theremino

•the•real•modular•in-out•

System Theremino

Electronics
ion chamber

Before starting an important warning

In the document on the construction of the chamber we wrote that **you have to treat well the thread tension Central.** But this critical point has often been overlooked. Who does not want "trouble" must read this page carefully.

The material of guy who tends the central wire should be chosen with care. It must be resistant to stretching, perfectly insulating and non-hygroscopic. If the tendon stretches the central wire loses tension and the chamber becomes unstable and sensitive to mechanical movements.

It seems incredible but some materials, apparently insulating, conducting enough to cause severe electrical disturbances (oscilloscope trace of TP3 very noisy, even up to half a volt of noise). The tests with ropes of hemp or cotton gave results "terrible."

Defects can go from having a chamber very sensitive to mechanical movements to sudden bursts of noise and the reasons are:

- Wire is not taut, tie rod that is stretched.
- Guy hygroscopic which is moistened and internal shocks is small.
- Temperature changes that cause stretching and consequent crunches.

To secure good guy, you have to put a drop of Attack at the point where they exit from the hole and bends. While the Attack dries secured with transparent tape drive "Scotch." You should not use black electrician's tape because it is rubbery and deforms before it dries the Attack, and at the end of the wire is not taut.

We have already written but it should be remembered: The cover that holds the electronics has an important function of elasticity. While pulling and paste the rod, you have to hold down the lid.

If necessary, get help from someone who held down while attaching the tie rod. At the end of work check that the wire is tensioned by pressing the center of the lid. Check again a few hours later and sand the lid by pressing it sells, then the guy is not enough tension and you have to redo the draft.

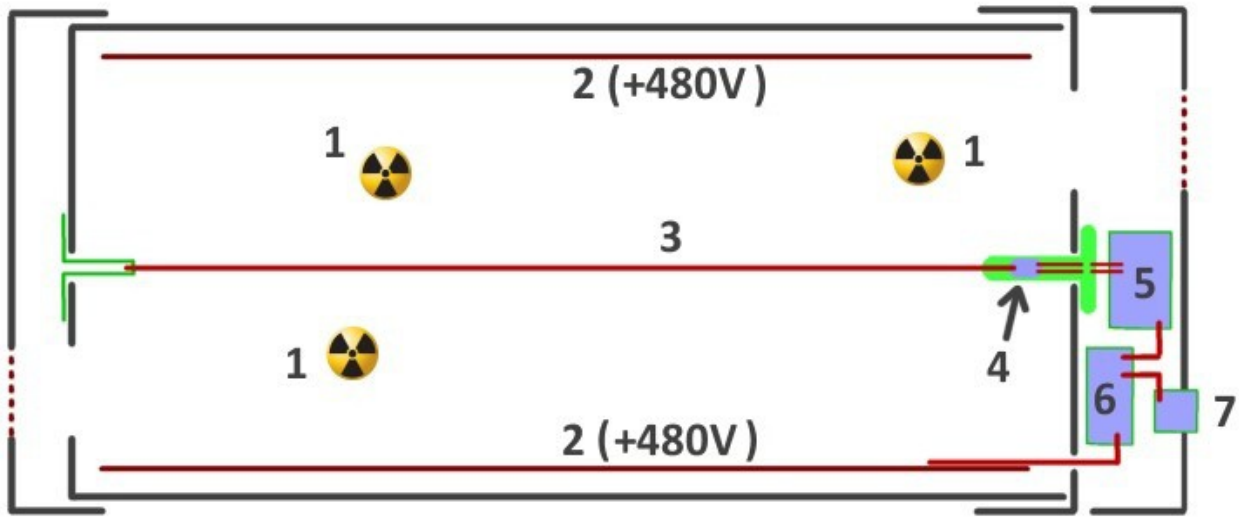
In the picture to the left you see a thread made by isolation outside of a telephone wire. The first chambers were well done, but it is difficult to use it because if you pull too much tears. Then, after several failed attempts with strands of hemp and cotton, we tried the nylon of the image to the right. It works but it's too hard, it is hard to bend and tends to slide while it is fixed.

In the end we found the perfect solution, nylon ties!

They are perfectly insulating, resistant to any traction without stretching and without tearing. They are flat, they bend easily and also have lines that help to prevent them from slipping while you fix.

You must use cable ties very small, about two millimeters wide and about six inches long.

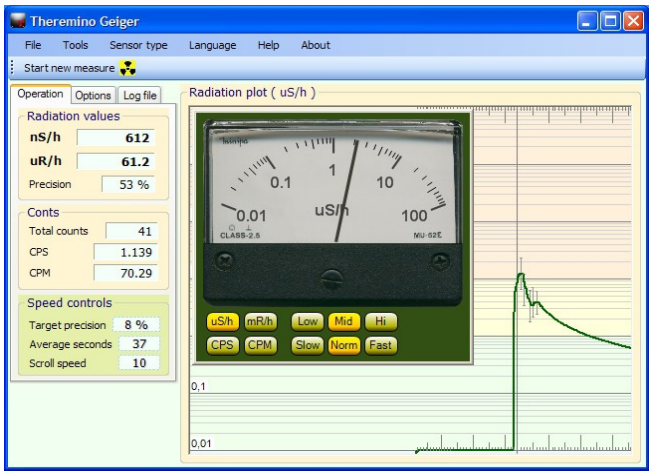
Wiring diagram functional



Each disintegration of Radon **(1)** ionizes the air and produces thousands of electron-ion pairs. The strong electric field in the chamber quickly attracts the ions toward the center electrode **(3)** and the electrons toward the coating **(2)**.In a few milliseconds all the electrons produced by the disintegration of the single crossing the high voltage generator **(6),** the amplifier **(5)** and the FET **(4)** and recombine with the positive ions.

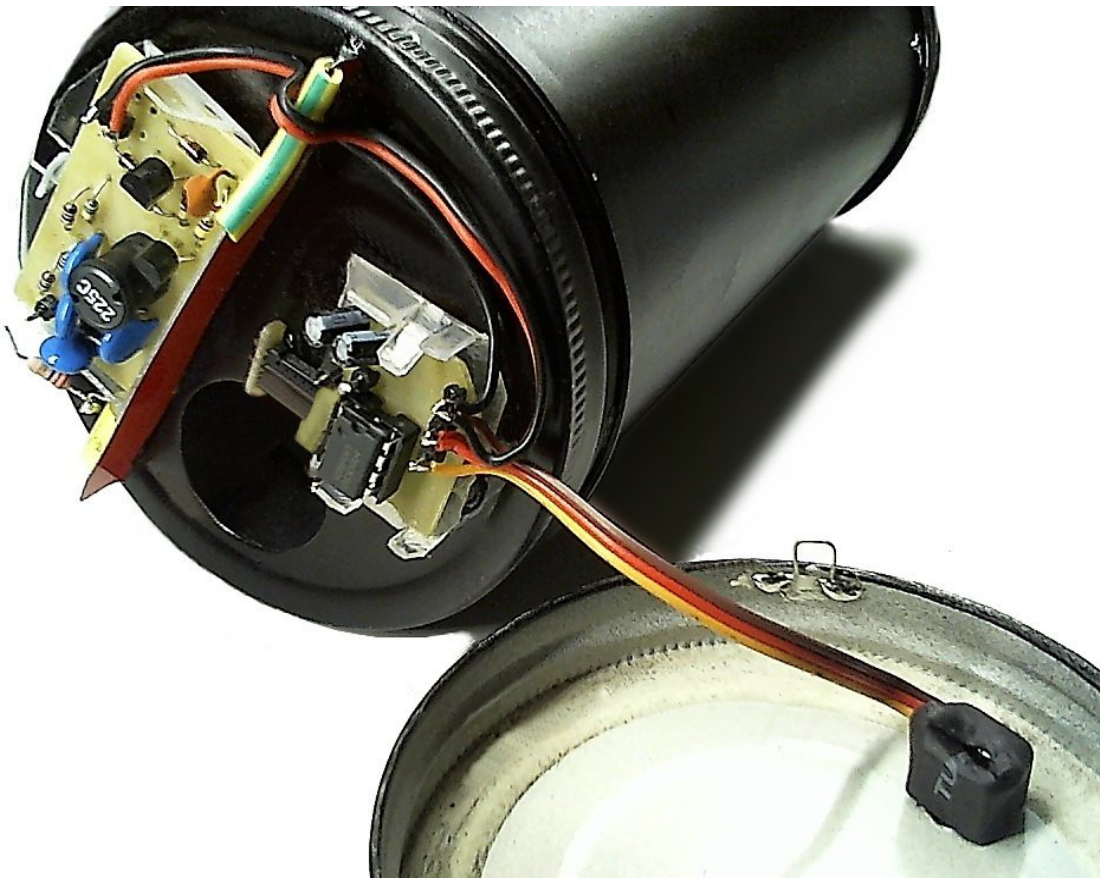
The weak current of electrons is first amplified by the FET. Then the'Amplifier and discriminator pulse width **(5),** discard pulses of low energy and the island sun alpha disintegrations produced by radon and its descendants.

The output connector **(7)** can be connected directly to a Standard PIN configured as a simple "Counter" (Not "FastCounter" that would be wasted for a few pulses per second of Radon).



Normally you use a module Theremino_Master that provides the power for the ion chamber and sends counts to Theremino_Geiger software, via USB. Only one Master can power up to six ion chembers, with links to hundreds of meters long and collect all of the data. Some of these could be replaced with six chambers probes Geiger rays for Alpha, Beta and Gamma or with environmental sensors, to measure, for example, the mm of rainfall, temperature and humidity.

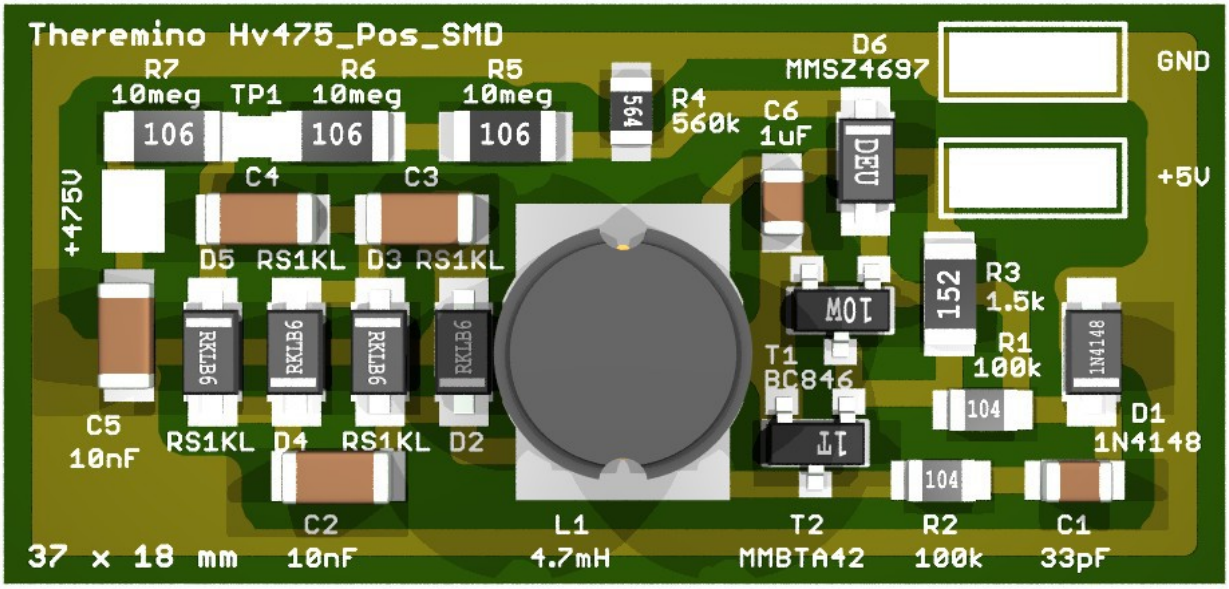
View all links

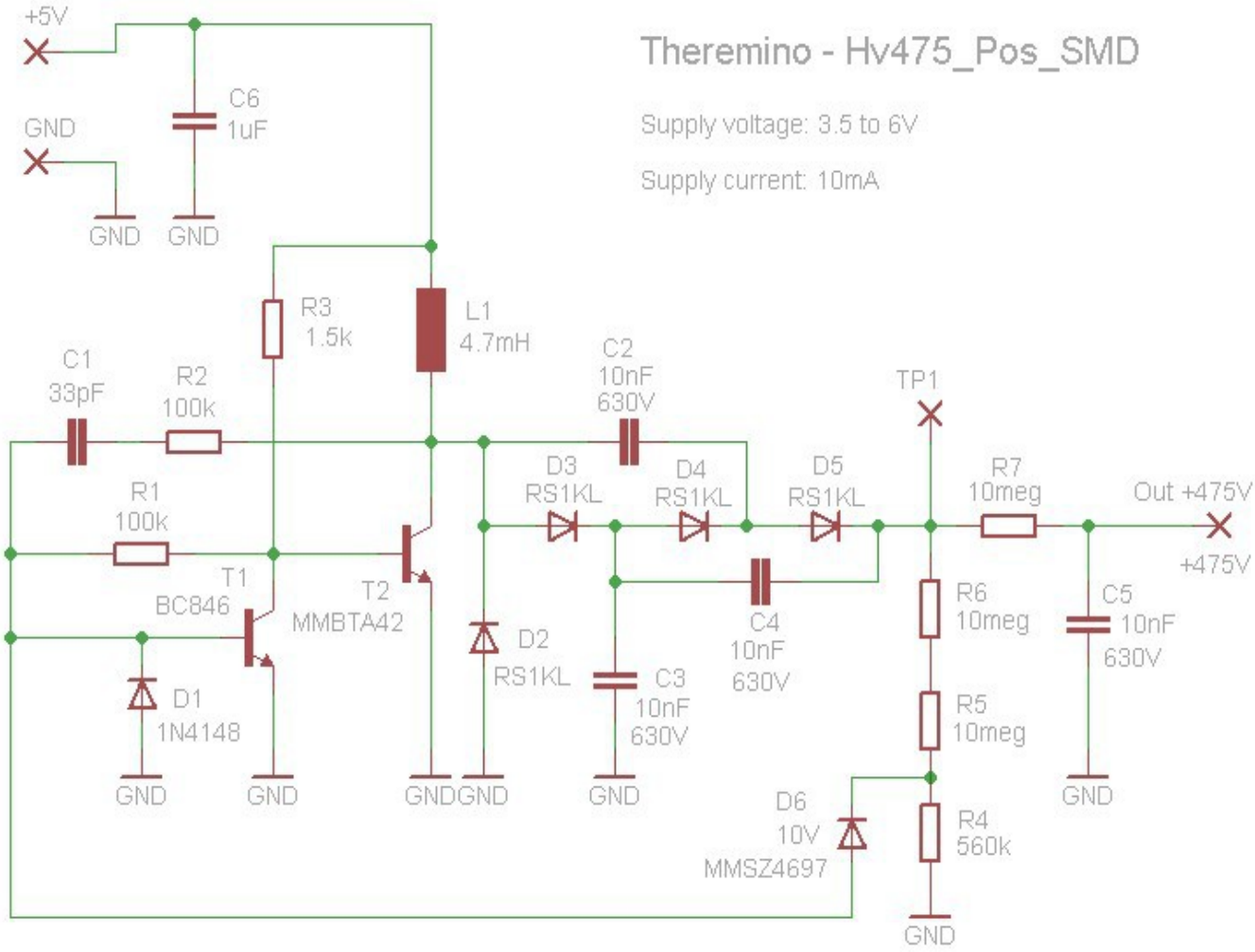


In this picture you see the new simplified wiring. In early versions of the modules were interconnected with connectors, but it was difficult to make them fit in the small space available.

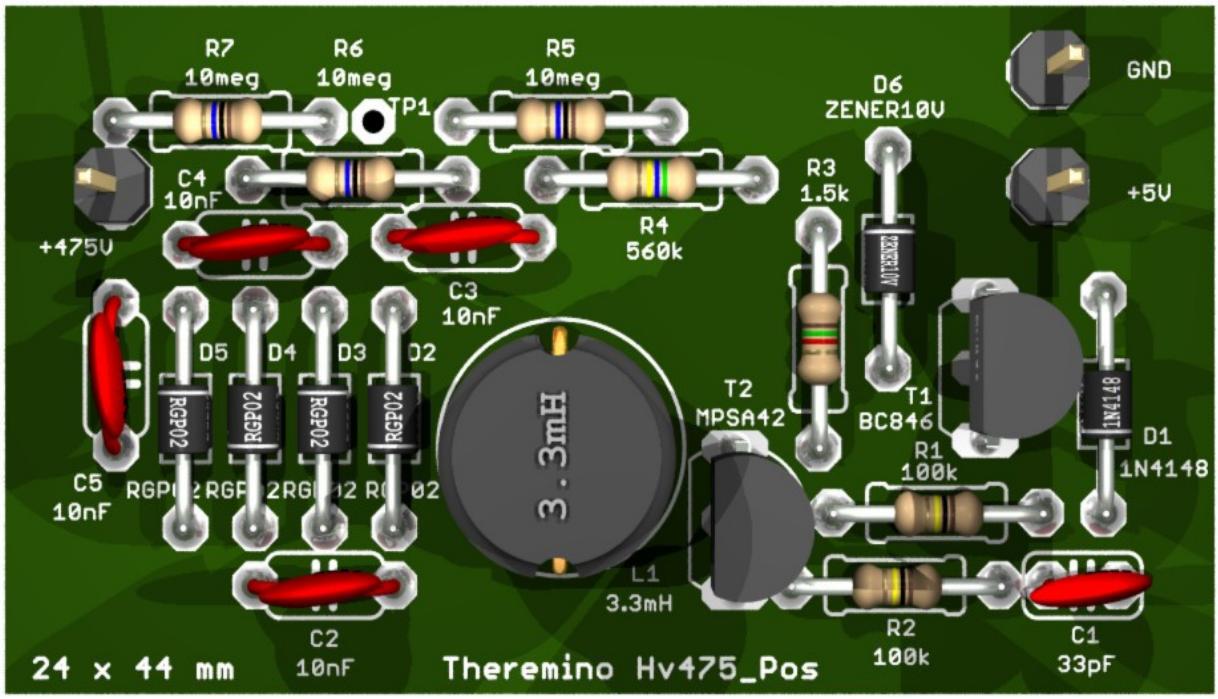
By eliminating the wiring connectors has become very simple. And also you can intervene without connectors on the modules easily, just pull them out and turn them upside down. If you need to make operations difficult, just unsolder the resistor voltage and all modules can be separated from the chamber.

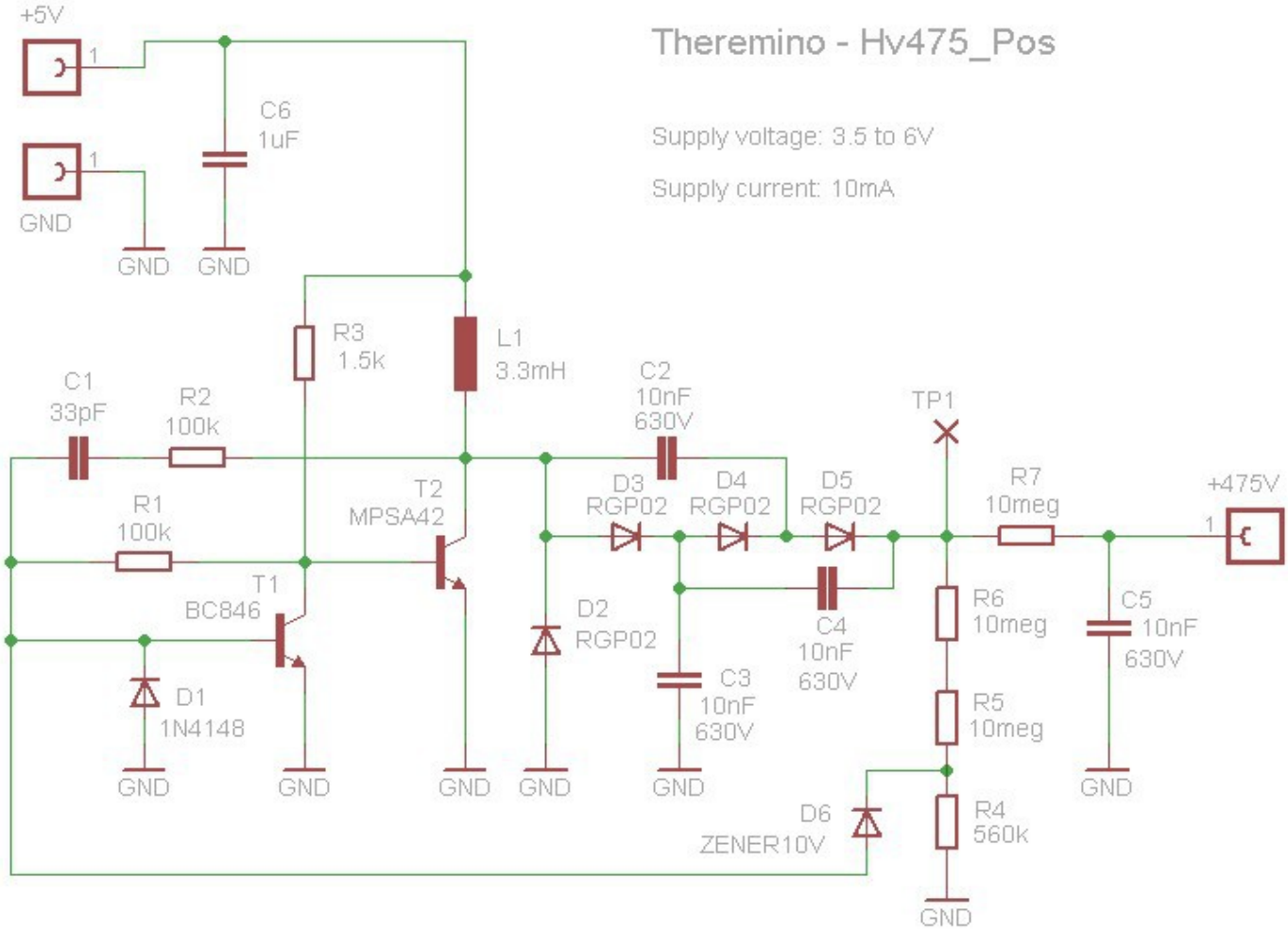
High Voltage Generator – SMD version





High Voltage Generator – ThruHole version





High voltage generator - Notes

There are two versions of the high voltage generator. Some people prefer to do it entirely in SMD, others prefer the traditional resistors. For both versions the circuit diagram is the same, the connectors are in the same position, and also the arrangement of the components is very similar.

These circuits are called HV400 because initially they used a voltage of 400 volts but later we decided to raise the tension and we have established a nominal 475 volts.

The output voltage of about 475 volts is not critical, the number of counts changes very little with voltages from 450 to 500 volts, but if possible it should control it. It would also be good to try that is able to rise to at least 600 volts. This margin ensures that the stabilization will continue to operate, even with extreme ambient temperatures. (Avoid, however, to work the chamber outdoors for long periods because it suffers from moisture).

It is not possible to measure the voltage with a regular tester, use the probe of this page:
http://www.theremino.com/blog/gamma-spectrometry/hardware-tests # hv

Check that the voltage can go up to 600 volts and over

To do this control remains connected to the voltage meter and connecting a second 680k resistor in parallel with R4. In this way halves R4 and the voltage should go up to 1000 volts.

Normally, the voltage will not rise up to 1000 volts but at about 600-700 volts. If the voltage exceeds 600 volts you can rest assured that the stabilization will always work well, if you do not exceed this could be due to a too low L1 (2.2 mH) or to other components a bit out features.

To increase this tension reduce **R3** to 1k or 820 ohm (if with 820 you can not reach 600 volt then there is some error or some damaged component).

When everything is OK, you remove the resistor in parallel to R4, the voltage stabilizes between 450 and 500 volts, and this control is finished.

Changing R3 causes a change in the working voltage, you will probably have to retest it, and even retouch R4.

Ensure the working voltage to be between 450 and 500 Volt

The nominal value of the voltage is 475 volts. A voltage of less than 450 or greater than 500 volts could be caused by the zener, not exactly 10 volts or by other components.

- To increase the tension reduce **R4** at 560k, 470k, 390k.
- To decrease the tension increase **R4** at 820k, 1Mega and beyond.

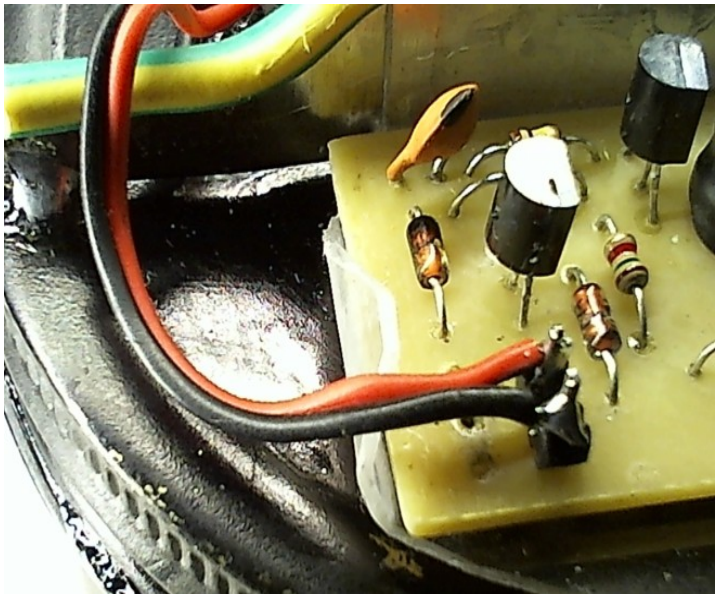
To calibrate the voltage more accurately, use for R4 the closest standard value, but higher, so that the voltage is a bit low. Then put in parallel a resistor between 1 and 10 Mega, up to bring the voltage to approximately 475-480 volts. Finally welding this resistor in parallel to R4.

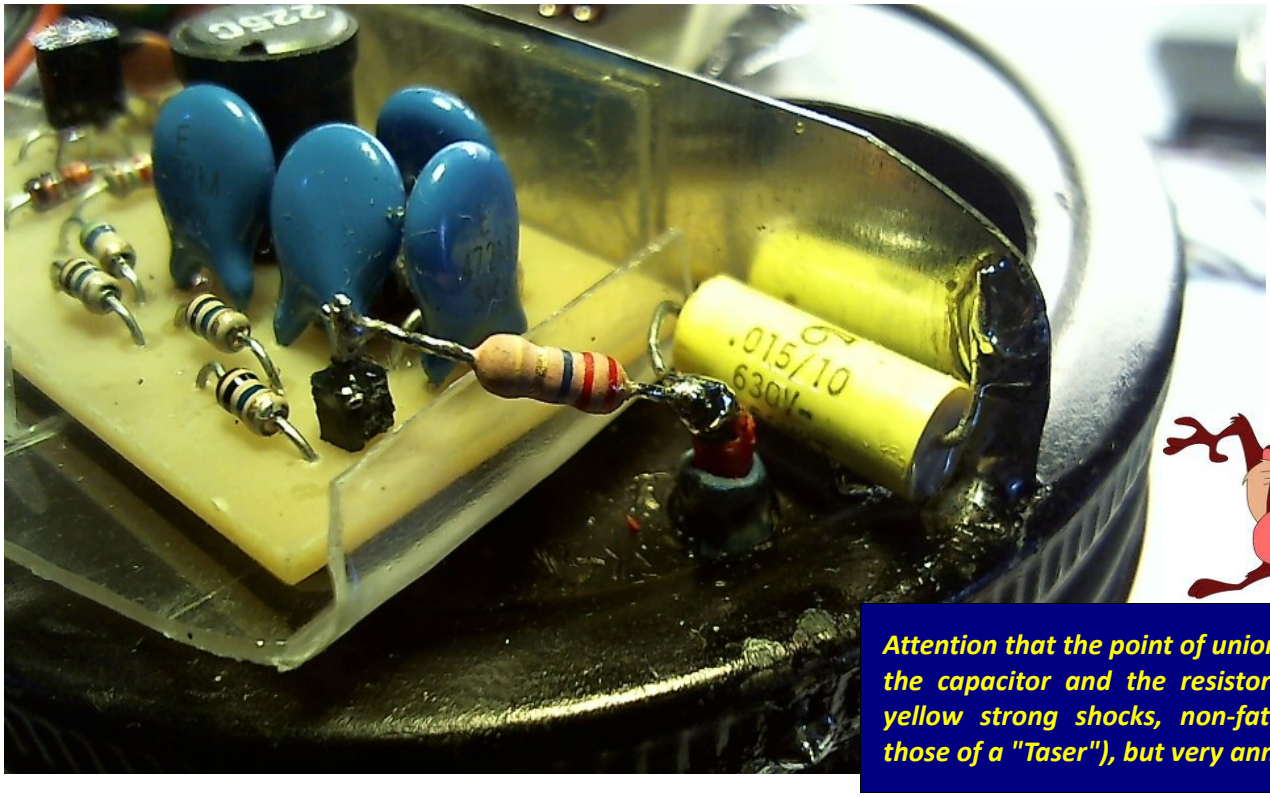
High Voltage Generator - Links

Here you see the new wiring method, with the wires soldered, without connectors.

The high voltage generator is connected with only two wires:

- Black wire = Ground
- Red wire = +5 V





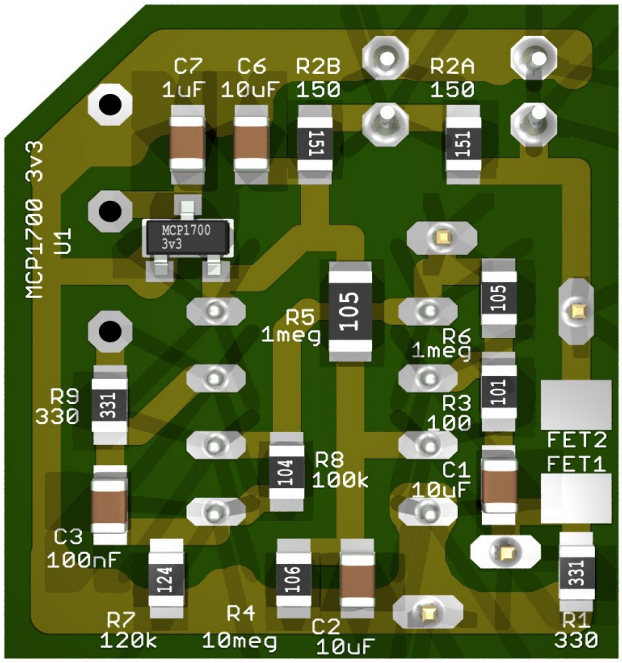
Attention that the point of union between the capacitor and the resistor can give yellow strong shocks, non-fatal (below those of a "Taser"), but very annoying.

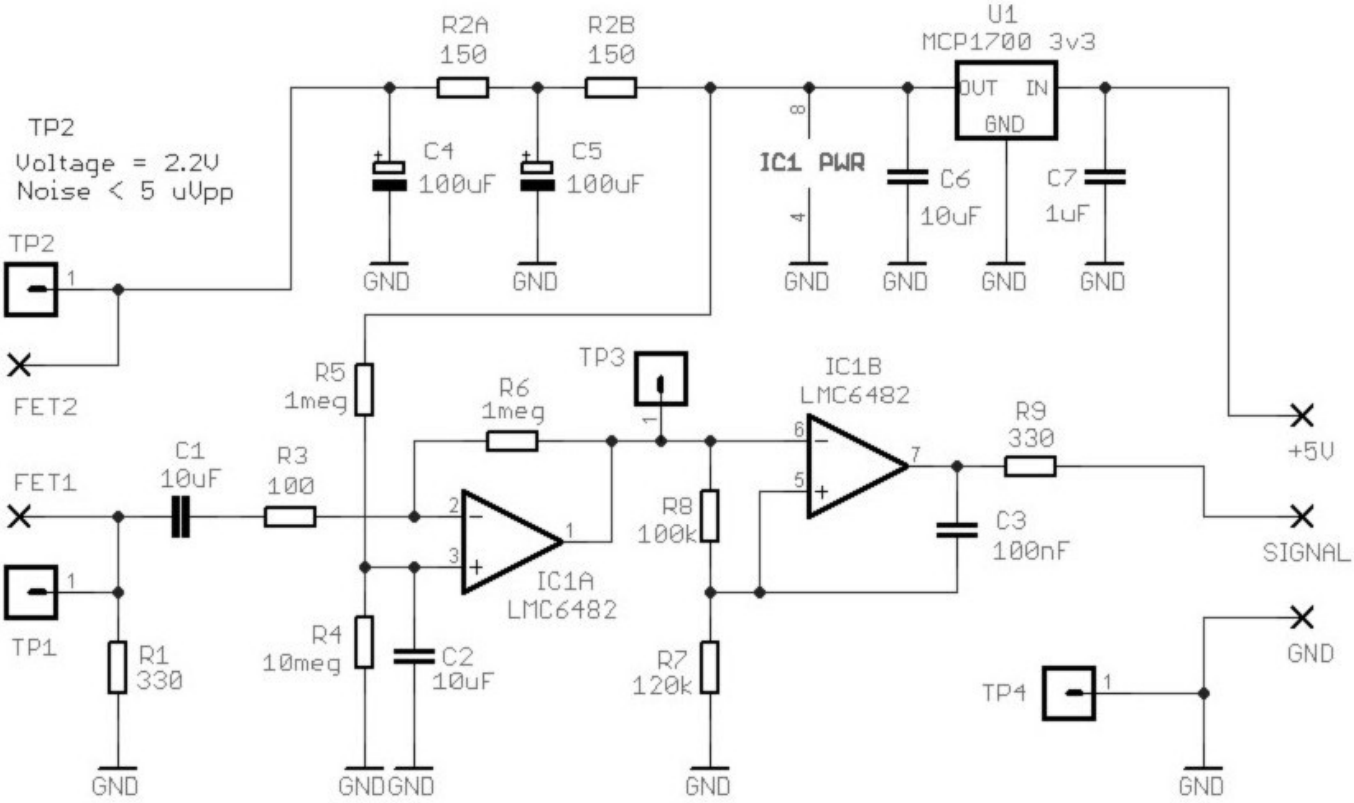
The high voltage output is connected with a single 22 Mega ohm resistor (if it is, it could also fit a single 10 Mega ohm resistor, or two in series).

Between the terminal of the high voltage and the mass of the can is welded a capacitor of at least 600 volts and at least 10 nF (even better if it is from 15 nF, 33nF or even higher, up to 100 nF).

*To minimize the uptake of electrical noise must **maintain very short** the connections of the junction between the resistor, capacitor and high voltage terminal.*

Amplifier signal - Scheme





TP1	IC1A	TP3	IC1B	SIGNAL OUT
Voltage = 1.1V Noise < 50 uVpp Pulses 0.5 to 2.5 mV	Gain 60 dB Noise out < 50mV pp	Voltage 3V Neg. pulses 0.5 to 2.5 Volt	Schmitt trigger Pulse sensitivity 1 Volt (approx)	Normally 0 Volt Pulse 3.3 Volt Pulse time 5 mS

Signal Amplifier - Operation

The controller **U1** transforms the 5 Volt USB, which is very noisy (even 100 mV of noise), in a 3.3 Volt very stable and with noise around 500 uV. **R2A, R2B, C4 and C5** filter further 3.3 volts and feed the **FET** with a voltage of 2.2 volts almost noise-free (less than 5 uV peak-peak).

The **FET** amplified approximately 5000 times the weak current pulses (about 1 pA), produced by ionization and high pulses produces about 5 uA. These pulses pass through **C1** which eliminates the DC component and lets only the changes. The current pulses are then amplified by **IC1A** and transformed into voltage pulses of a few volts negative amplitude.

R3 acts as a "shock absorber." If you lower **R3** (Eg 10 ohms), the pulse edges of **TP3** become more steep, if the rises (for example to 1000 ohms) the pulses will soften. It 'good that the pulses are fairly square but not too "overshoot". A resistor **R3** from 30 to 100 ohms is a good compromise. Anyone wishing to make the perfectionist could lower R3 to try to get the best possible shape for the pulses. But it is more like the satisfaction of seeing beautiful oscilloscope, function and the number of counts do not change.

R5, R4 and C2 produce a well-filtered voltage of 3 volts establishing a precise reference to **IC1A**, Which then stabilizes with an output voltage of 3 volts.

The exit of **IC1A** about **TP3** are the pulses produced by the disintegrations but are not all of the same amplitude. The weakest down from 3 volts to 2.5 volts base, the strongest fall to zero. This happens because some disintegrations occurring near the outer wall or in the end zones of the cylinder, where the electric field is weaker.

R8, R7, C3 and IC1B act as "schmitt trigger" that only passes pulses that exceed a certain voltage. The voltage limit is given by the value of **R7**.

With R7 = 100k you count only pulses that go down at least a volt and a half.
With R7 = 220k you count only pulses that go down to at least 1 volt.
With R7 = 330k you count only pulses that go down to at least 0.7 volts.
With R7 = 470k you count only pulses that go down at least half a volt.

Increasing the value of **R7** also enhances the sensitivity of the chamber as you collect also the events that happen in the end zones of the cylinder where the electric field is weaker. But increasing the sensitivity also makes the chamber more sensitive to mechanical disturbances. It should not exceed 220k, otherwise the chamber would become too sensitive to external noise and vibration.

In the past we used ion chambers **for R7** a standard value of **220k**.

At the output of **IC1B,** pulses are positive and standardized, both in height and in width (3.3 volts and about 5 mS)

The resistor **R9** carries the signal to the output cable and the island **IC1B** by the capacity of the cable itself. In this way not generate auto-oscillations and overshoots even with long cables. You can then use cable lengths of up to several hundred meters.

Amplifier signal - Connecting Cables

If the wire that goes to the Theremino Master PIN is short you can use the normal male female extension cables unshielded. It can also connect several extensions in series to increase the length.

If the cable is longer than a few meters it is good that it is shielded (a standard microphone cable with the cord strain relief and the two wires red and black is fine).

For safety reasons and according to the law, the cable, even if shielded, should not go in the ducts or pipes in the electrical system.

Important: If the cable is longer than a few meters, you must stop the signal wire and connect it through a 100k resistor, placed within a few centimeters from the Master PIN. This prevents noise from the cable may exceed the tolerable voltage input from Pin (3.3 volt maximum). If it exceeds 3.6 volts, with current greater than 100 uA, the micro-controller interrupts the communication with the USB. If communication is lost then you must manually restore the HAL application, press the button "Recognize"

Amplifier signal - Check the voltages

To ensure that the chamber works well, just mount it carefully and test it with Theremino Geiger. But, having a meter, it would not hurt to also give a controlled voltages.

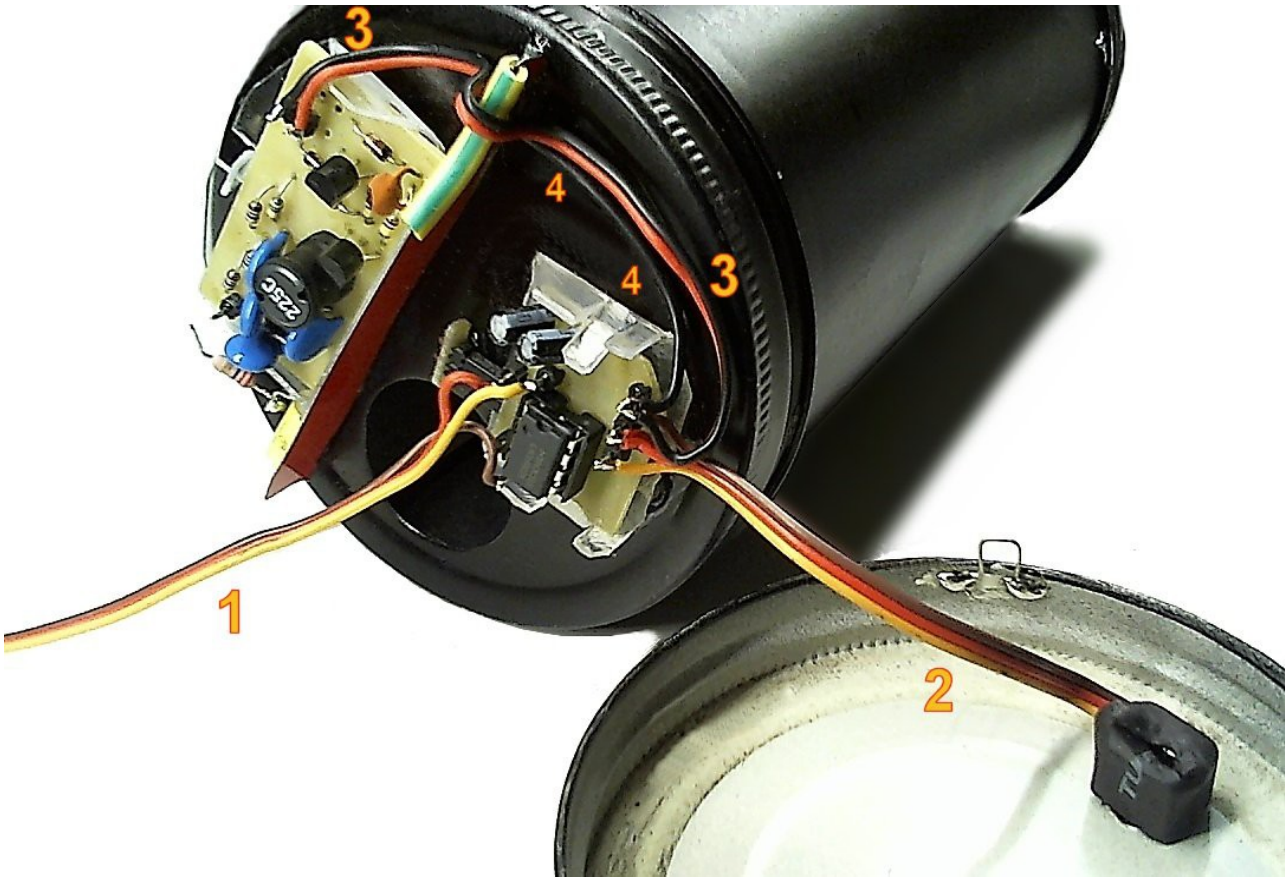
Turn on, wait thirty seconds, and then check with a multimeter the voltage between GND and points TP1, TP2 and TP3.

During this check, since you are taking the top cover open, you must try not to disturb the FET. Do not put your hand in the hole, remove any energy-saving lamps. Avoid shaking the chamber and maybe connect the tester with wires and wait 30 seconds, without moving anything, that tensions stabilize. Also seek to shield the upper part, partially closing the lid. All lids and jar must be earthed. Those with their lower and upper anchors welded wire with a provisional, so that you can open and close during the tests.

- On TP1 there must be about 1.1 volts (minimum 1 volt and 1.2 volt maximum)
- On the TP2 there should be about 2.2 volts (minimum of 2 volts and 2.4 volts maximum)
- On TP3 there should be about 3 volts (minimum 2.9 volts and 3.1 volts maximum)

By placing an oscilloscope you can either measure the noise at TP3 show that the pulses, as explained in the last pages of this document.

Amplifier signal - Links



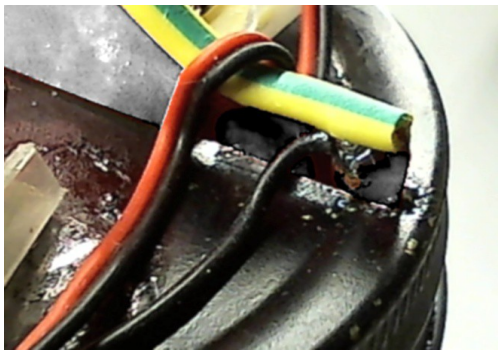
(1) The three wires that you see on the left are provisional, they pass into the gap between the cylinder and cover, and are used to connect an oscilloscope to test points. In this image were soldered to GND, TP2 and TP3 but it would be best to connect them to GND, TP3 and SIGNAL output. These three wires are unsoldered at the end of the test, before sealing the chamber.

(2) The wires SIGNAL (yellow or white), +5 V (red) and GND (brown or black) ranging from amplifier module to the connector on the lid.

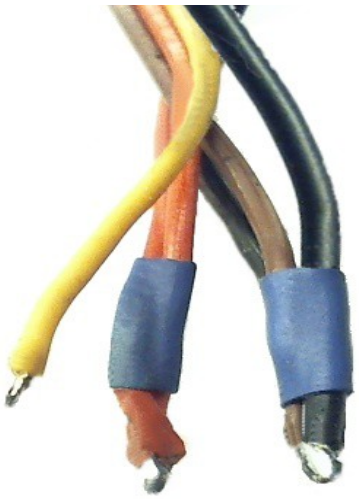
(3) From the amplifier module also includes a two-wire cable: +5 V (red) and GND (black), which brings power to the high voltage generator.

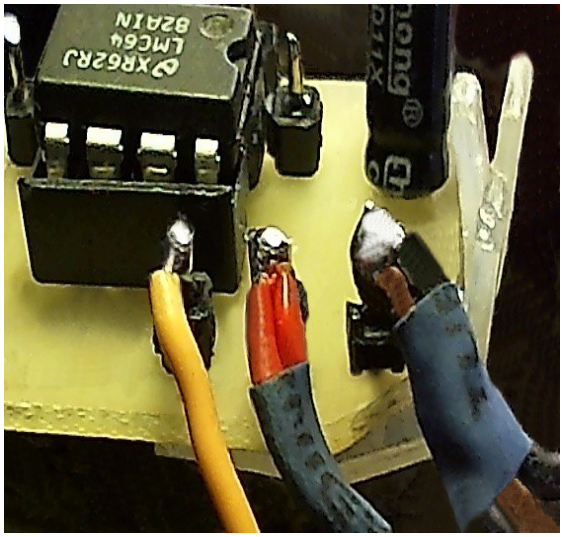
(4) From the mass of the amplifier also includes a black wire (barely visible), which connects to ground containers.

In the picture to the right you can see the black wire that connects the cylinder with the mass of the printed circuit board. The wire is welded to the vertical plate under the insulator yellow green.



Solder the wires





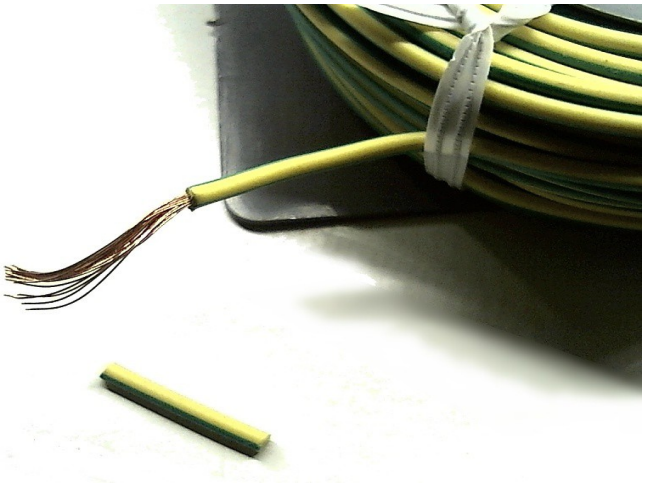
When the wires are two (or three) it is good to keep them together with a piece of the sheath. This makes it much easier to weld and unbrazed terminals of printed circuit boards.

Before making connections all the wires must be stripped, tinned and curled one by one. The pond must be leadedWith flux and thin (half a millimeter). Even the terminals of the circuit boards must be prepared, stagnandoli with a nice shiny ball.

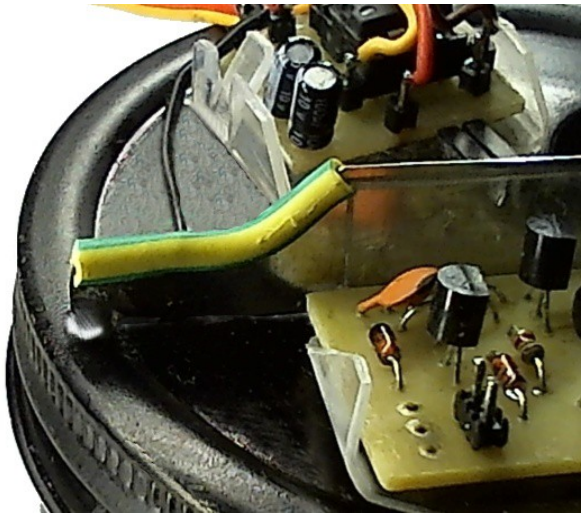
When welding you do not have to "brush" with a soldering iron. The welder must supported and held stationary for a few seconds in order to heat well. While it warms you add a little 'tin cool. Just stop smoking you move the welder. If you do it right the weld is shiny and round.

Protection on the metal separator

This protection serves to prevent the plate can cut the threads which pass above.



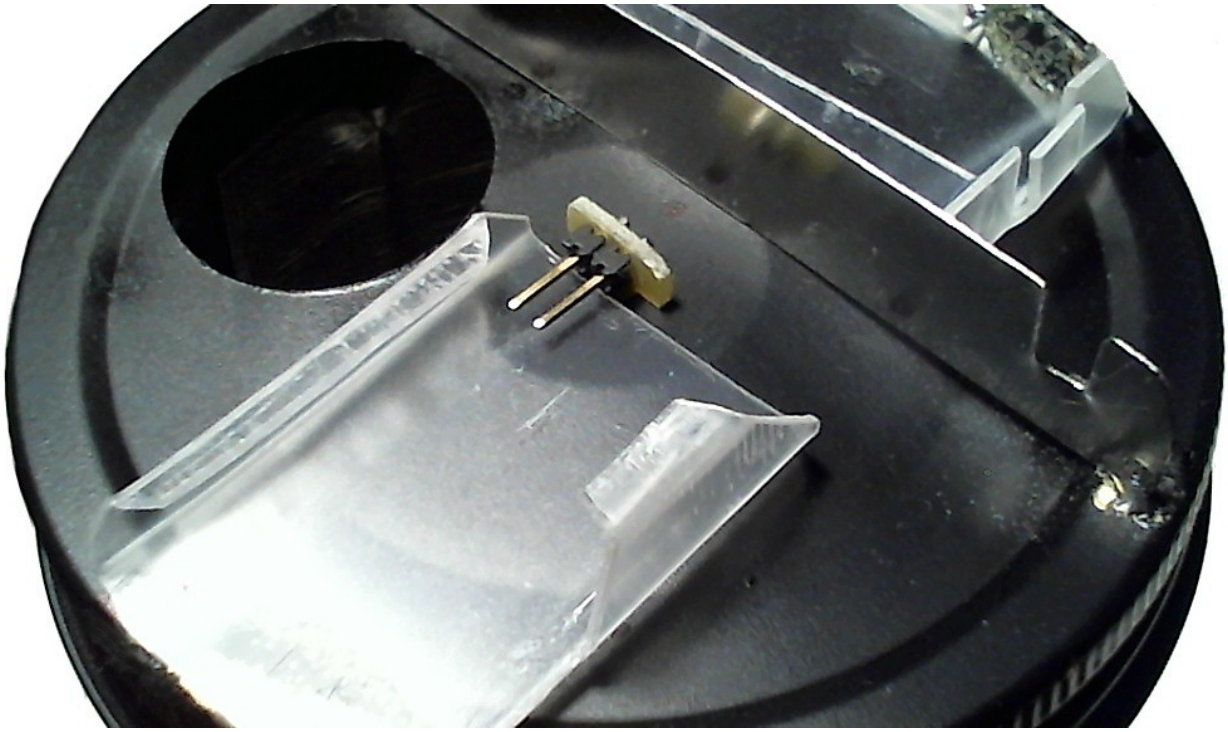
Peel a few inches of wire for electrics and cut it to length with the clippers.



Pour two drops of Attack in the tube and paste it on the transition zone of the wires.

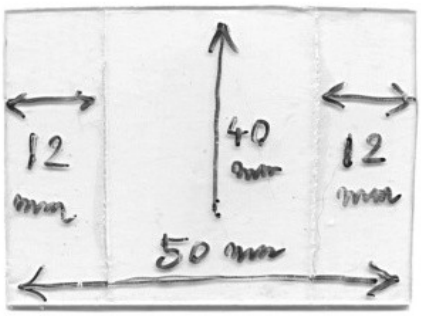
The insulators plastic

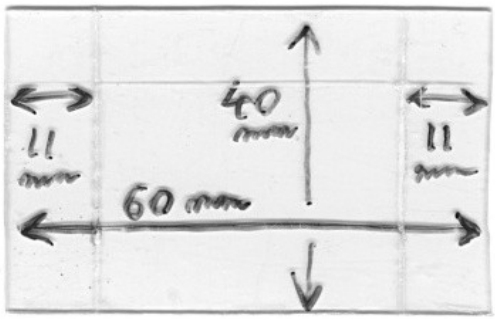
Use thin plastic (from 0.4 to 0.8 mm), otherwise it becomes difficult to bend. If the plastic is not thick keeps the folds, it makes too much force, ripping the paint and come loose easily.



How to glue you can use the Bostik, preferably transparent, or the Attack or, better yet, a two-component glue.

The insulators are glued only on the outer edge to free up the center of the lid. The lid has an important function of elasticity and must be able to move vertically.

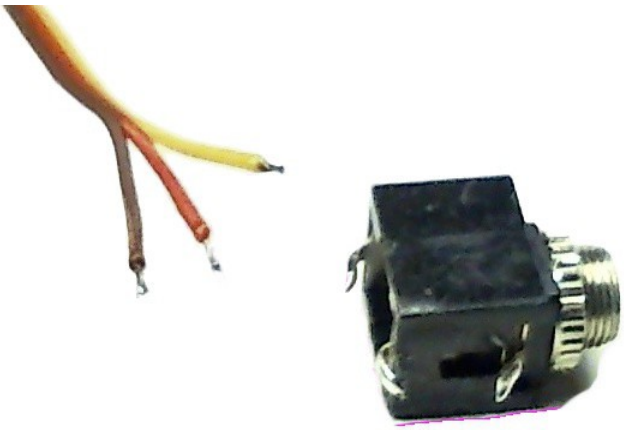


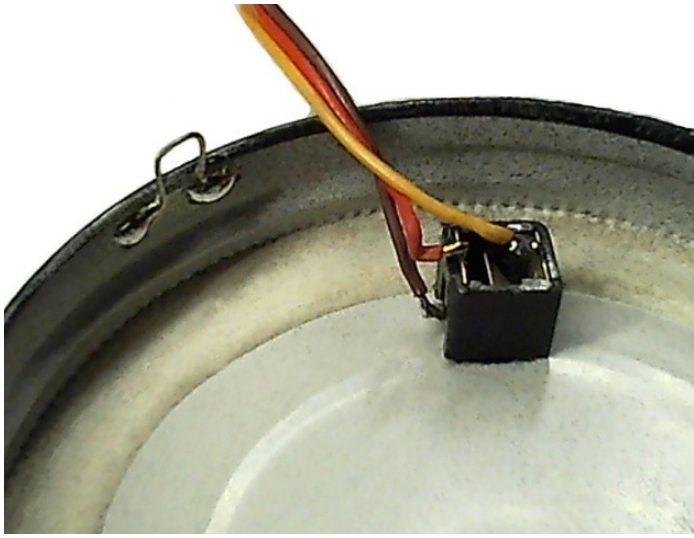


Prepare the jack

The threads of good quality are obtained by extension male-female, we must get used to sacrifice. From a single extension yields a female with 15 cm cable and a length of 15 cm cable (the male is usually not needed and it is thrown away). Sacrificing the extension costs less than buying separate cables and connectors.

First of all, strip, and tin arricciolare well the three wires.





Shorten the terminals of female jack with the clippers, stagnarli well and finally solder the three wires to the socket. Check that the brown wire is connected to the base, the red wire to the central and the yellow wire to the tip of the jack. If necessary, insert a jack and check with the tester.

Place a piece of heat-shrinkable sheath, heat it with the lighter or even better with a hot air gun or with a modified dryer (with an outlet pipe metal to reduce the size of the flow of outgoing air).

The connector should be well insulated and the cable must exit the base. Cut the top of the sheath, heat and crush again. Minimize the size of the connector. If it is too large it becomes difficult to close the cover.

Connect to ground covers

The treble hooks that connect with the jar lids have not only a mechanical function, but also serve to connect them electrically grounded.

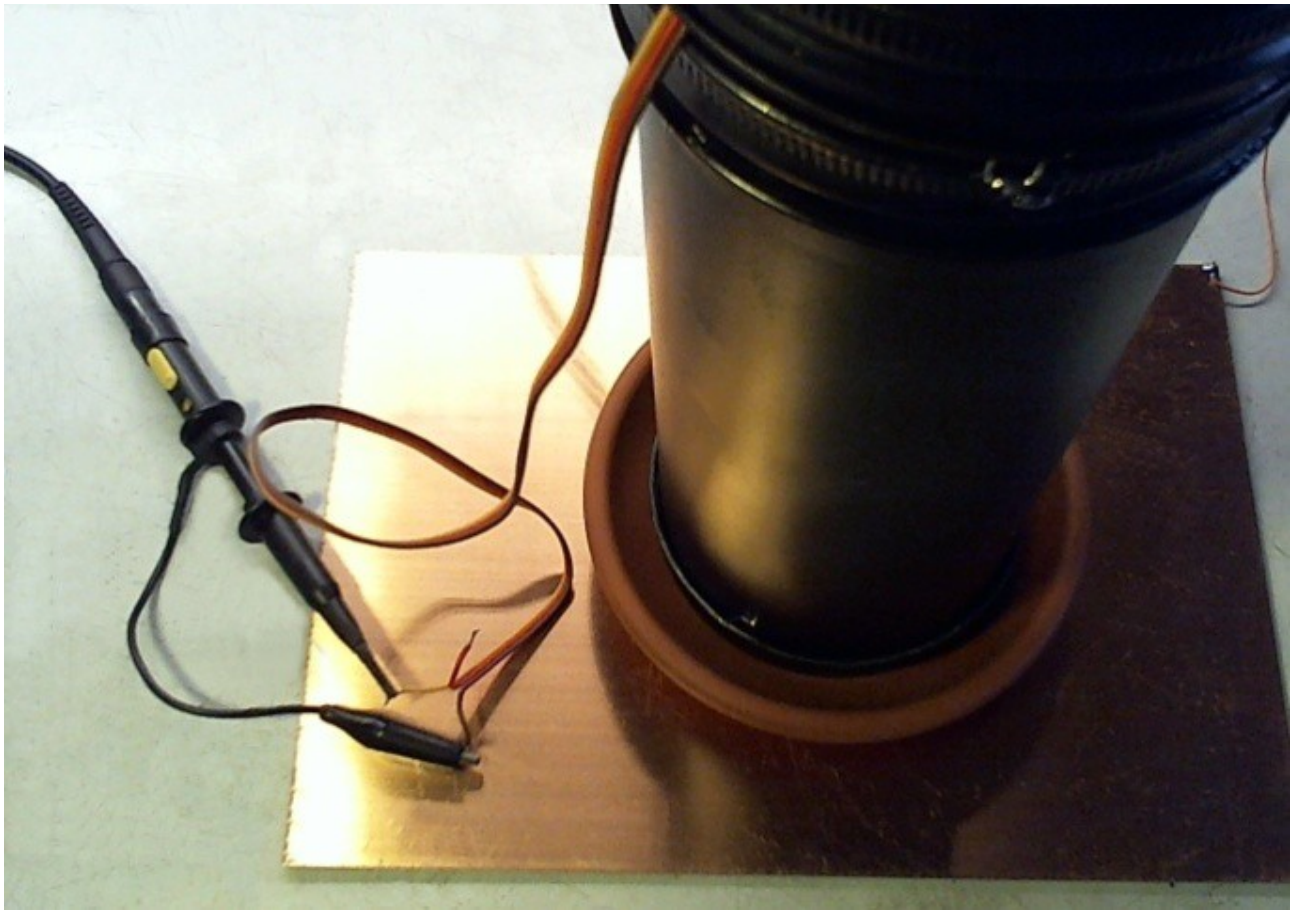
Before doing the electrical tests, you must connect both the bottom cover, the two top covers. We recommend that you solder the treble of the first top cover and saldarne at least one for each of the other two.

The ion chamber is terribly sensitive to electric fields. If you miss part of the shield does not work, Or generates additional pulses, which do not come from Radon but from the surrounding environment.

If you miss part of the shield also tests on noise TP3 with the oscilloscope will not be significant and you will see a strong ripple at mains frequency (20 msec cycle equal to 50Hz).

Test the chamber with the oscilloscope

To ensure that the chamber functions well enough to mount it carefully and test it with ThereminoGeiger but who possessed an oscilloscope could also do some additional tests.



In order not to introduce noise do you pass a wire into the gap between the two top covers and closes the lid. If possible, the chamber should also be placed on a grounded metal with a wire. You can use a sheet of aluminum, iron or copper foil vetronite.

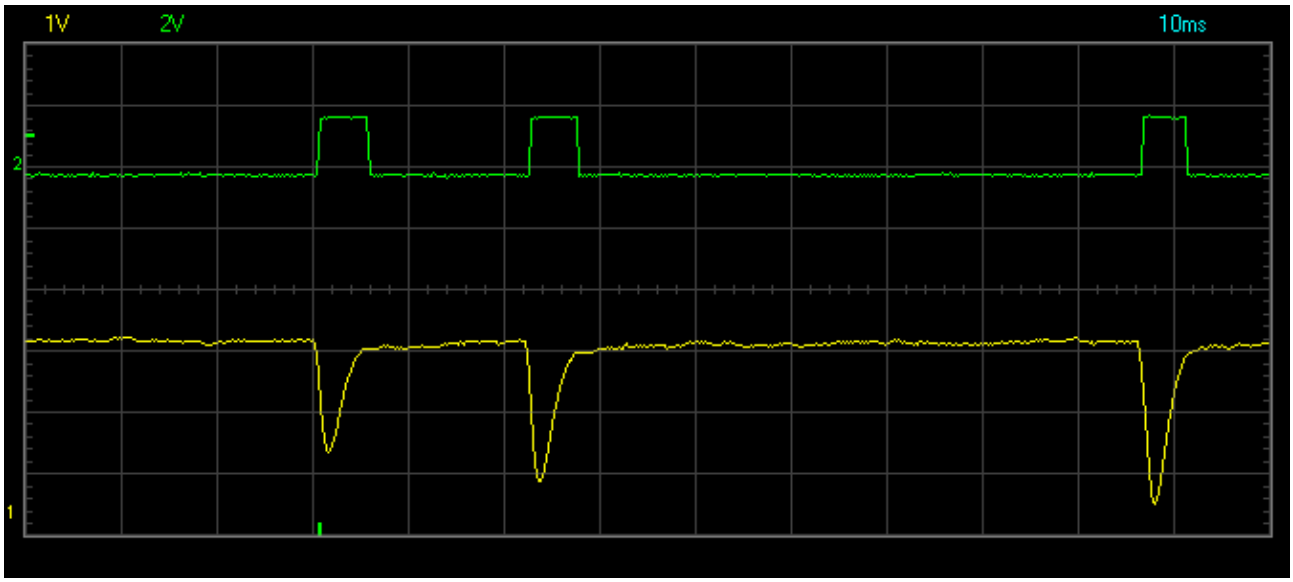
Normally you connect a three-wire cable to GND, TP3 and OUTPUT.

Instead, if you want to measure the voltage across the FET connects TP2 instead of OUTPUT. In this picture you can see a three-wire cable connected to GND (brown), TP2 (red) and TP3 (yellow).

Note 1 *- Never connect TP1. If TP1 is connected to a long wire will introduce disturbances that prevent good measure of the signal on TP3.*

Test the chamber with the oscilloscope - 2

In the test with the oscilloscope should especially check that the signal is noise-free signal that is that the parties are flat with no pulse. If the chamber is well-built noise should be less than 100mV (less than a tenth of a yellow square on the graph, which is set to 1 volt per panel).



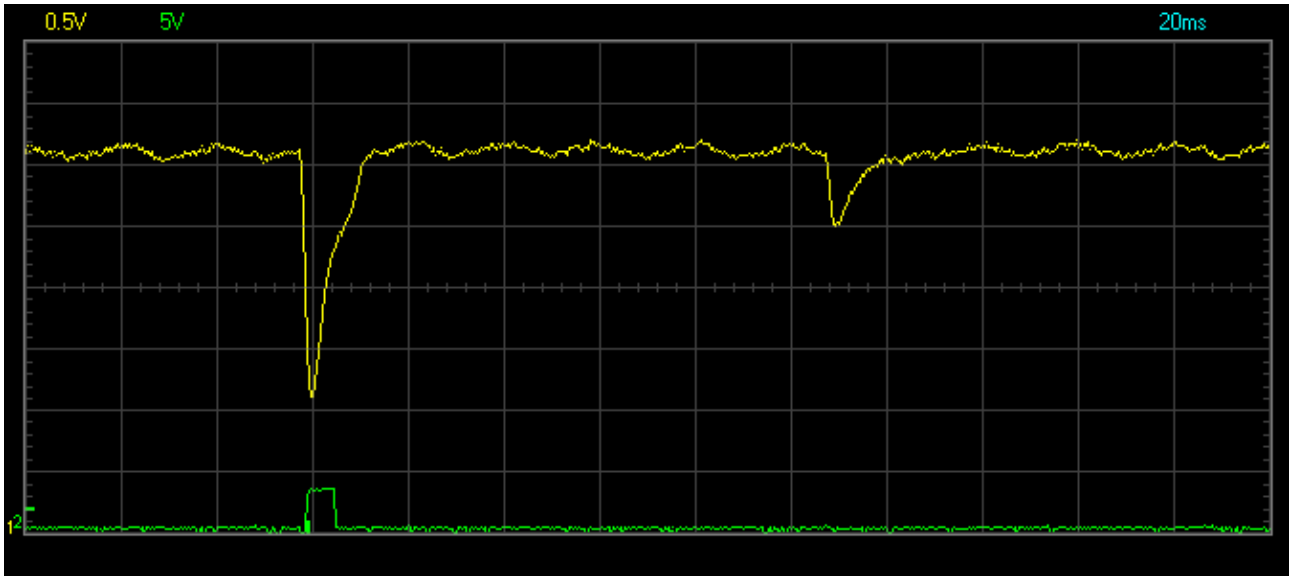
The yellow trace is the signal on TP3. In this point the pulses produced by the Radon are wide few milliseconds and fall of some volts, compared to the normal voltage that is approximately 3 Volts.

Some impulses down only half a volt, others may be much stronger and drop to zero volts but most of the pulses is expected to fall to a volt or two.

The pulses of amplitude greater than about 1 volt, produce a positive pulse output off about 5 or 10 mS (green trace). To see also the output pulse must be connected one of the oscilloscope probes to the output signal, called "Signal" in the wiring diagram.

Test the chamber with the oscilloscope - 3

The graph below shows an ion chamber with the top cover slightly raised specifically to increase the noise. The yellow trace (which corresponds to TP3) has been set to a half volts per square so as to highlight the undulations.



In this image, the noise coming from the electrical obvious cause high waves about 150 mV and with a period of 20 ms (50 Hz electricity network). The track will also see small steps very thick, produced by switching power supply.

The maximum tolerable noise are approximately 500 mV peak-to-peak, besides you can check false counts produced by the noise and the loss of several pulses of Radon.

If the noise exceeds 200 mV (in practice when they begin to become apparent to the oscilloscope) you should try to figure out where to come and find ways to eliminate them.

Very noised track

It can happen that the track is noisy, with random noise, also very large. The track swings in an uncontrolled way and, in some moments causes bursts of counts. The bursts of pulses are easily recognizable by ear. Their appearance in the graph of Theremino Geiger is shown on the following pages (Appendix 3).

The reasons that cause these noises may be many:

- Core wire not securely attached that is flowing into the hole or wire very loose.
- Sparkles caused by moisture or sections of coating is not electrically connected.
- Adjustments of mechanics.
- Dust or other small particles (midges), which are then attracted to and repelled by the high voltage. (the particles are charged and discharged repeatedly like these: **Video1** – **Video2** - **Video3**)

A chamber newly built or mistreated is noisier. After a certain time the high voltage paste all the particles to the walls and mechanical stabilizes. If it does not, thoroughly clean the inside with compressed air and check the mechanics, the weldings and the internal conductive coating.

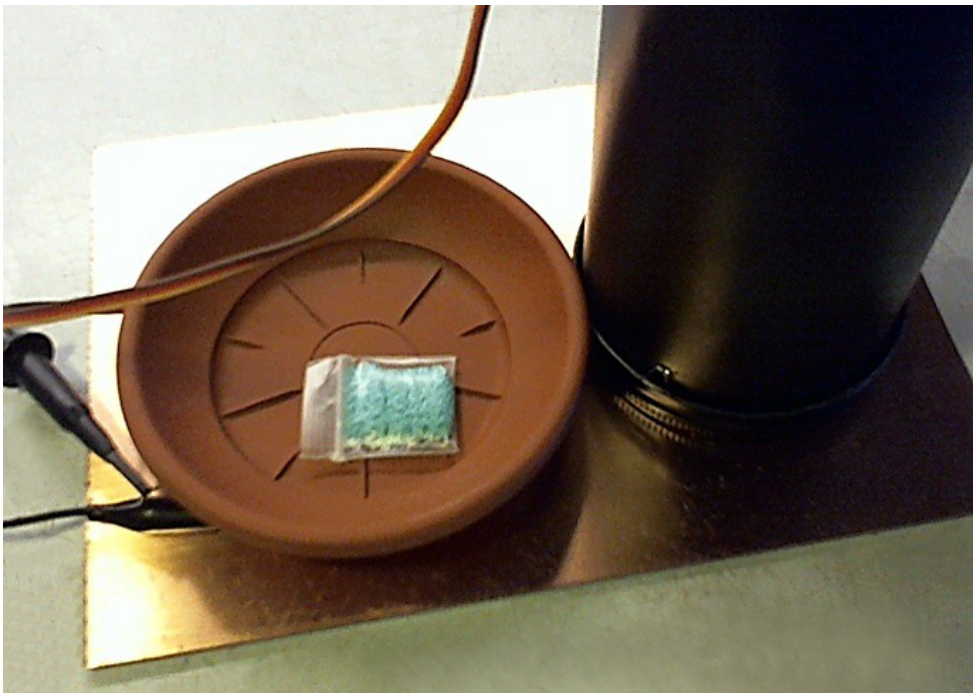
Test the chamber with thorium - 1

Normally the chamber generates approximately one pulse every two minutes, then test and see signals with an oscilloscope is pretty boring. Fortunately, in addition to Radon (Rn222) there is also the isotope Thoron (Rn220) that seems made to test the ion chambers. The Thoron behaves like the Radon but you can create and remove quickly. The Thoron decade also much faster than the Radon (about 1 minute instead of 4 days).

Radon comes down from the Radio and uranium (relatively abundant in the natural environment) and Thoron descends from Torio, who was also present in nature and readily available with good concentration in the gas mantles for camping lamps.

The nets can be bought on eBay for a few dollars, look for words such as: "Thorium", "Mantle", "Geiger counter test source", "Thorium", "Mantle camp." There are also meshes that do not contain Thorium then make sure you buy the right ones. If in doubt, write to the seller, to confirm explicitly that the mesh is slightly radioactive.

The nets are not dangerous if you avoid spread around their fragments, of respirarli or eating them. The nets can lose fragments and dust of thorium, then immediately seal them in plastic bags thick and not ever open them. When I'm not in a plastic bag, you have to handle them with care. If you want to split them into several samples gear well. Use a mask to avoid breathing the fragments, cover the table with a sheet of paper. Do not blow or breathe loudly while you work. At the end of the sheet of paper, folded carefully, it will contain dust and microscopic fragments that are harmless when diluted in water or in the ground (it is from them that come).



To fill the chamber ion Thoron you have to act a bit 'weird. The Thoron (and Radon) are highly volatile and need very little gas to disperse in the air. Therefore you must keep the mesh in a closed area without drafts. The ideal is that it fits on a saucer jar of the chamber, you lay the mesh in the saucer and then pose the chamber above. In this way the Thorium is located in a chamber almost sealed and slowly fills Thoron.

Test the chamber with thorium - 2

The Thoron is heavier than air, so it fills up before the saucer and then begins to fill the jar from the bottom. Within a few minutes the pulses generated from the chamber and greatly increase the frequency of a few tens of minutes after the chamber is completely full of Thoron.

In this graph we see that the area to the left, without net, the pulses are from one minute to one every several minutes. After positioning the mesh pulses thicken almost immediately. But the climb is very slow because the integration time is set to 1800 seconds to 30 minutes. Wanting a quicker response, you should press "New Measure", immediately after placing the rack.

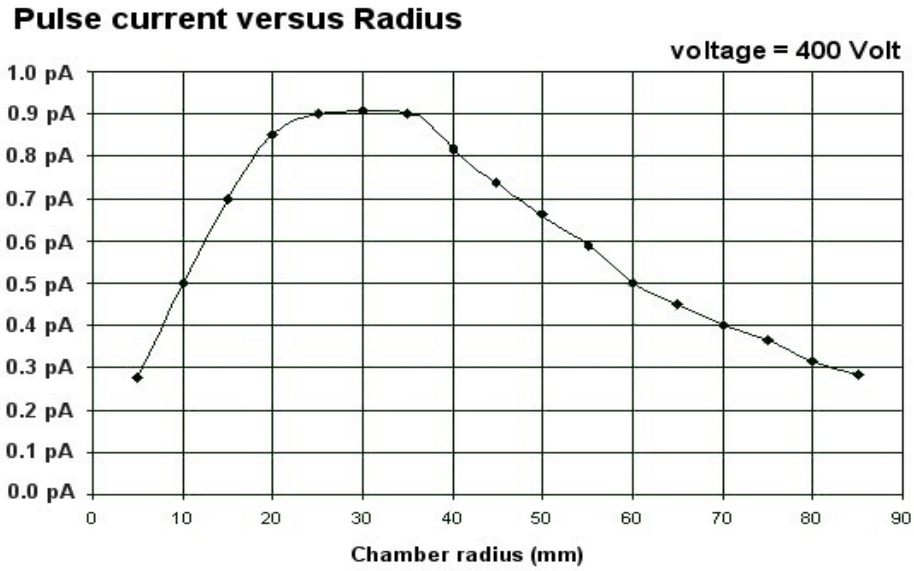
If the saucer close properly and there are no strong air currents, the number of counts can increase to more than 300 Bq/m3 (more than 10 pCi/l). Sometime you should hear even more ticks per second.

To make the rebuttal takes off the saucer and is passed clean air in the chamber, holds it up and waving a piece of cardboard. Better not blow into the chamber because the wind could dampen it.

By doing these tests it turns out that it takes some time to clean the chamber. Probably the Thoron paste electrostatic effect on the walls and the chamber remains "dirty" long. This same effect occurs if you make measurements in locals little radioactive, after measuring a local very radioactive. Radon has a much slower decay of Thoron so the chamber can remain contaminated for weeks. We therefore recommend that, before every important measure, to position the camera outdoors or in a very airy and check that the number of pulses per minute is low. Wait until the pulses fall, or clean the chamber with plenty of air. Better to use a dryer with cold air and compressed air that would be too violent.

Appendix 1 - Dimensions and electric field

The literature indicates that the ion chambers for maximum electrical signal beam ion chamber should be comparable to, or greater than, the average path of the alpha rays in the air (about 4 cm), In addition, the electric field must be sufficient to deliver fast electrons and ions, before they recombine.



According to this graph, we need at least 110 volts per centimeter and the chamber must have a minimum radius of 25 mm.

We have verified this information with our chamber one and a 40 mm radius:

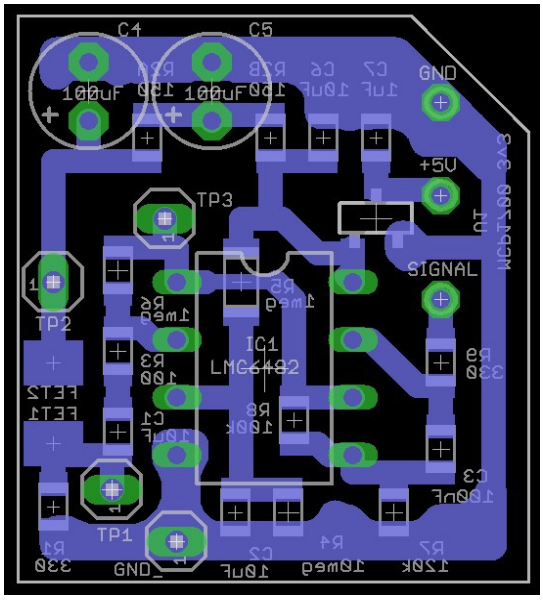
```
Chamber Pulse Pulse
voltage Volts / cm voltage rise time
   (1)                    (2)
-----------------------------------------------
20 Volt 5 0.6 Volt 15.0 mS
40 Volt 10 1.0 Volt 9.0 ms
100 Volt 25 1.2 Volt 4.0 mS
150 Volts 38 1.5 Volt 3.0 mS
200 Volt 50 1.5 Volt 2.5 mS
300 Volt 75 1.6 Volt 2.0 mS
400 Volts 100 1.7 Volt 1.5 mS
500 Volt 125 1.8 Volt 1.1 mS
800 Volt 200 1.9 Volt 1.0 mS
```

(1) *chamber radius = 40 mm*

(2) *voltage amplified by 1000*

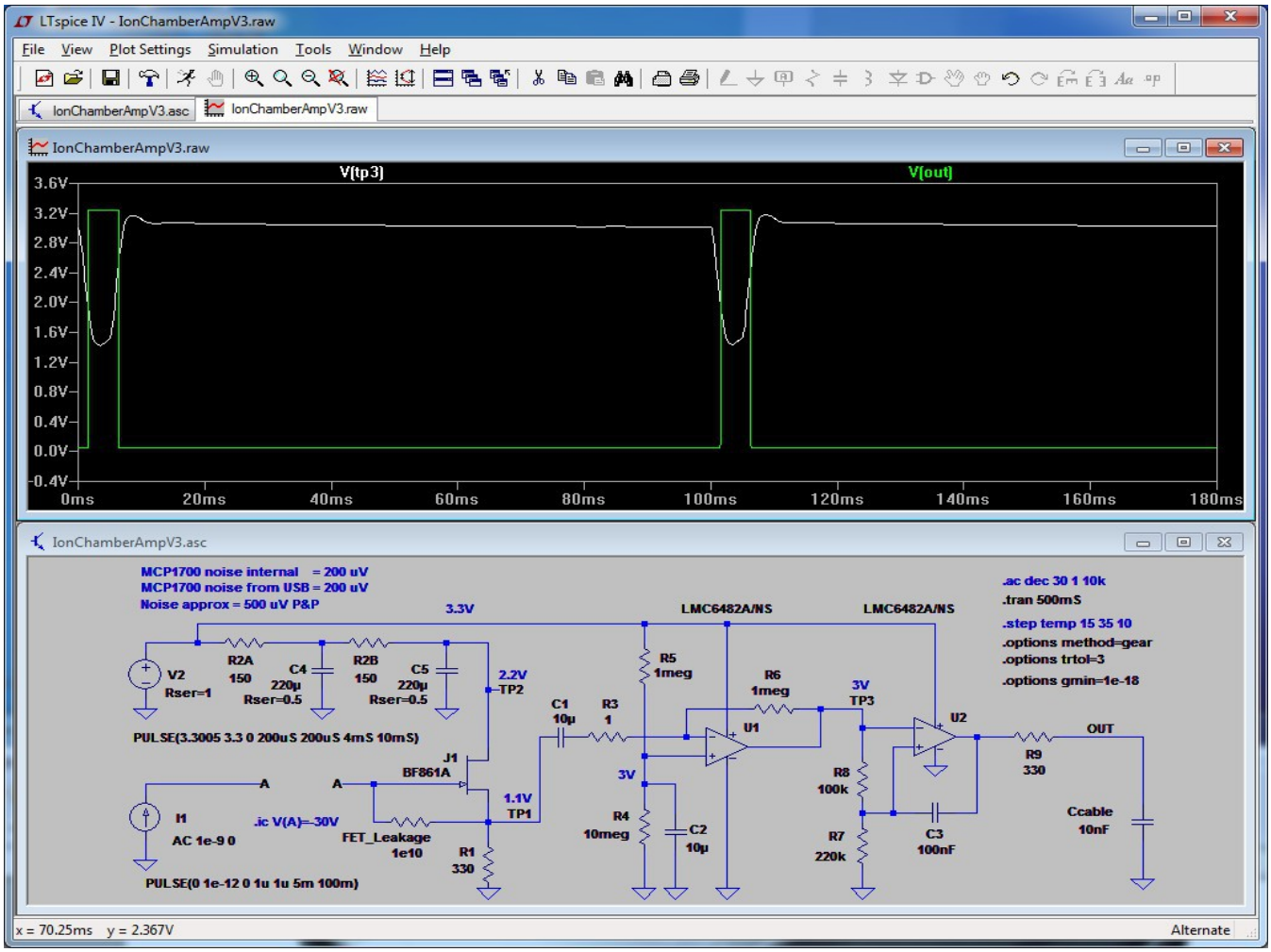
Therefore we decided to use an electric field of about 120 volts per centimeter, as the radius of our chamber is 4 cm, the voltage should be about 480 volts.

Appendix 2 - Simulations and printed circuits



In File: "Theremino_IonChamber_PCB.zip" are available wiring diagrams and PCB in Eagle format, the rendering of Eagle3D and electrical simulations in LTSpice format.

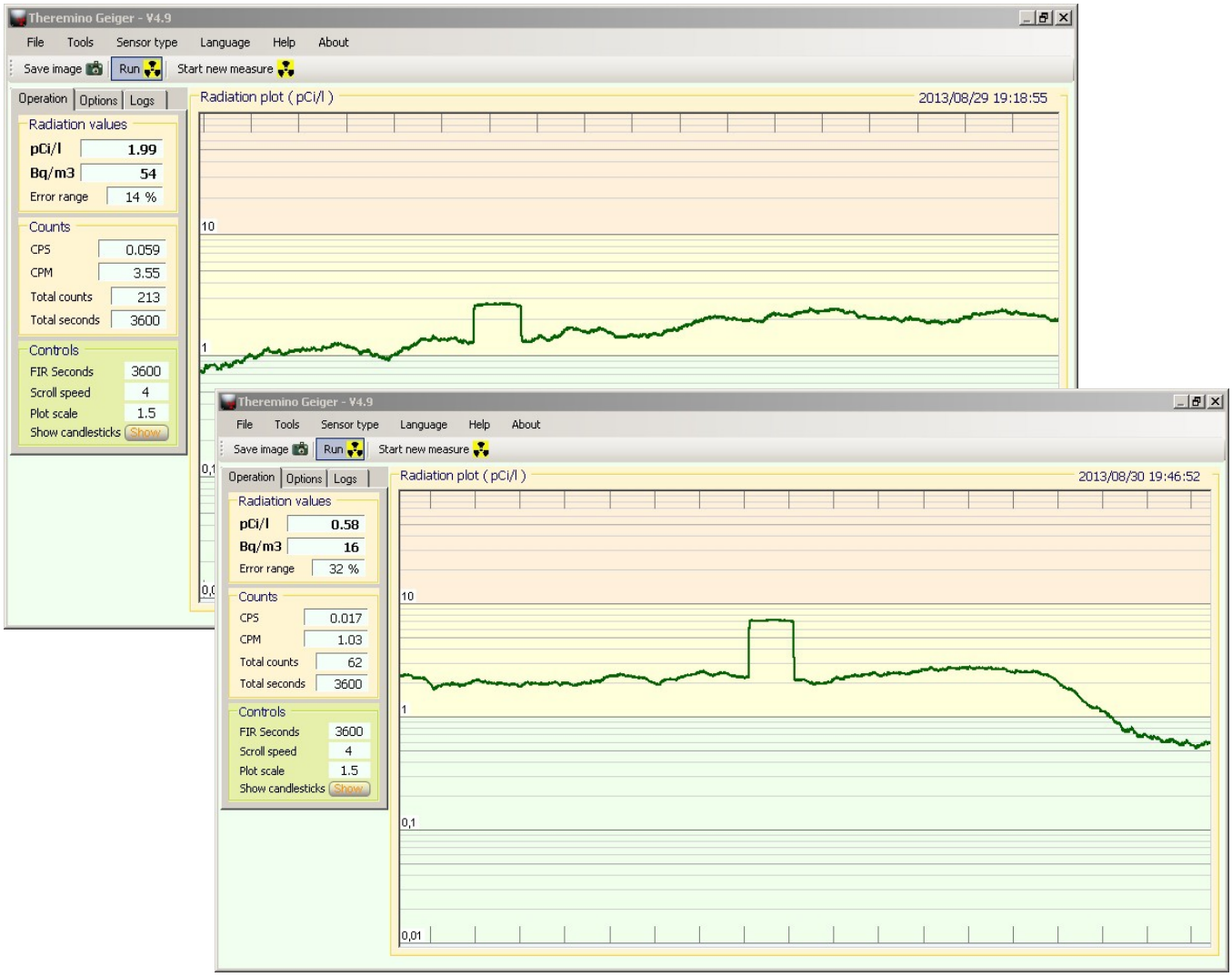
The latest version of this file can be downloaded from here:
http://www.theremino.com/hardware/inputs/radioactivity-sensors



Appendix 3 - Pulses not caused by Radon

Various mechanisms may produce spurious pulses, not caused by radon. For example, the core wire is not taut swinging or stretching with the change of temperature and strip the holes passing through. Or a dust particle can enter (dust jumps between the two electrodes and creates many problems). Or a heavy vehicle passing could produce strong vibrations..

In all these cases are produced bursts of many pulses concentrated in a short time. These events are easily distinguishable because they cause a step in the graphs of duration equal to the set filter. In the next image the filter was 3600 seconds (one hour) and you see that when the time of the filter curve returns to its normal level.



To avoid these problems, use dust filters on the two external covers, insert an isolation for vibration, with soft foam and place the camera on the floor near a wall or in a sheltered corner. In difficult cases, you may think to prepare a plan isolated with a large heavy tile, granite or marble, suspended on a layer of foam.

Avoid that the environment in the extent to produce loud noises, animals or children can move the camera and avoid too violently to open the windows and doors slamming.

Appendix 4 – Dust filters

The dust filters are two, on the outside covers holes. Here is a simple and effective way to secure them. A second square of brass mesh is welded on one corner. On the opposite corner is welded a metal plate or a piece of stiff wire. In this way, the filter can be taken on and off easily. Place the filter being careful to cover well the hole and fold the plate to secure it.

The filter can be open cell foam (try to blow the air to see if it goes well). Or it could be filter paper for vacuum cleaners or even a piece of thin cloth.

The presence of a second brass mesh, greatly increases the shielding for the electromagnetic fields. With double mesh, also approaching a hand to the hole, the noise at mains frequency (measured with the oscilloscope on TP3) do not increase appreciably.