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05.22.14

Application Note 129 Heart Rate Variability

Analyses: Statistical Measures

SDANN
SDNN - index

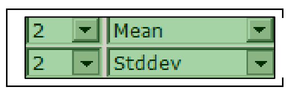
The **SDANN** is the **standard deviation of all the 5-minute NN interval (normal RR) means** (i.e., the standard deviation of 288 NN means), while the **SDNN-index** is **the mean of all the 5-minute of NN interval standard deviations** during the 24-hour period (i.e., the mean of 288 NN standard deviations),

SDANN will be calculated in one of two methods, based on whether the R-R interval is calculated using **Find Cycle** or the **Find Rate**.

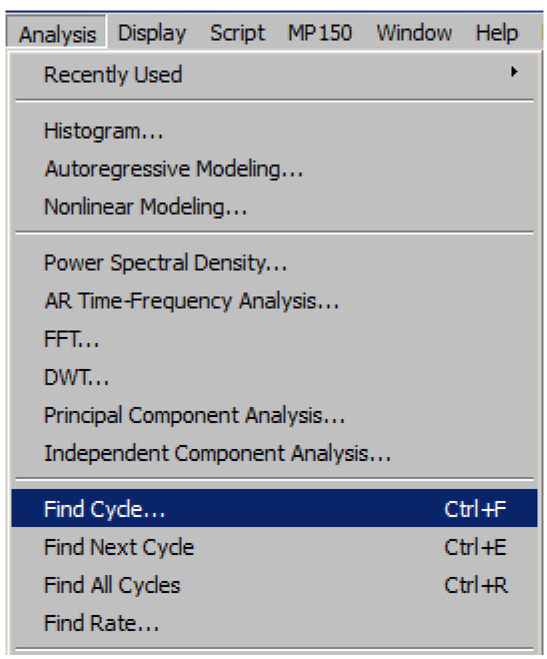
<u>RR interval calculated using Find Cycle</u>

To obtain SDANN and SDNN-index, first obtain the mean heart rate at 5-minute intervals. The following steps outline the procedure.

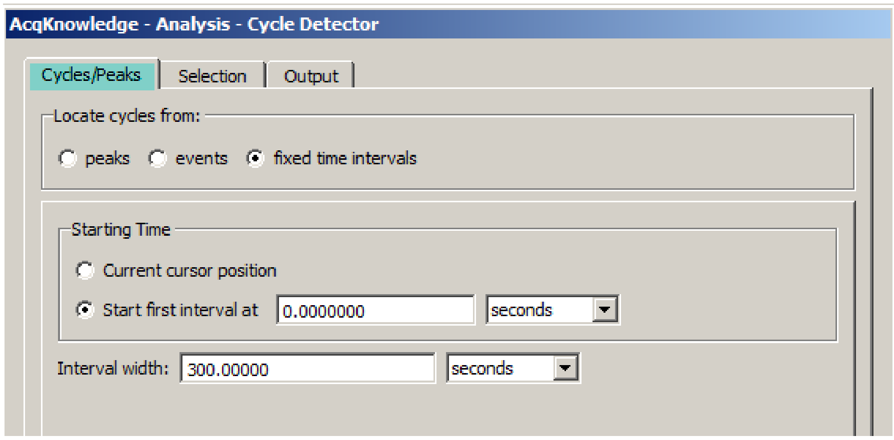
1. On the acquired data, set measurements for **Mean** and **Stddev** on the R-R interval channel.



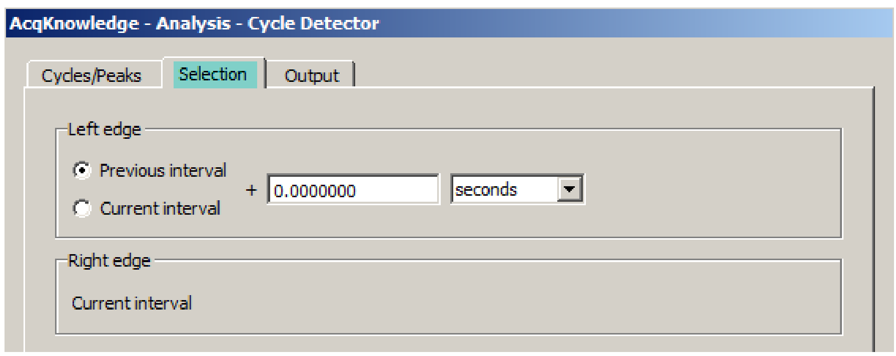
2. Choose **Analysis > Find Cycle**.



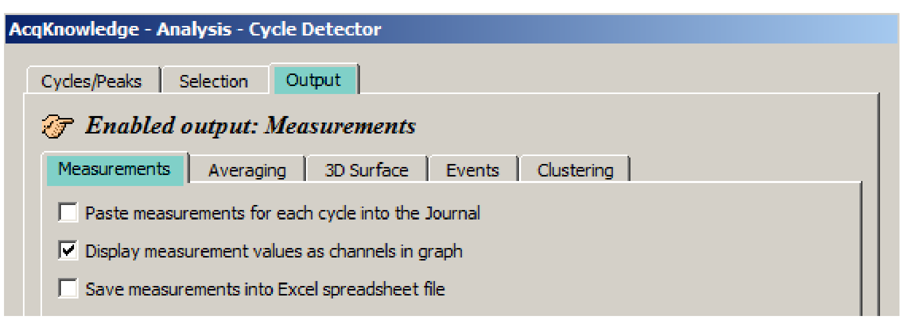
3. In the **Cycles/Peaks** tab, select “fixed time intervals”.
    - Select starting time = “Start first interval at 0.0000 seconds”
    - Set interval width = 5 minutes or 300 seconds.



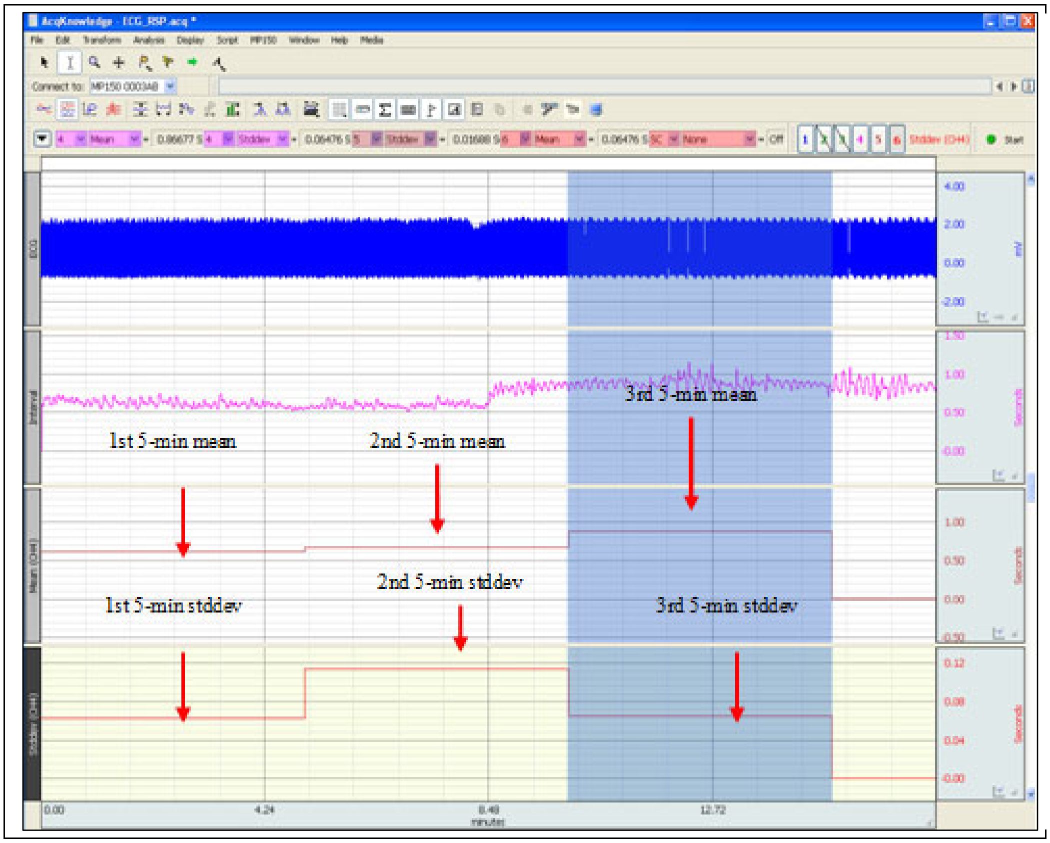
4. Click on **Selection** Tab. Set Left edge to “Previous interval + 0.000000 seconds”



5. Click on the **Output** Tab. Select “Display measurements as channels in a graph” as the output option.



6. Choose **Analysis > Find All Cycles**.
    - The following graph displays the Mean and Stddev of the R-R intervals every 5 minutes.



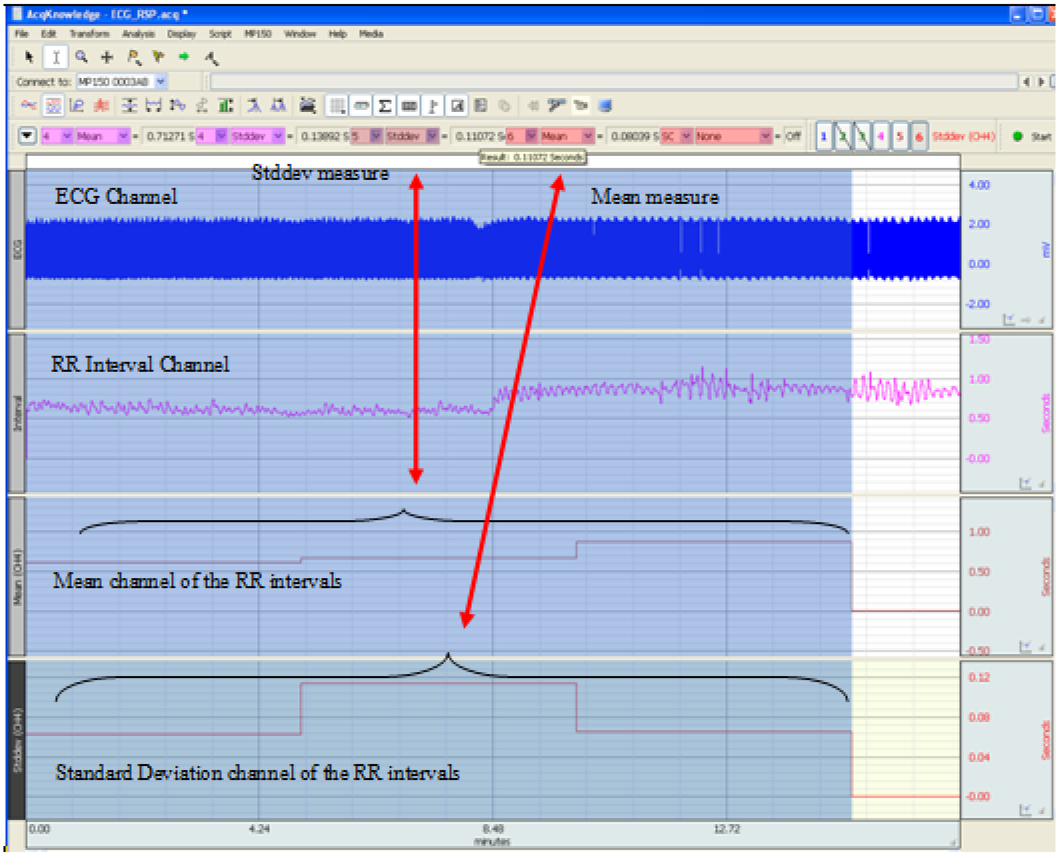
Find All Cycles output for Steps 2-6

7. Set a measurement box to Stddev assigned to the Mean channel and assign the Mean measurement to the Stddev channel.

The **SDANN** consists of the standard deviation of all 5-minute RR interval means.

The **SDNN-index** consists of the mean of all 5-minute RR interval standard deviations.

8. To obtain **SDANN** and **SDNN**-index, use the I-beam tool to highlight valid 5-min intervals. (Example on next page.)



SDANN and SDNN-index for ECG signals captured in real-time.

RMSSD

NOTE: A BIOPAC Basic Script for computing RMSSD, SDSD and pNN50 statistics is available for download at: http://www.biopac.com/ScriptDetails.asp?ID=1045

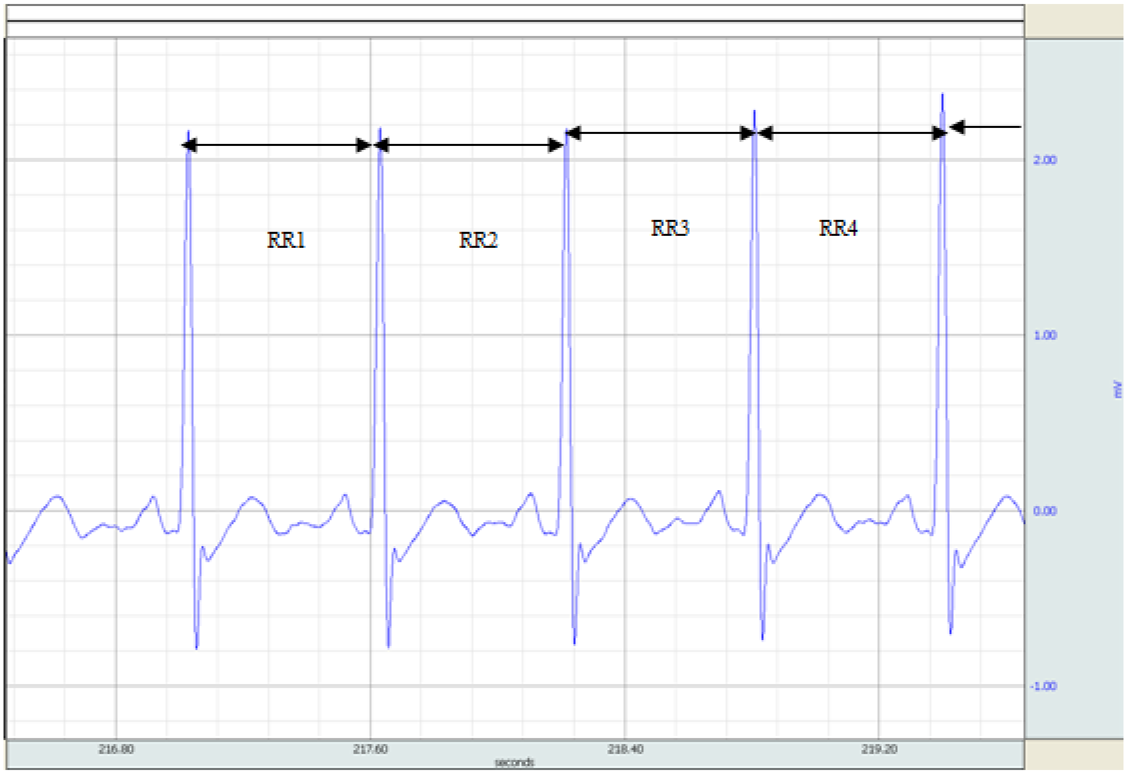
The **RMSSD** is the RMS of the Successive Difference between adjacent R-R intervals. Referring to the figure below, the successive differences would be:

$$RR_1 - RR_2 = D_1$$
$$RR_2 - RR_3 = D_2$$
$$RR_3 - RR_4 = D_3$$
$$\ldots$$
$$RR_{n-1} - RR_n = D_{n-1}$$

These differences are then used in the RMS equation:

$$RMSSD = \sqrt{\frac{\sum_{i=1}^{i=n-1} D_i^{\,2}}{n-1}}$$

Where i = interval index
n = number of total intervals
n - 1 = number of interval differences

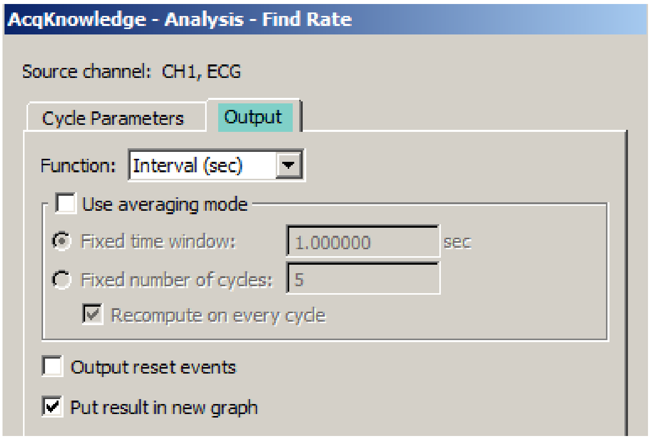


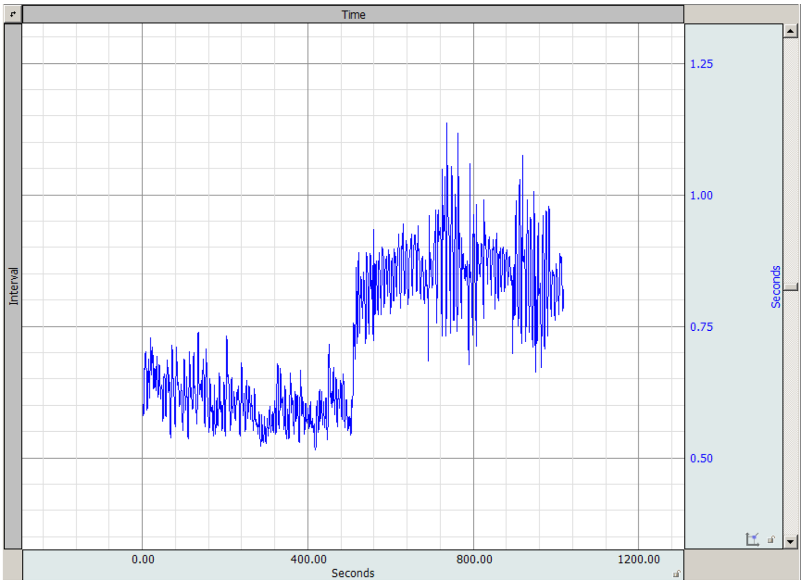
Successive R-R intervals used for the calculation of the RMSSD

The following page offers a suggested procedure for calculating the RMSSD using the R-R interval derived for the SDANN-index/SDNN-index metrics.

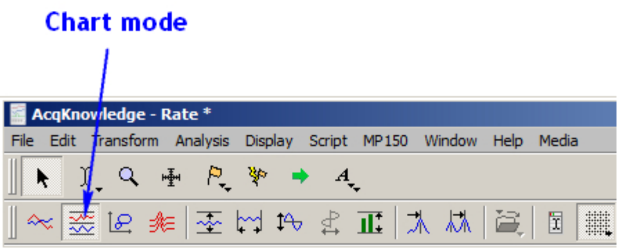
Deriving the RMSSD metric through the RR interval waveform

1. Create a separate R-R Interval graph from the source ECG waveform.
2. Select the ECG channel.
3. Choose **Analysis > Find Rate** and select the Output tab.
4. Choose **Interval (sec)** as the Function.
5. Check the "Put result in new graph" and click **OK**.



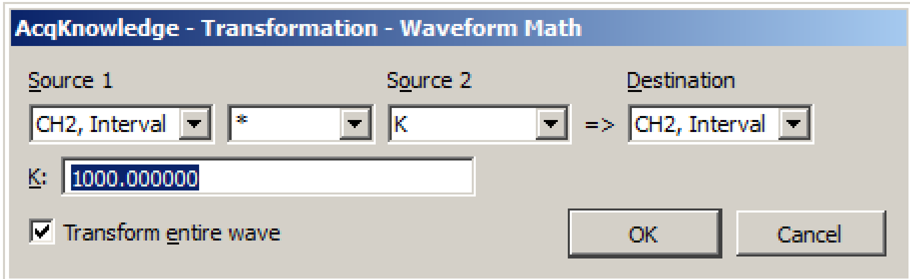


6. Switch the new R-R interval graph view to **Chart** mode.

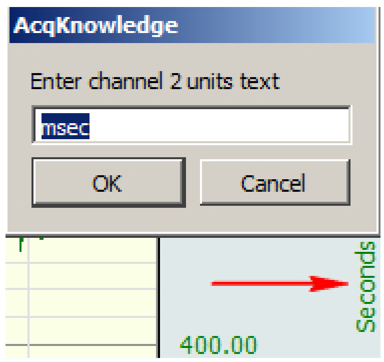


7. Hide or delete the R-R graph TIME channel and expand the Interval view using **Display >Autoscale Horizontal**.

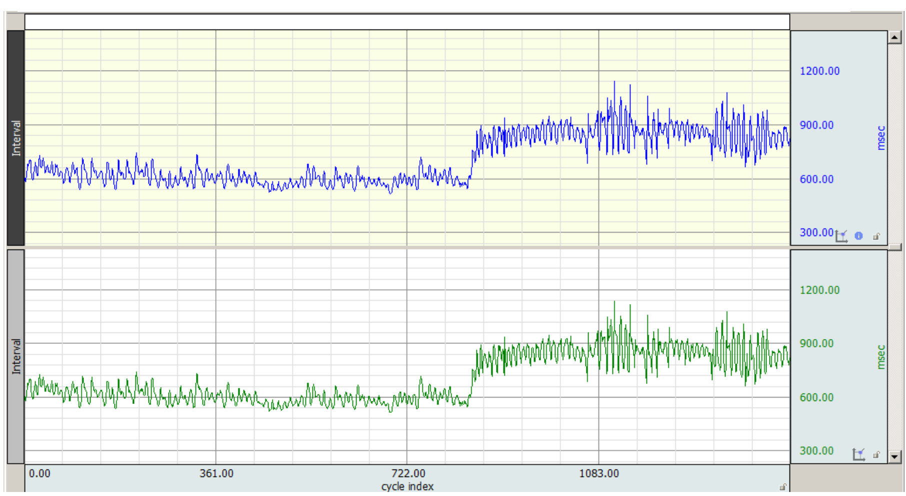
8. Convert the R-R interval graph from seconds to msec. Choose **Analysis > Waveform Math** and enter parameters as shown in the following figure.
    - Use the channel containing the RR interval as the Source and Destination.
    - Set operand to multiply (*)
    - Set "K" value to 1000 and click **OK**.



9. Double-click on the vertical axis units label; rename units to "msec" and click OK.



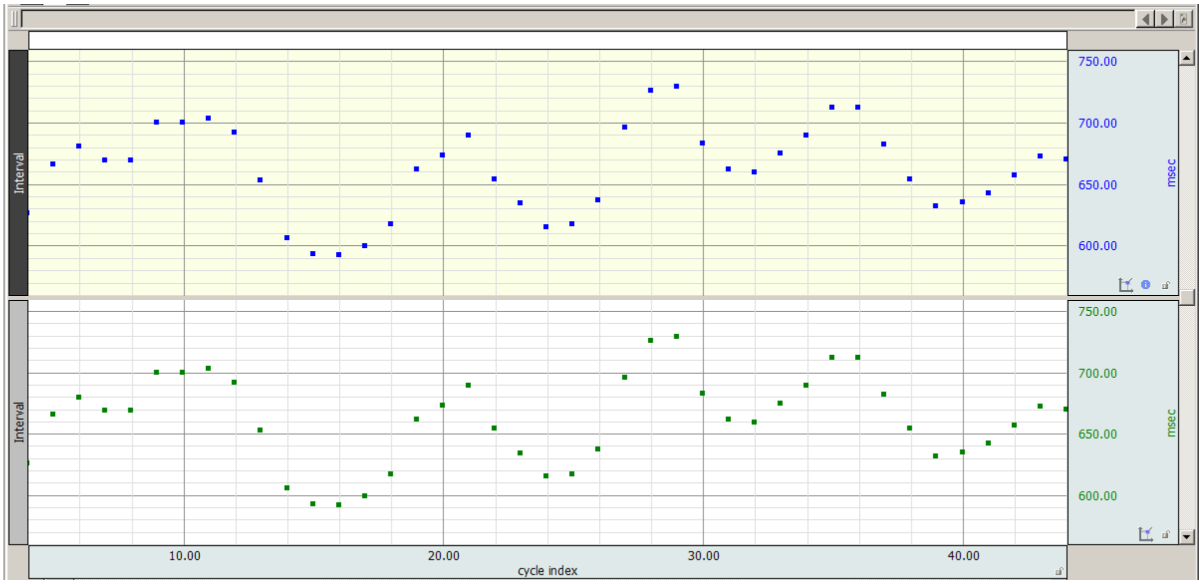
10. Duplicate the R-R Interval channel using: **Edit > Duplicate Waveform**.



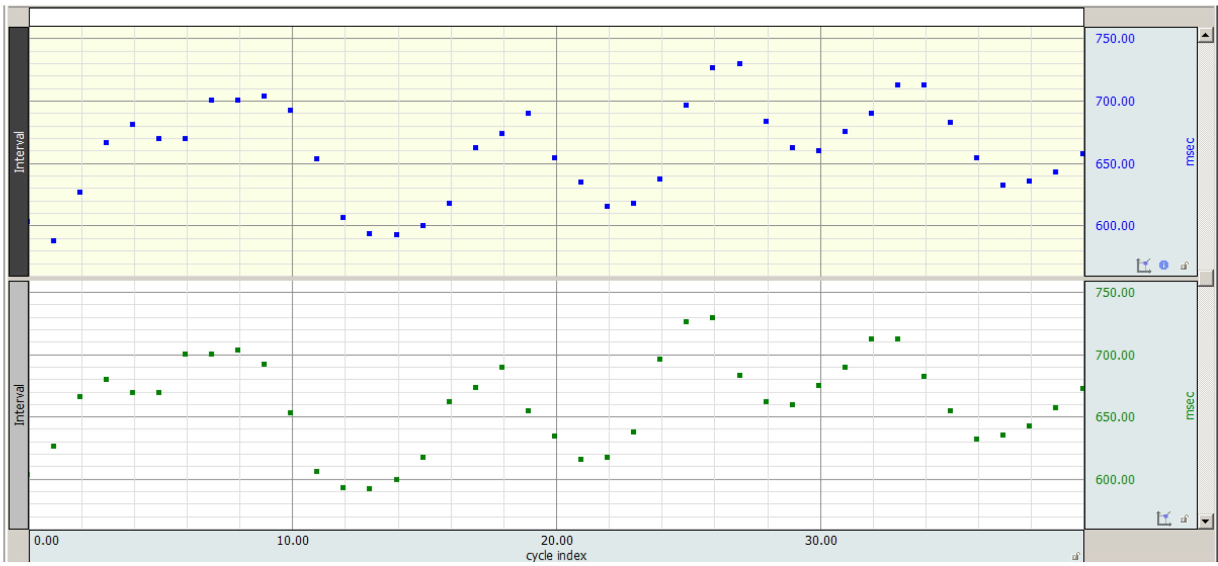
11. Select a measurement of 

12. Set the line style for each channel to dot plot using: **Display > Show > Dot Plot**

13. Use the Zoom tool  to display the first few samples of each channel.



14. **Select** the **top** interval channel, highlight a section of **2 samples** (Delta S = 2) then use: **Edit > Cut** to remove.
15. **Select** the **duplicate** interval channel, highlight a section of **3 samples** (Delta S = 3) then use: **Edit > Cut** to remove.

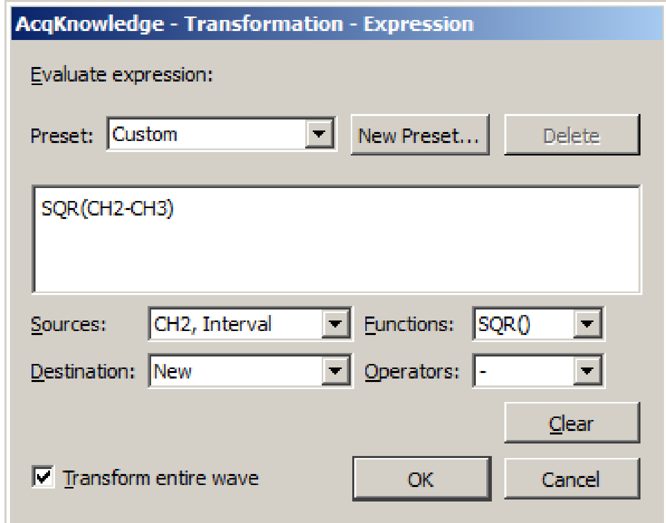


The resulting graph should contain two R-R waveforms separated by one beat.

(Check by choosing Select > All with Delta S selected for both channels)

16. Revert back to a line plot style on both R-R Interval channels: **Display > Show > Line Plot**
17. Use the Expression transformation to take the square of the difference between the two channels.
    - Choose **Transform > Expression**.
    - Enter **SQR(CH2–CH3)** into the Expression field.
    - Destination: **New**
    - Click **OK**.

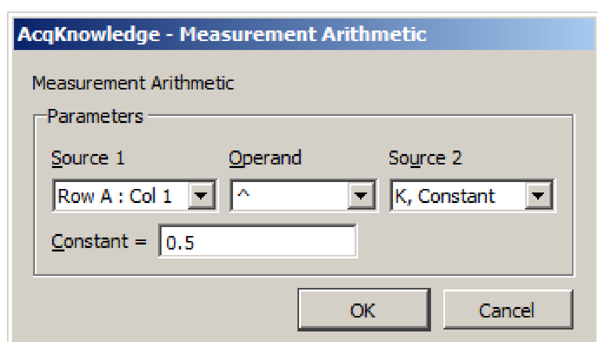
    NOTE: Your original and duplicate R-R Interval channel number assignments may vary from that used in the above and example formula. If so, use the correct channel numbers in your expression.



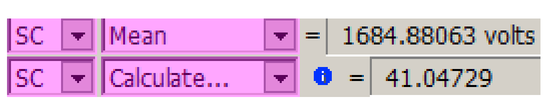
18. Vertically and horizontally Autoscale the resultant **SQR** waveform and choose: **Edit > Select All**.

19. Set a measurement to:  to get the mean of the square of the differences.

20. Set a measurement to **Calculate** to extract the square root of the mean:
    - Source 1 = the Mean
    - Operand = ^ (exp)
    - Source 2 = 0.5 (Constant)
    - Press **OK**.



21. Result: **RMSSD = Calculate**



Application Note 129- Part 2 Heart Rate Variability-SDSD & NN50 Calculation

The **SDSD** is the Standard Deviation of the Successive Difference between adjacent R-R intervals. Referring to Figure 1 below, the successive differences would be:

$$RR_1 - RR_2 = D_1$$
$$RR_2 - RR_3 = D_2$$
$$RR_3 - RR_4 = D_3$$
$$\ldots$$
$$RR_{n-1} - RR_n = D_{n-1}$$

These differences are then used in the SDSD equation:

$$SDSD = \sqrt{\frac{\sum_{i=1}^{i=n-1}(D_i - D_{mean})^2}{n-1}}$$

Where:
i = interval index
n = number of total intervals
n- 1 = number of interval differences

$$D_{mean} = \frac{1}{n-1}\sum_{i=1}^{i=n-1} D_i$$

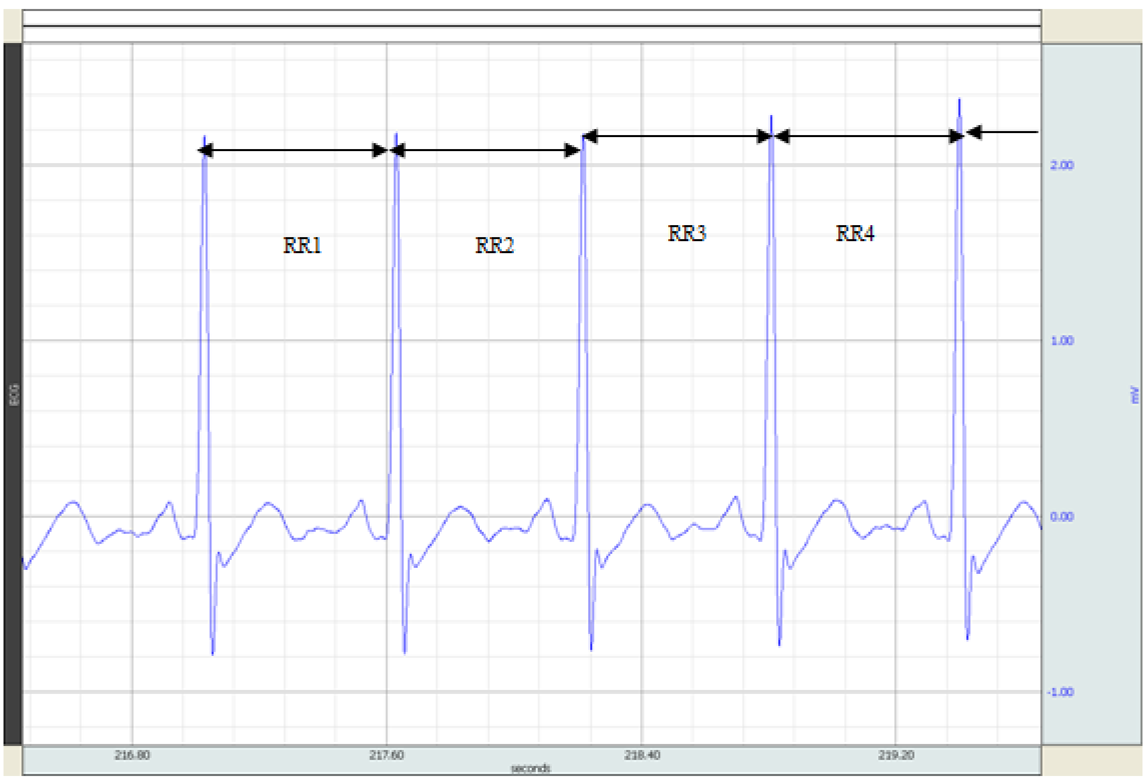
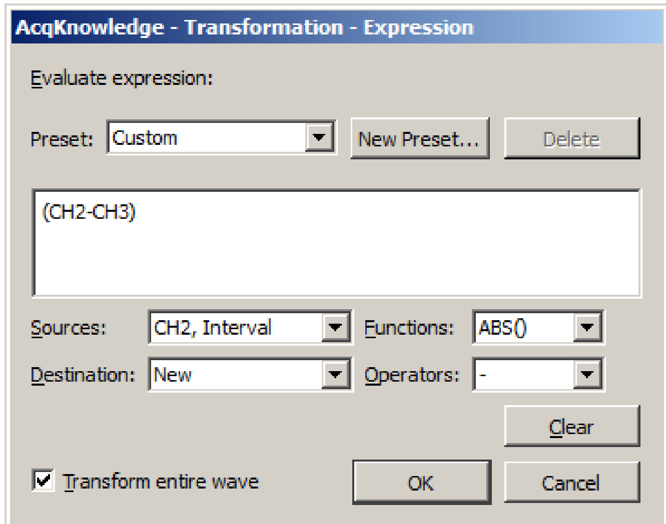
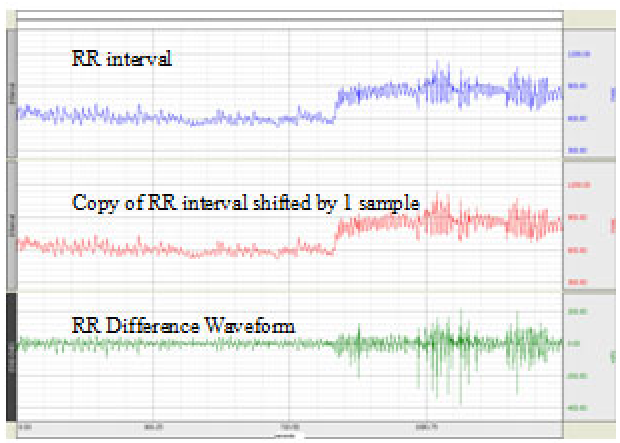


Figure 1 - Successive RR intervals used for the calculation of the SDSD

Deriving the SDSD metric:

1. Select the duplicate-channel R-R interval graph used in the **RMSSD** section in Part 1. (For easier viewing, hide the SQR channel used in the previous section by selecting and choosing Alt+Click.)
2. Use the Expression tool to **just** take the difference between the two channels: (original – duplicate).
   - Choose **Transform > Expression.**
   - Enter (CH2–CH3) into the Expression field. (Or enter your channel numbers containing the original and duplicate R-R interval. These may vary from the example)
   - Destination: **New**
   - Click **OK**.





3. Change the Difference vertical scale units from “Volts” to ”msec” to reflect the R-R interval channel units. (Click on the Difference channel’s units label to open the units text dialog.)
4. Set the Difference waveform to a 

measurement, and then choose: **Edit > Select All**.

   Result:

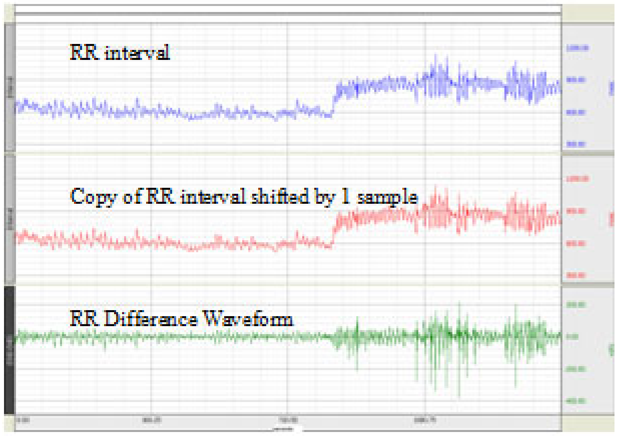
   SDSD = Stddev

NN50 count

pNN50

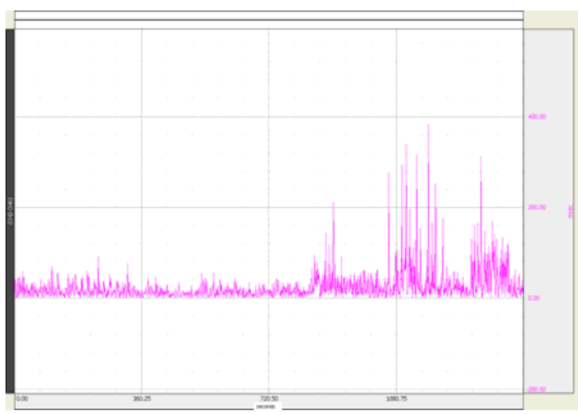
The **NN50** count is the number of pairs of adjacent **NN** intervals differing by more than 50 ms. This value can be derived using a waveform created by the difference between an R-R interval graph and a 1-sample shifted copy of the interval.

1. Use the R-R Difference Waveform created in Step 2 of Page 2 to calculate the NN50 count metric.



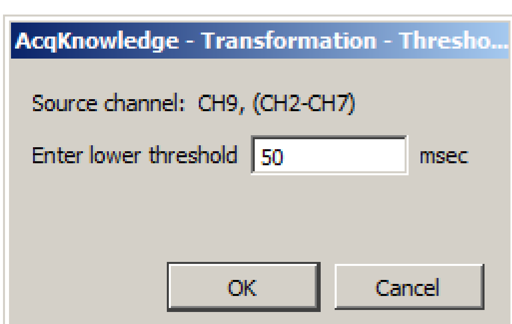
2. Perform the following operations:
   - Duplicate the R-R Difference Waveform: **Edit > Duplicate Waveform**
   - Select all of the duplicate waveform: **Edit > Select All**
   - Take the absolute value: **Transform > Math Functions > Abs**

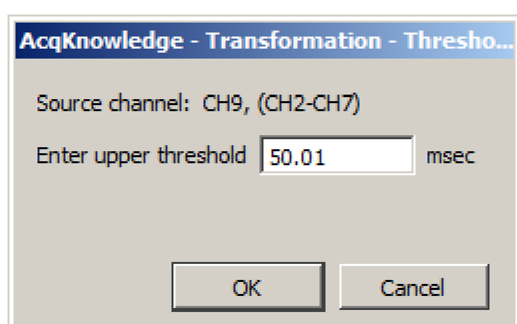
The resulting waveform should resemble the image below:



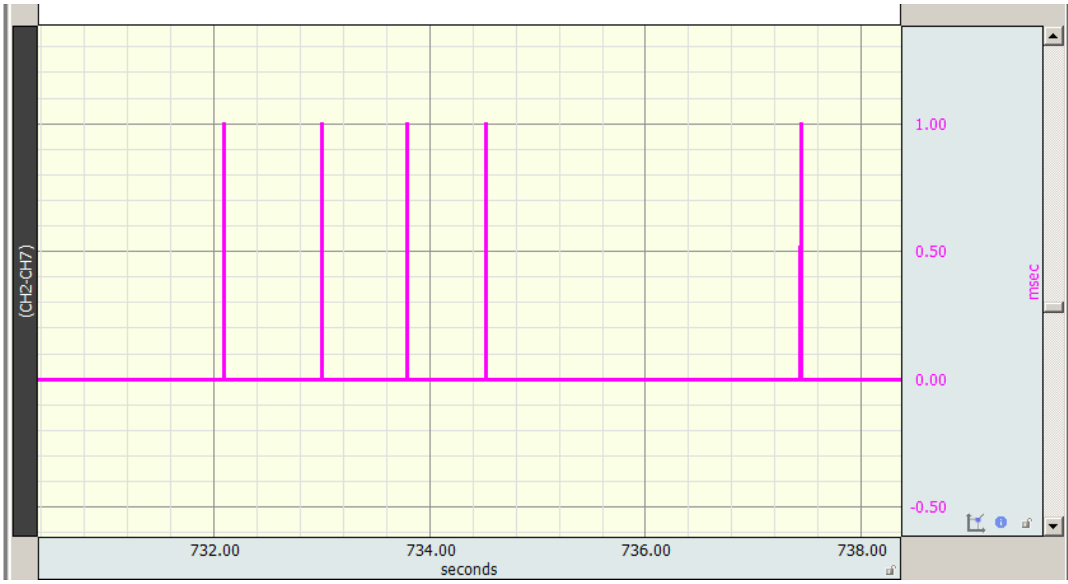
Abs of the R-R Difference waveform

3. Now apply a Threshold transform to count how many peaks are > 50 msec. **(Transform > Math Functions > Threshold)**





4. After autoscaling, a waveform showing a series of spikes with a maximum value of 1 when a threshold value exceeds 50 msec and 0 otherwise. The following image is an expansion of a region.



5. Select the **Threshold** channel
    - Set the first top row measurement for **Area**.
    - Choose **Edit > Select All**.
    - The Area measurement result will reflect the number of peaks > 50 msec.

NN50-count = Area

Area = 145.00000

Peak count after applying Area measurement

6. Set another measurement to **Delta S** to obtain the total number of samples.

Delta S = 1441 Samples

pNN50 = 145 / 1441 * 100 = 10.06 %

Application Note 129- Part 3 Heart Rate Variability

Geometric Measures

Geometric measures are most applicable to long term recordings (24 hours preferred), where any histogram of values follows a normal distribution. A comprehensive overview of the metric is provided in Guidelines: Heart Rate Variability, European Heart Journal (1996) 17, 354-381, http://eurheartj.oxfordjournals.org/content/17/3/354.full.pdf

HRV triangular index

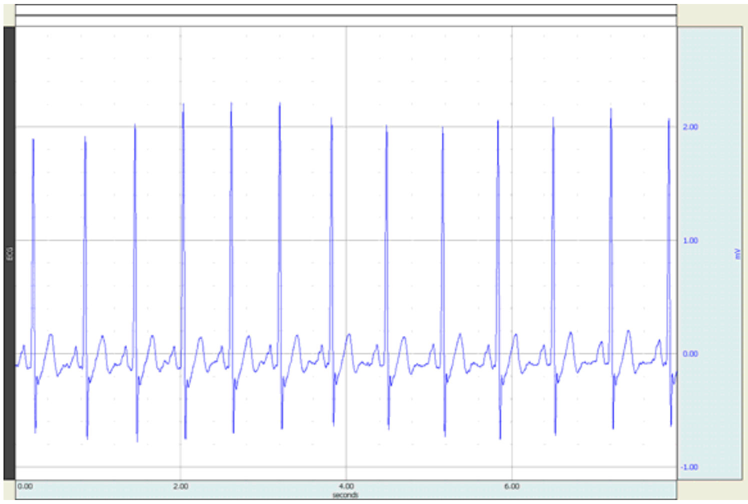
TINN – Triangular Interpolation of NN

Using a discrete scale, the measurement is approximated by:

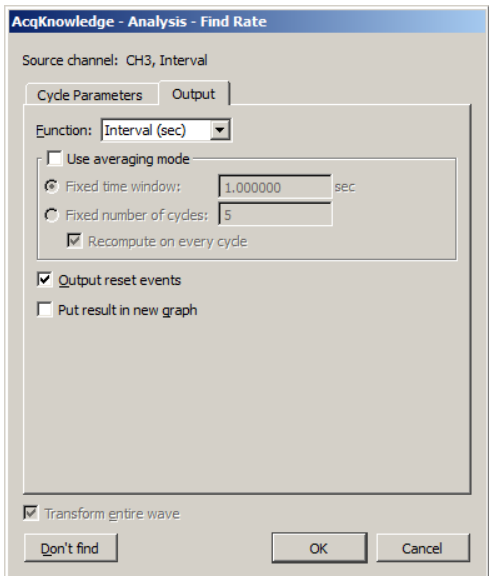
(Total number of NN intervals) / (Height of the histogram of all NN intervals using 7.8125 ms bins)

Note, most experience has been obtained with a bin length of approximately 8 ms (precisely 7.8125 ms=1/128 seconds), which corresponds to the precision of current commercial equipment (Guidelines: Heart Rate Variability). The following steps outline a procedure to determine the index.

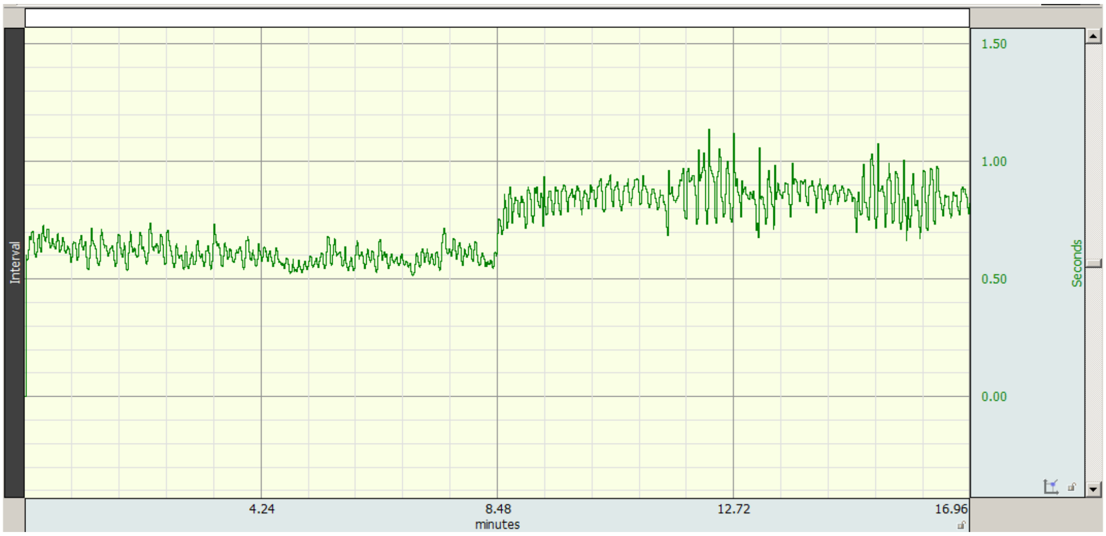
1. Obtain the ECG waveform.



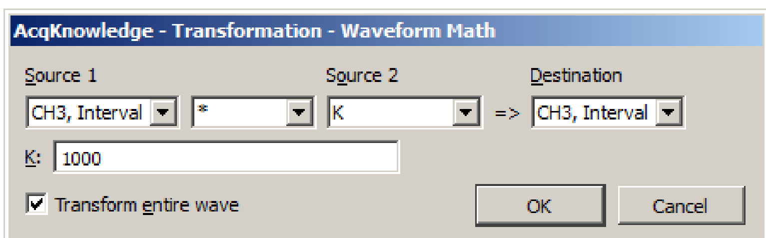
2. Duplicate this waveform in another channel and select that channel.
3. Choose **Analysis > Find Rate** and set the output function to **Interval**.
4. Click **OK** to output the R-R intervals to a new channel.



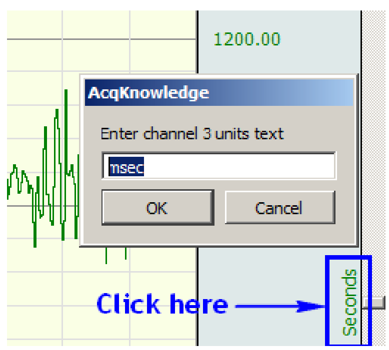
5. Autoscale and select the R-R interval channel.



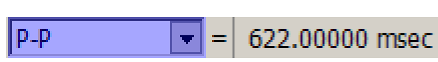
6. Convert the graph from an amplitude scale of seconds to milliseconds using **Transform > Waveform Math**.
   - Set Interval channel as Source 1 and Destination
   - Set operand to * and Source 2 to K.
   - Set K value to 1000 and click **OK**.



7. Autoscale the waveform and change scaling units to “msec”. (Click on “Seconds” label to launch units text dialog.)

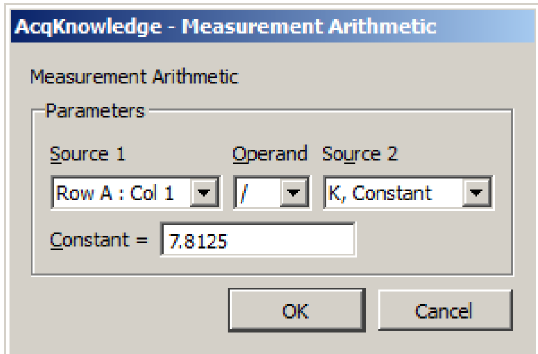


8. If the first few data points are suspected to be corrupted with artifact, use the Selection tool to highlight as many points as necessary, then remove those points from the waveform using: **Edit > Cut.**
   - Use the Zoom  tool to accurately check data quality at the start of the graph. (Zoom back after checking.)

9. Choose **Edit > Select All** to highlight the entire waveform.
   - Set a measurement for **P-P** (Peak to Peak). 

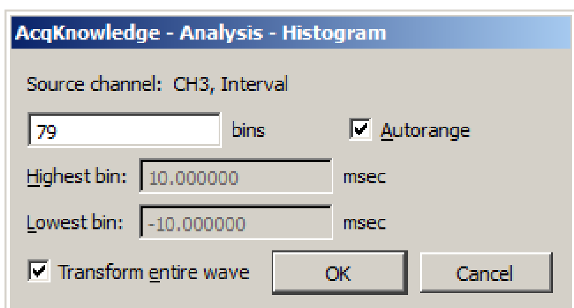
   - Set another measurement for **Samples** or **Delta S**. (Will be used for the triangular index calculation → the total number of NN intervals.)

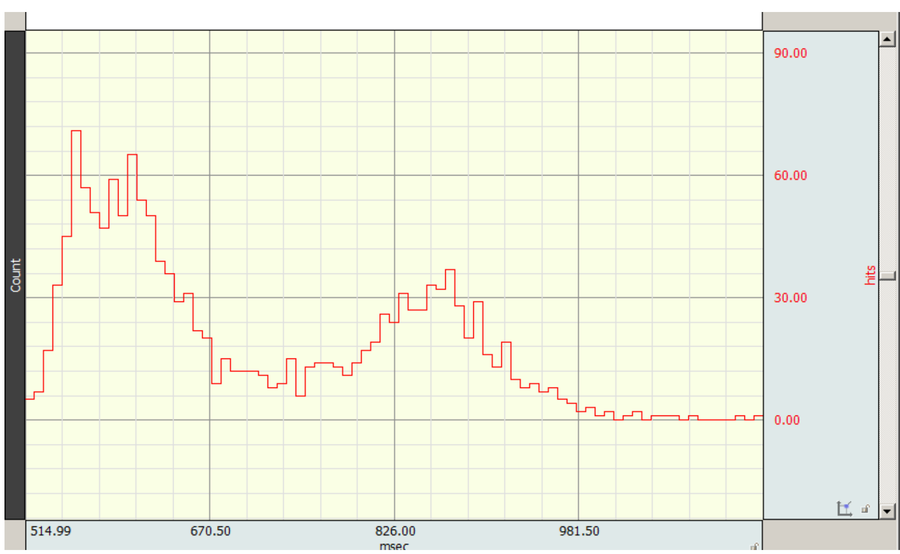
10. Set a measurement to **Calculate** and establish the following parameters:
    - Source 1 = Row A: Col 1 (or corresponding location of P-P measurement)
    - Operand = /
    - Source 2 = K, Constant
    - Constant = 7.8125
    - Click **OK**.



The Calculate value renders the number of "7.8125" msec bins for the Histogram.

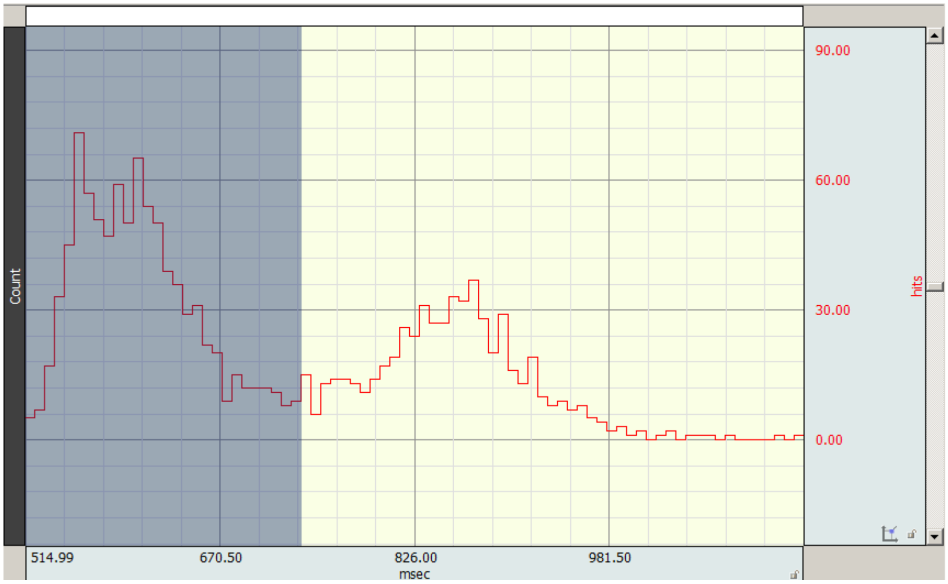
11. Choose **Analysis > Histogram**.
    - Enter the measurement value derived from **Calculate** and select "Autorange."
    - Click **OK**.





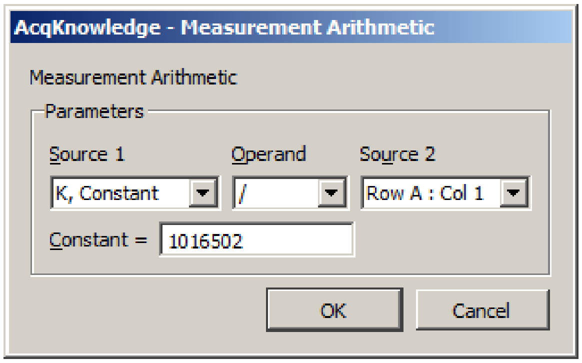
Histogram output from R-R interval example

12. Using the I-Beam tool, highlight the area between the point of initial increase on the bell curve distribution and the end of the decrease (a return to a baseline or flat-line) to encompass the curve maximum.



13. Within the **Histogram** graph:
    - Set the initial first row measurement to **Max**.
    - Set another measurement to **Calculate**.

14. For **Calculate**, set the following parameters:
    - Source 1 = K, Constant
    - Operand = /
    - Source 2 = Row A: Col 1 (or corresponding location of **Max** measurement).
    - Constant = Samples or Delta S value from source graph (= 1016502).



(Total number of NN intervals) / (Height of the histogram of all NN intervals using 7.8125 ms bins)

Triangular index = 1016502 / 40002 = 25.41