User Manual

MYTHEN Detector System

Version: V3

DECTRIS Ltd.
5405 Baden-Daettwil
Switzerland
www.dectris.com

Table of Contents

1. Document History

1.1. Current document

Version	Date	status	prepared	checked	released
3	18.11.2015	released	DJ	**AM**	**AM**

1.2. Changes

Version	Date	Changes
1.0	28.02.2012	First public revision
1.1	11.06.2012	Section about trimming/settings modified
2.0	19.10.2012	Adapted for the improved calibration with automatic gain and for the web client
2.1	10.06.2013	Adapted CD
3	11.11.2015	Updated for new Postal Address

2. How to use this documentation

Before you start to operate the MYTHEN detector system please read the User Manual and the Technical Documentation included in the documentation package carefully.

This document has been designed for the MYTHEN detector systems.

2.1. Address and Support

DECTRIS Ltd.
Taefernweg 1
5405 Baden- Daettwil
Switzerland
Phone: +41 56 500 21 02
Fax: + 41 56 500 21 01

Website:

- www.dectris.com → support → Technical Notes → MYTHEN
- www.dectris.com → support → FAQ
- www.dectris.com → support → Problem Report

Email:

- support@dectris.com

Should you have questions concerning the system or its use, please contact us via phone, mail or fax.

⚠ **Do not ship the system back before you receive the necessary transport and shipping information!**

2.2. Explanation of Symbols

Symbol	Description
	Important or helpful notice
	Caution. Please follow the instructions carefully to prevent equipment damage or personal injury.
	DC-current
	AC-current
	Ground
	Functional earth

2.3. Explanation of Terms

Term	Description
ASIC	**A**pplication**-S**pecific **I**ntegrated **C**hip
DAC	**D**igital **A**nalog **C**onverter
GUI	**G**raphical **U**ser **I**nterface
DCS1	**D**etector **C**ontrol **S**ystem for **1** detector module
DCS6	**D**etector **C**ontrol **S**ystem for up to **6** detector modules
DCS24	**D**etector **C**ontrol **S**ystem for up to **24** detector modules
Detector module	The smallest fully functional unit of the detector (1280 channels).

2.4. Disclaimer

DECTRIS Ltd. has carefully compiled the contents on this manual according to the current state of knowledge. Damage and warranty claims arising from missing or incorrect data are excluded.

DECTRIS Ltd. bears no responsibility or liability for damage of any kind, also for indirect or consequential damage resulting from the use of this system.

DECTRIS Ltd. is the sole owner of all user rights related to the contents of the manual (in particular information, images or materials), unless otherwise indicated. Without the written permission of DECTRIS Ltd. it is prohibited to integrate the protected contents published in these applications into other programs or other Web sites or to use them by any other means.

DECTRIS Ltd. reserves the right, at its own discretion and without liability or prior notice, to modify and/or discontinue this application in whole or in part at any time, and is not obliged to update the contents of the manual.

3. Warnings

Please read these warnings before operating the detector system.

- DO NOT TOUCH THE ENTRANCE WINDOW OF THE DETECTOR.
- Place the protective cover on the entrance window of the detector when it is not in use.
- The detector is not specified to withstand direct beam at a synchrotron. Such exposure will damage the exposed channels.
- The detector system should have enough space for proper ventilation. Operating the detector outside the specified ambient conditions could damage the system.
- The air inlets and outlets of the detector control system should not be blocked.
- Power down the detector system before connecting or disconnecting any cable.
- Before connecting the power supply to the main-supply, check the supply voltage with the label on the power supply. Using an improper main voltage will destroy the power supply and could damage the detector.
- Make sure the cables are connected and properly secured.
- Avoid pressure or tension on the cables.
- Opening the detector, the detector control system or the power supply housing without explicit instructions from DECTRIS Ltd. will void the warranty.
- The embedded Linux operating system on the detector control system has customized software for controlling the MYTHEN detector system. Do not make any changes to the Linux operating system without explicit instructions from DECTRIS Ltd.

4. Detector System

4.1. Overview

All MYTHEN detector systems consist of the following components (see Figure 1 and Figure 2):

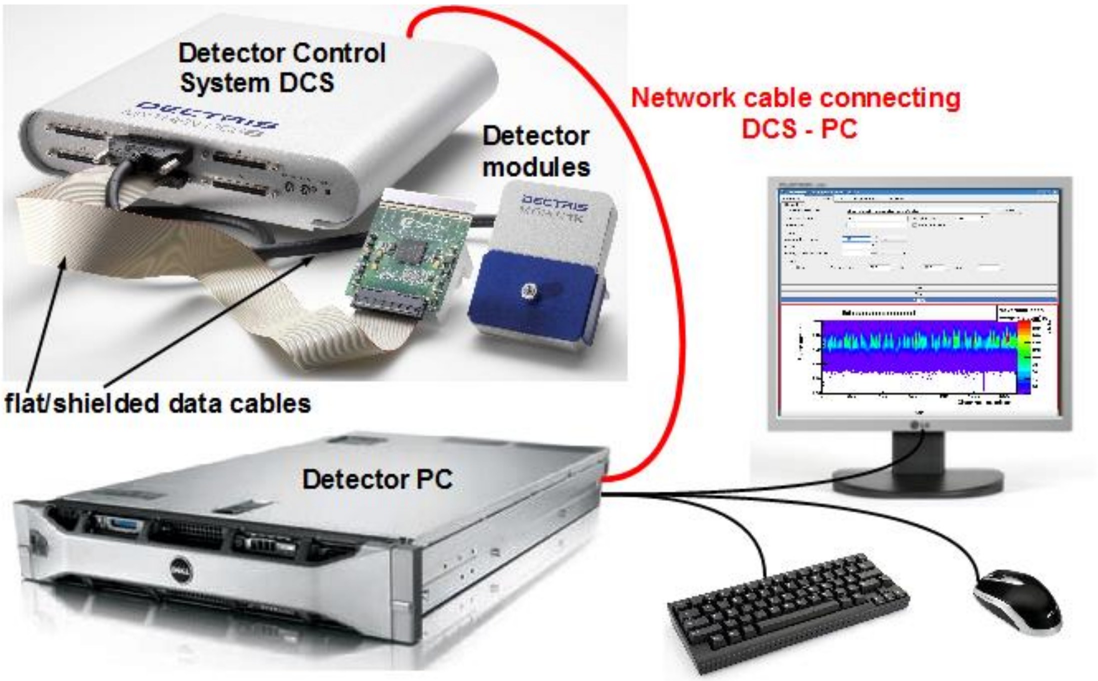

Figure 1 Overview of the MYTHEN detector system setup (monitor and PC are not included; the system components could differ from the shown ones).

- Detector module
  - 1 – 24 detector modules depending on the system type
  - with housing (CE certified detector version only)
  - without housing
- Detector Control System (DCS)
  - DCS1 for one detector module
  - DCS6 for up to 6 detector modules
  - DCS24 for up to 24 detector modules
- Power Supply
  - DCS1: 5 V / 2.4 A
  - DCS6: 5 V / 5 A
  - DCS24: not applicable since power supply is integrated
- Data cable(s)
  - Flat cable
  - round shielded cable (CE certified detector version only)

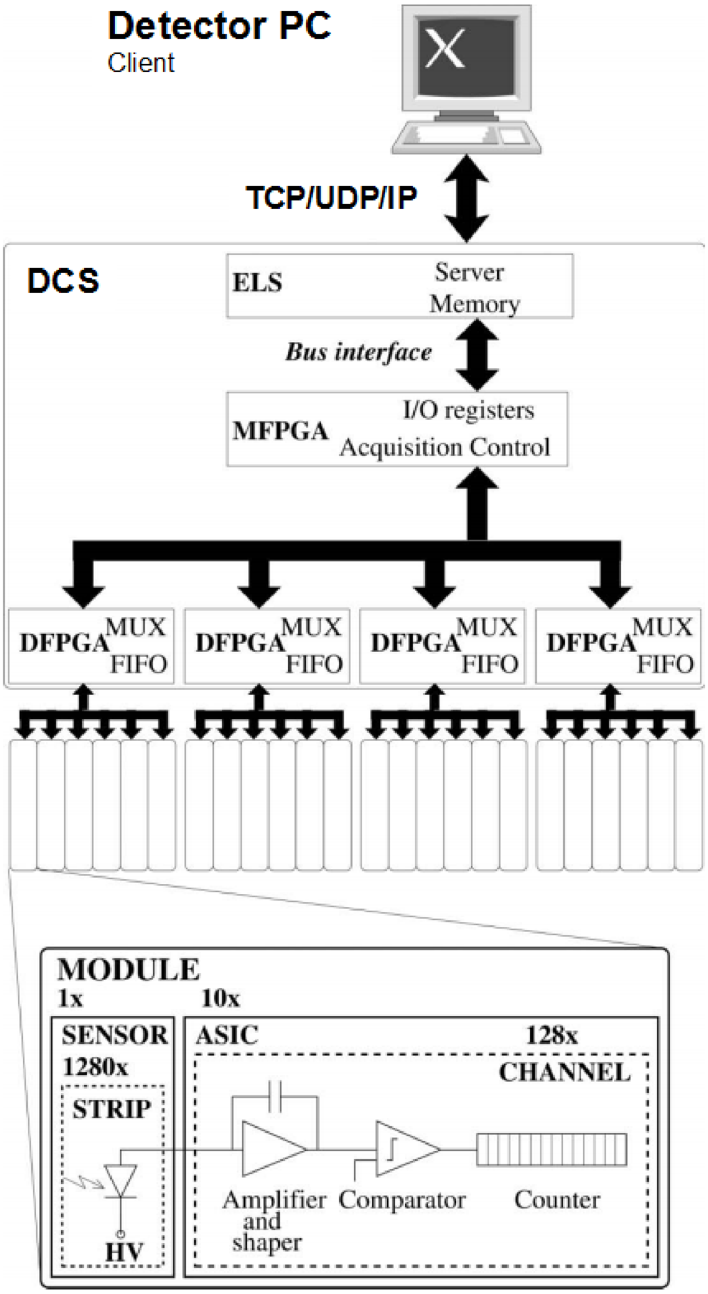

Figure 2 Schematic overview of the MYTHEN detector system (MYTHEN24K).

For detailed description of all detector components see **Technical Documentation** available at DECTRIS Ltd. (see 2.1 for support).

4.2. Technology

4.2.1. Overview

DECTRIS Ltd. X-ray detector systems operate in “single-photon counting” mode and are based on the newly developed hybrid technology.

The main difference to existing detectors is that the X-rays are directly converted into electric charge in the silicon sensor (Figure 3). The signal is processed in the connected CMOS readout chips. This absolutely new design shows no dark current or readout noise and leads to a high dynamic range of 16'777'216 (24 bits) per channel per image, short readout times of less than 0.3 ms, a high framing rate[1] of up to 700 images/s and an excellent spatial resolution (channel width 50 µm). The quantum efficiency of the different available silicon sensors (thicknesses of 320 µm, 450 µm or 1000 µm) is optimal for experiments in the energy range from 5 to 15 keV (Figure 4), however the detectors can be used for higher X-ray energies with the corresponding lower efficiency.

The counting rate is above 10^6 counts/s/channel in order to handle the high flux of modern synchrotron light sources. However, the detector cannot withstand a direct synchrotron beam due to potential radiation damage.

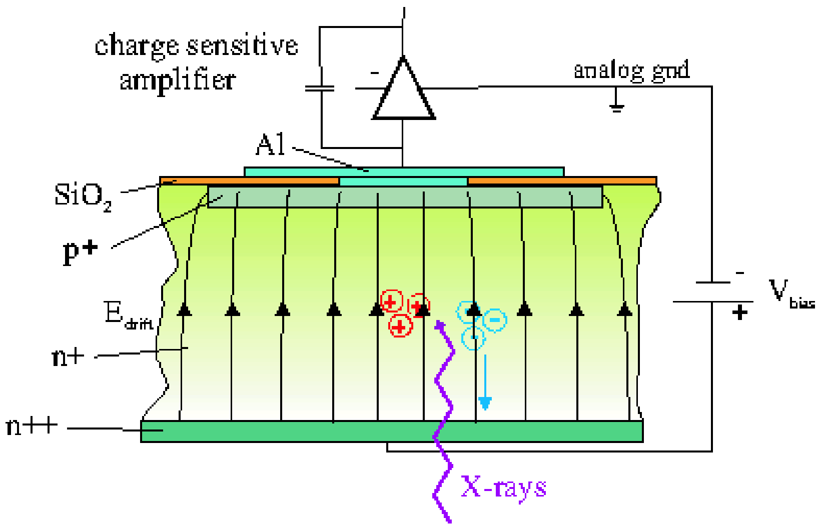

Figure 3 Principle of direct X-ray detection

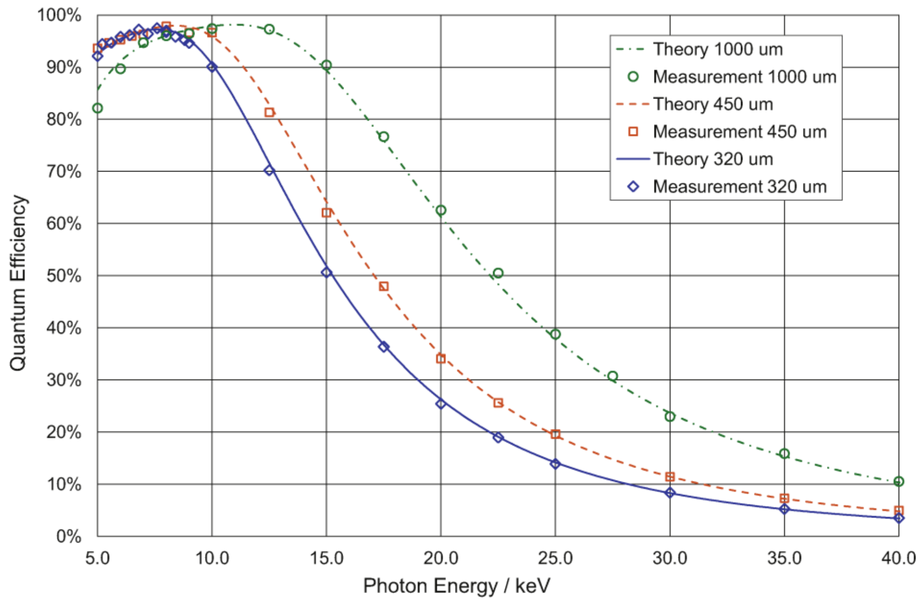

Figure 4 Theoretical efficiency for different Silicon sensor thicknesses.

4.3. Hybrid technology

DECTRIS Ltd. hybrid detectors are composed of a segmented silicon sensor and the corresponding ASIC readout chip.

The sensor is a one or two dimensional array of reverse biased, depleted pn-junctions usually processed in high-resistivity silicon, connected to an array of readout channels designed with advanced CMOS technology. Each readout channel is connected to its corresponding detecting element by a one by one wire-bonding technique (one dimensional array) or by a microscopic indium ball (two dimensional array).

The great advantage of this approach is that standard technologies are used for the silicon sensor and the CMOS readout chips, which guarantees highest quality. Both of them can be optimized separately, as the best silicon substrates for X-ray detection and for high-speed/high-quality electronics are very different. Moreover, the small size of the channel and of the interconnection results in a very low capacitance, which has the beneficial effect of reducing the noise and power consumption of the channel readout electronics.

4.4. “Single-photon counting”

A comparison of the “single-photon counting” mode with the integrating mode of *e.g*. CCD detectors clarifies the functional principle.

The first plot in Figure 5 shows the X-ray energy randomly deposited in time versus time. The second plot shows the collected charge pulses versus time. The third plot illustrates how an integrating detector works. It integrates all collected charges over a certain time including the leakage current of the sensor. Compared to this, plot four demonstrates the functional principle of the “single-photon counting” mode. Only the collected charge pulses that are higher than the pre-defined comparator threshold (plot two in Figure 5) cause a pulse at the output of the comparator, which is counted by the counter. The readout of the counters is done digitally and has no impact on the result of the measurement.

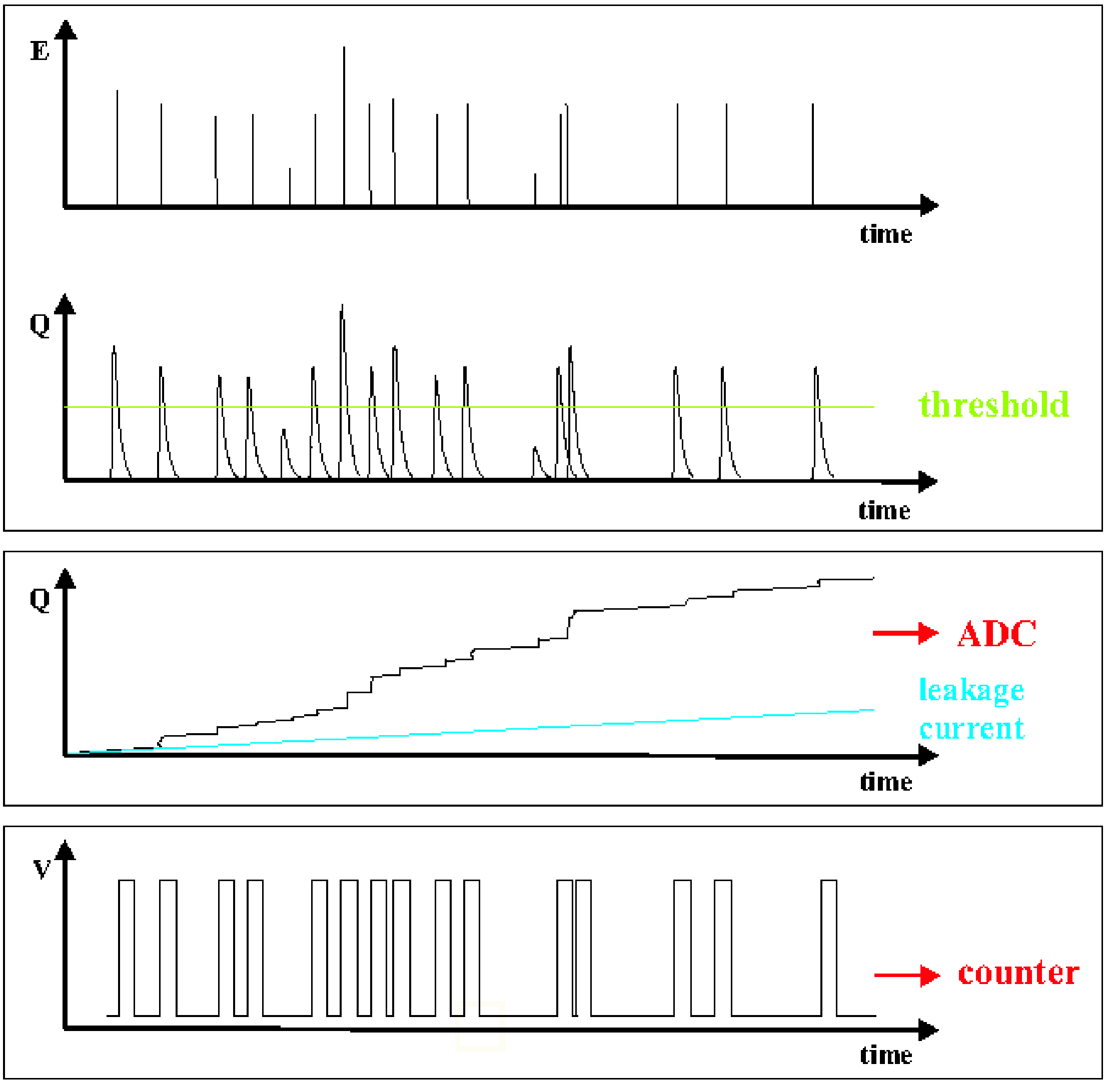

Figure 5 Comparison of the “single-photon counting” mode and the integrating mode.

A big advantage of the “single-photo counting” mode with the adjustable threshold is the background and fluorescence suppression by setting the threshold appropriately.

In principle there are only two possibilities of faked counts: background due to the high energy cosmic counts or noise counts that are caused by the readout chip intrinsic electronic noise. The former cannot be suppressed and the latter could be suppressed by setting the threshold appropriately. However, if the X-ray energy is quite low compared to the electronic noise level, the threshold has to be set even lower and therefore noise counts have to be taken into account.

4.4.1. “Single-photon counting” in the MYTHEN system

X-ray data collection can be improved with detectors operating in “single-photon counting” mode.

A hybrid channel which features “single-photon counting” comprises a charge-sensitive preamplifier (Preamp in Figure 6), which amplifies the collected charge signal generated in the sensor by the incoming X-ray. The preamplifier is followed by two shaping gain stages and a comparator (comparator in Figure 6) with a globally adjustable threshold. To correct the channel to channel variation in the globally set threshold, each comparator threshold can be adjusted by six individual trim bits (see 4.5). The comparator produces a digital signal if the incoming charge exceeds the pre-defined threshold (Figure 6). The output signal of the comparator feeds a 24 bit counter, which leads to completely digital storage and noiseless readout of the number of detected X-rays in each pixel.

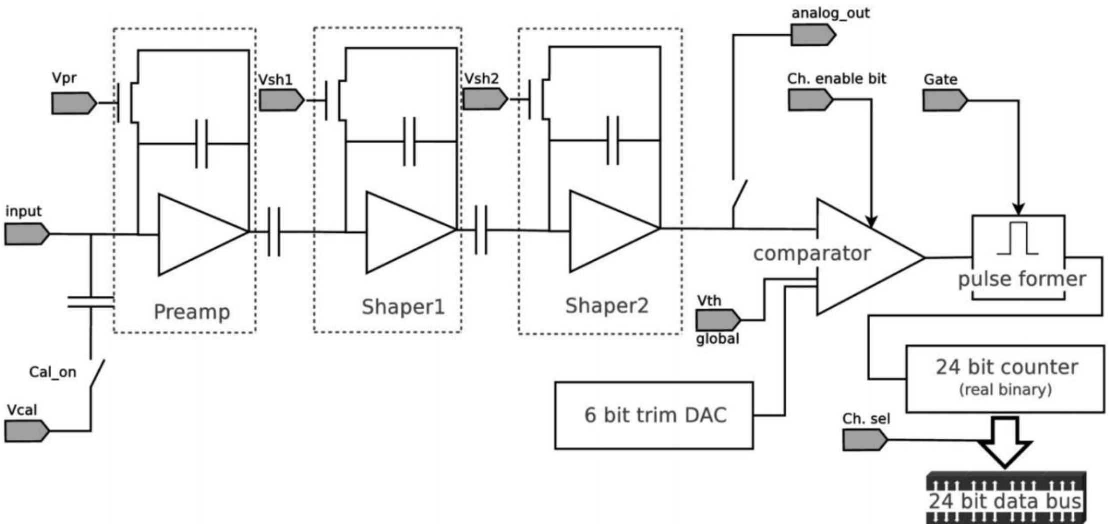

Figure 6 Design of the readout electronics of each channel.

4.5. Threshold Trimming

The analog part of the readout electronics of each channel is shown in Figure 6. The globally adjustable threshold of the comparators of a module (1280 channels) is set by a DAC 10-bit wide placed on the module control board. Therefore all channels of a module have the same threshold in DAC values, but due to the transistor variations caused by the production process of the CMOS wafers of the readout chips, the threshold varies between individual channels in terms of X-ray energy. To minimize the threshold dispersion on the module a threshold equalization technique (trimming) is applied, using the internal 6-bit DAC of each channel. In principle the trimming is a kind of fine adjustment of the comparator thresholds on a channel-by-channel basis.

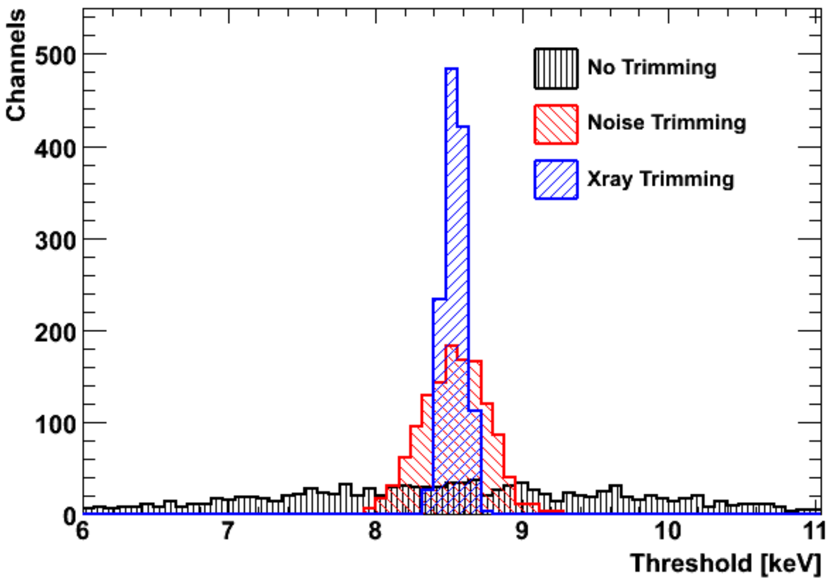

Figure 7 Threshold dispersion of an untrimmed, noise trimmed and X-ray trimmed module.

A correct trimming of the detector reduces the threshold dispersion by a factor of about 10. Figure 7 displays the threshold dispersions of a untrimmed module, an electronic noise trimmed module and a X-ray trimmed module. Since the channel to channel variations depend on the energy threshold, trim files for different energy thresholds are delivered with each MYTHEN detector system. The MYTHEN control software ensures that optimal settings are used.

4.6. Detector settings

The analog part of the readout electronic of each channel is shown in Figure 6. The gain and therefore the shaping time of each amplifier stage can be adjusted by the globally set DAC values V_{rgpr}, V_{sh1} and V_{sh2}. A high gain is related with a longer shaping time τ_s, resulting in a low maximal counting rate. Furthermore the gain is related to the electronic noise of the readout chip. A high gain correlates with a lower intrinsic electronic noise level and therefore enables to measure lower X-ray energies.

The MYTHEN software will always chose optimal gain settings based on the threshold energy in use. For a given threshold energy, the gain is set as low as the electronic noise level allows to. This avoids noise counts from the electronic while keeping the shaping time as low as possible. At threshold energies about 4-5 keV the gain reaches it maximal value. For threshold energies below this value, the gain and shaping time stay constant, while the noise rate starts to increase, see Figure 8.

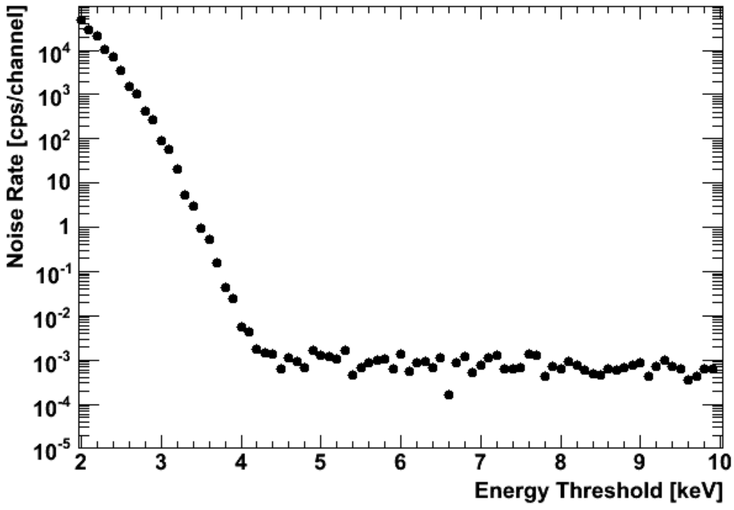

Figure 8 Noise rate as a function of energy threshold

In the simplest case, the user only specifies the X-ray energy and lets MYTHEN software choose a suitable energy threshold. The energy threshold is chosen as shown in Figure 9. For energies above Molybdenum (17.8 keV), the threshold energy is the half the X-ray energy. Below 17.8 keV, the threshold energy is interpolated between 6.4 keV for Copper (E = 8.05 keV) and 4.8 for Chrome (E = 5.41 keV). The threshold energy can also be customized by the user. In that case, the user specifies the energy and threshold energy independently.

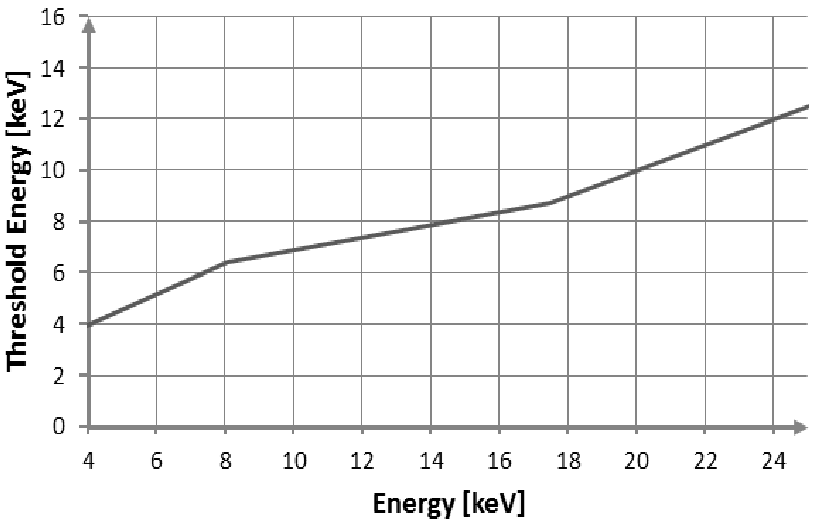

Figure 9 Threshold energy as a function of X-ray energy.

4.7. Flatfield correction

Due to variations in the charge collection efficiencies of the sensor and geometrical effects (*e.g*. channels next to the edge of the sensor collect charge from a larger sensor volume) there are differences in the number of counted X-rays on a channel to channel basis. Since these variations are stable in time, a flatfield correction can be applied. The flatfield correction is based on uniformly illuminated images with high statistics. DECTRIS Ltd. provides flatfield files for typical monochromatic X-ray energies, which are used to correct acquired images.

4.8. Count rate correction

At high fluxes a photon-counting system will miss some photons due to pile-up of the amplified signal. The loss of efficiency for the MYTHEN detector can be modeled by an ideal, paralyzable detector, for which each photon leads to a dead-time of fixed length. In this model the observed rate $N_{observed}$ depends on the incoming rate $N_{incoming}$ according to:

$$N_{observed} = N_{incoming} e^{-N_{incoming}\tau},$$

where τ is the detector dead time, which depends on the shaping time. As explained above, the gain (and therefore the shaping) is chosen based on the threshold energy. Therefore the dead time depends on the threshold energy. The recommended rate below which more than 97% of the photons are detected is shown in

Figure 10. The determination of these values was based on the model comprising two modules, with 320 µm thick sensor. The exact values can differ from module to module, especially for modules with thicker sensors. It should be noted, that when applying a rate correction based on the above formula, the incoming rate can still be determined up to rates, which are about 15 times higher than the recommended rate.

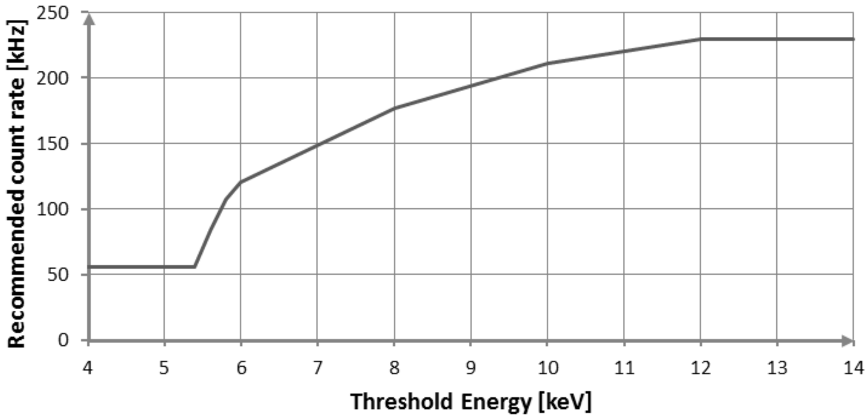

Figure 10 Recommended count rates as a function of the threshold energy. More details are given in the text.

4.9. Detector module

The fundamental unit of the DECTRIS Ltd. MYTHEN detector system is the one dimensional detector module, consisting of a single fully depleted monolithic silicon sensor wire-bonded to an array of 10 CMOS readout chips. Each sensor is a continuous array of 1280 channels without dead areas covering an active area of 8 x 64 mm^2. The readout chips are wire-bonded to the underlying print on which the sensor and the readout chips are glued to. Together with its readout control electronics the sensor with readout chips form the complete detector module (Figure 11).

Figure 11 The MYTHEN detector module is the basic element of all DECTRIS Ltd. one dimensional detector systems

4.10. Triggering and Gating

The MYTHEN detector system can be triggered or gated to synchronize the system with other devices. For details see **Trigger Notes** available at DECTRIS Ltd. (see 2.1 for support).

4.11. Interface

The MYTHEN detector system offers different possibilities for communication.

If you want to operate the detector system as a stand-alone device, there is a **web client** available for controlling the detector system. For details see **Quick Start Guide** available at DECTRIS Ltd. (see 2.1 for support).

If you want to integrate the detector system in your environment, the **socket interface** is recommended. For details see **Socket Interface Specifications** available at DECTRIS Ltd. (see 2.1 for support).

For Integration there is also the possibility of **SPEC**. For details see **Socket Interface Specifications** available at DECTRIS Ltd. (see 2.1 for support).

5. Appendix

5.1. List of Figures

5.2. Referenced Documents

All the following documents are available through DECTRIS Ltd. homepage.

https://www.dectris.com/technical_mythen.html#main_head_navigation

Term	*Description*
Firmware Update Guide	Firmware_Update-MYTHEN-V2.pdf
Module Handling Instructions	Handling_Instructions-MYTHEN-V3.pdf
Linux Installation Guide	Linux_Installation-HowTo_MYTHEN-V2.pdf
Network Settings	Network_Settings-MYTHEN-V2.pdf
Quick Start Guide	QuickStart-MYTHEN-V3.pdf
Socket Interface Specifications	Socket_Interface_Spec-MYTHEN-V3.1.0-V1.pdf
Technical Documentation	Technical_Documentation-MYTHEN-V2.pdf
Trigger Notes	Trigger_Note-MYTHEN-V3.pdf
User Manual	User_Manual-MYTHEN-V3.pdf