



RX1200 User's Manual

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Table of Contents

1.	INTRODUCTION	4
1.1.	THEORY OF OPERATION.....	4
1.2.	RAYCODE AND DIGITAL SIGNAL PROCESSING IN FPGA	6
1.3.	SPECIFICATIONS AND FEATURES.....	7
1.3.1.	<i>Hardware (RX1200) Specifications</i>	7
1.3.2.	<i>Firmware (RayCode) Specifications</i>	8
2.	GETTING STARTED	9
2.1.	PACKAGE CONTENTS	9
2.2.	INSTALLATION AND SETUP	9
2.2.1.	<i>Installing USB Driver</i>	9
2.2.2.	<i>Installing RayPanel software</i>	10
2.3.	USING RX1200	10
2.3.1.	FRONT PANEL.....	10
2.3.2.	REAL PANEL.....	11
3.	USING RAYPANEL SOFTWARE	13
3.1.	OVERVIEW	13
3.2.	SETTING ACTIVE DEVICE.....	13
3.3.	PROGRAMMING SETTINGS	15
3.4.	SCOPE PANEL	16
3.5.	MCA PANEL.....	17
3.5.1.	<i>MCA Settings</i>	18
3.6.	DISPLAY SETTINGS.....	20
3.7.	REGION OF INTEREST (ROI).....	21
3.8.	ENERGY CALIBRATION	22
3.9.	DAC-OUT SETTINGS	24
3.10.	LOG BOX	25
3.11.	RAYPAR FILE	26

1. Introduction

RX1200 is a single-channel, 200 MHz digital data acquisition system designed for radiation detection and spectroscopy. RX1200 can be used with almost any type of radiation detector. With 12-bit sampling resolution, **RX1200** is well suited for spectroscopy applications with scintillation detectors.

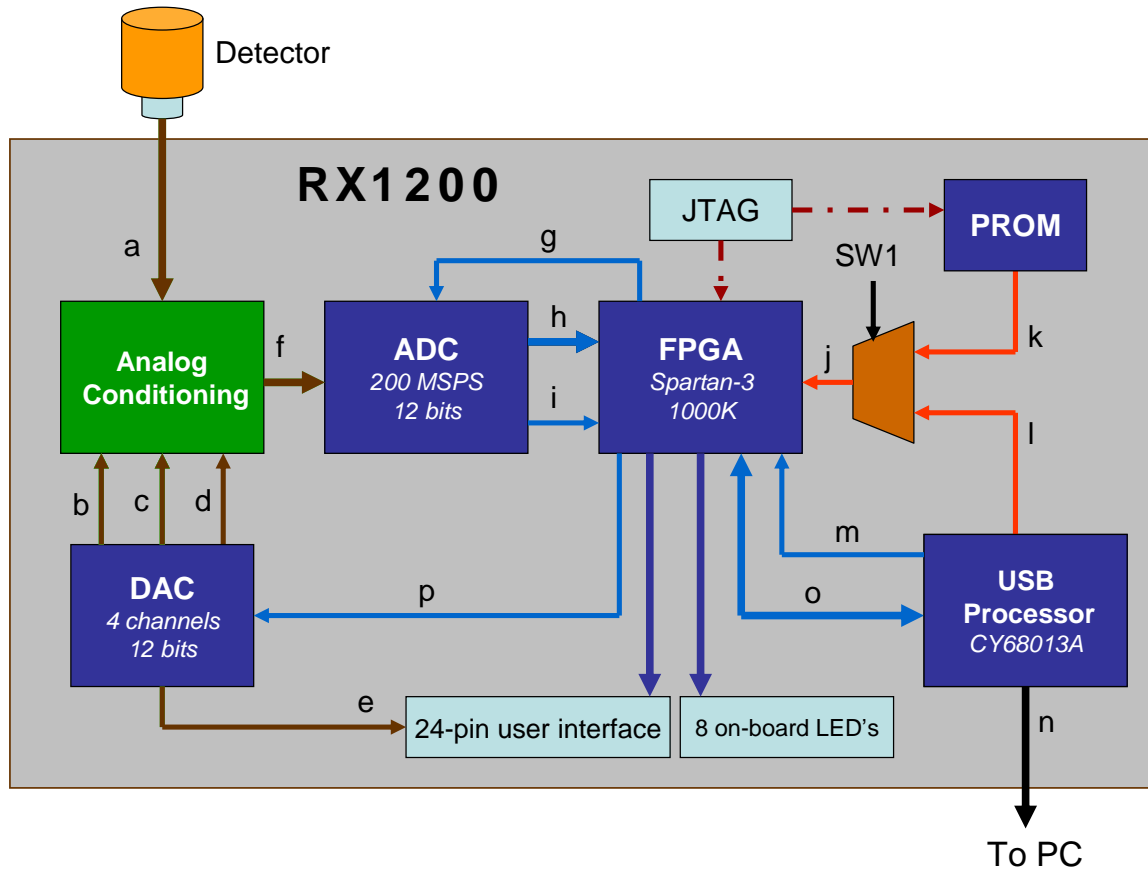
1.1. Theory of Operation

Unlike traditional analog spectroscopy systems in which only one sample from shaped pulses is taken by a peak-sensitive Analog-to-Digital Converter (ADC), in a digital spectrometer, the whole signal pulse is captured by a fast ADC to determine the corresponding energy deposition in detector. This brings significant improvements to the world of radiation spectroscopy, among them: pulse processing is easy to edit, no bulky electronics, post-processing is possible, more cost effective, effects like pile-up can be rejected in the processing level, and much less power requirement.

In **RX1200**, signal pulses from the radiation detector are sampled every 5 nanoseconds or with a sampling rate of 200 MHz. As depicted in the functional block diagram, the input signal from detector (a) is passed through an analog conditioning stage before it is digitally captured by the ADC. In this stage, the detector signal level is adjusted by three signals (b, c and d) from an on-board Digital-to-Analog Converter (DAC). These signals, which are digitally adjustable from the PC side, determine three parameters at this stage: *amplification gain*, *input offset* and *ADC offset*. The same DAC provides another analog signal (e) which can be used to control an external high-voltage unit. These four analog signals can be adjusted in 4096 steps (12 bits). At the end of this stage, a third-order low-pass Bessel filter (anti-aliasing filter) with a cutoff frequency of 90 MHz is used to remove high-frequency components from the input signal.

Filtered analog signal (f) is digitally captured by a fast ADC (200 MHz, 12 bits). Digital samples (h) from the ADC are then fed into a Field-Programmable Gate Array (FPGA) for further digital pulse processing. The input clock for the ADC (g) is provided by the FPGA. The FPGA synthesizes this clock from a reference clock (USB_CLK, 48 MHz) generated by the USB processor (m). The ADC itself generates a clock output (i) which is

synchronized with its data output (h). To minimize the clock skew and to relax the setup-time constraints, the FPGA uses this clock for all ADC's data related registers.



Functional Block Diagram of RX1200

- | | |
|-----------------------------------|---|
| a) Analog signal input | k) Configuration bit stream from PROM |
| b) Gain adjustment signal | l) Configuration bit stream from USB port |
| c) Input offset adjustment signal | m) USB clock output |
| d) ADC offset adjustment signal | n) USB cable |
| e) DAC output (0V to +3.3V) | o) FPGA/USB data bus |
| f) Filtered analog signal | p) DAC data |
| g) ADC clock input (LVDS) | SW1 : Configuration mode switch |
| h) ADC data output (LVDS) | |
| i) ADC clock output (LVDS) | |
| j) FPGA configuration port | |

1.2. RayCode and Digital Signal Processing in FPGA

All the digital pulse processing functions necessary for radiation detection and spectroscopy are implemented in the on-board FPGA. Therefore, before using the spectrometer, the FPGA needs to be programmed. In ***RX1200***, the FPGA can be programmed via on-board PROM memory, JTAG header or USB port from a programming file saved in your PC. ***RX1200*** can be reprogrammed via high-speed USB port in a small fraction of second. This feature along with 24-pin user interface (0.1”) and eight LED’s on board makes the ***RX1200*** a perfect solution for developing customized FPGA firmware for digital radiation measurement and spectroscopy.

RayCode is a FPGA firmware (200 MHz) developed for ***RX1200*** to capture and digitally process signal pulses from scintillation detectors. It includes Scope module to capture radiation pulses and Multi-Channel Analyzer (MCA) module to collect the energy spectrum. In the Scope module, incoming waveform is captured in a circular buffer and is transferred to the PC upon a request. The waveform length is about 5 microseconds (1024 samples). The MCA is implemented in a 4K, 32-bit memory configuration.

The on-board PROM in ***RX1200*** is shipped with the ***RayCode*** firmware.

RayCodeX is an open-source FPGA project (VHDL) provided for developers who want to use ***RX1200*** as a development tool for digital spectroscopy. ***RayCodeX*** includes the source code for Scope module. Please read ***RX1200’s Programming Manual*** for developing your customized digital spectrometers.

1.3. Specifications and Features

1.3.1. Hardware (RX1200) Specifications

<i>RX1200 (Hardware)</i>					
<i>Parameter</i>	<i>Minimum</i>	<i>Typical</i>	<i>Maximum</i>	<i>Unit</i>	<i>Comments</i>
Sampling Rate	50	200	210	MHz	200 MHz on RayCode
Sampling Resolution	12			Bit	-
Gain	-14		46	dB	4096 steps
Input Offset	-330	0	+330	mV	4096 steps
ADC Offset	-625	-	+625	mV	4096 steps
DAC Output	0	-	+3.3	V	4096 steps
Input Impedance	50			Ohm	-
Input Bandwidth	90			MHz	Third-order Bessel filter
Supply Voltage	4.2	5.0	5.5	V DC	-
Gate Input	LVCMOS/LVTTL				Compatible Logic
Interface	High-Speed USB2.0 (480 Mbps)				
FPGA Device	Xilinx SPARTAN-3, XC3S1000-5FTG256C				
FPGA Configuration	Via USB port, on-board PROM or JTAG				
User Interface	24-pin header with 8 on-board LEDs				

1.3.2. Firmware (RayCode) Specifications

<i>RayCode (FPGA Firmware)</i>					
<i>Parameter</i>	<i>Minimum</i>	<i>Typical</i>	<i>Maximum</i>	<i>Unit</i>	<i>Comments</i>
MCA Memory Length	4,096			Channel	-
MCA Memory Width	32			Bit	-
Dead Time (MCA)*	30			Nanosecond per event	6 clock periods
Trace Capture Size	1,024			Sample	@12 bits
Time between samples	5			Nanosecond	1 clock period
Trigger Threshold	0	-	65,535	ADC unit	-
Trigger Filter Peaking Time	55			Nanosecond	22-tap triangular filter
Integration Time	0	-	20,475	Nanosecond	5 nanosecond increments
Time Measurement Resolution (TMR)	0.655			Millisecond	2 ¹⁷ clock period
Live Time	0	-	781.875	Hour	TMR increments
Real Time	0	-	781.875	Hour	TMR increments

* When both the *pileup* and *baseline-waiting* inputs are off.

2. Getting Started

2.1. Package Contents

Your RX package should be shipped with the following items:

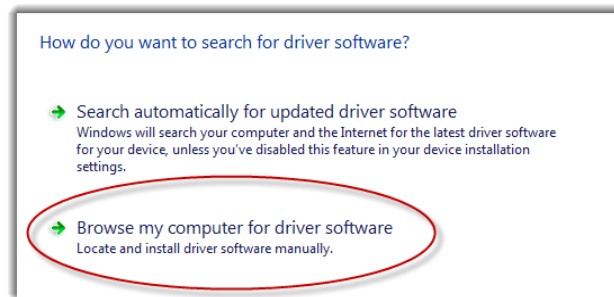
- RX1200-B (board), or RX1200-D (desktop)
- 5VDC Power Supply
- USB Cable
- Installation CD-ROM

Please contact us if any of the above items is missing in the package.

2.2. Installation and Setup

2.2.1. Installing USB Driver

To allow Windows install the USB driver, connect the RX1200 to your PC using included USB cable and power up the device. Wait until the “Found new hardware wizard” pops up to install the USB driver. Click on the “Browse” button and locate **“USB Driver”** on the installation CD. Click “OK” to install the driver.



2.2.2. Installing RayPanel software

Insert the installation CD and follow the on-screen instruction. If the installation process does not automatically begin, do the following:

1. Insert the installation CD into the CD-ROM drive.
2. Click the Start button and select My Computer.
3. Right Click the CD-ROM drive that contains the installation CD, and select Explore.
4. Double-click the *setup.exe* file.
5. Follow the on-screen instructions to complete the installation and setup

2.3. Using RX1200

RX1200 is offered in two versions: board-only version (RX1200-B) and desktop version (RX1200-D). Both versions have a 24-pin user interface and 8 on-board LED's for development purposes. In the following, features installed on the desktop version (RX1200-D) are explained.

2.3.1. Front Panel

The RX1200-D can be turned on and off using the power switch located on the front panel. The detector output should be connected to the **INPUT** jack (SMA female) on this panel.



RX1200-D, front panel

Two indicator LED's, *ACQUIRE* and *RATE*, are also installed on this panel. The anode pin of these LED's are connected to pins 20 and 18 of user interface header, respectively. The *ACQUIRE* LED is turned on if either MCA or Scope functions are running. The light intensity of the *RATE* LED is changed with the rate of radiation pulses (activity). This LED will have its maximum light intensity at 50,000 counts per second. The *RATE* LED indicates the count rate all time regardless of what mode you are working with.

2.3.2. Real Panel

Power supply (5VDC) should be connected to power jack (2.1 x 5mm) provided on the real panel. Central pin of this jack has positive polarity. RX1200 is connected to the PC by connecting provided USB cable to the USB port on this panel.



RX1200-D, real panel

Two SMA jacks, *GATE* and *DAC OUT*, are also provided on the real panel. *Gate* is a LVCMOS/LVTLL compatible input and can be used for coincidence or anti-coincidence experiments. Functionality of the *Gate* input can be selected in the *RayPanel* software (see MCA Settings). *GATE* input is internally connected to pin 16 of user interface header. *DAC OUT* is an analog output and can be set from 0 to 3.3V (4096 steps) from inside RayPanel software. *DAC OUT* can be used to control an external high voltage power supply.

The programming switch (SW1, see below) can be accessed from the real panel and is used to force the **RX1200** (on-board FPGA) to be programmed either from the USB port or from the on-board PROM after the **RX1200** is powered. When the SW1 is set to “PROM”, the device will be programmed automatically from the on-board PROM when it is powered. If the SW1 is set to “USB”, the device will not be programmed and will wait for a USB programming. Programming mode in the **RayPanel** software (see Programming Settings in section 3.3) should be changed if the mode of programming is changed by SW1.



Programming switch on real panel

3. Using RayPanel Software

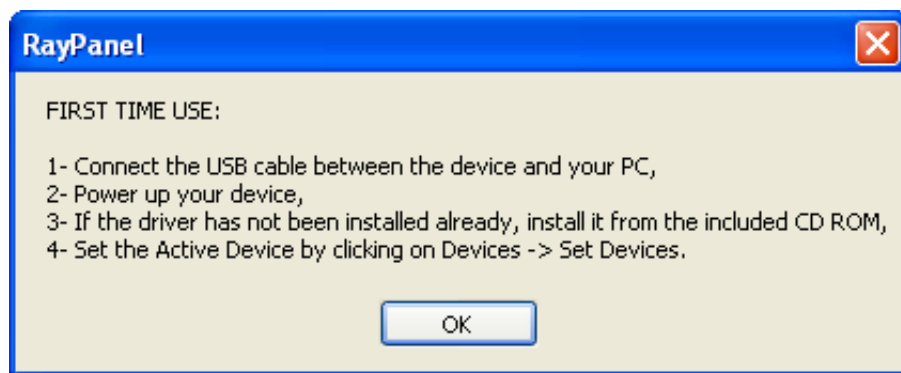
3.1. Overview

RayPanel is a Graphical User Interface (GUI) application developed to use **RX1200** as a high-performance digital spectrometer for scintillation detectors. Using the **RX1200** programmed with the **RayCode**, the user will be able to graphically set various operational and processing parameters including input offset, ADC offset, trigger threshold, amplification gain, DAC output (to adjust detector high voltage power supply) collection time (real time or live time), pulse integration time, scintillation type, region of interest, energy calibration and more.

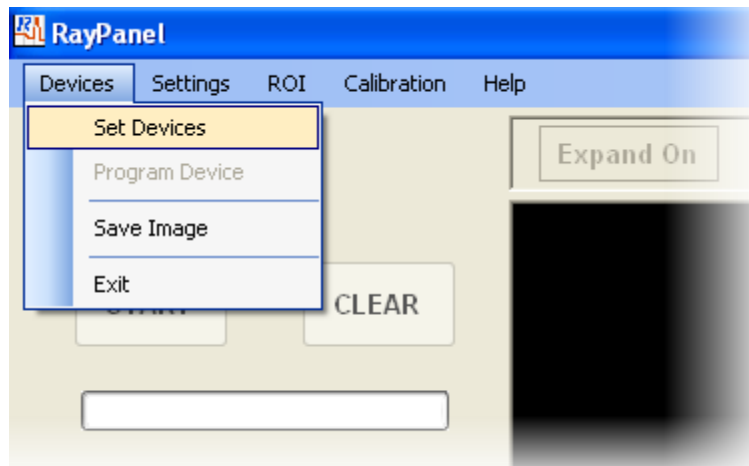
In **RayPanel**, detector signal traces and energy spectrum are displayed in two separate panels: the Scope and MCA panels, respectively. Before collecting energy spectrum in the MCA panel, user can run the **RX1200** in Scope mode to make sure that the detector pulses are in appropriate amplitude and offset by adjusting pulse capture settings.

3.2. Setting Active Device

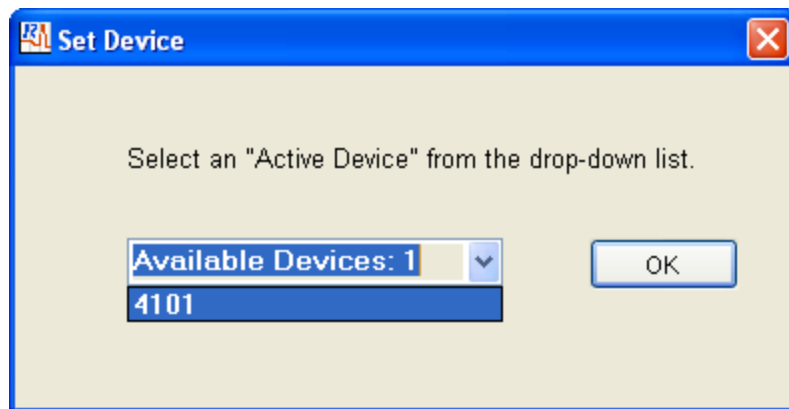
To work with a RX series device such as RX1200, RayPanel should know the device ID number (DID) of the active device. In other word, the user should first set the active device. If you use the device for the first time, a pop-up message (see below) prompts you to set the active device.



The user can set the active device by clicking on *Devices* tab then *Set Devices* as is shown below. Notice that the USB driver should be installed before setting the active device.

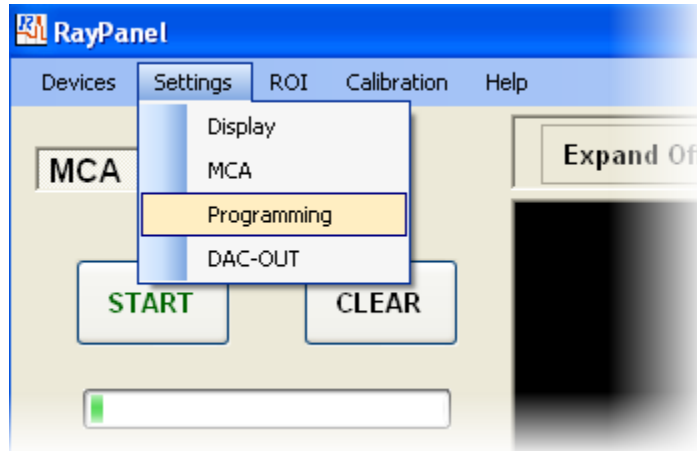


A pop-up window, as shown below, then let the user to set the active device by clicking on an Device ID number (DID) from a list of connected devices. The DID of selected active device is saved in *RayPar.txt* file for the future communications between the RayPanel and RX1200.

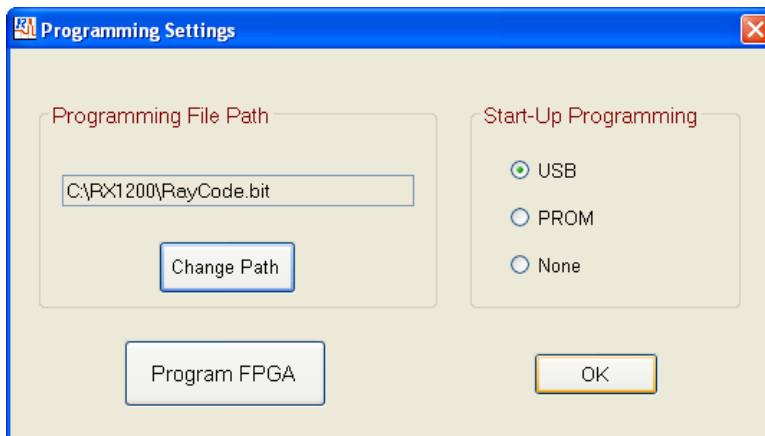


3.3. Programming Settings

By clicking on *Settings* tab then *Programming*, user can access the *Programming Settings* window.



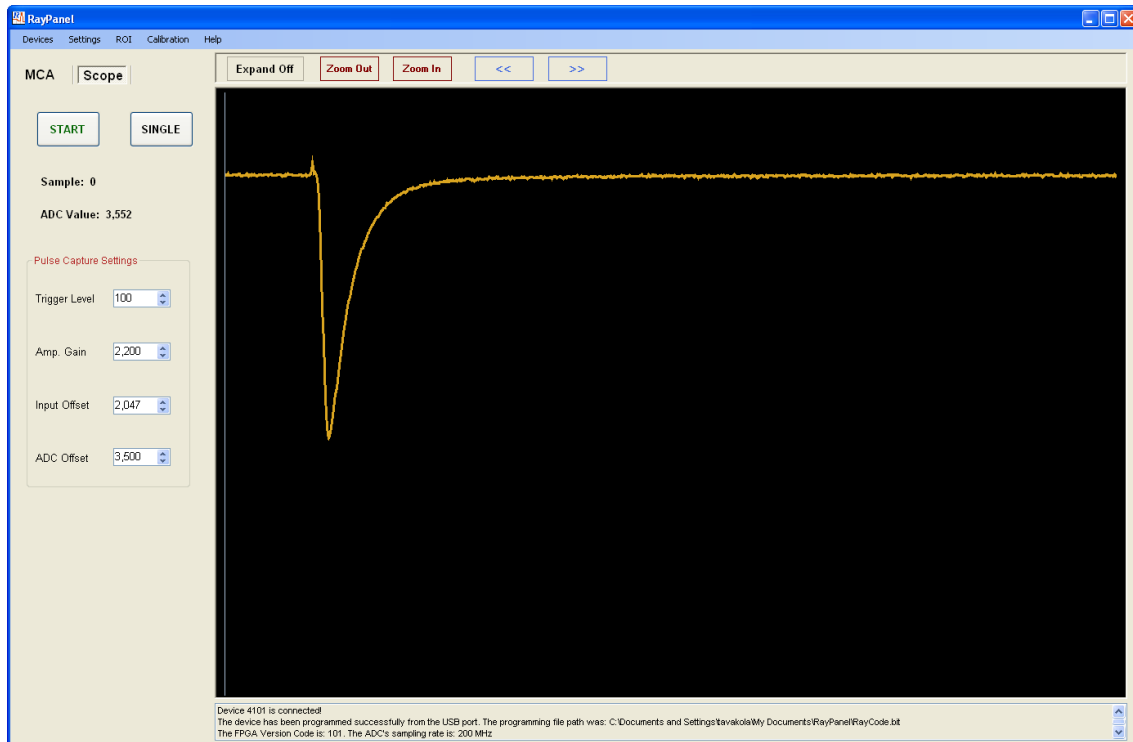
In the *Programming Settings* window, the user can set the Start-up Programming mode. The SW1 on the real panel should be set to the same mode (USB or PROM). When “None” is selected, the active device will not be automatically programmed when it is powered. When a USB programming is selected, a file path in the *Programming File Path* will be used to locate the programming file (default file is *RayCode.bit*). At any time, by clicking on *Program FPGA*, the RX1200 device can be manually programmed from the selected programming file.



3.4. Scope Panel

In the RayPanel, detector pulses can be monitored easily using *Scope* panel. The user can set the pulse capture parameters such as *Trigger Threshold*, *Amplification Gain*, *Input Offset*, and *ADC Offset* on this panel. By clicking on “START” button, the RayPanel captures and displays detector pulses with about 20 mseconds time between each capture. By clicking on “Single” button, only a single pulse is captured and displayed. The ADC value for each sample from the captured pulses can be viewed by changing the location of blue cursor using either left-clicking on mouse or clicking on keyboard’s right/left arrows. The *Scope* panel displays 1024 samples (5,120 nanoseconds when programmed with RayCode firmware) from the captured pulses.

Except for *Trigger Threshold* which can be set from 0 to 65535 (2^{16} steps), other parameters in the *Scope* panel can be set from 0 to 4095 (2^{12} steps).

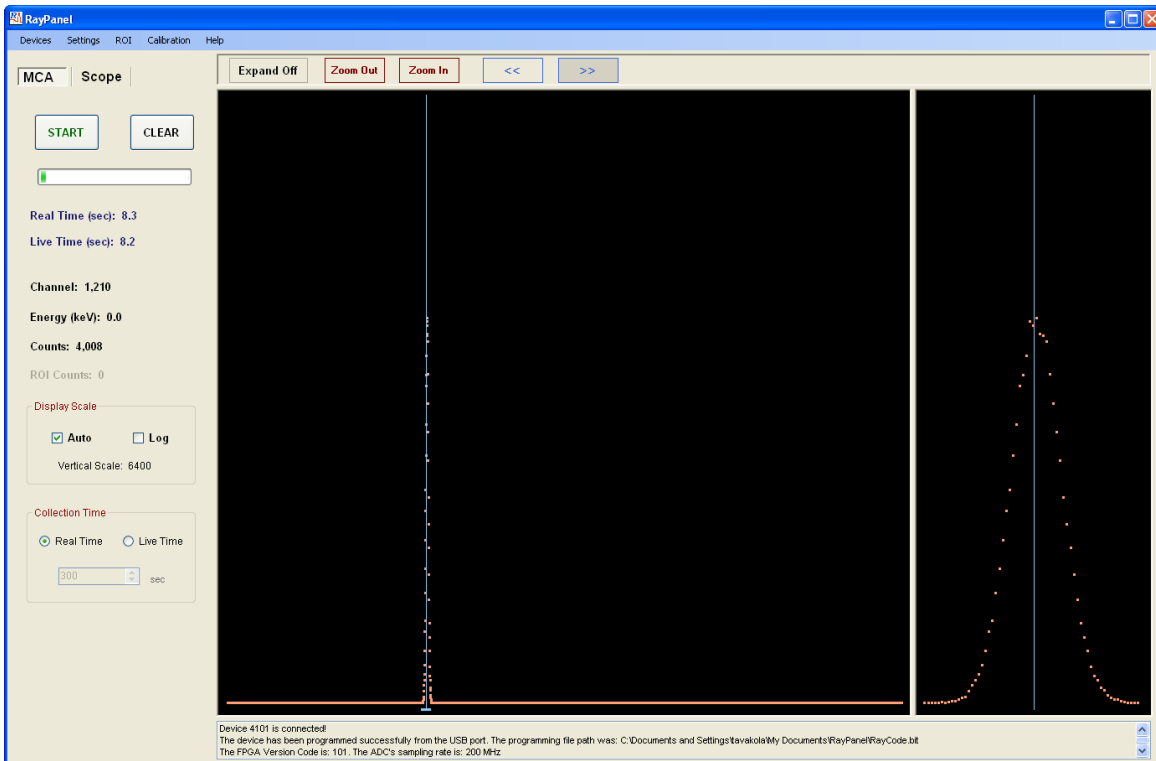


A snapshot of Scope panel in the RayPanel

3.5. MCA Panel

In the *MCA* panel, pulse height spectrum of detector pulses is displayed. The panel can be expanded by clicking on *Expand On* button. Two Buttons, *Zoom In* and *Zoom Out*, are provided at the top of this panel to zoom in or zoom out the expanded MCA panel.

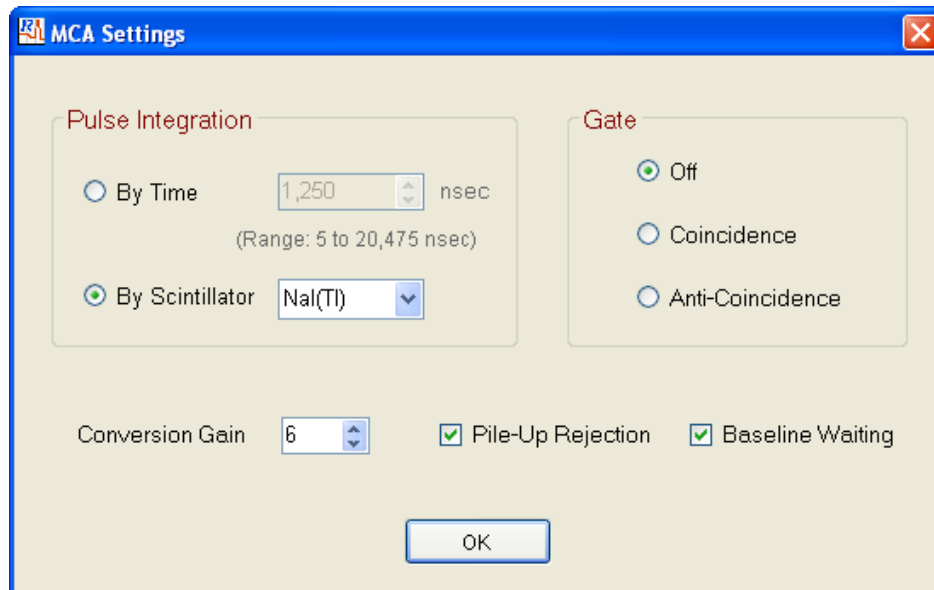
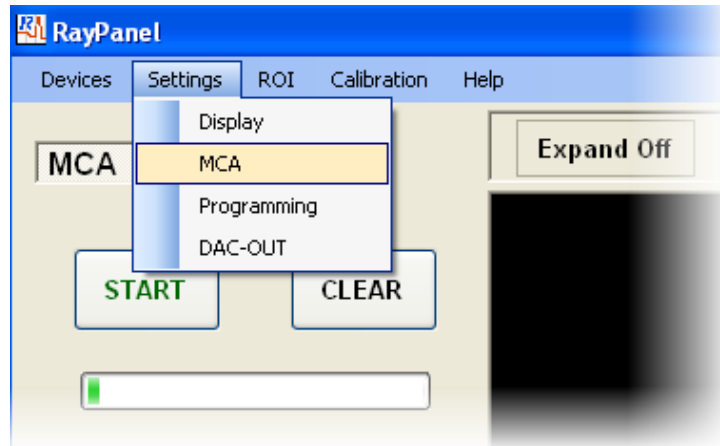
Counting information such as *Real Time*, *Live Time*, *Channel number*, *Energy*, *Counts*, and *ROI Counts* are displayed in the MCA's control panel (left side of MCA panel). With the "Auto" check box selected in the "Display Scale", the vertical axis of spectrum will be scaled up automatically. By checking the "Log" check box, the spectrum is displayed in logarithmic scale. Collection time in seconds for a MCA run can be entered at the bottom of the MCA's control panel. Here, the user has a choice to select either *Real Time* or *Live Time* styles for the MCA collection time. The "START" and "STOP" buttons start and stop the MCA, respectively. "Clear" button clears the content of MCA histogram.



A snapshot of MCA panel in the RayPanel

3.5.1. MCA Settings

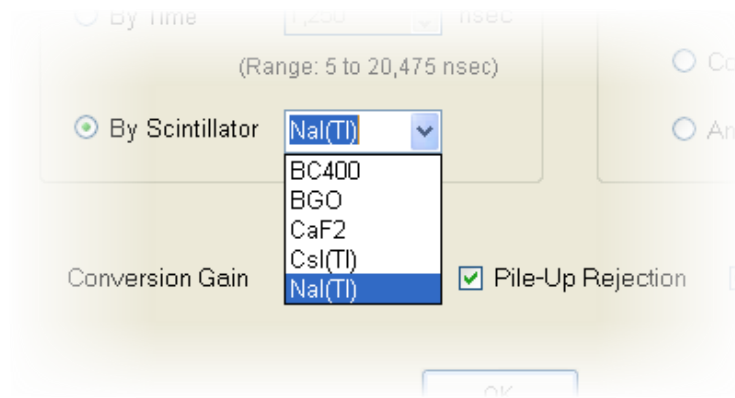
By clicking on *Settings* tab then *MCA*, user can access the *MCA Settings* window.



MCA Settings window

In the *MCA Setting* window, a variety of MCA parameters can be set. In the *Pulse Integration* section, user can set the pulse integration time parameter which is used by the MCA to calculate the corresponding deposited energy in the detector. This parameter can be set either by entering the integration time in nanoseconds or by selecting the type

of scintillator from the drop-down list. If the integration time should be set by selecting the scintillation type, RayPanel uses five times the scintillation decay time to calculate this parameter. If the desired scintillator is not available in the drop-down list, user can check “By Time” check box then enter the integration time manually.



List of available scintillators in the current version of RayPanel

For coincidence or anti-coincidence measurements, the **Gate** section allows the user to set the appropriate configuration logic. In these measurements, a LVCMOS/LVTTL compatible signal from the secondary detector is connected to the GATE input (on the real panel of RX1200) to gate analog pulses from the primary detector. Any other standard logic input to the GATE input may cause permanent damage to the RX1200.

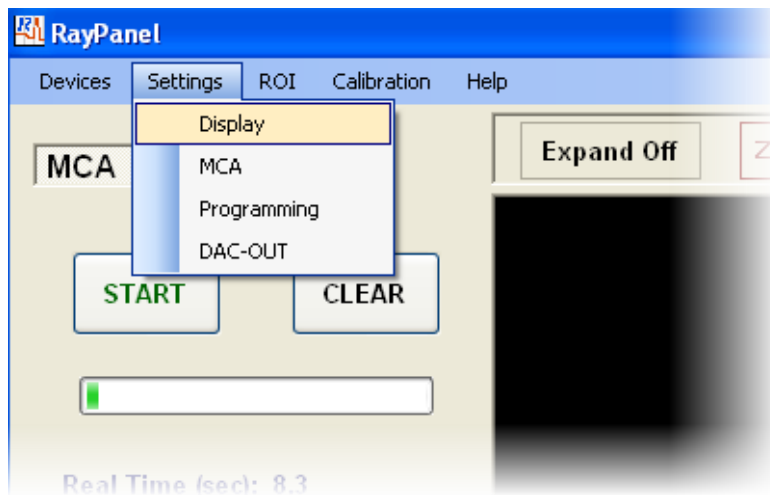
The **Conversion Gain** parameter can be used to change horizontal scale of the MCA. To compress the energy spectrum into fewer channels, a larger value is used whereas to expand the energy spectrum into more channels, a smaller value is used. The **Conversion Gain** ranges from 0 to 15 and scales the MCA channels by 2^{-cg} , where cg is the **Conversion Gain** value.

If the **Pile-Up Rejection** check box is checked, the MCA rejects pile-up events when a secondary pulse arrives within the integration time of previous pulse.

If the *Baseline Waiting* check box is checked, the MCA will not allow processing any new pulse until two times the integration time is elapsed from the previous pulse. This feature eliminates small errors in calculating deposited energy in detector when a pulse arrives on the tail of previous pulse. Particularly for high-rate sources, checking this parameter will increase the system dead time.

3.6. Display Settings

By clicking on *Settings* tab then *Display*, user can access the *Display Settings* window.



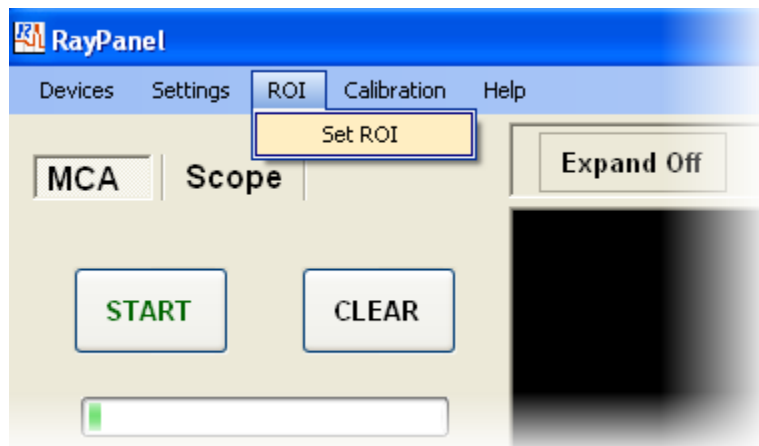
In the *Display Settings* window, various properties of the *MCA* and *Scope* panels can be set independently. For both panels, one of two plot modes can be selected: *Dot* or *Line* modes. There are three pixel sizes that the user can select for displaying data samples on these panels. Also the color of background, spectrum, pulse, cursors, and ROI can be changed in the *Display Settings* window.



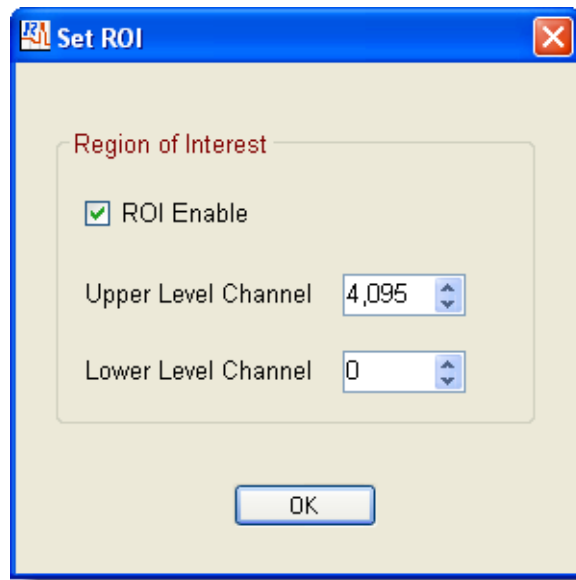
Display Settings window

3.7. Region Of Interest (ROI)

By clicking on **ROI** tab then **Set ROI**, user can access the **Set ROI** window.



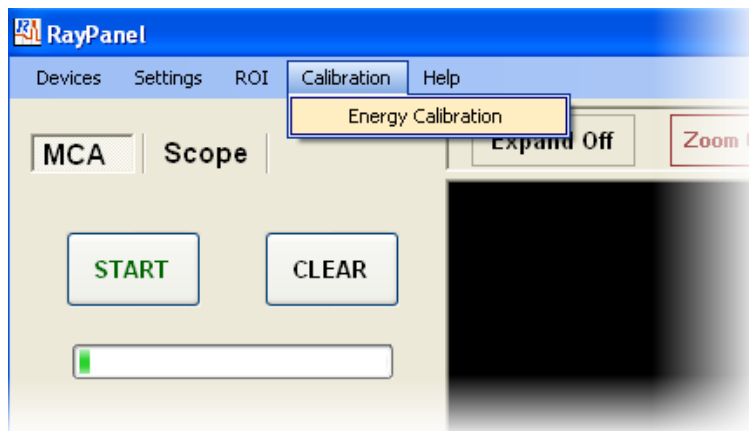
In the **Set ROI** window, user can enable or disable the ROI feature. When the ROI is enabled, a Region Of Interest can be defined using **Upper and Lower Level Channels** (channels 0 to 4095). Then when the MCA is running, the total count of ROI (ROI Counts) will be displayed in the MCA control panel. The ROI will have its color (set in the **Display Settings** window) when the ROI Enable is checked.



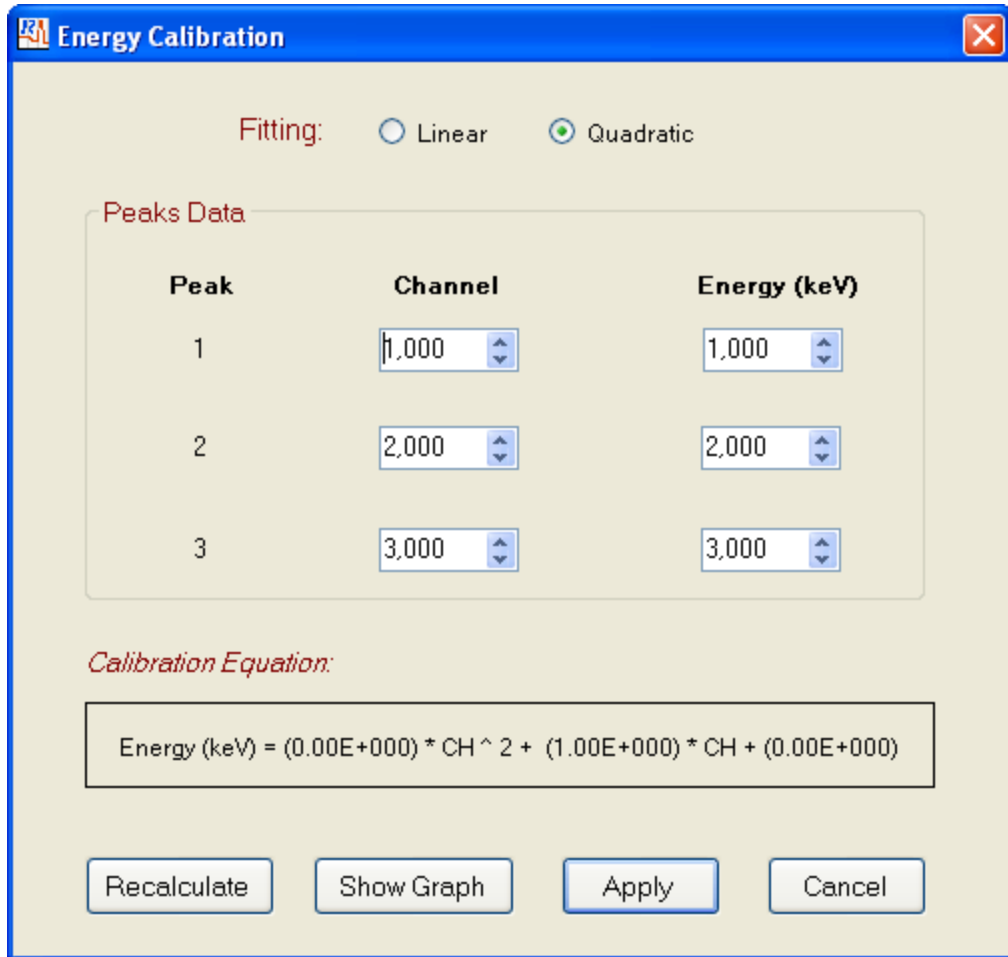
Set ROI window

3.8. Energy Calibration

By clicking on **Calibration** tab then **Energy Calibration**, user can access the **Energy Calibration** window.

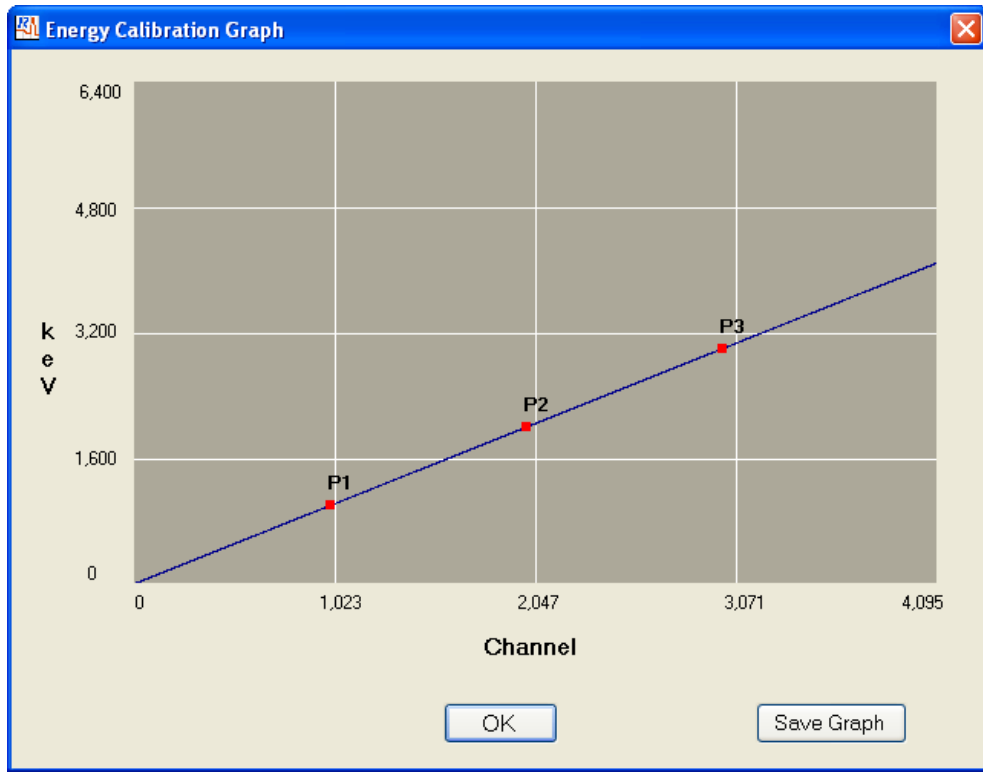


In the *Energy Calibration* window, the channel numbers of two or three peaks and their corresponding energies are used to calibrate the detector for energy measurements. For a *Linear* fitting, the channel numbers of only two peaks are required. Three peaks are needed for a *Quadratic* fitting. By clicking on Recalculate button, the energy calibration equation is calculated and displayed at the bottom of this window.



Energy Calibration window

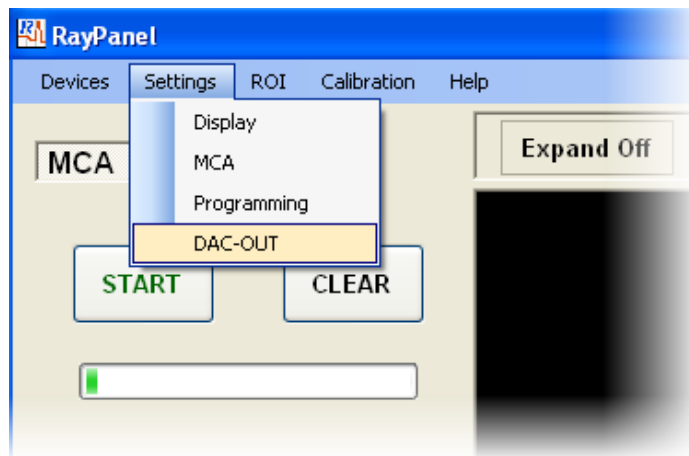
By clicking on *Show Graph*, the user can view the graph of energy calibration. User can save the calibration graph by clicking on *Save Graph*.



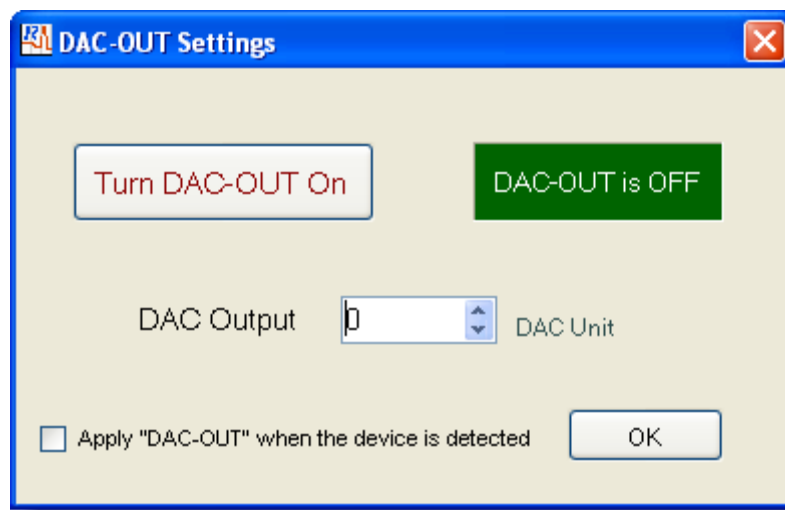
Energy Calibration Graph window

3.9. DAC-OUT Settings

By clicking on *Settings* tab then *DAC-OUT*, user can access the *DAC-OUT Settings* window.



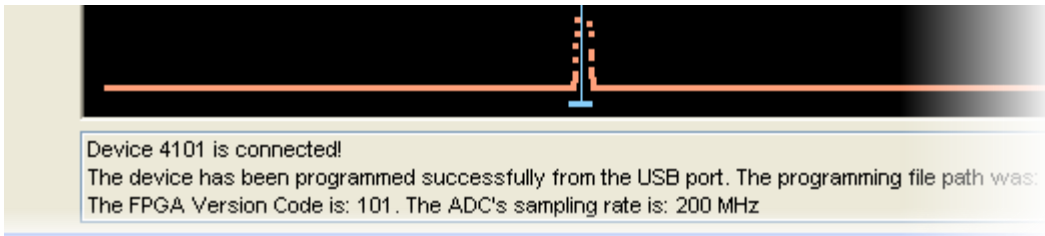
DC voltage appeared at the **DAC OUT** jack (on the real panel of RX1200) can be set in the **DAC-OUT settings** window. DAC OUT can be set from 0 to 4095 in DAC units (0V to 3.3V). DAC OUT can be turned on and off by clicking on the provided button. If the check box provided at the left bottom is checked, the voltage setting will be applied automatically when a RX1200 device is detected by the RayPanel. One application of **DAC OUT** output is to control an external high-voltage module powering the scintillation detector.



DAC-OUT Settings window

3.10. Log Box

Some useful operational information such as presence of the active device, programming file path, firmware version, sampling rate, total counts from a MCA running, and more are displayed in the **Log Box** located at the bottom of MCA and Scope panels.



A snapshot from Log Box

3.11. RayPar File

When user closes the software, all the setting information in the RayPanel software will be saved in a text file, *RayPar.txt*, in My Documents folder. RayPanel then uses this file to retrieve the previous settings. When RayPanel is launched for the first time or when a *RayPar.txt* file is not found in this folder, RayPanel will make one from default settings. User is advised not to change the content of this file manually.