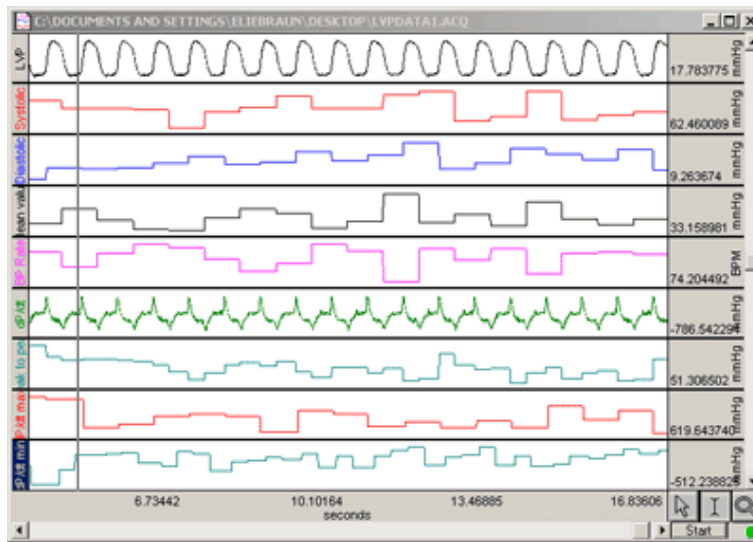# APPLICATION NOTE

Application Note 115:   Hemodynamic Measurements

Raw BP and Eight Hemodynamic Measurements Displayed in Real Time

In addition to basic blood pressure measurements such as Systolic, Diastolic, Mean and Rate, Acq*Knowledge* supports the extraction of a number of hemodynamic measurements. These measurements can be performed during acquisition (on-line) or post-acquisition (off-line).

Note that in Acq*Knowledge* versions 4.1 and higher, post-acquisition hemodynamic analysis can be easily performed by selecting the Analysis menu > Hemodynamics option and applying any of the various hermodynamic analysis routines.

If using BSL *PRO* with MP36 hardware, or to manually extract hemodynamic measurements in Acq*Knowledge*, refer to the following procedure.

The following eight parameters can be extracted from one arterial pressure input signal.

- Systolic Blood Pressure
- Diastolic Blood Pressure
- Mean Blood Pressure
- Heart Rate (in BPM)
- Derivative of Raw Blood Pressure (dP/dt)
- Diastolic to Systolic Delta Pressure (Pk-Pk)
- Maximum of dP/dt
- Minimum of dP/dt

Of these measurements, the following are "cyclical" in nature, which means that measurements are performed on a beat-by-beat basis and are thus updated every time the raw blood pressure repeats a cycle.

- o Systolic Pressure
- o Diastolic Pressure
- o Pk-Pk blood pressure (Systolic-Diastolic)
- o dP/dt maximum
- o dP/dt minimum

SETUP

Equipment:

Data acquisition unit - MP100, MP150 or MP36(R)

Universal Amplifier - UIM100C (MP100 or MP150)

General-purpose Transducer Amplifier - DA100C (MP150)

Precision Pressure Transducer - TSD104A (MP150) or SS13L (MP36/36R)

Subject:

The arterial pressure signal is typically obtained via a pressure transducer invasively attached to an artery.

For MP150 Hardware:

1. Connect the pressure transducer (TSD104A) directly to the general-purpose transducer amplifier (DA100C).
2. Connect the DA100C output to the UIM100C unit.
3. Set switch on top of DA100C to Channel 1.
4. Set the 300 Hz low pass filter to ON.
5. Set the low pass filter on the DA100C to 10 Hz.
6. Set the high pass filter to 0.05 Hz.

For MP36/36R Hardware

Connect the SS13L pressure transducer to CH1 of the MP36 or MP36R unit.

Software:

Acquisition Setup: MP menu > Set Up Data Acquisition > Length/Rate
For the purposes of this application note, we will assume the raw BP signal used an acquisition sample rate of 2000 samples/second.

Channel Setup: MP menu > Set Up Data Acquisition > Channels

- *Analog*: Establish the raw BP signal from the pressure transducer input on CH A1
- *Calculation*: Complete channel setup as described below for real-time calculations.
- *Off-line*: Complete channel setup as described below for post-acquisition transformations.

Calibration MP150 hardware:
It's important to verify the pressure transducer calibration. The transducer can be calibrated using a blood pressure cuff or other device with known values.

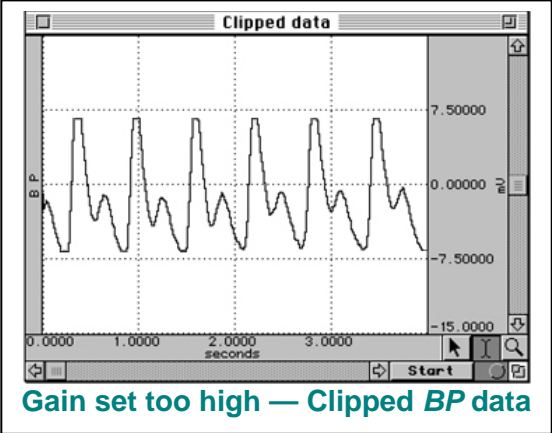To calibrate the pressure transducer in Acq*Knowledge* versions 4.1 and higher:

1. MP150 menu > Set Up Data Acquisition > Channels and choose "View by Modules."
2. Choose "Add New Module," select "DA100C" from the module list and click "Add."
3. Select "CH1" in the subsequent "Choose Channel" dialog and click OK.
4. Set the hardware settings in the subsequent prompt to match those of the DA100C physical settings described above in "Hardware."
5. Choose "TSD104A Blood Pressure" from the "Connected to" menu and click OK.
6. Follow the onscreen calibration prompt.

Calibration MP36R/36 hardware:

Calibrating a blood pressure transducer is a two step process. The first step involves finding the optimal gain setting for the transducer and the second step is the actual calibration.

To find the optimal gain setting:

1. Start with the software Presets (in this case, a gain of 1000)

- To set the Presets: **MP3X** menu > **Set Up Data Acquisition** > **Channels** > **Analog Presets** > select "**Blood Pressure (Arterial)**"

2. Bring the transducer to the approximate maximum and minimum expected pressures.

3. Collect data for a few seconds at these settings.

4. Inspect the sample data; look for data that is "railed" or "clipped." This occurs when the input signal (times the gain setting) is too large relative to the maximum input range. An example of clipped data is shown at right.

5. If the signal is clipped, decrease the gain setting by one step (e.g., from x5000 to x2000) and collect new data at the lower gain setting.

Gain set too high — Clipped *BP* data

- To access the Gain setting: **MP3X** menu **> SetUp Data Acquisition > Channels** > **Blood Pressure (Arterial)** preset channel > **Setup** button > **Gain** pull-down menu

6. Repeat this procedure until the signal no longer appears "clipped."

Once an optimal gain setting for the transducer has been established, this same gain setting can be used for other similar transducers and similar measurements.

The next step is to actually calibrate the transducer, which means mapping the input signal to more meaningful units (such as mmHg). To do this:

1. Access the Channel scaling dialog box (**MP3X** menu > **Set Up Data Acquisition** > **Channels > Blood Pressure (Arterial)** Preset channel > **Setup** button > **Scaling** button).
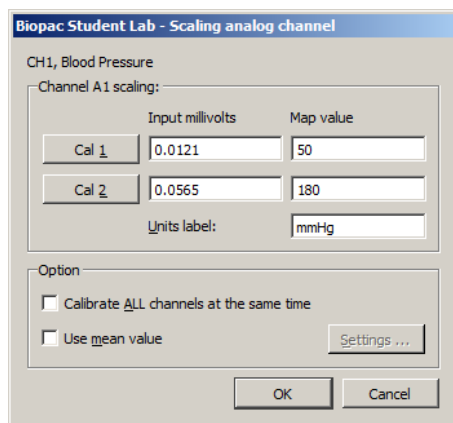
Note:
In this sample dialog, the transducer was brought to a pressure of 50 mmHg before clicking Cal 1.
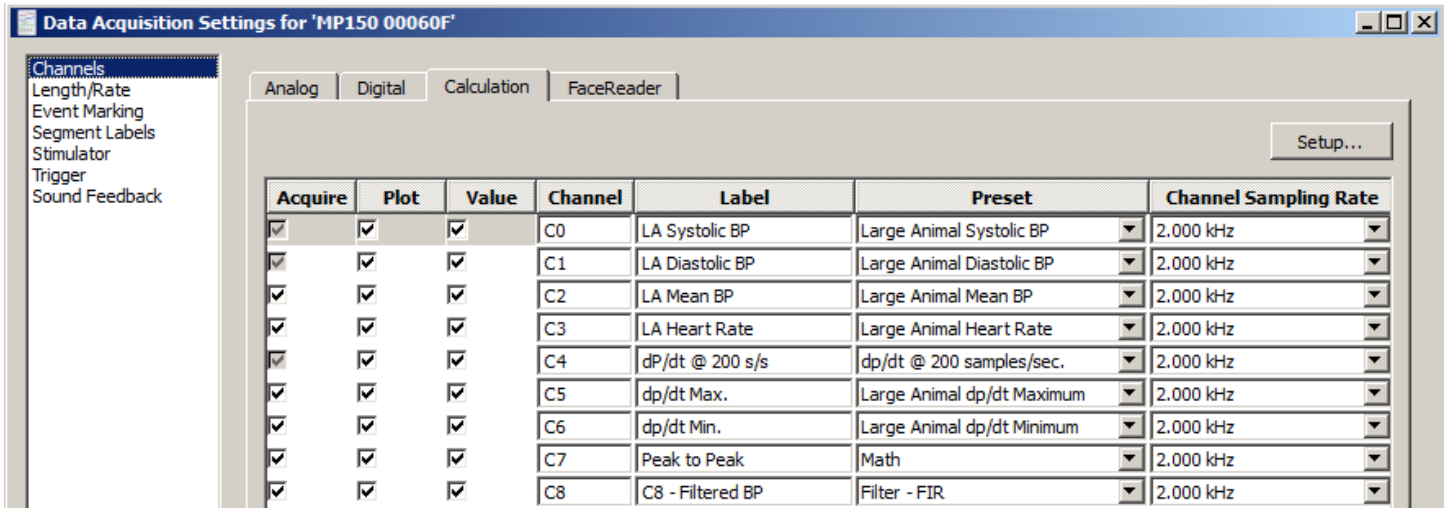The transducer was then brought to a pressure of 180 mmHg before clicking Cal 2.

2. Bring the transducer to the lowest expected pressure.

3. Click the Cal 1 button in the Channel scaling window.

4. A voltage value will be automatically entered in the corresponding Input value box.

5. Bring the transducer to the highest expected pressure.

6. Click the Cal 2 button in the same scaling window.

- A voltage value will be automatically entered in the corresponding **Input value** box.

The software will now interpolate between these two calibration points to give accurate measurements in mmHg.
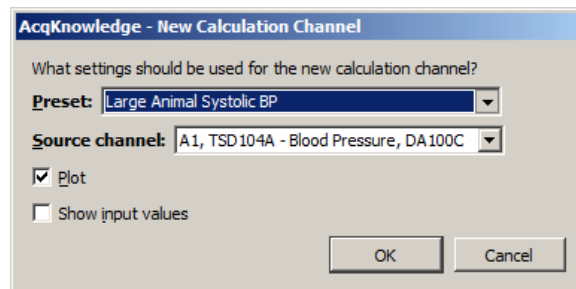
REAL-TIME CALCULATIONS

- To obtain these hemodynamic parameters in real time, set up five **Calculation channels** (C0-C4) with the raw BP signal as input and three **Calculation channels** (C5-C7) that extract data from previous calculation channels as input. If the raw BP signal has a lot of noise, then it may be a good idea to filter it and use the filtered BP signal as input.

1. **Systolic Pressure - Calculation Channel C0**
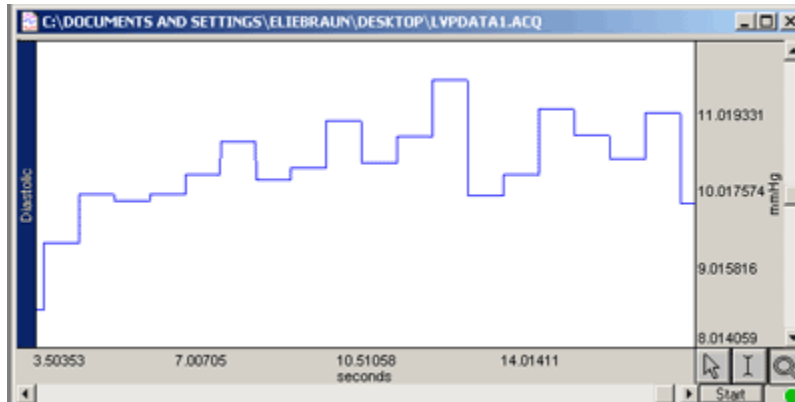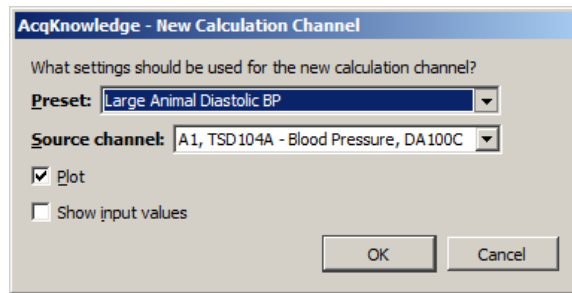   Choose Preset: "Large Animal Systolic BP;" Source: A1 Raw BP signal.

Note: These settings assume the measurements are being done on Large Animals, but there are equivalent Presets for Small Animals.
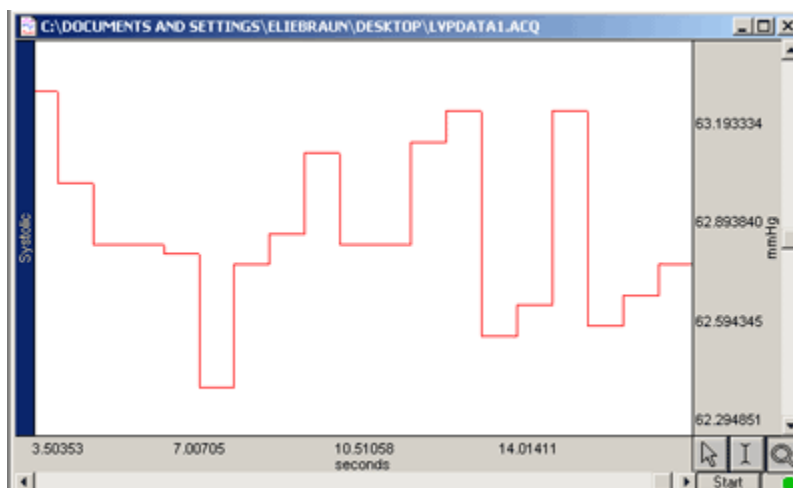
Systolic Pressure

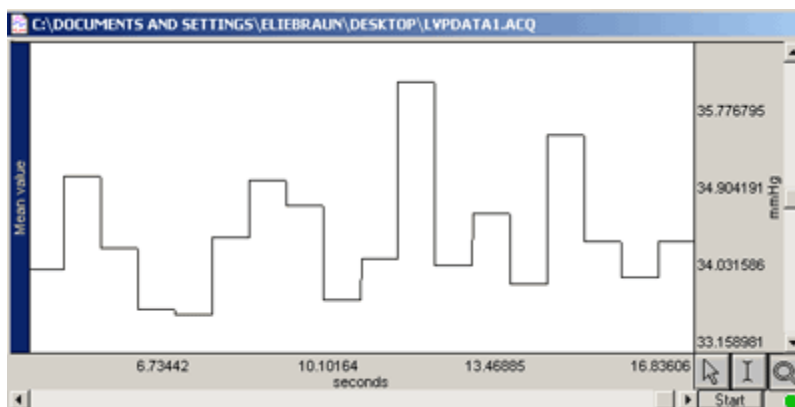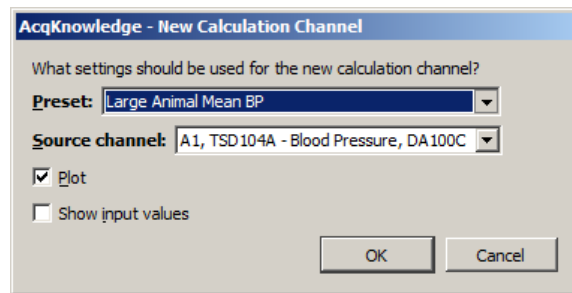2. **Diastolic Pressure - Calculation Channel C1**
   Preset: "Large Animal Diastolic BP;" Source: A1 Raw BP signal.

Diastolic Pressure
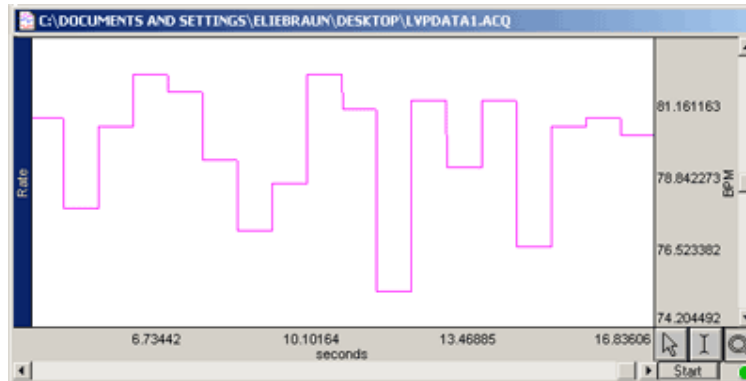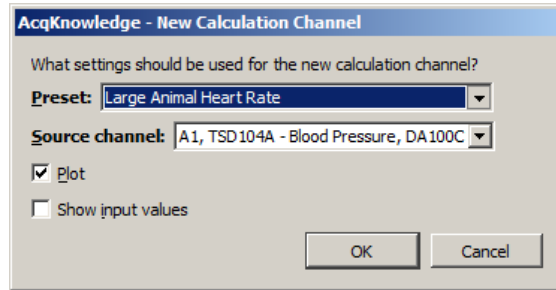
3. **Mean Pressure - Calculation Channel C2**
   Preset: Large Animal Mean BP; Source: A1 Raw BP signal.

Mean Pressure

4. **Blood Pressure Rate - Calculation Channel C3**
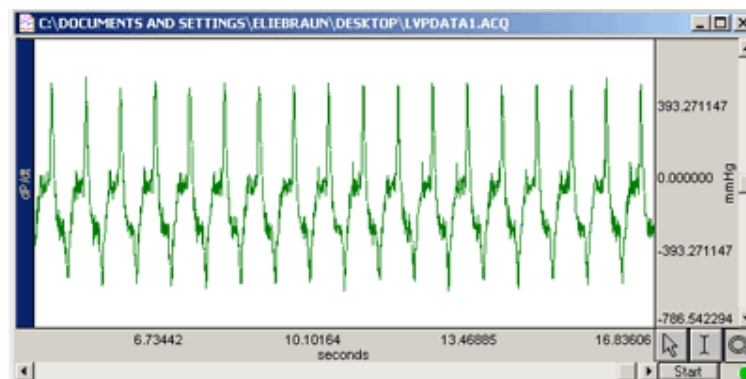   Preset: Large Animal Heart Rate; Source: Raw BP signal.

Blood Pressure Rate

5. **Derivative of Blood Pressure - Calculation Channel C4**
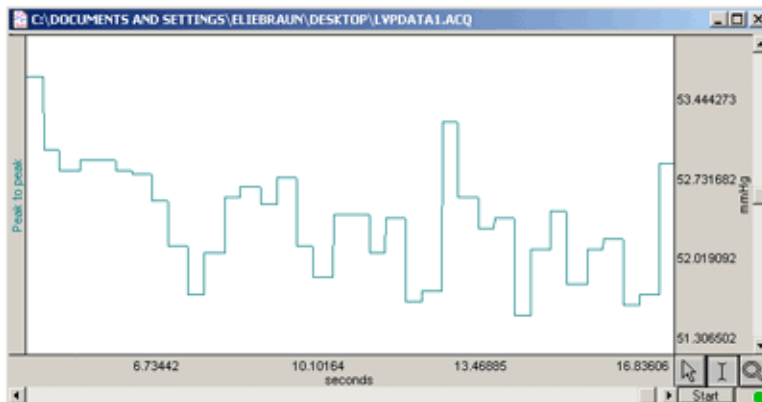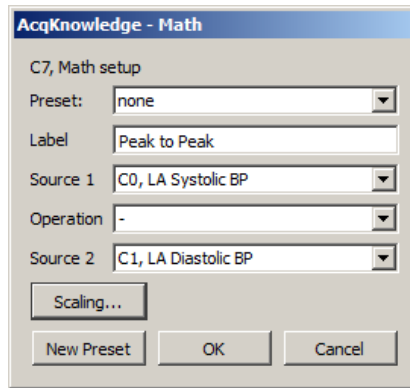   Preset: dp/dt; Source: Raw BP signal; Interval: 1 interval; Units: mmHg/sec.

   - In this case, the derivative of the raw blood pressure signal will be calculated on a point-to-point basis.

dP/dt Derivative of Blood Pressure

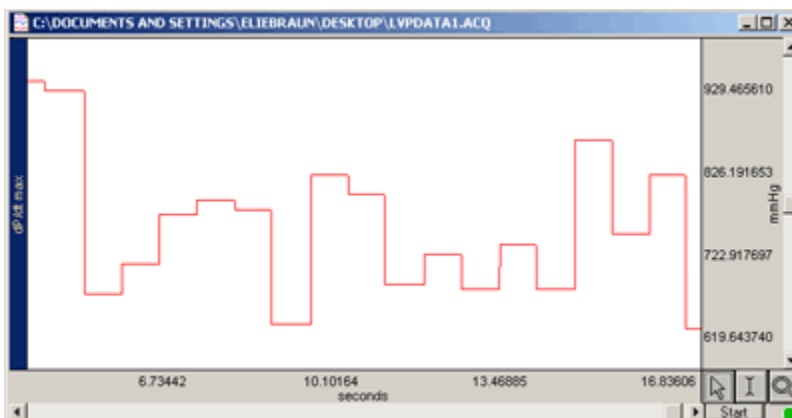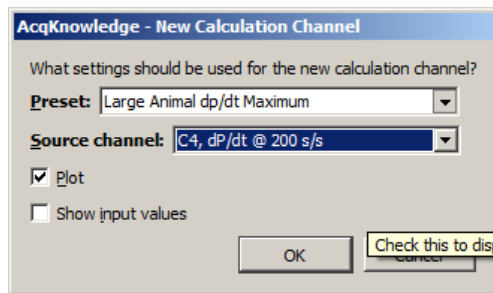6. **Pk-Pk Pressure - Calculation Channel C7**
   Preset: New > Math; Setup: Channel Preset: Pk-Pk; Source 1: Systolic (C0); Source 2: Diastolic (C1); Operand: Subtraction

Pk-Pk Pressure

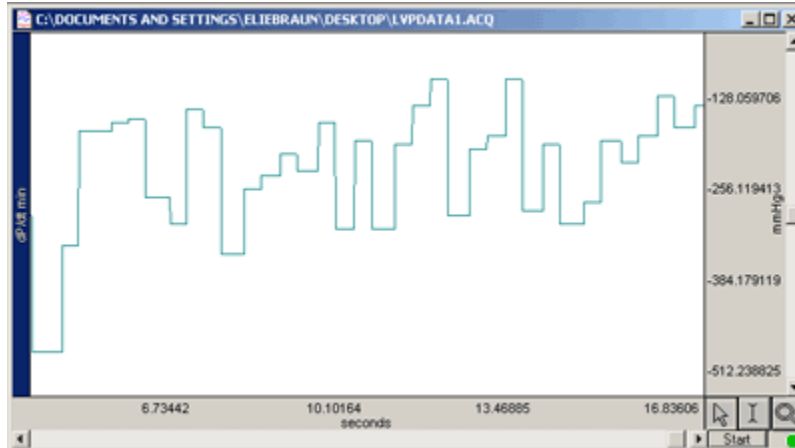7. **dP/dt Maximum - Calculation Channel C5**
   Preset: Large Animal dp/dt Max; Source: Derivative of the blood pressure channel (C4);

dP/dt Maximum

8. **dP/dt Minimum - Calculation Channel C6**
   Preset: Large Animal dp/dt Min; Source: Derivative of the blood pressure channel (C4);
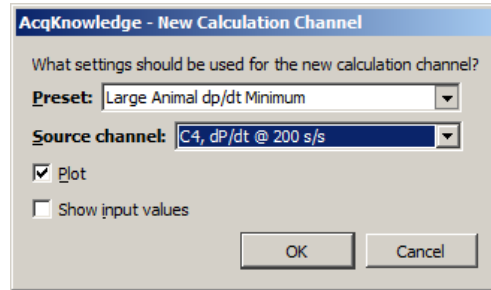
dP/dt Minimum

9. **Filtering - Calculation Channel C8** *Optional*
   Preset: Filter; Source: Raw BP input; Type: Low pass filter;
   Cut-off: somewhere in the range of 5 to 10 Hz. You may want to change the label to "Filtered BP."

   To use the output from this low pass filter calculation channel as the input for the Hemodynamic parameter channels, change the Source from CH 1 Raw BP to CH 8 Filtered BP.

When collecting data with this real-time setup, the graph data should resemble this example:

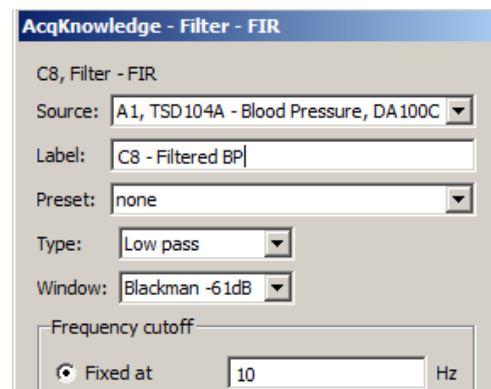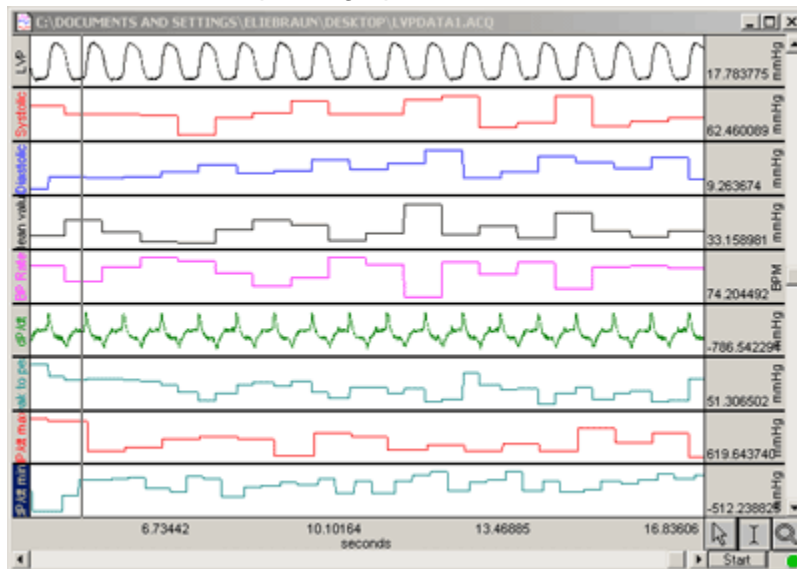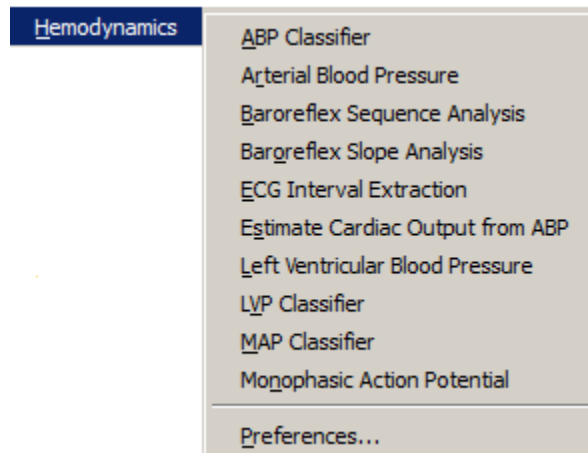**Raw BP and Eight Hemodynamic Measurements
Displayed in Real Time**

Off-Line Calculations

In Acq*Knowledge* versions 4.1 and higher, post-acquisition hemodynamic analysis can be easily performed by selecting the Analysis menu > Hemodynamics option and applying any of the following hemodynamic analysis routines.

To manually calculate hemodynamic parameters after data is collected, use the following tools under the **Transform** and **Analysis** menus in lieu of online calculation channels.

1. **Systolic Blood Pressure: Analysis > Find Rate** (see guidelines)
   Choose Function: Max

2. **Diastolic Blood Pressure: Analysis > Find Rate** (see guidelines)
   Choose Function: Min

3. **Diastolic to Systolic Delta Press: Transform > Waveform Math**
   Calculate the Pk-Pk pressure (Systolic-Diastolic); subtract the Diastolic channel from the Systolic channel, and place the result in a new channel.

4. **Mean Blood Pressure: Transform > Smoothing**
   Calculate the Blood Pressure Mean over a 5 second period.

5. **Derivative of Raw BP (dP/dt): Transform > Difference**
   a. The Difference transformation will overwrite the data, so it's advisable to duplicate the original blood pressure waveform by selecting the original waveform and choosing Edit > Duplicate.

b. Select the duplicate waveform and choose Transform > Difference, and set the interval to one (1).

6. **dP/dt Maximum: Analysis > Find Rate** (see guidelines)
Choose Function: Max

7. **dP/dt Minimum: Analysis >Find Rate** (see guidelines)
Choose Function: Min

8. **Heart Rate (BPM): Analysis > Find Rate** (see guidelines)
Choose Function: Rate (BPM)

9. *Optional* **Filtering: Transform>Smoothing**

a. The Smoothing transformation will overwrite the data, so duplicate the original blood pressure waveform by clicking in the original and choosing Edit>Duplicate.

b. Select the duplicate waveform and choose Transform>Smoothing, and then set the number of points to five (5).

c. To use the smoothed data as input to the Rate transformations, change the Source from A1 Raw BP to C9 Filtered BP.

Rate Guidelines

Usually, the default parameters for the **Rate** function work quite well to calculate the desired hemodynamic parameter. If you experience difficulty in getting accurate results, try changing the default parameters for the **Rate** function.

-   To insure that the correct settings are used in the **Rate** window, visually inspect the waveform prior to processing.

-   Establish that the BPM Min/Max settings are correct.

    These Min/Max settings tell the **Rate** function what range the actual signal BPM falls into. The closer these values are to the true BPM range, the better the **Rate** detector will work. Naturally, if you estimate a little high or low, that's OK, but try to create the approximate range.

-   **Remove Baseline** and **Auto-Threshold Detect**

    These options help the **Rate** function track a signal with a moving baseline. Keep these options clicked ON.

-   **Noise Rejection**

    A setting of about 5% works well for your typical raw BP signal.