DIY detector building

August 2, 2022

1 Build the detector

More information can be found on the original project website: https://scoollab.web.cern.ch/diy-particle-detector

1.1 Before starting

Before you start building the circuit take a look around your workspace and get familiar with the tools like multi-meter, soldering iron, power supplies etc. For later debugging also a couple of oscilloscopes and microscopes are available.
Get your components by passing them around the table or picking them up from the storage desk.

1.1.1 Practice soldering

If you don't feel yet confident to start soldering don't hesitate to request some spare board and components to practice.

1.1.2 Measuring equipment

Get used to the multi-meter by measuring voltages (battery, power supply) or resistance values for example.

1.2 Enough talking, let's build

Build the circuit by following the instructions Assembly Intructions without soldering the diodes yet. Also **DO NOT** attach a battery prematurely.
Before soldering any cable connections, check the layout together with the tin box to make sure everything fits as intended.
Once you are done soldering the detector, a couple of checks should be executed before proceeding:

- Check the resistance between the power supply leads ("-" and "+9V"). You should measure a resistance of 9 kOhm.
- Conduct a continuity test between the audio cable pins and ground and signal on the PCB (plug in audio cable for this)
- Power the circuit with an external power supply by using crocodile clips (ask tutor). Be careful with the polarity! The current consumption should be in the mA range.
- Test the voltages at the probe points from yesterday (test1, test2) and compare with the expected values. Stop if they do not agree.

- (optional) Test with injection circuit. An external pulse can be fed into you circuit, just like in the simulation. Ask a tutor.

After all tests are passed, assemble the diodes onto the board. Make sure they face the right direction and are assembled onto the right side of the board.

1.3 Observe real noise (and maybe signals)

Once the detector is complete observe its output signal on an oscilloscope. You can use an audio-to-BNC cable or try a more adventurous combination of crocodile clamps, banana cables and BNC adapters. Another option is to use dedicated oscilloscope probes and attach them with hooks or crocodile clamps. Ask your favorite tutor for help.
Investigate the influence of opened/closed box and light on the output signal. You can notice interesting noise and saturation patterns. For a good signal shielding from EM sources as well as from light is important. Use black tape to improve light shielding if necessary.
Finally, use a piece of uranium glass to observe real signals from ionizing particles! Wow! An example output signal is shown in fig. 1.1. You expect to see signals around 200 mV.

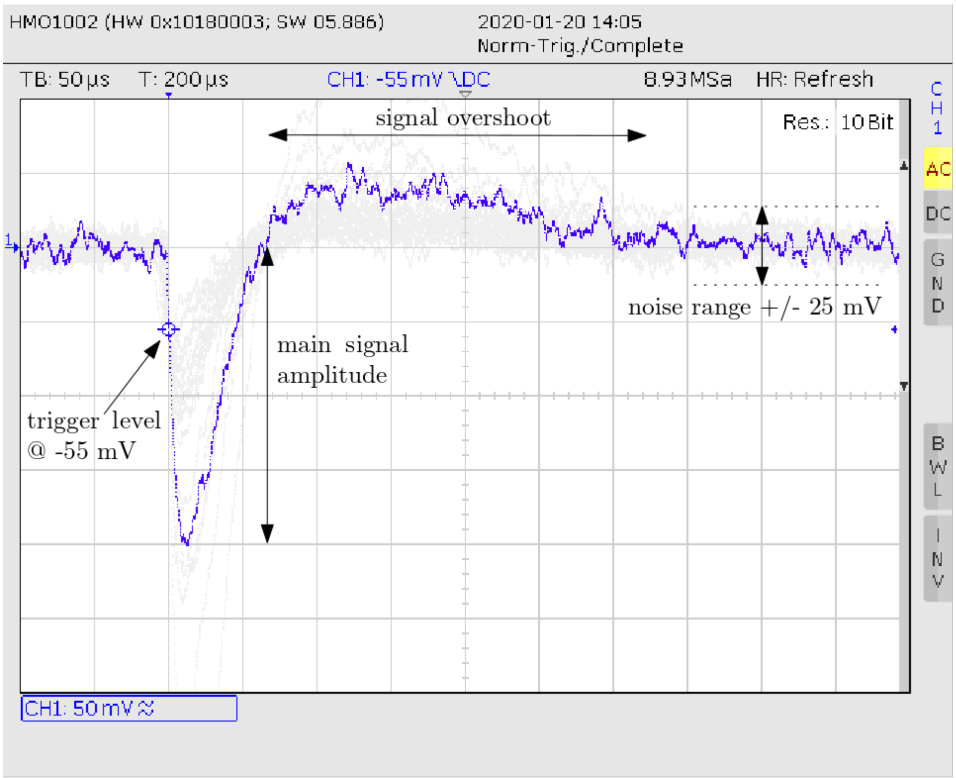


Figure 1.1: Example output signal of the detector

1.4 PC based measurement

Since an oscilloscope is too expensive for the average home user and also does not necessarily offer the most convenient interface to a computer you can use a standard sound card to read out the detector signal.

This part is experimental. If you get stuck or would rather skip it feel free to continue with more circuit experimentation in the bonus task.
Please follow the instructions here to read out the signal with the provided sound cards: https://github.com/ozel/DIY$_particle_detector/wiki/Softwaresignal-display--pulse-counting$
ATTENTION: Usually your laptop audio plug will not work, because it has 4 pin connectors for headsets (stereo audio, plus a microphone). The connectors and cables for the detector need dedicated microphone jacks with 3 poles (standard stereo audio cable). Therefore we provide you with an external USB soundcard.
You can try the dedicated python script or the web interface to get the signal on the computer. Make sure you see at least random fluctuations before looking for actual signals. The sampling frequency of the soundcard and the length of the pulses might make detection complicated. What is your sampling frequency? Compare that to the length of the pulse. If you want you can try modifying the circuit by using a larger feedback resistor for the CSA, which leads to slower discharge and therefore longer pulses.

2 Bonus task

In order to know if the detector is working it needs to be plugged to a PC or an oscilloscope. Another solution is to visualize the output signal via an LED. Because of the low voltage and length of the generated pulse, it needs to be elongated and converted to higher voltage.
In this section you build the circuit on a breadboard after simulation on LTspice.

2.1 Generate long pulse

To extend the duration of the pulse, the NE555 timer is used in mono-stable operation. Please refer to the datasheet for detailed information. Monostable operation is initiated when TRIG voltage falls below the trigger threshold (1/3 of vcc). The output pulse duration is approximately $1.1 \times RC$. With $10\,\mathrm{K\Omega}$ and $10\,\mu\mathrm{F}$, the pulse of 0.1 s is sufficient to be visible on the led.

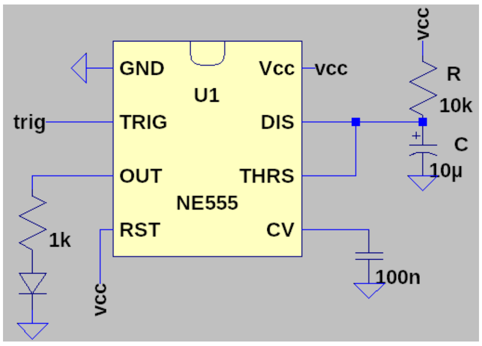
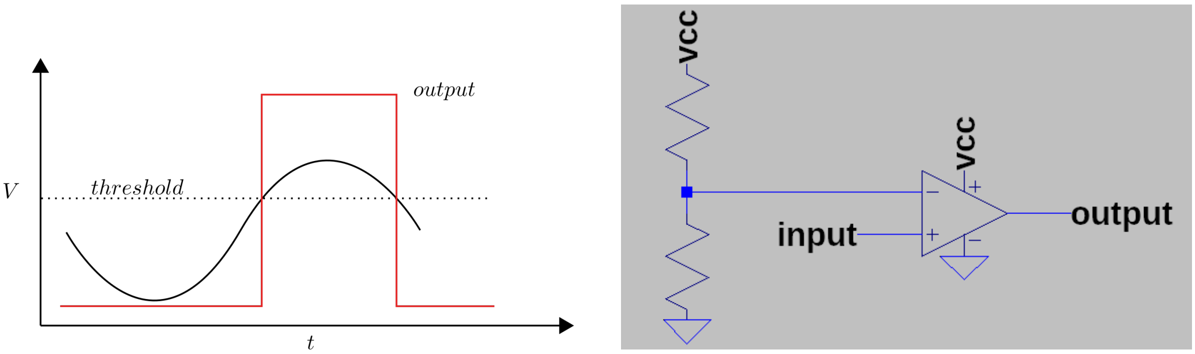


Figure 2.1: NE555 schematic.

On LTspice, draw the schematic shown in section 2.1. The NE555 can be found in the component library already. You can generate a trigger using a voltage source as a pulse.
On the breadboard, build the circuit. Using a pulse generator you can test the circuit.

2.2 Adapt voltage.

The pulse generated by the detector is used as trigger for the NE555 circuit but its low peak voltage ($\approx$ -150 mV) is not adapted. Any trigger bellow 3V will start the monostable operation. The idea is to use an operational amplifier set up as a comparator. Without any input, the output of the comparator is 0. If the input, the pulse from the detector, goes higher than a defined threshold, the output is set to vcc. The comparator circuit and waveform are shown in fig. 2.2. A voltage divider is used to create the threshold from vcc.



(a) (b)

Figure 2.2: Comparator.

2.2.1 Choose the threshold voltage.

The comparator circuit is powered by single 9 V supply. However, the output pulse is negative. It is only negative after the last capacitor C10. Before the output filter C10/R9, the signal has an offset of 4.5 V. This signal is therefore used for the comparator while the threshold voltage is set to 4.4 V.
In your current LTspice schematic, add the comparator using the TLE2072 model and connect the output of the second stage of the detector to the non-inverting pin. Connect the 4.4 V threshold to the inverting pin. You can either use a voltage divider or use a voltage source.

On the detector, solder a wire from the C9 resistor (not the side connected to the ground) to the middle contact of the stereo jack connector.
Since the threshold is obtained from the battery whose voltage decreases over time, the voltage divider is designed using a linear potentiometer.
On the bread board, next the the monostable cicuit, build the comparator. With a voltmeter, control the level of the threshold. With a function generator and an oscilloscope, control that the comparator is working.

2.3 Connect everything.

Plug the jack cable to your detector. On the other side, ising the crocodile cable, connect the middle contact to the input of the comparator. Connect the ouput of the comparator to the the TRIG pin of the NE5555.
After placing a source on top of the detector, the led will turn on every-time particle has been detected.