BLOOD PRESSURE SENSOR
0377i

USER'S GUIDE

CENTRE FOR MICROCOMPUTER APPLICATIONS

http://www.cma-science.nl

Short description

The Blood Pressure sensor 0377i is used to measure arterial blood pressure in humans (non-invasively). It measures the pressure signal caused by the interaction between the cuff and the blood flow through the brachial artery.
The pressure sensor uses the SenSym SDX05D4 pressure transducer. This element has a membrane that flexes as pressure changes. It is arranged to measure differential pressure. The sensor produces an output voltage that varies in a linear way with pressure. Special circuitry minimizes the errors that might be caused by changes in temperature. The sensor is delivered with standard adult size adjustable cuff (27 cm to 39 cm) and bulb pump (with release valve).
The Blood Pressure sensor can be directly connected to the analog BT inputs of the CMA interfaces.

Important: *The Blood Pressure sensor is not appropriate for medical applications. This sensor is to be used only for educational purposes. Read this manual before you start measurements with the sensor. Notice that over inflation of the cuff may cause pain and/or injury.*

Sensor recognition

The Blood Pressure 0377i has a memory chip (EEPROM) with information about the sensor: its name, measured quantity, unit and calibration. Through a simple protocol this information is read by the CMA interfaces and the sensor is automatically recognized when it is connected to these interfaces. If your Blood Pressure sensor is not automatically detected by an interface you have to manually set up your sensor by selecting it from the Coach Sensor Library.

Calibration

The Blood Pressure sensor is supplied calibrated. The output of the Blood Pressure sensor is linear with respect to pressure. The calibration function is:

$$p\ (\text{mm Hg}) = 64.94 * V_{out}(\text{V}).$$

The Coach software allows selecting the calibration supplied by the sensor memory (EEPROM) or the calibration stored in the Coach Sensor Library. For better accuracy the pre-defined calibration can be shifted.

About blood pressure

During each heart beat the arterial blood pressure varies between two utmost values: the systolic and the diastolic pressure. The peak pressure in the arteries is the systolic pressure and the lowest pressure is the diastolic pressure. In between these is the Mean Arterial Pressure (MAP),which is used to describe the average blood pressure.

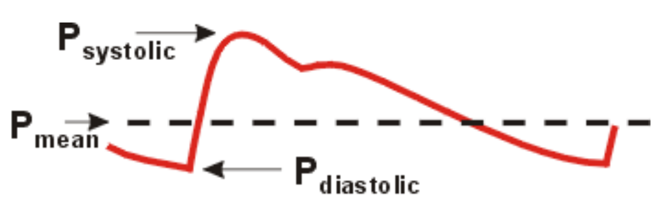

Figure 2. Pressure course of the heart beat in the brachial artery.

Oscillometric Method

The blood pressure sensor can be used to determine blood pressure via the so-called oscillometric method. With this method, which is non-invasive, a cuff is placed around the arm and inflated by means of a pump, after which the cuff deflates via an automatic valve. The sensor measures the cuff pressure. This pressure varies because of the blood flow in the brachial artery.

With inflation of the cuff, the external pressure on the artery rises, and hence the artery is increasingly compressed. At pressures exceeding the systolic blood pressure, the artery will be occluded. There are weak pressure pulses against the cuff in the rhythm of the heart beat which shows as small peaks in the graph.

When the cuff is slowly deflated, the cuff pressure, and hence the external pressure on the artery will be lowered to that of the systolic blood pressure. Now, the artery is no longer continuously occluded. At systolic blood pressure, small amounts of blood pass through the compressed artery segment and cause changes in the artery volume, conducted to the cuff. This leads to pressure oscillations in the cuff. These oscillations increase with lower cuff pressure values, as more blood passes through the compressed artery. The maximum oscillation amplitude is reached around the mean arterial blood pressure. Then, as the pressure decreases until the cuff becomes fully deflated, the blood flow returns to normal and the oscillation amplitude decreases in the cuff decreases and small pulses remain at a low level below diastolic pressure.

The point at which the largest oscillations are occurring corresponds to the mean arterial pressure (MAP). The point above the mean pressure at which the pressure difference grows rapidly correlates to the systolic pressure. The point below the mean pressure where the differences start to get small corresponds to the diastolic pressure.

A similar method is used during the regular blood pressure measurement, a clinician, using the stethoscope, listens at the brachial artery for characteristics sounds of the pressure pulses (so-called Korotkoff sounds).

Measurements with the Blood Pressure sensor

When performing blood pressure measurements, it is best to work with a partner.

1. Connect the Blood Pressure sensor to your interface. Attach the rubber hose from the cuff to the connector on the sensor.
2. Wrap the cuff firmly around your partner’s arm, approximately 2 cm above the elbow. The two rubber hoses from the cuff should be positioned over the bicep muscle (brachial artery) and not under the arm.
   Important: *The person having his or her blood pressure measured must remain still during data collection—no movement of the arm or hand during measurements.*
3. Start your measurement in the Coach program.
4. Quickly and repeatedly squeeze the bulb to inflate the cuff on your partner’s arm. Continue inflating the cuff to a pressure between 150 and 170 mm Hg. The measured by the sensor value is displayed on the sensor icon in Coach. When the maximum pressure is reached, set the bulb pump down onto the table. The built-in pressure release valve will slowly deflate the cuff.

5. After the pressure drops to 50 mm Hg, press down on the pressure release valve to release any air left in the cuff. If the pressure does not reach 50 mm Hg by the time data collection ends, adjust the exhaust rate of the pressure release valve.

Adjusting the Pressure Release Valve

The pressure release valve is set to release at a rate of 3.0 mm Hg/second on an arm of 32 cm in circumference. For arms much larger or much smaller it may be necessary to adjust the valve so that the exhaust rate stays in the range of 2.0–4.0 mm Hg/s. With the bulb in hand and the hose leading away from you, place a screwdriver into the metal slot on the top of the release valve. To increase the rate of exhaust, turn the screwdriver clockwise. To decrease the rate of exhaust, turn the screwdriver counter-clockwise. The larger a subject's arm the slower the release valve will exhaust.

Helpful Tips

Blood pressure readings will differ from person to person and even between measurements on the same individual. Do not expect to receive the same measurements each trial since there are many factors that cause a person's blood pressure to increase or decrease. Use the following tips to take accurate measurements.

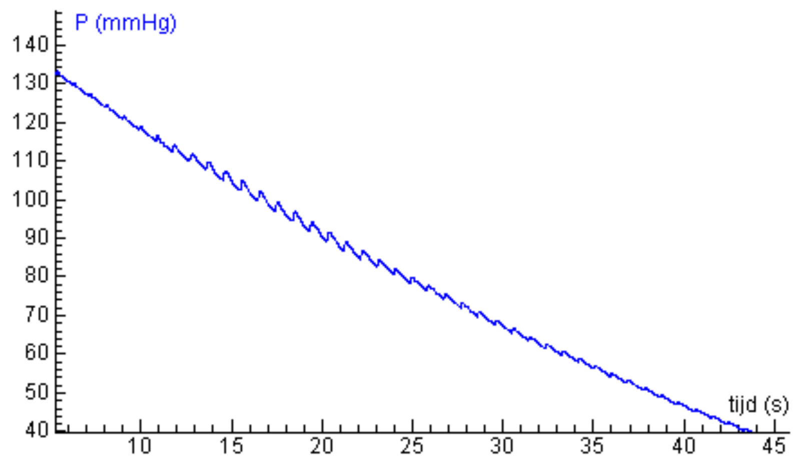

Figure 3. A typical measurement with the Blood Pressure sensor. The cuff is slowly deflated and arterial blood pressure pulses are detected.

- The subject's arm and hand must remain still during measurements (hand open – no fist!).
- The arm should be at heart level and is best supported.
- Proper placement of the pressure cuff will increase the accuracy of your blood pressure measurements. The rubber hoses from the cuff should exit over the brachial artery and 2 cm above the crease in the elbow.
- Remove any clothing that may cover or constrict the portion of the arm being measured.
- For most individuals it is not necessary to inflate the pressure cuff higher than 170 mm Hg. ***Over inflation of the cuff may cause pain and/or injury***.
- If the pressure release valve is exhausting slower or faster than 2.0–4.0 mm Hg /s, then adjust the exhaust rate of the pressure valve.
- There should be at least 10 minutes break between two measurements on the same individual.

- The blood pressure increases with the age. The rule of thumb for the normal systolic pressure is the formula 100 + age.
- Blood pressure values are rounded to 5 mmHg.

Calculating the blood pressure in the Coach software

The blood pressure cannot be read directly from the measurement graph. A detailed description of the data processing is given in this chapter.

The result of the measurement with the Blood pressure sensor is a pressure - time graph in which the pressure pulses of the blood are superposed on the decaying trend pressure of the cuff. The pressure pulses, when extracted from the cuff pressure, form an oscillating waveform. The peak-to-peak amplitudes of this waveform create a bell shaped “envelope curve” vs. pressure. Within the envelope, the pulse amplitudes increase through the systolic blood pressure and continue increasing until a maximum amplitude (Mean Arterial Pressure - MAP), is reached. After that the pulse amplitudes decrease further until hardly noticeable.

Generally, the systolic blood pressure is calculated by determining the point along this bell-shaped envelope for which p>MAP using a known percentage of the maximum amplitude (usually 50%). Diastolic blood pressure is calculated using the same method and the portion for p<MAP (usually 75%). These percentage values are obtained from empirical research.[1]

The bell shaped “envelope curve” is extracted from the measurement graph as the difference graph of the pulse pressure graph (the maximal values of the pressure pulses) and the trend pressure graph.

Important: Save your original blood pressure measurements. These are needed for the data processing.

Determination of the cuff pressure

1. Determine the number of the measured points in your measurement (from the measurement settings or from the measurement table).
2. Select in the diagram window menu the *Process > Select/Remove data* option.
3. Select the method *Point-by-point*.

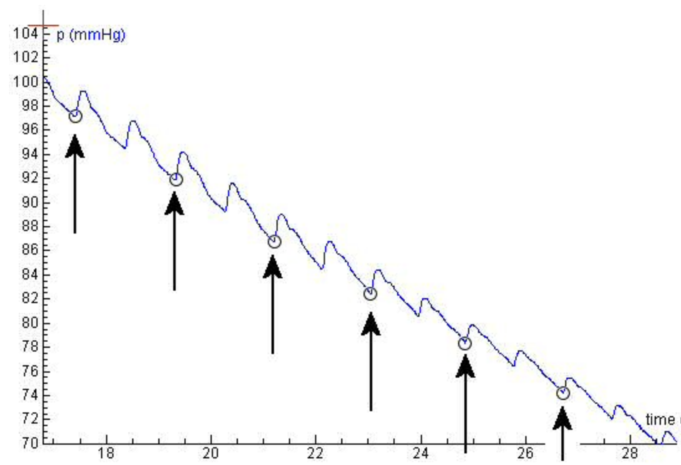

Figure 4. Select the points at which the pressure value

4. Mark the very first point, very last point and points where the pressure values are locally minimal. These points indicate the graph of the deflating pressure trend of the cuff (i.e. without the pulses). It is enough to take every second minimum (see figure 4). **Tip:** Use the cursor key to go through points. Find the point where the pressure value

[1] Mehlsen J et al (1999). Vejledende retnigslinier for hjemmeblodtryksmåling. Ugesk Læ Klaringsrapport nr. 8, 1999. Online beschikbaar op http://www.hypertension.suite.dk/klar899.pdf

(displayed in the pressure coordinate field) is locally minimal. Select/Deselect with space key. In Coach 6 you can maximize the Select/ Remove dialog.

5. Mark *Keep selected* and click *OK*. As the result you get circa 25 points of the lower part of the envelope curve. These points determine the graph of the trend pressure.
6. To get a smoothed graph with the number of points of the original graph through these points you are going to use the Spline function. Select the option *Process > Smooth*.
7. Select as Function type *Spline*. Click Start to draw the smooth graph. If needed adjust smooth factor. When you are satisfied mark *Replace data* and click OK. Type the original number of points (determined in step 1) in the Number of Points field and confirm. The calculations may take some time.
8. Rename the pressure quantity p to 'p-trend'.
9. Save the results under the new name 'Trend pressure' by using the option *Save as…*.

Determination of upper pressure values

1. Open the original measurement results.
2. Repeat the steps 2 to 6, but this time mark the maximal pressure values, the tops of the pulses.
3. Rename the pressure quantity to 'p-pulse' and save the results as 'Pulse pressure'.

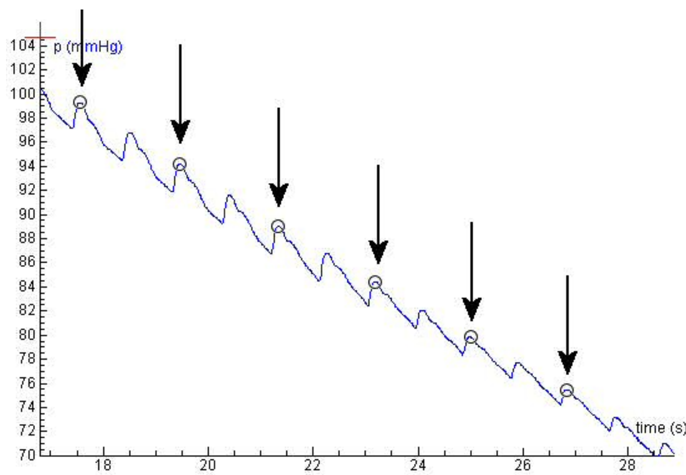

Figure 5. Selection of the upper pressure points.

Determination of the envelope curve

You have now two result graphs from which the difference graph should be made.

1. Open the original measurement result. Place the measurement table in one of the Coach panes.
2. Select in the Table menu the *Import data > Coach Result* option.
3. Select in the dialog the result 'Pulse Pressure'.
4. In the Import data dialog column C1 is selected in the Original data part, select in the Import as part 'Column: none'.
5. Click column C2 in the Original data part and set in the Import as part 'Column: C3'. Do not change other options. Click OK.
6. In the same way import to the Column C4 the pressure data from the 'Trend pressure'.
7. Open the Create/Edit Table dialog by clicking the *Create/Edit Table* menu option.
   - Make data ranges C3 and C4 invisible.
   - For C5 select 'Formula' and create, using the Formula Wizard, the formula [p-pulse] – [p-trend]. Name this quantity 'p-difference'. Make this column also invisible.
8. Create a new diagram with the name Envelope curve.
   - Select for the data range C1 'Manual: p-trend'.
   - Select for the data range C2 'Formula: p-difference'.

An example of a bell shaped envelope curve is shown in the diagram below.

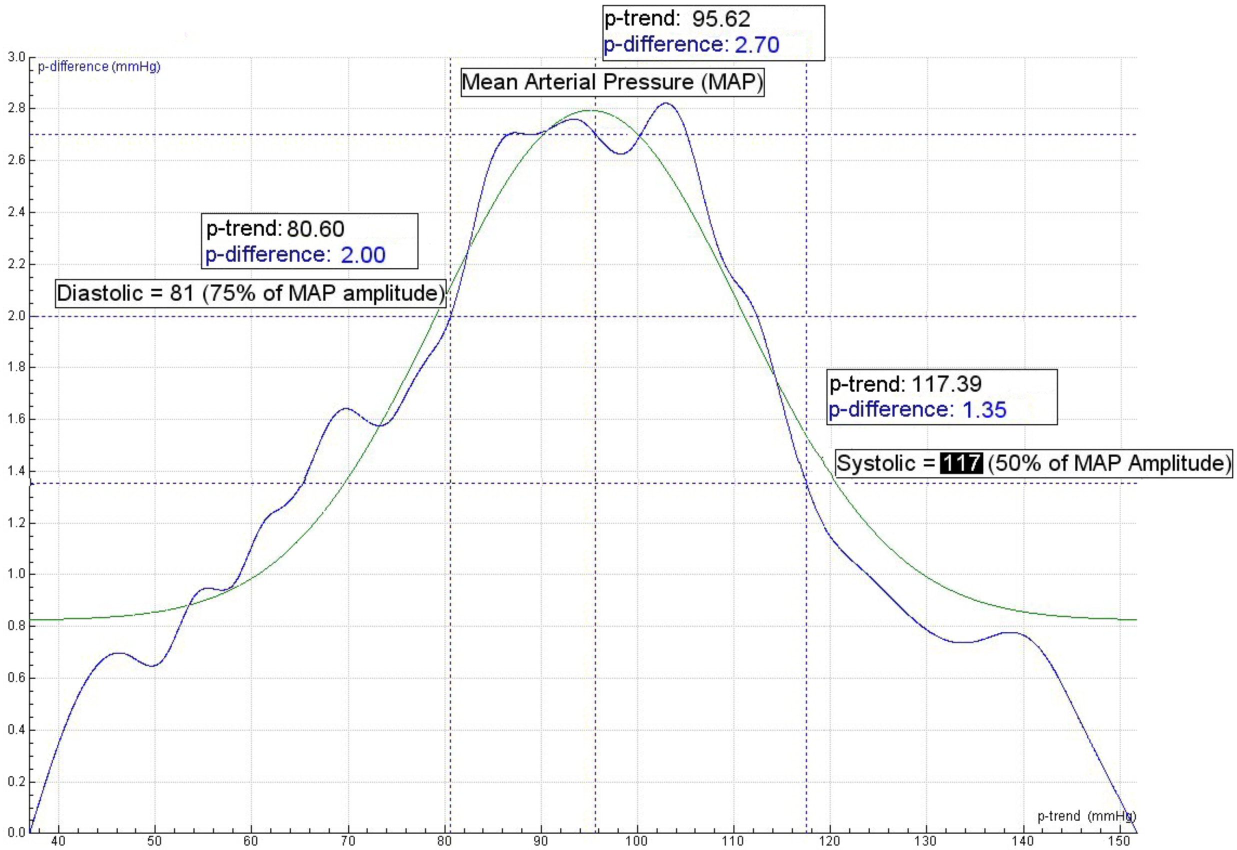

Figure 6: A bell shaped "envelope curve" vs. the trend pressure. As blood pressure values are usually rounded to 5 mmHg we find a blood pressure of 120/80. A best-fit bell-shape envelope is sketched in the graph to find the maximum (MAP).

Age	Heart frequency per minute		Systolic pressure average ± SD		Diastolic pressure average ± SD	
	boys	girls	boys	girls	boys	girls
10 jr	132	129	108±12	109±13	67± 9	64±11
11 jr	160	131	109±11	110±12	65±11	66±10
12 jr	150	147	111±13	114±14	65±10	68±10
13 jr	144	141	116±14	116±14	66±11	68±10
14 jr	127	143	118±14	116±12	66±10	69± 8
15 jr	128	127	123±14	116±11	66±11	68±11
16 jr	106	135	125±14	118±12	68±11	69± 9
17 jr	107	115	126±13	121±13	70±11	70±10
18 jr	85	85	129±15	122±14	71± 9	71±11
19 jr	94	77	131±15	120±12	71±10	70±10

Table 1: Normal heart frequency and blood pressure values for boys and girls for ages between 10-19 years old. (From: van den Brande, Heymans & Monnens, *Kindergeneeskunde*, Elsevier)

Technical Specifications

Sensor kind	Analog, generates an output voltage between 0 - 4.5 V
Measurement range	0 .. 250 mm Hg
Typical accuracy	± 3 mm Hg
Calibration function	p (mm Hg) = 64.94 * V_{out}(V)
Max. pressure	1030 mm Hg without permanent damage
Temperature compensated	0°C to 50°C
Combined linearity and hysteresis	typical ±0.2% full scale
Response time	100 microseconds
Connection	Attached cable with right-hand BT (British Telecom) connector

Warranty:

The Blood Pressure sensor 0377i is warranted to be free from defects in materials and workmanship for a period of 12 months from the date of purchase provided that it has been used under normal laboratory conditions. This warranty does not apply if the sensor has been damaged by accident or misuse.

Note: *This product is to be used for educational purposes only. It is not appropriate for industrial, medical, research, or commercial applications.*

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