specifiaction of an extension, the value shall be returned. The extension can be omitted, if the channel is sampled at the rate of the trend and does not contain a change mask. In this case it is simply a slow channel.

2 Analog 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; this is indicated by setting $N = 0$. All data points in version 2 are stored as single precision floating point numbers with the excpetion of N which is stored as a 32 bit integer.

2.1 Conventions

The following conventions were chosen (quantities marked by an 'x' have to be present in the frame file, quantities marked by 'o' are required if $N > 1$, and quantities marked by '+' are calculated on-the-fly):

		vers. 1	vers. 2
Number of points	N_s	x	o[1]
Data index	$i = 1, 2, 3, \ldots N_s$		
Data points	x_i		

Mean	$\overline{x_s}$	x	x
Maximum	$x_s^{\max}$	x	o
Minimum	$x_s^{\min}$	x	o
RMS	x_s^{rms}	x	+
Standard deviation	σ_s	+	o

1. Default is $N = 1$.

The number of data points within one second interval is equal to the sample rate of the corresponding channel. In version 2, only the mean has to be present if the trend is derived from a single data point, or if one can safely assume $N = 1$, $\overline{x_s} = x_s^{\max} = x_s^{\min}$ and $\sigma_s = 0$. For example, a channel sampled at 1 Hz would produce a reduced second trend only, but a full minute trend with mean, maximum, minimum and standard deviation.

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 Analog 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 (indicated by $N = 0$). All data points in version 2 are stored as single precision floating point numbers with the excpetion of N which is stored as a 32 bit integer.

3.1 Conventions

The following conventions were chosen (quantities marked by an 'x' have to be present in the frame file, quantities marked by 'o' are required if $N > 1$, and quantities marked by '+' are calculated on-the-fly):

		vers. 1	vers. 2
Number of points	N_m	x	o[1]
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	x
Maximum	$x_m^{\max}$	x	o
Minimum	$x_m^{\min}$	x	o
RMS	x_m^{rms}	x	+
Standard deviation	σ_m	+	o

1. if omitted assume $N = 1$.

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 Analog 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. All data points are transferred as single precision floating point numbers with the excpetion of N which is stored as a 32 bit integer.

4.1 Conventions

The following conventions were chosen (quantities marked by an ‘x’ have to be present in the frame file, quantities marked by ‘o’ are required if $N > 1$, and quantities marked by ‘+’ are calculated on-the-fly):

index denoting new binning	h	
Number of points	N_h	+
Number of one-minute points/ 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^{rms}	+
Standard deviation	σ_h	+

4.2 Formulae

The arbitrary binned trend is calculated as follows:

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

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

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

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

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

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

5 Digital Second Trend

For the vast majority of bit encoded values the one second sampling rate is the natural acquisition rate and there is no need for decimation and for computing the change mask. For the few binary channels which are aquired at a faster rate, we use the following convention (quantities marked by an ‘x’ have to be present in the frame file, quantities marked by ‘o’ are required if $N > 1$, and quantities marked by ‘+’ are calculated on-the-fly):

Number of points	N_s	
Data index	$i = 1, 2, 3, \ldots N_s$	
Data points	x_i	
Decimated	x_s^{dec}	x
Change Mask	x_s^{chg}	o

The formulae are as follows:

$$x_s^{\text{dec}} = x_1$$

$$x_s^{\text{chg}} = (x_2 \text{ xor } x_1) \vee (x_3 \text{ xor } x_1) \vee \ldots \vee (x_{N_s} \text{ xor } x_1)$$

6 Digital Minute Trend

the following convention (quantities marked by an ‘x’ have to be present in the frame file, quantities marked by ‘o’ are required if $N > 1$, and quantities marked by ‘+’ are calculated on-the-fly):

Number of points	N_m
Data index	$i = 1, 2, 3, \ldots N_m$
Data points	$(x_s)_i$

Change mask in second trend	$(x_s^{\text{chg}})_i$	
Decimated	x_m^{dec}	x
Change Mask	x_m^{chg}	o

The formulae are as follows:

$$x_m^{\text{dec}} = (x_s)_1$$

$$x_s^{\text{chg}} = ((x_s)_2 \text{ xor } (x_s)_1) \vee ((x_s)_3 \text{ xor } (x_s)_1) \vee \ldots \vee ((x_s)_{N_m} \text{ xor } (x_s)_1) \\ \vee (x_s^{\text{chg}})_1 \vee (x_s^{\text{chg}})_2 \vee (x_s^{\text{chg}})_3 \vee \ldots \vee (x_s^{\text{chg}})_{N_m}$$

A digital trend with a rate other than second or minute can be calculated from the same equations.