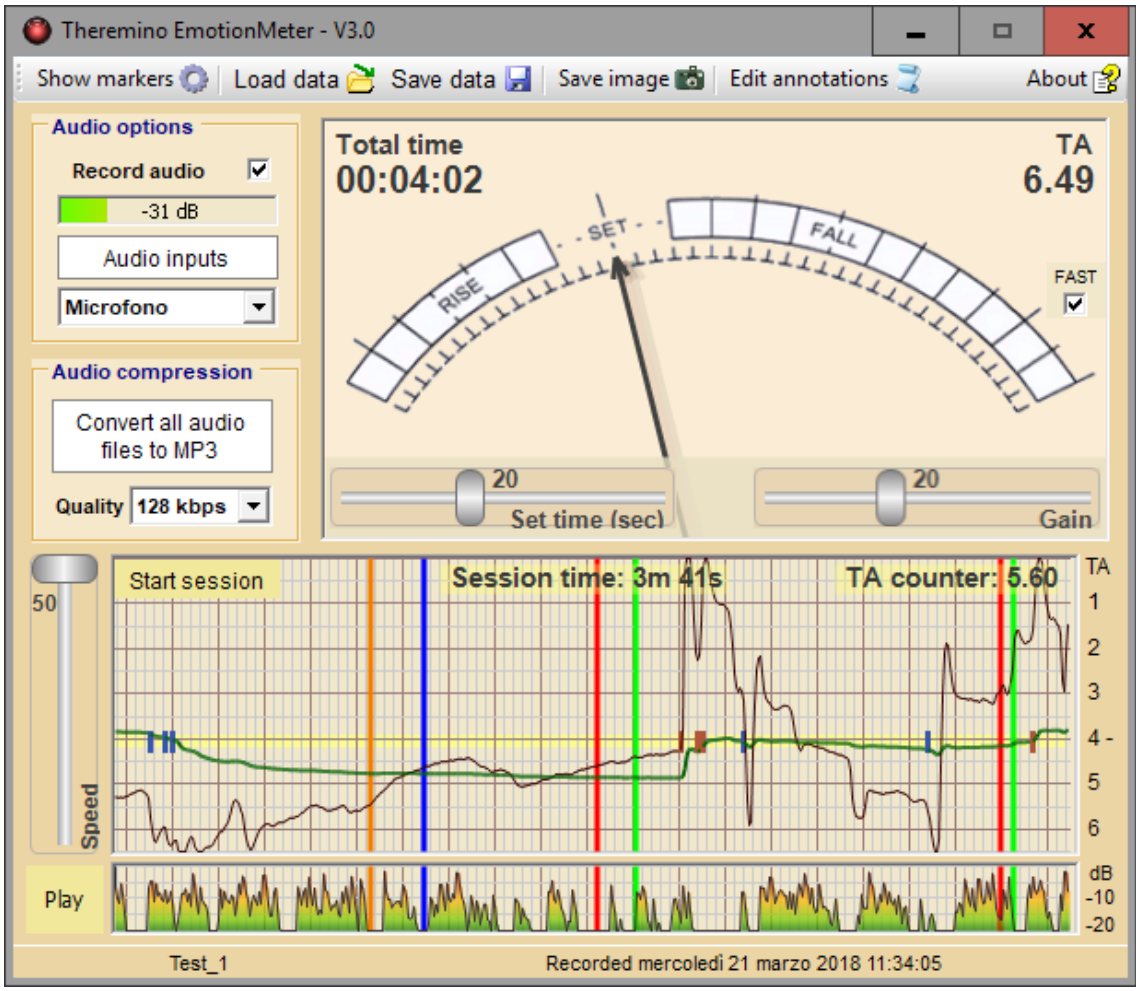
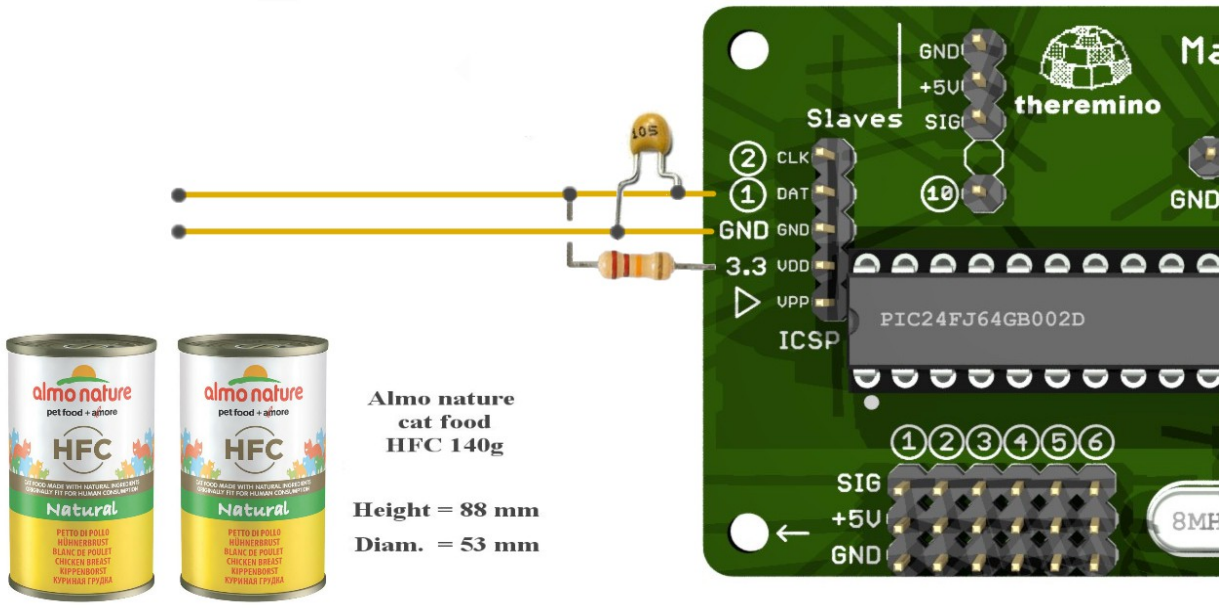
**System Theremino**



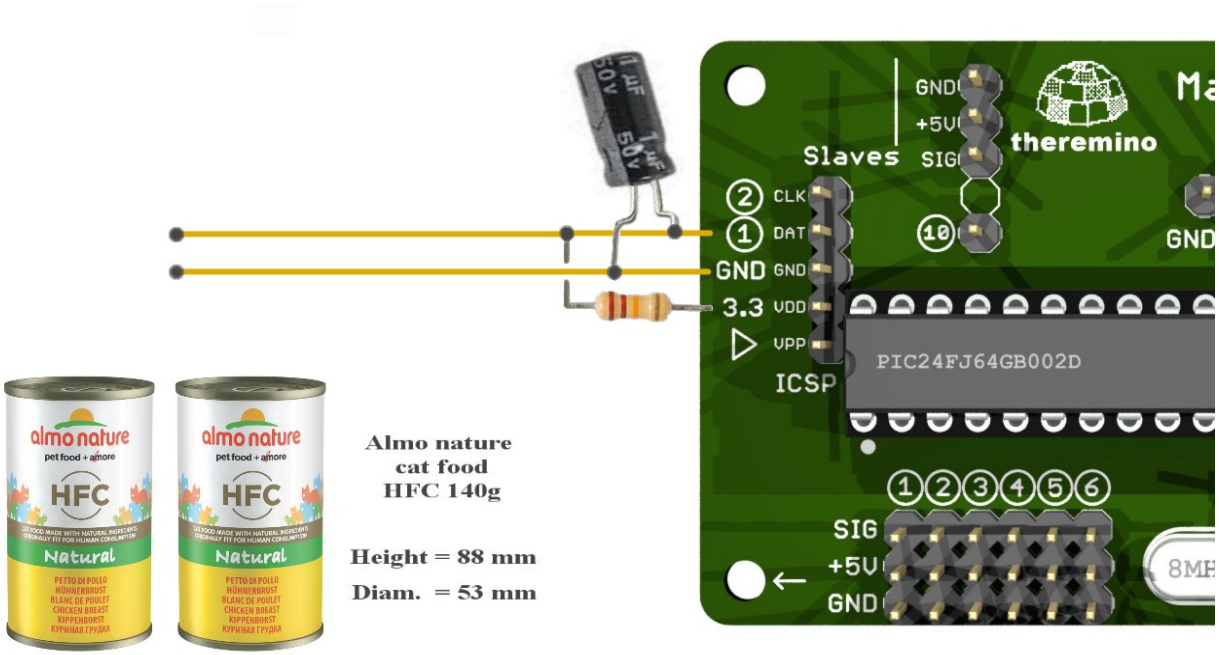

# Emotion Meter Hardware

# Assembly plan

With theremino system we can build a great eMeter with just three components, a Master module, an 1 uF capacitor and a 22k resistor (and two cans of cat's food). Total cost just over ten euros.




If you can not find an 1 uF ceramic capacitor, you can replace it with an electrolytic type. Do only care that the negative side is connected to GND.



# Mechanical construction

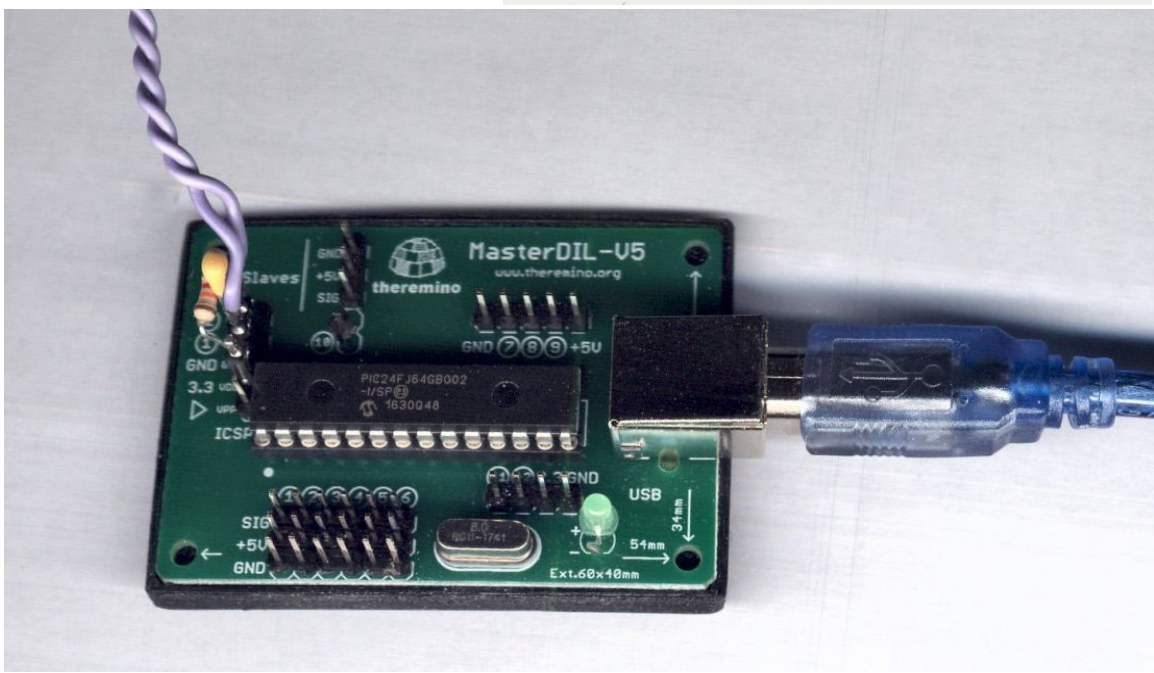
Take a three-pin female connector and welding the resistor between the two extremes.

Then weld the capacitor between the center and an extreme.

And finally, weld two wires in parallel with the capacitor.

The wires must be small and soft and it is good twist them to each other because that will form a convenient and flexible cord to the cans.

In the next image you can see the Master joined to the connector.




You can put all in a plastic box, or you can leave it open, as can be seen above, and it will work just as well.

If you leave without box be careful not to place it on metal surfaces while it is on.

# Electrodes

The type of electrodes used affects system performance.

The electrode must have a diameter such that when the hand holds it, must wrap it, without superimposing the thumb to the other fingers, but without being too space between them. So when used with people with larger hands or smaller than average, you may need to use a different diameter.

The electrodes used in the original instruments were made from two cans of tinned iron of about 4.5 cm in diameter, which are fine for most people.

In the 80's these cans were used to contain spray paint, deblocking oil or flux. The label was in paper, and was fixed to the tin can with a thin strip of glue, so it was very easy to remove and use them as electrodes.

The electric contact was made with two alligator clips, one for each cans, connected to the wires that ended in the measuring instrument. The cans were drilled at the insertion point of the alligator clipls to obtain a more stable connection.

Some versions uses a jack connector, as shown in the picture alongside.

# That cans use

A good choice are the cans of food for cats from 140 grams.

- They cost less than 2 euro and is also happy few cats.
- They have a diameter of 53 mm which is fine for all hands.
- Opening them remains a thick edge that does not cut.
- The edge often keeps them in shape even if you press a lot.
- The label and the adhesive can be easily removed.
- They are made of iron and coated with pure tin.
- You can also be soldered with the soldering iron, to stably connect them to the connecting wires.


**Almo nature**
**cat food**
**HFC 140g**

**Height = 88 mm**

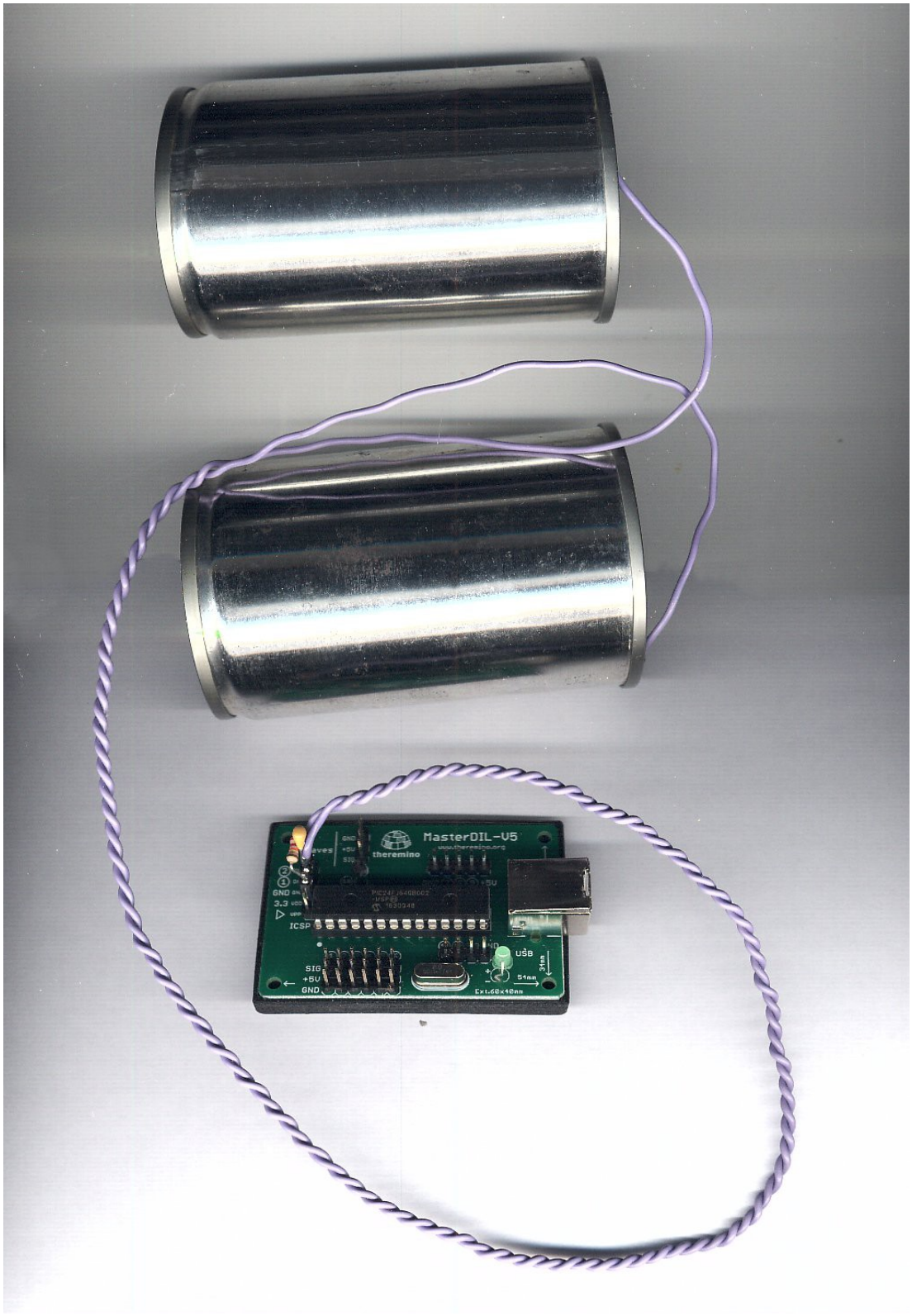
**Diam. = 53 mm**

The can be found here:
***www.arcaplanet.it/almo-nature-classic-140-g***

And even on eBay:
***www.ebay.it/itm/Cibo-umido-naturale-gatto-gatti-adulti-Almo-Nature-Cat-Classic-vari-gusti-140g***

Probably within a few years these links will become invalid, if so, just copy them into the search box of Google or eBay to find similar.

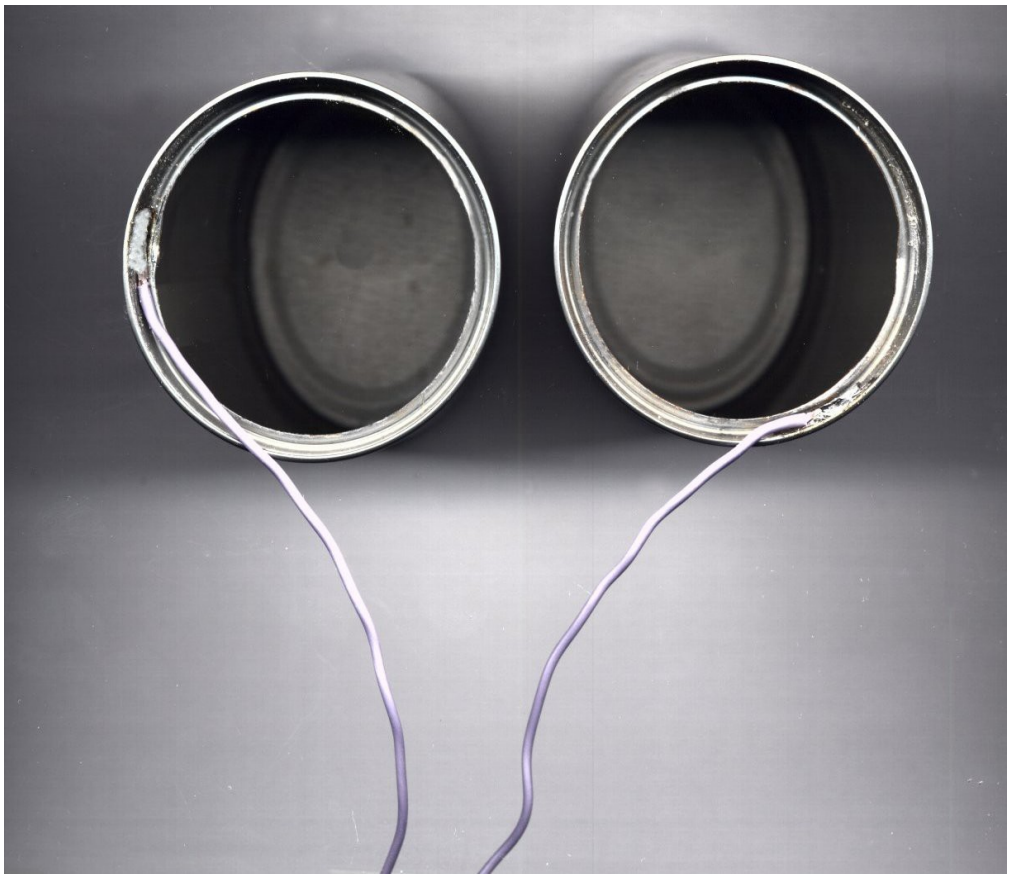
# Connection to cans

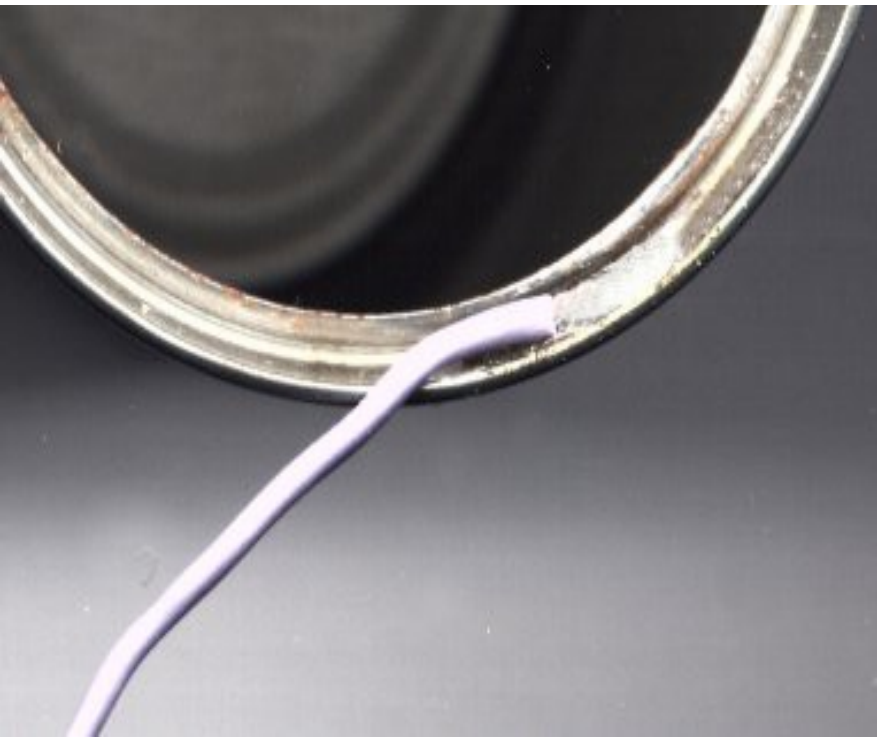



Use soft wires and small, long about fifty centimeters.

# Solder the wires to cans

The cans are tinned so it is easy to weld them. If they are not new, it is good to clean the welding point with sandpaper.



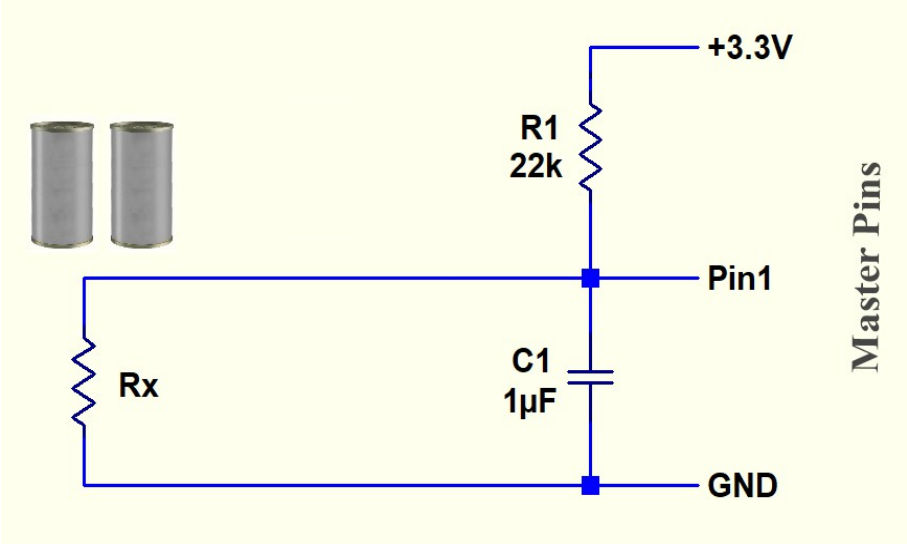


Here we see how to weld the wire.

If desired, you could also close the can with a plastic disc glued on the upper edge.

Then you could strengthen the thread, fixing the insulating sheath to the metal with a drop of hot glue.

# Principle of operation




The resistor R1, and the cutaneous resistance Rx, form a voltage divider.

This divider divides the 3.3 volts and produces a voltage in the central point which depends on the value of Rx.

The voltage is sent to Pin 1 of the master module, and an Adc measures it with accuracy better than 0.1%.

The condenser removes noise at line frequency induced by the mains electrical system, and any RF noise from mobile, WiFi, Bluetooth and other wireless devices.

The software knows the value of the voltage (3.3 volt stabilized by the regulator that is located in the master) and the value of R1 (22000 ohms) and thus can accurately calculate the value of Rx.

- - - - -

The Rx value is exactly the skin resistance value.

The measurement accuracy is greater than what you can get with analog circuits and do not even need to adjust the trimmers.

- - - - -

In a second step, the software calculates the value of TA (Tone Arm) starting from the skin resistance. The calculation is exactly the same as the original theta-meter. Only that the theta-meter to do the calculations they need someone to rotate the tone-arm potentiometer to balance the bridge, while the software calculates the TA instantly, without an human to help him.

# The resistance and TA calculation

We present the formulas of this page for educational purposes only.
You do not need to use them or even understand them.
All those calculations are done automatically in the software.

These formulas does exactly the same calculations that were performed by the original equipment by means of resistors, potentiometers and transistors.

Having a computer these calculations are made more easily, and with much more precision.

## The calculation of the skin resistance

The formula for calculating the resistance from "Vin" value, measured by the master module and normalized from 0 to 1000, is:

Res = 22000 * Vin / (1000 - Vin)

## The calculation of the TA

The formula for calculating the TA from the resistance is:

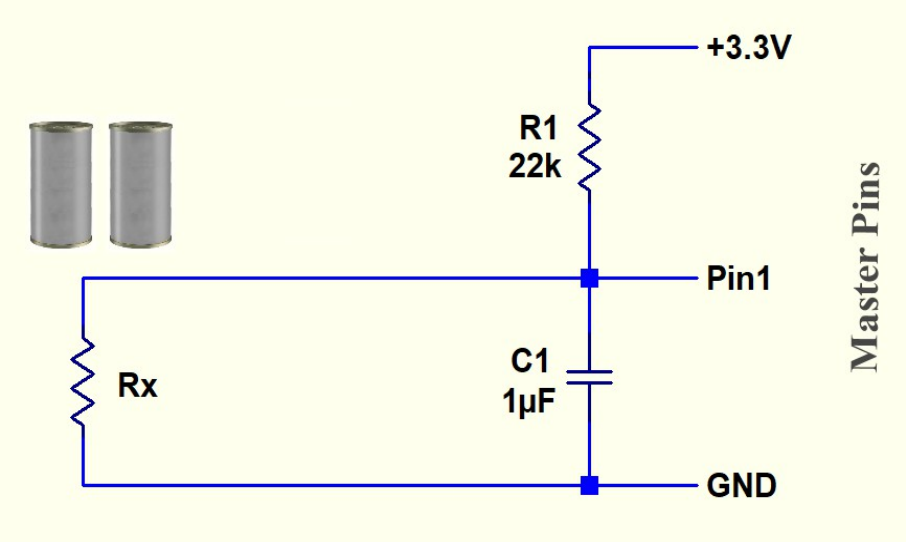
TA = Res / (Res + 21250) * 5.559 + 0.941

## Table of TA and resistance values

The following table shows the main TA values and the corresponding resistance values.

| TA | Resistance (Ohms) |
|---|---|
| 0.941 | 0 |
| 1 | 227 |
| 2 | 5 k |
| 3 | 12.5 k |
| 4 | 26 k |
| 5 | 57.5 k |
| 6 | 215 k |
| 6.49 | 12 megs |
| 6.5 | Infinity |

# Accuracy without calibration




One of the merits of this scheme and that when the device is just mounted then it is already calibrated. There are no trimmer to adjust.

Plus you get an absolute stability in time, because there are not transistors that can vary in characteristics with temperature, it components which can change in value over time, or trimmers that can move or get dirty.

The only component that determines the accuracy of measurement is the 22k resistor. A resistor from 22k to 5% (red orange red gold) has more than sufficient precision for the measures that need to be done with this unit. You already get the precision of a classic eMeter well calibrated.

IMPORTANT NOTICE
An exaggerated calibration is useless,
a 5% precision is already more than enough for these devices.

But, if you really want …

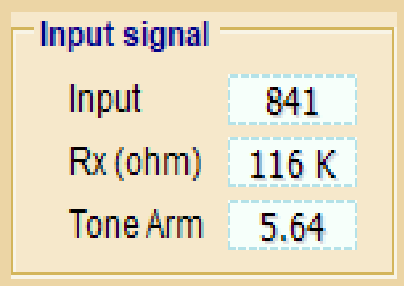
## Get more accuracy

Using a digital meter, measuring about twenty resistors and using the one that comes closest to 22000 ohms.

If there is a resistor with a value between 21800 and 22200 it gets towards the 1% accuracy.

And wanting the possibility also exists to perform a digital calibration, which can push the accuracy to 0.1%, as explained in the next page.

# Precision calibration




The software directly measures the resistance and converts it into TA with a mathematical formula, then with an absolute precision.

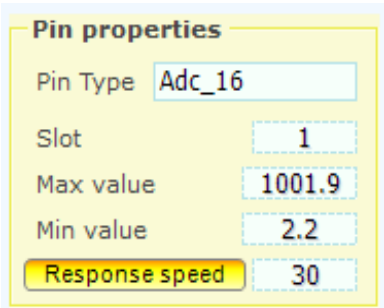
So we do not need expensive and hard to find 5000 and 12500 ohms resistors, prescribed to get exactly the values 2.0 and 3.0 of the TA. But we can use conventional resistors with standard values, and even not precision type.

This method also compensates for input leakage currents Adc and can arrive to 0.1% accuracy (in the area of the possible skin resistances, ie approximately between 10 kohm to 200 kohm).

The calibration is fully digital, there are no trimmer or other components that can age, so the accuracy will remain unchanged over time.

**Instructions for calibration.**

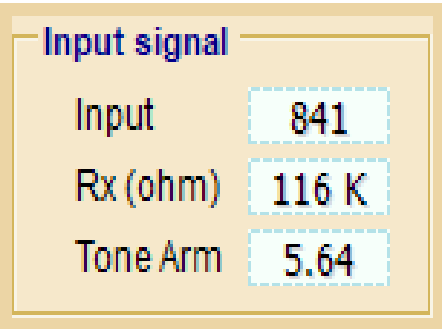
- Obtain an approximately 1000 ohm resistor (would be fine from 680 ohms to 1500 ohms).
- Obtain a second resistor of approximately 470 kohm (would be fine by 330 kohm to 680 kohm).
- Measure the two resistors with a digital tester and then connect them, one at a time, to the two electrodes of the Emotion Meter.
- Select the Pin 1 on the application HAL and adjust the "Min Value" and "Max Value" boxes to get the same measurements that are obtained with the tester.
- Adjust "Min Value" when measuring the low resistor value and adjust "Max Value" when measuring the highest value resistor.
- Repeat several times the two settings because they affect a little each other.
- Normally you adjust the two boxes (handwriting the decimals) with slightly higher values of one thousand and zero, as seen in the image at right.




- During the measurements it is good to stabilize the measured resistance value, by enabling the "Response speed" button (must turn orange).

  Remember then to disable this button (which must return to light color), otherwise the EmotionMeter needle will be slowed.

# What is measured




What is measured is not the internal resistance of the body. To verify this just wet your hands with water and salt, or with conductive paste for ECG, tighten the cans and measure the resistance.

In this way it reduces almost to zero the contact resistance between the hands and the cans and what remains is a measure of the internal resistance of the body.

With this experiment you verify that the internal resistance of the body is less than 500 ohms, hundreds of times lower than the normal resistance due to the contact between the hands and the cans.

Possible variations of the body's resistance could presumably be in the range of a few tens of ohms, thus totally negligible.

So the resistance detected by the E-Meter is practically only the contact resistance between the skin and the metallic surface of the electrodes.

This resistance is influenced by the sweat, the salinity and the pressure that is exerted, which increases the skin's surface that comes into contact with the metal.

- - - - -

Sweating, of course, it is linked to emotional state. But there is a second mechanism which causes faster reactions.

When the skin is damp from the sweat and keep the electrodes as prescribed, without pressing, may be enough minimal muscle twitching, unconscious and entirely unintentional, to cause rapid and very large resistance changes.

Summing up:

- The slow and continuous decrease of the resistance, what in the literature is called "Electrode heating", is caused by the accumulation of moisture in the space between the skin and the metal.
- The slow variations are caused by variations in the sweating.
- The rapid changes are caused by pressure involuntary changes.