MCA527 OEM/ OEM+

DIGITAL MULTICHANNEL ANALYZER

USER MANUAL

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REVISION SHEET

Release No.	Date	Revision Description
Rev. 01	06/03/2018	First official revision
Rev. 02	06/07/2019	- PCB Layout (add Boot Jumper & Dimensions, Page 9) - Chapter 10 Firmware update information - revised technical correctness

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PACKAGE CONTENTS

Your MCA527 OEM package includes:

- One MCA527 OEM printed circuit board (PCB)
- One power cable
- Software package on USB-stick

ESD Precaution

PLEASE NOTE THAT THE MCA527 OEM BOARD AND ITS COMPONENTS ARE EXPOSED FOR FINGER TOUCHES – AND THEREFORE EXTRA ATTENTION MUST BE PAID TO ESD (ELECTROSTATIC DISCHARGE) PRECAUTION.

MAKE IT A HABIT ALWAYS TO FIRST TOUCH THE METAL SURFACE OF ONE OF THE USB OR ETHERNET CONNECTORS FOR A FEW SECONDS WITH BOTH HANDS BEFORE TOUCHING ANY OTHER PARTS OF THE BOARDS. THAT WAY, YOU WILL HAVE THE SAME POTENTIAL AS THE BOARD AND THEREFORE YOU MINIMIZE THE RISK FOR ESD.

1.   Introduction

Thank you for buying GBS Elektronik' MCA527 OEM.

This document is a User Guide that describes the *MCA527 OEM* hardware, digital signal processing and software parameter settings.

The MCA527OEM / OEM+ is a compact and low power consuming multichannel analyzer PCB. Designed for the use of NaI- and CdZnTe- detectors, but it may be also usable for other applications such as neutron counters or CsI detectors and other low or medium resolution gamma detectors.

The OEM+ Version operates with 16k channel resolution and is usable for high-resolution HPGE detector purposes.

The range of application can be in portal monitors, handheld devices or any other`s where an OEM Version meets customer equipment integration- and budget requirements.

The MCA527OEM / OEM+ is equipped with a RJ45 Ethernet socket and USB-B socket for flexible and immediate computer communication. The OEM is prepared for autonomous measurement modes with its on board µSD-card holder and software support.

The software programs of our MCA family are available free of charge and allow to run in several operation modes such as a universal counter, oscilloscope, Gate Mode Autonomous Repeat Mode, Sample Mode or Multi Channel Scaling Mode.

1.1   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.

Another 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.

2. Hardware Description

The MCA527OEM / OEM+ is a PCB-only version of the MCA527, which is hardware- and software- compatible with the MCA527 but not identical. It is intended for customers who wants to integrate an MCA into their own devices or systems. *Figure 1* shows the board outline and its connections.

The size is 134mm x 60mm without USB- and Ethernet connector. The MCA527OEM is equipped with Ethernet-, USB-, and 2x RS232 interfaces. The board is powered through the 6-pin power connector (9). The Ethernet works with voltages between 3.3V and 9V while USB needs an input voltage of 4.5V to 9V. Powering the MCA527OEM through the USB port is not possible.
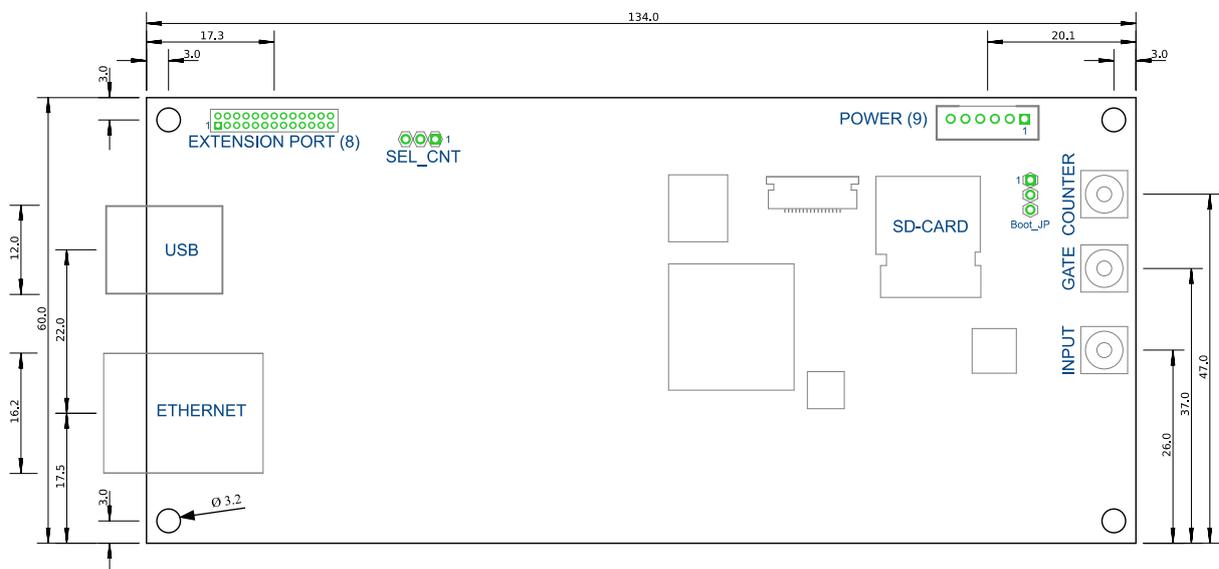
Figure 1 MCA527OEM Dimensions & Connections

The MCX coaxial connectors (Telegärtner J01271A0131, series J0127) are used for the signal input, gate input and the counter input. Corresponding plugs, such as the J01270A0161, should be used for connecting these signals to the MCA527OEM. The MCA527OEM is also equipped with an extension port. The extension port signals are available on the OEM extension port connector (8).

The Jumper SEL_CNT switches the counter input. It must be in the 1-2 position if the MCX coaxial connector would be used as counter input. If it is in the 2-3 position, the pin 25 of the extension port connector can be used as counter input.

The boot jumper must be in 1-2 for normal operation of the card. Position 2-3 is provided in case of problems, for example, the board does not boot up in any way and the firmware has to be reloaded onto the PCB.

Table 1 *Pinout of the Power Connector (9)*

PIN	Signal		Description
1	V_{in}	input voltage (3.3V...9V), 1W	Main supply for OEM board
2	GND		
3			
4	V_{RTC}	3.3V power supply for real time clock	Supply for on-board real-time clock. Clock setup can be done in WinSpec
5	SDA	I²C-interface data line	Usable for temperature sensor of Detector or ambient temperature Sensor, or similar
6	SCL[7]	I²C-interface clock line	

Table 2 Pinout of the OEM Extension Port (8)
(Male Header 2 x 13, Pitch 1.27mm)

Contact	Signal	Description / Application example
1	shield extension port	Cable shield
2	shield RS232 interface	Cable shield
3	RxD_{ext} RS232 extension port	Usable for GPS, - Bluetooth or similar applications
7	TxD_{ext} RS232 extension port	
5	GND_{ext} extension port	
4	RxD RS232 interface	Computer Interface
6	GND RS232 interface	
8	TxD RS232 interface	
9, 10, 13, 15	not connected	
11, 12, 17, 18, 23, 24	GND	
14	SDA I^2C-interface data line	Usable for temperature sensor of Detector or ambient temperature sensor
16	SCL I^2C-interface clock line	
19	$O1_{ext}$ / TxD_{extTTL} (output)	Digital output ➔ setup in WinSpec
20	3.3V / 100mA power output	Supply for ext. devices
21	$I1_{ext}$ / RxD_{extTTL} (input)	Digital input
22	$O2_{ext}$ (output)	Hardware extension, signal output etc.
25	$I2_{ext}$ (input)	Counter input
26	$5V_{ext}$ / 100mA power output	supply for external devices (GPS, Bluetooth, etc.)

2.1. Computer Interfaces

Three different communication interfaces are existing by the MCA527OEM. Depending on the situation each interface has various advantages. The standard RS232 interface is available via OEM Extension Port. (8)

Three different baud rates are supported by the MCA527, 38.400, 115.200 and 307.200 Baud. All newer application programs for the MCA are using always the highest possible baud rate depending on the computer hardware.

Because the firmware of the MCA527 is able to detect the hosts baud rate automatically, usually no manual interface configuration is necessary. If the host computer offers an USB host controller, communication can be done via the USB interface. Independent of the application program and the host computer hardware, the used baud rate is always 3MBaud.

The MCA527OEM 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, to use Zero Configuration Networking (also named Automatic Private IP Addressing), but it is also possible to set a fixed customized IP address. For that a special program is required.

3.   Getting Quick Started

3.1.   Detecting MCA527OEM on PC

1. **Install the WinSpec software on your PC**. It is important to do this before the MCA527 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. **Connect the MCA527 with your PC** and possibly with an external power supply.

3. **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 MCA527 is listed, mark it and press "Select".

4. In case your MCA527 is not listed, there can be several reasons for it.
   - If the MCA527 is connected via Ethernet, it may take up to some minutes until the connection is ready to use.

3.1.2 Parameter Setting

In the next steps, the configuration is adapted to the special characteristics of the detector, to the sample to be measured and the task to be done. The detector has to be supplied with its operating voltage and the recommended high voltage from your detector supplier.

- **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 enter the "Input Polarity". (This parameter depends from the detector output.)
- **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.
- **Next, set the PZC (Pole Zero Cancelation)**
  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.

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 2 Range of Interest marked in green with related
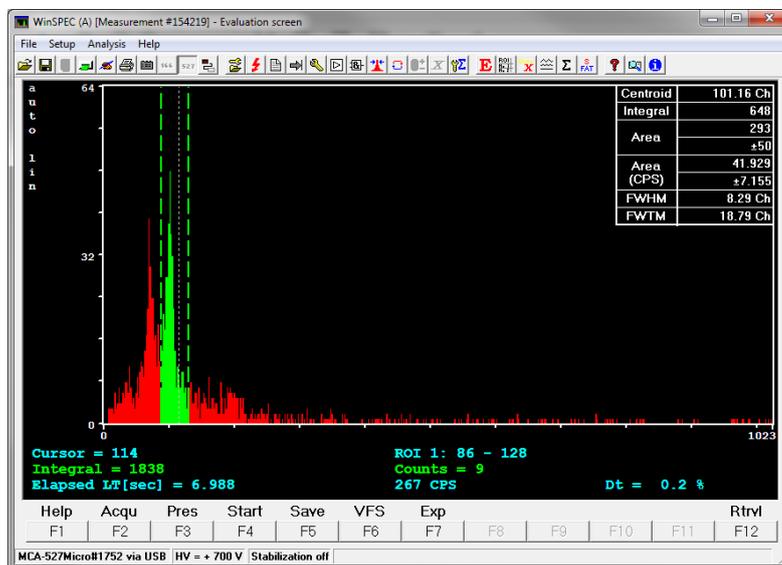*ROI values in the upper right corner*

- 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.

4.   Pulse Height Spectroscopically Measurements

4.1   Introduction 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 rate, and the amplitude is calculated from a multitude of measurements. The MCA527 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.
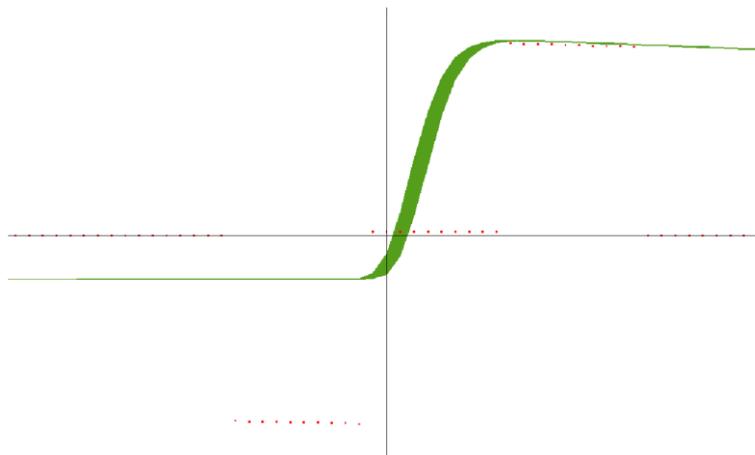

Figure 3 Example of a digital filter applied to a voltage step. Here the flattop-time is 1µs (10*100ns) and the shaping time 0.5µs (≙ 1µs rise time)

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.

The 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 MCA527 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 considered:

- A voltage step sitting on top of a previous step should be calculated to the same amplitude as if it was starting from the MCA 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.

4.2   Adjustment and Settings

4.2.1 Coarse Gain

The coarse gain can be adjusted between 2 and 1000 but only settings between 2 and 100 affect the signal input amplifier / attenuator. It defines which signals can be processed.

Table 3 Input signal acceptance range depending on coarse gain

Coarse Gain	Full Input Range	Useable Input Range Positive Polarity	Useable Input Range Negative Polarity
2 (OEM+)	12.50V	-1.25V…11.25V	-11.25V…1.25V
5 (OEM+)	5.00V	-0.5V…4.5V	-4.5V…0.5V
10	2.50V	-0.25V…2.25V	-2.25V…0.25V
20 (OEM+)	1.25V	-125mV…1125mV	-1125mV…125mV
50 (OEM+)	0.50V	-50mV…450mV	-450mV…50mV
100 (OEM+)	0.25V	-25mV…225mV	-225mV…-25mV

For best resolution, the coarse gain setting should be chosen as high as possible but still fits into the input acceptance range. However, above a coarse gain of 20 the improvements are marginal, and coarse gain settings above 100 have been omitted as there is no benefit for this and are just calculated.

4.2.2 Fine Gain

The fine gain is to fine adjust the gain and therefore the energy to channel ratio. This gain is just a mathematical factor used for calculation of the filter. The highest dynamic range (ratio of low energy cutoff to maximum energy in spectrum) and best resolution can be achieved when using a rather high coarse gain and a low (e. g. 0.5) fine gain. With higher count rates (>10kcps) it is however recommended to stay with fine gain above 1 and to reduce coarse gain.

The adjustment range is 0.5 to 6.5, default is 1. This adjustment range was chosen to be compatible to MCA166 which has a range of 0.5 to 1.5, and to extend it also to larger values which is useful for real high-count rates.

4.2.3 Trigger Filter

The trigger filter is applied continuously to the incoming signal to check for events (voltage steps). Also, here are selections possible which represent tradeoff between time resolution and sensitivity. The simplest trigger filter is the -1, 1 filter which just checks the difference between subsequent incoming values and therefore performs a single differentiation. Even more sensitive is the -1, 0, 1 filter which checks the difference between incoming signals of 200ns distance.

The best pulse pair resolution (ability to distinguish between close following events) is however achieved with a double differentiating filter as the 1, -2, 1. But double differentiating increases the noise level and therefore this filter is not as sensitive. A compromise is the 1, 0, -2, 0, 1 trigger filter, which has still a good time resolution but a better sensitivity then the 1, -2, 1.

Table 4   Properties of different trigger filters. Dynamic range tested with GL2010R, amplification 5*0.5, 4096 channels, shaping time 2µs flat 0.8µs

Trigger Filter	Pulse Pair Resolution	Best Dynamic Range Possible	Lower Energy Cutoff in % of Full Scale
-1, 0, 1 (OEM+)	860ns	1:625	0.16%
-1, 1 (OEM+)	760ns	1:353	0.28%
1, 0, -2, 0, 1	330ns	1:325	0.30%
1, -2, 1 (OEM+)	240ns	1:169	0.60%

Default is the 1, 0, -2, 0, 1 filter as a good compromise for both sensitivity and time resolution. In case of a low count rate (<5kcps) and a required high dynamic range (low energy part of the spectrum also important) the filter -1, 0, 1 is recommended. The 1, -2, 1 is best at high count rates and where the lower end of the spectrum is not really important. The -1, 1 is more a bad compromise and just here because it is the shortest and needs the least processor power.

For best pulse pair resolution, the preamplifier signal should be steep, but it should not exhibit any ringing. In case of ringing or overshoot, the trigger filter will trigger multiple times on a single signal and therefore consider this erratically as pile up. A preamplifier ringing or overshoot problem can be suspected if dead time is much higher than expected. In such a case try a single differentiating trigger filter such as -1, 0, 1 or -1, 1.
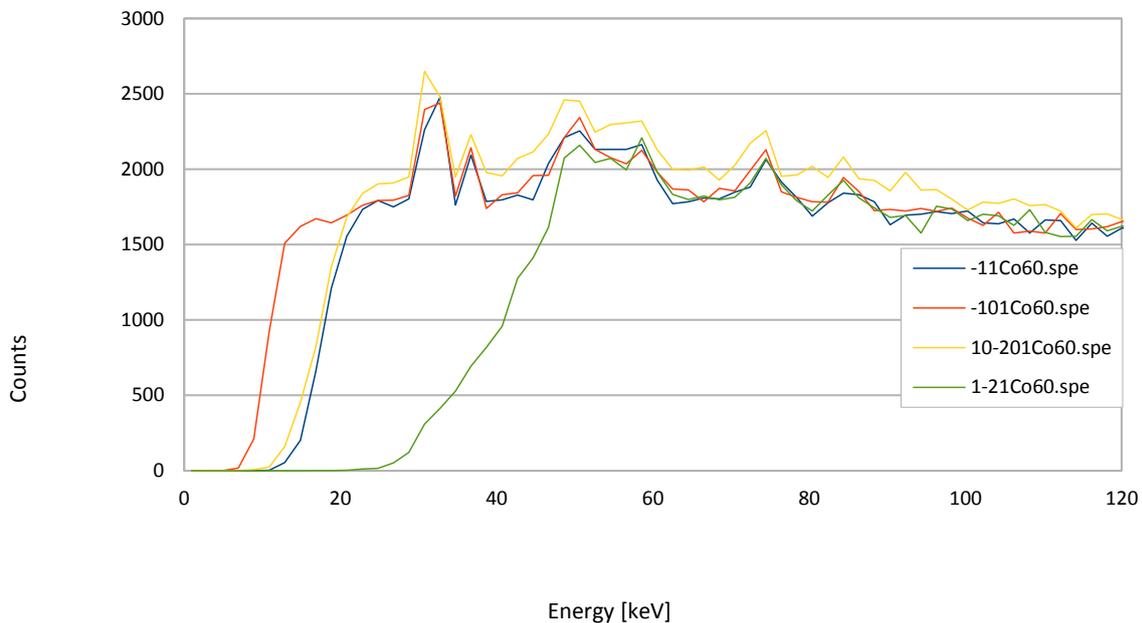If this does not help, switch pile up rejection off.

Figure 4 Low-end spectrum cutoff depending on trigger filter. Spectrum range in all cases is 8MeV, whereas the 1, -2, 1 cuts off the spectrum already at a quite high energy of 48keV, the -1, 1 and the 1, 0, -2, 0, 1 go down to 23keV, and the -1, 0, 1 allows still energies down to 13keV to be seen.

4.2.4 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 readjust 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.
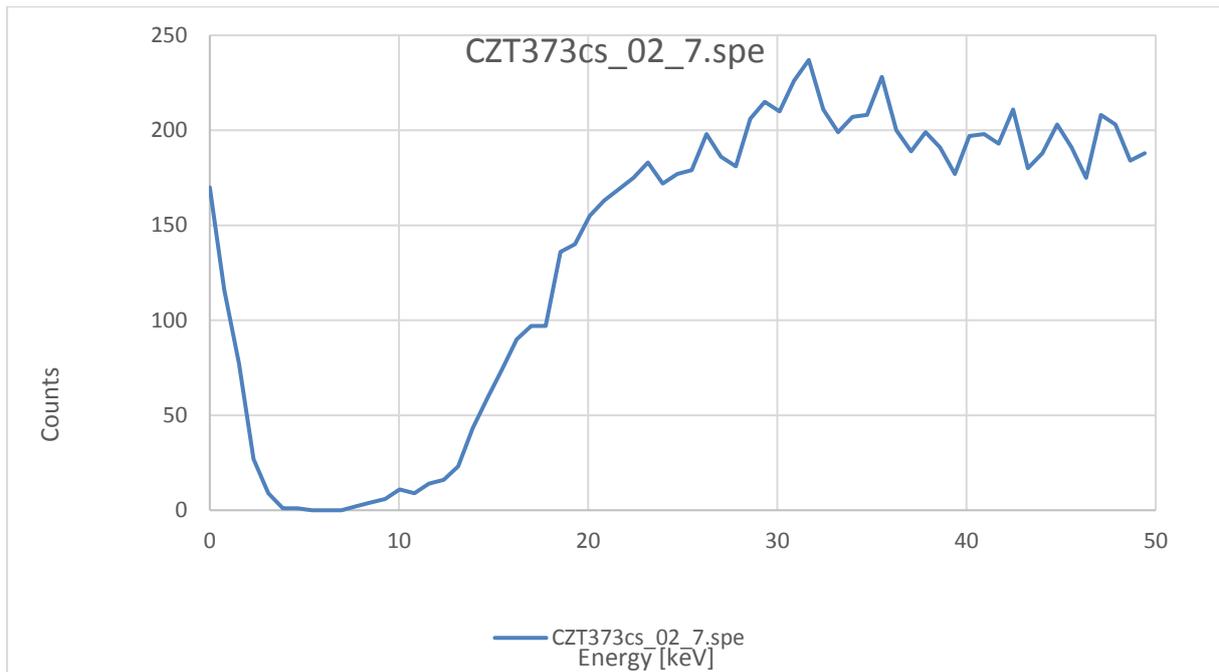
Figure 5 Lower end of a CZT spectrum. The counts left of the valley near 0keV are caused by electronical noise and a too low trigger filter setting

4.2.5 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, see table 11.

The PUR setting is by default on, and may only be switched off for troubleshooting, checking the performance of the pile-up rejector or with some really weird preamplifier signals (overshoot or ringing).
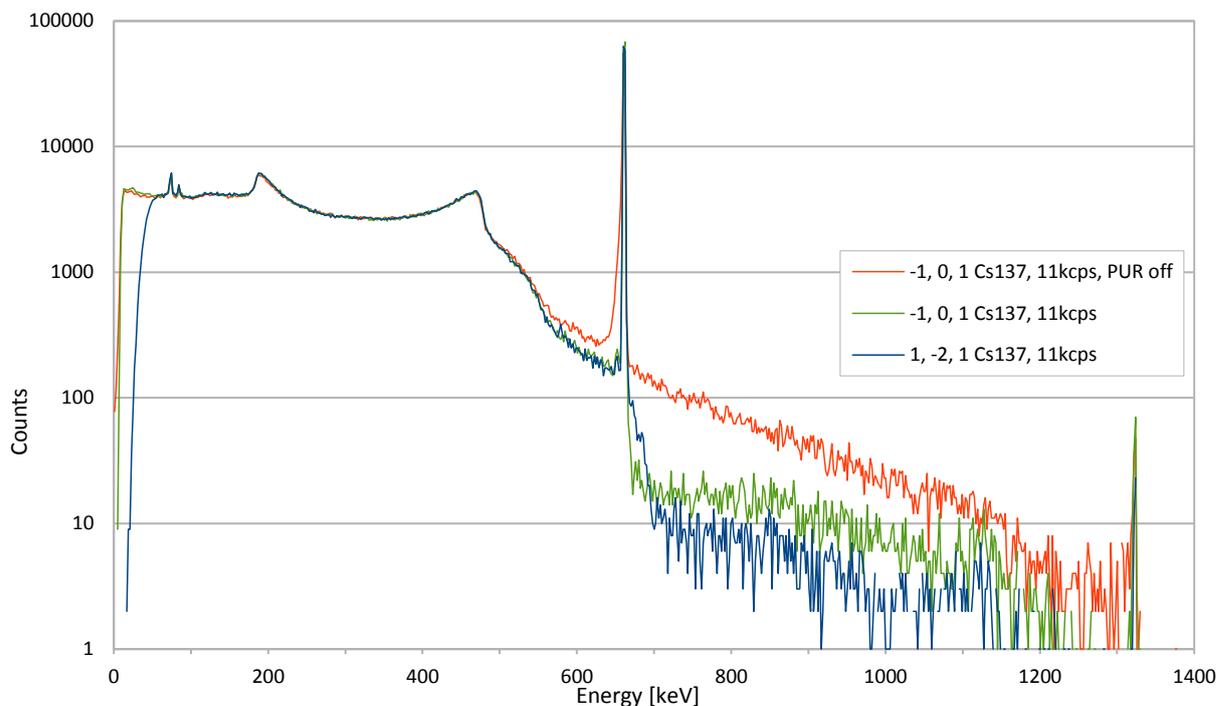

Figure 6 Effects of PUR setting on spectrum, here a Cs137 spectrum taken with 11kcps. Everything right of the prominent Cs137 peak in the middle of the spectrum is due to pile-up. The lowest pile-up component in the spectrum is achieved with the 1, -2, 1 trigger filter. The -1, 0, 1 filter is not as good in suppressing pile-up, but still much better than pile-up switched off.

4.2.6 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 coaxial HPGe detector the optimum is typical something like 4µs...6µs, for a CZT the best may be 0.7µs and for a NaI 0.2µs. 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.
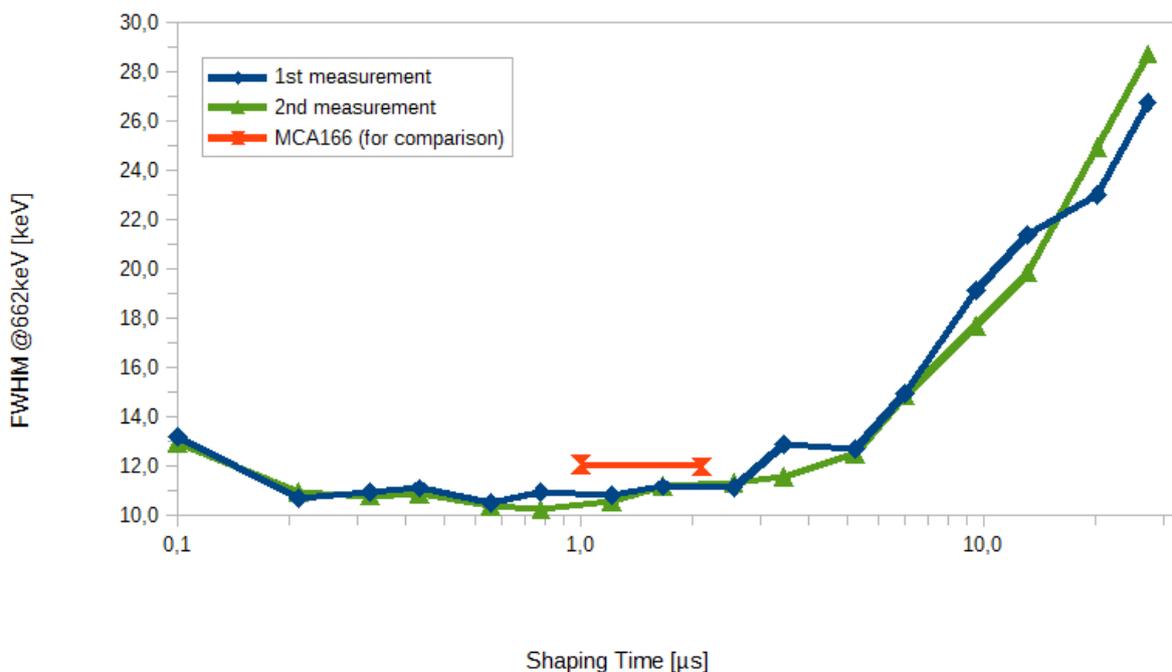
Figure 7 Dependence of resolution on shaping time for a CZT500 detector. Shaping times between 0.5µs and 1µs seems to be optimum.
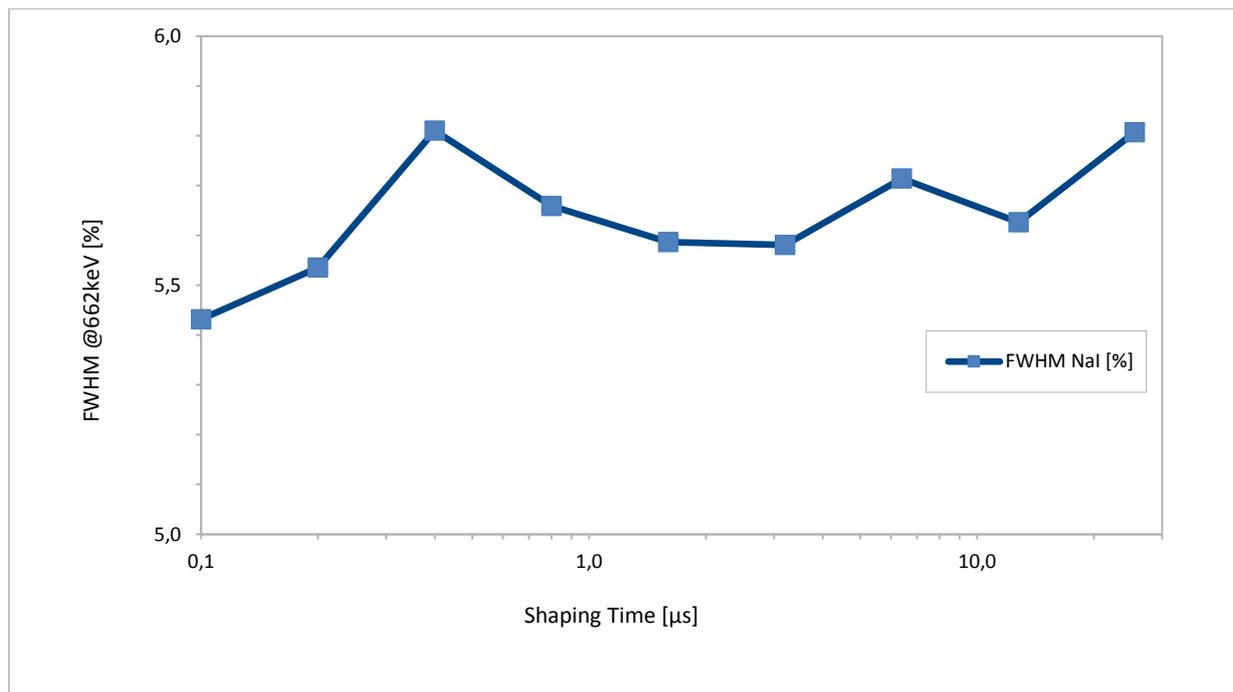
Figure 8   *Dependence of resolution on shaping time for a good NaI.*
                    The shortest possible shaping time is long enough

4.2.7 Flat Top Time

Flattop is a parameter introduced with digital multi-channel analyzers. Basically, this is adjusted to the rise time of the preamplifier. 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. See Figure 9 as an example.
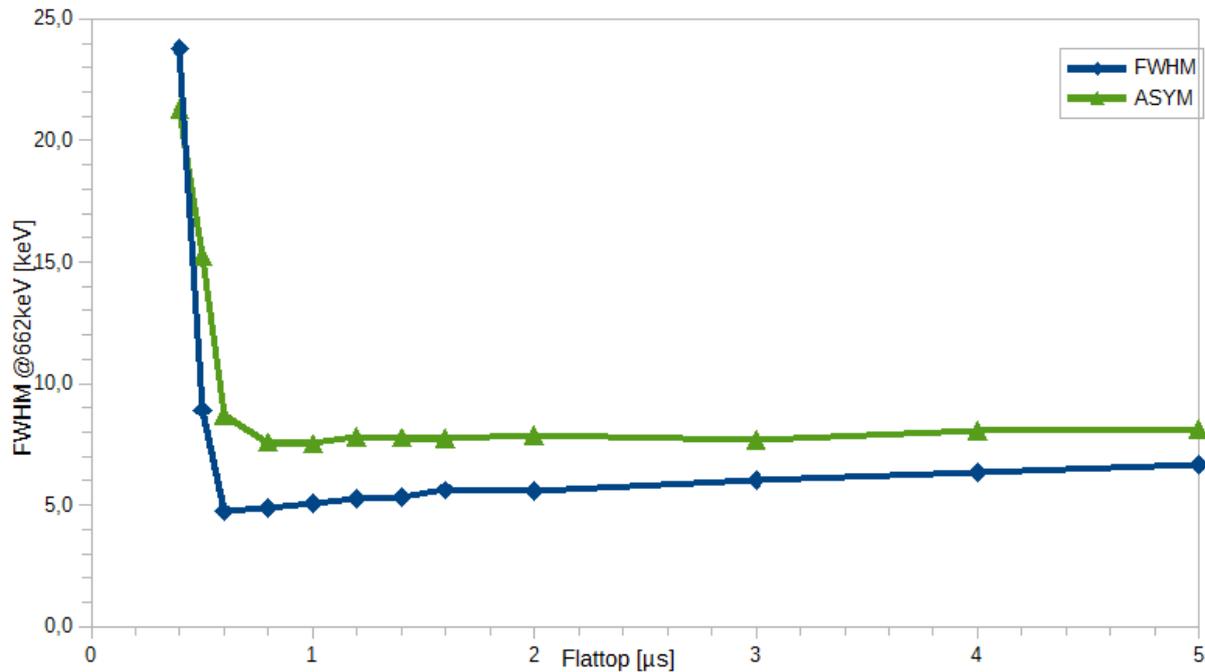
Figure 9 Resolution depending on flattop with a CZT detector. FWHM is here the Gaussian, ASYM the exponential part of the peak form.

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. For HPGe detectors something between 0.8µs and 1.2µs may be optimum. For a NaI with a rather slow rise time something like 1.6µs may be better.

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.
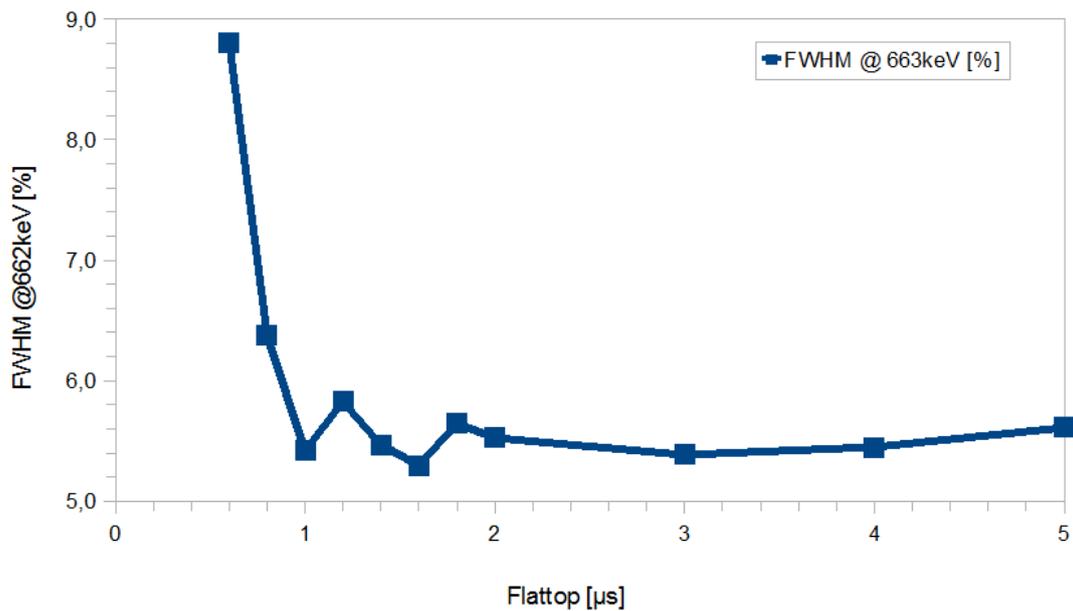
Figure 10   Dependence of resolution on flattop setting using a NaI detector. As a NaI detector exhibits slower rise times, a bit longer flattop yields best results.

4.2.8 Offset

Offset is normally set automatically. The internal offset DAC can be adjusted such that the input range goes from 0V to +U_{max} or from -U_{max} to 0V. Typically it is set such for positive signals the MCA line is at 10% of the ADC range and for negative signals the MCA line is at 90% of the ADC range.
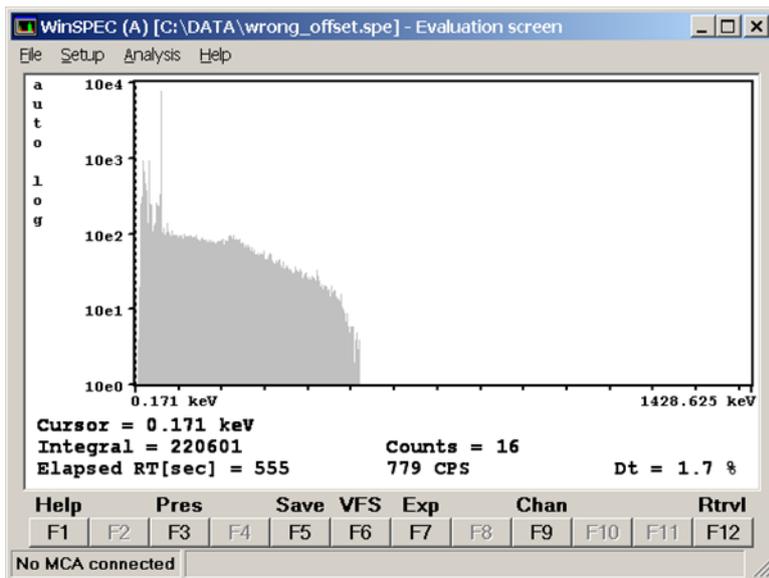
Figure 11 Spectrum with wrong offset setting. The spectrum just cuts off somewhere in the middle
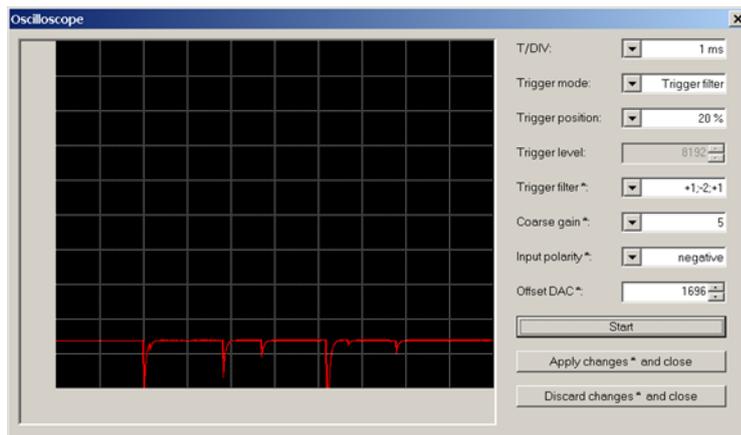
Figure 12 Wrong offset setting. The offset setting for negative signals should be at 90% and not at 14% as shown here. So, it is not possible to measure high amplitude signals as they are cut off.

4.2.9 Pole Zero and Jitter Compensation

The pole zero correction is applied to make sure that a voltage step starting from the MCA 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, for compatibility reasons the same as with MCA166. This value is proportional to the amount of DC added for correction. It is reciprocal connected with the decay time constant by:

$$t = \frac{88650\mu s}{PZC}$$

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 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 closely 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. Misadjustments will cause characteristic deformations of the peak shape as shown in Figure 13, next page.
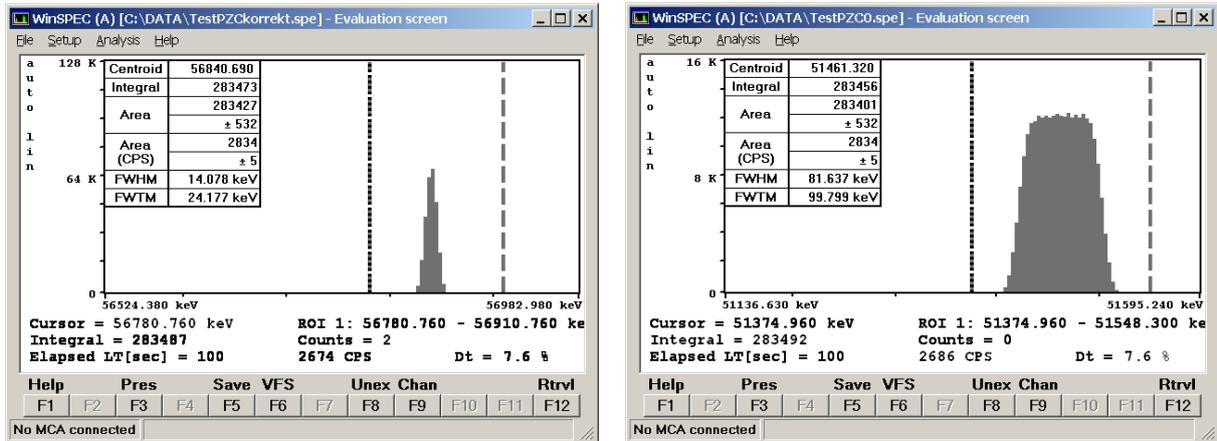
Figure 13 Measuring a periodic signal generator signal.

> *Left: Correct PZC setting and Jitter compensation.*
> *Right: PCZ=0, no Jitter compensation, the jitter error gives a rectangular distribution.*
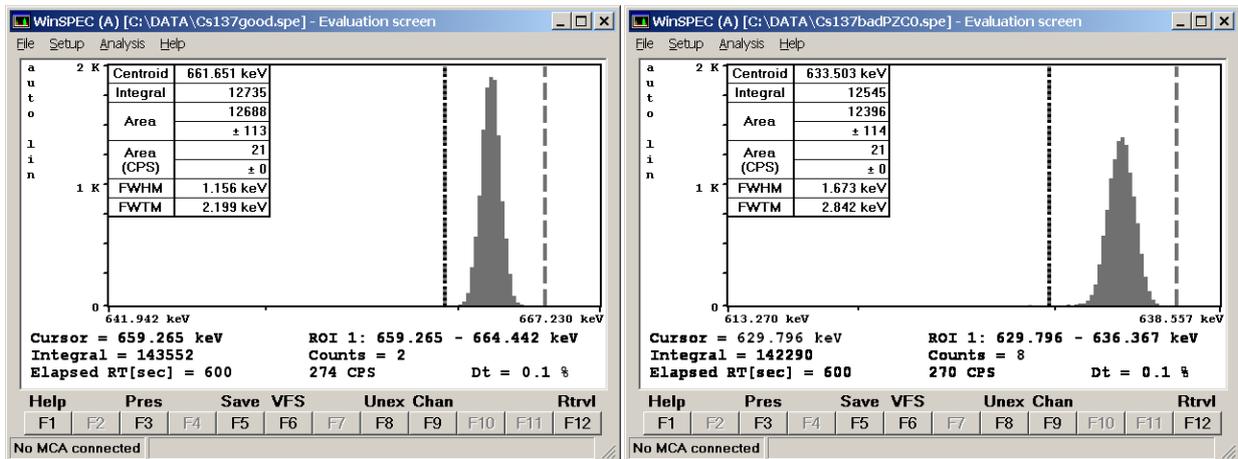
Figure 15 Measuring Cs137 with different PZC settings

Left: Measured Cs137 peak with correct settings. The calculated ration 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.
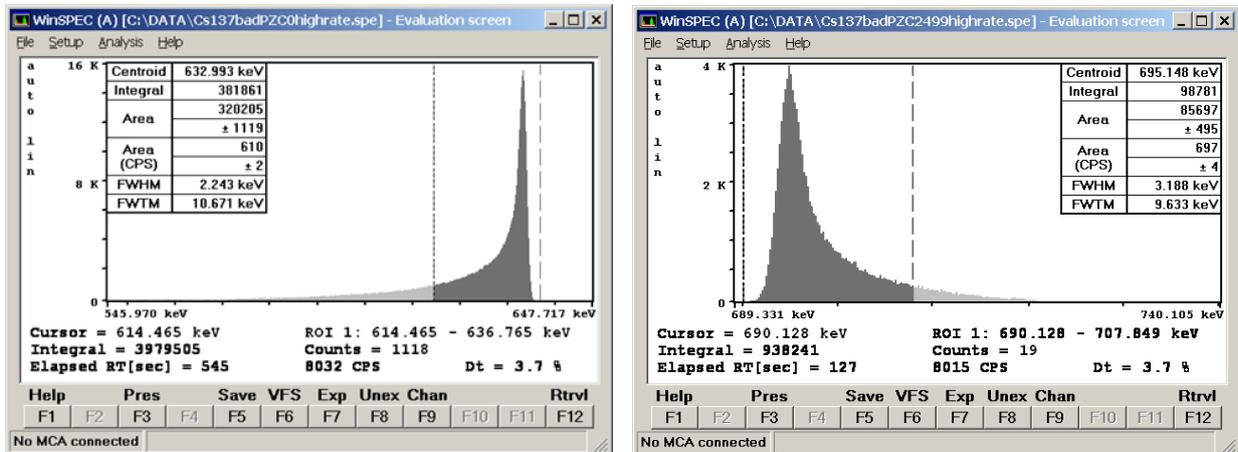
Figure 14 Measuring Cs137 with different PZC settings, jitter correction always on

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

4.2.10 MCA 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 such as often found HPGe preamplifier offset drift. Furthermore, it is desired that an energy of 0keV is found in channel 0 and the spectrum does not have offset. This is corrected by the baseline 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 is, that the baseline measurement itself has 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. There is also a second very slow baseline restorer which concerns the analog part of the device and just readjusts the analog offset such that the MCA Baseline is at the 10% or 90% input range of the ADC.
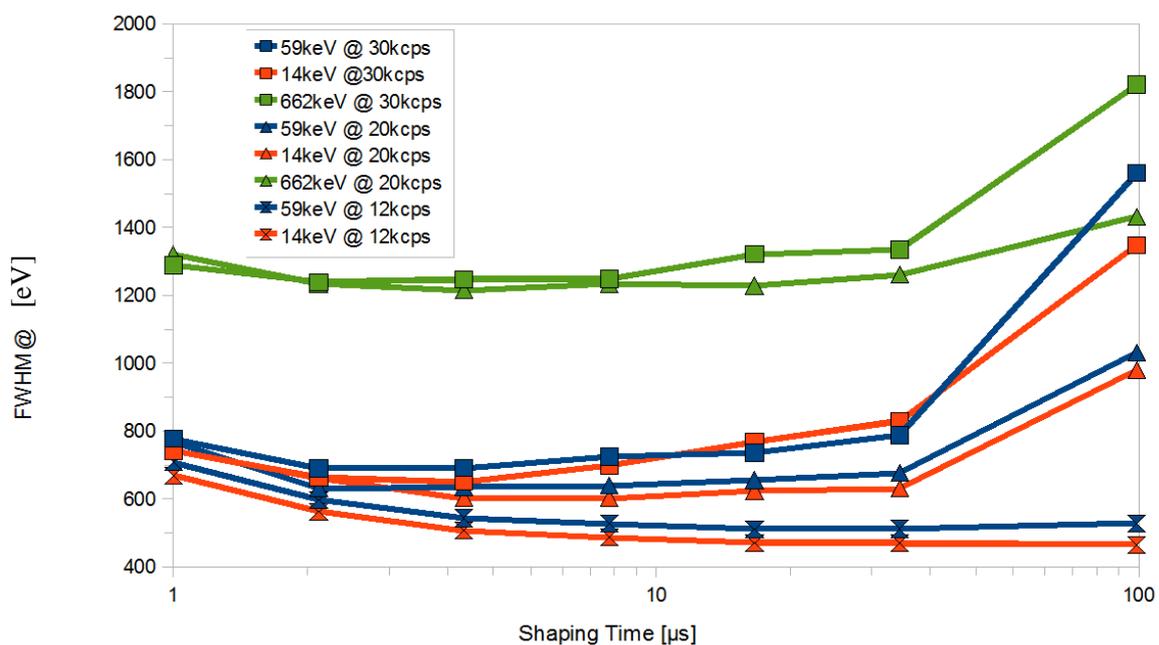
Figure 16 Dependence of resolution on base line restorer setting, as example a planar HPGe detector, operating with different count rates.

4.2.11 Jitter Correction

Another approach to care about the timing error problem is to use for exact timing the 1, -2, 1 trigger filter and to interpolate the zero crossing of the second derivate. This should increase the timing accuracy to something like 10ns...20ns. The amplitude is then correspondingly interpolated. Jitter correction may give a resolution improvement in some cases, but it is still experimental. Default is off, this feature is only available with MCA527OEM+.
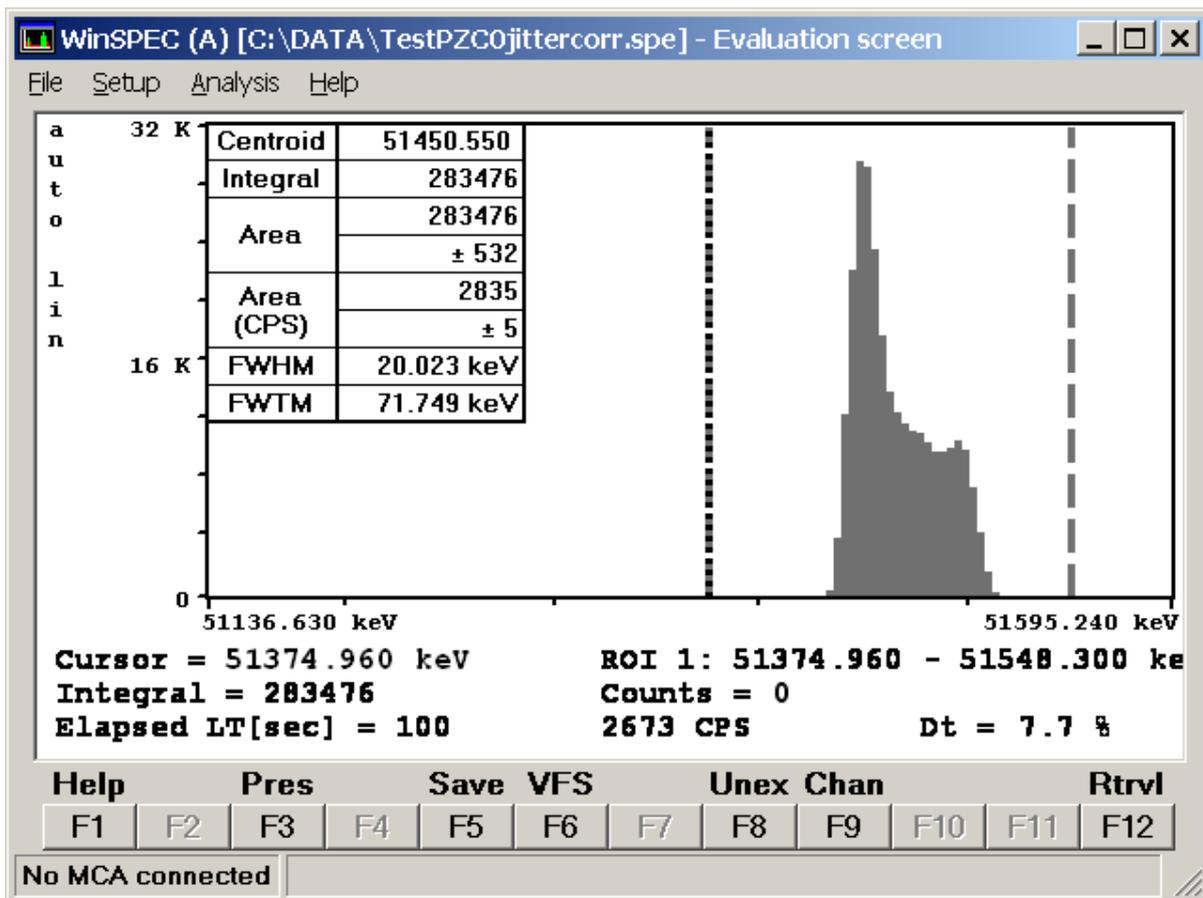
Figure 17 Measurement same as Figure 19, PZC=0 but with jitter correction

4.2.12   Low Frequency Rejection

Low frequency rejection is a special triple differentiating spectroscopic filter for use in environments with strong low frequency noise components, e. g. microphonics with a HPGe or higher leakage currents with a CZT. Principally this filter does not only evaluate the voltage step, but also the slope of the MCA Baseline before and after the voltage step. Because of this, the low frequency sensitivity is such low that Pole zero adjustment is not necessary. However, as this filter is triple differentiating, the amount of high frequency noise is increased, even as this filter is optimized for lowest error. This filter gives best results with twice or triple as high shaping times, so throughput may be a bit limited with this. Resolution can be almost as good as with the standard filters in a quiet environment. In a noisy environment, the low frequency filter can yield orders of magnitude better results and be invaluable when forced to work in such environments. Use this option in the presence of significant low frequency interference. Default is off, this feature is only available for the MCA527OEM+.
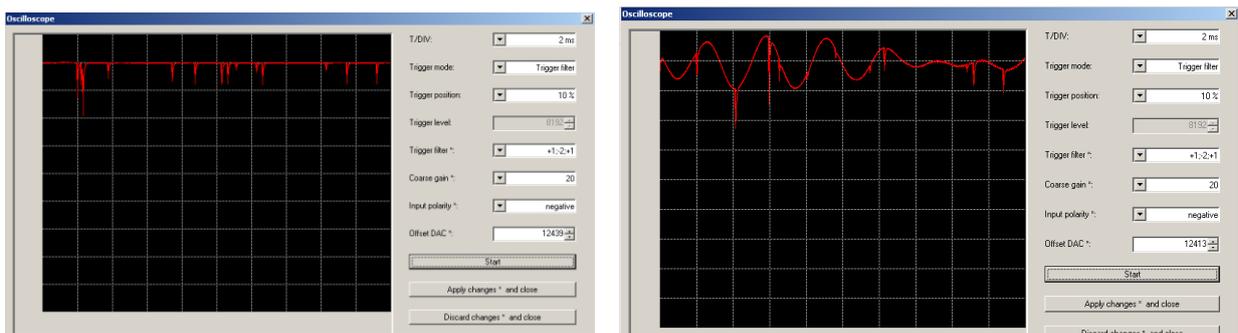
Figure 18 Preamplifier signal of a HPGe detector in a quiet and noisy environment

Left: Preamplifier signal of a HPGe measuring Am241 in a quiet environment.

*Right: Preamplifier signal of a HPGe measuring Am241 in an extremely noisy environment,
            here a grinding machine nearby running.
            The signal exhibits oscillations in the 300 Hz range, which may be twice as high as the signal measured.*
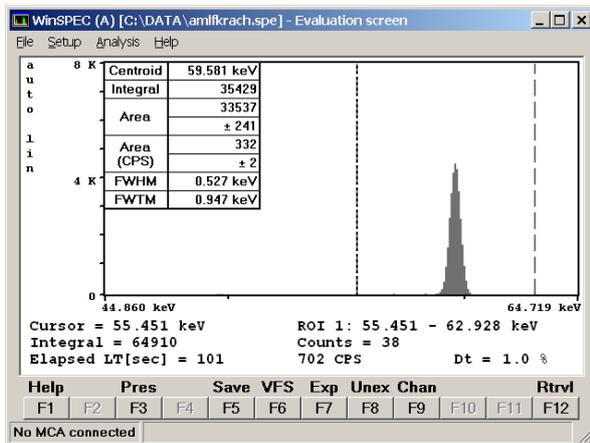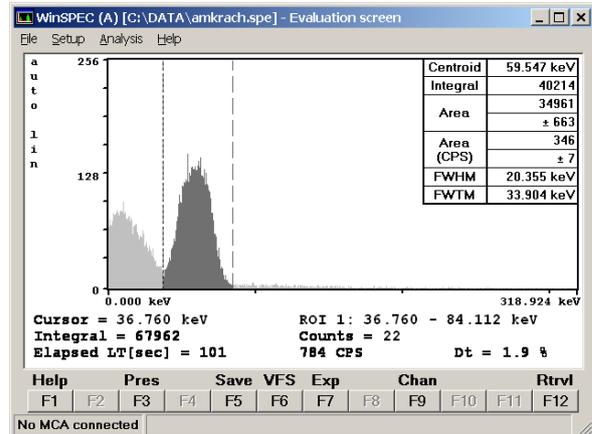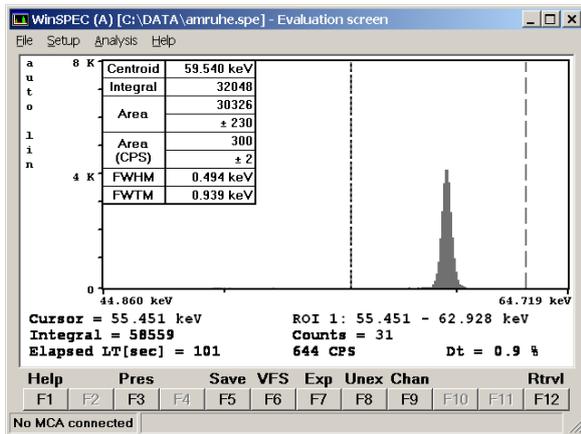
Figure 19 *Effect of Low Frequency Rejection*

Left: *60keV peak of Am241, measured in a quiet environment. A resolution of 0.49keV FWHM can be obtained. Settings: shaping time 6µs, flattop 0.8µs, BLR32.*

Right: *60keV peak of Am241, measured in a very noisy environment. Settings same as figure on the left. The resolution degrades from 0.49keV to20keV, measurement is futile.*

Bottom: *60keV peak of Am241 measured in a very noisy environment, low frequency reject on, all other settings same as figure on the left.*

4.2.13   Number of Channels

The number of channels to which the spectrum is distributed can be chosen between 128, 256, 512, 1024 and 2048 (2k MCA527OEM) and further up 4096, 8192, 16384 with the MCA527OEM+ (16k channels). The useful setting depends mainly on the detector connected. If setting is too low, details of peaks may not be seen, if 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.

A good setting for most cases is achieved if the FWHM of interesting peaks is between 3 and 8 channels. The most useful setting when taking full range gamma spectra with a HPGe is 8k. 16K may be only beneficial when taking spectra with a good planar HPGe in a range of 3MeV, but the interest is in low energy peaks; or for electrical performance testing .

For CZT or LaBr, 1024 channels are reasonable, more than 2k is not necessary. For a NaI, typically 512 channels are enough. Default is 4k with MCA527OEM+ and 1k with MCA527OEM.

4.2.14   Threshold

This setting is a legacy of MCA166, where the default setting is 2% and everything below is cut away. The effect of this setting is very similar to LLD, just that here the value is in percent of the full spectrum and not in channels.

The MCA527 allows to measure much more in the low energy range. Depending on amplification and trigger filter, the low energy cutoff may be at 0.2%, therefore allowing a very high dynamic range.

Default setting is 0, but it may be a good idea to set this to 0.3%...0.5% to cut out the noise peak.

4.2.15   LLD / ULD

The LLD / ULD settings (lower level discriminator, upper level discriminator) determine, which part of the spectrum is actually 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.

4.2.16   MCA527 Setup Examples for Use with Different Detectors

This table shall just give an overview of possible settings useful with the MCA527. It is far from being complete. For actual settings with your detector, see the detectors manual.

Table 5 Parameters for different detectors

Type	Model	Manufacturer	HV [V]	12V	-12V	24V	-24V	Input Polarity	Channels	ShapingTime [µs]	Flattop Time [µs]
CdZnTe	SDP/Z/60	Ritec	+300	x	x	-	-	neg	1024	0.8	0.7
CdZnTe	SDP/Z/20	Ritec	+500	x	x	-	-	neg	1024	0.8	0.7
CdZnTe	CZT500	Ritec	+600	x	x	-	-	pos	1024	0.8	0.7
NaI	Scintiblock	Crismatec	+500					pos	512	0.2	1.6
NaI	25825	Scionix	+550	x	x	-	-	pos	512	0.2	1.6
NaI	40*40	Amcrys-h	-800	x	x			pos	512	0.2	1.6
CsI	Sc1010	Eurorad	-	x	x	-	-	neg	256	1	
HPGe	GMX-20190-S	Ortec	-3000	x	x	x	x	neg	4096	4	0.8
HPGe	GEM 15-190	Ortec	+3000	x	x	x	x	pos	4096	4	
HPGe	GR 2018	Canberra	-3000					neg	4096	4	
HPGe	GL 0310	Canberra	-2000	x	x	x	-	neg	4096	2	
Si planar	7865S	Ortec	-1000					neg	4096		
HPGe	EGC 30-190R	Eurisys	-3000					pos	4096	4	
HPGe	EGPC 25-185	Eurisys	+2000					neg	4096	4	

Table 6 Further settings, optimized for different count rates, as example a coaxial HPGe

	Shaping time	Flat top	Trigger filter	Baseline restorer	Gain	PZC
low count rate (<4kcps), optimization for best resolution and dynamic range.	4µs	0.9µs	-1 0 1	16	high coarse gain, small fine gain (0.5…1)	
general purpose, medium count rates 4-20kcps	2µs	0.8µs	1,0, -2, 0, 1	8		
high count rate and throughput, input >20kcps,	1µs	0.7µs	1-2, 1	4	lower coarse gain to avoid overrange	adjustment critical!

- Pile up rejection should be always on, except there is a preamplifier signal with overshoot and the pile up rejector rejects everything.

- Jitter correction should be always off, it is s an experimental feature to improve resolution.

- LF rejection should be used if there is a problem with low frequency noise (e. g. 50Hz) microphonics (machinery nearby running) or similar. If using this, increase shaping time by factor 3 at the same time.

- Input polarity setting depends on detector; if no spectrum can be seen change this; check with oscilloscope mode.

- PZC should be always adjusted

4.3   Gated Measurements

The gate input is useful if spectra should only be measured during a certain time or if certain events should be rejected, e. g. if using a Compton shield as for low radiation measurements. By software it can be set

- if gating is used or not

- what gate input level enables measurement (low or high)

- delay time. The gate level is checked an adjustable (0μs...25μs) delay time after the rise of the preamplifier signal, then the decision is made.

- Discard or sort mode. In case of sort mode, the rejected events are counted in a second spectrum. Sort mode is an option if doing stabilization with a LED pulses on a NaI detector. See also measurements with stabilization.

The gate input signal has to be TTL-compatible (3.3V nominal, but input is 5V-tolerant). An input voltage <0.8V is considered low, an input voltage >1.6V is considered high.

4.4   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 has to 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 has to be selected, and a centroid to which to stabilize a peak. If the selected peak originated from a LED light pulse, and the detector provides also a gate signal for the LED signal, gating with sort mode should be selected, and then stabilization on the gated spectrum. This causes that the stabilization light peak does not disturb the measured spectrum, and the stabilization is not disturbed by real peaks in the spectrum. The quality of the stabilization can be influenced by the settings for stabilization area and time. The stabilization time is the minimum time for a stabilization cycle, where fine gain is readjusted. Default is 10 seconds, and this is suitable for most cases.

The stabilization area defines the minimum counts in the area of 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]:

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

$FWHM$ = 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.

Example:

A big NaI detector shall be stabilized with the 1460keV peak from the K40 background. Within a 300 seconds measurement the 1460keV peak has an area of 3721 counts and a FWHM of 72keV. The possible detector drift is expected to be in the order of 5·10^{-6}s^{-1}. The optimum area setting then calculates as:

$$N_{opt} = \left(\frac{72\text{keV} \cdot \frac{3721}{300s}}{2 \cdot 1460\text{keV} \cdot 5 \cdot 10^{-6} s^{-1}} \right)^{\frac{2}{3}} = 1552$$

Here, setting the stabilization area to 1500 should yield the best results.

---

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

4.5   Direct Input Pulse Height Analysis

This mode is useful when dealing with Gaussian pulses which may be the output of a shaping amplifier or detector signals with a preamplifier decay time constant <40µs. However, this cannot be used with high count rates as the fast rise of a preamplifier signal is missing and pile up rejection does not work.

Furthermore, a significant part of the signal needs to be the MCA line, as this is required to determine peak height.

Function of this is simple. Measurement is triggered if the input signal deviates some 6σ of the baseline noise. Then the algorithm checks if the signal reaches a maximum. If the maximum is reached, the 4 highest values around are averaged, subtracted by the MCA line average and this, multiplied by fine gain setting, is the value to be determined. After that, it waits until the MCA line is reached again, and the algorithm continues.

In contrary to MCA166, coarse gain and fine gain settings work here and affect the outcome of the spectrum.

4.6   Measurement Time Presets

For non-infinite measurements, the MCA527 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.

4.6.1 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 has to 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 has to 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.

4.6.2 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 has to 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.

4.6.3 Autonomous Repeat Mode

This Mode allows to run the MCA527OEM in repeat mode without any computer connected. Data transfer will resume after computer is reconnected.

4.6.4 Multichannel Scaling (MCS)

This mode is for semi-automated measurements of time distributions with any radiation detector (HPGe, NaI, CdZnTe and neutron counters). The software used for this is WinMCS.

It allows to measure a time distribution of count rates, and in case of a spectroscopically detector, measurement of an integral spectrum at the same time.

Input can be set to the following:

- TTL input (no spectrum possible in this case)

- 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. Other and Auxiliary Measurements

5.1 Oscilloscope Mode

Oscilloscope mode is in 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.
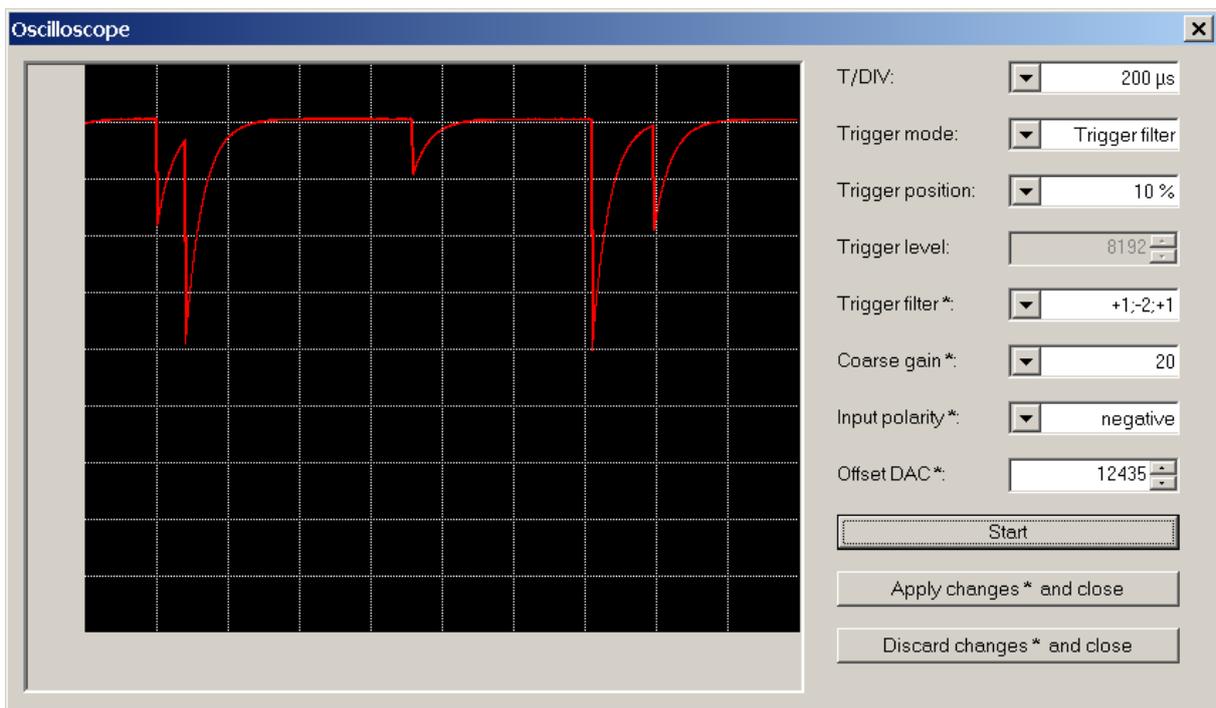
Figure 20   Typical preamplifier signal how it is seen by the MCA. Here the signal is from a planar HPGe detector.

5.1.1 Internal Temperature

The MCA527OEM has an on-board 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 9K higher than the environmental temperature due to self-heating of the PCB.

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 main 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

These programs support semi-automated measurements of time distributions with any radiation detector (HPGe, NaI, CdTe, CdZnTe and neutron counters). 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 (see above).

6.4 WinU235

These programs support stabilized U235 enrichment verification measurements with a NaI or CdZnTe detector (PMCN, PMCC). The algorithm MCAs 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, but optimized for HPGe detectors. Only one intensity calibration measurement is necessary.

6.6 WinS CAN

WinSCAN is used for candu bundle verifications. WinSCAN is in its features somewhere between MCA and MCS. It can measure up to 500 Spectra and save them in one file. Evaluation is similar to MCS, just that there is not only an integral spectrum but one spectrum for every point, so it is possible to evaluate courses off arbitrary net or integral ROI areas.

6.7 MCA Touch

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

6.6 Auxiliary Software for Analysis, Presentation and Miscellaneous Functions

6.6.1 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 MCAd 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

6.6.2 MCAPlot and MCAPrint

MCAPlot and MCAPrint 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. MCAPlot is not included in the MCA price. MCAPrint is a free downgraded version of MCAPlot.

6.6.3 MCA_WAND

MCAWand 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 7 Supported file formats by MCA_WAND

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)	

6.7   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 8 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	13.3. y	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 MCA 527OEM /OEM+

Spectrometric Performance	
Example: (OEM+) Resolution: 16k channels Detector: HPGE 500mm^2 planar, Count rates <10kcps Source: Am241 @ 59keV	(FWHM) @ 2µs shaping time <460eV
Example 2: Resolution 2k channels Input: Test generator signal	(FWHM) <<0.1%
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	✓
Autonomous Repeat Mode	✓
Gate Mode (by time)	✓ (OEM+)
Gate Mode (by state)	✓ (OEM+)
List Modes (optional)	✓ (OEM+)

Digital Signal Processing

Trigger Filter	double differential filtering
Trigger Filter (OEM+)	single and 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	0.1µs to 2µs, step 0.1µs 0.1µs to 25.5µs, step 0.1µs (OEM+)
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 (OEM) 128, 256, 512, 1024,2048, 4096, 8192, 16384 (OEM+)
Base Line Restorer	Fixed averaging (OEM) Adjustable averaging (OEM+)
Pole Zero Adjustment	Decay time down to 40µs can be compensated
Peak Stabilization Modes	standard mode LED mode

Amplifier Unit	
Amplifier Type	DC coupled, offset adjustable
Linearity; Bandwidth (3dB)	<0.1%; 0 – 1.4Mhz
Coarse Gain Steps	10 (OEM) 2, 5, 10, 20, 50 (OEM+)
Full Scale Input Ranges	2.5V (OEM) 12.5V, 5V, 2.5V, 1.25V, 0.5V (OEM+)
DC Offset Adjustment Range	(-10% to 90%) of full scale for positive input signals (-90% to 10%) of full scale
Analog Digital Converter	
Sample Rate	10MS/s
Resolution	14bit
Integral non-linearity	≤ 0.05%
Power Supply	
Input Voltage DC (via JST PH06)	3.3V - 9V (Ethernet Interface) 4.5V - 9V (USB-Interface)
Power consumption	~0.6W
Mechanical	
Dimensions LxWxH (in mm)	140 x 60 x 18
Weight	48g

Communication & Connections	
Computer Interfaces	USB 1.1-3.0, Ethernet10/100Mbit, 2xRS232

Sockets:

- USB (Type B), RJ45(Ethernet),
- 3x MCX plug FEMALE for: Signal-IN, Gate-IN, Counter-IN (TTL)
- JST PH06 socket for Power supply,
- µSD card holder,
- 2xRS232 @ 26pin header, for ext. devices e.g. GPS Mouse, Bluetooth…

Environmental Conditions	
Operation Temperature Range	-20°C – 60°C
Humidity	≤90%, non-condensing
IP Protection Class	IP00

9. Troubleshooting

General Remark:

Before changing anything concerning the hardware, plugging or pulling cables etc. shut down the high voltage and power supply. 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 external power supply
   - Check cable between MCA and Computer. Communication cable may be loose or not connected.
   - Try another cable.
   - The MCA is not recognized (" MCA not connected")
   - Disable Power Save Mode for COM Port
   - 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.

   - This may be a problem with high count rates and high coarse gain settings. Please check the preamplifier signal with the oscilloscope mode: Is the base line correct at 10% (or 90% for negative signals)? Does the signal fit into the oscilloscope window or does it overflow very often? In such cases, reduce coarse gain and readjust offset if necessary.

   - 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. Try to use another preamplifier or just switch the pile-up rejector off.

   - Similar effects can be seen if detector-cables are too long.

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.
- Preamplifier signal is out of range most of the time. Check with oscilloscope window, reduce coarse gain, readjust offset.
- Electronic noise in the system.

5. Everything should be okay, but the MCA gets no signals or just measures strange spectra

- wrong input polarity. Check input polarity just toggle it for a test.
- The amplification is severely wrong set.
- wrong input mode. Check also ADC input mode

6. Very bad resolution in a HPGe spectrum

- Check settings: Pole zero, shaping time, flat top.
- Detector worn out or defective. Change and regenerate detector.
- Check cables. Keep them away from switch mode power supplies and other possible sources of electromagnetic noise.
- In case of low frequency interference: Try BLR setting =1 or LF reject.

7. Bad resolution in a HPGe spectrum or from a test generator, specially at high amplification factors

- Check electrical noise and EMC compatibility of surroundings. Some laptops and also some switch mode power supply battery chargers may disturb. Remove all connections from the MCA to ground or to mains voltages. Try a different computer / laptop.
- Winding the cable to the detector / computer several times around a ferrite ring also may help

8. 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.

9. Too high count-rate

- Keep a bigger distance to radiation source. Try a less sensitive detector. Watch for your personal safety!
- Check detector
- Check for disturbances of switch mode power supplies etc.

Typical errors which may be observed with the detector preamplifier signal are:

- Rise time is too slow. This may cause degraded resolution in some cases. Increase flattop time.

- The fall time is too fast (time constant resp. 1/e fall time < 40µs). This causes that the pole-zero setting cannot be correctly adjusted. Consequences may be peak shift and peak broadening with higher count rates. Try direct input or try to use another preamplifier.

- Preamplifier signal exhibits ringing: This may trigger the Pile up rejector and lead to missing parts of the spectrum. Try a different trigger filter or switch PUR off.

- LF noise on the base line: Try BLR setting =1 or LF reject.

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 on 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 recommended 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[2] 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

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[2] 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