

DGF-4C application note DGF-AN-001

Optimizing the energy resolution with the DGF-4C

X-Ray Instrumentation Associates

8450 Central Avenue

Newark, CA 94560

Phone: (510) 494-9020

Fax: (510) 494-9040

Web: www.xia.com



How to optimize energy resolution with the DGF-4C

1.1 Start up

For spectroscopy with germanium detectors it is in general advisable to use a 4-bit decimation FiPPI file. **FiPPI** stands for Filter Processor and Pileup Inspector and denotes the trigger/filter FPGA. FiPPI file names are found in the firmware folder. The filenames are of the form STDN.bin. The N indicates the decimation. The default settings chosen by the digital signal processor (**DSP**) are a good first approximation. Be sure you have activated the ballistic deficit correction.

1.2 DC-offset adjustment

Click **RuncontrolPanel[Tau]**, set dT to 5 μ s for the channel of interest and close the TauDisplay. Observe the menu bar at the top and find Windows \rightarrow Graph Macros \rightarrow DCDisplay. Now click **RuncontrolPanel[Offsets]**, and you will see a 10 ms trace for the selected channel, probably with lots of pulses. If they are positive, your polarity selection is correct. If they are negative you need to choose the opposite polarity in the CCSRAeditPanel. For unipolar signals the DC offsets should hover around 400 ADC units. The exact value is immaterial.

1.3 Adjusting τ and noise analysis

For a quick noise analysis you will find a Fourier transform of your signals helpful. Find Windows \rightarrow Graph Macros \rightarrow FFTdisplay in the pull-down menu. Since this is going to be a noise analysis, remove your radioactive source, and lower the trigger threshold into the noise (visit the InstrumentPanel through **RunControlPanel[Module]**).

Now click **RuncontrolPanel[Tau]** again and press **TauDisplay[Run]**. If you always get to see traces that begin with falling exponentials your threshold is not low enough. If you don't get any triggers, it is too low. Hint, keep the UserDelay short for this measurement. If you get noise triggers watch the Fourier transform display. Vary dT between 0.1 μ s and 500 μ s to cover the entire frequency spectrum. If you find sharp lines in the 10kHz to 1MHz region you may need to find the cause for this and remove it.

Next, set dT to 0.1 μ s and increase the threshold way above the noise, and bring back the radioactive source. Keep the count rate at around 1000 c.p.s. Click run until you find a nice strong signal. Choose a fit region wide enough to cover the exponential and the DC-baseline. Click DoFit and watch the fit result. If you like it click TauOK. Set dT back to 5 μ s before you close both, TauDisplay and FFTdisplay.

Click **RuncontrolPanel[Save]** to store the current status to disk. Now increase the count rate to what you want it to be and hit **DCdisplay[Refresh]**. If the trace for the

selected channel has moved too far away from the optimum DC value, hit **RuncontrolPanel[Offsets]** again.

Briefly visit the InstrumentPanel and make sure that the energy filter gap time is at least $1.2\mu\text{s}$ for 4-bit decimation and at least $0.3\mu\text{s}$ for 2-bit decimation. In general the gap time needs to be wide enough to accommodate the longest signals from the detector. In addition to that the gap needs to be at least two decimated clock cycles longer than that minimum. As a result we recommend to use 4-bit decimation filters (FPGA file STD4.bin) with coaxial Ge-detectors. For Ge-strip detectors with short rise times (100ns) the gap time should be set to $1.2\mu\text{s}$. Set Averaging to 2 and use a trigger filter length and gap of $0.1\mu\text{s}$. An initial choice of a trace length of $1.6\mu\text{s}$ and $0.8\mu\text{s}$ for the user delay is a good one.

For multichannel analyser (MCA) histogramming initially choose combining 2^n with $n=3$ bins when you use only one channel (Histogram energies must be off in all others, see CCSRAeditPanel). When using 2 channels choose $n=4$, and use $n=5$ when using three or more channels. This will let you see the entire spectrum range, which spans 65535 counts, each being worth $1/16^{\text{th}}$ of a waveform digitizer ADC unit. With these settings you can cram all full spectra into the available 8192 words of MCA memory. Click **InstrumentPanel[Apply]** and close it. Save your settings to file with **RuncontrolPanel[Save]**.

Now click **RuncontrolPanel[Start]** to begin data taking. Choose MCA mode and do a short run. Examine the results in the MCA display.

1.4 Energy filter peaking time

Begin by scanning the energy filter peaking time. Try $2\mu\text{s}$, $4\mu\text{s}$, and $8\mu\text{s}$. If $2\mu\text{s}$ yields the best results, switch to using the 2-bit decimation FiPPI. Click **RunControl[Files]** to open the SetFilesPanel. Type the new FiPPI file name into the line saying FPGA file. Close the panel, and hit **RunControl[System]**. In the opening panel check the box load new FiPPI or DSP code and hit start up. Close when done.

The new FiPPI has been downloaded and the DSP has been rebooted. Some of your earlier settings are lost. Now visit the InstrumentPanel again. Set the energy filter gap time to at least the sum of signal rise time and $0.3\mu\text{s}$. Actually, $1\mu\text{s}$ is a good best guess. Now choose an energy filter peaking time of $2\mu\text{s}$, Click the apply button and close the InstrumentPanel. Save your settings to file. Now start runs with peaking times of $2\mu\text{s}$, $1\mu\text{s}$, and $0.5\mu\text{s}$. Once you found a best peaking time stay with it.

1.5 Averaging

Now vary the **Averaging** variable in the InstrumentPanel. For input count rates below 50,000 c.p.s. best values are usually between 2 and 5. Choose the smallest one

you can get away with. In general you will find that the higher count rates will require less averaging, i.e. smaller values.

1.6 Trace length

In most applications the performance especially at energies below 300keV improves when the **trace length** is reduced to the minimum. Keep in mind that the first quarter of the acquired traces must be pre-trigger, baseline data. The trace should then fully cover the rising edge of the signal, but does not need to be any longer. In fact, in noisy environments you don't want it to be any longer. The trigger point occurs roughly a user delay after the trace start. I found that with larger germanium detector a trace length of 1.2 μ s and a user delay of 0.6 μ s works quite well.

You can examine acquired traces by starting a run in list mode. Choose ListMode as the 'Run type' in the RunPanel, and observe how many events per buffer (ie per spill) you will get. Then choose a number of spills and hit **Run**. When the run has finished click **RunControlPanel[Events]** and observe the traces. (You have to change the event number at the top of the display once to view a current trace.)

1.7 Pile up rejection

When running at count rates in excess of 10,000 c.p.s. you may want to optimize the pile up rejection. Find a main peak and its pile up at exactly twice the energy¹. Measure the main peak count rate and the pile up to main ratio (P/M). Then visit the InstrumentPanel and click Advanced. In the opening panel find the variable MaxWidth. MaxWidth measures a time in 25ns steps. When zero, it is inactive. When non-zero it applies a rise-time and double pulse cut to the output from the trigger filter. Set MaxWidth to the sum of signal rise time plus 2 times trigger filter length plus trigger filter gap. Click apply. Start a run and measure the main peak count rate. Gradually reduce MaxWidth until you start losing efficiency in the main peak. Now measure P/M again.

1.8 High count rate performance

At count rates beyond 10,000 c.p.s. the exact value of τ becomes important. Scan a 10% range by typing the τ values into the "tau=" field of the TauDisplay and hitting TauOK. Then do an MCA run to determine the energy resolution. Settle on the optimum τ that you find and stay with it in the future.

¹ Co-60 users take note: 2505keV=1173keV+1332keV is not a pile up energy, but due to the simultaneous detection of both gammas.

If at input count rates (**ICR**) beyond 20,000 c.p.s. you are more interested in high throughput rather than best energy resolution, you may switch off the ballistic deficit correction (CCSRAeditPanel), set the trace length and user delay to zero and then click **InstrumentPanel[Advanced]**. In the opening panel find PafLength and TriggerDelay. Set both of them to 1. Click apply and exit. Note, whenever you change one of the energy filter values, or one of the trace parameters these two variables will be reset by the DGF-Viewer.

In the InstrumentPanel click Edit next to the coincidence pattern variable and in the panel that opens up set CoincWait to 1. This is a wait time in 25ns steps. Close the CoincidencePanel, click apply in the InstrumentPanel, and you are all geared up for the highest throughputs.

Use the Dcdisplay, especially at high count rates, to verify that your signals stay well within the wave form digitizer ADC range, which spans 0..4095 units.