

DC+AC composite power supply for safe operation of resistive detectors

Rui De Oliveira

RD51 WG6 18/06/2021

Introduction

- We have now produced at MPT several hundreds of resistive detectors.
- We can now say that they are more stable and robust , but also more sensitive to dust during handling and assembly , compared to metallic detectors.
- We know also that they can develop permanent leakage current if they are too long exposed to instabilities due to dust or not adapted voltage settings. Most of the time during the first power up.
- Resistive detectors have usually only one amplification gap, so the working point and the max voltage are close . But the question is how close? A margin of 30V to 50V is mandatory for safe operation and it should be measured at one point.
- It is always tricky to check this margin above the working point without taking the risk to bring the detector in a critical region , and potentially create a problem.
- This is a problem for the users , we have received back a significant quantity of detectors for cleaning. But it is also a problem for us (producer) because this multiply the number of cleaning before qualifying a detector.

So the main question triggering this talk is :

What could we do to start detectors safely even in presence of dust , and define precisely the margin without any risk ?

outline

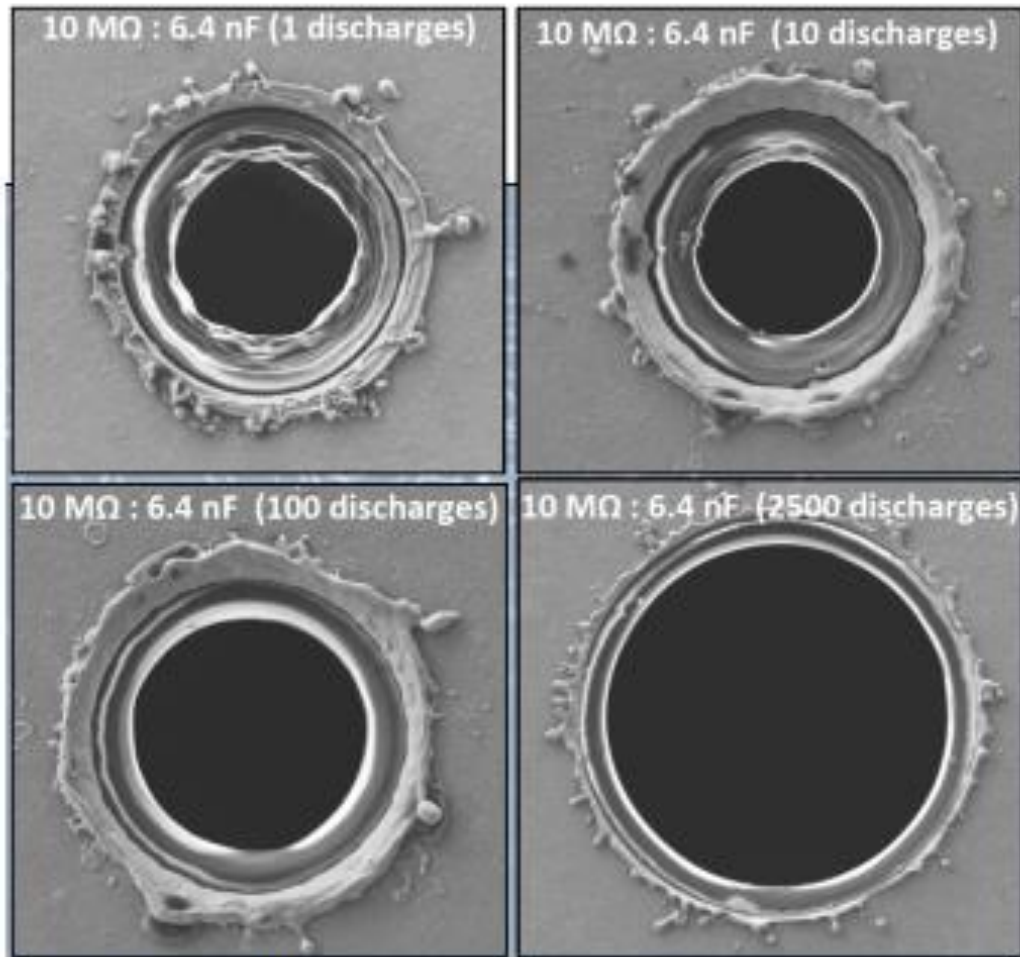
- Which parameters influences spark damage .
- Spark Energy versus detector type.
- Repetitive sparks in resistive structures.
- AC+DC composite voltage supply.
- Next steps.

Parameters influencing spark damage .

3 main parameters :

- **1/The most important : level of released energy**
 - Obviously a spark in a large detector will deposit locally more energy than in a small one
 - That's why electrodes are segmented and why resistive layers have been introduced → reduce capacity
- **2/Materials thermal conductivity**
 - For a given energy , materials with high conductivity will diffuse the local heat
 - We have observed , with STD Micromegas, that in extreme condition the SS cathode mesh melts while the copper anode is not so much affected .
 - For a given metal , thick layers will better diffuse the local heat
 - 35um electrode THGEM are always less damage than the 5um copper electrodes in GEMs
- **3/Material melting point or degradation temperature**
 - For a given energy released , a material with higher melting point or higher degradation temp is less damage.
 - Kapton burns at 500 deg , epoxy burn at 300 deg
 - Tungsten, Nickel electrodes are less damage than Cu electrodes

Let's look at some examples just to get a filling of the complexity
I'm not going to develop point 2 and 3 in this presentation, too long!

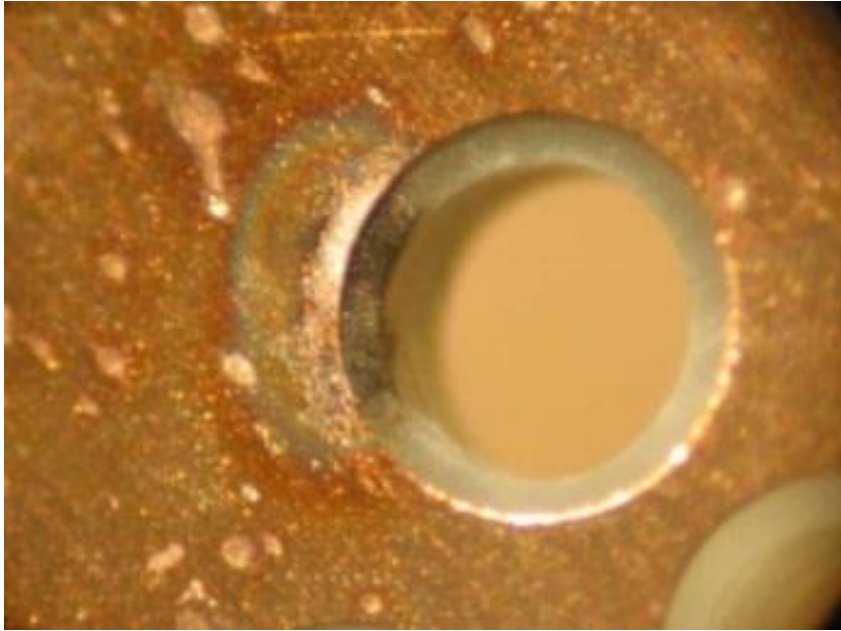


Single hole GEM simulating a 100mm x 100mm GEM

- The Copper have melted (temp above 1085 deg)
- We see a polyimide evaporation with no residues
- What is the temperature during PI evaporation?
- And does the gas helps to create this clean evaporation?

© J. Merlin et al.

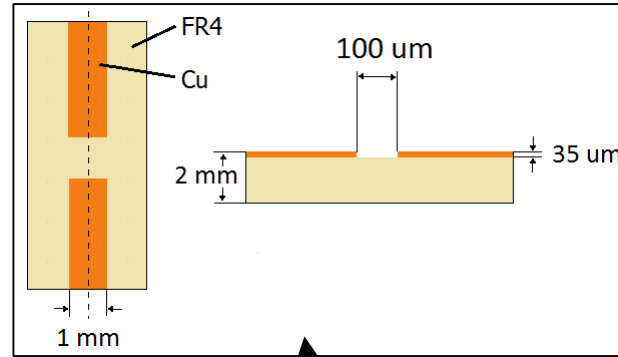
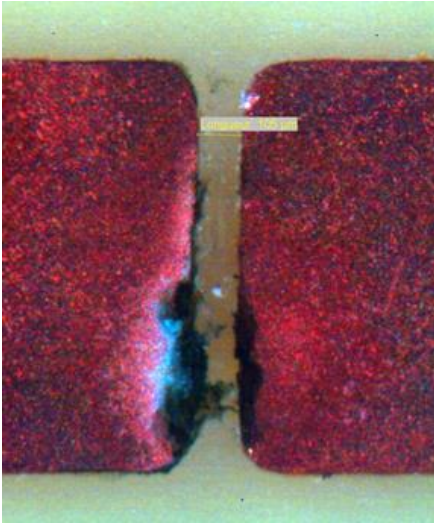
<https://indico.cern.ch/event/709670/contributions/3008626/>



THGEM 1mm thick , 0.7mm holes, 1mm pitch in Air

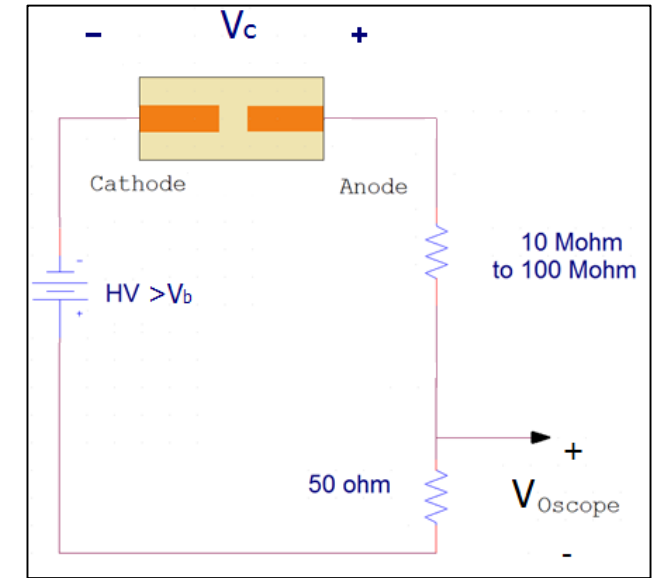
- No copper melting
- Clear sign of excessive heat on the copper (but below 1000 deg)
- Clear signs of epoxy carbonization (above 300deg)
- But no melting nor evaporation of copper and epoxy !

22 minutes of continuous sparks
6.6M sparks



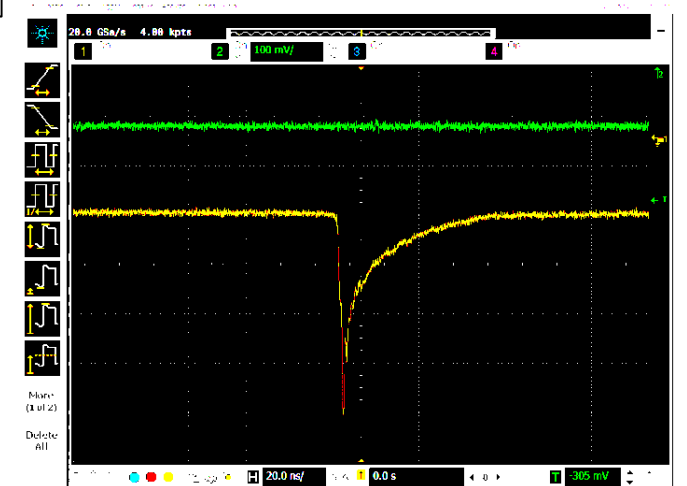
2 small electrodes 1mm x 3mm side to side in air
Low capacity structure close to resistive detectors

- We see epoxy carbonization and evaporation
- We see also copper evaporation , but no melting !



After cleaning

Initial situation:
fall time 2ns
Apparent recharge time 50ns
1V pulse in 50 Ohms \rightarrow 20mA
Spark rate 5Khz



Cosimo Cantini 19/04/2012
RD51 presentation

Single spark released energy versus detector type

- GEM, 50um thick 10cm x 10cm, 500V → 0.8mJ
- THGEM, 1mm thick, 10cm x 10cm, 1000V → 0.2mJ
- uRwell , 50um thick , (10MOhms/sqr) , 500V → 0.7uJ
- A spark in a resistive detector is typically 1000 time less energetic
 - → A single spark cannot create any damage
- But if we reach 1000 sparks during 1 sec the total energy released will be equivalent to the one released by one spark in a GEM.
- Important : We've never seen any structural defects after repetitive sparks in resistive detectors as we can observe with other detectors.
 - → I think we can conclude that tiny energetic spark, distributed in time, creates only skin effect .

Repetitive sparks in resistive structures

- In a resistive detector the local capacitor releasing energy during a spark can be in the range of 5pF (this is an estimate for a 10Mohms/square layer)
- The capacitor charging time ($2.2 \times RC$) during a spark is really short , R in this case is the impedance of the conductive channel created by the spark in the gas .
 - Charging time \rightarrow negligible : a few nS.
- When the capacitor is fully charge , the local field cannot sustain anymore the conductive channel and the spark stops.
- The local capacitor is then discharged through the resistive layer
 - Discharge time $2.2 \times RC$: $2.2 \times 5\text{pF} \times 10\text{Mohms} \rightarrow$ approximately 100uS
- In case of a single spark triggered by a single highly ionizing event , the process stops \rightarrow negligible energy is released \rightarrow no damage \rightarrow no problem .
- If the problem triggering the spark have not been removed , a new spark occurs . In this case the spark rate can reach in theory 10k sparks/sec.

With repetitive sparks we have observed (many times) 2 different behaviors:

Short spark repetitions , of less than a sec (0.1s? 1000 sparks? Difficult to say), reduces the leakage currents.

- It looks like the defects or dust are evaporated in a clean way without any carbonization.

Repetitive long repetitions , of 10 sec or more , increases the leakage current.

- It looks like evaporated compounds are carbonized and deposited around the sparking location.

Can we control repetitive sparks ?

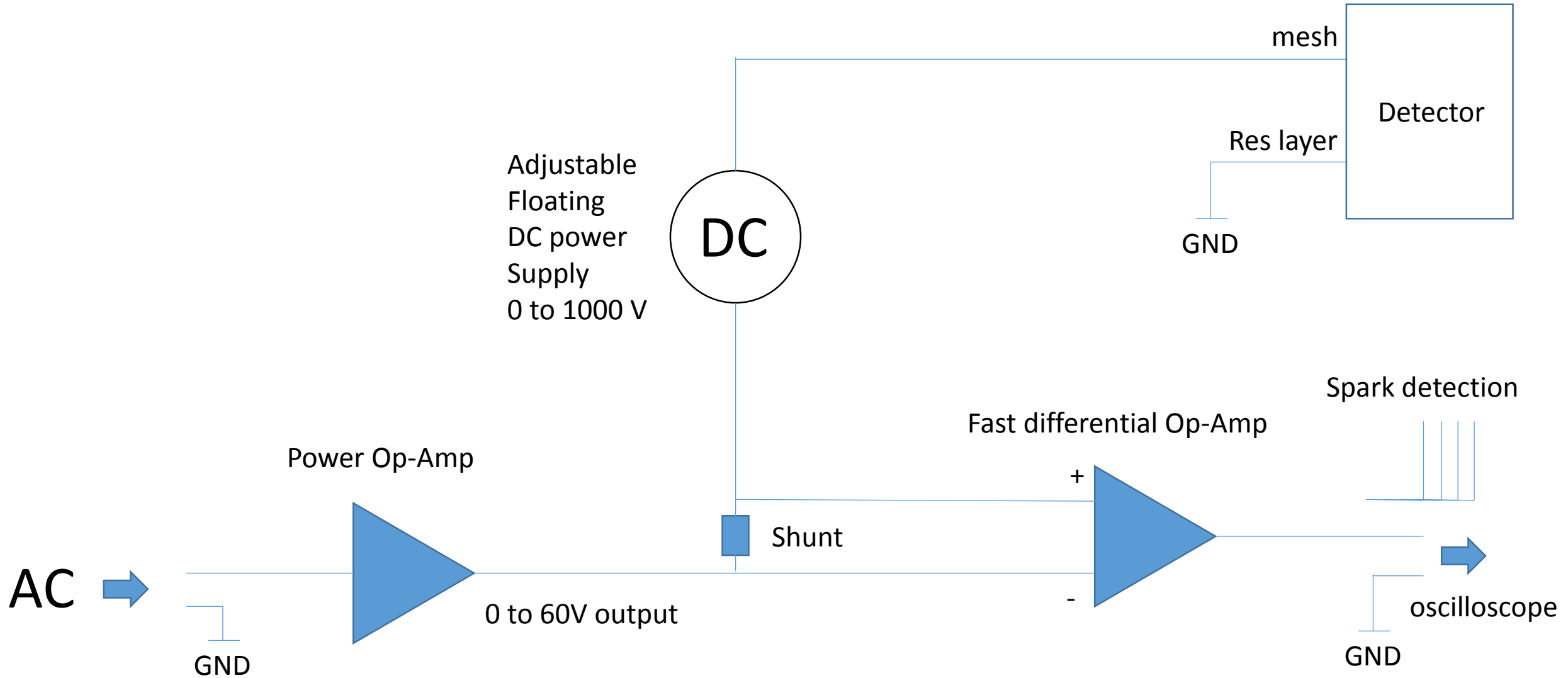
Can we adjust precisely the energy release ?

- Can we detect a spark repetition and stop it when it last too long ?
- For example by sharply reducing the voltage by 50 V , 100 V ?
- Can we simply clean a detector electrically ?

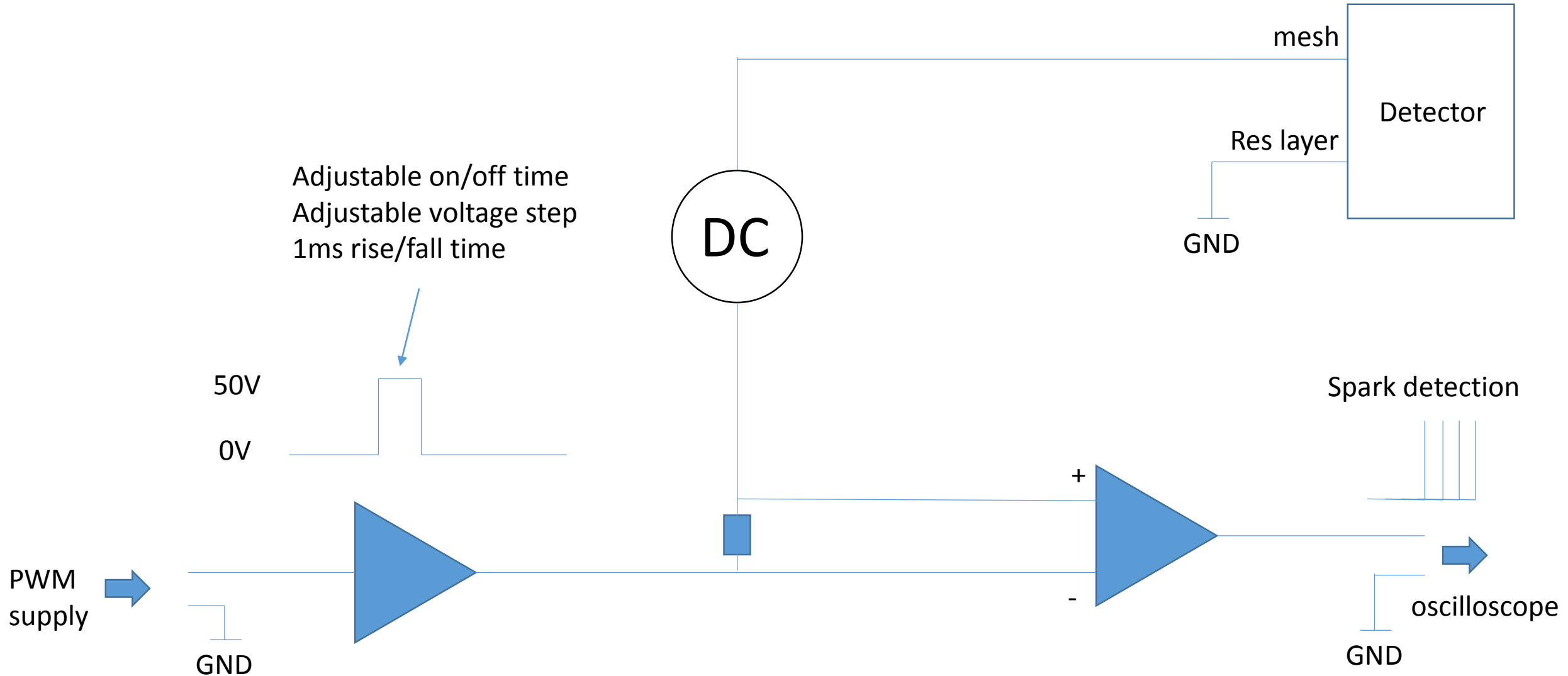


- In order to give an answer to all these question we have designed a HV supply that should be able to change the voltage by 60V on a 10nF capacitor in less than 1ms.

Block diagram

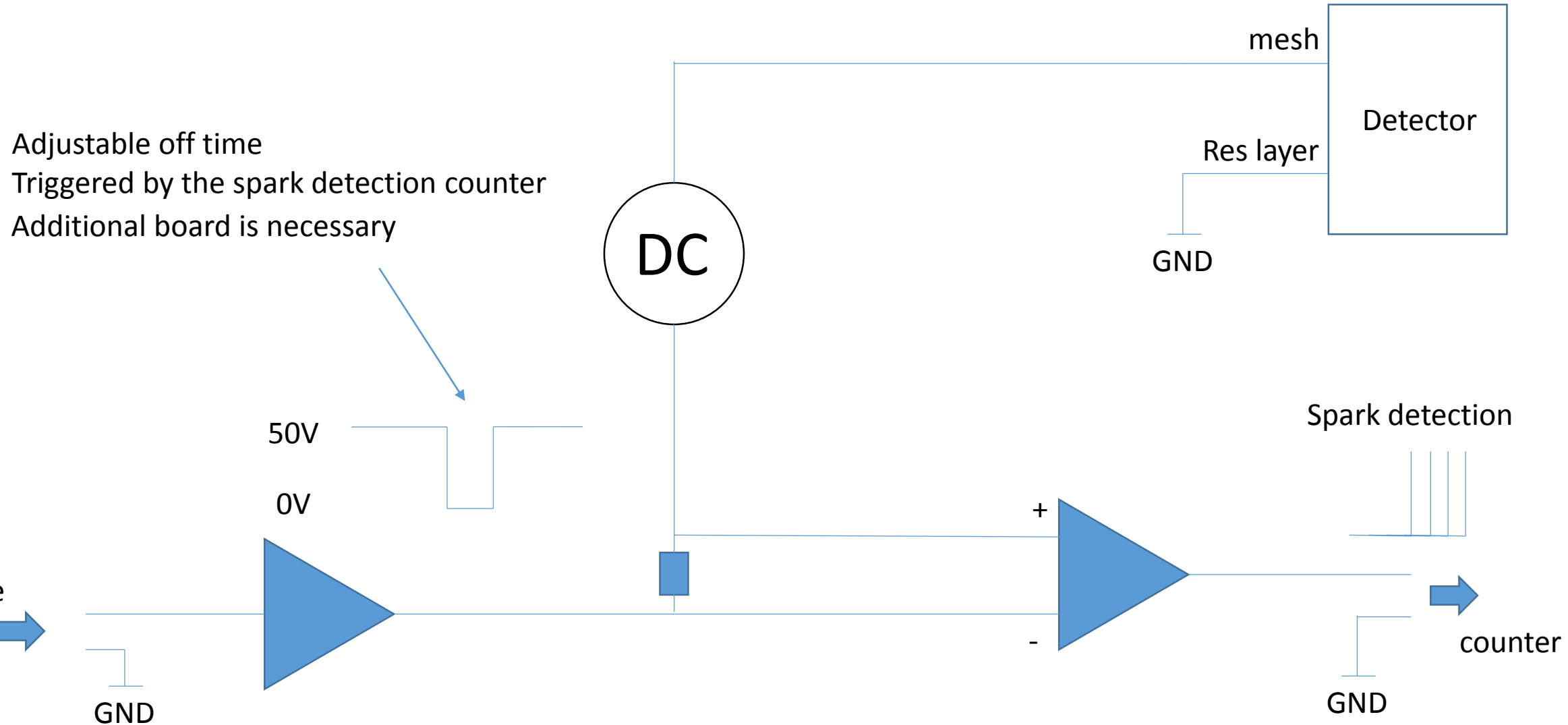


First power up



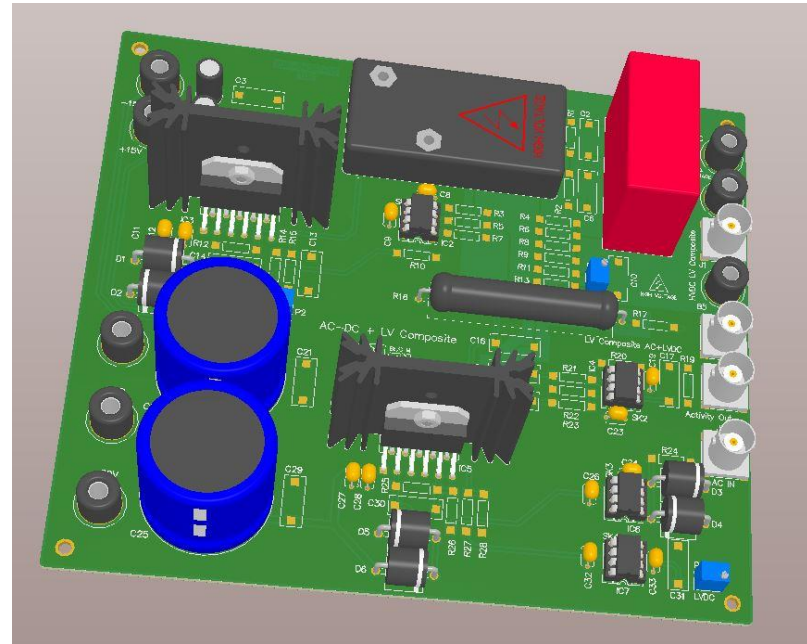
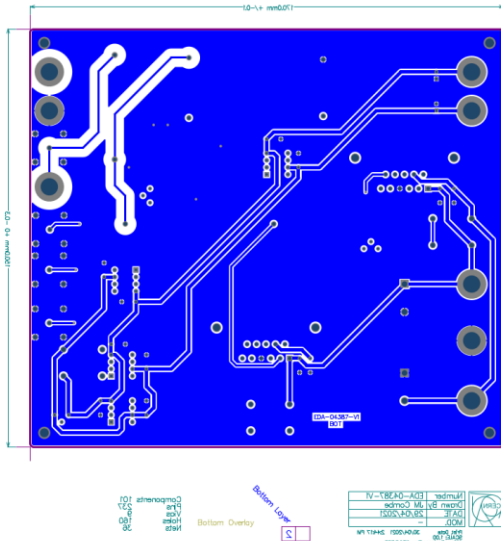
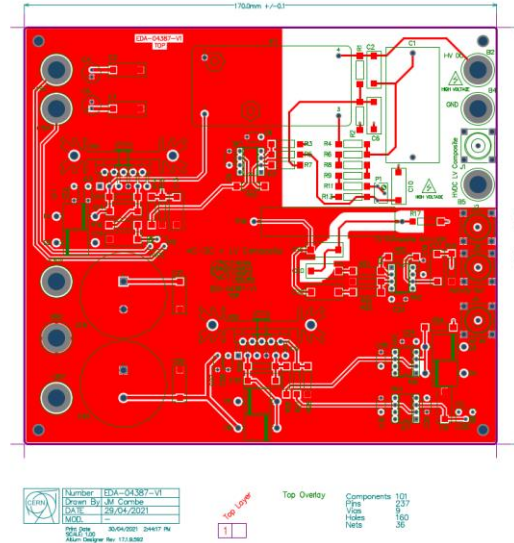
In this example the detector voltage is raised in a classical way, with regular controlled excursions at 50V above.
→ This should first clean the detector and we should safely discover the maximum possible voltage without risks

Operation mode



In case we detect long spark repetition at 550V the detector can be immediately put in safe mode at 500V. If it does not recover immediately we can go back to the previous cleaning mode.

Next steps



- Board is under production (ready in 3 to 4 weeks)
- still waiting for components (10 weeks for the floating DC module)
- AC PWM → Ok
- Oscilloscope → Ok
- DC power supply → Ok



We expect some answers confirming or not this strategy within 3 to 4 months

Thanks

- It is hard to say that we can select optimum materials and then do a structure.
 - For example we can imagine a THGEM made of Aluminum nitride dielectric with thick Tungsten electrodes, but how to produce this?
- Usually it is the opposite. To create a structure we select an existing production technic and then look for possible materials, and unfortunately the materials we can use are not the best to resist against sparks.
 - At the end a THGEM is made of glass epoxy with copper electrodes
- It is not impossible to select first materials with better heat conductivity or better melting point, but processes to structure them become rapidly complex , most of the time limited in size and too costly.
- So Let's keep the materials we have now and let's dig again the direction to reduce or have a better control of the released energy.
 - Single stage detectors without sectors → multi stage reducing voltage → sectors → resistive layers → ???