APPLICATION NOTE

Application Note 120   X/Y Loop Area Analysis

Pressure/volume loops (PV Loops) measure blood pressure and flow from a catheterized system. This automated analysis tool (available as a licensed feature in Acq*Knowledge* 5 and higher) extracts various measures of heart function, including contractility, elasticity and ventricular characteristics.

For earlier versions of Acq*Knowledge* that don't support the PV Loop analysis licensed feature, or for users who lack this feature, the following application note details how to calculate PV Loops using standard Acq*Knowledge* tools.

Area calculation of X/Y loops are commonly required for a variety of physiological investigations. Significant among these is the pressure/volume relationship manifest in hemodynamic and pulmonary measurements. In these cases, the area of the pressure/volume loop increases in proportion to the power exerted or work performed.

For quick determination of work performed the loop display offers an immediate visual advantage over the conventional time domain presentation of the pressure and volume data. One can more easily see if the work performed has increased or decreased by simply visually inspecting the loop size.

Although the P/V loop display is a valuable investigative tool, accurate quantification of the loop size is difficult to determine visually. By using the pressure and volume data in it's fundamental form, it's easier to make precise loop area or power measurements.

This application note covers a method by which P/V loop area can be calculated in real-time using Acq*Knowledge*. The following graph shows idealized pressure and volume signals displayed in an X/Y mode.

As can be seen from the plot, the pressure/volume relationship may typically appear as a series of somewhat concentric loops. The loops often have rapidly changing shapes and areas.
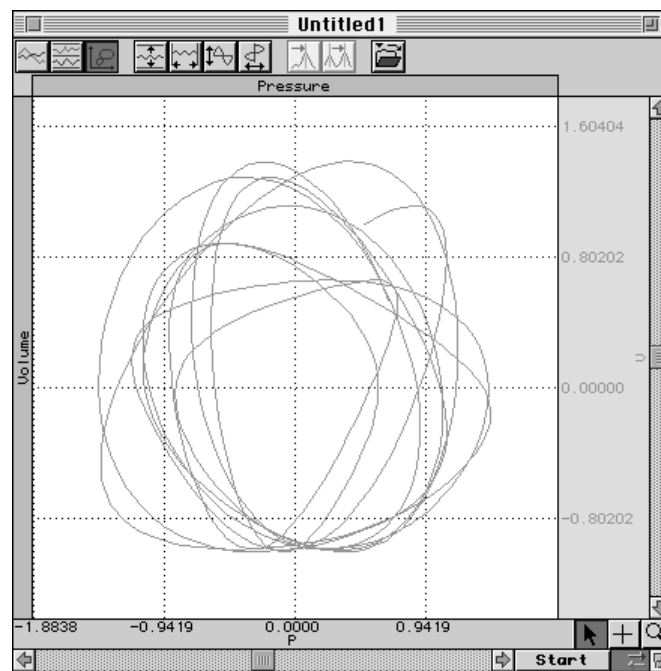
Pressure versus Volume Loops

In the above graph, the P/V loop has been displayed for approximately 9 cycles in X/Y mode. The pressure appears as the X axis and volume appears as the Y axis. This same data can be displayed as a function of time as well. In this later case, both the pressure and volume signals would appear as separate graphs each varying as a function of time.

Acq*Knowledge* provides a mechanism by which the areas of these loops can be calculated in post-processing (after the data is collected) or real-time (during the data collection).

The following illustrates the sequence of waveform calculations required to determine P/V loop area in real-time.

- The first wave is the idealized pressure signal - (A0)

- The second wave is the idealized volume signal - (A1)

- The third wave performs a derivative calculation on the pressure signal - (C0)

- The fourth wave performs a summation calculation on the volume signal - (C1)

- The fifth wave multiplies the derivative signal by the summation signal - (C2)

- The last wave determines the cycle by cycle integral of the fifth wave - (C3)

The first and the second waves are simply acquired into Acq*Knowledge* using the MP1xx. The pressure signal typically comes from a pressure transducer connected to the DA100C differential amplifier. The volume signal can be derived by integrating a flow signal, but it can also be directly acquired via a linear displacement transducer or equivalent.

The third wave is the derivative of the pressure signal. The DIFFERENCE function under Setup CALC channels is used to calculate the derivative in real-time. The number of points over which the difference is performed is "1."
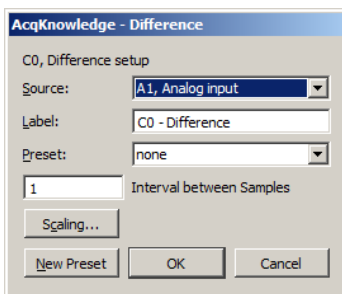
The math equivalent is: $P(n+1) - P(n)$: where "n" is the sample number.

The fourth wave performs an ongoing summation of two adjacent volume points. The INTEGRATE function under Setup CALC channels is used to calculate the summation in real-time. The number of points over which the summation is performed is "2." In this case, it is also necessary to scale the output from the INTEGRATE function. Adjust the numbers in the Scaling dialog so the mapping numbers are scaled up by [Sample Rate/2].
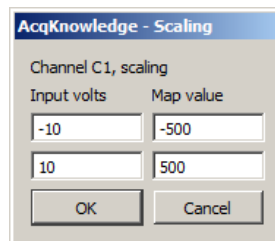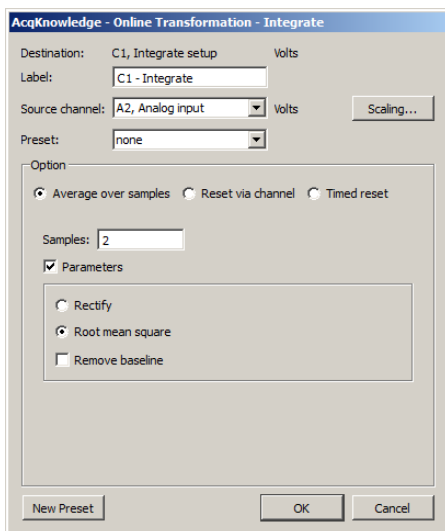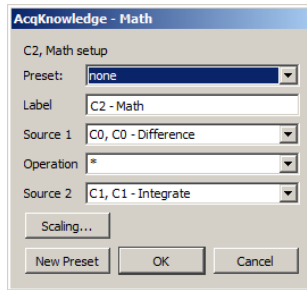

Data for this example was sampled at 100 Hz (100/2 = 50), so the INTEGRATE scaling needs to be adjusted as shown above.

- -10 volts needs to map to: -10 x 50 = -500

- +10 volts needs to map to: 10 x 50 = 500

The math equivalent is: $[V(n+1) + V(n)]/2$: where "n" is the sample number.

The fifth wave multiplies the derivative and summation channels together:

The math equivalent is: $[P(n+1) - P(n)] \times [V(n+1) + V(n)]/2$: where "n" is the sample number.

The sixth wave performs an area calculation on the fifth wave. This last wave provides a cycle by cycle measurement of the pressure/volume loop area in real-time. In effect, this wave provides a cycle by cycle update of work performed.
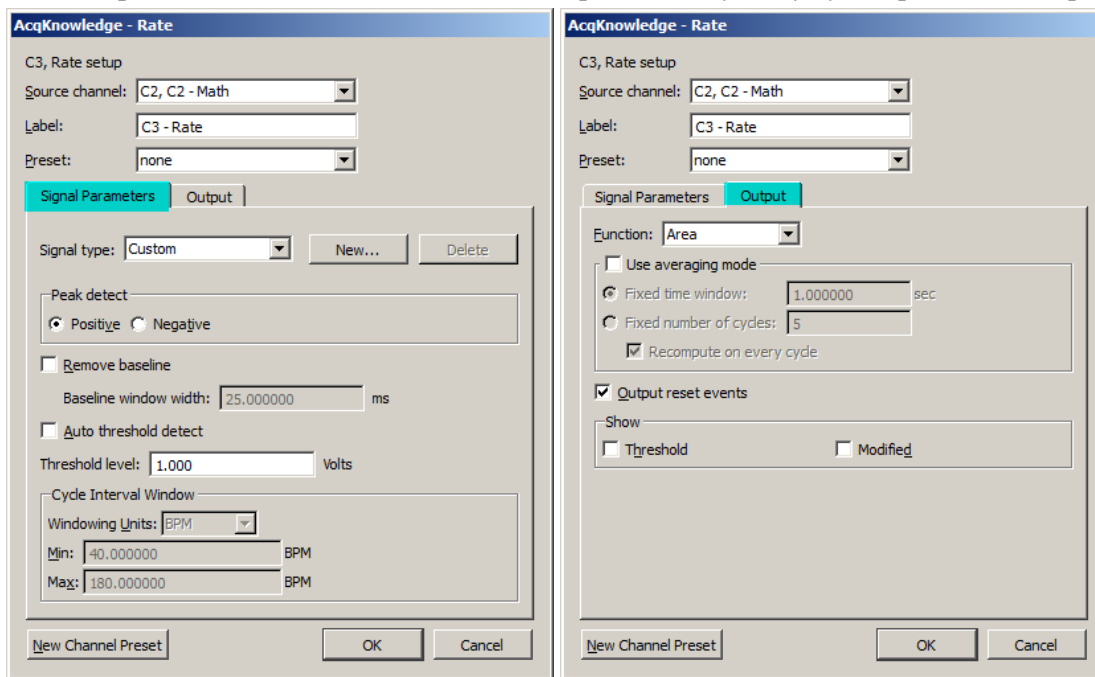
**Rate Setup for Sixth Wave (Signal Parameters and Output tabs)**

The math equivalent is: $\sum [P(n+1) - P(n)] \bullet [V(n+1) + V(n)]/2$.

When all waves are displayed the results appear as follows. The last wave (P/V Loop Area) can simultaneously be displayed as a Bar Graph via the INPUT VALUES function under the Acq*Knowledge* MP menu. In this fashion, the bar graph height would constantly update and be directly proportional to the work performed on a cycle by cycle basis.
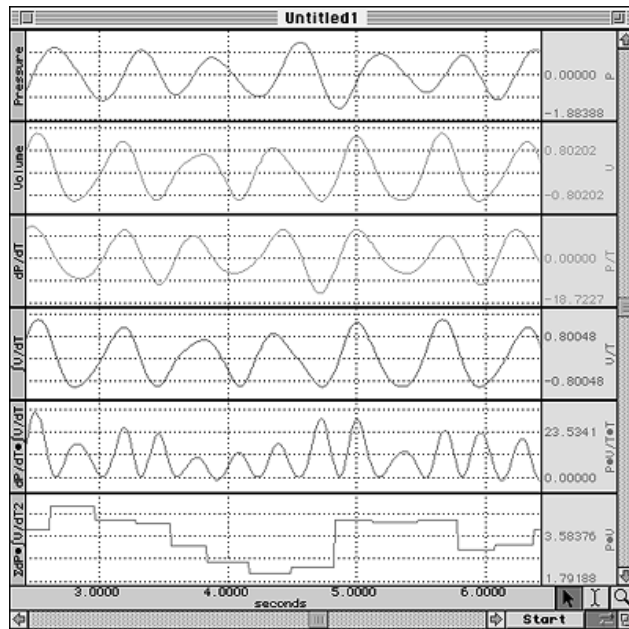
Pressure / Volume Loop Area Calculated in Real-Time

The intermediate calculations don't have to be displayed for the calculation to take place. Usually, just the three relevant waves would be displayed namely, Pressure, Volume, and P/V Loop Area (Work).
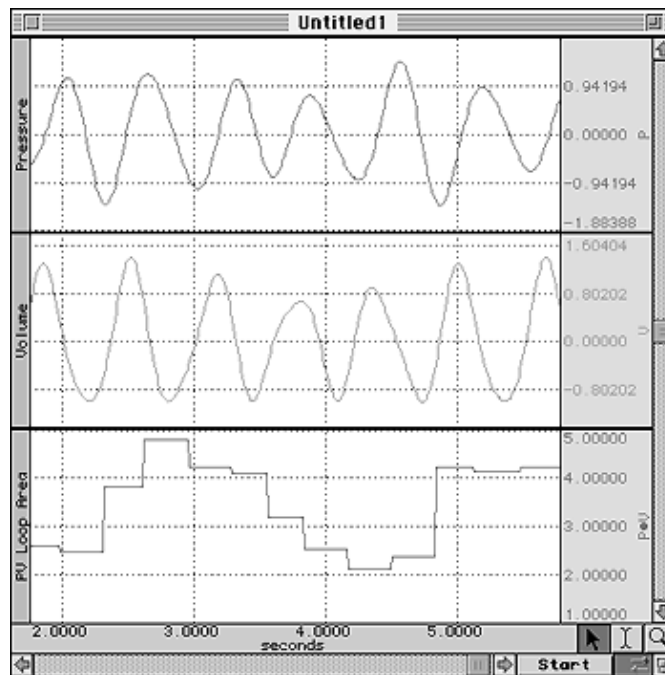
Simplified Real-Time P/V Loop Area Display