Handmade Air Geiger Counter

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http://einstlab.web.fc2.com

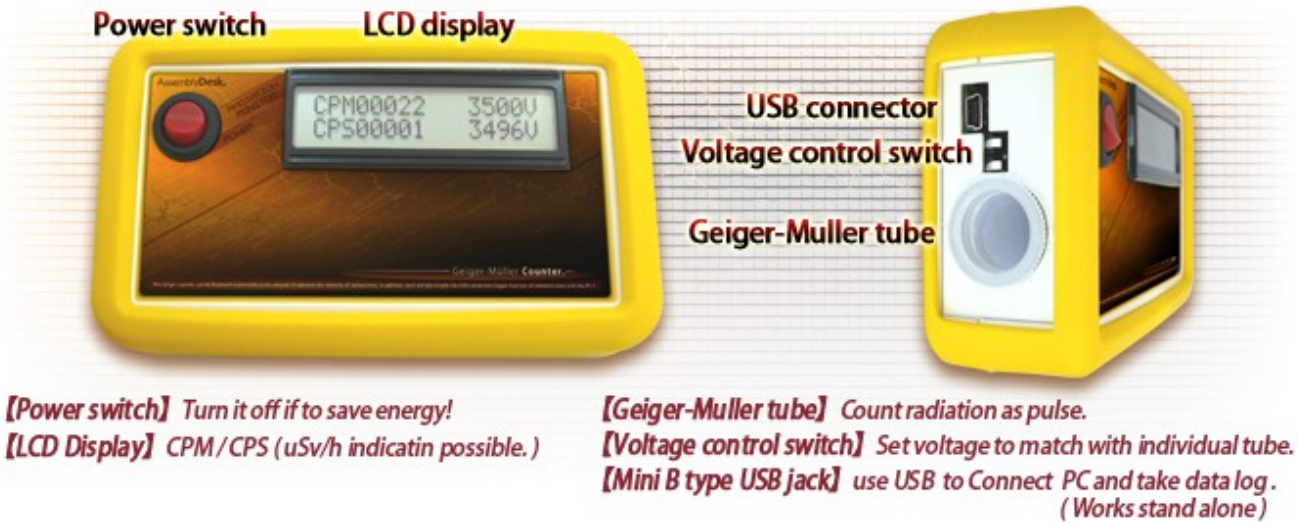
You can make it easily. No special parts. Even if GM tube made of a film case.

Section 1 Introduction

There is radioactivity. The radioactive rays are invisible. We are suffering from it. The sun is a nuclear fusion reactor. Are the radioactive rays dangerous? How far do we take a distance from radioactive obstacle for our safety?
I had lots of questions. First, I had wanted to measure radioactivity to understand the effect from the field.
Geiger counter, dosimeter, is a measurement device. But it is very expensive. I made a sensor, geiger muller tube, with low cost. And I had success to count it.

Caution:
Use this document at your own risk!
Danger high voltage in the geiger counter.

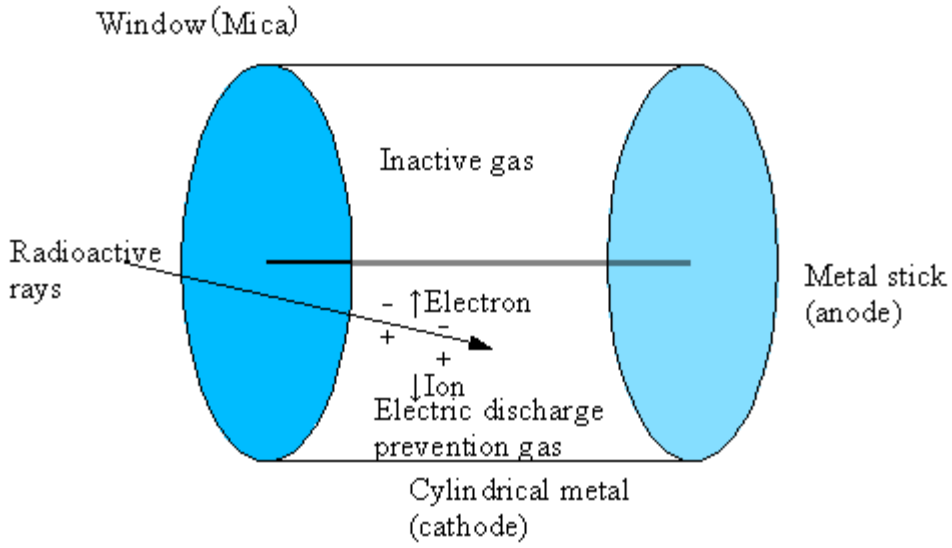
Note:The Air Geiger Counter Kit has been launched by Bit Trade One, LTD which I have licensed. Please visit http://j-kosaku.jp/Products/001E-GM/index.html



Section 2 Geiger Muller tube

In 1925, Johannes Wilhelm Geiger who was a physicist in German and Walter Muller who was a student, invented a sensor to detect radioactive rays. In short, GM tube.
Although the high voltage is needed for the center of cylindrical metal (negative pole) by what has arranged metal stick (anode), radiation is measurable one by one. The intensity (speed) of radiation cannot be measured. Quantity (number) is measured. Sensitivity can be comparatively made high. It is fit for detection of alpha rays and a beta ray. Although a gamma ray is also detectable, it is said that the detection probability is about several %.

The Geiger Mueller counter is decompressed by 0.1 atmospheric pressure, and it fills up with inactive gas (Ar, helium) and halogen gas (bromine) as continuation electric discharge prevention.
Voltage from DC 500V to 700V necessity. The voltage region suitable for this measurement is called Plateau voltage.



Geiger muller tube device

Work theory of GM tube.

1. Radiation (alpha, beta, gamma) carries out incidence. It collides with a gas molecule (inactive gas), and gas is ionized (ionization).

2. The generated electron is accelerated by high voltage field.

3. Further, an acceleration electron collides gas and is excited.

4. When the excited gas return to a base state, ultraviolet rays are generated.
5. Ultraviolet rays ionize gas and cause an electronic avalanche.
6. An electronic avalanche reaches the anode and is detected as a pulse.
7. On the other hand, plus ion gas reduces voltage field.
8. Thereby, the electronic avalanche ceases.
9. Plus ion gas moves to the negative pole(Since it is a molecule, movement takes time).
10. Current flows, and an electronic avalanche is promoted.
11. An electronic avalanche does not stop. Then, electric discharge prevention gas is put in.
12. Electric discharge prevention gas receives a plus electric charge.
13. Although electric discharge prevention gas reaches the negative pole, an electronic avalanche is not promoted at this time.
14. Electric discharge prevention gas returns to a molecule.

Section 3 Air geiger muller tube

It is hardly to get geiger muller tube. The domestic maker stopped most production. It is expensive even if it is able to obtain. It is restricted also overseas.

- LND Inc.(USA)
- CENTRONIC Ltd(UK)
- canberra(France)
- saint-gobain Inc.(France)

In fact, one atmospheric pressure is also measurable using air. However, the high voltage of 3000V to 5000V is required (influenced by the caliber). Sensitivity can be made high, so that a caliber is large.
Since most in air is the nitrogen near inactive gas, it becomes substitution of inactive gas.

Composition in air

Nitrogen	78.080%
Oxygen	20.950%
Argon	0.930%
Carbon dioxide	0.035%

Butane gas (gas of a lighter) is used instead of halogen gas as continuation electric discharge prevention gas. Alcohol is sufficient.
It is for preventing those without electric discharge (equivalent to the oscillation state said in an electronic circuit). As for electric discharge, sparks do not come out. By the eye, it cannot check.

Comparison	Geiger muller tube	Air geiger muller tube
Inactive gas	Ar, He	N
Continuation electric discharge prevention gas	Halogen gas	Butane gas
Inner pressure	0.1 Atmospheric pressure	1 Atmospheric pressure
Operation voltage	500-700V	3000-5000V
Window	Mica	Kitchen wrap

(Oxygen changes to ozone by electric discharge.)

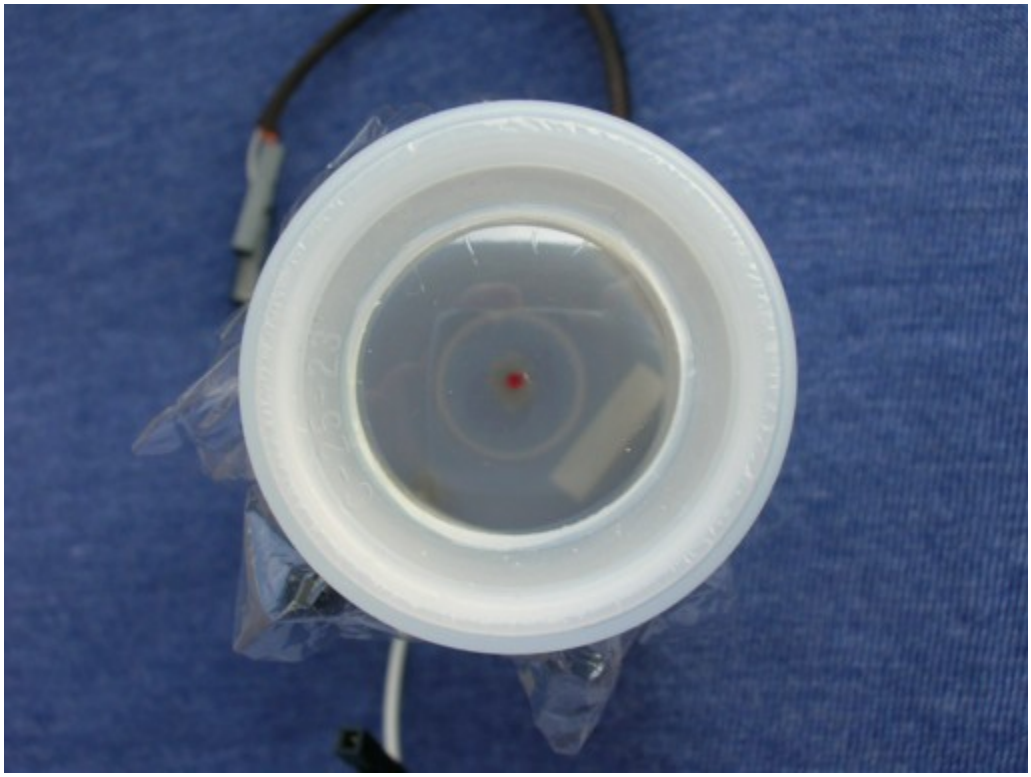
Section 4 Handmade air geiger muller tube

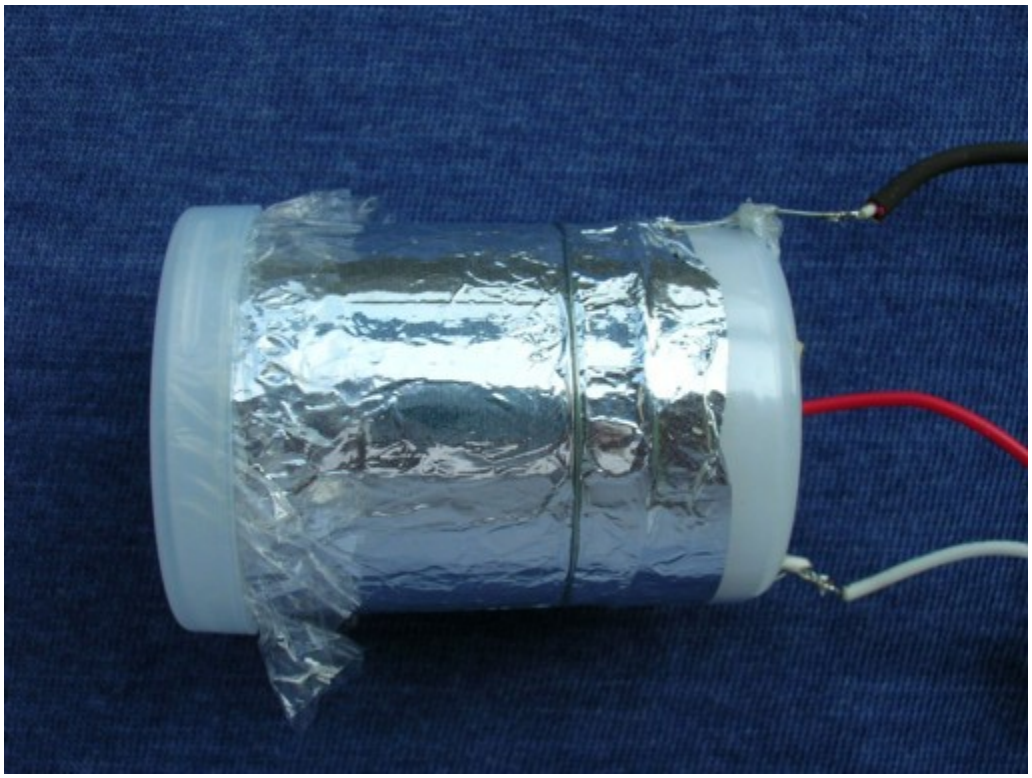
An air Geiger Mueller counter is manufactured in a film case and paper. It is made of the familiar things which are easy to get.

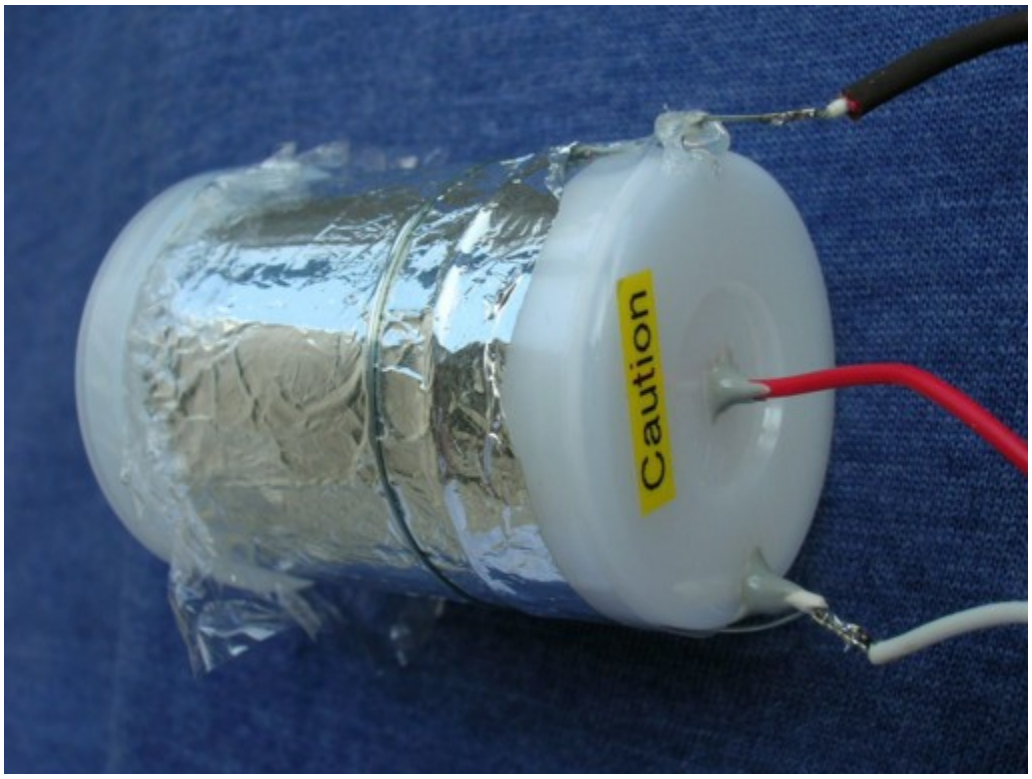
Parts table

Film case	a camera film case	
Lead	Red (for the anodes 16cm), White(for the Cathode 15cm, 5cm), Brown (for detection 15cm) Outer diameter 1mm Tin plating. Since copper tends to oxidize, it is not suitable.	
Tin plating wire	It uses in order to connect aluminum foil with a wire. Outer diameter 0.5mm, 12cm x2	
Paper	Regular paper becomes the negative pole and paper is suitable as a high resistance film.Since it is hard to turn at pasteboard, it is not suitable. Also avoid colored paper.	
Aluminum foil	A little. It becomes a detection part and a shield.	
Kitchen wrap	A little. It becomes a window film and an isolated film.	
Gas cigarette lighter		1
Scotch tape		1
Epoxy resin bond		1

First, look photographs. And hold an image.
Red lead for the cathode, White lead for the anode and Brown lead for the detection part.





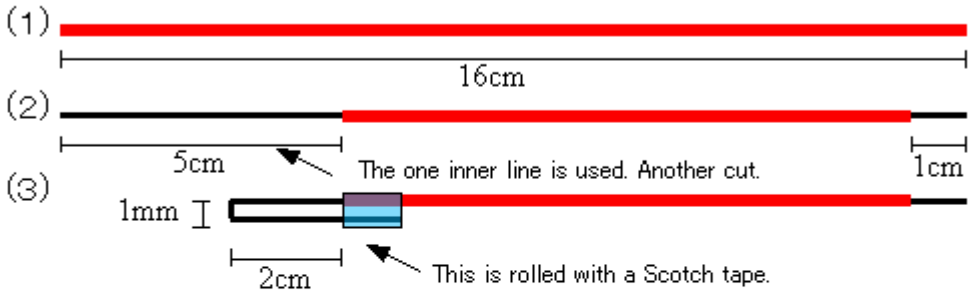


Tips on manufacture

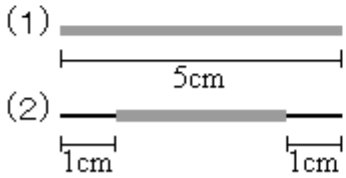
- Let's make finely. Especially the inside of a film case and the anode lead are good to wipe with alcohol. If there are finger marks, it will not operate correctly.

- Let's make carefully. It may short-circuit, if it makes coarsely. A noise mixes and it does not operate correctly.

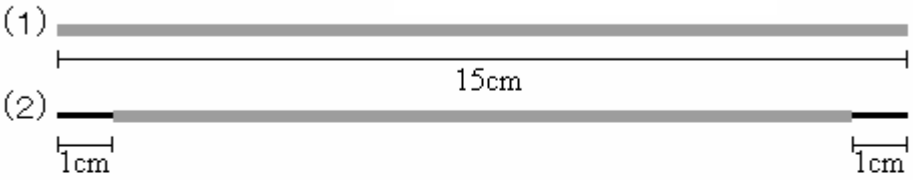
Processing anode line



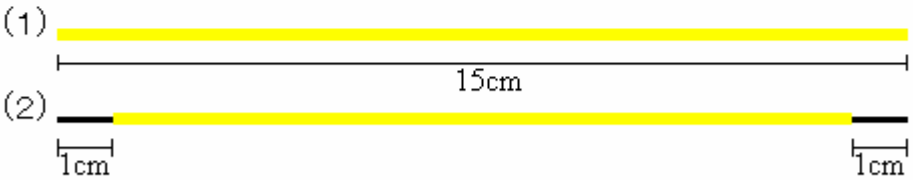
Processing cathode line

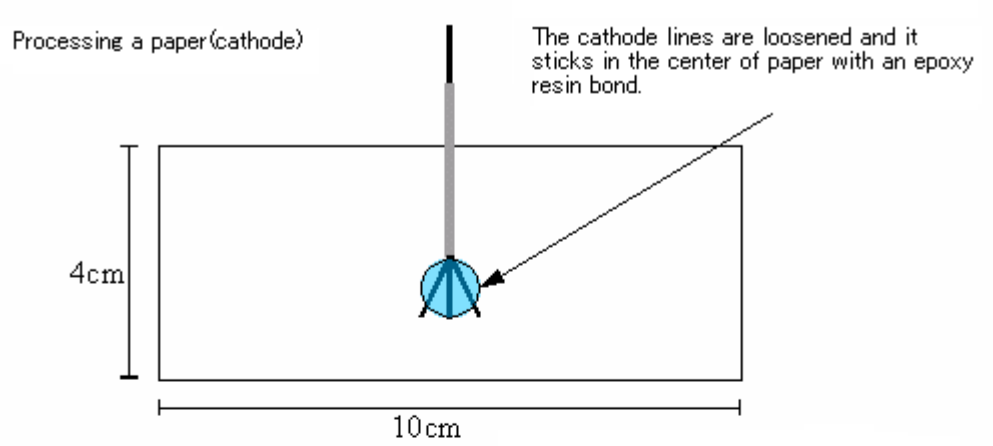


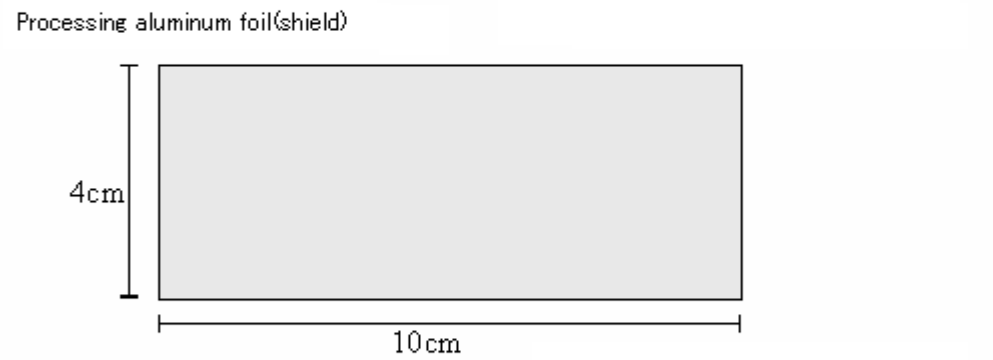
Processing shield line

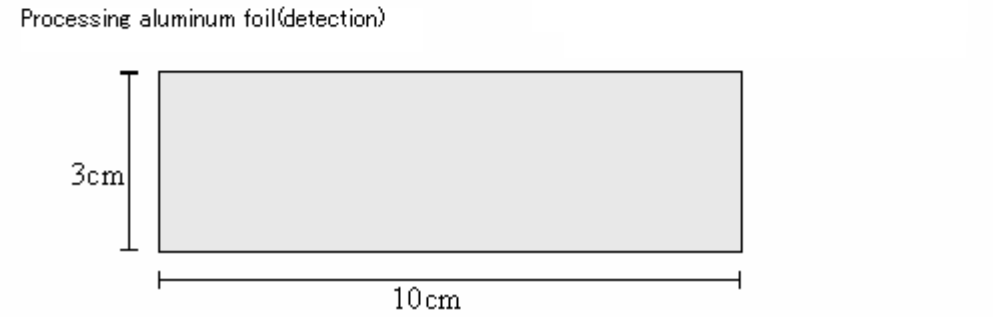


Processing detection line

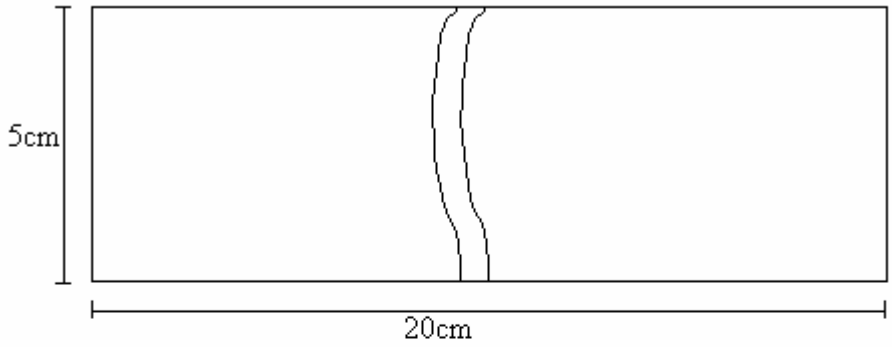




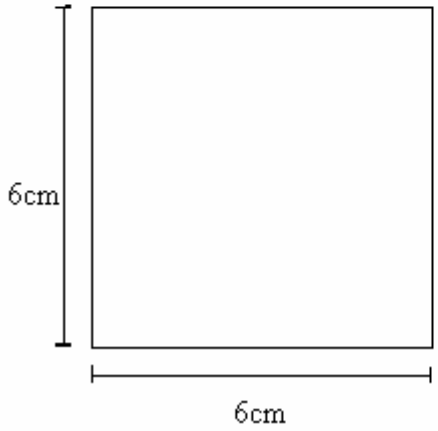


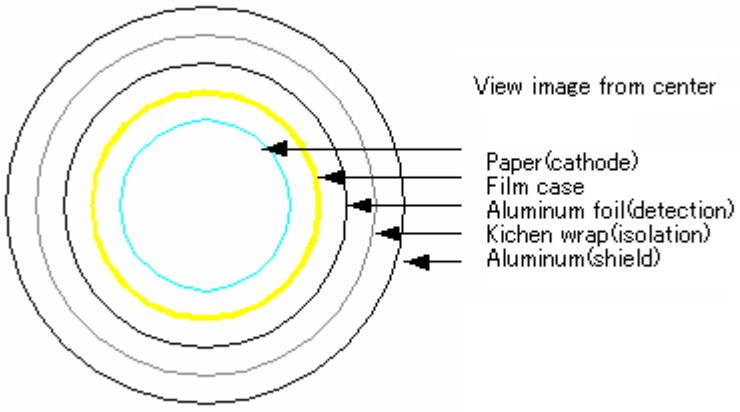


Processing a kitchen wrap(isolation)



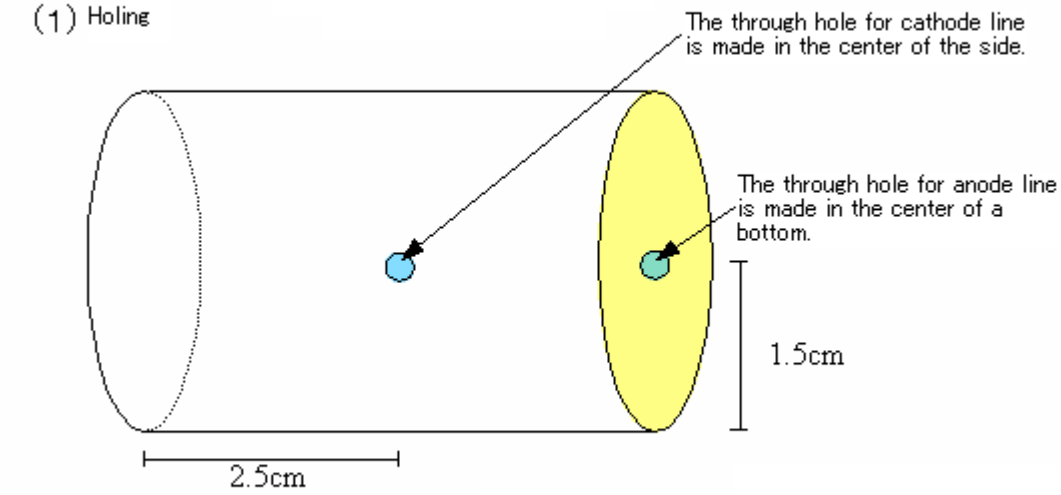
Processing a kitchen wrap(window)



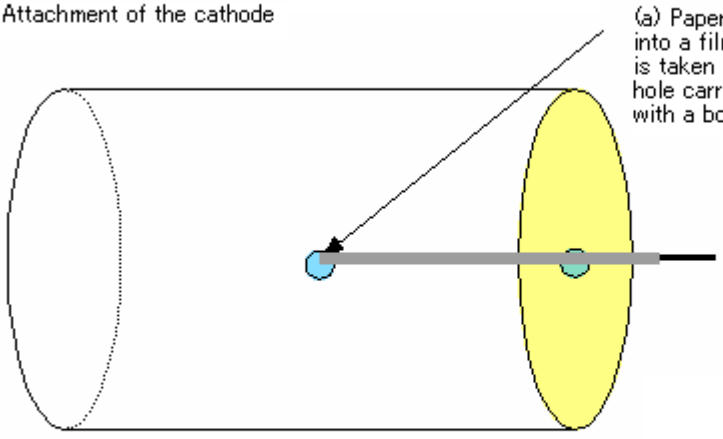


Processing film case

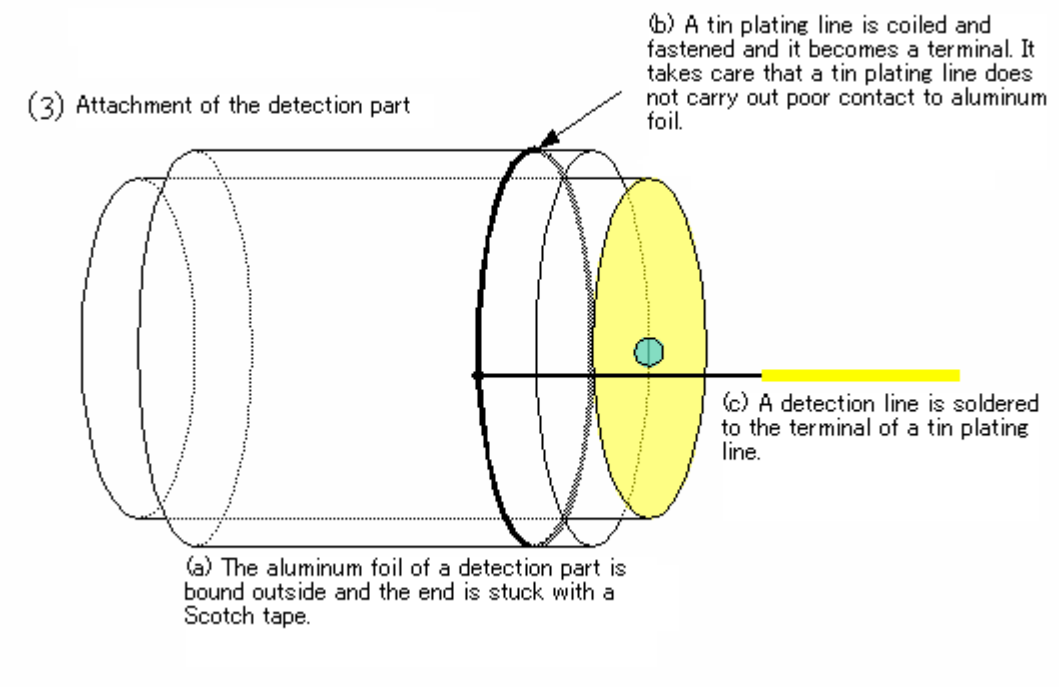
(1) Holing

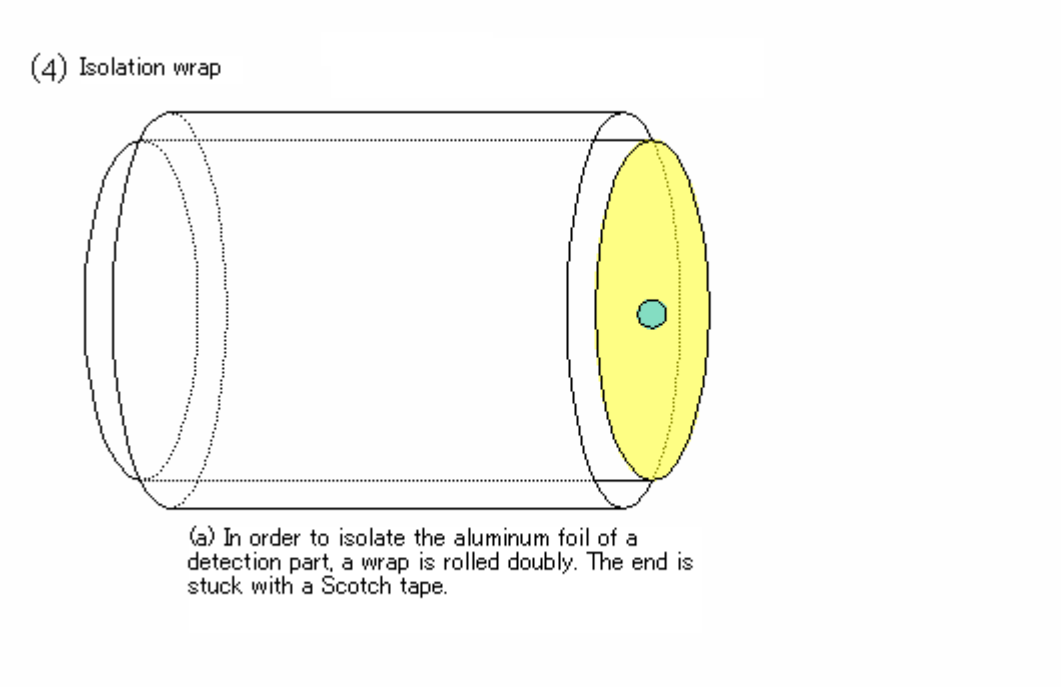


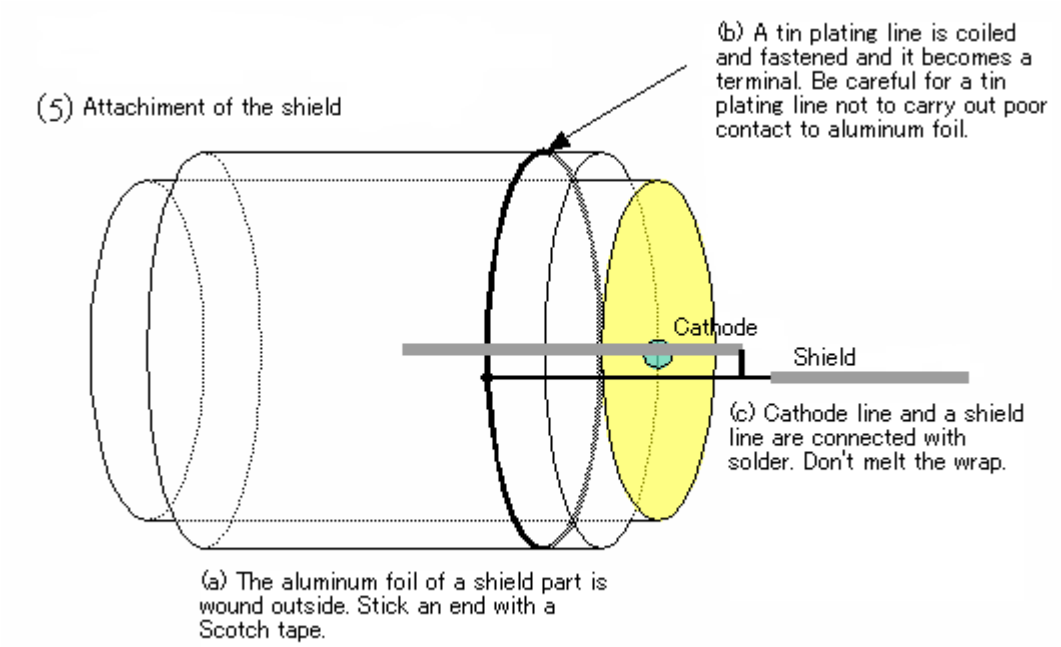
(2) Attachment of the cathode

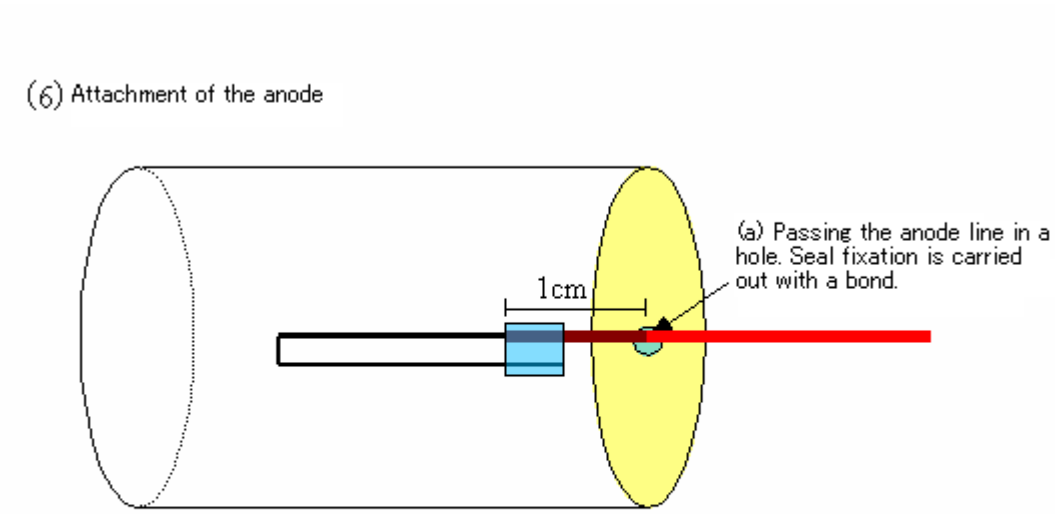


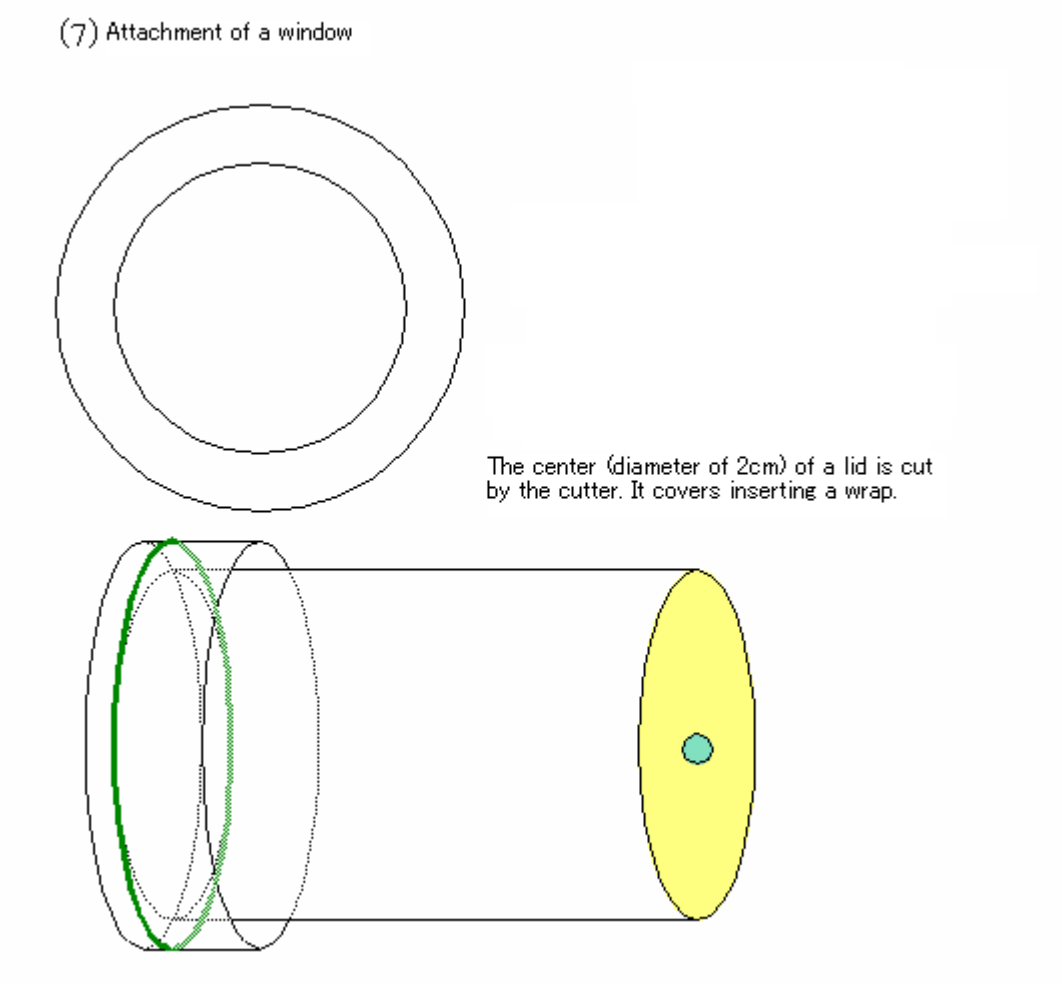
(b) Paper is put in in accordance with a film case, and the end of paper is stuck with a bond.











Checking

- Make sure that the shield does not touch the detection part.
- Cathode and a shield line are connected.

Section 5 Geiger counter

Features

- Small and lightweight
- Low current consumption
- Operation Voltage monitor
- Detection sound
- Easy to get parts

Specification

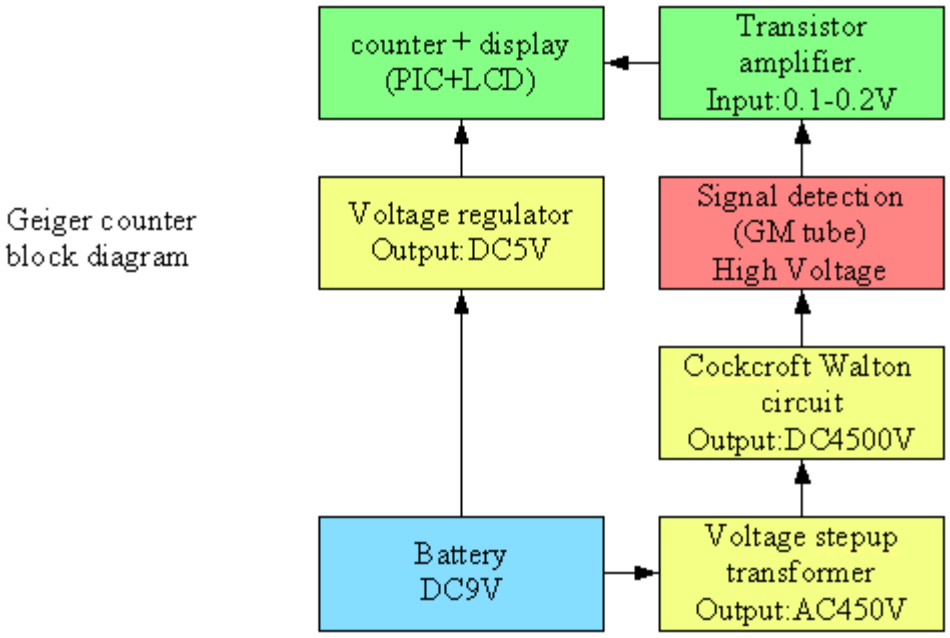
Detection radiation	alpha, beta, gamma and X-rays
Measurement range	0.006[uSv/h] above. Detection of the nature radiation is possible. It is dependent on butane gas density and operation voltage.
Display range	0-65536[cps], 0-65536[cpm], The remaining measurement time:0-59[sec], Operation voltage:0-8192[V]
Size	W117xD84xH41mm
Weight	140g
Monitor	Detection sound, Operation voltage
Battery	006P 9V Alkaline
Current consumption	approximately 25mA
Battery life	approximately 10hours
Cost	$30, not for sale

Caution(High Voltage)

- The high voltage of 3000V to 5000V should not bring a terminal close in order to cause a 3 to 5mm atmospheric discharge.
- When an atmospheric discharge is carried out, the high voltage may damage a surroundings lump and electronic products all over a circuit.
- Protect the PCB size of a high-voltage part. If a pattern interval is narrow, it will discharge on a PCB.
- The glass epoxy PCB for a high-voltage part is desirable.

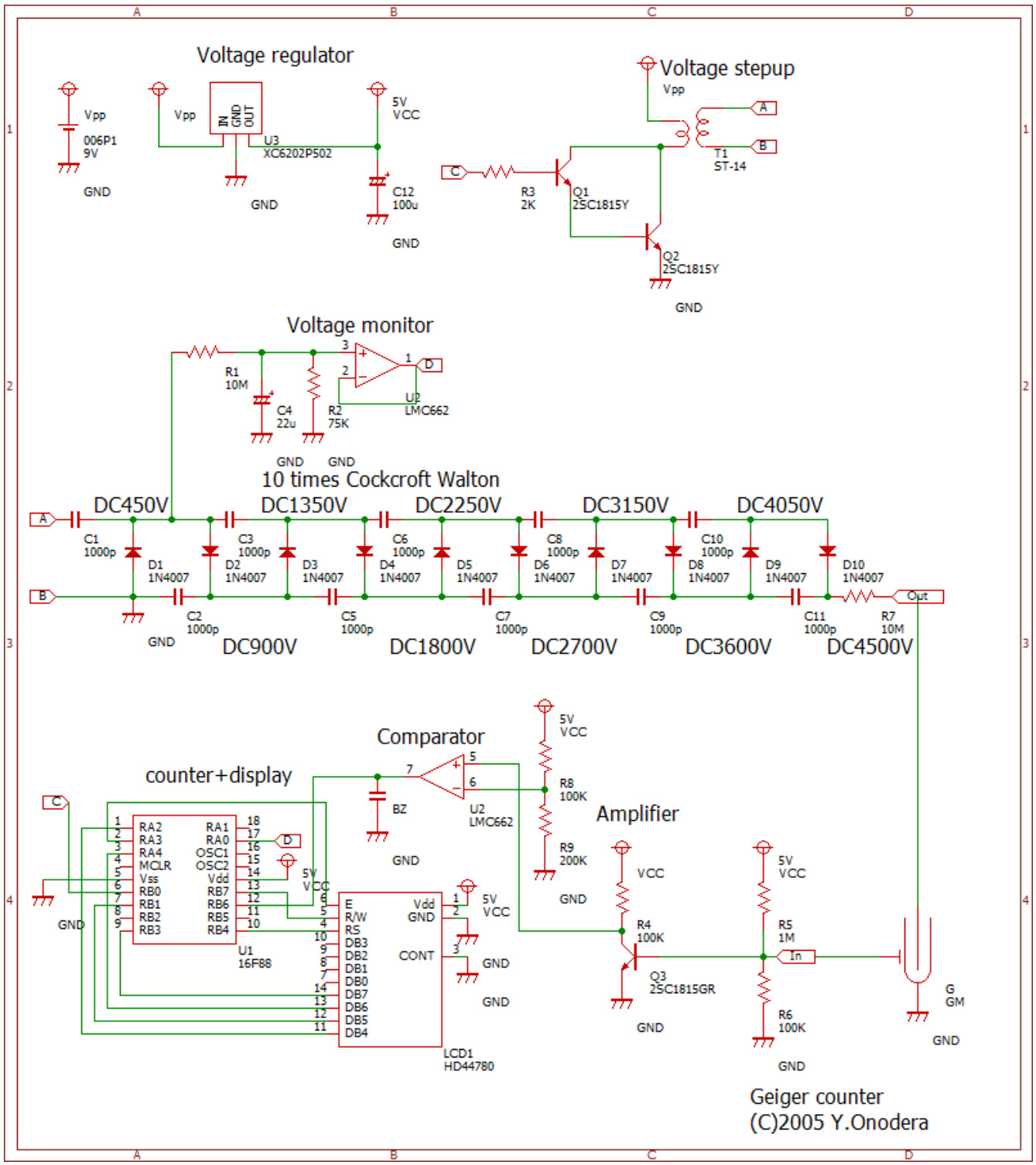
- Be sure to separate the PCB of a high-voltage part. When it makes from the same board, electric discharge by surroundings lump of an electric charge may be caused.
- Keep the restriction range of a high-voltage part.

Section 6 Block diagram



The 10 times high voltage is generated using the Cockcroft Walton circuit.

Section 7 Circuit



- At voltage stepup of a transformer, the current profit is earned by the Darlington connection using two 2SC1815(s).
- The Cockcroft Walton circuit generates the 10 times as many high voltage as this.
- The bias of 0.4V is applied to the detection pulse by R5 and R6. A noise and a detection pulse are separated.
- 3.3V are generated by R8 and R9, and this voltage standard and comparator are formed by the operational amplifier. A pulse shaping is carried out.
- The monitoring of operation voltage is pulled out from Cockcroft's first step. If it pulls out from the last stage, operation voltage will be affected due to impedance.
- A piezo-electric element makes detection sound as PUCHIPUCHI.
- When using an external power supply, it is good to use the stable power supply of 9V.

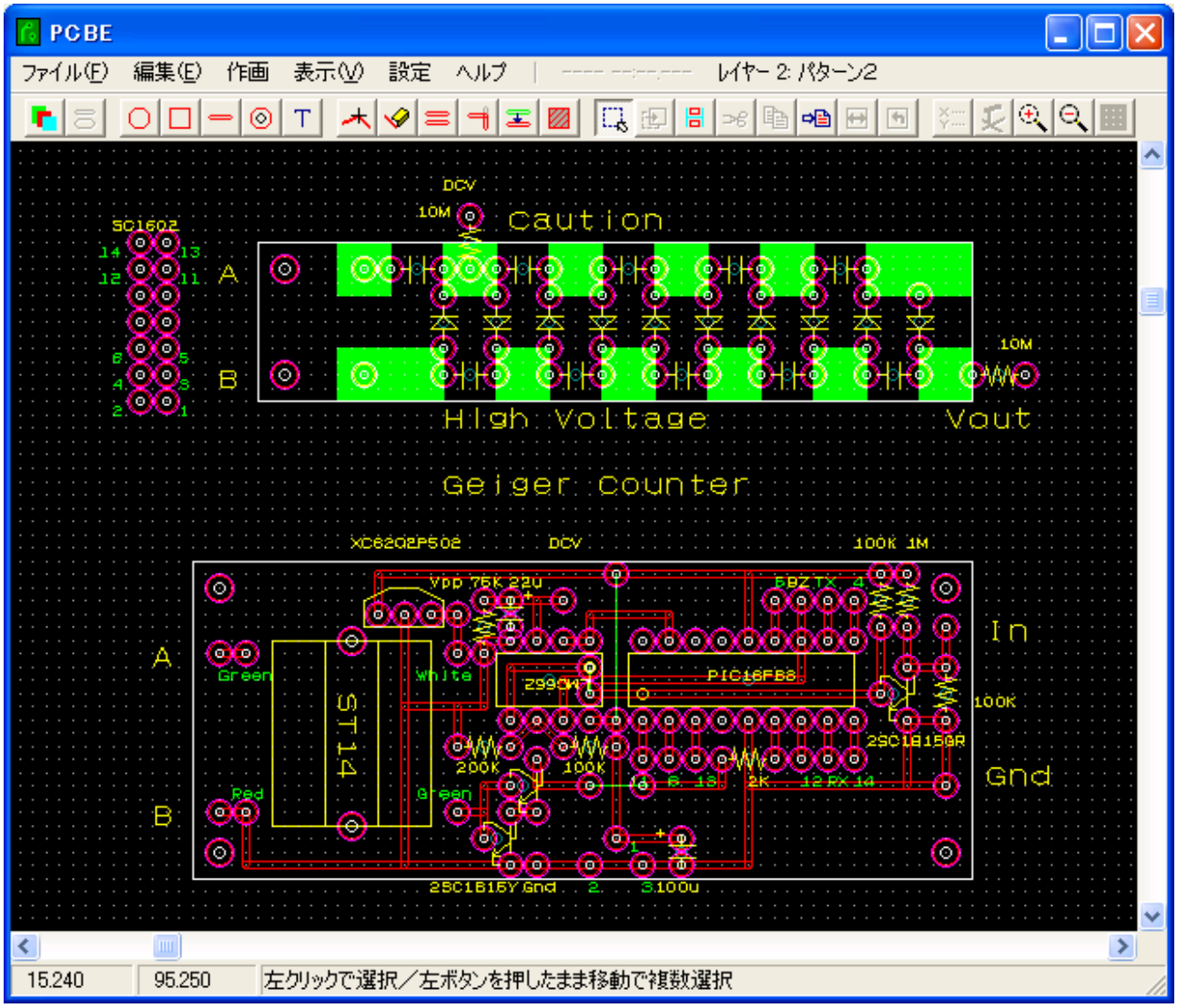
Section 8 Parts table

Part value	quantity	Part number	Note
1000p	10	C1,C2,C3,C5,C6, C7,C8,C9,C10,C11	Ceramic capacitor,Voltage-proof 1KV
22u	1	C4	Chemical capacitor,Voltage-proof 16V
100u	1	C12	Chemical capacitor,Voltage-proof16V
1N4007	10	D1,D2,D3,D4,D5, D6,D7,D8,D9,D10	power diode,Voltage-proof 1KV
HD44780	1	LCD1	16 rows 2 lines LCD, SC1602B with HD44780
2SC1815Y	2	Q1,Q2	NPN general purpose transistor, hfe range:120-240, compatible 2PC1815Y, Not pin compatible 2N3904
2SC1815GR	1	Q3	NPN general purpose transistor, hfe range:200-400, compatible 2PC1815GR, Not pin compatible 2N3904
10M	2	R1,R7	Carbon resistance 1/4W
75K	1	R2	Carbon resistance 1/4W
2K	1	R3	Carbon resistance 1/4W
100K	3	R4,R6,R8	Carbon resistance 1/4W
1M	1	R5	Carbon resistance 1/4W
200K	1	R9	Carbon resistance 1/4W
ST-14	1	T1	SANSUI Transformer (impedance 500K:1K)
16F88	1	U1	PIC
LMC662	1	U2	CMOS Operational amplifier
XC6202P502TB	1	U3	Voltage regulator 5V, same as 78L05
9V	1	006P	Alkaline battery, Nickel hydrogen battery is good.
BZ	1	BZ	A piezo-electric element
Case	1	Case	Case 117x84x41mm

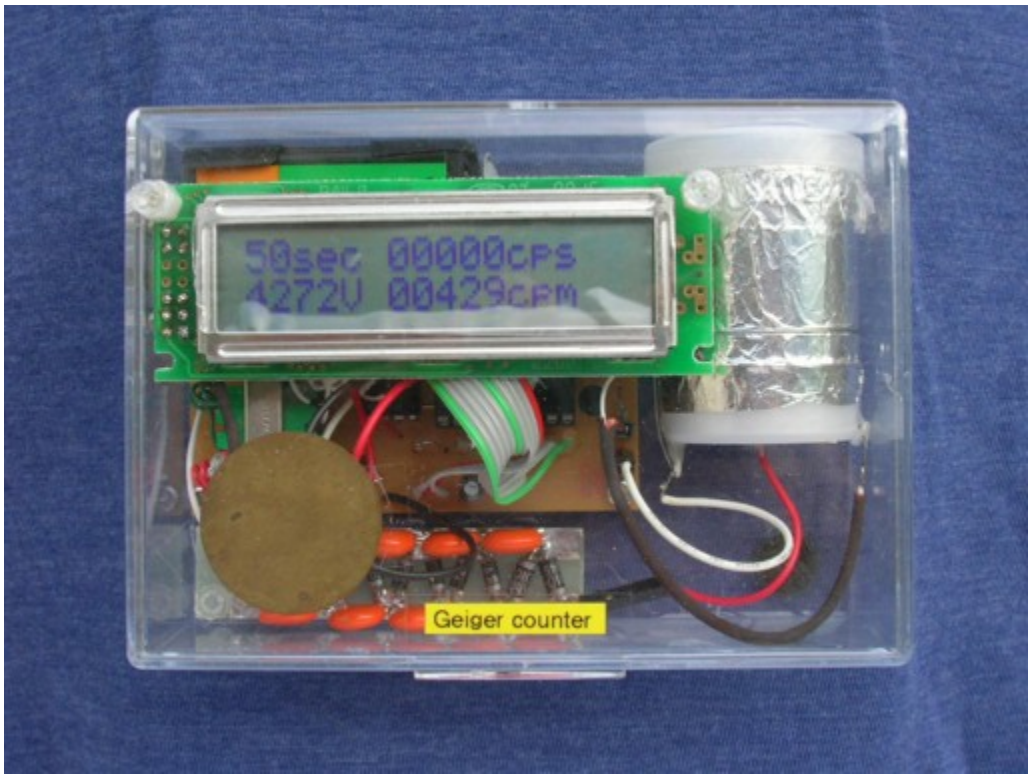
- LMC662 is CMOS and Rail-to-Rail type.
- 78L05 has about 2mA of self-consumption current.
- It can be substituted for the rank Y of 2SC815 also at GR.
- DC resistance of ST-14 6.3K:32. When a transformer is damaged, resistance is out of order.

Section 9 PCB

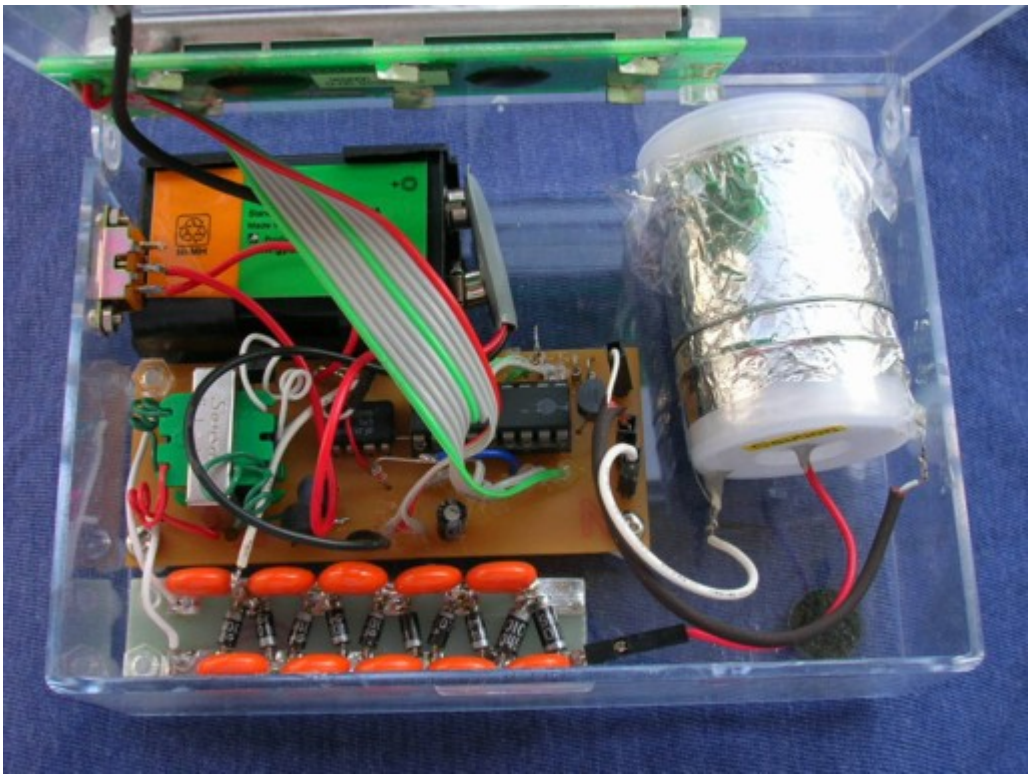
PCB was designed with electronic CAD.

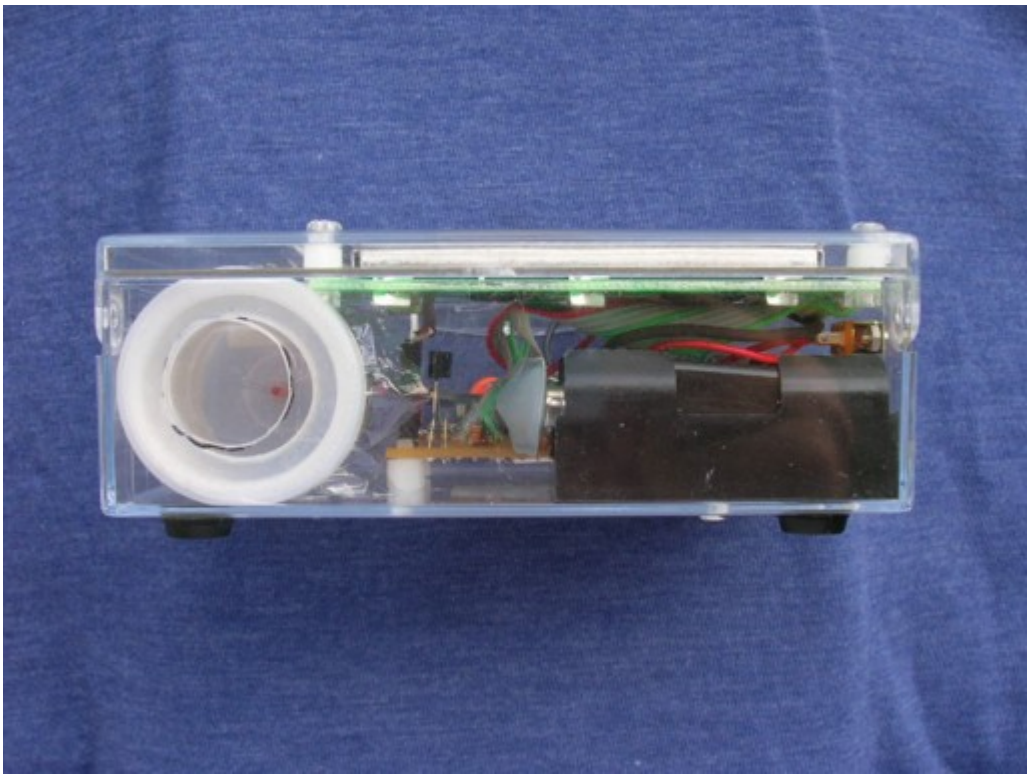


Section 10 Photos



Upper left=Remaining time[sec], Upper right=[cps], Lower left=Operation voltage[V], lower right=[cpm]

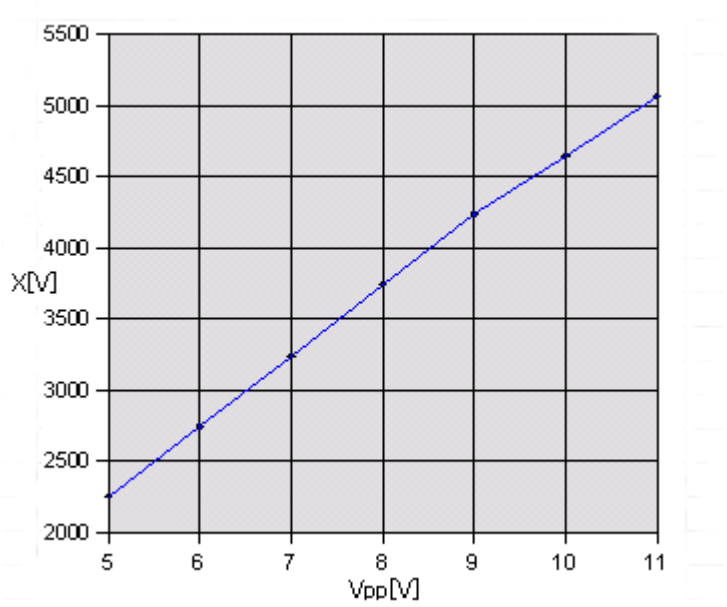




It was finished very compactly.

Section 11 Operation voltage feature

The power supply voltage Vpp is changed and operation voltage is measured. The high voltage of 3000V to 5000V cannot be measured by high impedance, the special measurement circuit is needed.



Vpp voltage vs. operation voltage to GM tube

Vpp voltage[V]	A/D	Operation voltage X[V]
5	1.38/282	2256
6	1.67/343	2744
7	1.98/405	3240
8	2.29/468	3744
9	2.58/529	4232
10	2.84/581	4648
11	3.09/633	5064

It is changing linearly. The analog voltage A and the operation voltage X can be drawn from the following expression of relations.

- Expression of relations with analog A and digital D(10bit resolution、5V reference)
  A[V]＝D / 1024 x 5

- Expression of relations with operation voltage V and analog voltage A(Voltage separation of resistance and 10 times of Cockcroft Walton)
  X[V]＝alpha x A x 10M / 75K x 10, alpha is a coefficient by the waveform.

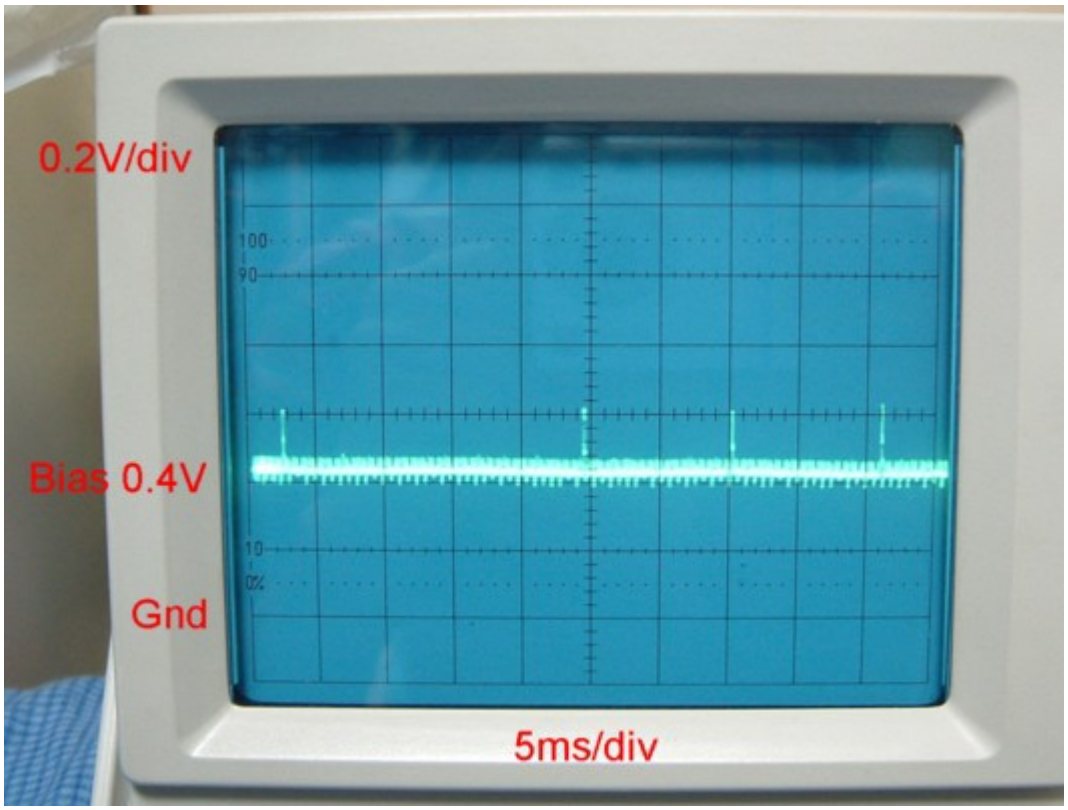
At last, operation voltage X is

X[V]＝alpha x6.5 xD

If digital value D is known, the operation voltage X is known. In order to simplify the digital calculation by PIC, it is referred to as X[V] =8xD. If it is 8 times, only shift operation is required.
75K has counted backward as divided resistance.(To be set to alpha x 6.5 = 8). Although there are some errors (several 10 V), it is used enough.
In addition, the resolution of the above-mentioned thing to operation voltage is 8V.

Section 12 Detected pulse

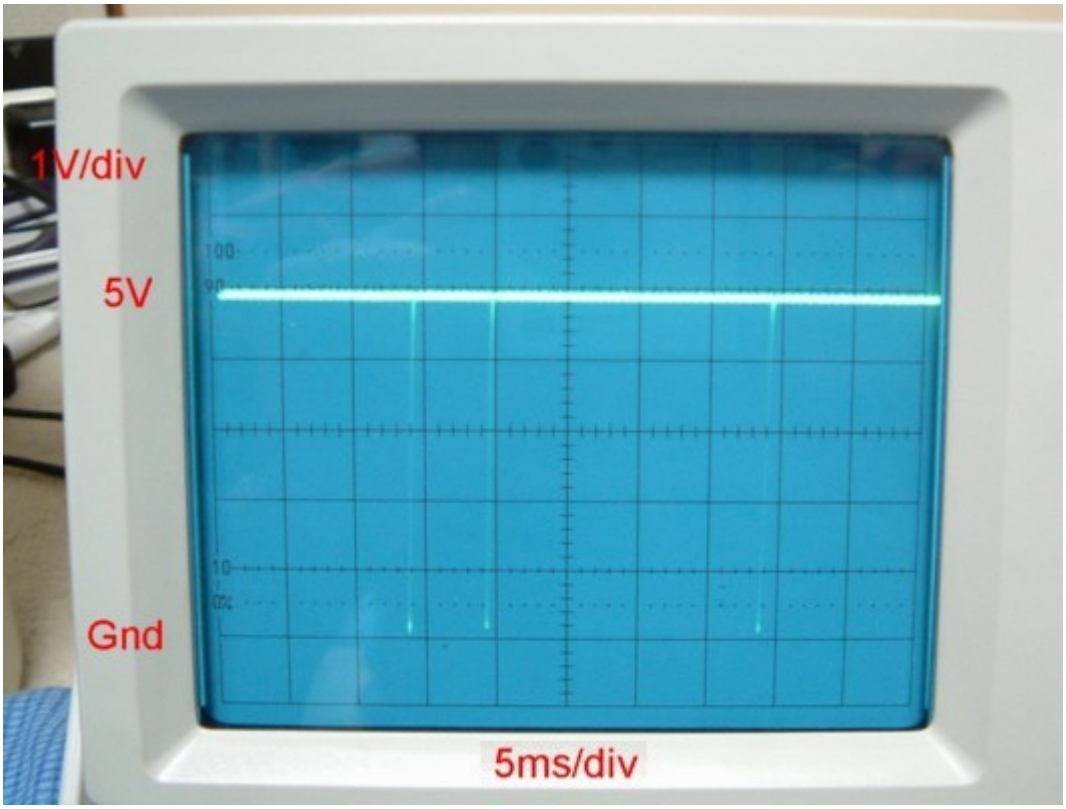
Operation voltage is raised gradually and the voltage from a detection part was observed with the oscilloscope.



A detection pulse is about 0.2 Vpp(Voltage Peek to Peek).
Since the signal of 0.2 Vpp is insufficient to input 0.6V(ON) of a transistor, BIAS 0.4V have been applied.
Thereby, a transistor will be turned on if detection pulse 0.2Vpp + BIAS 0.4V amount to 0.6V.
The noises from the Cockcroft Walton circuit are about 0.07 Vpp.
In order to avoid this noise, exquisite BIAS is set up.
In case of signal under a noise, a shield is required.

The signal of transistor observed with an oscilloscope.

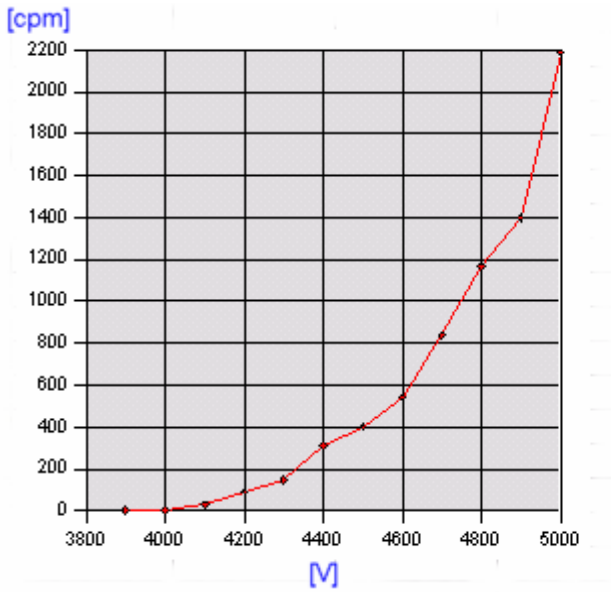
A noise is separated and 5 Vpp outputs from a transistor. A pulse is about 50[us]. This signal is counted.

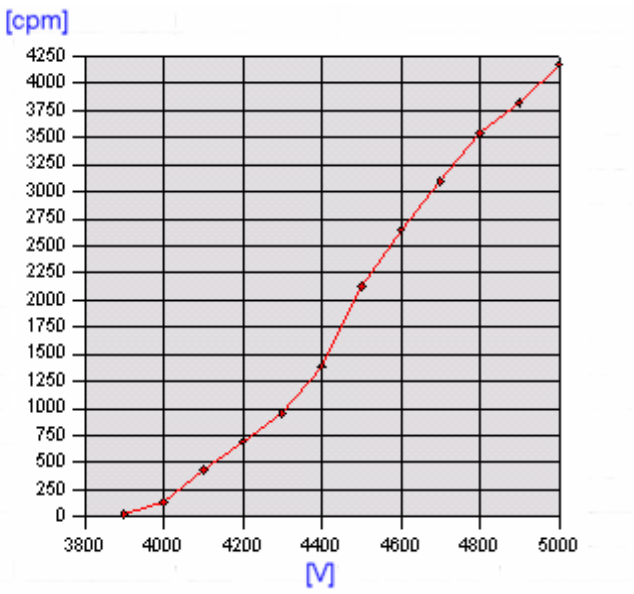


Section 13 Butane gas density and the counter

It investigated how it would be different by the existence of butane gas in a certain sample. It was made to make it filled as much as possible with butane gas.

Operation voltage[V]	Butane 100%[cpm]	Butone 0%[cpm]
3900	0	23
4000	3	138
4100	29	431
4200	94	690
4300	148	954
4400	311	1389
4500	402	2126
4600	540	2652
4700	837	3093
4800	1165	3542
4900	1398	3819
5000	2185	4177





When there is no butane gas which is prevention gas, there are many counts. If the existence of radiation is investigated, butane gas is not needed in order to make sensitivity high.
If butane gas is put in, the number of counts will rise rapidly more than from operation voltage 4600V.
From about 4100 to 4600V are stable. This range is suitable for measurement. It is designed to be set to operation voltage 4232V at Vpp=9.

Measurement unit

- cps:count per second
- cpm:count per minute

Section 14 Dead time

Measurement impossible time (Dead Time) exists in a Geiger Muller counter after observing a particle before the next observation. This is for taking time to recover a series of electric reactions. Actual detection pulse width is about 50 us.
In the case of too much many radiation, the omission in measurement is caused.

Section 15 Window film

In fact, a kitchen wrap is the optimal film. Polyethylene film is not suitable. The kitchen wrap is made of polyvinylidene chloride (PVDC), and is very thin as 11um. Therefor, it is easy to pass along radiation.
Oxygen permeability is very low, and it is convenient to hardly pass gas.
The molecule of butane(CH_3-CH_2-CH_2-CH_3) gas is larger than oxygen(O_2).

Oxygen permeability[cc/m^2-day・atm]

Polyvinylidene chloride	50
Polyethylene	9000

Section 16 Conversion from CPM to uSv/h

The rough conversion method from cpm to dose-of-radiation[uSv/h] is shown. It is based on a background. As for the background in Japan, the following things are known in general.

Outdoors	0.04(0.01 - 0.08)[uSv/h]
Indoor	0.06(0.02 - 0.12)[uSv/h]
On the sea	0.006[uSv/h]
Altitude 10,000m	5[uSv/h]

Section 17 Natural radiation

Let's measure radiation. A sample that acquisition is easy and safe is low-salt used for the dietary therapy for high blood pressures. Weight distribution: Sodium chloride 50%(NaCl) and potassium chloride 50%(KCl). You can get it in a supermarket.
0.0117% of the potassium in a nature is ^{40}K of radioisotope. ^{40}K emits a beta ray.
Calculating from an atomic weight, 3mg per 100g of this low-salt ^{40}K is included.
The salt (NaCl 99%) which does not contain potassium chloride for comparison is also prepared.

Preparation

1. Put the gas of a lighter into an air Geiger Mueller counter. Butane gas is heavier than air.(Air:Butane=1.00:2.08). It takes 10 seconds. Butane gas is flammable gas. Be careful not to ignite.

2. Measure a background. A relative dose of radiation is measured on the basis of this.

3. Wrap a sample to use easily. A beta ray passes a wrap.

Tips on measurement

- Butane gas slightly escapes from a wrap gradually. Put in gas before measurement. You may have a experience that the helium gas balloon has shrunk on the next day.
- Power on and wait until the operation voltage is stable. A background is stable.
- Keep away the sample which is not measured several meters from a Geiger-Muller counter. To keep low background. A beta ray progresses the inside of air several meters, colliding with a molecule. You can observe this phenomenon with a misty box.
- Since measurement is accompanied by the error, it is good to carry out a sample several times and to average.
- Don't wrap a sample doubly.

Measurement result

Sample	First[cpm]	Second[cpm]	Average[cpm]
Background	11	9	10
Low salt(NaCl+KCl)	25	21	23
Salt(NaCl)	9	13	11
glow tube starter(Fluorescent Starter)	2111	2173	2142

Consideration

- The low-salt containing potassium shows 2 times the value compared with a background.
- Natural salt shows a slightly larger value than a background.
- The promethium ^{147}Pm is used for the old glow tube starter, ^{147}Pm emit the beta ray. The beta ray is protected by glass and does not leak. Long luminous paint is used instead of the radiation element, and then the latest glow tube starter does not have radiation.
- In addition, there is a mineral-rich sediment of a hot spring as a sample which can be obtained comparatively safely. It is known that the radiation element is contained in mineral-rich sediments, such as a radium hot spring.

All the food containing potassium emits radiation.

Section 18 Measurement at a hot spring

Background

The source of a hot spring

Measurement result

Sample	Value[cpm]
Background	164
The source of a hot spring	752

The hot spring is gushing and the sand containing radioactivity can be extracted.

Section 19 Measurement of space radiant rays

Let's measure the difference in the dose of radiation by altitude. You had better do on the plane. I measured it on the alpine road shown altitude. It is the Fuji Subaru line of Yamanashi Prefecture.

Measurement result

where	Altitude[m]	Average[cpm]
The second stage	1596	455
Osawa parking	2020	1027
The fifth stage	2305	3270

Amazing!
The atmospheric pressure inside the air GM tube falls as altitude goes up. And then probably, detection efficiency increased.

Section 20 Frequently Ask Question

- Why uses paper for the negative pole(cathode)?
  Paper is a high resistance film (G ohms), and makes electric charge disappearance quiet. It is immeasurable if a detection pulse is too short.

- Is the electrical connection of paper and the lead carried out with a bond?
  In the high voltage, paper carries out behavior near a conductor. An electric charge moves to the lead from paper.

- It sounds beep from a transformer.
  Transformer voltage step-up is oscillated by outside. The oscillation vibrates the transformer slightly and becomes the sound.

- Even if turning off, it sounds small PUCHIPUCHI from an air Geiger Mueller counter.
  This is the electric discharge sound by radiation detection. Since operation voltage does not immediately fall even if turning off.

- How much Butane gas should be put in?
  It seems that there is optimal density.

- It seems that geiger counter will count, turning to the sun.
  It seems that the ultraviolet rays from the sun have influenced measurement. Try to paint the window with black magic, to omit ultraviolet rays.

