Gamma-Radiation CdZnTe Microspectrometer with exchangeable detector modules µSPEC

User Guide

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EXCLUSION OF LIABILITY

The ZRF Ritec SIA is not liable for errors and does not guarantee the specific utility of the µSPEC software or firmware. The ZRF Ritec SIA is not liable for indirect or subsequent damages due to errors of the µSPEC software or firmware.

The information in this manual has been carefully reviewed and is believed to be accurate and reliable. However, the ZRF Ritec SIA assumes no liabilities for inaccuracies in this manual. This manual is subject to change without notice.

SAFETY INSTRUCTIONS

1. Only skilled and or trained personnel should operate the µSPEC.
2. Do not open the µSPEC! Risk of an (mild) electrical shock will be present!
3. Do not operate the device without plugged detector!
4. Do not pull off/ plug in the detector while HV is operating!
5. Always make sure the detector-connector is free of dust or dirt before plug in!
6. Do not place the product on heat-generating devices such as radiators or fans!
7. Apply the µSPEC only in its designated purpose!

ATTENTION!

Please read the operator's manual carefully and make sure you understand the instructions before using the equipment and pay a special attention to items marked with this sign.

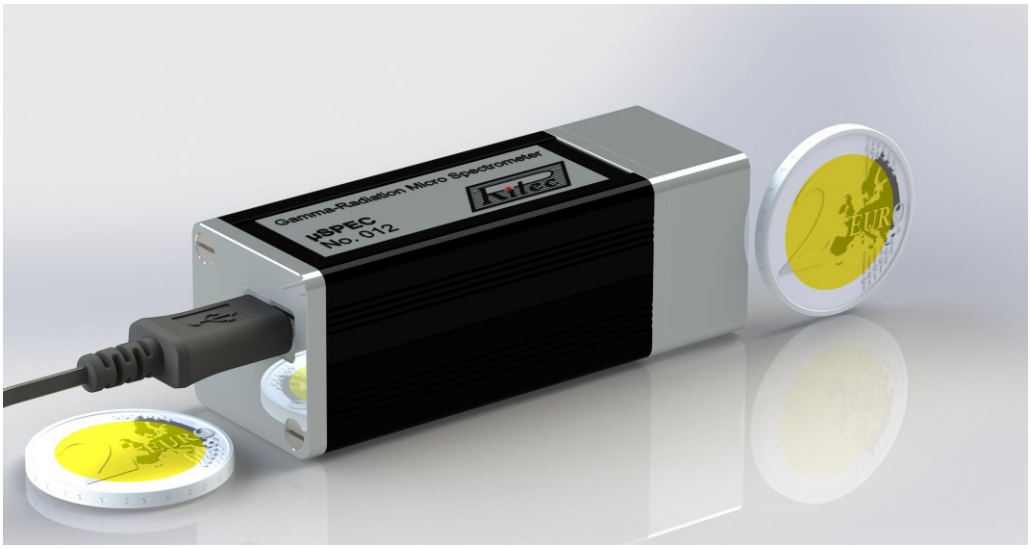
CONTENTS

1. INTRODUCTION

Gamma-Radiation CdZnTe Microspectrometer is a high-performance device based on application of room temperature operating CdZnTe semiconductor detectors and a very small and low consuming digital multichannel analyzer (MCA) MicroMCA527 (GBS-Elektronik GmbH). It is allowing measuring gamma-radiation spectra and storing it for processing in a PC through the USB port.

The microspectrometer is self-sufficient device and consists of two modules - a base MCA module µSPEC/µSPEC+ and a replaceable detector module. The base module contains an amplifier, a digital signal processor, a high voltage power supply of the detector, a low voltage power supply and computer interface. Exchangeable detector modules contain a charge sensitive preamplifier and a high quality CdZnTe detector. There are detector modules with different CZT detector volumes from 5 mm^3 to 1600 mm^3.

The microspectrometer is communicated and powered by a PC via USB port. It is made to operate under control of MS Windows based GBS-Elektronik GmbH WinSPEC or WinMCS free of charge software.



MAIN FEATURES

Very compact

Replaceable CdZnTe detector modules

High energy resolution and efficiency

High count rate capability

USB powered

Easy-to-use

MAIN APPLICATIONS

Gamma-radiation spectroscopy

Environmental monitoring

Nuclear power plants

Nuclear material flow monitoring

Home land security

Unmanned aerial vehicle

2. SPECIFICATIONS

- Detector type ..... CdZnTe quasi-hemispherical
- Detector volume:
  - µSPEC60 *with detector module DM60* ..... 60 mm³
  - µSPEC500 *with detector module DM500* ..... 500 mm³
  - µSPEC1500 *with detector module DM1500* ..... 1600 mm³
  - µSPEC310/01/A *with detector module DM310/01/A* ..... 1 mm³
  - µSPEC310/05/A *with detector module DM310/05/A* ..... 5 mm³
  - µSPEC310/20/A *with detector module DM310/20/A* ..... 20 mm³
  - µSPEC310/60/A *with detector module DM310/60/A* ..... 60 mm³
  - µSPEC500/A *with detector module DM500/A* ..... 500 mm³
  - µSPEC1500/A *with detector module DM1500/A* ..... 1600 mm³
- Energy range ..... 20 keV to 3.0 MeV
- Energy resolution (FWHM) at 662 keV@25°C:
  - µSPEC60 ..... <2.0%
  - µSPEC500 ..... <2.2%
  - µSPEC1500 ..... <3.0%
  - µSPEC310/XX/A:
    - for detectors volume 1 mm³, 5 mm³, 20 mm³ ..... <1.5%
    - for detectors volume 60 mm³ ..... <2.0%
  - µSPEC500/A ..... <2.0%
  - µSPEC1500/A ..... <3.0%
- Maximal throughput ..... >100 kcps
- Number of channels:
  - with base MCA module µSPEC ..... up to 4k
  - with base MCA module µSPEC+ ..... up to 16k
- Shaping time:
  - µSPEC ..... 0.1 µs to 2 µs, step 0.1
  - µSPEC+ ..... 0.1 µs to 25.5 µs, step 0.1
- Flat top time ..... 0 µs to 15 µs, step 0.1
- Power supply ..... USB, 4.5 V … 5.2 V, 100 mA max
- Dimensions without removable probe..... 25 mm × 25 mm × 72 mm
- Connecting cable length µSPEC310/XX/A, µSPEC500A, µSPEC1500A ..... up to 20 m
- Weight:
  - µSPEC60 ..... 60 gram
  - µSPEC500 ..... 65 gram
  - µSPEC1500 ..... 70 gram
  - µSPEC310/XX/A *with 20 cm cable* ..... 100 gram
  - µSPEC500A *with 20 cm cable* ..... 140 gram
  - µSPEC1500A *with 20 cm cable* ..... 160 gram
- Operation temperature range ..... 5°C … 50°C
- Humidity ..... ≤90%, non-condensing
- IP protection class IP00

3. DESIGN FEATURES

The µSPEC are consists of a base module and exchangeable different type detector modules.

Appearance of the µSPEC was shown in fig. 1.

Outer dimensions of base module µSPEC / µSPEC+ presents on Fig. 2.

The outer dimensions of changeable detection modules are presents on Fig.2 … 6.

The microspectrometer holder and waterproof holder, that can mount on tripod for comfortable using are presents on Fig. 7, 8.

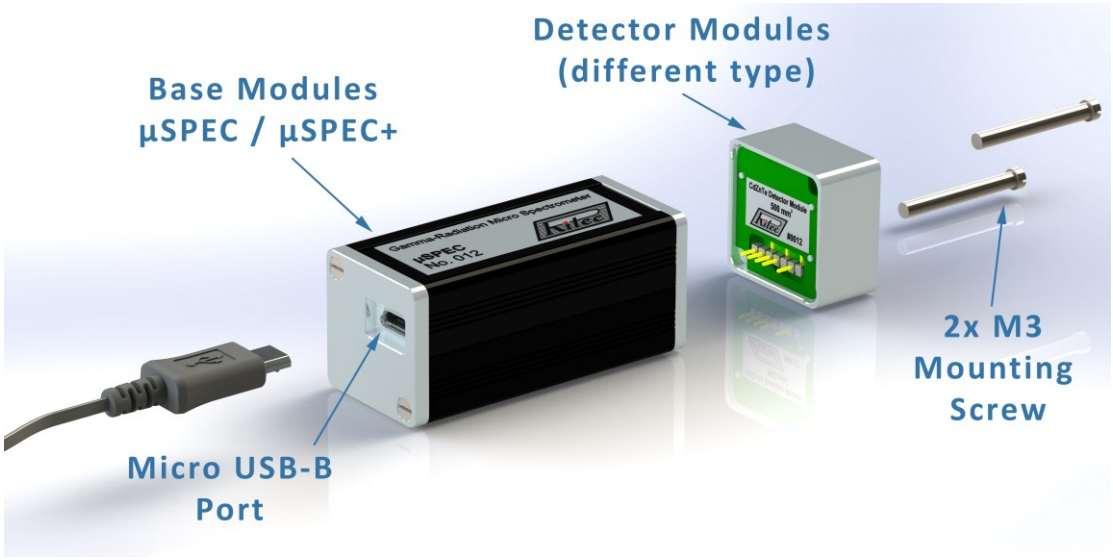


Fig. 1. Design feature of the µSPEC.

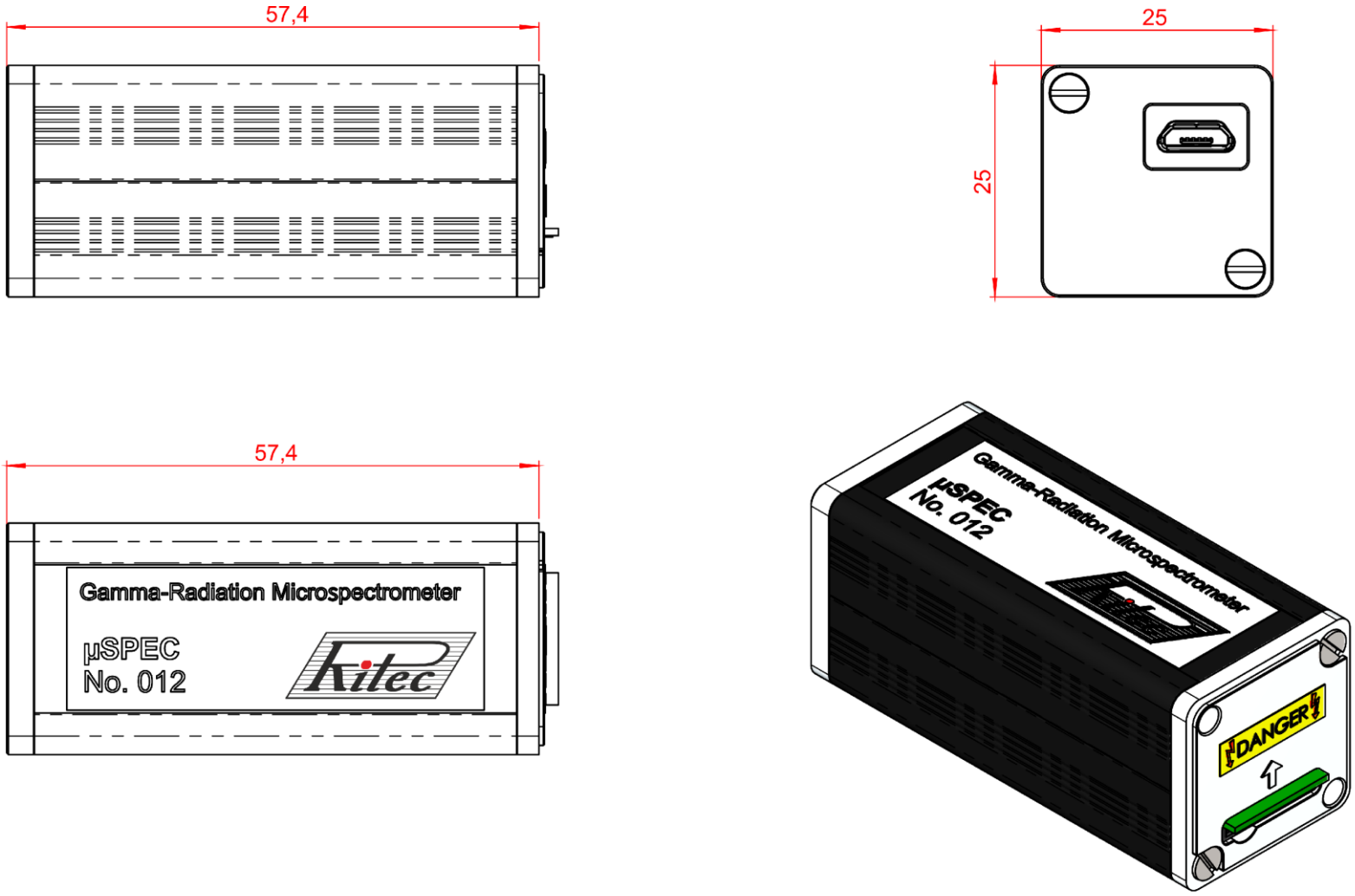


Fig. 2. Base Modules µSPEC / µSPEC+ outer dimensions.

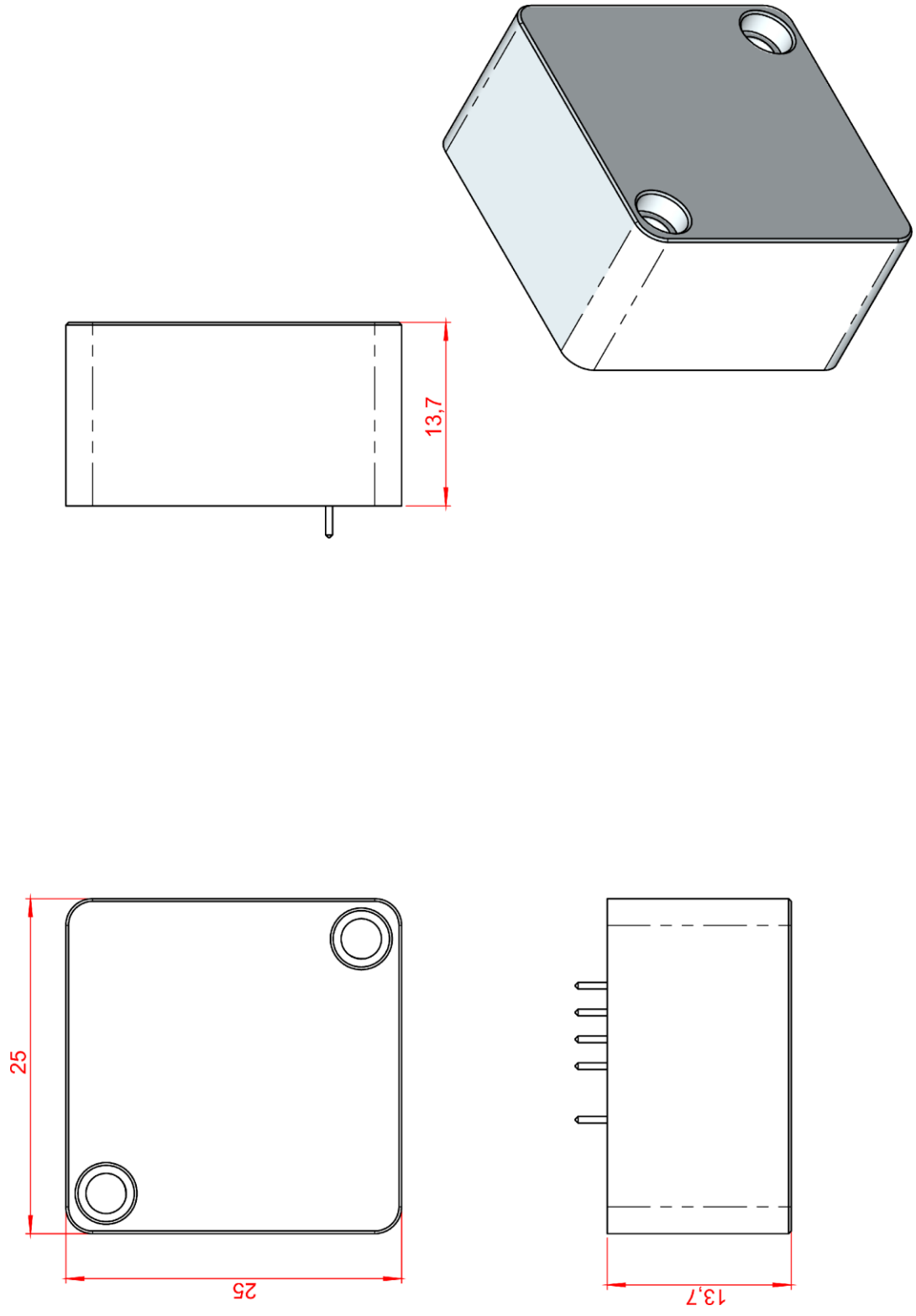
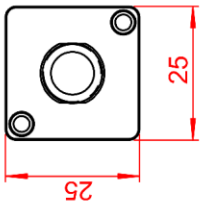


Fig. 3. Detector Modules DM60 / DM500 / DM1500 outer dimensions.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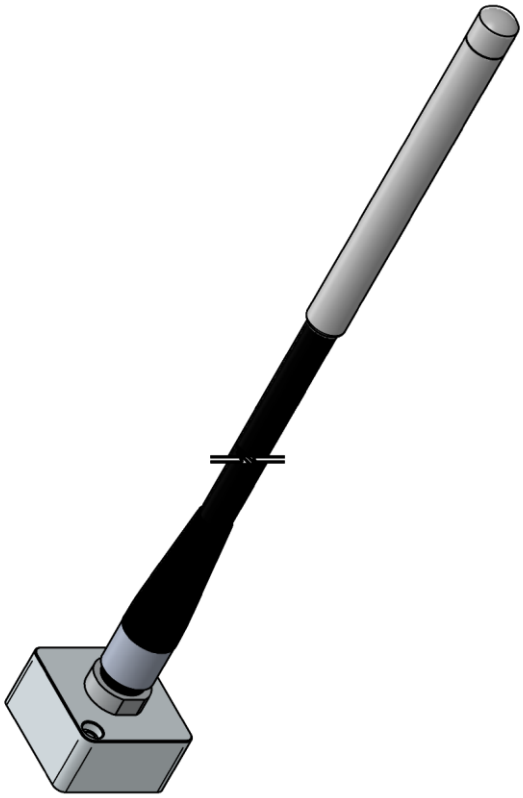

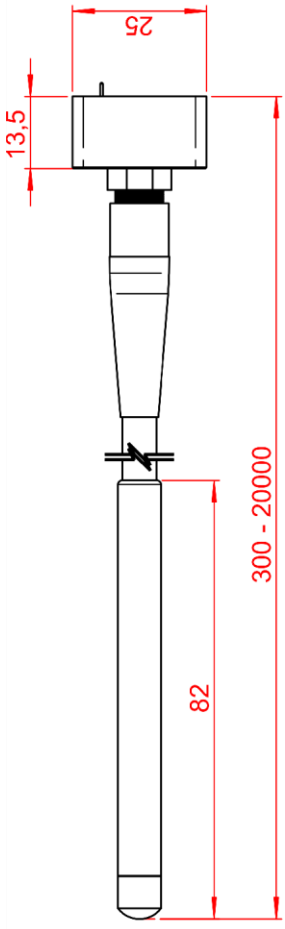
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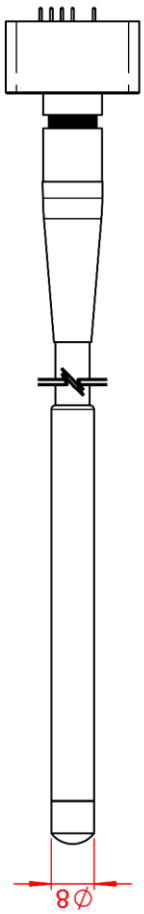
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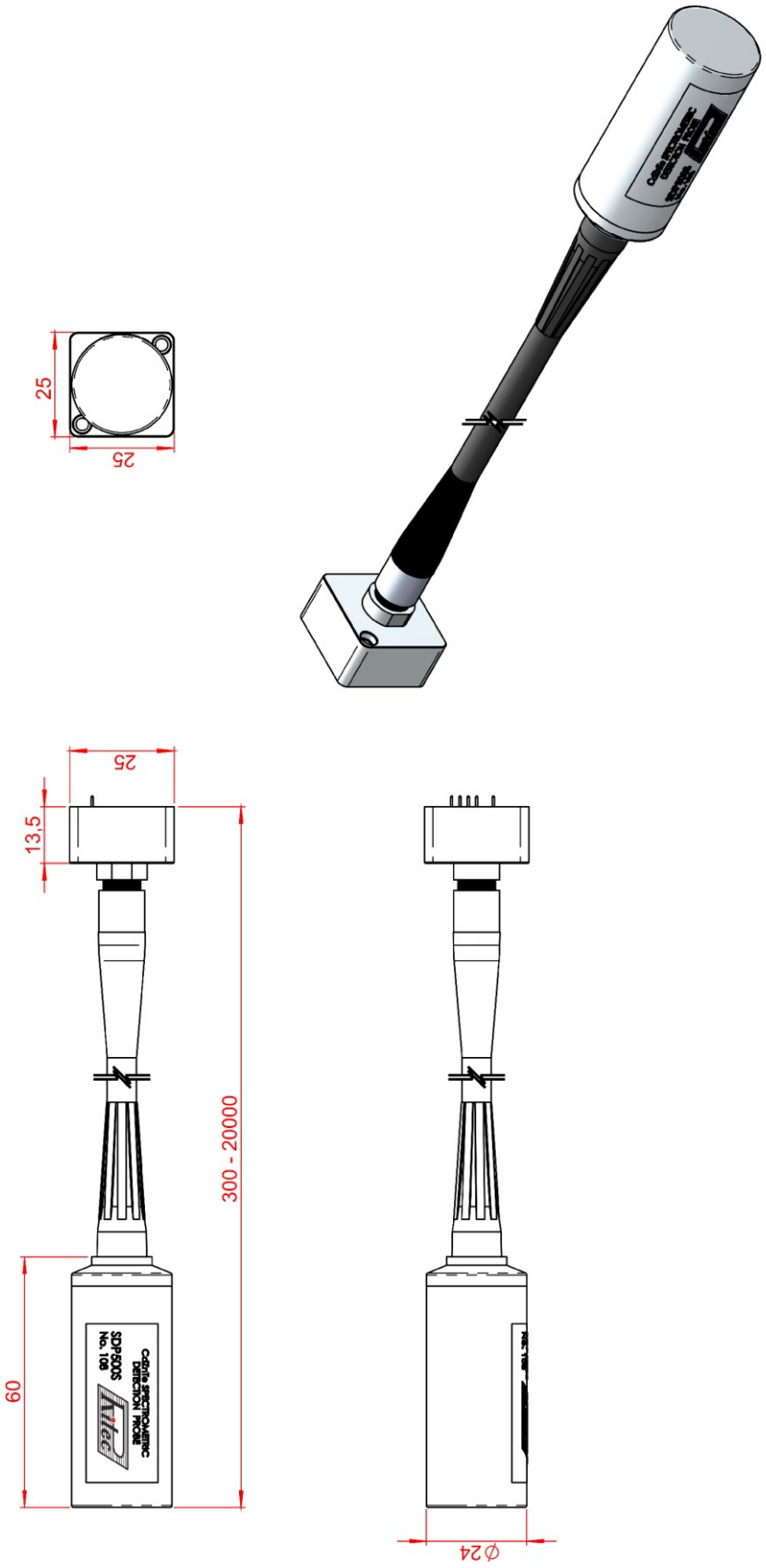


Fig. 5. Detector Modules DM500/A, DM1500/A outer dimensions.

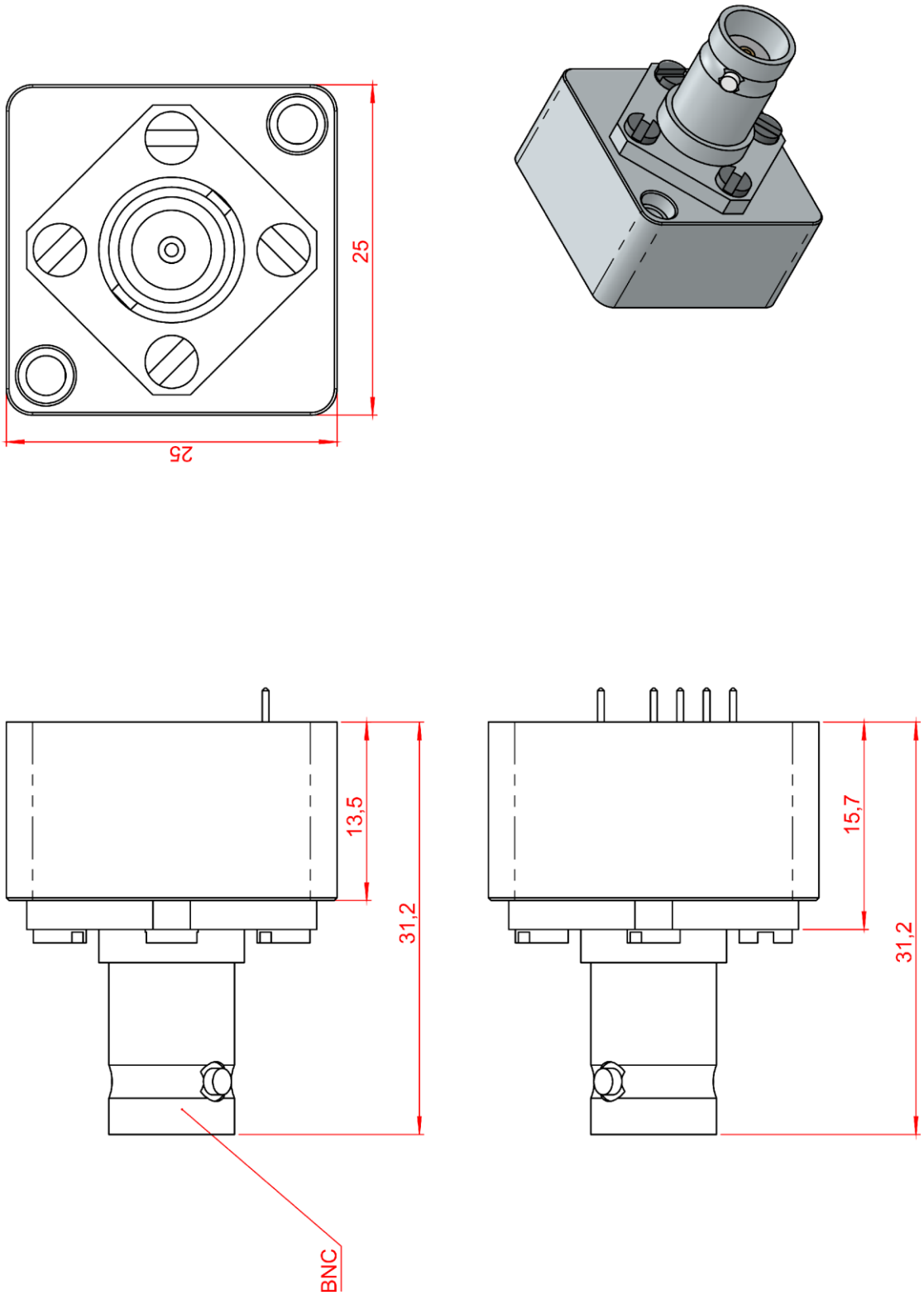


Fig. 6. Preamplifier Module PM120 outer dimensions.

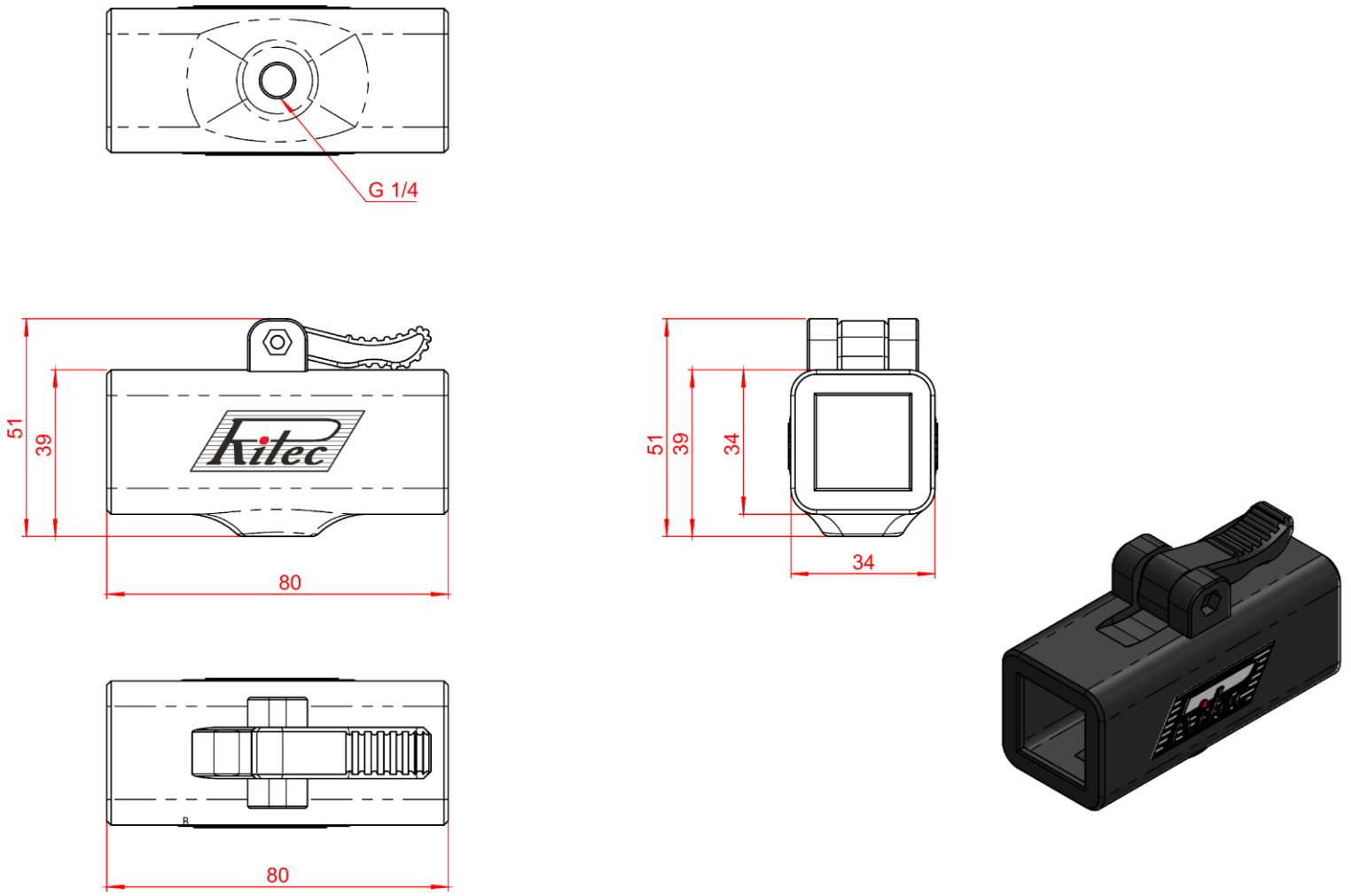


Fig. 7. Microspectrometer holder outer dimensions.

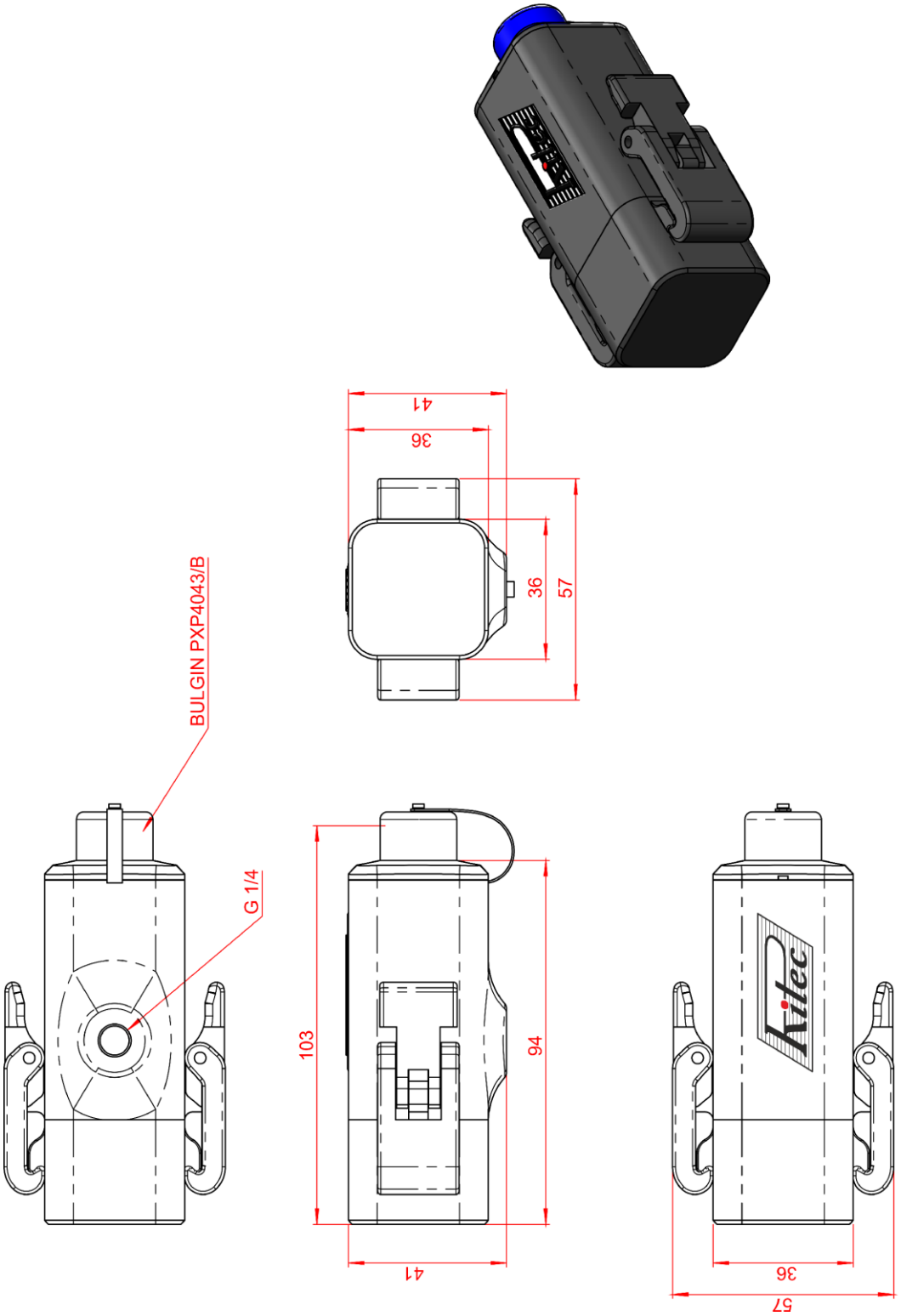


Fig. 8. Waterproof microspectrometer holder IP67 protection class outer dimensions.

4. QUICK START GUIDE

4.1 DETECTING µSPEC ON PC

1 Install the ***"WinSPEC for inspectors"*** (WinSPEC) software on your PC. It is important to do this before the µSPEC is connected with the PC, because required drivers being preinstalled during the software setup. The software is included in the delivery or can be downloaded from GBS-elektronik homepage.

2 The µSPEC is delivered together with a detachable detector module or with a charge sensitive amplifier PM120. First of all, you must attach the detector module DM to the base module µSPEC, if it is not already attached. If you are using a charge sensitive preamplifier PM120, you must connect a detector to it.

CAUTION. Never connect or disconnect the base and detector modules with the power on, when the microspectrometer is connected to a running computer through the USB port.

3 Connect the µSPEC with your PC using USB to Micro-USB cable. The USB interface is USB2.0 compliant and allows to power the microspectrometer and to communicate with the computer.

NOTE. A high-power device USB port (500mA) must be present!

4 Start ***"WinSPEC for inspectors"***. The program starts with the detection of available MCAs. Detected MCAs are displayed in a list within the communication build up dialog. If your µSPEC is listed, mark it and press ***"Select"*** (see Fig. 9). The WinSPEC picture will appear and then the next window displayed. Select ***"Yes"***.

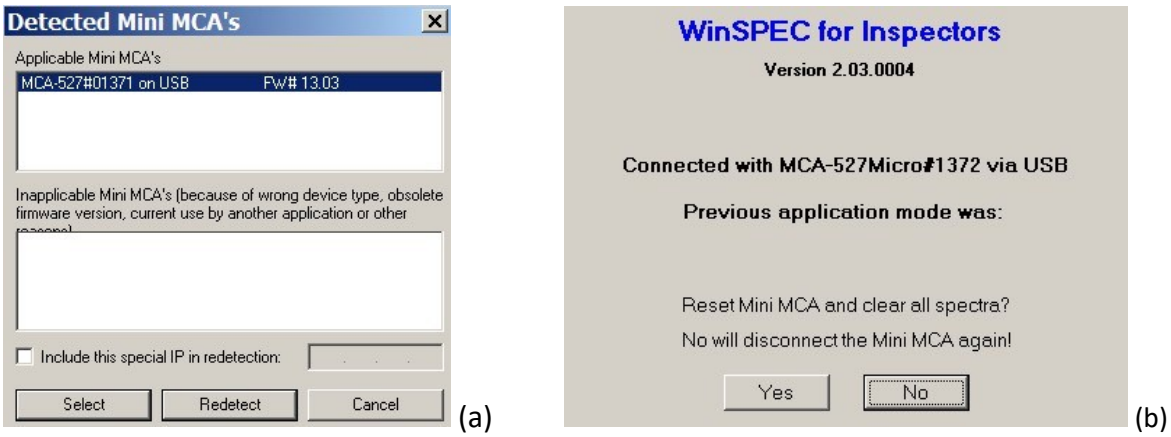


Fig. 9. Window of detected MCAs (a) and Start window of WinSPEC (b).

The user interface of the ***"WinSPEC for inspector"*** software will appear (Fig. 10):

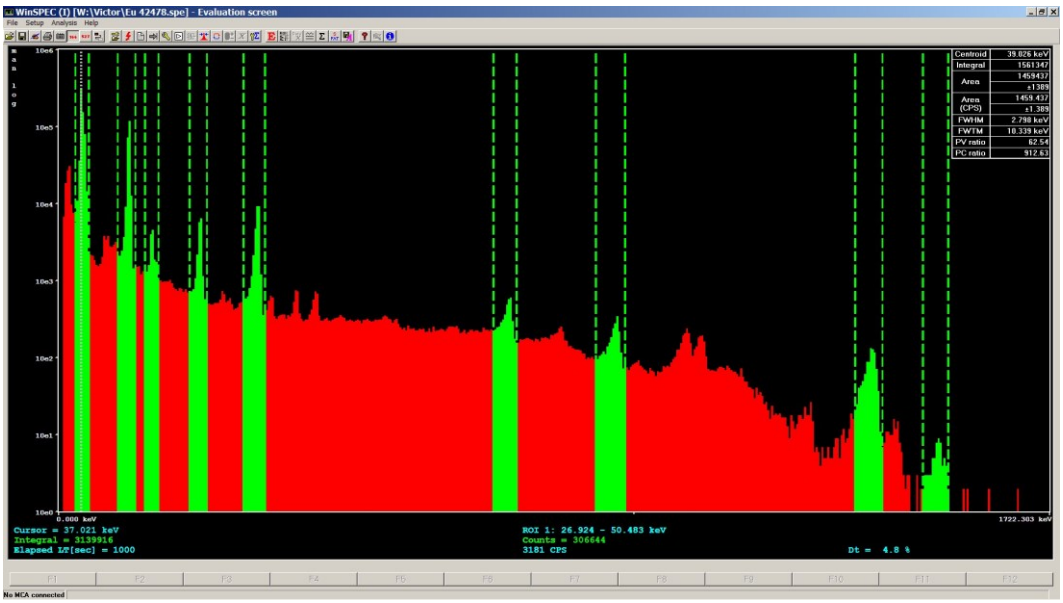


Fig. 10. User interface of the WinSPEC.

The µSPEC is ready for operation

4.2 SETTING HIGH VOLTAGE

The spectrometer can be equipped with removable modules with memory in which the module parameters are recorded or without memory.

If the µSPEC is not equipped with a detector module that provides information about it-self or if it is equipped with a charge-sensitive amplifier, it must be configured by the user. In any case, the high voltage must be adjusted according to the specifications of the detector manufacturer. To do so,

- Execute the menu command ***"Setup" / "High Voltage"*.**
- Insert the recommended value in the text box and press ***"OK"***.

4.3 FURTHER PARAMETER SETTING

In the next steps, the configuration is adapted to the special characteristics of your detector, to your measuring sample and the task to be done.

- Execute the ***"Setup"/"MCA ..."*** menu command.
- Select the channels number according to the resolution of your detector. (It makes no sense to use a high channels number if the resolution of the detector does not yield that.) The other parameters of the dialog should remain unchanged.
- Execute the ***"Setup"/"Amplifier ..."*** menu command.

⚠ **NOTE.** To adjust the parameters of this dialog, you need a gamma reference source that is positioned in front of the detector.

- First adjust the PZC (pole zero cancelation). For it, Press ***"PZC adjustment"*** and subsequently press ***"Automatic PZC by offset minimization"*** in the appearing dialog. This starts a routine that tries to minimize the zero offset.

- Adjust the gain (represented by coarse and fine gain). The best way for the gain adjustment is to use: ***"Visual amplifier adjustment ..."*.** Change the gain until the energy peak is on the intended position.

The other parameters of the amplifier setup should remain unchanged. The defaults guarantee a good measurement result. The measurement result can be optimized by changing the remaining parameters. To do so, expert knowledge is needed.

- Execute the ***"Setup"/"Presets ..."*** menu command. The dialog allows presetting the stop condition for the measurement. If you want to use the ROI (Range of Interest) integral or area as stop condition, you must set a ROI within the spectrum diagram before (Fig. 11). To set a ROI, move the cursor (dotted line within the spectrum diagram) with the direction keys or the mouse pointer to the indented ROI begin. Press the shift key. Move the cursor to the indented ROI end. Release the shift key.

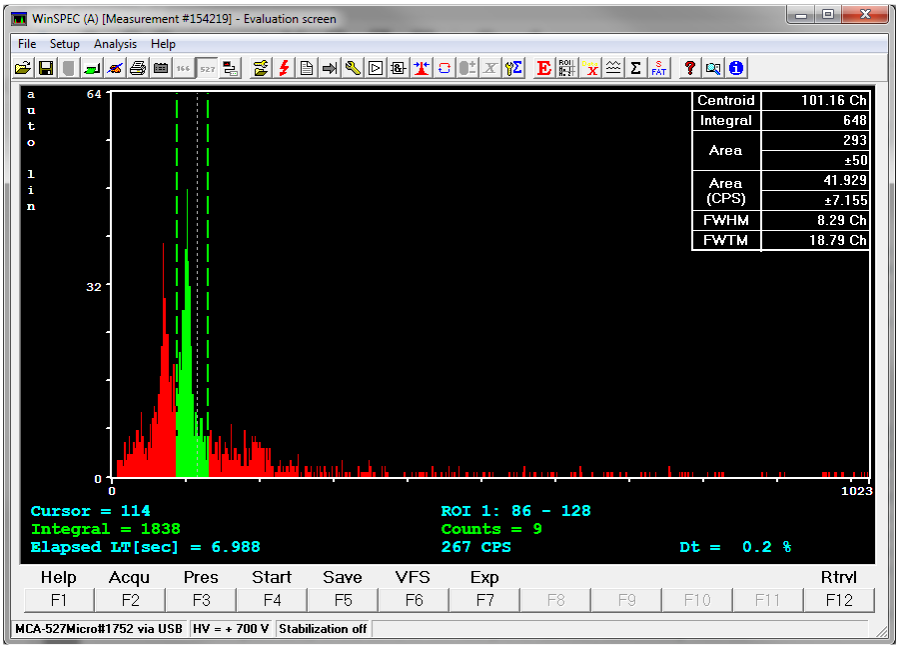


Fig. 11. Range of interest marked in green with related ROI values in the upper right corner.

- Optionally, the ***"Setup"/"Stabilization ..."*** menu command can be executed. Stabilization is useful for long measurements. Read the online help of WinSpec for more information.

After you have completed the adjustment, the measurement can be started with the function key ***F4***. Learn more by reading the online help of WinSpec.

5. DIGITAL MCA SETTINGS

5.1 COARSE GAIN AND FINE GAIN

For the µSPEC Spectrometer, there is one hardware-specific coarse gain level available. The adjustable levels in the software, for example WinSpec, are created in the respective firmware. There are no real amplifier levels present.

Which means, in case of an overflow, the reduction of the coarse gain level in the software won't have an effect.

The fine gain adjusts the gain and therefore the energy to channel ratio. This gain is just a mathematical factor used for calculation of the filter.

5.2 TRIGGER FILTER AND TRIGGER LEVEL

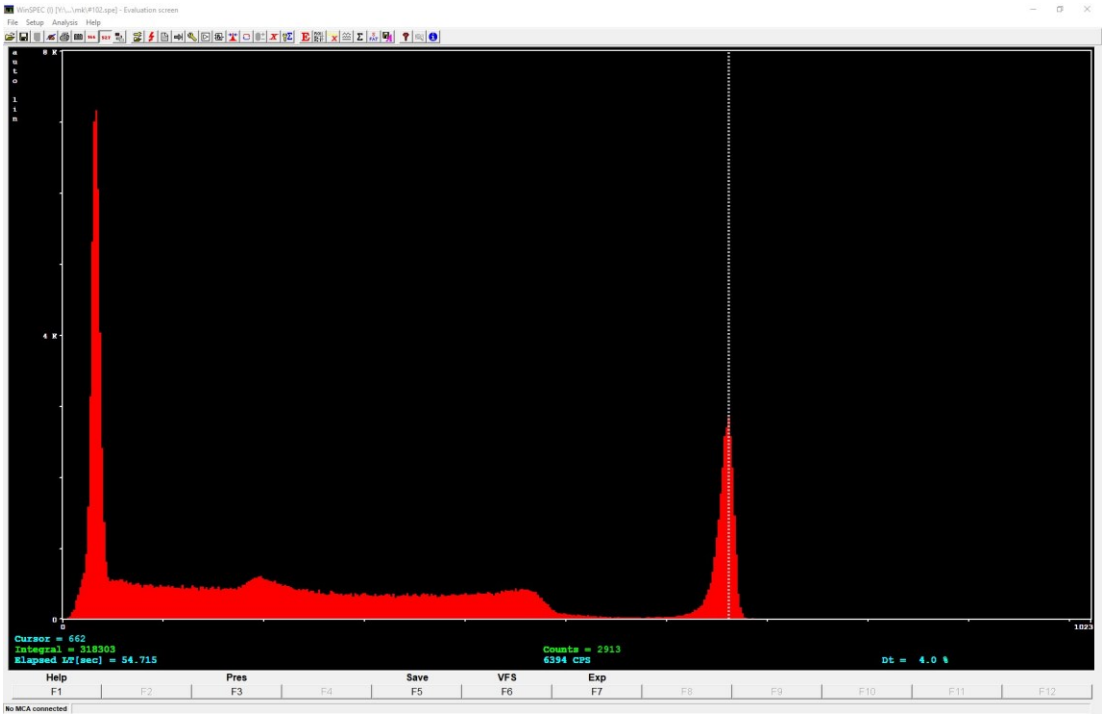
The trigger filter is applied continuously to the incoming signal to check for events (voltage steps). The µSPEC series have a double differential filter which is a very good compromise between good time resolution and sensitivity.

- Trigger Filter .....1, 0, -2, 0, 1
- Pulse Pair Resolution 330ns
- Best Dynamic Range Possible 1:325
- Lower Energy Cutoff in % of Full Scale 0.30%

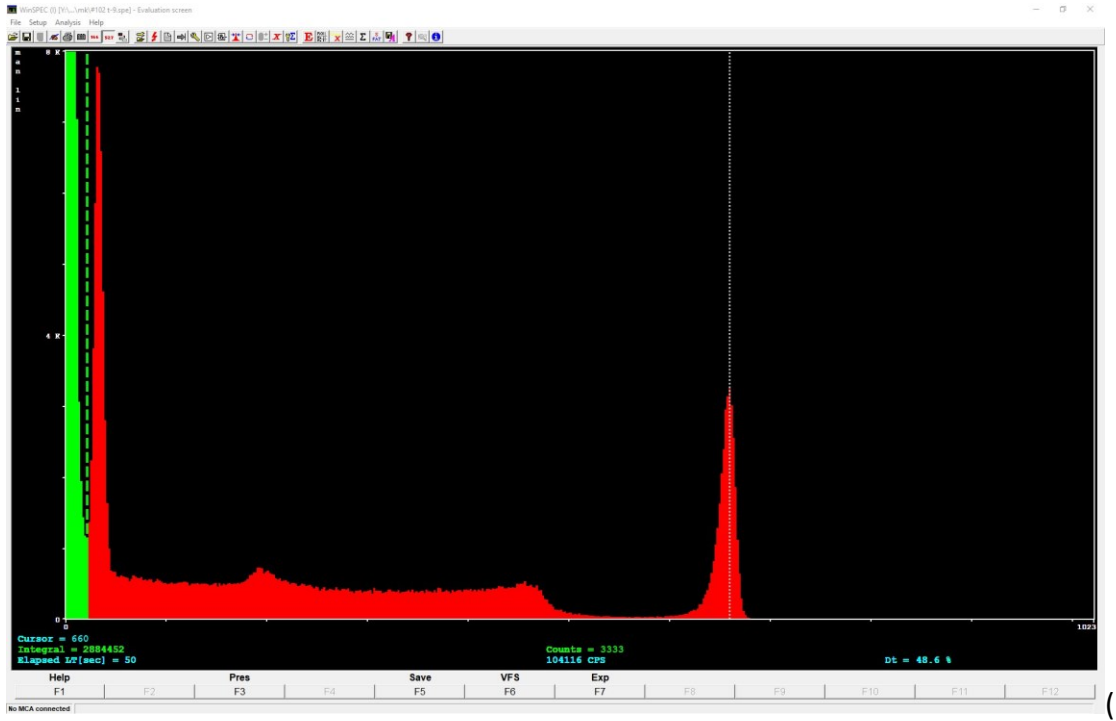
The trigger level is normally automatically adjusted to 7 times the evaluated RMS noise level by default. This works fine for almost all tasks. However, a detector may exhibit non-Gaussian noise or there may be other high frequency disturbances around and therefore a reason to read just trigger level. Some software allows this.

Symptoms of too low trigger level are:
- There is an unusual high-count rate with some detector and no sources present.
- Left of the normal spectrum cutoff there is a significant peak right at 0keV in the energy scale.

If this noise count rate and the noise peak are annoyingly high (Fig. 12), the trigger level may be increased. It may be increased just such high, that the noise peak disappears. Further increasing of the trigger level just increases the low energy cutoff unnecessary and impairs the ability to reject pile up with low energy events.



(a)



(b)

Fig. 12. An example of a correctly (a) and incorrect (b) configured trigger level. Noise pulses in the green ROI near 0 keV are caused by electronical noise and a too low trigger level setting.

5.3 PILE-UP REJECTION

Pile-up rejection is to prevent the spectroscopically filter to be applied to events too close following each other to be evaluated properly. If there is another voltage step within the length of the filter, the energies are partially or fully added. Pile up is a problem getting increasingly worse with filter length and count rate. It can be easily seen as background right of a peak and sometimes as pile-up peak at exactly double energy.

Recognizing pile-up is task of the trigger logic. The ability to prevent pile-up depends very much on the time resolution, and therefore on the used trigger filter.

5.4 SHAPING TIME AND FLAT TOP TIME

The shaping time defines the length of the spectroscopically filter, or how many values before and after the voltage step are averaged to evaluate the pulse height. The shaping time is half the rise or integration time. So, for a shaping time of 1µs 20 values before and 20 values after voltage rise are averaged. Depending on the detector and its noise spectrum, very different values can be optimum for best resolution. A long shaping time eliminates a lot of high frequency noise but is more sensitive for low frequency noise.

For a CZT the best value may be 0.7µs. The best shaping time to set depends also on expected count rate. For higher count rates a lower shaping time is useful, as pile-up probability and necessary processing power decreases with decreasing shaping time.

Default value for shaping time is 1µs.

Flattop is a parameter introduced with digital multi-channel analyzers. Basically, this is adjusted to the rise time of the preamplifier in the detector module. Reason is that digitizing the amplitude can be done with quite high accuracy, down to 0.01% error. But the input bandwidth (3MHz) is rather high compared to the sample rate (10MHz), and so during the rise of the preamplifier signal, the value may change by 20% within 100ns and a timing jitter in this order may cause a significant error. Therefore, values where the signal is rapidly changing must not be used for evaluation.

This is adjusted with the flattop setting. As the signal to the ADC is bandwidth limited, there is a finite rise time of around 300ns even for infinitely fast rising signals, settling time may be twice as long. Therefore, the shortest useful flattop time may be 0.6µs, which may be suitable for fast rise time, medium resolution detectors such as CZT.

If flattop setting is too high, the spectrum will become more sensitive to low frequency noise and resolution will degrade slowly. Below a certain setting, the spectrum will degrade very rapidly.

Default value for flattop is 1.2µs.

5.5 POLE ZERO COMPENSATION

The pole zero correction (PZC) is applied to make sure that a voltage step starting from the base line is evaluated with the same amplitude as signal sitting on the falling slope of a proceeding step. Without correction the slope is causing an error.

If the decay time constant of the signal is known, the slope can be easily calculated from the amplitude. In practical terms pole zero correction is achieved by adding a defined amount of DC from the input to the result. The pole zero value to be set is a value from 0...2499. It is reciprocal connected with the decay time constant τ by:

$$\tau = 88650\ \mu S/PZC$$

For pole zero adjustment, go to the pole zero settings window of the software. There the spectroscopically filter is applied to the signal before and after a voltage step, but where the result should be zero. The difference between those both measurements is the pole zero offset

and the results are averaged over 0.8 s. The pole zero value has now to be adjusted such that the pole zero offset becomes zero.

5.6 NUMBER OF CHANNELS

The number of channels the spectrum is distributed to can be chosen between 128 and 4096 (4k). The setting depends mainly on the connected detector. If the setting is too low, details of peaks may not be seen, if the setting is too high, the statistics for a single channel is bad so the spectrum looks very noisy and of course storage of the spectra takes more space. Default is set to 1024.

5.7 LLD / ULD

The LLD / ULD settings (Lower Level Discriminator, Upper Level Discriminator) determine, which part of the spectrum is counted. This setting is most useful in MCS (MiltiChannel Scaling) mode for taking time dependent rate for a special part of the spectrum. In PHA (Pulse Height Analyze) mode, typically the full spectrum is counted.

Default setting for LLD is 0, for ULD it is the resolution - 1; e. g. for a 4k resolution this is 4095.

5.8 MEASUREMENTS WITH STABILIZATION

Stabilization is an option if the gain of a detector system is not fully stable. It allows to adjust fine gain during a measurement to keep a certain peak in the spectrum at its place.

Stabilization is mostly used with temperature sensitive detectors and for long term or series measurements.

For stabilization, a peak must be selected from spectrum, which:

- should be always present;
- should be significant and not disturbed by other peaks;
- is preferably in the upper part of the spectrum.

For selecting a peak, a stabilization ROI must be selected, and a centroid to which to stabilize a peak.

5.9 MEASUREMENT TIME PRESETS

For non-infinite measurements, the µSPEC offers 4 choices to limit the measurement time.

Real Time

The simplest method. The measurement will take as long as the time given. This is also the choice if doing repeat measurements.

Live Time

Often chosen if quantitative evaluation of the spectrum is done. Very similar to real time, only with high count rates live time measurements will take a bit longer than real time measurements, as live time is the real time with the dead time subtracted.

Integral

The measurement will continue until a certain number of counts in the spectrum or in a ROI are achieved. This is a choice if a certain statistic is needed in a spectrum.

Area

The measurement will continue until a certain net area of a peak is reached. This is a choice if the area of a distinct peak has to be measured with a defined accuracy.

5.10 DEAD TIME CALCULATION

Dead time calculation is a crucial task when doing high rate measurements and still expecting accurate quantitative measurement results.

Dead time with µSPEC has several components. At first there is the limited pulse pair resolution of the trigger filters. The pulse pair resolution (the minimum time distance between two subsequent events which is needed to count them separately) depends on trigger filter and must be found out experimentally.

Next is the time interval which corresponds to the length of the digital filter within which no other pulses are tolerated for correct calculation. Here different subsequent pulses can be distinguished but are rejected as pile-up.

Also, the time where the input signal is out of range must be considered as dead time. At last, also the time where the processor is busy with other tasks and cannot process events is dead time.

5.11 REPEAT MODE

Repeat mode is basically a feature realized by software. It comprises just starting a new measurement after the previous one has finished. Number of repetitive measurements are determined by application software.

A problem for some tasks however can be that the spectrum must be transferred to the computer before the next measurement is started. As this takes some time it may not be tolerable to some tasks, especially if measurement time is very short. For that, there exists the firmware repeat mode which allows to start immediately the next measurement while transferring the data of the previous spectrum simultaneously.

6. EXTRA FEATURES

6.1 OSCILLOSCOPE MODE

Oscilloscope mode is in WinSPEC a sub-menu of the amplifier settings menu. Its main purpose is troubleshooting; so, without the necessity of an extra oscilloscope it can easily be seen, if there is a preamplifier signal present, and if it fits correctly to the MCA signal input. Compared to a regular oscilloscope, the bandwidth is with 3MHz and 10MSps rather limited, but the noise level is extremely low and measurements down to the µV level are possible.

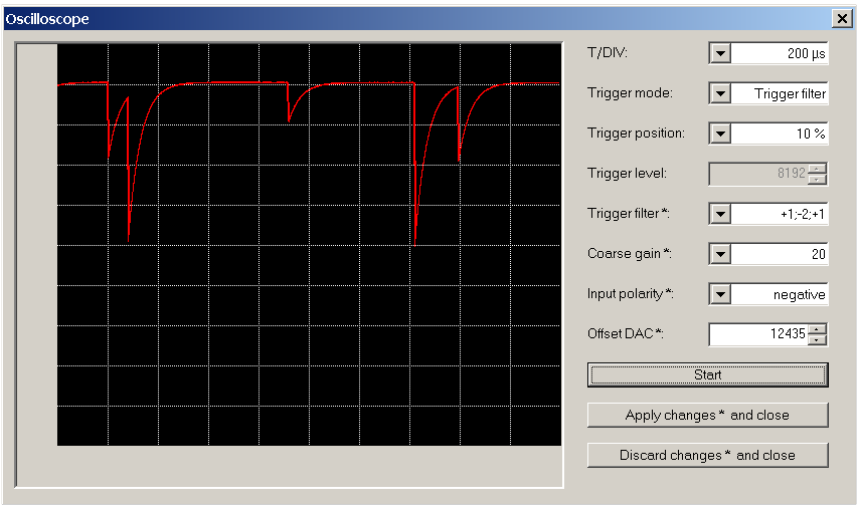


Fig. 13. Typical preamplifier signal how it is seen by the MCA.

6.2 INTERNAL TEMPERATURE

The µSPEC spectrometer series have an onboard temperature sensor to log the operation temperature of the MCA. Main purpose of this is troubleshooting and quality control in case of remote measurements. This internal temperature is shown in the diagnostics menu and it is written in saved spectrum files. It is typically 9°C higher than the environmental temperature.

6.3 MULTICHANNEL SCALING (MCS)

This mode is for semi-automated measurements of time distributions. The software used for this is WinMCS. It allows to measure a time distribution of count rates, and in case of a spectroscopic detector, measurement of an integral spectrum at the same time.

Input can be set to the following:

- Input rate (corresponds to the fast count rate of MCA measurements)
- LLD/ULD (corresponds to the content of a partial region of a spectrum, defined by the lower end LLD and the upper end ULD.

7. TROUBLESHOOTING

CAUTION. Before changing anything concerning the hardware, plugging or pulling cables etc. shut down the high voltage.

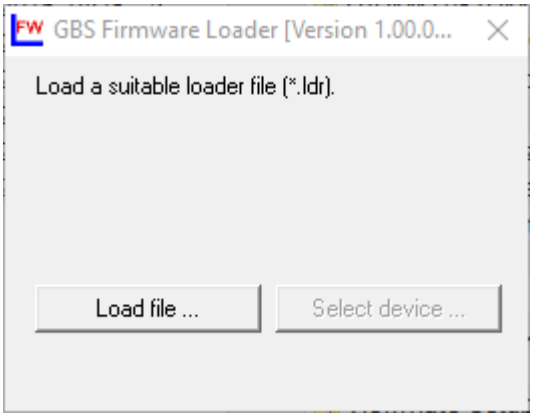
Soldering or manipulating with the SMD boards is strongly not recommended for users. If you have a problem which cannot be solved by the table below, contact us.

CAUSE OF MALFUNCTION	TROUBLESHOOTING METHODS
Software tells "MCA not connected!"	Check cable between MCA and Computer. Cable may be loose or not connected. Connect cable correctly. Try another cable. Try another interface.
The threshold of the spectrum seems to be much higher than expected.	If the lower cutoff rises by itself, this is most probable caused by the auto threshold circuit which is responsible for detecting the noise level and adjusting the threshold to it. Check for excessive noise in the system.
The high energy part of the spectrum is reduced or even missing.	Check if the behavior changes if the pile up rejector is switched off. Check the signal from the preamplifier. If the preamplifier signal rise time is slower than 500 ns, then there is the danger that regular pulses (especially the large ones) are misinterpreted as pile-up. The same may happen if the preamplifier signal exhibits overshoot or ringing.
Dead time shown is very high although the count rate is low.	Count rate may be extremely high so that the MCA is overloaded. Electronic noise in the system.
While opening a spectrum, the MCA program tells "Wrong data format" or "data format error"	Spectrum was created by another program or another program version. Check results just ignore.
Too high-count rate.	Keep a bigger distance to radiation source. Check for disturbances of switch mode power supplies etc.

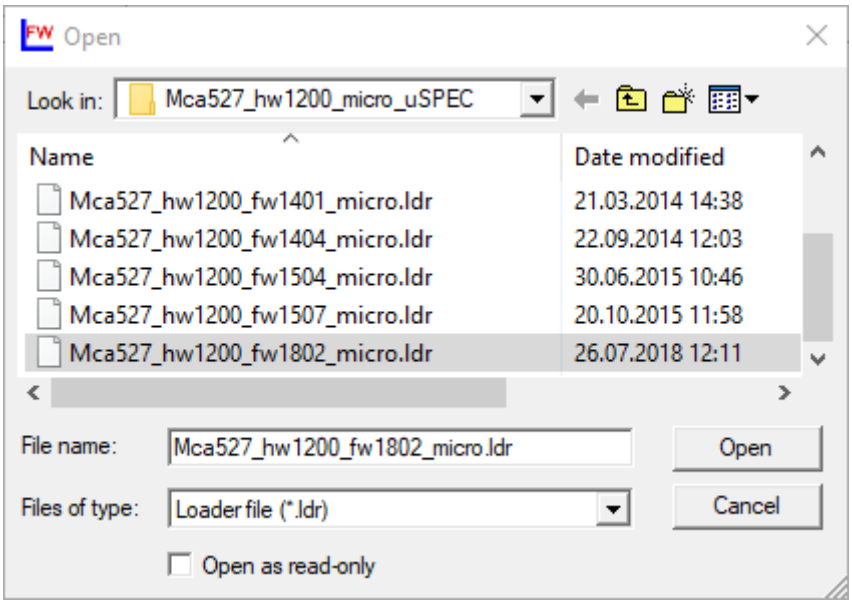
8. FIRMWARE UPDATE

Please follow these steps to update the firmware.

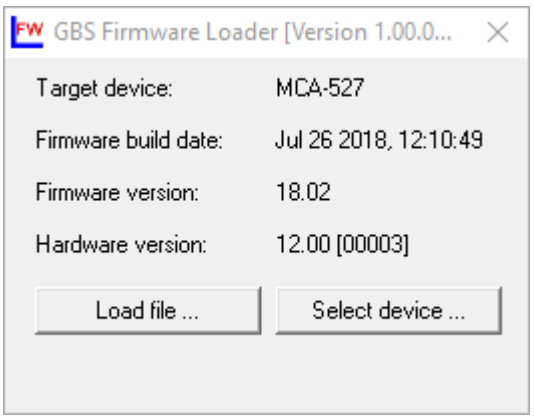
1. Download from GBS-elektronik MCA-527 Firmware (for hardware version 12.00') and unzip the zip file to a folder on your computer.
2. Download from GBS-elektronik GBS Firmware Loader Version 1.01.0001 and save the file to same folder on your computer.
3. Run the "FWloade.exe file". This program does not require installation. Press button "Load file…".



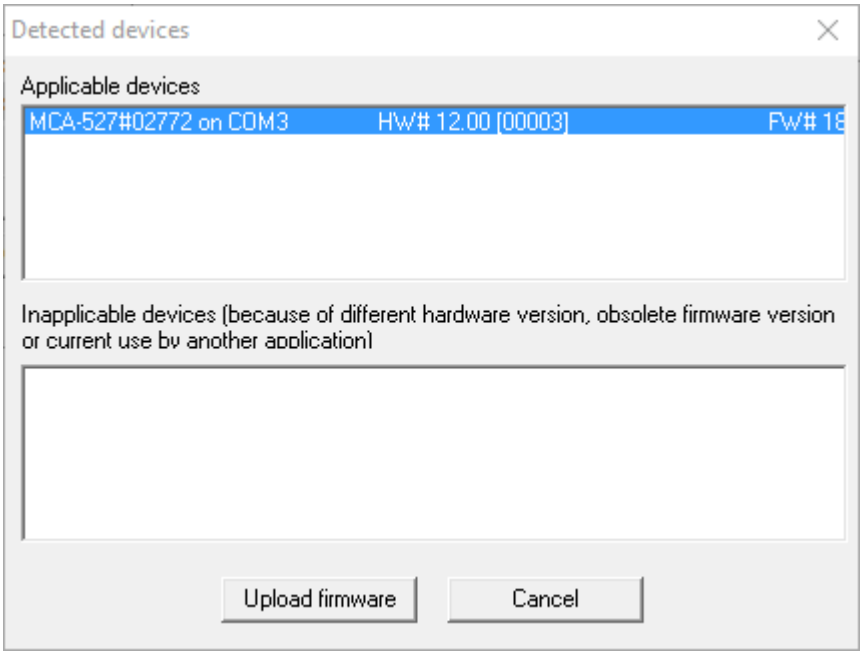
4. Select the "Mca527_hw1200_fw1802_micro.ldr" file to upload. Press button "Open".



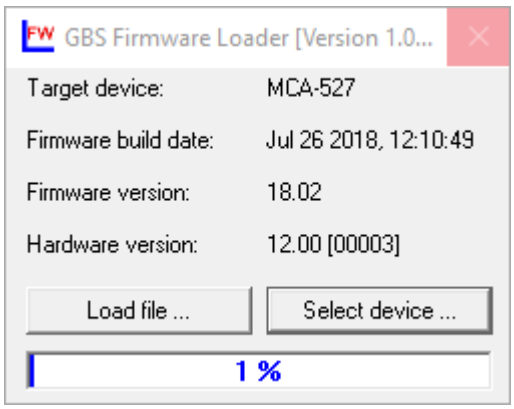
5. Connect the uSPEC you want to flash to your computer using the USB cable and Press button "Select device…".



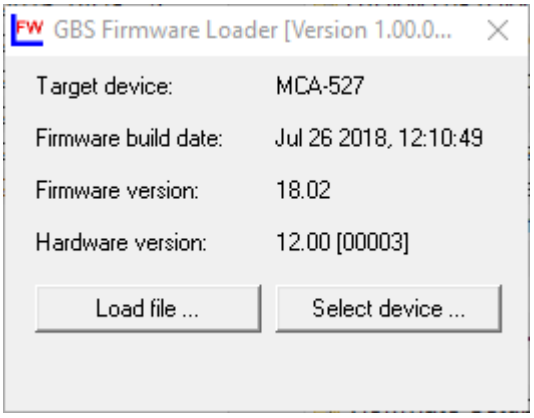
6. Select a connected device. Press button "Upload firmware".



7. Wait until the firmware update is complete. To update firmware takes approximately 5 minutes. A window showing the percentage of work completed may not move.



8. After the update is completed, close the program window or connect a new device and repeat the update.



WARRANTY

Equipment manufactured by ZRF RITEC SIA is warranted against defects in materials and workmanship for one year from the date of shipment. This warranty does not covered damages caused by improper use of the equipment.

If defects are discovered within 30 days of the time you receive the equipment, ZRF RITEC SIA will pay transportation costs both ways. After the first 30 days, you will have to pay the transportation costs.

Examine shipment carefully when you receive them for evidence of damage caused in transit. If damage is found, notify ZRF RITEC SIA immediately. ZRF RITEC SIA is not responsible for damages sustained in transit.

Equipment, which is no longer covered by warranty, may be returned to ZRF RITEC SIA freight prepared for repair. After the equipment is repaired, it will pass through pre-shipment checkout procedure.

Before returning equipment for repair you must contact ZRF RITEC SIA for instruction in writing, by e-mail or fax.

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