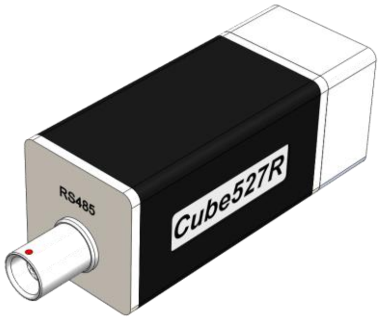
CUBE527 SPECTROMETER SERIES

DIGITAL MULTI CHANNEL ANALYZER

USER MANUAL



Exclusion of liability

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

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For software updates or problems exceeding the frame of this manual refer to:
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REVISION SHEET

Release No.	Date	Revision Description
Rev. 01	26/04/2018	First official revision
Rev. 02	12/19/2018	Added Chapter Safety Instruction and Update Firmware
Rev. 03	03/28/2019	Revised Chapter 1.1 (safety)
Rev. 04	06/09/2020	Chapter 3.2 - corrected outer Dimensions - corrected mounting holes distance dimensions

TABLE OF CONTENTS

1. FOR YOUR SAFETY

1.1 SAFETY INSTRUCTIONS

1. Only skilled and or trained personnel should operate the Cube527.
2. Do not open the Cube527! 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 Cube527 only in its designated purpose!

1.1.1 INTENDED USE

Use the Cube527 only in its designated purpose as described in this User Manual, for example in Chapter 2.1, "Product description", on page 9.
Observe the operating conditions and performance limits stated in the "Technical Specifications" in chapter 8 or in the respective *datasheet.*

In general, the Cube527 series have been developed for the measuring of gamma ray radiation in a laboratory environment with non-safety relevant applications with plugged detector. Furthermore, it is not allowed to open the device in any case.

1.1.2 MAINTENANCE

The Cube527series is completely maintenance-free. However, before every usage, check visually for proper condition, especially the detector-connector must be free of dirt.

1.1.3 CLEANING

For cleaning the device and connector use only a lint-free and dry cloth!

2. INTRODUCTION

Thank you for buying GBS Elektronik' Cube527.
This document is a User's Guide that describes the Cube527 spectrometer series in hardware, digital signal processing and software parameter settings.

2.1 PRODUCT DESCRIPTION

The Cube527 spectrometer series offers high performance gamma-spectroscopy at very low power consumption.
The smart design allows to swap the CZT detector module in a minute and increases the field of application in terms of spectroscopy performance and sensitivity, as well as customers budget requirements.
There are three detector modules with different crystal volumes available.
The ultra-small dimensions and the very low weight of the Cube527 offering an excellent mobility and access to hard-to-reach areas, for instance with a drone. The Cube527 series are categorized in their respective computer interfaces and comes either with USB-Interface for powering and computer connection *(Cube527)*, Ethernet & USB- *(Cube527E)* or with a RS485 *(Cube527R)* computer connection.
The Cube527E is powered from the USB interface port or by "Power over Ethernet ". Furthermore, we offer fixed cable versions for each computer interface version.
Due to the integration of all hardware components, which are required for a full gamma spectroscopy system in one package, only one USB - or Ethernet cable is necessary to connect the system to a computer or network switch. The Cube527 series can be operated with our free of charge software programs, such as WinSpec or WinMCS.

KEY FEATURES

- *All-in-one spectrometer with up to 4k channel resolution*
- *CZT Detector module can be exchanged in a minute*
- *Very low weight and ultra-small outer dimensions*
- *Very low power consumption*
- *Detector modules with three crystal volumes of 60mm³, 500mm³ or 1500mm³ available*
- *Fully digital signal processing*
- *Fixed cable version on request*
- *Eloxed aluminum housing*
- *Three threaded fixing holes on the bottom side*

2.2 FIELDS OF APPLICATIONS

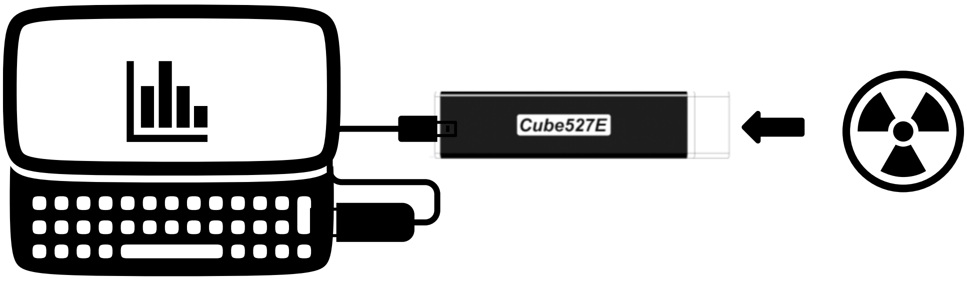


FIGURE 1: CUBE527 WITH CONNECTED COMPUTER AND DISPLAYED SPECTRUM FROM THE RADIOACTIVE SUBSTANCE

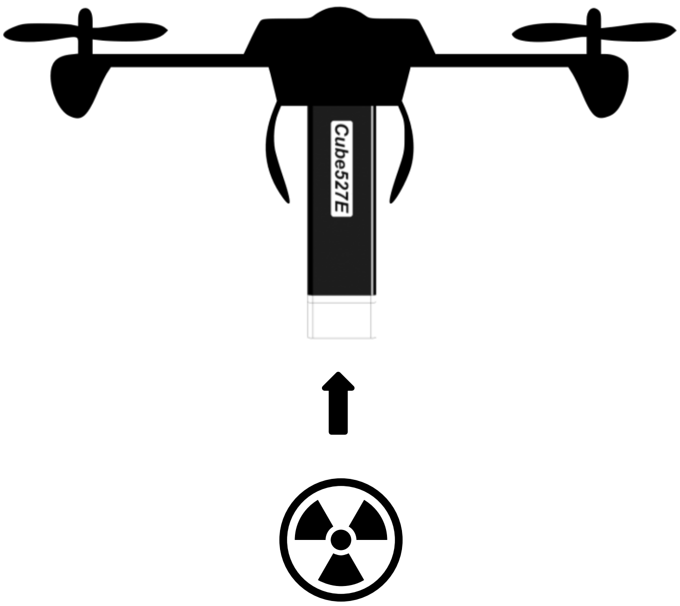


*FIGURE 2: CUBE527 INSTALLED ON A DRONE,
WITH ON BOARD DATA AQUSITION.
ACCSESS TO HARD-TO-REACH-AREAS.*

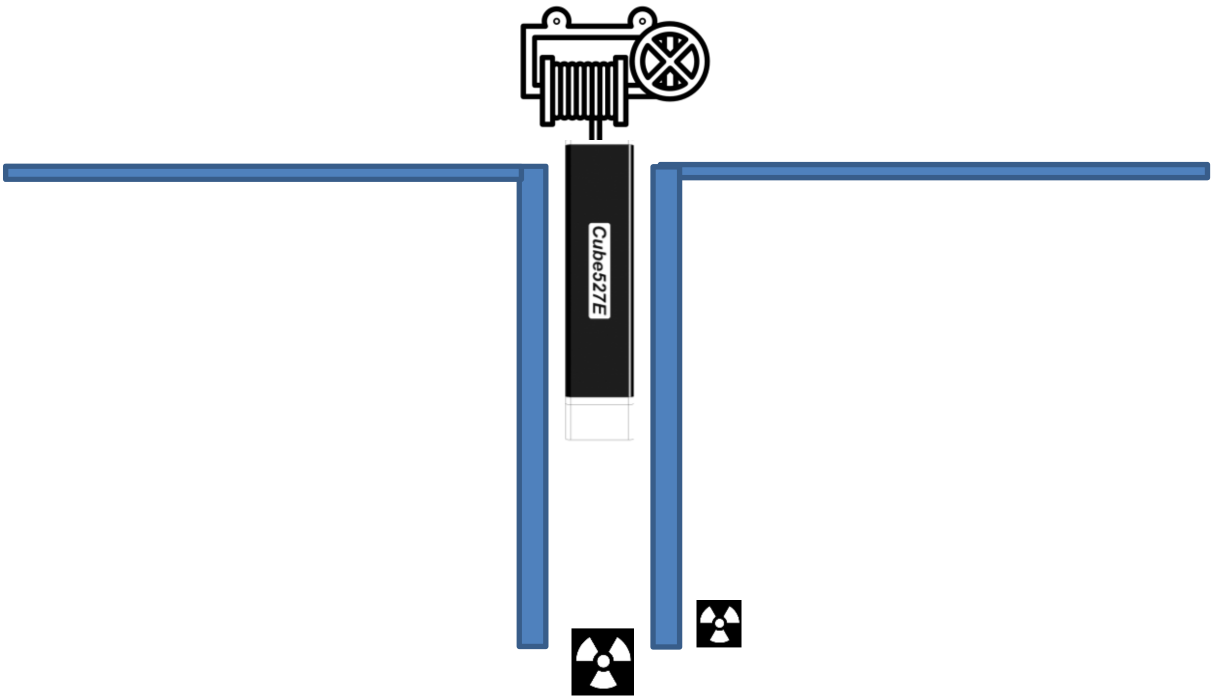


FIGURE 3: CUBE527 ATTACHED TO A WINCH
ACCSESS TO HARD-TO-REACH-AREAS
SUCH AS DEEP NARROW GAPS

2.3 GENERAL INTRODUCTION INTO GAMMA SPECTROSCOPY

The main application of gamma spectroscopy is to measure the radiation emitted from decaying radionuclides and from this conclude on the type and quantity of isotopes present. In most cases, the gamma radiation is most suitable to distinguish between different radioisotopes. Gamma radiation consists of photons, similar as light. But whereas the typical photon energy for visible light is 1eV ($1.6*10^{-19}$ Joule) the gamma photon energy from radioactive decay is much higher and typically between 3keV and 3MeV. For measuring this gamma radiation, a suitable detector is needed. This can be a semiconductor detector, which converts an absorbed photon directly into a small charge quantity. Or it can be a scintillation detector, which converts an absorbed photon into visible light, which is then converted by a photomultiplier into a charge. After the preamplifier, which is usually integrated within the detector, the charge appears as voltage step on the output signal.

The task of the multi-channel analyzer is now to measure the amplitude of these voltage steps with best possible accuracy and make a histogram of all measured amplitude values. This is called pulse height analysis (PHA) mode.

The second most important operation mode is to record count rate in dependence of time, using defined time channels. This is called multichannel scaling (MCS) mode. Various other measurement modes are possible and described later in this manual.

3. HARDWARE

3.1 GENERAL HARDWARE DESCRIPTION

The Cube527 series are complete spectrometer with exchangeable CdZnTe detector modules. Because the detector module is directly mounted on the MCA, no cables are required between both components. Therefore, any electrical influences are minimized or even turned off. Furthermore, the system is more compact and user-friendly.
Currently there are 3 different CZT detectors ($60mm^3$, $500mm^3$, $1500mm^3$) available.
The Cube527 computer interfaces provide flexible solutions for networking (Ethernet, RS485) or simply communication via an USB connection.

3.2 HARDWARE OVERVIEW CUBE527E

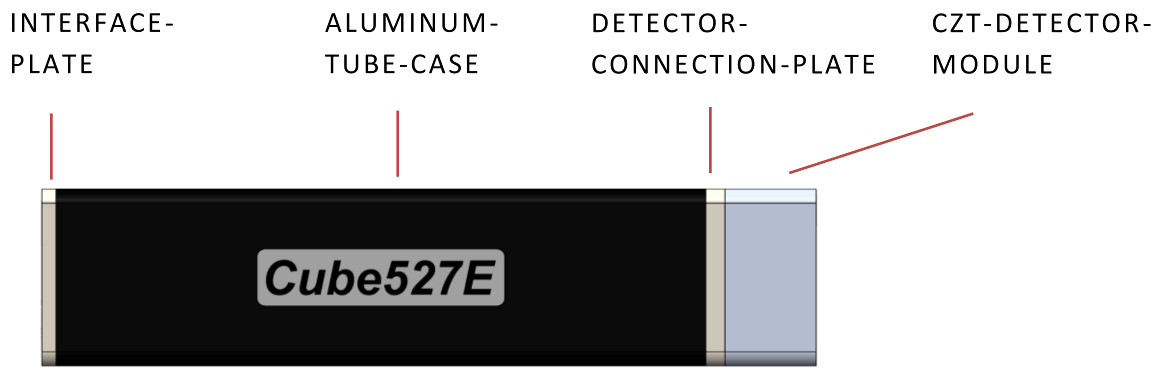


FIGURE 4: CUBE527E SECTIONS (SIDE VIEW)

FIGURE 5: CUBE527E DEVICE MOUNTING HOLES M2, DEPTH 3MM (BOTTOM VIEW)

FIGURE 6: CUBE527E OUTER DIMENSIONS (TOP VIEW)

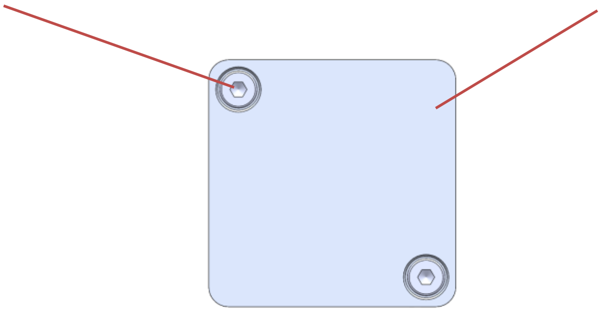


FIGURE 7: CUBE527E DETECTOR MODULE (FRONT VIEW)

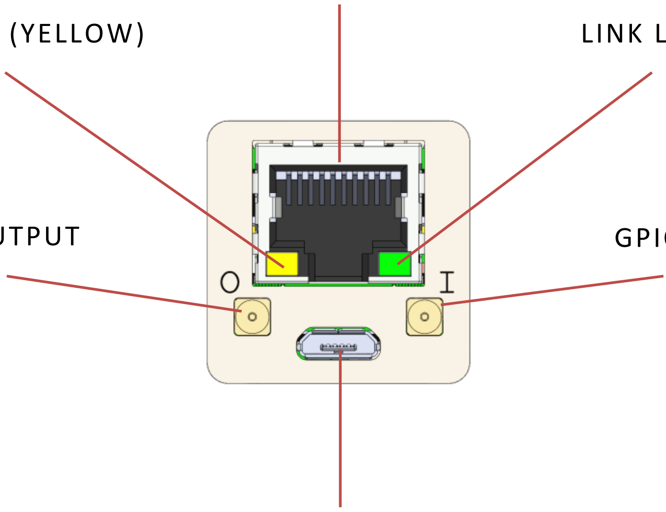


FIGURE 8: CUBE527E INTERFACES (REAR VIEW)

3.3 CUBE527E INTERFACES

3.3.1 ETHERNET PORT

The Ethernet interface supports 10/100Mbit/s. By default, it is configured to obtain the IP address automatically from a DHCP server or if not available, using Zero Configuration Networking (also named Automatic Private IP Addressing).
The maximum cable length between Cube527E and switch can be up to 100 meters.

3.3.1.1 POWER-OVER-ETHERNET (POE)

Power over Ethernet is an extension of the IEEE802 Ethernet standard, which enables devices to be powered via a network. For this purpose, after a prescribed request between the terminal and the supplying device (for example a PoE switch), a voltage of nominal 48V feeds the cable. It is preferable to use the data lines or the four free wires of an 8-pin CAT5 cable. The Cube527E can be powered over Ethernet in both ways.
Note: A normal Laptop or Desktop PC usually does not supply PoE.

3.3.2 MICRO-USB

The USB interface is USB2.0 compliant and allows to power the Cube527E, and to communicate with the computer. It's also possible to power the device via USB and to communicate with Ethernet.
Note: A high power device USB port (500mA) must be present!

3.3.3 GPIO

The General-Purpose-Input-Output (GPIO) allows the Cube527E to interface with external devices. It is possible to trigger signals, loop through it and even evaluate it.
Another purpose is to use the interface as a digital pulse generator (3.3V TTL) or as a counter, e.g. for neutrons. The programming of the GPIO will be done with the free of charge software "WinSpec". The sockets are "Mini MCX" connectors (female).

3.4 HARDWARE OVERVIEW CUBE527R

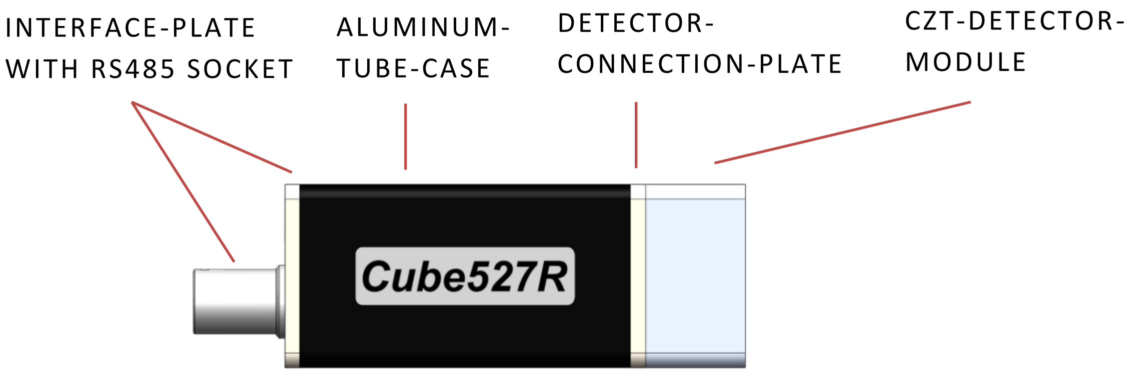


FIGURE 9: CUBE527R SECTIONS (SIDE VIEW)

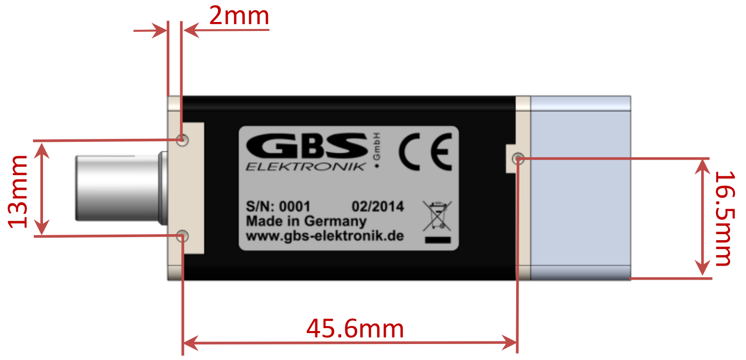


FIGURE 10: CUBE527R DIMENSIONS DEVICE MOUNTING HOLES, M2 DEPTH 3MM (BOTTOM VIEW)

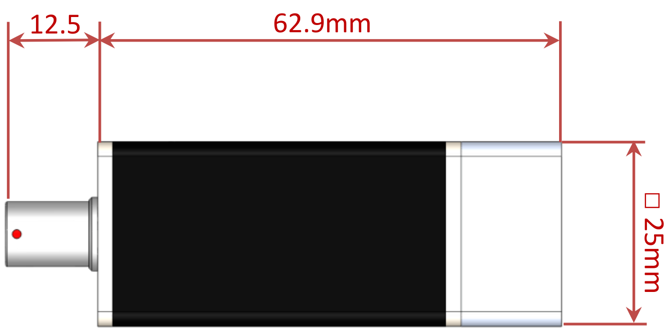


FIGURE 11: CUBE527R OUTER DIMENSIONS (TOP VIEW)

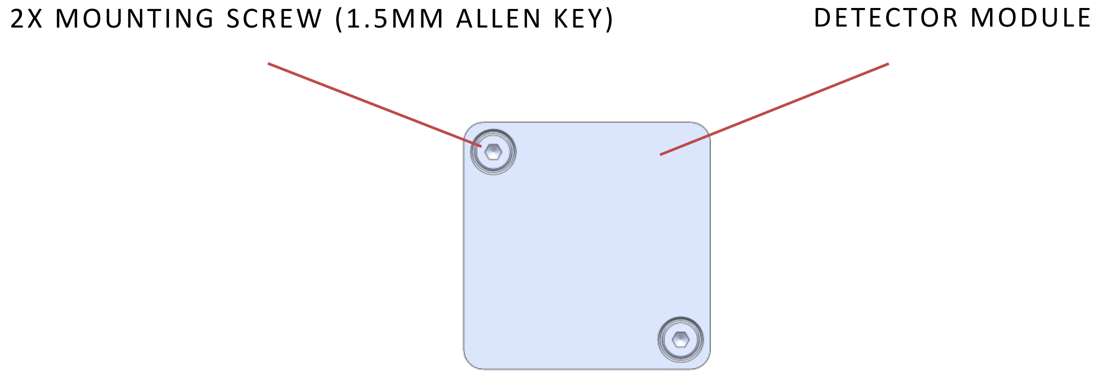


FIGURE 12: CUBE527R DETECTOR MODULE (FRONT VIEW)

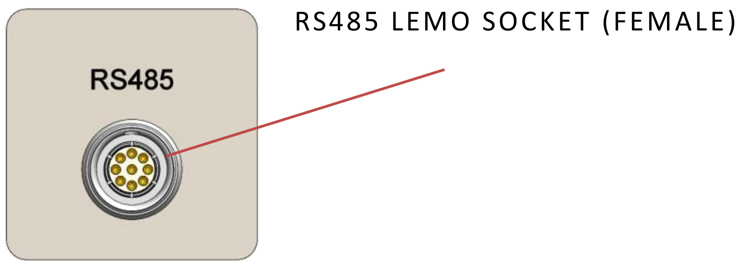


FIGURE 13: CUBE527R RS485 INTERFACE (REAR VIEW)

3.5 RS485 INTERFACE

The RS485 interface has been developed for high-speed serial data transmission over long distances and is becoming popular in the industrial sector. The RS485 is designed as a bidirectional bus system. An RS485 bus can be set up as a 2-wire and 4-wire system.

3.5.1 CUBE527R RS485 CONFIGURATIONS

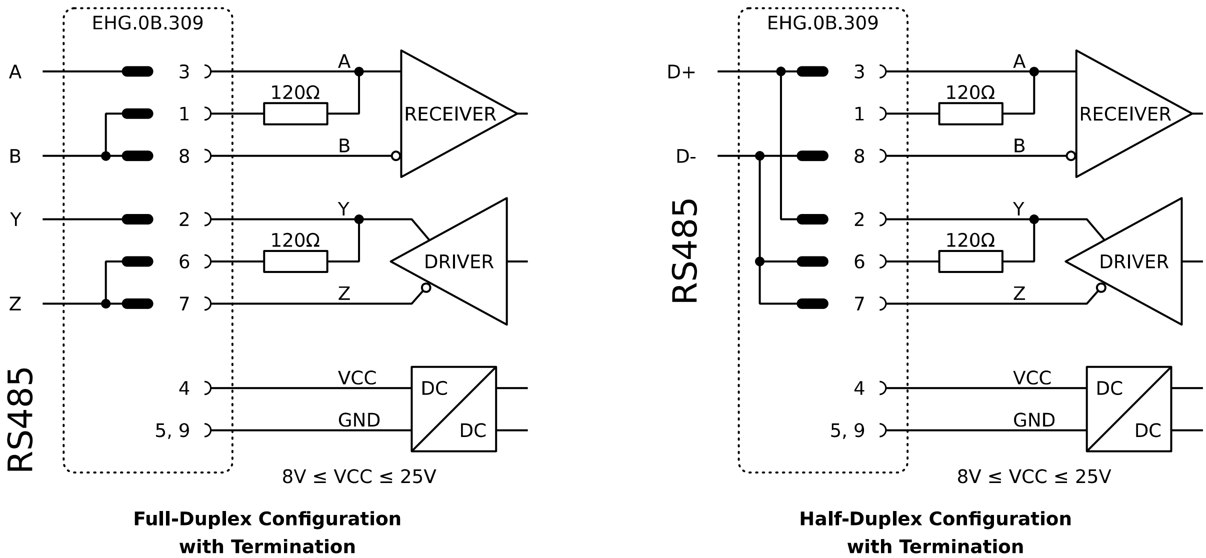
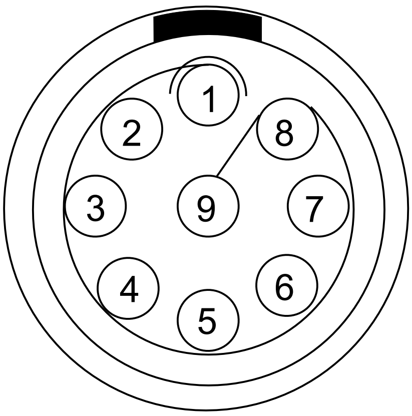


FIGURE 14: WIRING OF POSSIBLE CONFIGURATIONS WITH THE CUBE527R

3.5.2 RS485 LEMO SOCKET PINOUT



1 - TA
2 - Y
3 - A
4 - VCC
5 - GND
6 - TY
7 - Z
8 - B
9 - GND

Socket: EHG.0B.309.CLL

FIGURE 15: CUBE527R LEMO FRONT VIEW

3.6 HARDWARE OVERVIEW CUBE527

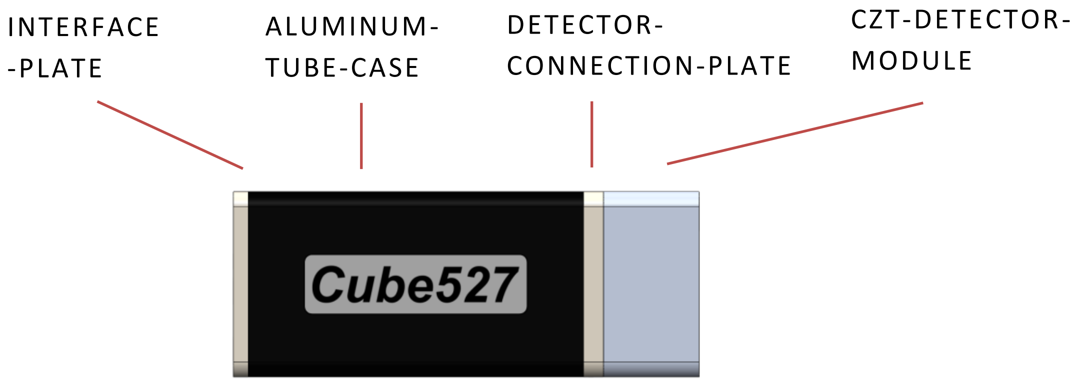


FIGURE 16: CUBE527 SECTIONS (SIDE VIEW)

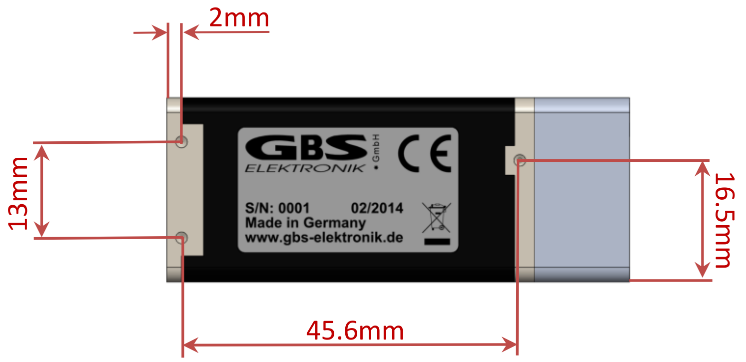


FIGURE 17: CUBE527 DIMENSIONS DEVICE MOUNTING HOLES, M2 DEPTH 3MM (BOTTOM VIEW)

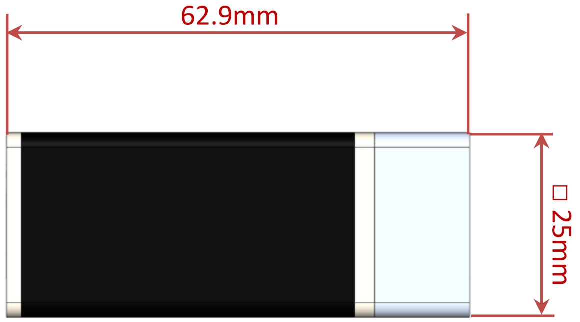


FIGURE 18: CUBE527 OUTER DIMENSIONS (TOP VIEW)

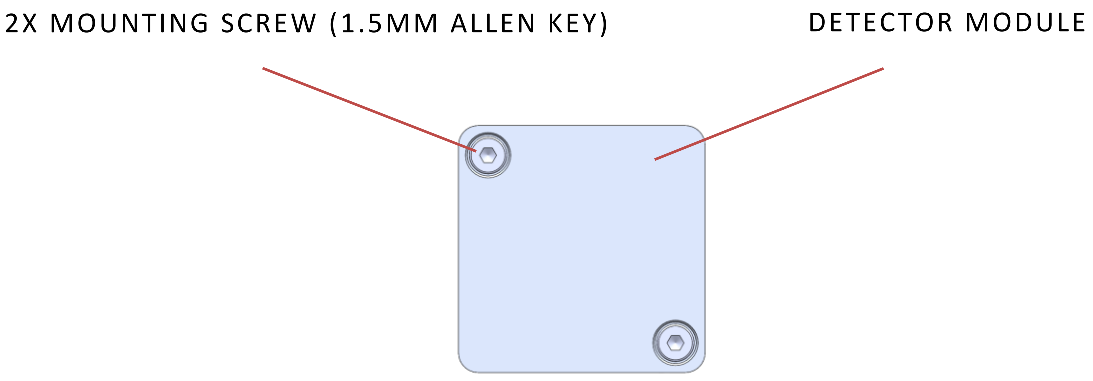


FIGURE 19: CUBE527 DETECTOR MODULE (FRONT VIEW)

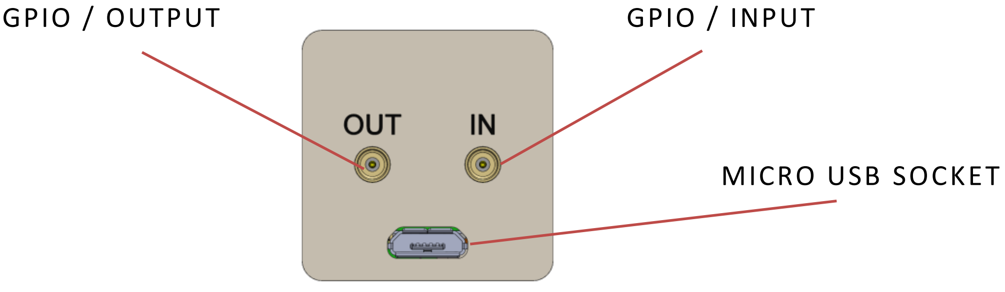


FIGURE 20: CUBE527 INTERFACES (REAR VIEW)

3.7 CUBE527 INTERFACES

3.7.1 MICRO USB

The USB interface is USB2.0 compliant and allows to power the Cube527 and to communicate with the computer.
Note: A high power device USB port (500mA) must be present!

3.7.2 GPIO

The General-Purpose-Input-Output (GPIO) allows the Cube527 to interface with external devices to trigger them, loop through their signal and even evaluate it.
Another purpose is to use the interface as a digital pulse generator (3.3V TTL) or as a counter, e.g. for neutrons. The programming of the GPIO will be done with the free of charge software “WinSpec”. The sockets are mini MCX connectors (female).

4. GETTING QUICK STARTED

4.1 DETECTING CUBE ON PC

1. **Install the WinSpec software on your PC**. It is important to do this before the Cube527 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 our homepage: www.gbs-elektronik.de.

2. Normally, the Cube527 is delivered together with a detector module or with a charge sensitive amplifier (PA). If so, **connect your detector with the PA.**

3. **Connect the Cube527 with your PC** and possibly with an external power supply. (see chapters 2.4 – 2.7)

4. **Start WinSpec**
   The program starts with the detection of available MCAs. All detected MCAs are displayed in a list within the communication build up dialog. If your Cube527 is listed, mark it and press "Select".

5. In case your Cube527 is not listed, there can be several reasons for it.

   - If the Cube527 is connected via Ethernet, it takes up to some minutes until the connection is ready to use. Wait and press "Redetect".
   - If the Cube527 is configured for use within a RS485 bus system, the serial number must be included for the detection. Insert the serial number in the provided text box and press "Redetect".

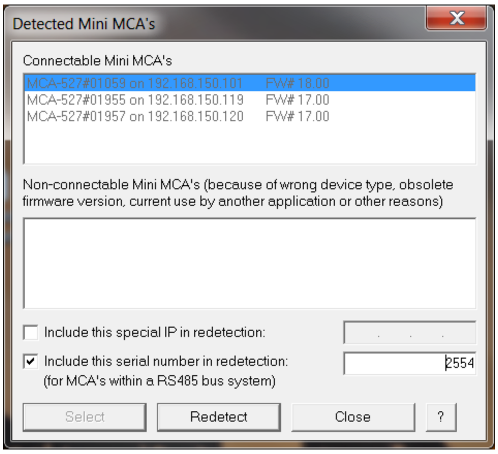


FIGURE 21: CUBE527R WITHIN A BUS SYSTEM, THE SERIAL NUMBER NEEDS TO BE ENTERED

4.1.1 SETTING HIGH VOLTAGE

If the Cube527 is not equipped with a detector module that provides information about itself 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".**

4.1.2 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.

Now 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 integral or area as stop condition, you must set a ROI within the spectrum diagram before. To set a ROI (Range of Interest), 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.

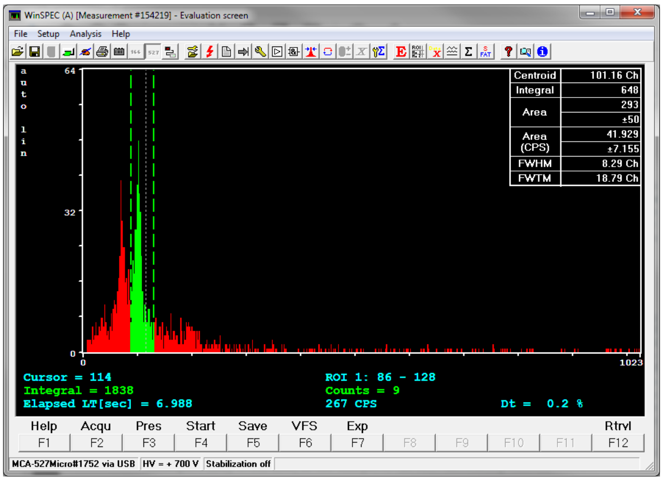


FIGURE 22: RANGE OF INTEREST MARKED IN GREEN WITH RELATED ROI VALUES IN THE UPPER RIGHT CORNER

- 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 and Chapter 4.

5. PULSE HEIGHT SPECTROSCOPICALLY MEASUREMENTS

5.1 INTRODUCTION IN TO DIGITAL SIGNAL PROCESSING

The main task of a multi-channel analyzer is to measure the height of voltage steps. In a conventional analog MCA, the voltage step is converted by a Gaussian bandpass filter into a pulse with several microseconds pulse width, a peak detector converts this to a DC voltage, which is then measured with a single conversion of an analog to digital converter (ADC). Typical there is also a fast channel, which converts the signal to very narrow pulses for counting, triggering, and rejecting events which are in too short time distance to be measured correctly (Pile up rejection, PUR).

In a digital MCA the input signal is digitized with a high sample rate, and the amplitude is calculated from a multitude of measurements. The Cube527 samples the input signal with a 14-bit ADC and a rate of 10MS/s, this is one voltage measurement every 100ns.

Digital filtering with a finite impulse response (FIR) filter is now just multiplying the incoming train of measurement values with a fixed row of numbers and adding up all the results. This row of numbers is the digital filter. A signal processor is especially designed to perform such a task.

Also, with a digital MCA the signal processing is split up into a fast and a spectroscopically (slow) channel. A short trigger filter is applied to the incoming signal every 100ns, whereas the long spectroscopically filter is only applied if a valid event was found.

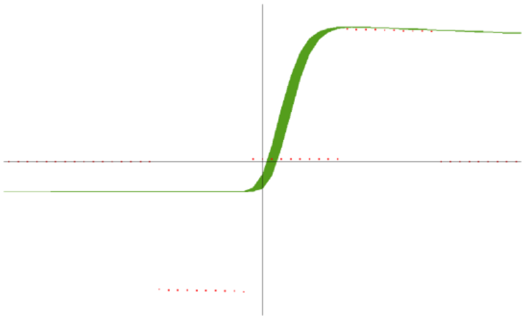


Figure 23: ***Example of a digital filter applied to a voltage step.***
Here: the flat top time 1µs (10*100ns) and the shaping time 0.5µs (≙ 1µs rise time)

The simplest method to measure the step voltage is to take one value before the step and one after the step and subtract them from each other. This would correspond to a digital filter looking like -1, 0, 0, 0, 0, 0, 0, 0, 0, 1. But such a filter would be quite unusual as the accuracy of this would be rather bad compared to what is obtainable.

The main errors of an ADC are amplitude noise and timing error. So, for minimizing the errors, it is advisable to use more than one voltage value before and after the step for averaging, and to avoid using voltage values where the voltage is changing quickly. So typically, between 10 and 100 values before and after the rise are averaged.

This time over which the values are averaged is often found as rise time. This rise time is in effect comparable to the shaping time of an analog shaping amplifier, and comparable results are achieved if the rise time is twice the shaping time. For compatibility reasons, the Cube527 uses still the term “shaping time” and the rise time is just twice as high as that.

Further the values near the voltage step are omitted from calculation. This parameter is called flattop. The above mentioned very simple filter would have a flattop of 0.8µs and a shaping time of 0.05µs.

But there are more things to optimize a digital filter for and to be taken into account:

- A voltage step sitting on top of a previous step should be calculated to the same amplitude as if it was starting from the baseline. This correction is adjusted with the pole zero setting.

The positioning of the filter has typically an accuracy not better than the sample rate, here 100ns. So, the filter should be adjusted such that the result is invariant to a shift of 100ns forward or backward. This correction is also derivate from the pole zero setting.

5.2 ADJUSTMENT AND SETTINGS

5.2.1 COARSE GAIN

For the Cube527 Spectrometer series, there is one hardware-specific course gain level available. The adjustable levels in the software, for example Winspec, are created in the respective firmware. There are no real preamplifier levels present.
Which means, in case of an overflow, the reduction of the course gain level in the software won’t have an effect.

5.2.2 FINE GAIN

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.

5.2.3 TRIGGER FILTER

The trigger filter is applied continuously to the incoming signal to check for events (voltage steps). The Cube527 series have a double differential filter which is a very good compromise between good time resolution and sensitivity.

Trigger Filter Cube527	Pulse Pair Resolution	Best Dynamic Range Possible	Lower Energy Cutoff in % of Full Scale
1, 0, -2, 0, 1	330ns	1:325	0.30%

5.2.4 TRIGGER LEVEL

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, 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.

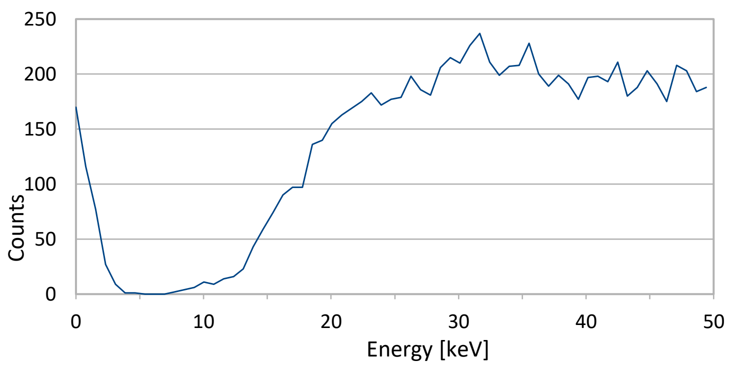


Figure 24: Lower end of a CZT spectrum.
The counts left of the valley near 0keV are caused by electronical noise and a too low trigger filter setting

5.2.5 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.

5.2.6 SHAPING 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.

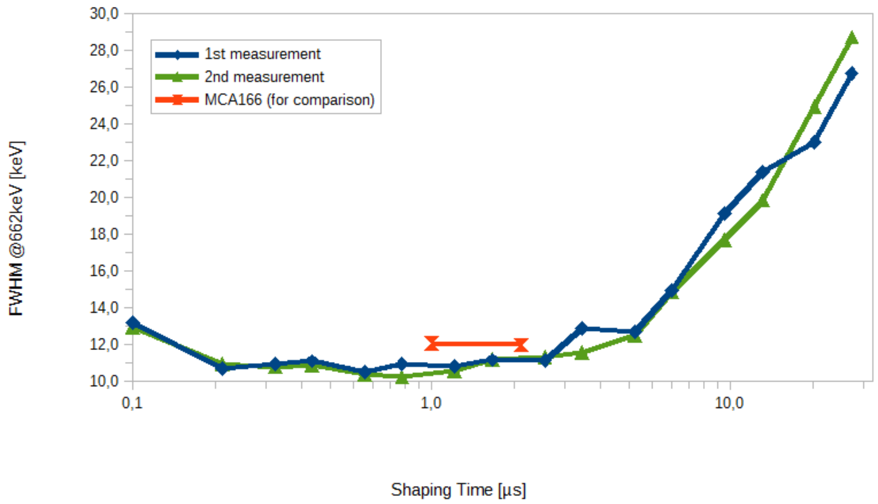


Figure 25: ***Dependence of resolution on shaping time for a CZT500 detector. Shaping times between 0.5µs and 1µs seem to be optimum.***

5.2.7 FLAT TOP TIME

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.

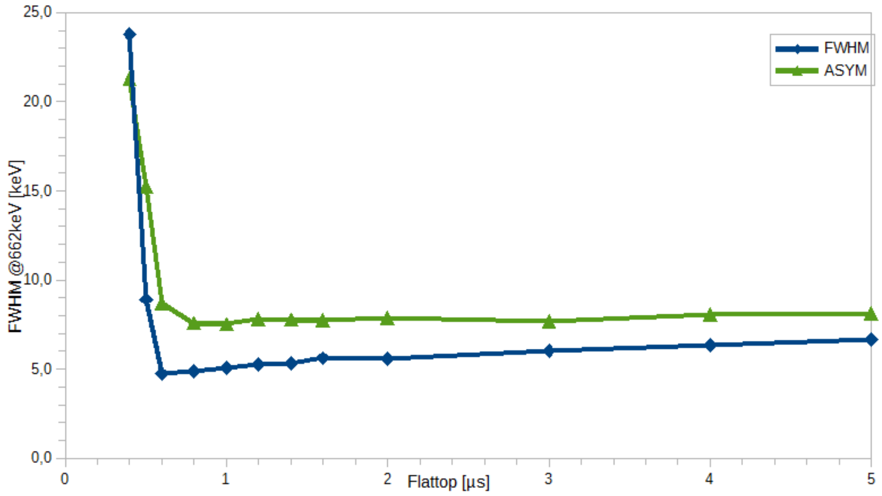


Figure 26: Resolution depending on flattop with a CZT detector. FWHM is here the Gaussian, ASYM the exponential part of the peak form.

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.

5.2.8 POLE ZERO AND JITTER COMPENSATION

The pole zero correction 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 by:

$$\boldsymbol{\tau} = \frac{88650\mu s}{PZC}$$

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 0.8s. The pole zero value has now to be adjusted such that the pole zero offset becomes zero.
Jitter is a typical problem of digital MCA and it is caused by the fact that registered events are asynchronous to the ADC sample clock. Therefore, the timing of the spectroscopically filter is always inaccurate by around 100ns. Assuming a decay time constant of 50µs, an inaccuracy of 100ns can may cause an error of 100ns/50µs=0.2%. This is unacceptable high for good spectroscopy. With some minor modifications the spectroscopically filter can be adjusted such that a shift of the spectroscopically filter of 100ns forward or backward will not change the result. This modification is also very close connected to the decay time constant of the preamplifier and therefore there is only one adjustment parameter which adjusts both for pole zero and jitter.

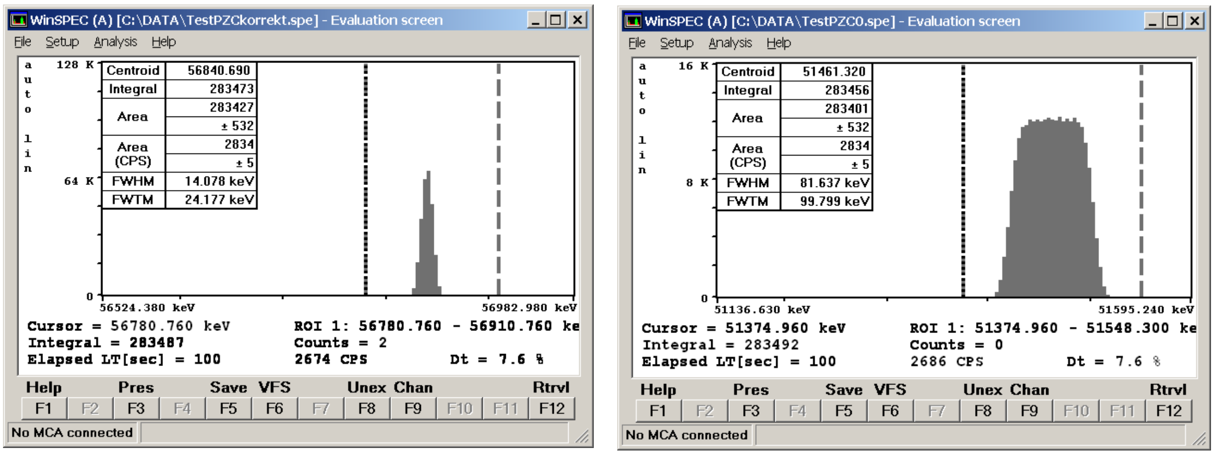


Figure 27: Measuring a periodic signal generator signal.

Left: ***Correct PZC setting and Jitter compensation.***

Right: ***PCZ=0, no Jitter compensation, the jitter error gives a rectangular distribution.***

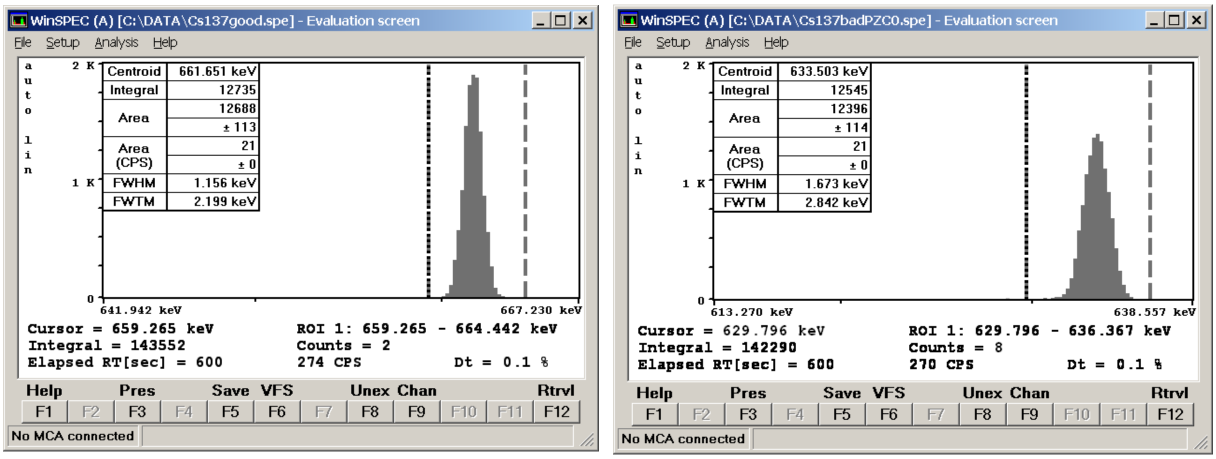


Figure 28: Measuring Cs137 with different PZC settings

Left: ***Measured Cs137 peak with correct settings. The calculated ratio of FWTM/FWHM is 1.91, which is reasonably close to the 1.82 expected from a gaussian distribution.***

Right: ***Spectrum without jitter or PZC compensation. As the jitter error has a rectangle like distribution, the FWTM / FWHM ratio is significantly smaller here and resolution is generally worse.***
The wrong pole zero does not really affect as the count rate is very low.

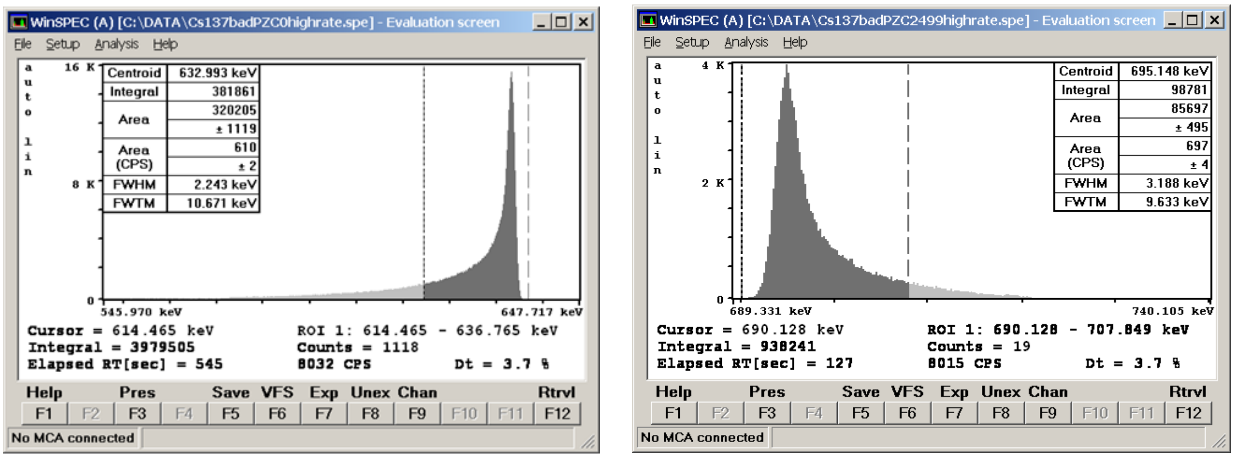


Figure 29: ***Measuring Cs137 with different PZC settings, jitter correction always on***

Left: ***Wrong pole zero has the worst effect with higher count rates. Here the characteristic low energy tailing typical for under-pole-zero can be seen, and the count FWTM / FWHM ratio is very high.***

Right: ***Too high pole zero setting causes tailing on the high energy side of the peak.***

5.2.9 BASELINE RESTORING

A disadvantage of the conventional approach of pole zero compensation by adding a DC component is, that now the result becomes sensitive to DC and low frequency disturbances, Furthermore, it is desired that an energy of 0keV is found in channel 0 and the spectrum does not have an offset. This is corrected by the base line restorer. The baseline restorer applies the spectroscopically filter to the signal immediately before the event if possible, and this result for the baseline is subtracted from the evaluated value for the event. The disadvantage of this is that the baseline measurement has itself an error, which adds to the total error and leads to some peak broadening. As the baseline should not change to fast, it is possible to do averaging. There are settings from 1 to 32 possible; 1 means no averaging and the baseline value always new measured, 32 is that the last measured value contributes only to 1/32 to the actual baseline.

Default is 16, which is best for good resolution and not too fast changing baseline. With increasing count rate and low frequency noise in the signal, smaller values down to 4 may be more optimum.

5.2.10 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

5.2.11 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 mode for taking time dependent rate for a special part of the spectrum. In PHA 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.

5.3 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 such as NaI 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.

Typically, peaks used would be the K40 peak (1460.5keV) which is always present in background, Am241 peaks, (gamma or alpha) as Am241 as source is sometimes integrated with NaI detectors, or a peak generated by LED light pulses, as present in special NaI detectors.

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

The stabilization area defines the minimum counts in the stabilization peak collected in a stabilization cycle before the fine gain is readjusted. The optimum value depends on the peak FWHM, peak count rate and peak drift rate. If the drift rate is high, then a rather low stabilization area is good to adjust the fine gain frequently. If drift is rather low a high stabilization area is better as then the centroid is calculated more accurate. Practical values are between 1000 and 25000. A formula to estimate the optimum area N_{opt}setting is given here[1]:

$$N_{opt} = \left(\frac{\mathrm{FWHM} \cdot \dot{n}}{2 \cdot 1460\mathrm{keV} \cdot 5 \cdot 10^{-6} s^{-1}} \right)^{\frac{2}{3}}$$

$FWHM$	= expected width of the stabilization peak in keV
$\dot{n}$	= peak area count rate
E	= energy of stabilization peak in keV
ϑ	= expected drift rate for the energy calibration.

[1]Jörg Brutscher, “Behavior of the MCA 166 at different Temperatures and Gain settings and limits of centroid accuracy”, internal report 2001

5.4 MEASUREMENT TIME PRESETS

For non-infinite measurements, the Cube527 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.

5.4.1 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 MCA527 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.

5.4.2 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.

5.5 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 spectroscopical 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.

5.6 OSCILLOSCOPE MODE

Oscilloscope mode is in WinSPEC-A 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.

5.7 INTERNAL TEMPERATURE

The Cube527 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 SOFTWARE

6.1 OVERVIEW

The following sections give brief descriptions of our programs. You can find more detailed information on the USB-stick delivered together with the device. You should also use the online help of each program.

6.2 WINSPEC

This program is the default program for measuring spectra. It supports semi-automated measurements of gamma ray spectra with the MCA. The spectra are stored on mass storage media on a computer. There are two variants of WinSPEC. WinSPEC-I (for Inspectors) was designed for standard use. WinSPEC-A (for Automation) was designed for unattended measurements. Special features of WinSPEC-A are:

- Automatic restart of the program after loss of mains power, program or operating system crash
- Writing zip files
- Data file retrieval to a flashcard
- Archiving of data files
- Writing a log file

6.3 WINMCS

This program supports semi-automated measurements of time distributions. There are two variants of WinMCS. WinMCS-I (for Inspectors) was designed for standard use. WinMCS-A (for Automation) was designed for unattended measurements. It contains the same special features as WinSPEC-A.

6.4 WINU235

These programs support stabilized U235 enrichment verification measurements. The algorithm bases on absolute intensity measurement of the 186keV photon energy. It also needs a two-point intensity calibration with two standards.

Reevaluation / recalibration using previously recorded spectra is possible. Verification results are documented in a report file, which is automatically saved with the extension *.rep.

6.5 WINUF6

SimilarWinU235. Only one intensity calibration measurement is necessary.

6.6 MCA TOUCH

Software made for safeguards purposes. The focus here is on usability and support of computers with small touchscreens and pocket computers.

6.7 AUXILIARY SOFTWARE FOR ANALYSIS, PRESENTATION AND MISCELLANEOUS FUNCTIONS

6.7.1 IDENTIFY

Identify is an intelligent, interactive software tool to evaluate spectra. It does peak search and nuclide identification. HPGe, CdZnTe and NaI detector gamma spectra are supported. For correct peak search a starting point for the detector resolution and efficiency is assumed based on detector type and size. Features are:

- includes full master library of gamma lines (derived from table of radioactive isotopes)
- editor for creating application specific evaluation libraries
- detector function is calculated from detector data sheet, no efficiency calibration needed
- automatic determination of FWHM of the peaks found in a spectrum as function of energy
- supports 1 to 3-point energy calibration
- linear, logarithmic, square root, and double log representation possible
- error estimations/confidence assessment for identified isotopes and visualization (by overlay of calculated spectrum for a certain isotope)
- switching between English and German languages
- interactive nuclide pattern identification
- nuclide assignment suggestions also for each single peak
- instant graphical comparison to simulated spectra by clicking on a nuclide
- Windows 3.1 version also available
- IDENTIFY is not included in the MCA price
- IDENTIFY routines are also available as library for MS Windows and Linux

6.7.2 MCA PLOT AND MCA PRINT

MCA Plot and MCA Print are programs to view and print spectra. Up to 32 spectra can be viewed at the same time and be printed on one page. Also, some evaluation functions are available. MCA Plot is not included in the MCA price. MCAPrint is a free downgraded version of MCA Plot.

6.7.3 MCA WAND

MCA Wand is a program for converting different file formats. Please note that there may be always a loss of information as not all kind of information about the spectrum is supported by every file format. The following information is converted:

- Channel Data
- Energy Calibration
- Energy Calibration points
- Live time, Real time
- Date and Time of measurement
- Spectrum Remark

The following file formats are supported for reading and writing:

Table 1: Supported file formats by MCAWAND

Source	Target
*.spe (MCA166 native)	*.spe (MCA166 native)
*.chn (Ortec)	*.chn (Ortec)
*.spe (Interwinner)	*.spe (Interwinner)
*.spc (Target)	
*.dat	*.dat (2 column: energy, channel content)
*.de1 (Canberra S100)	
*.dat (Silena Gamma 2000)	
*.spk (Röntgenanalytik)	
*.spa (Sarad)	
*.usf (URSA)	

6.8 MISCELLANEOUS

For communication and evaluation some libraries for MS Windows and Linux are available. This may help to make own application programs or to integrate the MCA527 into an existing system.

7 SOME OF THE MOST IMPORTANT PHOTON ENERGIES

Table 2: Photon energies for different isotopes

ISOTOPE	HALF-LIFE	ENERGY (KEV)	BRANCHING RATIO (%)
Am241	432.2y	26.34/59.54	2.4/36
Cd109	462.6d	88.03	3.63
Bi214	19.9min, daughter of Ra226	609.31	46.09
Ce139	137.64d	165.86	79.87
Co60	5.271y	1173.23/1332.49	99.85/99.98
Co57	271.8d	14.4/122.06/136.47	9.16/85.6/10.68
Cs137	30.07y	661.66	85.1
Eu152	13.3y	121.77/344.28/778.91/ 964.11/1112.07/1408. 00	28.38/26.59/12.98/14.46/ 13.57/20.85
Hg203	46.61d	279.19	81.84
Mn54	312.2d	834.82	99.98
Pb214	26.8min, daughter of Ra226	241.91/295.09/351.86	7.46/19.17/37.06
Ra226	1600y	186.11	3.28
Sn113	115.09d	391.7	64.89
Sr85	64.84d	514.0	98.4
U235	7.04E8y	143.78/163.37/185.73/ 205.33	10.53/4.7/53.15/4.7
Y88	106.65	898.04	94
Pb fluorescence x-rays	-	74.96/72.79/84.99/ 87.34	

8 TECHNICAL SPECIFICATION CUBE527 SERIES

CDZNTE DETECTOR MODULE	
- Quasi-hemispherical crystal shape - Energy Range: 20keV to 3MeV - Available with crystal volumes of $60mm^3$, $500mm^3$, or $1500mm^3$. - Cube527-500 (standard crystal size)	
SPECTROMETRIC PERFORMANCE	
Example 1 Resolution: 2k channels Detector crystal size: *60mm³*	(FWHM) @ 662keV <2.5%
Example 2 Resolution: 2k channels Detector crystal size: *500mm³*	(FWHM) @ 662keV <2.5%
Example 3 *Resolution: 2k channels* *Detector crystal size: 1500mm³*	(FWHM) @ 662keV <3.5%
Throughput into memory (input rate 150kcps, 0.2µs shaping time)	>100.000cps
OPERATION MODES	
PHA (Pulse Height Analysis)	✓
MCS (Multichannel Scaling)	✓
Sample Mode (Transient Record)	✓
Oscilloscope Mode	✓
Firmware Repeat Mode	✓

DIGITAL SIGNAL PROCESSING	
Trigger Filter	double differential filtering
Differential non-linearity	<1% (for 2k, @ 1µs shaping time)
Pile Up Rejection	✓
Pulse Pair Resolution	~400ns
Trigger Threshold Adjustment	automatically / manually
Shaping Time	0µs to 2µs, step 0.1µs
Flat Top Time	0µs to 15µs, step 0.1µs
Fine Gain Adjustment	0.5 to 6.5, step 0.0001
Channel Splitting	128, 256, 512, 1024, 2048, 4096
Base Line Restorer	BLR with fixed averaging
Pole Zero Adjustment	Decay time down to 40µs can be compensated
Peak Stabilization Mode	✓
AMPLIFIER UNIT	
Amplifier Type	ADC Driver
Bias supply	0V to 2000V, (software adjustable)
ANALOG DIGITAL CONVERTER	
Sample Rate	10MS/s
Resolution	14bit
Integral non-linearity	≤ 0.05%

POWER SUPPLY	
Cube527	- via USB PC-Port, ≤500mA
Cube527E	- Power over Ethernet ≤ 2W - USB PC-Port ≤ 500mA - USB wall-adapter ≤ 500mA
Cube527R	- LEMO[2] Pin 4 ➔ 8V ≤ VCC ≤ 25V Pin 5 ➔ GND
Power consumption (device running, without detector, HV off)	- 0.3W (Cube527) - 0.5W (Cube527E)
COMPUTER INTERFACE	
Cube527	USB 2.0 compliant
Cube527E	- Ethernet 10/100Mbit, RJ45 - USB 2.0 compliant
Cube527R	- RS485 up to 3Mbit/s (half or fullduplex) - RS485➔ USB adapter (on request)
EXTENDED INTERFACE GPIO	
Useable for a start signals, triggering, loop through mode, counter e.g. for neutrons, signal generator *(not available for Cube527R)*	

WEIGHT & DIMENSIONS (H x W x L)		
Cube527	25mm x 25mm x 65mm	80g
Cube527E	25mm x 25mm x 110mm	150g
Cube527R	25mm x 25mm x 85mm	90g
ENVIRONMENTAL CONDITIONS		
Operation Temperature Range	0°C – 50°C	
Humidity	≤90%, non-condensing	
IP Protection Class	IP40	

[2] see LEMO pinout, Chapter 2.5.2

9 TROUBLESHOOTING

General Remark:

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. We have specialists for that. If you have a problem which cannot be solved by the table below, contact us. If it is really a hardware fault, we can repair this for a fair price.

1. 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
2. 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.
3. 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 500ns, 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.
4. 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.

5. 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.

6. Too high-count rate
   - Keep a bigger distance to radiation source.
   - Check for disturbances of switch mode power supplies etc.

10 FIRMWARE UPDATE

GBS Elektronik maintains the firmware of the MCA527 continually. We improve the performance, add new features and fix bugs that have been known. In order that all MCA527 users can participate in the improvements, we provide the newest releases of the firmware on our download page in the internet.

The firmware of the MCA527 can be changed easily by yourself.
You only need the GBS Firmware Loader and the firmware file that suits to your MCA527. Both can be download from our internet page.

There are different variants of the MCA527 (Full, Lite, OEM and Micro) with different hardware versions. If you are unsure about the variant and the hardware version of your MCA527, look for this information within the diagnostics dialog of, for example, WinSPEC.

When all preparations have been completed, start the GBS Firmware Loader. You will be prompted to load a suitable loader file. After the file has been loaded, the button "Select device ..." is enabled. Press this button to search for devices. If your MCA527 is within a RS485 bus system, you have to input the RS485 address. The next dialog lists all detected devices. If all working steps have been done correctly, your MCA527 should appear within the list of the applicable devices. Select your MCA527 and start the firmware upload. It is recommendable to check the "Verify uploaded firmware" option.

A MCA527 ALGORITHM, FORMULAS

This appendix lists the algorithms used by the MCA for the following functions:

- Area, Area uncertainty
- Centroid
- FWHM
- Smooth
- Strip
- Energy Calibration

The Area and the Area Uncertainty Function:

The area algorithm calculates the number of counts above the background in a ROI. The background area is determined by averaging 4 points on both sides of the peak (the ROI limit points and 3 outer points) and linear fit:

$$Area = Integral - Background$$

$$Background = \frac{ROI_{end} - ROI_{begin} + 1}{8}\left(\sum_{i=ROI_{begin}-3}^{ROI_{begin}} Spectrum_i + \sum_{i=ROI_{end}}^{ROI_{end}+3} Spectrum_i\right)$$

$$Integral = \sum_{i=ROI_{begin}}^{ROI_{end}} Spectrum_i$$

$$Area\ Uncertainty = \sqrt{Integral + \left(\left(\sum_{i=ROI_{begin}-3}^{ROI_{begin}} Spectrum_i + \sum_{i=ROI_{end}}^{ROI_{end}+3} Spectrum_i\right)\left(\frac{ROI_{end} - ROI_{begin} + 1}{8}\right)^2\right)}$$

Where

$Spectrum_i$	= the absolute number of counts in channels i
ROI_{begin}	= the ROI's start channel
ROI_{end}	= the ROI's stop channel
i	= channel number

Centroid:

The peak centroid is the sum of the channel contents[3] times the channel number divided by the sum of the channel contents in the range of the channels above the half maximum:

$$Centroid = \frac{\sum_{i=l}^{h} i \cdot Spectrum_i}{\sum_{i=l}^{h} Spectrum_i} \text{where}$$

i = channel number

l = lowest channel above the half maximum

h = highest channel above the half maximum

$Spectrum_i$ = net contents of channel i

FWHM:

The Full Width at Half Maximum (FWHM) is the background corrected peak's width at one-half of its maximum amplitude. The algorithm first proceeds down one side of the peak until it finds a channel (e. g. 1203) whose counts fall below the half maximum channel. It is now made sure that the following channel (e. g. 1204) also falls below the half maximum channel. The same algorithm is applied for the other side of the peak. The left and the right FWHM points are the interpolated channels between the counts of the channel below and above the half maximum value.

Smooth:

Smooth averages the current spectrum (the original data will be overwritten) using a binomial formula:

3-point smoothing:

$$Spectrum_i' = \frac{Spectrum_{i-1} + 2 * Spectrum_i + Spectrum_{i+1}}{4}$$

5-point smoothing:

$$Spectrum_i' = \frac{Spectrum_{i-2} + 4 * Spectrum_{i-1} + 6 * Spectrum_i + 4 * Spectrum_{i+1} + Spectrum_{i+2}}{16} \text{where}$$

$Spectrum_i$ = the original contents of channel i

$Spectrum_i'$ = the smoothed contents of channel i

[3] background corrected

Strip:

Strip subtracts a specified fraction of the spectrum. The Strip factor can be “positive“or “negative“ :

$Spectrum'_y = Spectrum_y - F * Spectrum_x$where

$Spectrum'_y$ = Count content of channel i in the resulting spectrum

$Spectrum_Y$ = Count content of channel i in the original spectrum

$Spectrum_x$ = Count content of channel i in the spectrum to be subtracted

F = Strip factor

E-calibration:

The Energy calibration allows to convert the x-axis channel numbers into energy values in KeV. The following formula is used:

$E = S * Channel + O$where

S = slope

O = offset

$Channel$ = channel number

The coefficients can be set as numeric values or by linear fit of two energy channel/peak centroid pairs.

B FURTHER DOCUMENTS

The further documents are not intended for ordinary users but for developers and users which need more information about the MCA527. The further documents do not exclusively refer to the MCA527.

- MCA Spectral Data Format

  MCA_Spectral_Data_Format_XXXX_XX_XX.pdf

- Description of the MCA527 Firmware Commands

  MCA527_Firmware_Commands_XXXX_XX_XX.pdf

- Description of the MCA Communication DLL

  MCA_Communication_DLL_XXXX_XX_XX.pdf

- Use of MCA User Data Memory by Specific Applications

  MCA_User_Data_XXXX_XX_XX.pdf

- Description of the MCA527 Oscilloscope Mode

  MCA527_Oscilloscope_Mode_XXXX_XX_XX.pdf

- MCA Binary Data Format

  MCA_Binary_Data_Format_XXXX_XX_XX.pdf