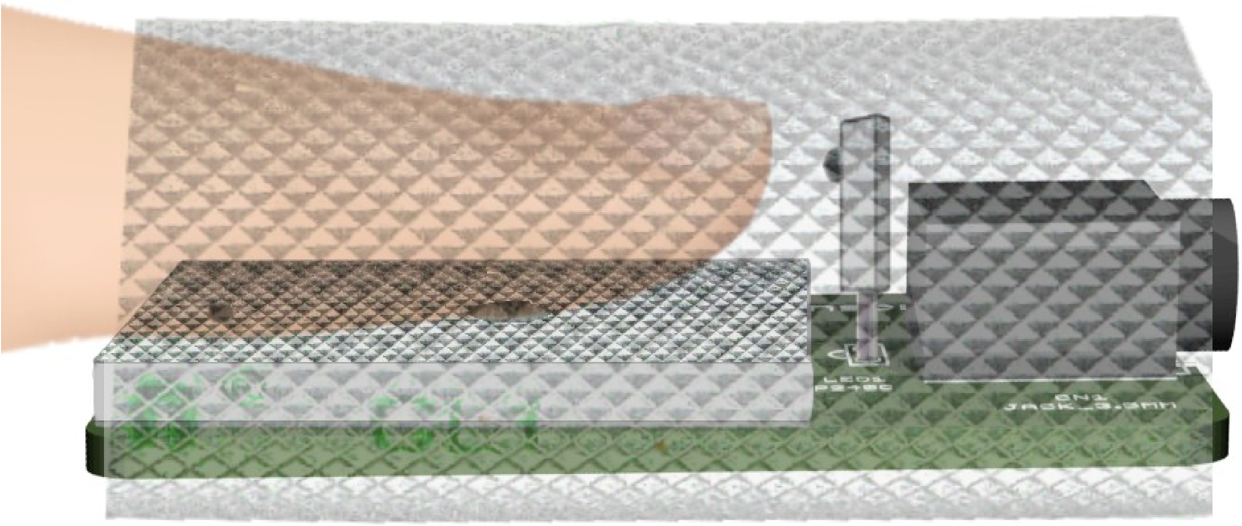
Theremino System

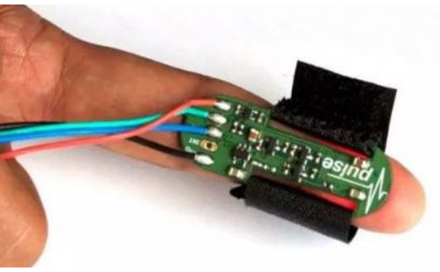


# Theremino pulsometer

## Optical sensor
## for the arrhythmia detection

# Sensors of all types

On the Internet there are many ideas to build optical sensors. From pegs for linen to the elastic, to Velcro. From pliers for hanging clothes to simple reflection sensors on which to place the finger.



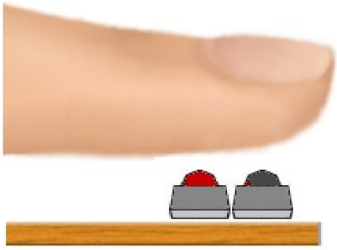
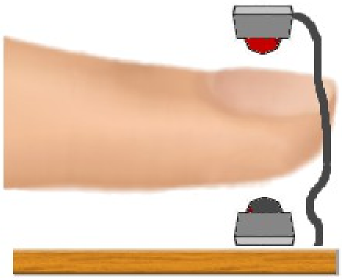
But who has tried knows that with people who have low blood pressure, calloused fingers or dark skin the signal deteriorates. You have to apply a little pressure for not stopping the blood and at the same time keep the finger firmly. And you should also make sure that the finger positions are of course in the best spot.

The whole thing should be light to track the movement of the finger without rocking and produce disturbances. It should have only one cable and a soft feel a bit 'better than a clothespin from linen, velcro strap or a rubber band.

And possibly the sensor should also be usable by the public in multimedia installations. So stably positioned on a table with the thread that arrives from behind, ready to shove the index finger, without the need to take it in hand to put or remove it.

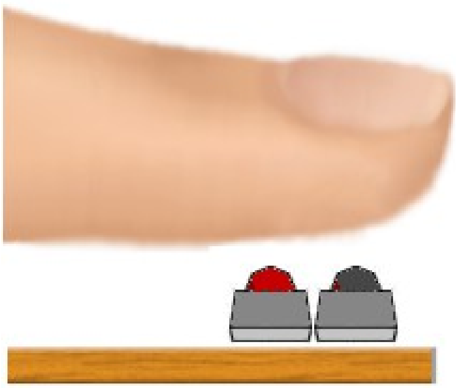
Getting these features with simple equipment and readily available materials is not easy.

# Types of sensors

Until now there were only two types of sensors. Those with the LED and the sensor close together and those with LEDs above and below the sensor.

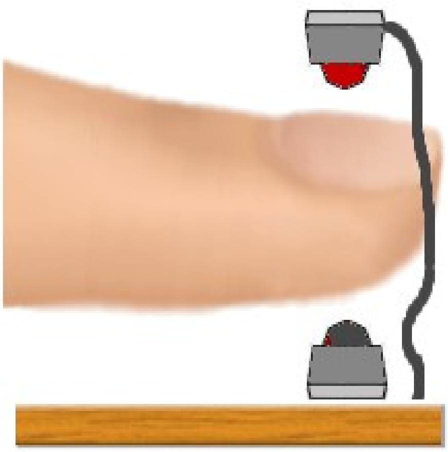
## First method



Advantages: Both the LED and the sensor are fixed to the base plate and so there are no connecting wires between the base and the area above the finger.

Disadvantages: With this configuration, the emitted light is reflected from the top layers of the skin dazzling the sensor and making the measurements highly dependent on the skin transparency. With people who have low blood pressure signal becomes unreadable.

## second method

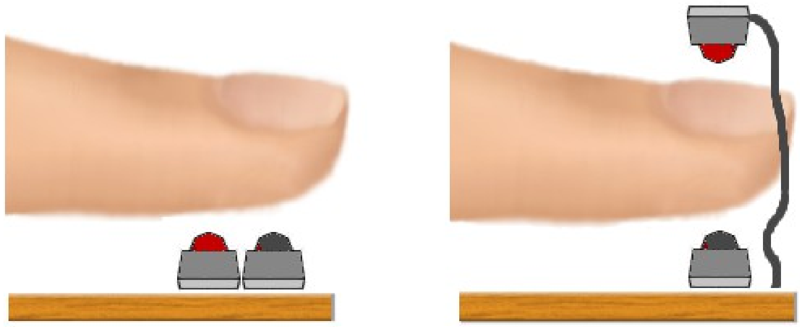


Benefits: There are not sensor glare problems. The light must necessarily pass through the finger.

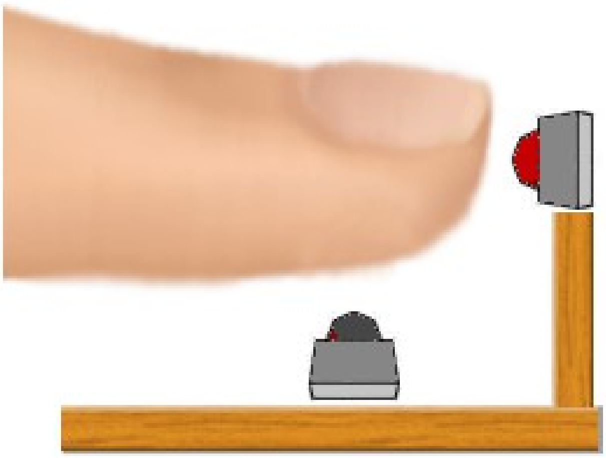
Disadvantages: The connecting wire makes it difficult to build them with non-industrial techniques. The upper zone must be elastic and do not press on the finger, for not stopping the blood, and the wire complicates the construction. In the presence of nail polish the signal drops and may become insufficient.

# Evolution of the sensors

## These were the two prior art methods until today

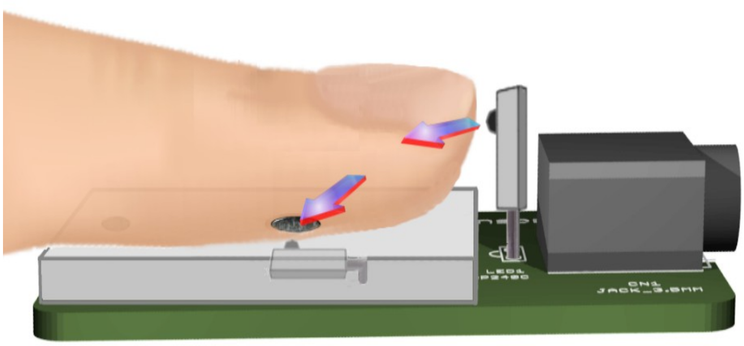


## This new provision is that we designed



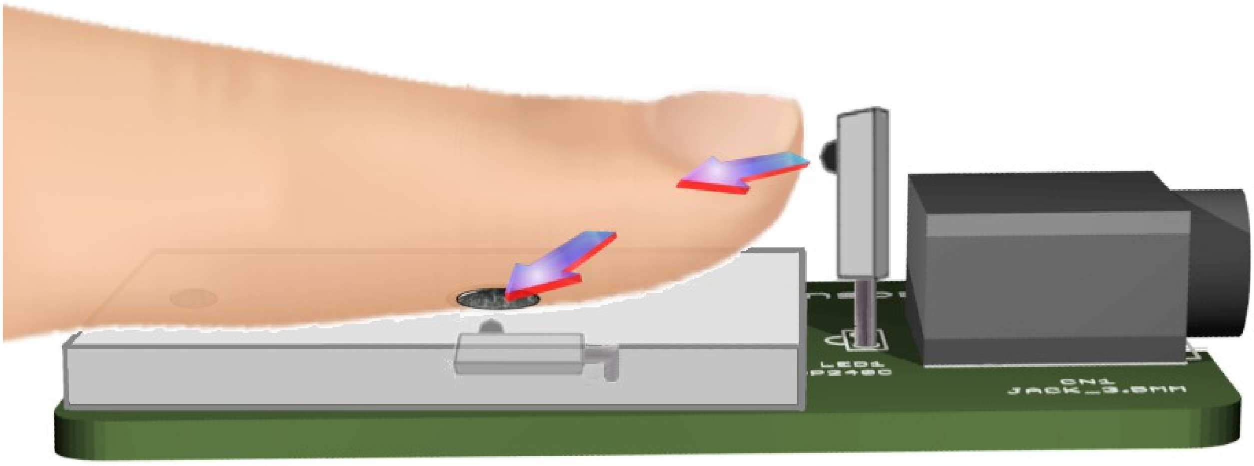
This arrangement combines the advantages of both previous methods.

- Both the LED and the sensor are rigidly connected to the base.
- The light does not pass through the nail and is not affected by its transparency and its color.



There is no glare sensor because the light necessarily passes through the finger. The light can only pass through the hole in the material that covers the sensor.

# Principle of operation



An infrared LED illuminates your finger from the tip. The infrared light passes through the skin and is more or less attenuated depending on the blood pressure. A photo-transistor (which is seen in transparency) collects light through a hole.

The gray block is made of spongy material is a soft base for the finger and at the same time isolates the sensor from the external light. The light can only pass through the finger and then from the hole.

With this arrangement you get a better signal, with respect to the sensors that work with LED and photo-transistor from opposite sides of the finger, and also with those who have both of them at the bottom.

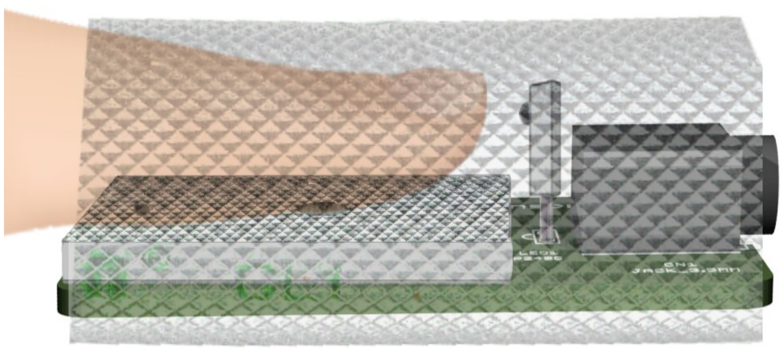
This sensor (when used with the amplifier designed by us) generates a fairly constant amplitude signal even with people who have dark skin or lacking in transparency, or have painting their nails and even with people who have low blood pressure.

# Sensor Materials

After many tests we were able to design a simple sensor to be built with common materials.

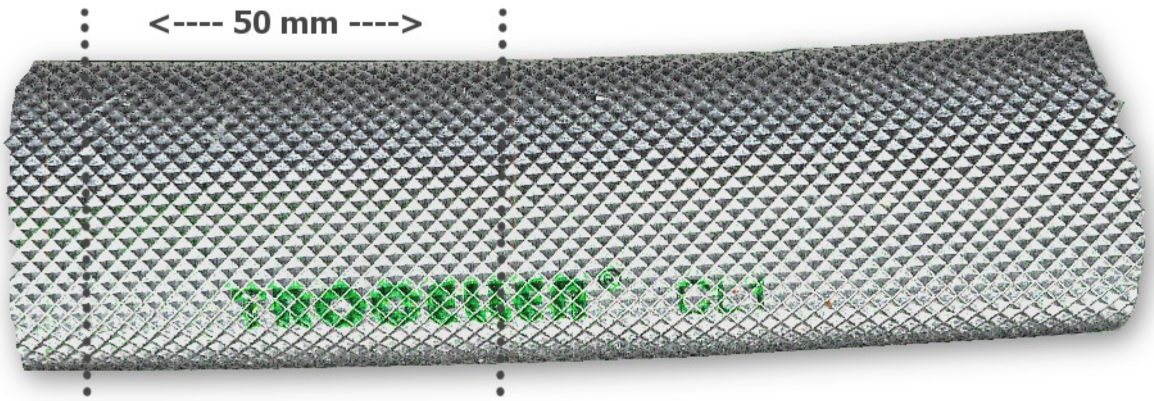
This is all you need:

- The two parties are silvery spongy material as explained on the next page.
- The countersunk screw the nut and washer are of 3 mm.
- On the printed circuit are welded Jack female, the LED and the photo-transistor.

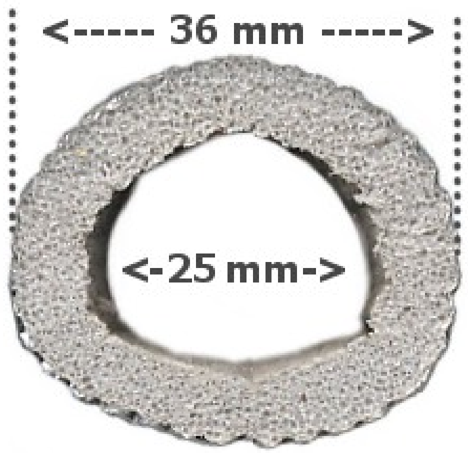


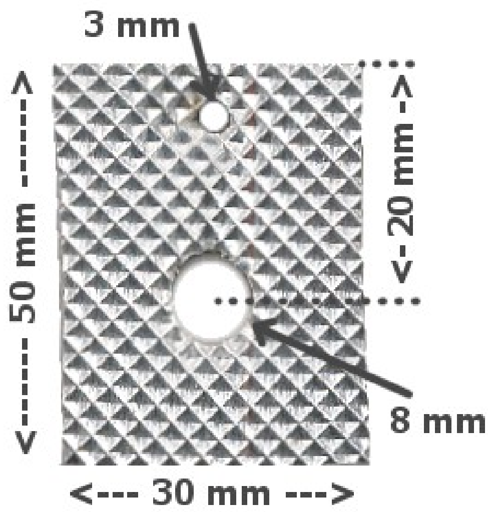
The finished sensor is lightweight and firmly keeps the finger without applying too much pressure. It fits so well to each diameter that it can be applied to the little finger or the thumb and the signal is always the same.

# Sensor Materials



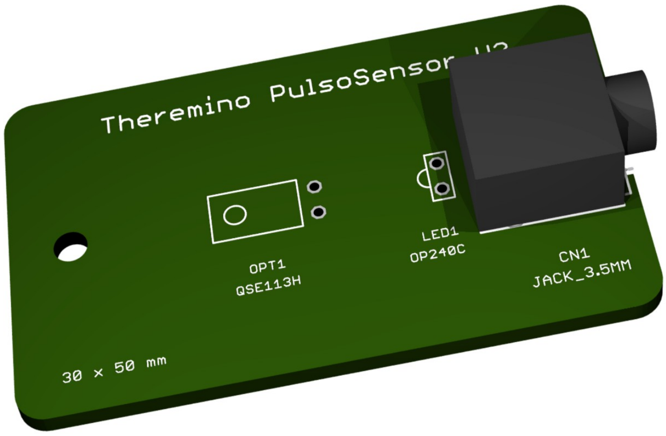

This is a piece of insulating coating for hot water pipes. you can find it in the hydraulic and thermo material retailers or by an installer of boilers or even by an hydraulic. They will give you a span without any problems or will sell a meter. It is a very cheap material.



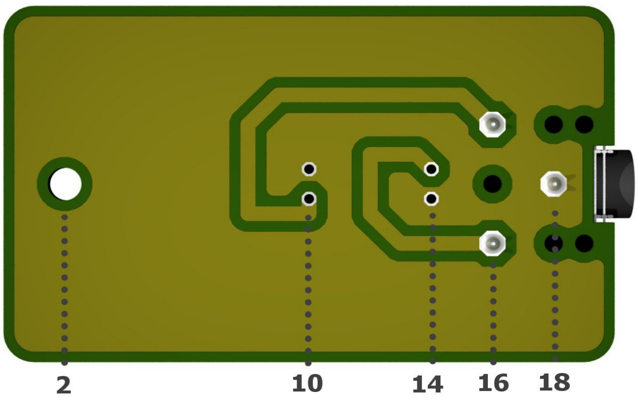




The tube should be of the diameter shown here (it is one of the most commonly used diameters).

# The printed circuit




In place of the printed circuit board you could use a piece of a thousand-holes.

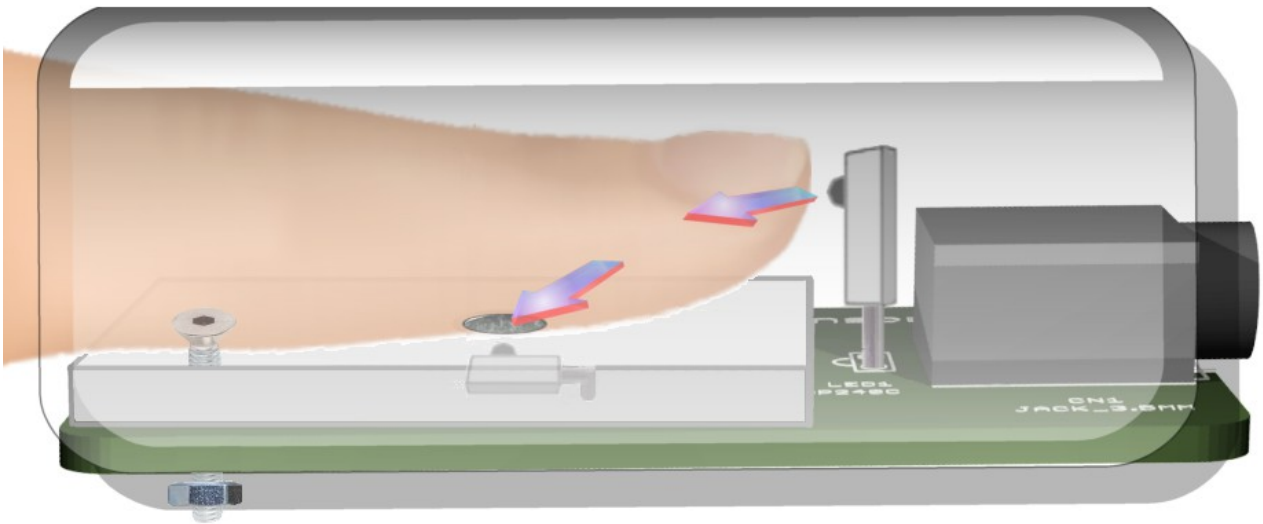



- Cut a piece of a thousand-holes base 30 x 50 mm.
- Place the components in the right holes, counting the holes as shown in the picture.
- Enlarge the hole indicated with "2" up to 3 millimeters.
- Insert the photo-transistor to the tenth hole height, lying to the left.
- Insert the LED to the fourteenth hole height, turned to the left.
- To insert the jack you must be widen a bit the holes for its plastic pins.
- Make connections with small insulated wires.

# Mounting the sensor

You begin by placing the rectangle with the two holes on the printed circuit.

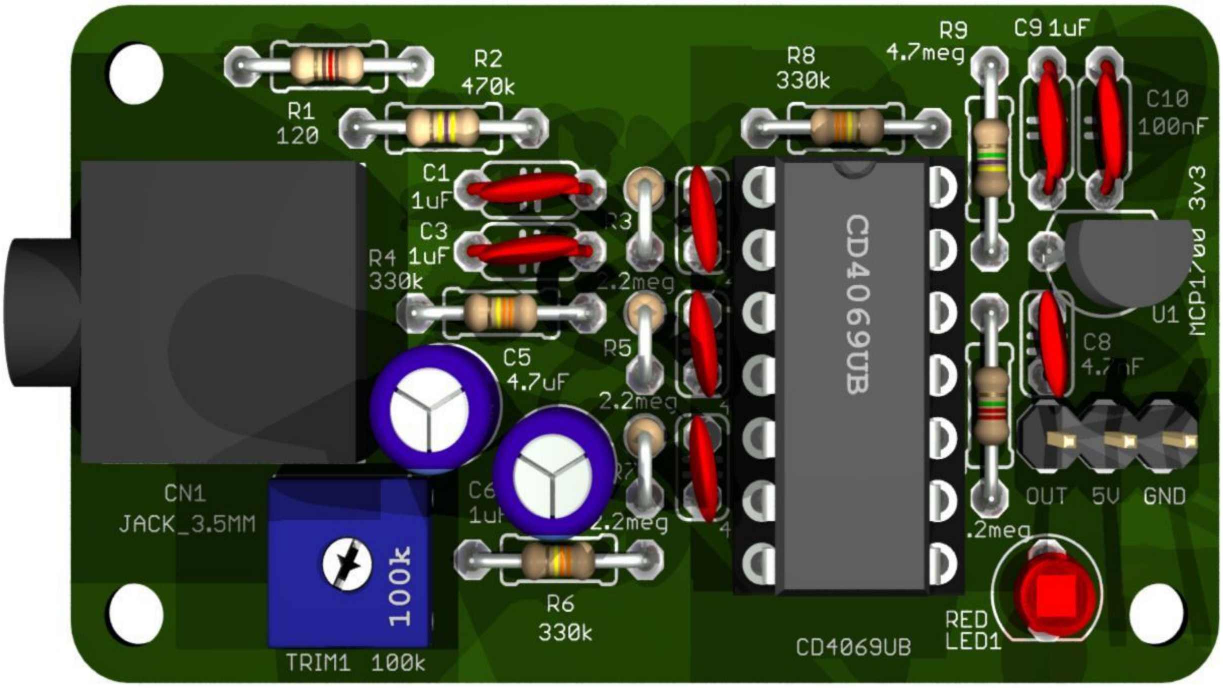
Then slip the cylinder with the hole downwards.



The screw will then be tucked inside. It will pass through the hole of the rectangle, the printed circuit board and finally released below through the cylinder bore.

It puts a washer on the screw coming out, tightens the nut and the mounting is finished.

# Amplifier




In this image it is to be noted the 1/8 watt resistors that allow a compact and orderly arrangement. In their place you can put those quarter-watt very tight bending.

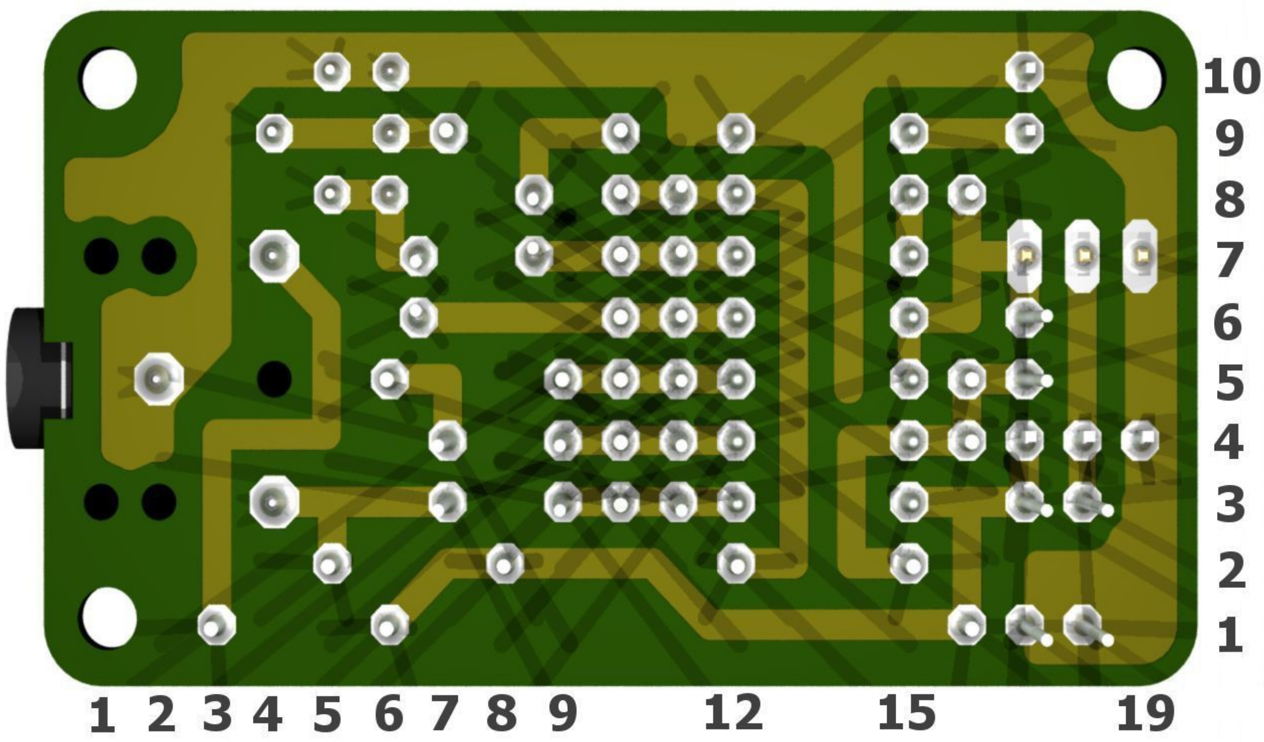
Three resistors were positioned vertically to maintain maximum compactness and shorter tracks (see the picture on the next page).

The short tracks, do not ride the goose as in "usual" printed, giving many advantages:

- They make the circuit insensitive to disturbances radiated from the electrical system and the appliances.
- It becomes easy and fast to make tracks with bare wires on a thousand-holes.
- The large isolations and the single-sided circuit make it possible to construct the printed circuit board with the cutter. Inside the project that you download from ***this page*** you will also find the GCode to mill this circuit. In a few minutes it is finished off, with the holes and also the cutting of the outer edge, all with a single 0.8 mm tip.

# Amplifier printed circuit

The connections between components are few and components are all positioned at 2.54 mm pitch. So it is possible to use a piece of a thousand-holes breadboard.

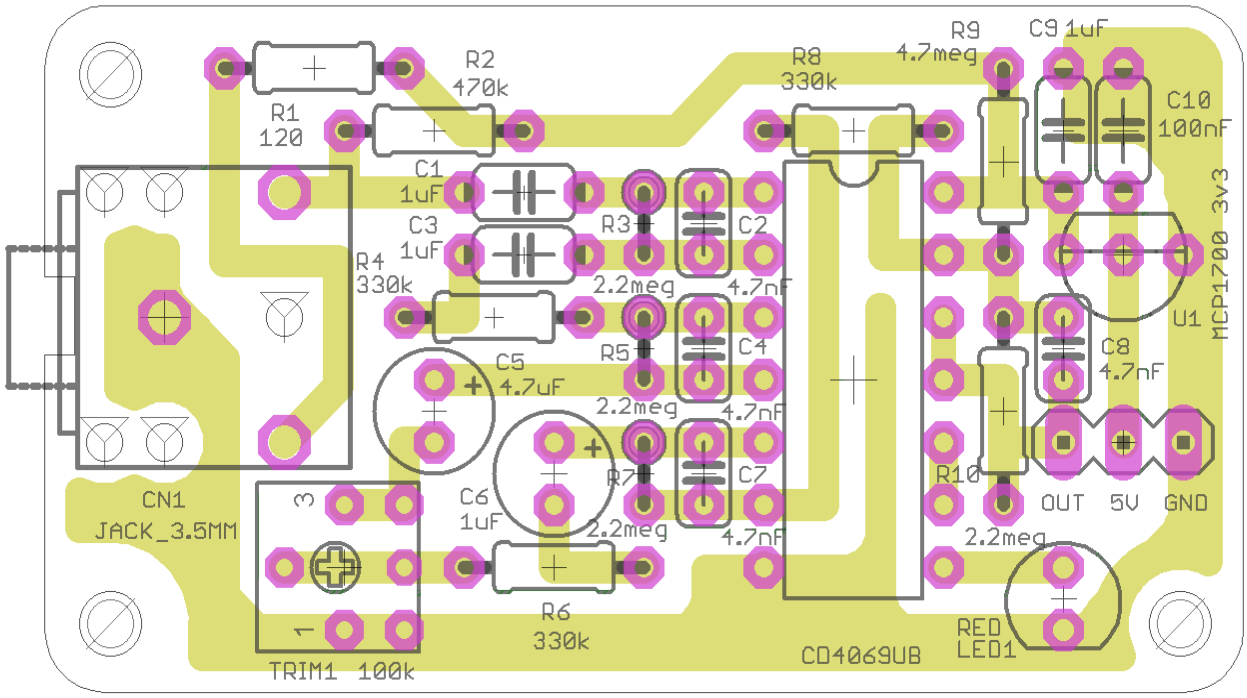



- Cut a 30 x 50 mm piece of a thousand-holes.
- Place the components in the right holes, counting the holes as shown in the picture.
- Make connections with small bare wires.

For the connections you can use the pins that were cut from the components. Choose thinner ones and use small tweezers and clippers.

The welder must be with small tip, hot at the right point, the tip must be clean and tin wire should be thin, with lead and flux.

# Printed circuit board seen from above




This transparency can be useful when placing and soldering the components.

The TRIM1 trimmer must be one of those small (7x7 or 8x8 mm at most). There are three extra holes that allow to use different models of trimmer, or rotate it 180 degrees, to make so that by rotating clockwise the signal increases.

All resistors can be a quarter of a watt, but if you can find them by an eighth of a watt is better. It will be easier to position them and are even more beautiful to see.

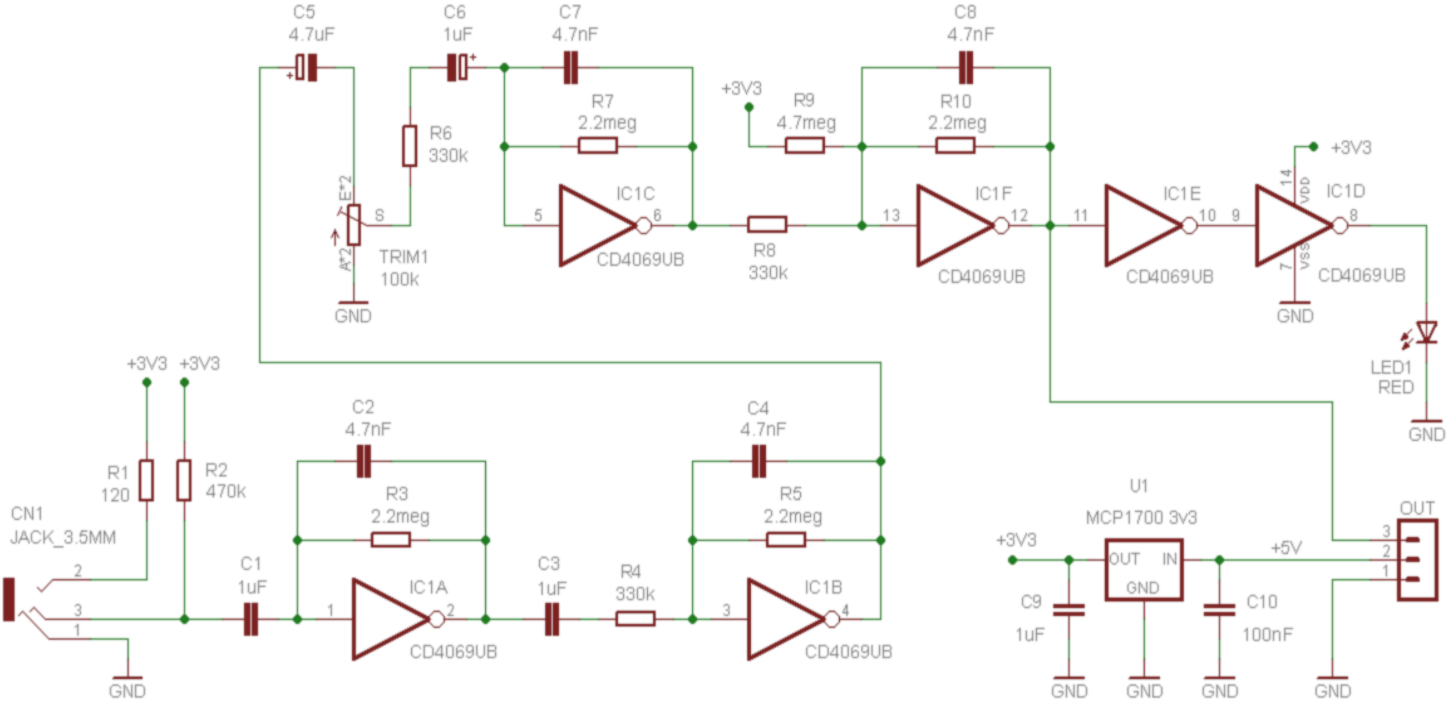
The resistors R3, R5 and R7 must be positioned standing, bending one of the two legs along the body. To avoid that the long legs can touch each other is good to arrange all three with the body on the same side. In the image it is seen that the bead at the top has the black edge and that side is the body of the resistance.

Note that the C5 and C6 capacitors are polarized and you have to rotate with the "+" as shown in this image.

For this circuit it is not necessary to use precision components. No need mylar capacitors, you can use small and economic ceramic capacitors.

The capacitors C1 and C3 they must **not** be polarized, and preferably from 470 nF to 1 uF, as explained in the following pages.

# Schematics




The resistor R1 sends a current of about 16 mA to the sensor LED.

The resistor R2, the highest value compared to similar schemes, provides a very low current to the photo-transistor (less than 5 uA). With this arrangement, when you remove your finger and the LED light it is no longer filtered, the voltage on the transistor drops from the normal two volts (approximately) at a very low value and the transistor goes into saturation. In this way it is eliminated the noise due to external light which might generate false signals.

The capacitors C1 and C3 from 1uF determine the low cut-off frequency. It is recommended to use the value of 1 uF or lower them to 470nF, as explained in the following pages.

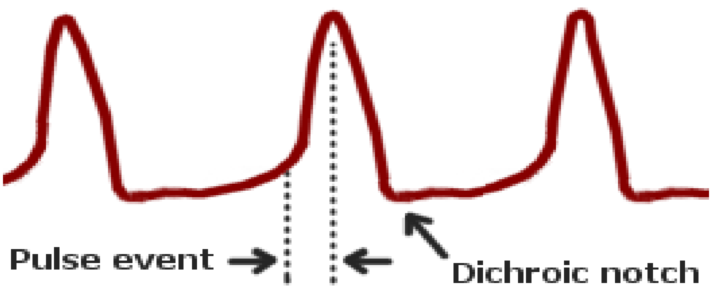
The sections IC1A, IC1B, IC1C and IC1F amplify the signal of more than a thousand times (66 dB with TRIM1 at maximum) and at the same time filtering out high frequencies effectively so as to completely eliminate the mains frequency noise.

The resistor R9 unbalances the last section so that the output at rest is below half of the voltage and the LED1 remains off. The IC1E IC1D sections and square off the signal and make the LED blink with each beat.

The regulator U1 stabilizes the 5 volts coming from the USB, to a stable and little noisy 3.3 volt.

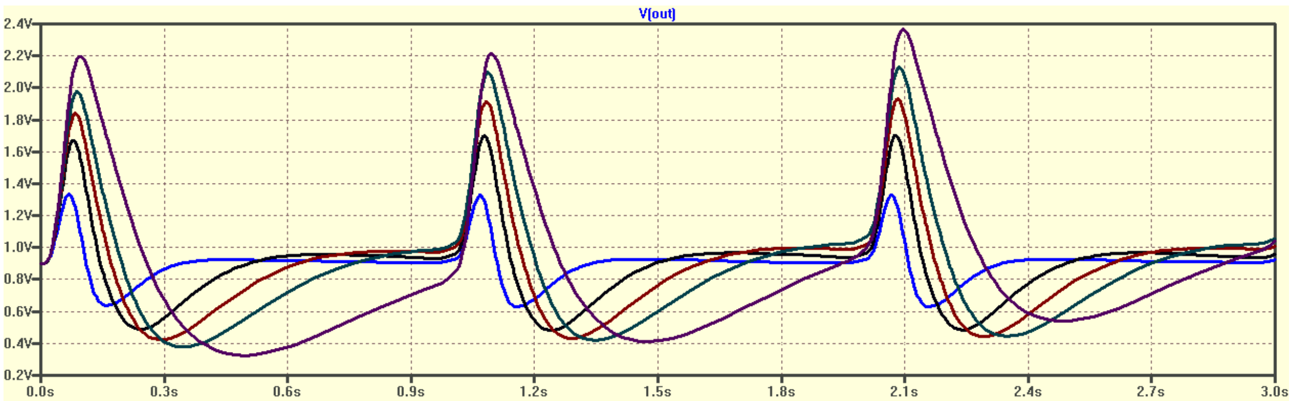
# Waveform pulse

The waveform caused by the blood pressure should be about the same as in this picture.




In practice, however, the waveforms that will achieve will be a bit different from this, because we will use a high pass filter to eliminate the rocking due to the movements of the hand.

To be effective, this filter will have to have a fast response and then a high enough cutoff frequency, and this inevitably deform the horizontal portion and extend the pulse descending part downwards.




Here we see how the shape of the pulses with C1 and C3 which are worth 100 nF (blue), 220 nF (black), 330 nF (red), 470 nF (green) and 1 uF (purple).

It should be noted that with 220 nF and 100 nF the amplitude of the signal is reduced much.

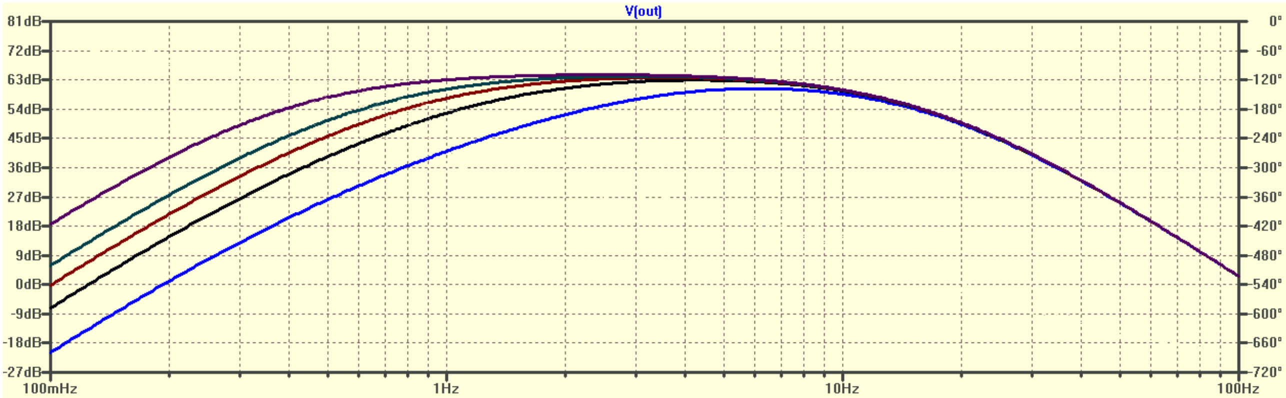
For the measurement of arrhythmia waveform has little importance. What matters it is to have an accurate measurement of the time between successive pulses and to achieve this it is good to sacrifice much the shape of the pulses.

# Bandwidth

There **high cut-off frequency**, which is seen in the right part of the image, it is located around 10 Hz and is determined by the capacitors C2, C4, C7 and C8.

Given that the filter has four poles, we can use a quite high cut-off frequency (10 Hz) and at the same time get a good attenuation of frequencies from 50 Hz up (about 40 dB ie 100 times in amplitude).

Raising these 10 Hz it has little relief for mains frequency interference and lowering them you would round the signal. The 10Hz frequency is therefore a good compromise and there is no reason to change it.




There **low cut-off frequency**, Which is seen in the left side of the image part, it is determined by the value of C1 and C3 capacitors which can be from: 100 nF (blue curve), 220 nF (black curve), 330 nF (red curve), 470 nF (green curve ) and 1 uF (purple curve).

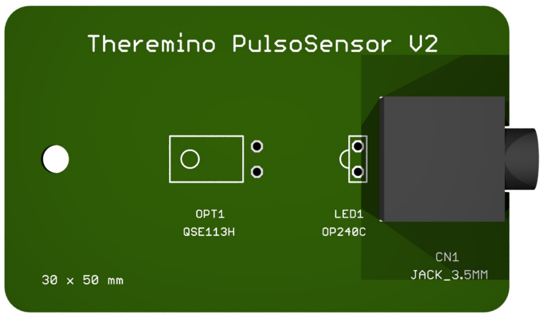
With the capacitors C1 and C3 from 1 uF, as shown in the circuit diagram, you obtain the minimum deformation of the shape of the pulses but a greater sensitivity to interference at very low frequencies (in rocking up and down caused by movements of the patient).

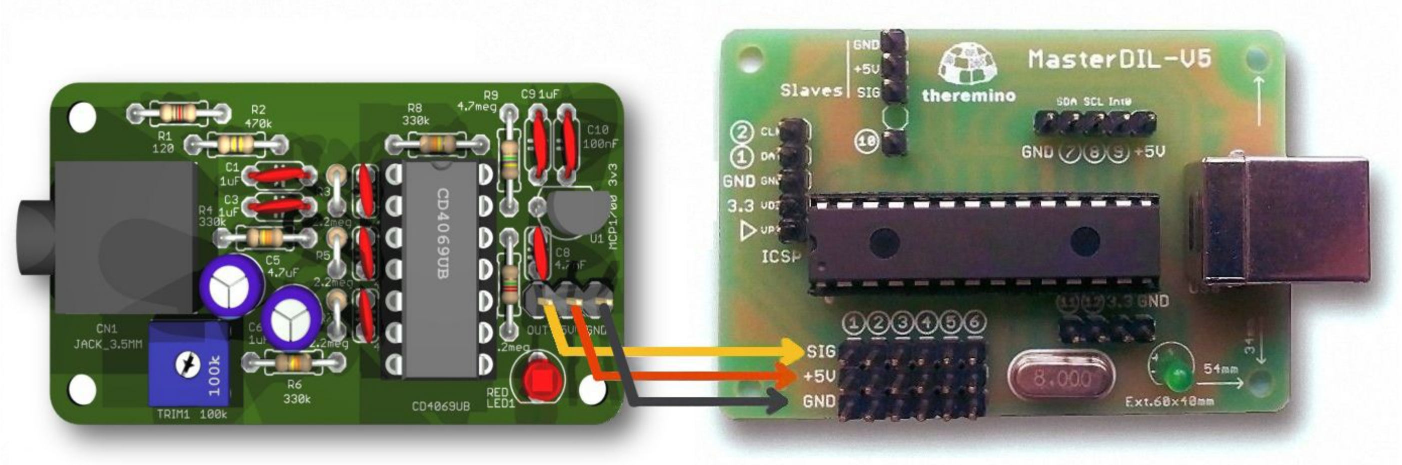
Going capacity to 330 nF or less could happen that the shape of the pulses of some patients is so deformed as to cause the double counting.

We therefore recommend to use for C1 and C3, 1 uF or at most 470 nF capacitors.

# Connections

To connect the amplifier sensor, use a shielded cable for audio connections, with jack 3.5mm male stereo. Beware that many cables, although with the gold connectors, soft and nice to look at, are not shielded. When you buy, make sure that the word "shielded" is clearly specified.




The connections between the amplifier and Theremino Master module are made with Dupont female female three-pin cable, as shown in this picture with the colors black, red and yellow. It is not necessary to use shielded cable for this connection.

# Finding components

They are often asked prices or ask us to build something in exchange for money. So it is important to remember once again that we in the Theremino system design and explain how to do, but do not sell anything. We do not work to order and everything we do is non-profit.

There are producers on the Internet that sell manufactured modules according to our projects, you can find them easily by searching for "Theremino" on Google. But these producers prefer the most requested forms and will likely take months before they build this sensor.

So until it will be available, you must do it yourself. And for that we have done everything possible to facilitate the self-construction.

Special features of our projects to facilitate the self-construction.

- The insulation is at least 0.8 mm wide to make PCB with the cutter.
- The arrangement is all in pitch 2.54 mm to be able to also use a thousand-holes breadboard.
- The components are chosen among the most common. Many should have almost all them in home.

# Sensor Project download

You can discharge the Eagle format printed circuit project from ***this page***.

The project includes installation plans, wiring diagram and other useful images to facilitate construction.

In the download files will also find the GCode for use with the cutter. As software we recommend ***Theremino CNC*** and a 0.8 mm cutter (model 626 that is seen in the CNC Theremino page, if you can not find it and press Ctrl-F 626).

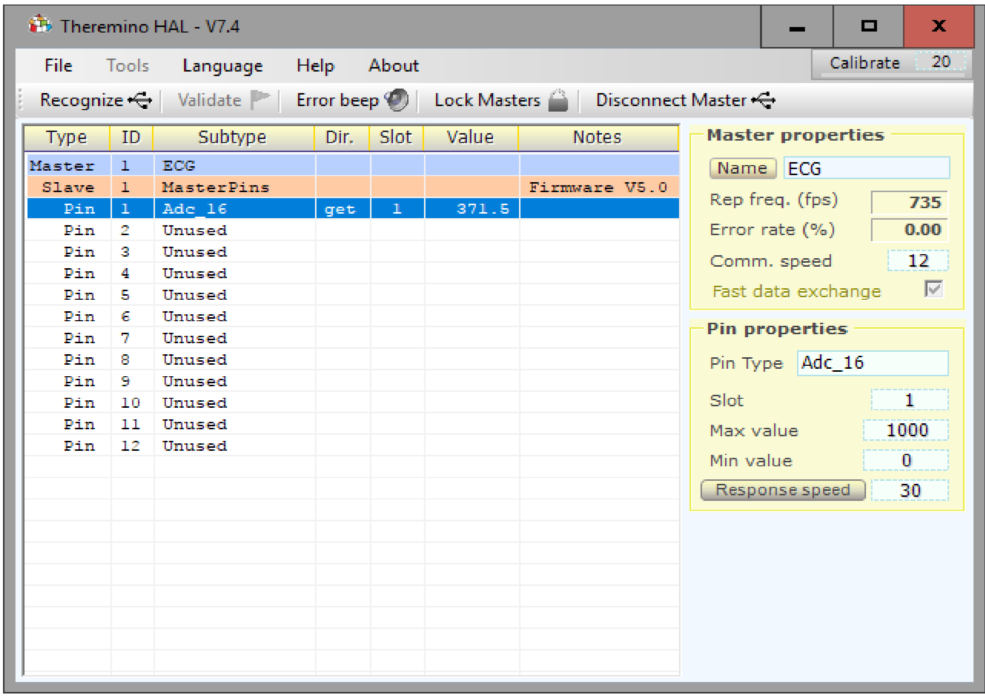
# Software for reading the sensor

The USB incoming signal is received with the HAL application you download ***from this page***.

The HAL application is configured as seen in this image.

You click on the Slot 1 row and then choose Adc16 as PinType.

The HAL application is then left running, maybe minimized but active.




Then to see ECG, but primarily for the detection of arrhythmia, you use the application Theremino ECG. Download it ***from here***.

The ECG application can automatically launch the application HAL.

To get this behavior copy the "Theremino_HAL.exe" file near to the exe file of the ECG application.