Instruments That Advance The Art

microDXP

Gain Specification

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ProSpect Software

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Introduction

This specification pertains only to the new (blue) microDXP pictured on the right below.

The original (green) microDXP used an off-the-shelf variable gain amplifier (VGA) to implement a continuously adjustable analog gain for both dynamic ranging and energy calibration. The single ‘base gain knob’ was easy to use, but we’ve found that VGA devices introduce excessive noise, temperature drift, and significant non-linearities into the signal.

In a significant departure from the previous design, the updated (blue) microDXP design now employs a digitally-controlled switched-gain amplifier architecture with 16 coarse analog gain settings to prepare the signal for digitization in concert with finely adjustable digital gain for energy calibration. This approach adds some complexity to command and control because there are now two separate ‘base gain knobs’, but yields a superior pulse-height measurement. As before, a separate bin width setting defines the granularity, and thus the file size, of the MCA energy spectrum.

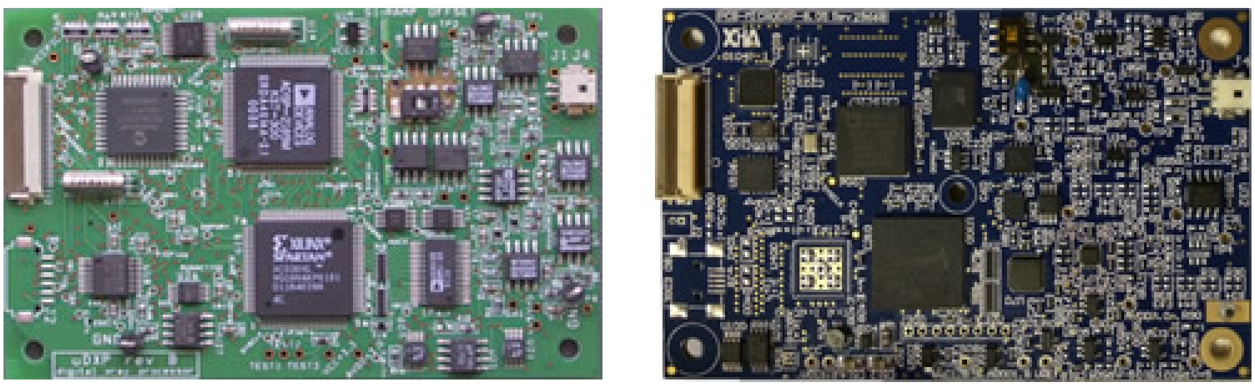

Figure 1: The new microDXP pictured on the right was released in 2015.

Target Audience Advisory

This document goes into various minute details of the microDXP hardware and firmware that most users will find tedious and confusing. Only those who intend to fine-tune the gain in the field, e.g. to account for temperature fluctuations or detector effects, will require the level of detail presented here.

XIA’s ProSpect software application provides an intuitive user interface atop the Handel device driver to directly set the gain and also to fine-tune it via ROI-based calibration. Unique gain settings can be stored in on-board non-volatile memory for every combination of peaking time and MCA format. For most applications ProSpect can thus be used in the lab to first fine-tune and save the required gain settings such that energy calibration is subsequently maintained without the need to fine-tune the gain in the field.

Hardware Implementation

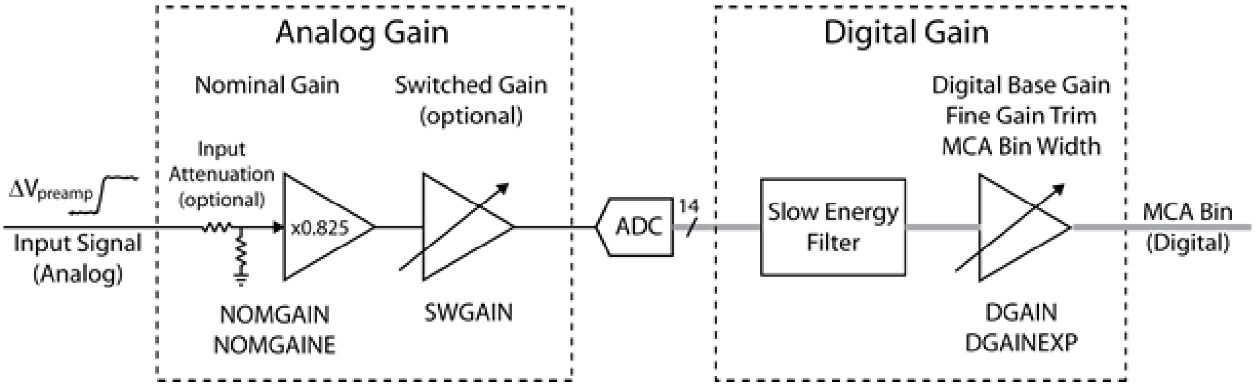

Figure 2: The new (blue) microDXP gain architecture

The new gain architecture is depicted above. The overall transfer function between an input x-ray pulse with height ΔV_{Preamp} and the resulting MCA Bin can be expressed as:

$$\text{MCA Bin} = \frac{\text{Digital Gain} * \text{Analog Gain} * \Delta V_{Preamp} * 16384}{2.0\ \text{V}}$$

Equation 1

Analog Gain

The Analog Gain includes all gain elements in the front-end analog circuitry, i.e. it determines the pulse-height at the ADC, $\Delta V_{ADC,}$ for an input pulse-height ΔV_{Preamp}:

$$\Delta V_{ADC} = \text{Analog Gain} * \Delta V_{Preamp}$$

Equation 2

The 14-bit ADC has an input range of 2.0V, thus the digitized pulse height in terms of least-significant-bits is:

$$\Delta ADC = \frac{\Delta V_{ADC} * 16384}{2.0\ \text{V}} = \frac{\text{Analog Gain} * \Delta V_{Preamp} * 16384}{2.0\ \text{V}}$$

Equation 3

The Analog Gain is defined as the product of a fixed component called the Nominal Gain and the software-controlled component called the **Switched Gain**:

Analog Gain = Nominal Gain * **Switched Gain**

Equation 4

The digitally-controlled **Switched Gain** circuit, with 16 discrete settings, allows the Analog Gain to be set according to the dynamic range of the input signal: it must be large enough such that electronic noise is sufficiently digitized, but small enough that the largest x-rays of interest fit well within the ADC input range. As a rule of thumb, the largest x-rays of interest should span no more than 50% of the ADC input range. Note that a customer-defined fixed-gain hardware assembly option, i.e. wherein the Nominal Gain is customer-defined and the **Switched Gain** circuit is omitted, is available in high-volume production for applications where the dynamic range of the input signal will not change.

Nominal Gain

The Nominal Gain is independent of software control. It is determined by the fixed amplification stages in the microDXP analog front-end circuit and by the Input Attenuation setting, described in the previous section. By default, the Nominal Gain is:

$$\text{Nominal Gain} = 0.825 * \text{Input Attenuation}$$

Equation 5

Attenuation Setting	*Input Attenuation*	*Nominal Gain*
0 dB (default)	1.00	0.825
-2.5 dB (option)	0.75	0.619
Custom	X	0.825 * X

Table 1: Relationship between Input Attenuation and Nominal Gain

Switched Gain

The **Switched Gain** is implemented with a new CMOS switched-feedback circuit with 16 discrete gain values controlled by the DSP parameter SWGAIN. The **Switched Gain** is linear-in-dB with SWGAIN, with approximately 1.7 dB increment, and units normalized to the **Base Gain** acquisition value in Handel.

SWGAIN	**Switched Gain** [dB]	**Switched Gain** [V/V]	**Base Gain***
0	11.71	3.848	3.848
1	13.38	4.668	4.668
2	15.13	5.711	5.711
3	16.79	6.913	6.913
4	18.49	8.408	8.408
5	20.17	10.20	10.20
6	21.93	12.48	12.48
7	23.58	15.11	15.11
8	25.23	18.25	18.25
9	26.91	22.15	22.15
10	28.66	27.09	27.09
11	30.32	32.79	32.79
12	32.16	40.55	40.55
13	33.84	49.20	49.20
14	35.59	60.19	60.19
15	37.25	72.85	72.85

* **Base Gain** values shown assume that the **Digital Base Gain** = 1.000

Table 2: Relationship between SWGAIN, **Switched Gain** and **Base Gain**

Analog Gain Options

The new switched-gain circuit is included in the standard assembly variant, allowing the microDXP to be optimized for a wide range of x-ray energies. The circuit is omitted in the fixed gain assembly variant. In either case the Analog Gain can be further optimized via input-attenuation as described below.

Fixed Gain Option

The microDXP can alternatively be built with a user-defined fixed analog gain, i.e. with custom Nominal Gain and the switched-gain circuit omitted. The gain tolerance will typically be a fraction of one percent, which is easily corrected via multiplication in the digital filter. The fixed-gain option may offer better performance and lower power consumption in applications where the dynamic range of the input signal will not change.

Hardware Setting: Input Attenuation

The microDXP includes a resistor divider circuit at the input. By default the divider is bypassed via the solder short at RG1, such that the Input Attenuation is 0 dB (no attenuation). A standard attenuation option can be selected with just a soldering iron, by opening the solder-short at RG1 and closing the solder-short at RG2. A customer-defined input attenuation circuit can be implemented in high-volume production.

Attenuation Setting	*Absolute Maximum Input Voltage*	*Input Impedance*
Default – 0dB Attenuation (RG1 short, RG2 open)	+/- 4.0 V	10 KOhms
Option – 2.7dB Attenuation (RG1 open, RG2 short)	+/- 5.5 V	655 Ohms
Custom Attenuation (R4, R11, RG1, RG2)	Customer-defined	Customer-defined

Table 3: The attenuation setting determines the absolute maximum input voltage range and input impedance

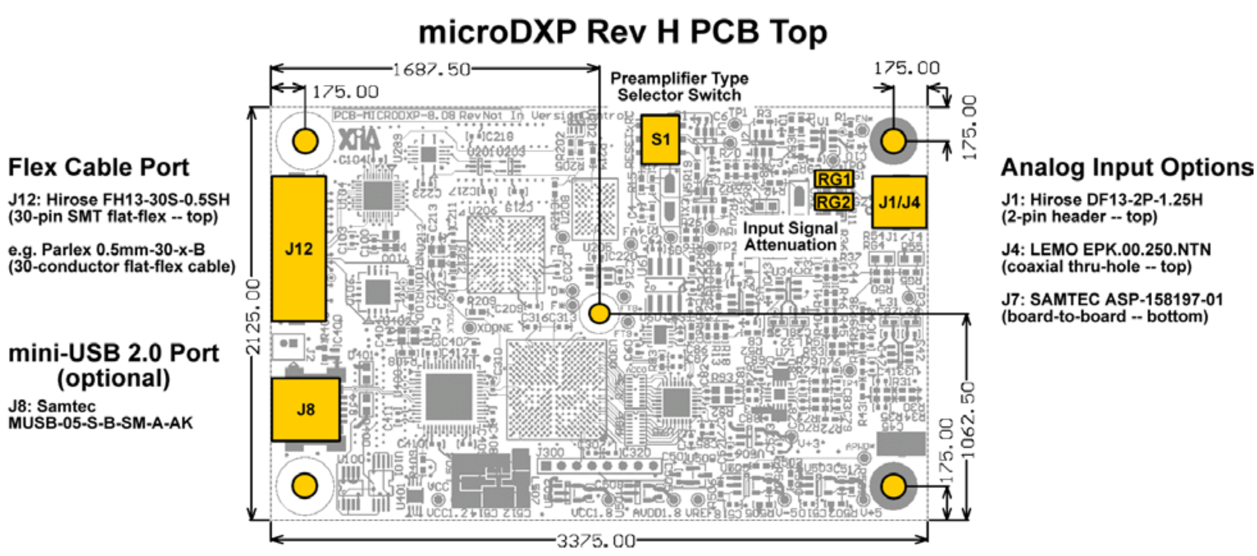

Figure 3: microDXP connector locations and part numbers, TOP SIDE.

Digital Gain

The Spartan-6 FPGA can perform digital multiplications in real time, allowing for a Digital Gain setting that is applied to the output of the slow energy filter to adjust the measured energy, i.e. the MCA bin, versus the digitized x-ray pulse amplitude.

$$\text{MCA Bin} = \text{Digital Gain} * \Delta\text{ADC}$$

Equation 6

The Digital Gain is controlled via three separate settings, i.e. Handel acquisition values: The **Digital Base Gain**, which compensates for the coarse Analog Gain, the **Fine Gain Trim**, which addresses any peaking-time-dependent shifts in the measurement, and the **MCA Bin Width**, which sets the granularity and thus file size of the MCA spectrum.

$$\text{Digital Gain} = \frac{\textbf{Digital Base Gain} * \textbf{Fine Gain Trim}}{2^{(\textbf{MCA Bin Width} - 1)}}$$

Equation 7

The resultant Digital Gain is stored in the DSP parameters DGAIN (UQ1.15 format unsigned mantissa) and DGAINEXP (2’s-complement signed exponent).

$$\text{Digital Gain} = \frac{\text{DGAIN}}{32768} * 2^{\text{DGAINEXP}}$$

Equation 8

Thresholds: Independent of Digital Gain!

The Digital Gain is applied as the very last step in the digital filtering pipeline, thus the Trigger, Baseline and Energy thresholds are independent of the Digital Gain. The **Digital Base Gain**, **Fine Gain Trim**, and **MCA Bin Width** can thus be modified with no effect on thresholds. The thresholds should, however, be adjusted any time the **Switched Gain** has been modified.

Software Control

The **Switched Gain**, **Digital Base Gain**, **Fine Gain Trim** and **MCA Bin Width** are controlled by the host computer or embedded processor. This section describes the settings both in the ProSpect software and at the RS-232 command level.

ProSpect/Handel: No Changes

The changes to the microDXP gain architecture are transparent at the ProSpect application level, i.e. the Handel driver determines the hardware revision and variant, and automatically adjusts the analog and digital gain according to the original acquisition values: **Base Gain** and **Fine Gain Trim**. As before, the bin size (**eV/Bin**) of the MCA spectrum is determined by the **MCA Bin Width** and **Dynamic Range** settings.

RS-232: Significant Changes

The new gain architecture requires significant changes at the RS-232 command level, because there are now separate analog and digital ‘base gain knobs’. The **Base Gain** is no longer directly modified via command 0x88. Instead the **Switched Gain** must be set via the new command 0x9B, and the **Digital Base Gain** set via the new command 0x9C. The **Fine Gain Trim** is still set via command 0x91, but the units of GAINTWEAKn have changed as specified in Equation 14 of this document.

Preliminaries

This specification does not apply to the legacy (green) microDXP! Furthermore, the switched gain circuit is not included on any fixed-gain hardware assembly variant of the new microDXP. The microDXP hardware revision and Gain Mode should thus first be verified to prevent misuse of the command set.

microDXP Hardware Revision

The microDXP hardware revision is encoded into the full serial number, retrieved with the command 0x48: Read Serial Number. The ASCII string looks like:

UDXxxVVxxxxxxxxx

Where “VV” is the hardware revision. The new microDXP has the letter “H”, the major revision, followed by a number representing the minor revision. If your microDXP has the letter “A” through “G” (rather than “H”), please ignore this specification and instead refer to legacy documentation.

ProSpect/Handel

The microDXP serial number is displayed along the bottom right of the main window in ProSpect, and also in the **Information** tab of the **Board Information** window, accessible under the **Tools** menu. Note that Handel, and thus ProSpect, determines the hardware revision and appropriately adjusts the gain according to the **Base Gain** and **Fine Gain Trim** acquisition values.

RS-232

The serial number is read via command 0x48: Read Serial Number.

Command	***Meaning***	***Response data***
0x48: Read Serial Number	Read serial number. Ndata = 0.	Ndata = 1 + SerialLength [data1] = Return status (0: ok) [data2 – lastdata] = serial number, ASCII, null terminated (16 character maximum, including null)

Table 4: RS-232 Command 0x48: Read Serial Number

Gain Mode

The Gain Mode (DSP parameter GAINMODE) defines the microDXP hardware gain variant, as shown in Table 5.

Gain Mode	***GAINMODE***	***Features***
Fixed + Digital	0	Analog Gain is fixed, equal to a customer-defined Nominal Gain Digital Gain is used exclusively for MCA scaling and calibration
Switched + Digital	3	Analog gain is the product of Nominal Gain and Switched Gain, which is adjustable in 16 discrete increments Digital Gain is used for MCA scaling and calibration

Table 5: Gain Mode definitions

ProSpect/Handel

The Gain Mode is displayed in the **Information** tab of the **Board Information** dialog, accessible under the **Tools** menu. It can alternatively be determined from the value of GAINMODE in the **DSP Parameters** window, also accessible under the **Tools** menu. Note that Handel determines the Gain Mode and appropriately adjusts the gain according to the **Base Gain** and **Fine Gain Trim** acquisition values.

RS-232

The Gain Mode is included in the response to command 0x49: Get Board Information.

Command	***Meaning***	***Response data***
0x49: Get Board Information	Read board information – versions, variants, clock information, FiPPI information. Ndata = 0	[Ndata] = 18 + 3*NFiPPI [data1] = Return status (0: ok) [data2] = PIC code variant [data3] = PIC code major version [data4] = PIC code minor version [data5] = DSP code variant [data6] = DSP code major version [data7] = DSP code minor version [data8] = DSP clock speed (MHz) [data9] = Clock Enable register [data10] = NFiPPI (number of FPGA configurations) [data11] = Gain Mode (0:Fixed, 3:Switched, 4:High/Low) [data12-13] = Nominal gain mantissa [data14] = Nominal gain exponent Nominal gain = (mantissa/32768)*2^(exponent) [data15] = Nyquist filter (0: 2 MHz, 1: 4 MHz, 2: > 4 MHz) [data16] = ADC speed grade (0: 20 MHz, 1: 40 MHz, 2: 65 MHz) [data17] = FPGA speed (0: normal, 1: fast) [data18] = Analog power supply (0: local regulators, 1: no local regulators) Then, for each FiPPI: [dataN] = FiPPI decimation [dataN+1] = FiPPI version [dataN+2] = FiPPI variant

Table 6: RS-232 Command 0x49: Get Board Information

Switched Gain

The **Switched Gain** circuit, if installed, is controlled by the DSP Parameter SWGAIN. It is constrained to the values 0 to 15, and should be set to match the dynamic range of the preamplifier input signal with the ADC. The **Digital Base Gain**, described in the next section, is then set to achieve a precise energy calibration.

Note that the Trigger, Baseline, and Energy thresholds, if enabled, should be re-adjusted after the Switched Gain has been modified.

ProSpect/Handel

ProSpect makes this part easy. In ProSpect the Handel acquisition values **Switched Gain** and **Digital Base Gain** are combined into a single setting called the **Base Gain**, a continuously variable number with units ranging from 1 to 100, with 3 digits of precision, which is equivalent to the original microDXP **Base Gain** setting.

$$\textbf{Base Gain} = \textbf{Switched Gain} * \textbf{Digital Base Gain}$$

Equation 9

The default **Base Gain** setting of 4.668 serves as a good starting point for most detectors. If the Preamplifier Gain is known, use Equation 10 as a starting point. However accurate the preliminary setting, the ROI calibration tool can subsequently be used to make adjustments, as described in the **Digital Base Gain** section below.

$$\textbf{Base Gain} = \frac{1184}{\textbf{Dynamic Range }[\text{keV}] * \text{Preamplifier Gain }[\frac{\text{mV}}{\text{keV}}]}$$

Equation 10

Note that the **Dynamic Range** is the energy range of the spectrum, expressed in keV, as described further at the end of this document.

RS-232

Pick the SWGAIN value from Table 2 for which the corresponding **Base Gain** best fits Equation 10, such that the largest x-rays of interest span roughly 50% of the ADC input range.

Command	***Meaning***	***Response data***
0x9B: Set/Get Switched-Gain	Set or read the 4-bit SWGAIN, which determines the discrete switched-gain. Ndata = 2 (set) or 1 (get) [data1] = 0: set, 1: get [data2] = SWGAIN[3:0]	Ndata = 2 [data1] = return status 0: OK [data2] = SWGAIN[3:0]

Table 7: RS-232 Command 0x9B: Set/Get Switched-Gain

Digital Base Gain

The **Digital Base Gain** compensates for the granularity of the analog **Switched Gain**, and as such should range slightly beyond the **Switched Gain** increment of 1.7 dB, or roughly +/- 22%. Its preliminary setting is derived from Equation 9 and Equation 10, based on the **Switched Gain** setting selected from Table 2.

$$\textbf{Digital Base Gain} = \frac{1184}{\textbf{Dynamic Range}\,[\mathrm{keV}] * \text{Preamp Gain}\,\left[\frac{\mathrm{mV}}{\mathrm{keV}}\right] * \textbf{Switched Gain}}$$

Equation 11

It is stored in a new pair of GENSET parameters DGAINBASE (UQ1.15 format unsigned mantissa) and DGAINBASEEXP (2’s-complement signed exponent),

$$\text{Digital Base Gain} = \frac{\text{DGAINBASE}}{32768} * 2^{\text{DGAINBASEEXP}}$$

Equation 12

For best results DGAINBASE should be constrained between 32768 and 65535, and DGAINBASEEXP between -2 and 1.

ProSpect/Handel

See the **Switched Gain** section above for a description of the combined **Base Gain** acquisition value in ProSpect. The preliminary setting from Equation 10 will almost certainly need to be adjusted in practice. ProSpect accommodates this easily via the ROI calibration feature.

1. At this point the **Fine Gain Trim** should be at its default value of 1.000. If this is not the case, reset the **Fine Gain Trim** in the PARSET area of the **Acquisition** tab to 1.000 and press the **[Apply]** button below.
2. After acquiring a preliminary energy spectrum in the **MCA** tab, select a known peak and enter its energy in the **Calib. (keV)** field of the **ROI** table. Make sure the selected ROI is active, i.e. it has the green check mark in the left-most column of the table.
3. Press the **[Calibrate ROI]** button to automatically adjust the **Base Gain**.
4. Press the **[Start Run]** button to acquire more data. Compare the **Mean** energy in the **ROI** table to the calibration energy entered.
5. If the **Base Gain** was modified significantly enough in step 3 above to change the coarse analog **Switched Gain** setting, the **Mean** energy may still be off by up to 1%. In this case, repeat steps 3 and 4 as necessary to achieve the desired accuracy.
6. Press the **[Save]** button to save the **Base Gain** to the current GENSET.

RS-232

A preliminary **Digital Base Gain** can be calculated from Equation 11, based on the **Switched Gain** setting that was selected from Table 2. The **Digital Base Gain** can then be adjusted via a calibration feedback loop implemented in software.

Command	***Meaning***	***Response data***
0x9C: Set/Get Digital Base Gain Value	Set or read the 16-bit DGAINBASE (0.16 mantissa) and signed 8-bit DGAINBASEEXP (exponent), which determine the Digital Base Gain. Ndata = 4 (set) or 1 (get) [data1] = 0: set, 1: get [data2] = DGAINBASE[7:0] [data3] = DGAINBASE[15:8] [data4] = DGAINBASEEXP[7:0]	Ndata = 4 [data1] = return status 0: OK [data2] = DGAINBASE[7:0] [data3] = DGAINBASE[15:8] [data4] = DGAINBASEEXP[3:0]

Table 8: RS-232 Command 0x9C: Set/Get Digital Base Gain

MCA Bin Width and Number MCA Bins

The microDXP MCA format is quite flexible, with adjustable **Number MCA Bins** ranging up to 8192, and adjustable granularity via the **MCA Bin Width** setting. The DSP doesn't constrain the relationship between these settings, so it's possible to define a spectrum that exceeds the practical limits of the ADC, which should be avoided. As a rule-of-thumb, the product of **Number MCA Bins** and **MCA Bin Width** should not exceed 8192.

Number MCA Bins	*MCA Bin Width*	*Bin Size*	*Energy Range*
8192	1	5 eV	40.96 keV
8000	1	5 eV	40.00 keV
4096	1	5 eV	20.48 keV
4000	1	5 eV	20.00 keV
4096	2	10 eV	40.96 keV
4000	2	10 eV	40.00 keV
2048	1	5 eV	10.24 keV
2000	1	5 eV	10.00 keV
2048	2	10 eV	20.24 keV
2000	2	10 eV	20.00 keV
2048	4	20 eV	40.96 keV
2000	4	20 eV	40.00 keV

Table 9: Bin Size and Energy Range as a function of **Number MCA Bins** and **MCA Bin Width**, with a **Dynamic Range** of 40 keV. Note that the product of **Number MCA Bins** and **MCA Bin Width** is always 8192 or less.

When the of **Number MCA Bins** and **MCA Bin Width** product equals 8000, the energy range of the MCA spectrum is exactly equal to the **Dynamic Range**, corresponding to voltage pulses that span 50% or less of the ADC input range, a practical measurement limit. Note that the Bin Size and Energy Range can be calculated according to Equation 17 and Equation 18 below.

The **Number MCA Bins**, stored in the GENSET parameter MCALEN, does not affect the Digital Gain. The **MCA Bin Width**, which defines the granularity of the MCA spectrum, *does* affect the Digital Gain, per Equation 7. It is defined by the GENSET parameters BINGRANULAR and BINMULTIPLE, as shown in Equation 13. When the user sets BINGRANULAR ≤ 3, the DSP then sets BINMULTIPLE. Alternatively, the user can set BINGRANULAR = 4 (custom setting), and then set BINMULTIPLE directly to any integer.

$$\textbf{MCA Bin Width} = \mathrm{BINMULTIPLE} = 2^{\mathrm{BINGRANULAR}}$$

Equation 13

For simplicity, we recommend setting the BINGRANULAR = 4, such that the **MCA Bin Width** is set directly via BINMULTIPLE.

ProSpect

The **Number MCA Bins** and **MCA Bin Width** are edited directly in the GENSET area of the **Acquisition** tab of the **Settings** panel. Note the corresponding change in the Bin Size (**eV/Bin** value), when **MCA Bin Width** is modified, per Equation 18 below.

RS-232

The RS-232 command to set MCALEN is 0x85. The bin width is set via command 0x84 according to the granularity required by the user.

Command	***Meaning***	***Response data***
0x84: Set/Get MCA Bin Width	Set the granularity of the MCA, or read the current setting. Ndata = 3 (set) or 1 (get) [data1] = 0: set, 1: get [data2] = Granularity 0: Very fine (e.g. 5 eV/ch) 1: Fine (e.g. 10 eV/ch) 2: Medium (e.g. 20 eV/ch) 3: Coarse (e.g. 40 eV/ch) 4: Custom For the custom setting (otherwise ignored): [data3] = Width in terms of the minimum (Very fine) bin width (e.g. a setting of 7 would give 35 eV/ch)	Ndata = 3 [data1] = return status 0: OK, 1: invalid setting [data2] = Current bin granularity [data3] = Custom bin scaling factor

0x85: Set/Get Number of MCA Bins	Set or read the number of MCA bins (max 8192) and the offset (normally 0). Ndata = 5 (set) or 1 (get) [data1] = 0: set, 1: get [data2,data3] = Number of MCA bins (low byte first) [data4,data5] = Offset (the first bin of the spectrum; can be nonzero)	Ndata = 5 [data1] = return status 0: OK, 1: invalid setting [data2,data3] = Current number of MCA bins (low byte first) [data4,data5] = Current MCA offset

Table 10: RS-232 Commands 0x84: Set/Get MCA Bin Width, and 0x85: Set/Get Number of MCA Bins

Fine Gain Trim

After the **Base Gain** and MCA settings have been chosen such that a calibrated energy spectrum is produced, the user may then change the **Peaking Time** only to find that the energy calibration is slightly off. To first order the spectrum should remain calibrated, but a slight shift in the pulse-height measurement is not uncommon. This is addressed by storing a unique **Fine Gain Trim** setting for each **Peaking Time**. The **Fine Gain Trim** can be ignored if the energy is already calibrated to the required accuracy.

The **Fine Gain Trim**, which defaults to 1 and ranges from 0.5 to 2, is transformed to the UQ1.15 format unsigned mantissa DSP parameter GAINTWEAKn, where n is the GENSET identifier. GAINTWEAKn is constrained between the values 16384 and 65535.

GAINTWEAKn = **Fine Gain Trim** * 32768

Equation 14

ProSpect

The **Fine Gain Trim** can modified directly in the **Acquisition** tab of the **Settings** panel, but it is typically adjusted via the calibration routine described below. Note that this should only be done after the **Base Gain** has been properly set as described above, such that **Fine Gain Trim** retains a value close to 1.

1. Select a known peak in the MCA spectrum and enter its energy in the **Calib. (keV)** field of the **ROI** table, if it hasn't been entered already. Make sure the selected ROI is Active.
2. Press the **[Adjust Gain Trim]** button to automatically adjust the **Fine Gain Trim**.
3. Press the **[Start Run]** button to acquire more data. Compare the **Mean** energy in the **ROI** table to the calibration energy entered.
4. Repeat steps 2 and 3 until the fields match to the required precision.
5. Press the **[Save]** button to save the **Fine Gain Trim** to the current PARSET.

RS-232

Note that GAINTWEAKn as a function of Fine Gain Trim, as indicated in Equation 14, has changed from the original microDXP specification!

Command	*Meaning*	*Response data*
0x91: Set/Get Gain Trim	Set or get GAINTWEAK value corresponding to current GENSET. NData = 3 (set) or 1 (get) [data1] = 0: set, 1: get [data2] = GAINTWEAK (low byte) [data3] = GAINTWEAK (hight byte)	Ndata = 3 [data1] = Return status [data2] = GAINTWEAK (low byte) [data3] = GAINTWEAK (hight byte)

Table 11: RS-232 command 0x91: Set/Get Gain Trim

Bin Size and Energy Range

Combining equations, we can express the MCA Bin corresponding to an x-ray with voltage amplitude ΔV_{Preamp} fully in terms of ProSpect settings and hardware settings, as:

$$\text{MCA Bin} = \frac{0.825 * \text{Input Atten} * \textbf{Base Gain} * \textbf{Fine Gain Trim} * \Delta V_{Preamp} * 16384}{2^{(\textbf{MCA Bin Width} - 1)} * 2.0\text{ V}}$$

Equation 15

The final step is to assign an energy value to the MCA bin, i.e. define the bin size (**eV/Bin**), such that:

$$\text{Energy} = \text{MCA Bin} * \textbf{eV/Bin}$$

Equation 16

And:

$$\text{MCA Energy Range} = \textbf{Number MCA Bins} * \textbf{eV/Bin}$$

Equation 17

Dynamic Range

In ProSpect the bin size is defined by the **Dynamic Range**, a software-only setting that assigns an energy in kilo-electron-Volts (keV) to an x-ray voltage pulse that spans 48.8% of the ADC input range.

$$\textbf{eV/Bin} = \frac{\textbf{Dynamic Range} * \textbf{MCA Bin Width}}{8000}$$

Equation 18

The **Dynamic Range** setting should correspond to the highest measurable energy, respective of the detector, preamplifier and experimental conditions. A typical x-ray dynamic range is 40 keV or 80 keV, though some thin-window detectors intended for soft x-rays may work best with the minimum 20 keV setting. Because this is a software-only setting, it is applied immediately upon selection from the drop-down list.

Example: 2.5 mV/keV Preamplifier and 40 keV Dynamic Range with 5 eV bins

This is an 8000-bin, fine-granularity spectrum with a typical x-ray detector preamplifier. We recommend that you use a known x-ray source at a moderately low input count rate, and first select a **Peaking Time** where near optimal energy resolution is expected.

ProSpect

1. Set **Dynamic Range** → 40 keV (**Acquisition** tab, GENSET area). Note that this software-only setting takes effect immediately.
2. Set **Base Gain** → 11.84 per Equation 10 (**Acquisition** tab, GENSET area).
3. Set **Number MCA Bins** → 8192 (**Acquisition** tab, GENSET area).
4. Set **MCA Bin Width** → 1 (**Acquisition** tab, GENSET area). Press the **[Apply]** button. Note that the **eV/Bin** field above changes to "5 eV".
5. Adjust thresholds as necessary and acquire a spectrum in the MCA tab via the **[Start Run]** / **[Stop Run]** button.
6. Select a known energy peak with the ROI tools and enter its energy in the **Calib. (keV)** field of the ROI table and then press the **[Calibrate ROI]** button to adjust the **Base Gain**.
7. Repeat steps 6 and 7 as necessary, until the **Mean** value in the ROI table matches the energy to the desired accuracy.
8. Now change the **Peaking Time**, adjust thresholds as necessary and acquire a spectrum in the MCA tab via the **[Start Run]** / **[Stop Run]** button.
9. If necessary adjust the ROI limits around the known energy peak and then press the **[Adjust Gain Trim]** button to adjust the **Fine Gain Trim** for the new **Peaking Time**.
10. Repeat steps 9 and 10 for other **Peaking Time** values as necessary.

RS-232

1. Set Dynamic Range = 40 keV. Although there is no Dynamic Range hardware setting, Equation 10 should still be used to calculate the preliminary Switched Gain and Digital Base Gain, i.e. the Base Gain.
2. Equation 10 yields Base Gain = 11.84
   a. From Table 2 we see that SWGAIN = 6 yields the best approximation, i.e. Base Gain = 12.48 (with Digital Base Gain = 1.000):

CMD = 0x9B, Ndata = 0x02, [data1] = 0x00 (set), [data2]= 0x06 (SWGAIN)

b. Digital Base Gain = 0.94872 such that Base Gain = 11.84, per Equation 9. Following Equation 12 we get DGAINBGASE = 62175 (0xF2DF), and DGAINBASEEXP = -1 (0xFF, in 8-bit 2's complement) :
CMD = 0x9C, Ndata = 0x04, [data1] = 0x00 (set), [data2]= 0xDF (DGAINBASE[7:0]) , [data3]= 0xF2 (DGAINBASE[15:8]) , [data4] = 0xFF (DGAINBASEEXP)

3. Set Number MCA Bins = 8192 (0x2000), with no offset:
CMD = 0x85, Ndata = 0x05, [data1] = 0x00 (set), [data2]= 0x00 (MCALEN[7:0]), [data3]= 0x20 (MCALEN [15:8]) , [data4]= 0x00 (MCALIMLO[7:0]), [data5]= 0x00 (MCALIMLO[15:8])

4. Set MCA Bin Width = 1:
CMD = 0x84, Ndata = 0x03, [data1] = 0x00 (set), [data2]= 0x04 (BINGRANULAR custom), [data3]= 0x01 (BINMULTIPLE)
or, equivalently:
CMD = 0x84, Ndata = 0x03, [data1] = 0x00 (set), [data2]= 0x00 (BINGRANULAR very fine), [data3]= 0xXX (BINMULTIPLE ignored)