Heart Rate Sensor

(Product No PC-3147)

Pulse rate
Range: 0 to 200 bpm
Resolution: 1 bpm

Waveform
Range: -2000 to 2000 mV
Resolution: 1 mV

Introduction
The Smart Q Heart Rate Sensor monitors the light level transmitted through the vascular tissue of the fingertip or the ear lobe and the corresponding variations in light intensities that occurs as the blood volume changes in the tissue.

The EasySense unit can detect that the Smart Q Heart Rate Sensor is connected and the range it is set to.

Connecting
- Hold the Heart Rate Sensor housing with the Smart Q label showing on the top.
- Push one end of the sensor cable (supplied with the EasySense unit) into the socket at the end of the Sensor housing with the locating arrow on the cable facing upwards.
- Connect the other end of the sensor cable to the Input socket on the EasySense unit (with the locating arrow facing upwards).
- Insert the jack plug from the finger/ear lobe clip (Pleth) into the jack socket at the end of the Sensor housing.
- The EasySense unit will detect that the Heart Rate Sensor is connected. Select the range required.

To set the range
The methods available to alter the selected range of the Sensor will depend on the type of EasySense unit used.

EasySense Advanced and Logger Users can set the required range from the unit:
- Use the scroll buttons (▲▼) on the unit to select the System Menu, ENTER.
- Use the scroll buttons to select ‘Set Sensor range’, ENTER.
- Select the number of the input that the Heart Rate Sensor is attached to e.g. Input 1 ENTER.
- Use the scroll buttons to view the ranges available i.e. Waveform or Beats / min
  An asterisk* will indicate the present range selected. Press ENTER to select the desired range.
- Press STOP to return to the main menu.
EasySense Advanced, Logger, Fast, and Real-time Users can set the required range using the Sensor configuration application in the Sensing Science Laboratory program:

- Connect the Heart Rate Sensor to the EasySense unit and run the Sensor Configuration program.
- Select the number of the input that the Sensor is connected to from the list.
- Click on the Set Range button. The current range will be highlighted.
- Select the required range and click on OK.

Exit the program. The Sensor range setting will be retained until reselected.

Measurement procedure

1. Attach the Pleth (finger/ear lobe clip) to either the fingertip or to the ear lobe. **Note:** Do not apply pressure to the Pleth as this could affect the signal.

2. Wait for a short while for the signal to stabilise. The subject should stay reasonably still – muscle movements will influence the signal. The red LED on the Sensor housing will start to flash in time with the heartbeat. If used on the finger the subject may feel a throbbing sensation.

   **Note for EasySense Advanced and Logger users:** if the red LED does not start to flash, and the LCD display on the EasySense unit is blank, press any of the buttons on the top panel of the EasySense unit to wake it up.

3. Once a regular heart rate is detected, begin recording data.

**Background**

The Smart Q Heart Rate Sensor is used to measure the cardiovascular pulse wave that is found throughout the human body. This pulse wave will result in a change in the volume of arterial blood with each pulse beat. This change in blood volume can be detected in peripheral parts of the body such as the fingertip or ear lobe using a technique called Photoplethysmography. The device that detects the signal is called a plethysmograph (or ‘Pleth’ for short).
The Pleth consists of:
- An infrared LED which illuminates the tissue and
- A light sensitive detector (LSD), which has been tuned to the same colour frequency as the LED, and detects the amount of light transmitted from the tissue.

The Pleth supplied with this sensor is a transmission mode plethysmographic signal (PPG) device, which uses transmitted light to estimate absorption.

The infrared LED and the light sensitive detector (LSD) are mounted in a spring-loaded device that can be clipped onto the fingertip or ear lobe.

The infrared light emitted by the LED is diffusely scattered through the fingertip or ear lobe tissue. A light sensitive detector positioned on the surface of the skin on the opposite side can measure light transmitted through at a range of depths. Infrared light is absorbed well in blood and weakly absorbed in tissue. Any changes in blood volume will be registered since increasing (or decreasing) volume will cause more or less absorption. Assuming the subject does not move, the level of absorption of the tissue and non-pulsating fluids will remain the same.

**Practical Information**

The amount of light that can be detected by the Light Sensitive Detector will vary as to the subject or whether the Pleth is attached to a fingertip or an earlobe. When the Heart wave range is selected, the amplitude of the heart wave will demonstrate this effect.

When attached to a finger:
• It is better to position the Pleth so that the Light Sensitive Detector is on the fleshy side of the finger.
• Fingers should be clean.
• Nail varnish may cause falsely low readings.
• Values should not be affected by skin colouring.
• Some subjects may have poor peripheral circulation (the extent to which the blood vessels in the fingertip are filled with blood), in which case another subject should be selected.
• If the heart rate does not seem to settle, try warming the hands by rubbing to increase the blood flow.
• If readings are lower than expected, try repositioning the Pleth to make sure a firm contact is obtained.

Attached to an Ear Lobe:
• Remove any earrings before attaching to the ear lobe.
• The Pleth can be made more secure by hooking the wire round the back of the ear or by using the clip on the lead to attaching it to the subject’s clothing.
• If the heart rate does not settle or if readings are lower than expected, try repositioning the Pleth to make sure a firm contact is obtained.

Each time the Pleth is attached to a fingertip or ear lobe, wait until the signal stabilises before starting to record data - the initial unstable signal will be due to compression from the Pleth being attached.

Stay reasonably still while recording data. Movement e.g. raising and lowering a hand, will alter the pressure the finger exerts on the Pleth whilst simultaneously causing a change in venous blood that will affect light transmission through the tissue.

It is possible to alter the heart rate by simply decreasing respiratory rate and relaxing. Encourage the subject to breath normally.

If the Pleth ‘loses contact’ with the pulse, the Sensor will attempt to re-establish communication. This may result in the reading momentarily dropping to zero.

The heart rate is averaged over every five beats to achieve a smoother reading.

This Sensor is not intended for medical diagnosis. Do not be alarmed if results do not correspond to the quoted numbers. These numbers represent typical averages and many healthy hearts have data that falls outside these parameters. It is quite normal for the heart to occasionally miss a beat.

It is possible for the dicrotic notch to be recorded as a separate pulse.

This Sensor is not waterproof. Clean the Pleth by wiping with a cloth that has been rinsed in disinfectant.

The Light Sensitive Detector in the Pleth can be sensitive to high levels of ambient infrared light e.g. strong sunlight.
Heart Rate

Blood passes through the heart in two phases that alternate continuously.

<table>
<thead>
<tr>
<th>Diastole (heart expanding)</th>
<th>Systole (heart contracting)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The muscles of the ventricles relax</td>
<td>The muscles of the ventricles contract</td>
</tr>
<tr>
<td>The atrio-ventricular valves open</td>
<td>The atrio-ventricular valves close</td>
</tr>
<tr>
<td>The arterial valves close</td>
<td>The arterial valves open</td>
</tr>
<tr>
<td>Blood flows from atria into ventricles</td>
<td>Blood flows from the ventricles into arteries</td>
</tr>
</tbody>
</table>

The blood forced into the aorta during systole moves the blood in the vessels forwards and sets up a pressure wave that travels along the arteries. This pressure wave expands the arterial walls as it travels and is felt as the pulse.

The pulse may be felt at points where arteries pass over bones, known as pressure points e.g. in the wrist and neck. Pulse rate is a direct measure of the number of heart cycles in a minute (heart rate).

Heart rate can vary with age as shown below:

<table>
<thead>
<tr>
<th>Age</th>
<th>Average Heart Rate (beats per minute)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newborn</td>
<td>140</td>
</tr>
<tr>
<td>7 years</td>
<td>85 – 90</td>
</tr>
<tr>
<td>14 years</td>
<td>80 – 85</td>
</tr>
<tr>
<td>Adult</td>
<td>70 – 80</td>
</tr>
</tbody>
</table>

In normal healthy individuals the heart rate, and thus the pulse rate, varies with the phases of respiration. Irregular changes in heart rate occur in all people. Heart rate may be increased by exercise, nervous excitement, stress due to mental effort, by adrenaline entering the bloodstream or with increase in temperature caused by fever. The heart rate decreases when asleep and some medical conditions may also cause a drop.

Effect of Exercise

Physical training can increase the efficiency of the heart and thus the resting heart rate is decreased. The athlete’s heart is usually larger than that of an untrained individual. Constant training, with its increased workload against which the heart must contract, results in enlargement of the myocardial fibres with associated biochemical changes. This modifies the performance of the heart, increasing stroke volume (the volume of blood pumped by the heart at each beat), and permitting the athlete to achieve the same cardiac output with a slower heart rate. The resting heart rate in an athlete may be as low as 40 – 50 beats per minute: but with an increased stroke volume of 100 – 110ml, compared with 70 – 80ml in an untrained individual.
With increased heart rate it would be expected that stroke volume would decrease because less filling time is available. In fact, during exercise the sympathetic nervous system acts to increase it, by increasing the vigour of myocardial contraction. As a result, the output of the heart per minute tends to increase proportionately with increase in heart rate.

**Recovery Time**
Following exercise it takes a while for the heart rate to return to resting level. This is the recovery time and gives an indication of the fitness of the individual. Recovery time may vary from less than five minute in very fit individuals to around 15 minutes.

**Safe Pulse Rates**
During experiments the safe heart rate should not be exceeded. The safe level is given as the maximum heart rate for age, minus 20 beats per minute

Maximum heart rate = $210 - (0.65 \times \text{age})$

<table>
<thead>
<tr>
<th>Age</th>
<th>Maximum Heart Rate</th>
<th>Safe Heart Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>202</td>
<td>182</td>
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<td>13</td>
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<td>18</td>
<td>198</td>
<td>178</td>
</tr>
</tbody>
</table>

It is important that investigations do not become a competition. Consider any possible health problems before selecting the subject.

**Waveform**
The heartbeat recorded by the *Smart Q* Heart Rate sensor is smoothed by the passage of blood through the capillaries and the pressure signal does not resemble the pulse seen in an electrocardiogram* (which is used to record the hearts electrical activity). However, the periodicity of the signal is unchanged and the Heart Rate sensor can be effectively used to detect changes in heart rate.

The upstroke, called the anacrotic limb, is abrupt and is due to contraction of the ventricle (systole). The downstroke is more gradual and corresponds to the elastic recoil of the arterial walls. The downstroke regularly shows a fluctuation known as the dicrotic notch. This is due to vibrations set up when the aortic valve snaps shut – it has no major significance as an indicator of health.
An Electrocardiogram (ECG) is a measure of the heart rhythms and electrical impulses. The contraction of the heart occurs due to electrical impulses that are generated within the heart. The P-Wave represents the impulse across the atria to the A/V Node. The QRS represents the impulse as it travels across the ventricles. The T wave represents the repolarization of the ventricles.

**Fastest Recording Time**

When used with EasySense Advanced and Fast, users can utilise Fast mode. The fastest speed that the Heart Rate sensor can be used with to capture data will depend on the EasySense unit’s operating system.

- Version 1.0 – 1.3 EasySense users can log at 40Hz* (25ms).
- Version 1.4 and upward can log at 50Hz (20ms).

If an intersample time of less than 20 milliseconds (or 25 milliseconds for EasySense operating system 1.0 – 1.3 users) is selected, then the values obtained will default to zero.

To check the version number of your EasySense unit,

- Select the **Sensor Configuration** application from the Sensing Science Laboratory program. Click on the **EasySense** Information button for the version number to be displayed.

- EasySense Advanced and Logger users can also check by carrying out a HARD RESET (by holding down the STOP, METER and ENTER buttons at the same time). The LCD will momentarily display the word **EasySense** and the version number of its operating system.

*To be consistent with the logging time of 40Hz, the Graph application of the Sensing Science Laboratory software has had an intersample time of 25 milliseconds added to the Fast menu. If the

For a healthy person at rest, the heart beats on average at about 60 beats per minute or one a second i.e. around 1Hz. This frequency is not constant (even in a healthy individual at rest).

It only takes approximately one second to record a complete wave, so it is usually best to select a short recording time.
version of your Sensing Science Laboratory software does not offer this speed as an option, please contact Arbor Scientific for upgrade information.

**Investigations**

- Monitoring fitness - after exercise pulse is timed until it gets back to the normal standing heart rate (this can be achieved by remaining in a sitting position and moving the legs).
- Monitoring resting
- Changes with mild stimulants (cups of coffee or cola – might show less effect on people who are accustomed to large amounts of caffeine).
- Variation in blood flow i.e. people who suffer with cold fingers will show a very low blood flow in their veins – try warming their hands
- Investigating pulse rate with different body positions (sitting, crouching, standing, laying down).
- The effect of music on pulse rate.
- The effect of the strictest teacher entering the room!

**Warranty**

All EasySense sensors are warranted to be free from defects in materials and workmanship for a period of 12 months from the date of purchase provided they have been used in accordance with any instructions, under normal laboratory conditions. This warranty does not apply if the sensor has been damaged by accident or misuse.