Spectrometer modules

Ultimate Power

Compendium
Spectrometer modules

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Content

Introduction 05

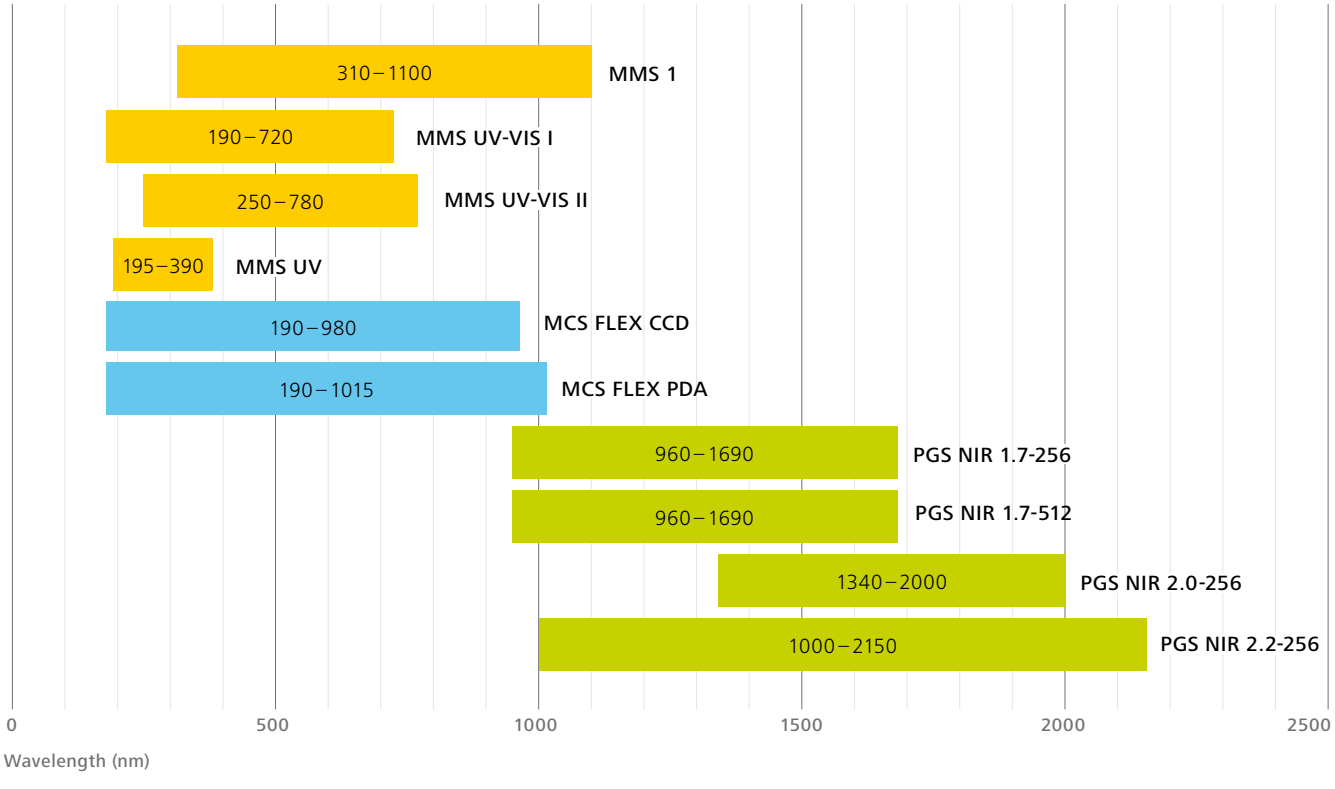
Spectrometer modules
MMS family 07
MCS FLEX family 13
PGS family 17

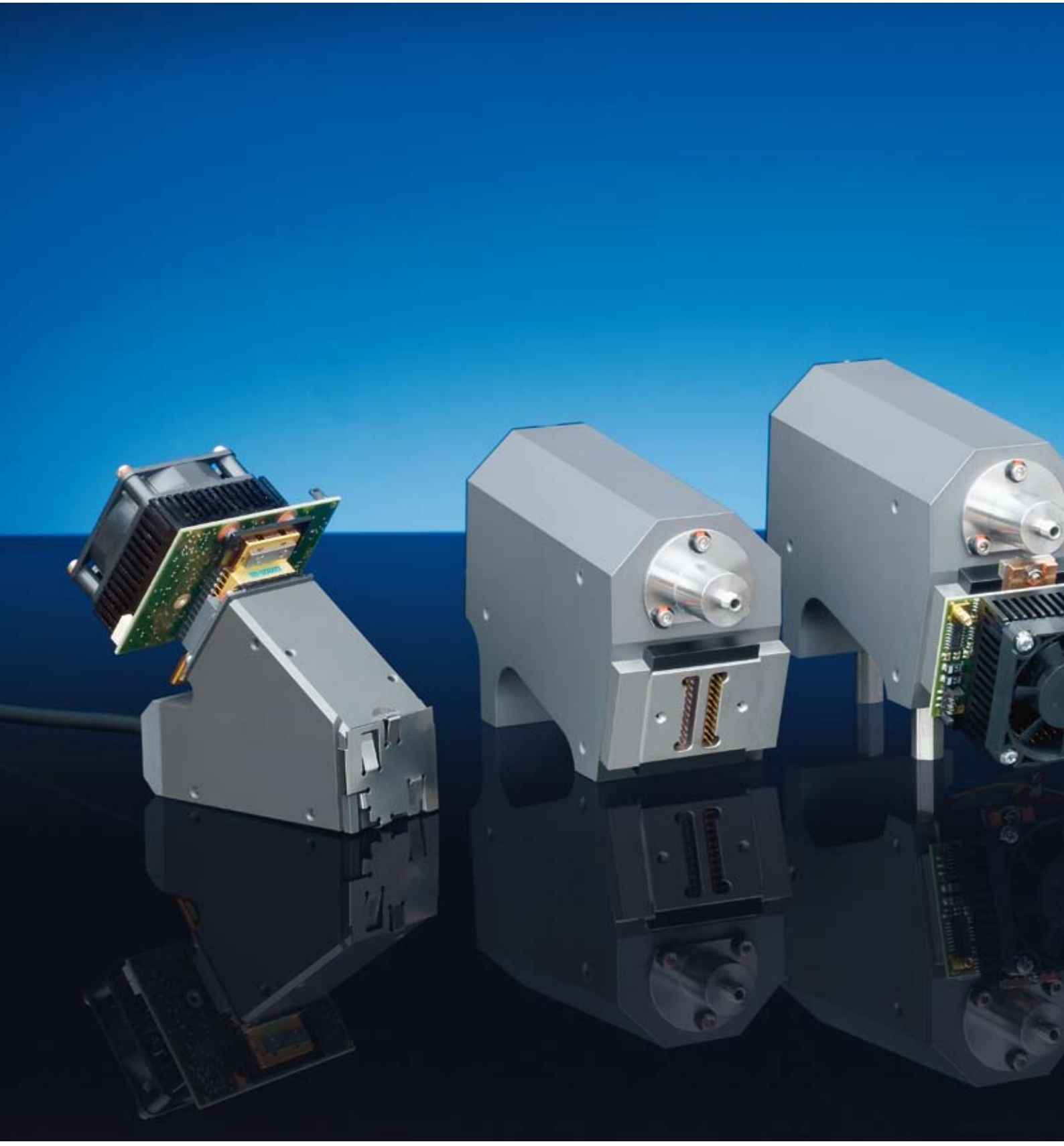
Electronics
Operating electronics for spectrometer modules 23
Operating electronics for MMS 25
Operating electronics for MCS FLEX PDA 29
Operating electronics for MCS FLEX CCD 35
Operating electronics for PGS 41

Software
Software products 49

Applications 55
Definitions and explanations of terms 59

Overview Spectrometer modules





Introduction
Your application – our drive

A classic spectrometer or a classic monochromator typically consists of a dispersive medium, entrance and exit slit, and imaging components which produce a parallel beam path. To record a spectrum, a detector located behind the exit slit must sequentially record the incident light, while the dispersive component or the exit slit is moved.

This mechanical movement requires time and is prone to failure. In many applications – in industry in particular – short measuring times and insensitivity to external influences are a major advantage. This is why, at the end of the 1970s, Carl Zeiss started to develop diode array spectrometers which feature a diode array instead of an exit slit and which simultaneously record a complete spectrum within a fraction of a second and hence make moving components superfluous. The concept of the spectrometer module family of Carl Zeiss is based on reducing the optomechanical design and the number of components to the physical minimum and, at the same time, to share a maximum number of components in all versions.

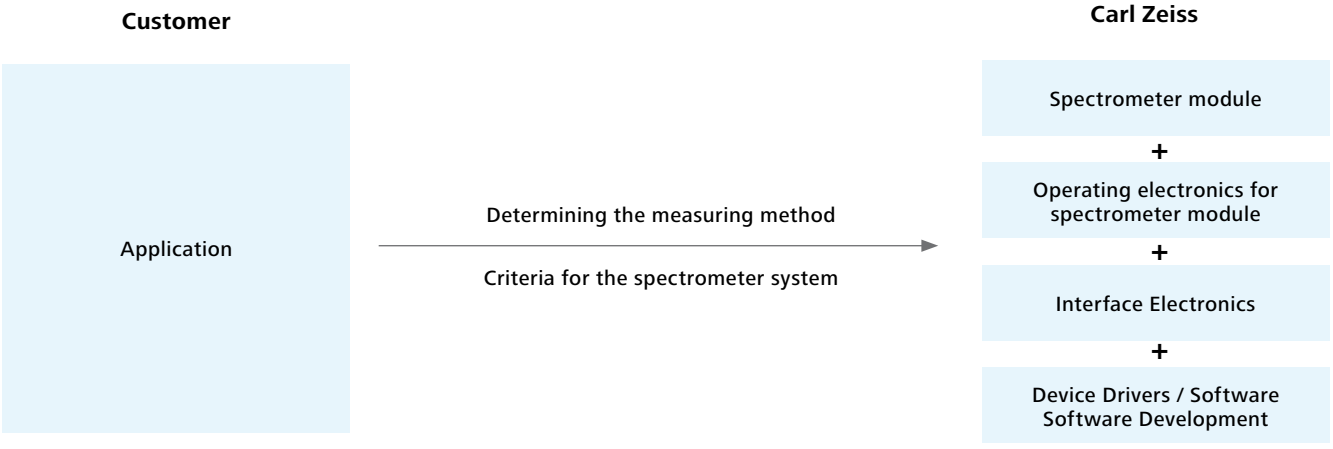
In the past few years Carl Zeiss has developed a large number of different spectrometer modules for a wide variety of applications and requirements, all of which offer a distinct benefit: All the spectrometer components are permanently attached to each other. This results in a very high level of isolation from mechanical vibrations and therefore also to a high degree of reliability. In addition, the entire setup is maintenance-free, i.e. recalibration is not necessary. The basis of the high quality offered by the spectrometers is the technological know-how of Carl Zeiss for mathematical designs, structuring (grating production and replication), coating and material processing. In addition, our assembly method is of key importance for the high level of insensitivity to such influences as vibrations and, above all, temperature changes.

The following spectrometer module families have been developed at Carl Zeiss:

- MMS – Monolithic Miniature Spectrometer
- MCS FLEX – Multi Channel Spectrometer
- PGS – Plane Grating Spectrometer

Customized configuration

The customized configuration of complete spectrometer systems received the same attention at Carl Zeiss as the development and production of spectrometer modules. After all, Carl Zeiss would not be Carl Zeiss if the overall solution was not specifically in line with the customer's needs. Accordingly, not only the suitable spectrometer modules are available for specific measuring tasks, but also the electronics, interfaces and processing software. Furthermore, this approach guarantees a consistently high level of performance and quality of all system components.



MMS family
Monolitical compact

The extremely compact design is a characteristic feature of the spectrometers in the MMS family. Small designs are possible because high repeatability, not high resolving power is required for many applications.

Optical components of the MMS family

- imaging grating
- cross-section converter as optical input
- diode array as opto-electronic output

are arranged around a central body and are attached to it. Depending on the version, the central bodies may have different designs. The two components important for the interfaces – the cross-section converter and detector – are common to all.

Central body
In the MMS 1, the central body contains a glass element similar to a lens. The imaging grating has been directly replicated on this glass element; the grating is thus permanently fixed and optimally protected against dust and gases. The use of an optically denser medium and the resultant larger aperture allows the use of small gratings. This leads to fewer aberrations.

For reasons of transmission, the solid glass element has been replaced in the UV-sensitive modules by a hollow shell to which the grating and the detector have been cemented. The overall stability is not impaired by the tube design; the temperature-induced drift of the wavelength has even been reduced.

Gratings
The gratings for the MMS family itself consist of so-called holographic blazed, flat field gratings. These gratings which are produced at Carl Zeiss in a stationary wave process achieve significantly higher degrees of efficiency (for non-polarized light) than gratings with a sinusoidal profile. In addition to its dispersive function, the grating must image the entrance slit on the detector array. By varying the groove density and using curved grooves, coma is corrected and the image plane flattened (flat field). This ensures that the image is optimized on the flat detector structure. Even with the short back focal distance of the MMS 1, flat spectra of a length of over 6 mm are obtained. The same grating design is used for the VIS and the UV-VIS versions. The master grating has its efficiency maximum at approx. 220 nm. Due to the higher optical density, the efficiency curve of the VIS module is shifted by the factor of the refractive index.

Cross-section converter
A fiber bundle, cross-section converter is used to further optimize the light sensitivity of the module. Single fibers in a linear configuration form the entrance slit (slit height h times the fiber diameter; slit width b ≈ core diameter). The diameter has been adapted to the pixel size of the diode array used and the imaging and dispersive properties of the flat field grating. Thus, light intensities near the theoretical limit are achieved. The cross-section converter is an integral component of the spectrometer design and is therefore not easy to modify. There is a possibility, however, of modifying the length of the fibers and the design of the input.

In addition, it must be taken into account that quartz fibers which are used in older MMS UV-(VIS-) modules form so-called solarization centers when they are exposed to deep UV light below 220 nm. That means that the transmission of the fibers is reduced when they are exposed to high-energy light. The shorter the wavelength of the light (higher photon energy) and the higher the intensity and the longer the exposure time, the stronger and sooner this effect occurs. This means that the transmission can even be restricted in the range of more than 220 nm to 250 nm. This solarisation effect can only be partly cancelled by heating, but it is possible to correct it by means of frequent reference measurements. For measurements below 225 nm, it is possible to equip the MMS modules with solarization stabilized fibers. In the standard modules, the use of a Schott WG225 filter with a thickness of 3 mm is definitely recommended.

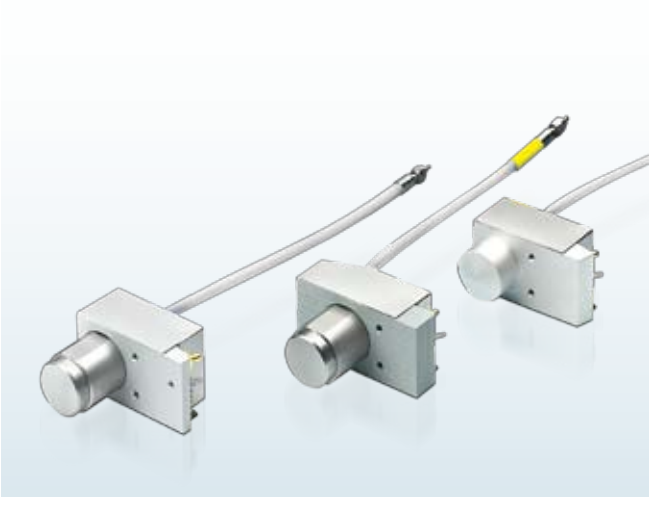
Detector

MMS
The silicon diode array S3904-256Q from Hamamatsu is incorporated in the MMS family. The MMS 1 NIR enhanced uses the Hamamatsu type S8381-256Q. This array is packed in a shorter special housing which results in a very small split-off angle, allowing an efficient grating design. When changing to a different detector, this angle and the approximate spectrum length of 6 mm must be taken into account.

To suppress the second order, the diode array has been directly coated with a dielectric cut-off filter.

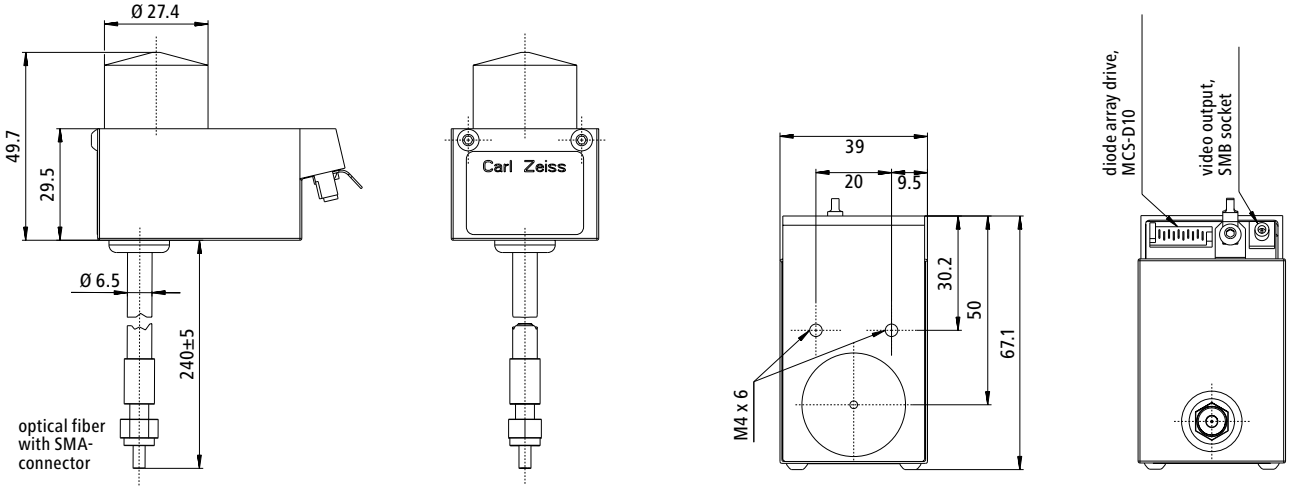
The following modules are available:

Module	Spectral range (nm)
MMS 1	310 – 1100
MMS UV-VIS	190 – 720 or 250 – 780
MMS UV	195 – 390



Technical Specifications

Optical entrance		Fiber bundle consisting of approx. 30 quartz glass fibers with 70 µm core diameter each, designed as a cross section converter
	input round	Diameter: 0.5 mm NA = 0.22 (has to be filled for full specification) mounted in SMA-coupling
	output linear	70 µm x 2500 µm (optical entrance)
Grating		Flat-field, 366 l/mm (center)
Diode array		Producer: Hamamatsu Type: S3904-256Q in a special housing (S5713) (S8381-256Q for MMS 1 NIR enhanced) Number pixels: 256
Spectral range		310 nm – 1100 nm specifications for the range 360 nm – 900 nm (UV-VIS enhanced) 400 nm – 1000 nm (NIR enhanced)
Wavelength accuracy		0.5 nm
Temperature – induced drift		< 0.01 nm/K
Mean spectral pixel pitch		$\Delta\lambda_{Pixel} \approx 3.3$ nm
Resolution		$\Delta\lambda_{FWHM} \approx 10$ nm
Sensitivity		$\approx 10^3$ Vs/J
Straylight		≤ 0.8 % with Halogen lamp for UV-VIS enhanced as transmission at 450 nm with filter GG 495 ≤ 0.2 % with Halogen lamp for NIR enhanced as transmission at 650 nm with filter RG 695
Dimensions	**total (with case)** **cross section converter (external length)**	70 x 50 x 40 mm³ 240 mm standard, up to 1 m available



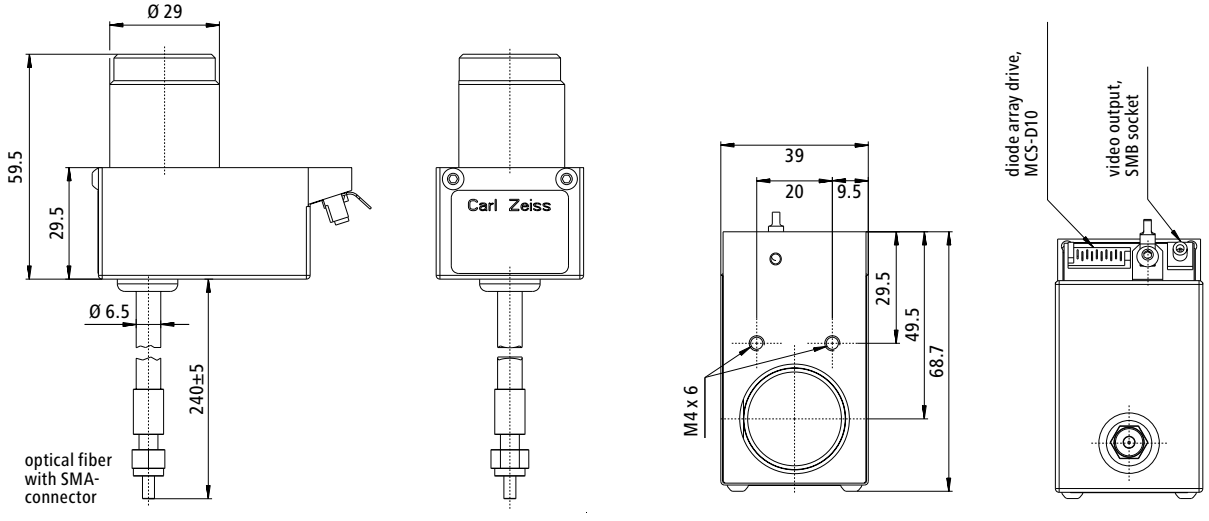
Order No.	Designation	Wavelength range	Description
224001-9001.000	MMS 1 UV/VIS enh.	310 – 1100 nm	PDA with 256 pixels, 240 mm external fiber length
224001-9011.000	MMS 1 UV/VIS enh.	310 – 1100 nm	PDA with 256 pixels, 180 mm external fiber length
000000-1233.038	MMS 1 NIR enh.	310 – 1100 nm	S8381 PDA with 256 pixels, 240 mm external fiber length

Order numbers for operating electronics ➔ Page 27, Order numbers for software products ➔ Page 53

MMS UV-VIS I / UV-VIS II

Technical Specifications

Optical entrance		Fiber bundle consisting of approx. 30 quartz glass fibers with 70 µm core diameter each, designed as a cross section converter
	input round	Diameter: 0.5 mm NA = 0.22 (has to be filled for full specification) mounted in SMA-coupling
	output linear	70 µm x 2500 µm (optical entrance)
Grating		Flat-field, 366 l/mm (center), blazed for approx. 220 nm
Diode array		Producer: Hamamatsu Type: S3904-256Q in a special housing (S5713) Number pixels: 256
Spectral range	**UV-VIS I**	190 nm – 720 nm specifications for the range 220 nm – 720 nm
	UV-VIS II	250 nm – 780 nm specifications for the range 250 nm – 780 nm
Wavelength accuracy		0.5 nm
Temperature – induced drift		≤ 0.006 nm/K
Mean spectral pixel pitch		$\Delta\lambda_{Pixel} \approx 2.2$ nm
Resolution		$\Delta\lambda_{FWHM} \approx 7$ nm
Sensitivity		$\approx 10^3$ Vs/J
Straylight		≤ 0.3 % with Deuterium lamp as transmission at 365 nm with $NaNO_2$-solution (50 g/l)
Dimensions	**total (with case)**	67 x 60 x 40 mm³
	cross section converter (external length)	240 mm standard, up to 1 m available

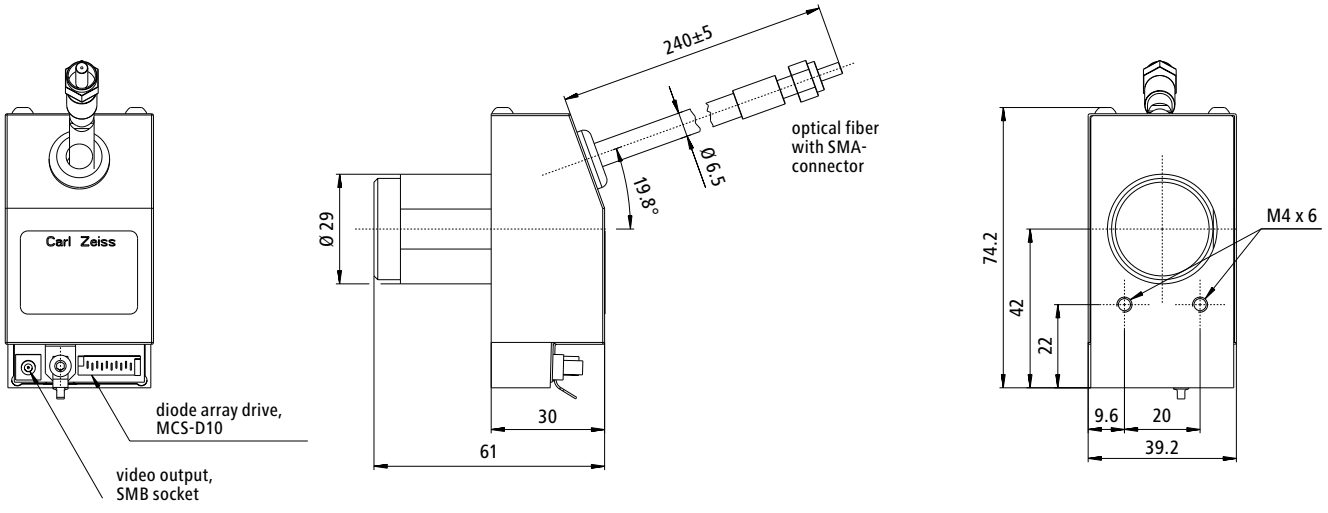


Order No.	Designation	Wavelength range	Description
224000-9001.000	MMS UV-VIS I	190 – 720 nm	PDA with 256 pixels, 240 mm external fiber length
000000-1410.176	MMS UV-VIS I	190 – 720 nm	PDA with 256 pixels, 240 mm external fiber length solarisation stabilized
000000-1090.197	MMS UV-VIS II	250 – 785 nm	PDA with 256 pixels, 240 mm external fiber length

Order numbers for operating electronics ➔ Page 27, Order numbers for software products ➔ Page 53

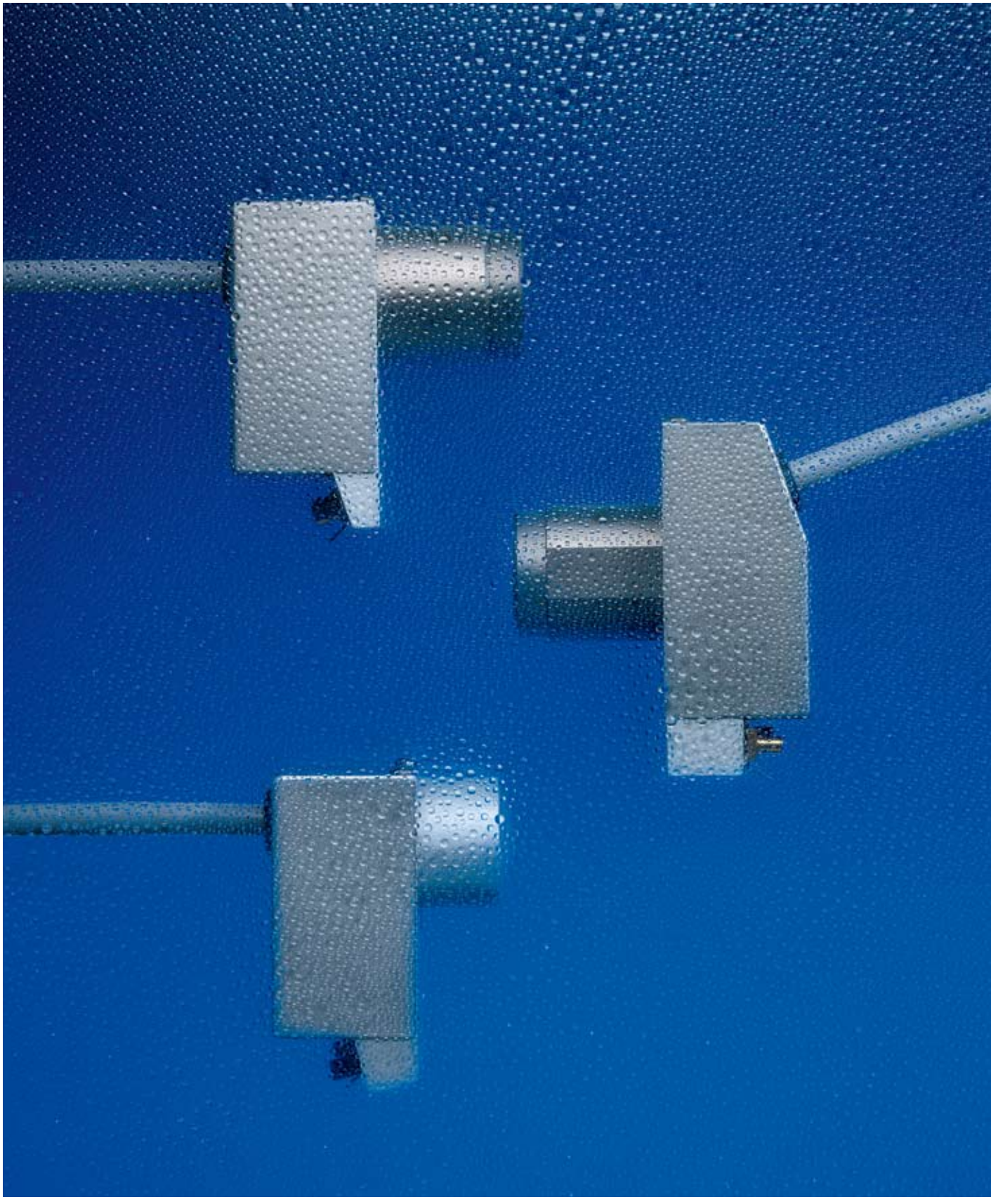
Technical Specifications

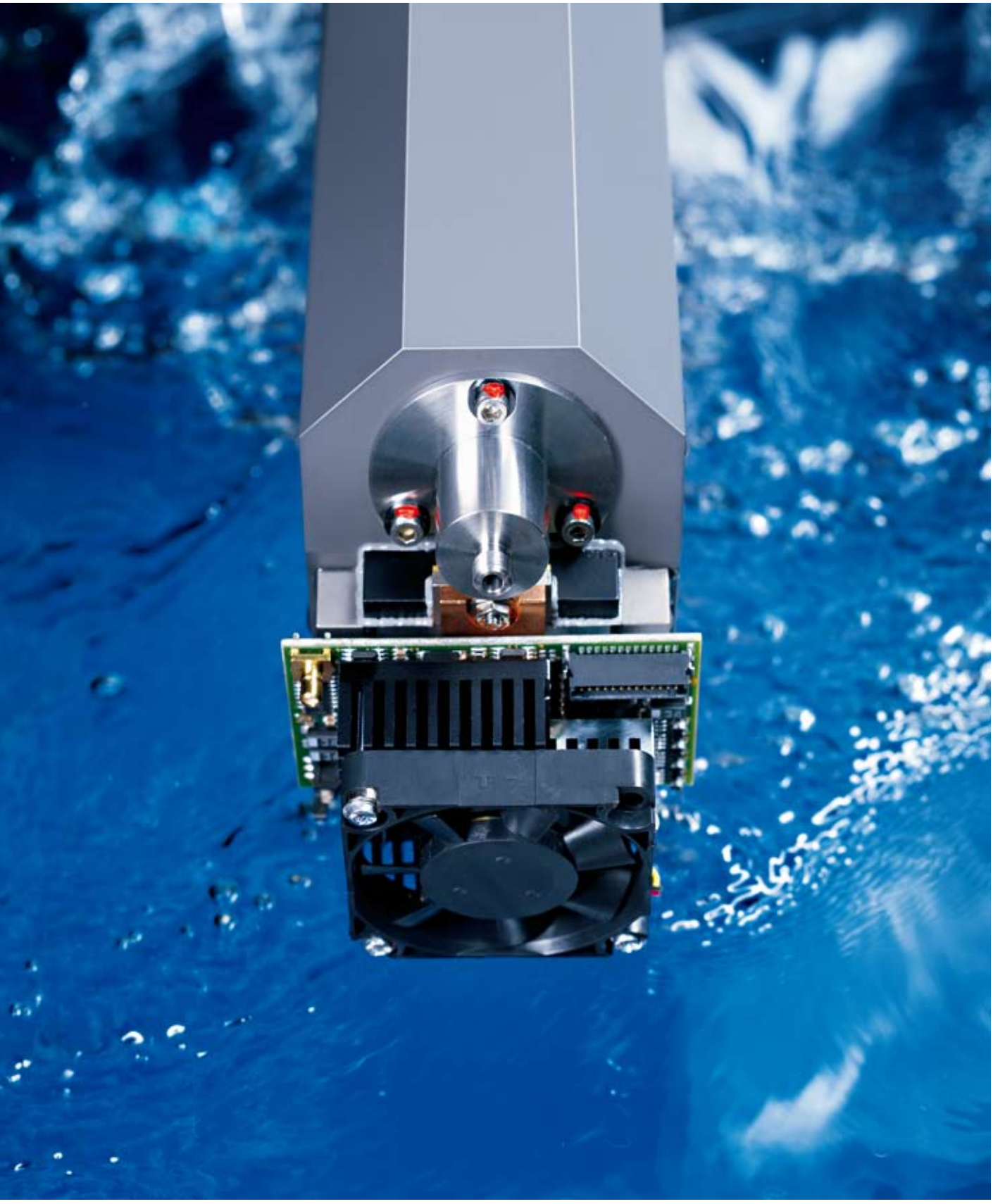
Optical entrance		Fiber bundle consisting of approx. 15 quartz glass fibers with 70 µm core diameter each, designed as a cross section converter
	input round	Diameter: 0.4 mm NA = 0.22 (has to be filled for full specification) mounted in SMA-coupling
	output linear	70 µm x 1250 µm (optical entrance)
Grating		Flat-field, 1084 l/mm (center) blazed for approx. 220 nm
Diode array		Producer: Hamamatsu Type: S3904-256N in a special housing (S5713) Number pixels: 256
Spectral range		195 nm – 390 nm specifications for the range 220 nm – 390 nm
Wavelength accuracy		0.2 nm
Temperature – induced drift		< 0.005 nm/K
Mean spectral pixel pitch		$\Delta\lambda_{Pixel} \approx 0.8$ nm
Resolution		$\Delta\lambda_{FWHM} \approx 3$ nm
Sensitivity		$\approx 10^3$ Vs/J
Straylight		≤ 0.3 % Deuterium lamp as transmission at 240 nm with NaJ-solution (10 g/l)
Dimensions	**total (with case)** **cross section converter (external length)**	70 x 60 x 40 mm³ 240 mm standard, up to 1 m available



Order No.	Designation	Wavelength range	Description
224002-9020.000	MMS UV	195 – 390 nm	PDA with 256 pixels, 240 mm external fiber length
000000-1392.178	MMS UV	195 – 390 nm	PDA with 256 pixels, 240 mm external fiber length solarisation stabilized

Order numbers for operating electronics ➔ Page 27, Order numbers for software products ➔ Page 53





MCS FLEX family
Unstoppable

The MCS FLEX family offers spectrometers which feature both high repeatability and good resolving power. To achieve a robust design, all optical components are permanently connected to each other via a central body.

Optical components of the MCS FLEX family

- imaging, aberration-corrected grating
- fiber cross-section converter or slit as optical input
- photo diode array or thermo-electrically cooled back-thinned CCD as opto-electronic output

In the MCS FLEX family, the different designs of the central body once again define the application of the system. The cross-section converter and detector are used in all the different versions.

Central body
For reasons of thermal stability, the central body of the MCS FLEX spectrometers is made of a special aluminum alloy (coefficient of expansion α~13E-6). The aberration-corrected grating, the cross-section converter (or mechanical slit) as the optical input and the detector are connected to each other via this housing, ensuring outstanding stability and reliability. The hollow shell design allows the use of the MCS FLEX for the complete spectrum from UV-NIR.

Gratings
The gratings used for the MCS FLEX family are holographically blazed, flat field gratings. Through additional ion beam etching, the maximum grating efficiency is optimized for the various wavelength ranges. Plane spectra are achieved over a length of 25 nm via the aberration correction. The grating diameter is dimensioned the way that the light of a fiber with NA = 0.22 can be hold.

Cross-section converters
A fiber-bundle, cross-section converter is used for further optimization of the light intensity. The entrance slit is generated by the linear arrangement of the individual fibers (slit height h, defined by the number of the individual fibers, slit width b – core diameter). The slit is adapted to the pixel size of the detector element used and to the imaging and dispersive properties of the flat field grating. In this way, light intensities are achieved at the theoretical limit. The cross-section converter is an integral component of the spectrometer design and cannot therefore be easily modified. However, there is a possibility of changing the length of the fiber and the design of the input. Furthermore, care must be taken as quartz fibers like those used in some types of MCS FLEX modules form so-called solarization centers when exposed to deep UV light under 220 nm. This means that the transmission of the fibers decreases with exposure to high-energy light. This effect is more pronounced, the shorter the wavelength (higher photon energy), the greater the intensity and the longer the exposure time. This can also lead to limitation of the transmission above 220 to 250 nm. This solarization effect can be partly reversed by baking, but can be corrected by frequent reference measurements. For measurements below 225 nm, it is possible to equip the MCS FLEX modules with solarization stabilized fibers. In the standard modules, the use of a Schott WG225 filter with a thickness of 3 mm is definitely recommended.

Detector

MCS FLEX PDA
In the MCS FLEX PDA the photo diode array S3904-1024Q from Hamamatsu is used. To suppress the 2nd order and the 3rd order, the diode array is directly coated with dielectric cut-off filters.

Module	Spectral range (nm)
MCS FLEX PDA	190 – 1015

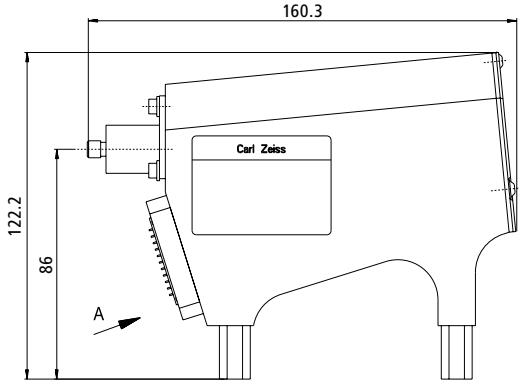
MCS FLEX CCD
In the MCS FLEX CCD module, the back-thinned CCD S7301-1006Q from Hamamatsu is used. Back-thinned CCDs offer excellent direct sensitivity to UV light. To reduce the dark current, this detector features an integrated Peltier element which has to be externally activated. In the MCS FLEX CCD, the heat removed by the Peltier element is routed to the fan-cooled heat sink. To suppress the 2nd order and the 3rd order, the CCD is directly coated with dielectric cut-off filters.

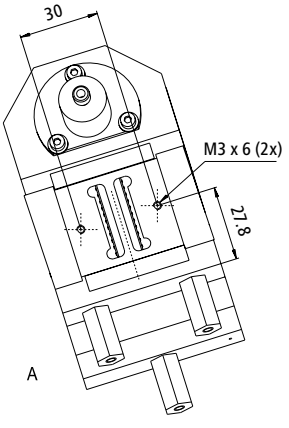
Module	Spectral range (nm)
MCS FLEX CCD	190 – 980

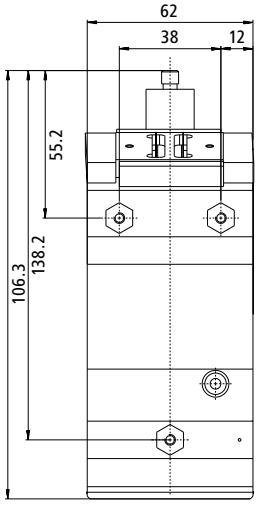
MCS FLEX PDA

Technical Specifications

Optical entrance	Cross Section Converter
CSC version	Diameter: 0.5 mm NA = 0.22 (has to be filled for full specification) mounted in SMA-coupling
Grating	Flat-field correction 248 l/mm (center), blazed for approx. 250 nm
Diode array	Producer: Hamamatsu Type: S3904-1024Q Number pixels: 1024
Spectral range	190 – 1015 nm
Wavelength accuracy	0.5 nm
Temperature – induced drift	≤ 0.009 nm/K
Mean spectral pixel pitch	$\Delta\lambda_{Pixel} \approx 0{,}8$ nm
Resolution	$\Delta\lambda_{FWHM} \approx 3-4$ nm
Straylight	≤ 0.1 % measured at 340 nm with Deuterium lamp (transmission of $NaNO_2$ solution, 50 g/l, 1 cm)
Dimensions	160.3 x 62 x 122.2 mm







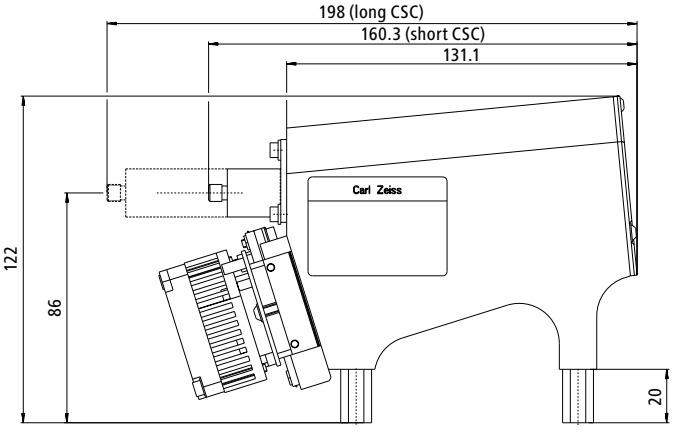
Order No.	Designation	Wavelength range	Description
000000-1459.276	MCS FLEX UV-NIR	190 – 1015 nm	PDA with 1024 pixels

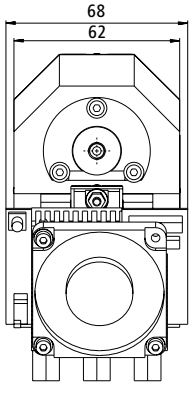
Order numbers for operating electronics ➔ Page 33, Order numbers for software products ➔ Page 53

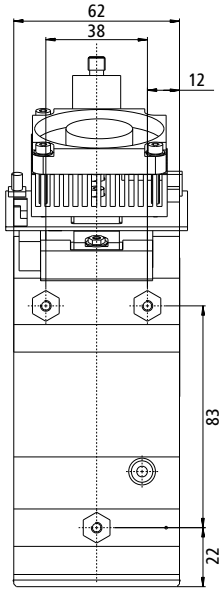
MCS FLEX CCD

Technical Specifications

Optical entrance	Cross Section Converter
CSC version	Diameter: 0.5 mm NA = 0.22 (has to be filled for full specification) mounted in SMA-coupling
Grating	Flat-field correction 248 l/mm (center), blazed for approx. 250 nm
Diode array	Producer: Hamamatsu Type: S7031-1006 Number pixels: 1044 x 64
Spectral range	190 – 980 nm
Wavelength accuracy	0.5 nm
Temperature – induced drift	≤ 0.009 nm/K
Mean spectral pixel pitch	$\Delta\lambda_{Pixel} \approx 0{,}8$ nm
Resolution	$\Delta\lambda_{FWHM} \approx 3-4$ nm (UV-NIR Version)
Straylight	≤ 0.1 % measured at 340 nm with Deuterium lamp (transmission of $NaNO_2$ solution, 50 g/l, 1 cm)
Dimensions	198 x 68 x 122 mm (long Cross Section Converter) 160.3 x 68 x 122 mm (short Cross Section Converter)

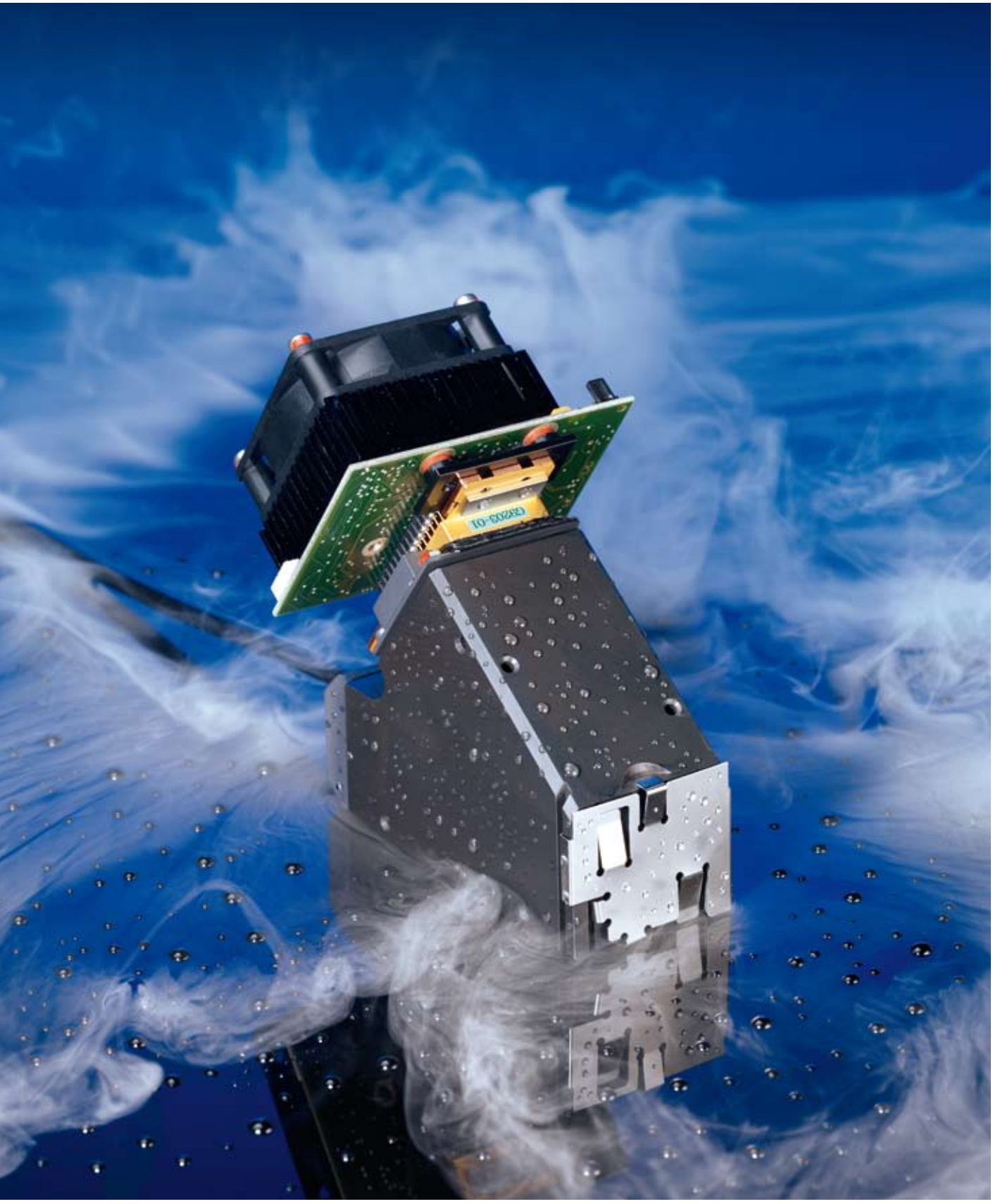






Order No.	Designation	Wavelength range	Description
000000-1423.352	MCS FLEX CCD UV-NIR	190 – 980 nm	with CCD Detector Hamamatsu S7031 with 1024 (1044) x 64 pixels, short CSC
000000-1761.535	MCS FLEX CCD UV-NIR	190 – 980 nm	with CCD Detector Hamamatsu S7031 with 1024 (1044) x 64 pixels, long CSC

Order numbers for operating electronics ➔ Page 39, Order numbers for software products ➔ Page 53



PGS family
The NIR Specialists

The spectrometers of the PGS family are designed for use in the NIR. InGaAs (indium-gallium-arsenide) is used as a detector material in this wavelength range. The special combination of aspheric collimator and focusing lens allows the use of plane gratings optimized for the NIR, while maintaining good flat field correction of the spectral imaging. Excellent long-term stability is ensured by the permanent connection of all optical components.

Optical components of the PGS family

- blazed plane gratings
- aspheric lenses
- mono-fiber with slit as optical input
- cooled InGaAs photodiode array as opto-electronic output

Central body
In the PGS family, a special aluminum alloy (coefficient of expansion α~13E-6) is used for the central body. This housing is the carrier of the blazed grating and of the aspheric collimator and focusing lens. The input fiber and the detector are permanently connected to the central body, therefore providing excellent stability.

Gratings
The gratings for the PGS family are mechanically ruled or holographically recorded plane gratings. The maximum efficiency is adapted to the special wavelength range in the NIR. The grating surface with the clear diameter of the lenses is dimensioned so that the light of a fiber with NA of up to 0.37 can be hold.

Input fiber
The coupling of light is performed in the standard way via a glass monofiber. These fibers have a diameter of 600 µm and a NA = 0.22. The end of the fiber features a slit with a height of 500 µm (NIR 1.7) or 250 µm (NIR 2.2). The slit heights at the entrance are adapted to the pixel heights of the InGaAs arrays. A crosssectional conversion similar to the silicon detectors is not necessary.

Detector
For the PGS NIR 1.7 standard InGaAs is used for the wavelength range up to 1700 nm. Detectors with 256 or 512 elements are available. To go up to the wavelength range of 2.2 µm the use of Extended InGaAs is necessary. In the PGS NIR 2.0 and PGS NIR 2.2 detectors with 256 elements are used. For the Extended InGaAs arrays, blocking filter for suppressing the 2nd diffraction order is applied to the array.

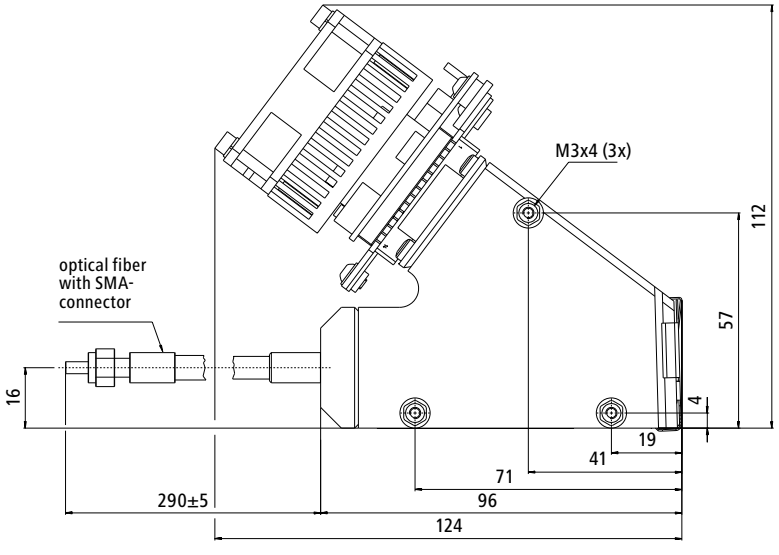
The following modules are available:

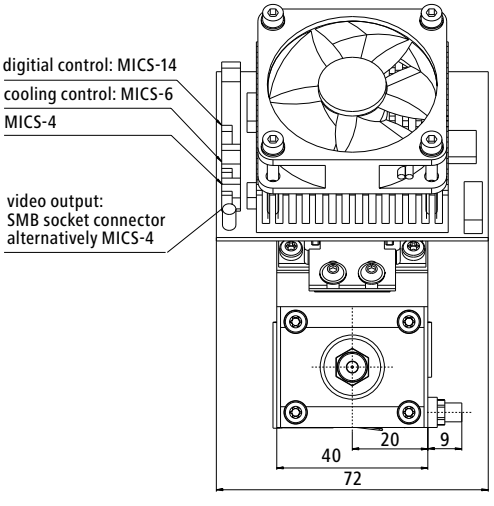
Module	Spectral range (nm)
PGS NIR 1.7-256	960 – 1690
PGS NIR 1.7-512	960 – 1690
PGS NIR 2.0-256	1340 – 2000
PGS NIR 2.2-256	1000 – 2150

PGS NIR 1.7-512

Technical Specifications

Optical entrance	Fiber consisting of Infrasil-quartz glass
input round	Diameter: 0.6 mm Length: 300 mm NA = 0.22 (has to be filled for full specification) mounted in SMA-coupling
output linear	Slit width: 80 µm
Filter	950 nm edge filter
Grating	Plane grating, 484 l/mm, blazed for approx. 1.2 µm
Diode array	Producer: Sensor Unlimited Inc Type: SU512LD-1.7 T1 Number pixels: 512
Spectral range	960 – 1690 nm
Wavelength accuracy	± 1 nm
Temperature – induced drift (10–40°C)	< 0.012 nm/K
Mean spectral pixel pitch	$\Delta\lambda_{Pixel} \approx 1.5$ nm
Resolution	$\Delta\lambda_{FWHM} \approx 5$ nm
Straylight	≤ 0.1 % as transmission of 10 mm water at 1405 nm (exposure from halogen lamp)
Weight	approx. 590 g
Operating temperature	0 – 40°C (standard, depending on cooling electronic)
Storage temperature	-40 – +70°C





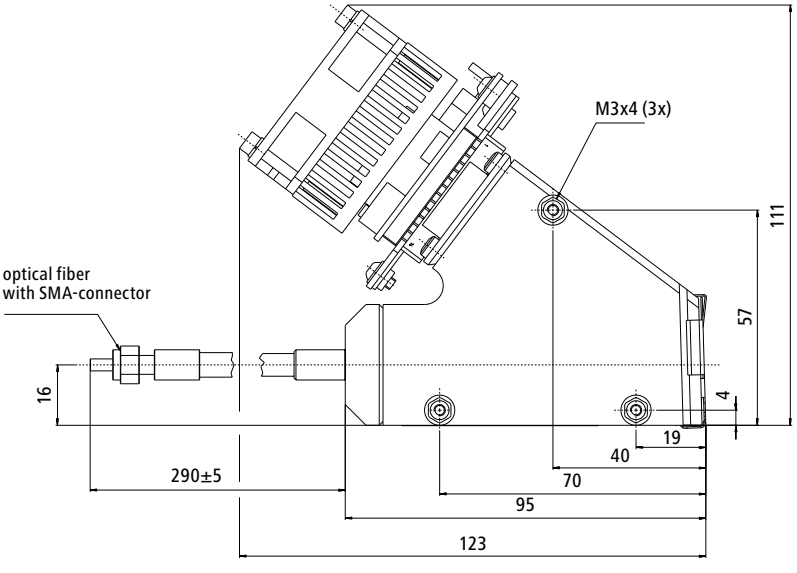
Order No.	Designation	Wavelength range	Description
000000-1307.412	PGS NIR 1.7 t1-512	960 – 1690 nm	NIR Spectral Sensor, Peltier cooled, InGaAs-PDA 1.7 µm (cut-off) 512 Pixel, Dispersion 1.5 nm/pixel, 300 mm external fiber length

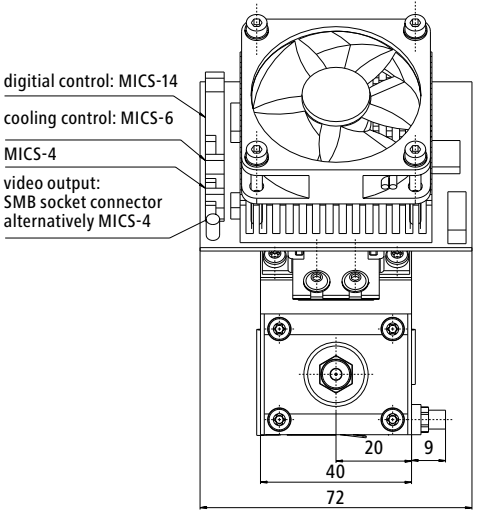
Order numbers for operating electronics ➔ Page 43, Order numbers for software products ➔ Page 53

PGS NIR 1.7-256

Technical Specifications

Optical entrance	Fiber consisting of Infrasil-quartz glass
input round	Diameter: 0.6 mm Length: 300 mm NA = 0.22 (has to be filled for full specification) mounted in SMA-coupling
output linear	Slit width: 80 µm
Filter	950 nm edge filter
Grating	Plane grating, 484 l/mm, blazed for approx. 1.2 µm
Diode array	Producer: Hamamatsu Type: S9203-256 Number pixels: 256
Spectral range	960 – 1690 nm
Wavelength accuracy	± 1 nm
Temperature – induced drift (10 – 40°C)	< 0.012 nm/K
Mean spectral pixel pitch	$\Delta\lambda_{Pixel} \approx 3$ nm
Resolution	$\Delta\lambda_{FWHM} \approx 8$ nm
Straylight	≤ 0.1 % as transmission of 10 mm water at 1405 nm (exposure from halogen lamp)
Weight	approx. 590 g
Operating temperature	0 – 40°C (standard, depending on cooling electronic)
Storage temperature	-40 – +70°C





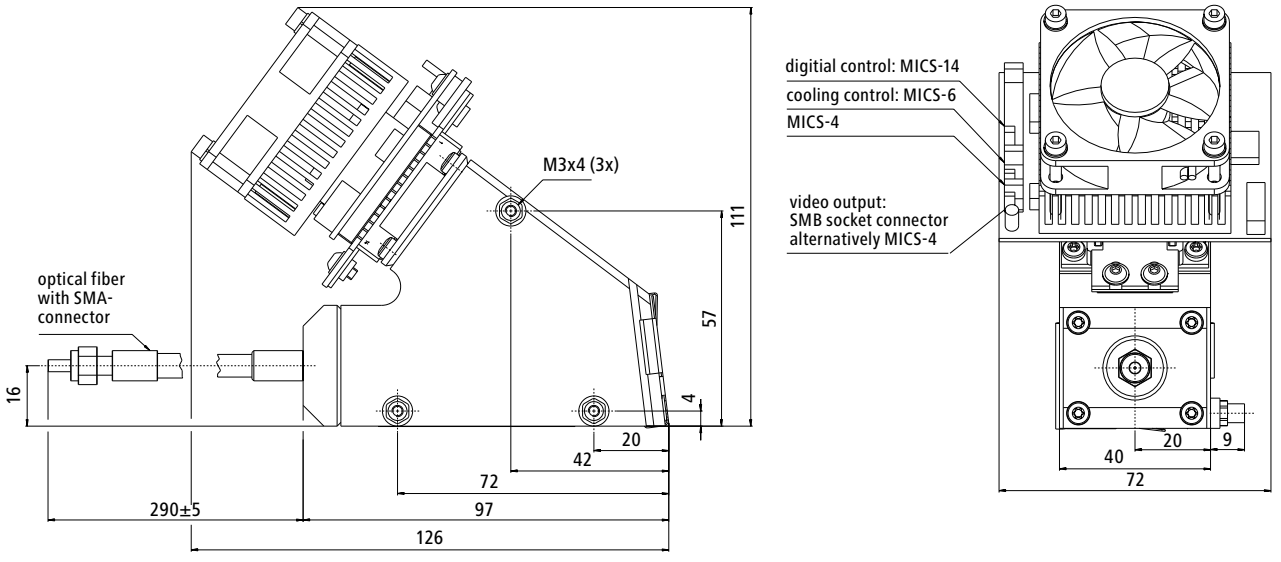
Order No.	Designation	Wavelength range	Description
000000-1381.397	PGS NIR 1.7 t1-256	960 – 1690 nm	NIR Spectral Sensor, Peltier cooled, InGaAs-PDA 1.7 µm (cut-off) 256 Pixel, Dispersion 3.0 nm/pixel, 300 mm external fiber length

Order numbers for operating electronics ➔ Page 43, Order numbers for software products ➔ Page 53

PGS NIR 2.0-256

Technical Specifications

Optical entrance	Fiber consisting of Infrasil-quartz glass
input round	Diameter: 0.6 mm Length: 300 mm NA = 0.22 (has to be filled for full specification) mounted in SMA-coupling
output linear	Slit width: 80 µm
Filter	1350 nm edge filter
Grating	Plane grating, 484 l/mm, blazed for approx. 1.4 µm
Diode array	Producer: Hamamatsu Type: G9206 Number pixels: 256
Spectral range	1340 – 2000 nm
Wavelength accuracy	± 1 nm
Temperature – induced drift (10–40°C)	< 0.012 nm/K
Mean spectral pixel pitch	$\Delta\lambda_{Pixel} \approx 3$ nm
Resolution	$\Delta\lambda_{FWHM} \approx 8$ nm
Straylight	≤ 0.1 % as transmission of 10 mm water at 1405 nm (exposure from halogen lamp)
Weight	approx. 590 g
Operating temperature	0 – 40°C (standard, depending on cooling electronic)
Storage temperature	-40 – +70°C



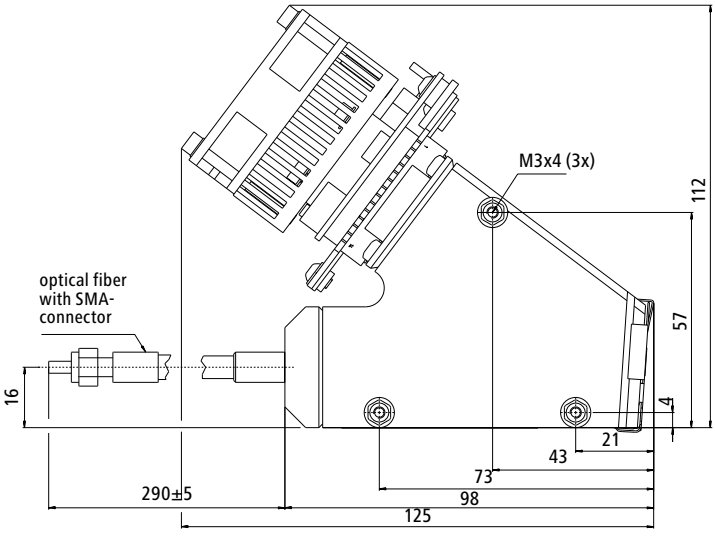
Order No.	Designation	Wavelength range	Description
000000-1396.757	PGS NIR 2.0 t2	1340 – 2000 nm	NIR Spectral Sensor, Peltier cooled, Extended InGaAs-PDA 2.2 µm (cut-off) 256 Pixel, Dispersion 5 nm/pixel, 300 mm external fiber length

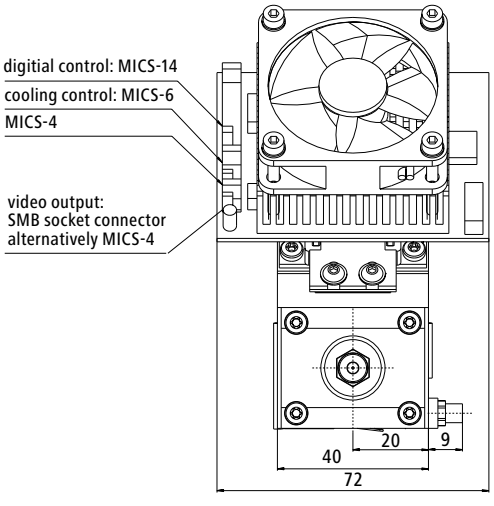
Order numbers for operating electronics ➔ Page 43, Order numbers for software products ➔ Page 53

PGS NIR 2.2-256

Technical Specifications

Optical entrance **input round** **output linear**	Fiber consisting of Infrasil-quartz glass Diameter: 0.6 mm Length: 300 mm NA = 0.22 (has to be filled for full specification) mounted in SMA-coupling Slit width: 80 µm
Filter	950 nm edge filter
2nd order filter on detector	Yes
Grating	Plane grating, 300 l/mm, blazed for approx. 1.4 µm
Diode array	Producer: Hamamatsu Type: G9206 Number pixels: 256
Spectral range	1000 – 2150 nm
Wavelength accuracy	± 1 nm
Temperature – induced drift (10 – 40°C)	< 0.012 nm/K
Mean spectral pixel pitch	$\Delta\lambda_{Pixel} \approx 5$ nm
Resolution	$\Delta\lambda_{FWHM} \approx 16$ nm
Straylight	≤ 0.1 % as transmission of 10 mm water at 1405 nm (exposure from halogen lamp)
Weight	approx. 590 g
Operating temperature	0 – 40°C (standard, depending on cooling electronic)
Storage temperature	-40 – +70°C





Order No.	Designation	Wavelength range	Description
000000-1332.256	PGS NIR 2.2 t2	1000 – 2150 nm	NIR Spectral Sensor, Peltier cooled, Extended InGaAs-PDA 2.2 µm (cut-off) 256 Pixel, Dispersion 5 nm/pixel, 300 mm external fiber length

Order numbers for operating electronics ➔ Page 43, Order numbers for software products ➔ Page 53

Operating electronics* for spectrometer modules

All components for the perfect solution

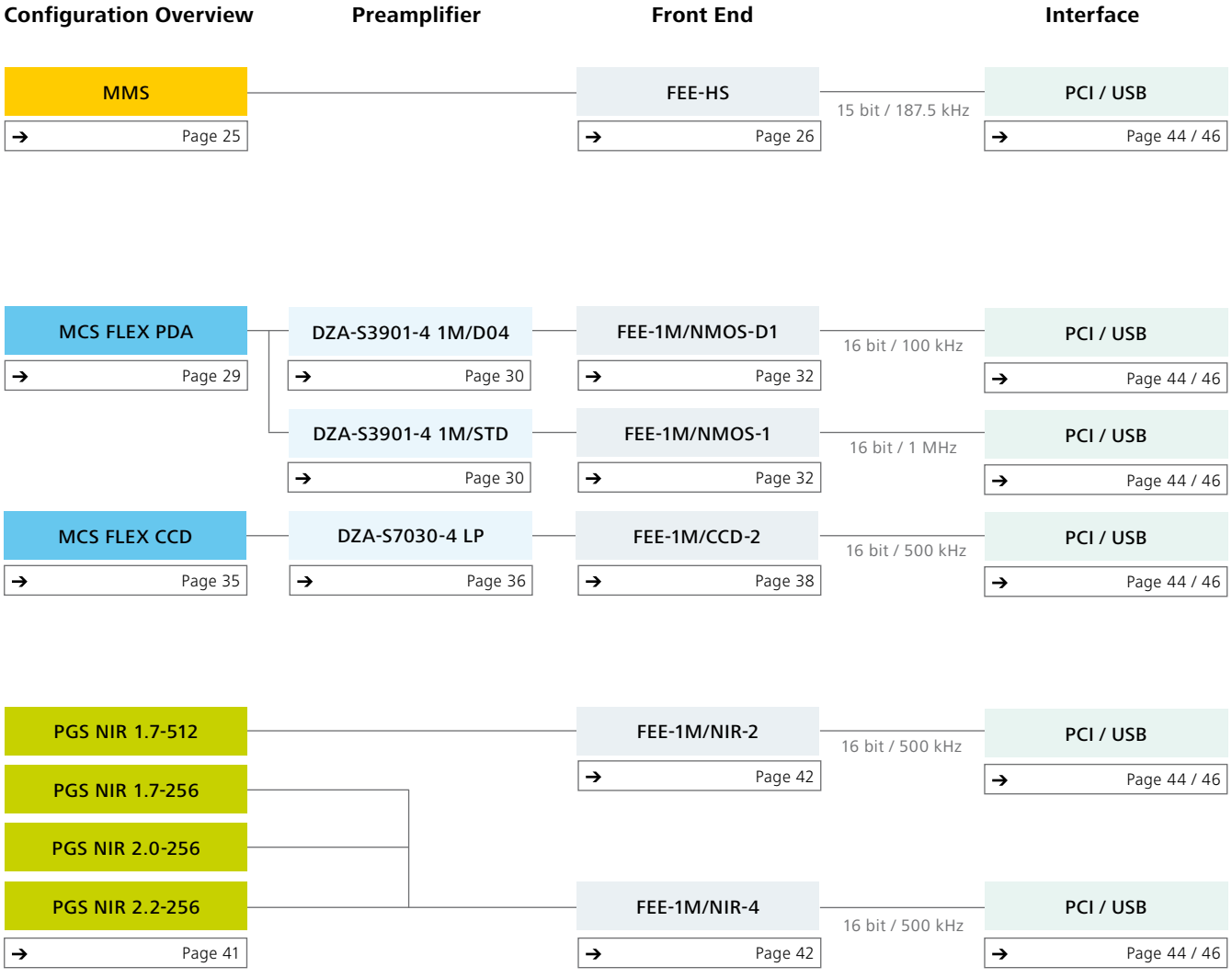
In addition to the spectrometer module, a preamplifier, front end electronics and interface electronics are required for a spectrometer system.

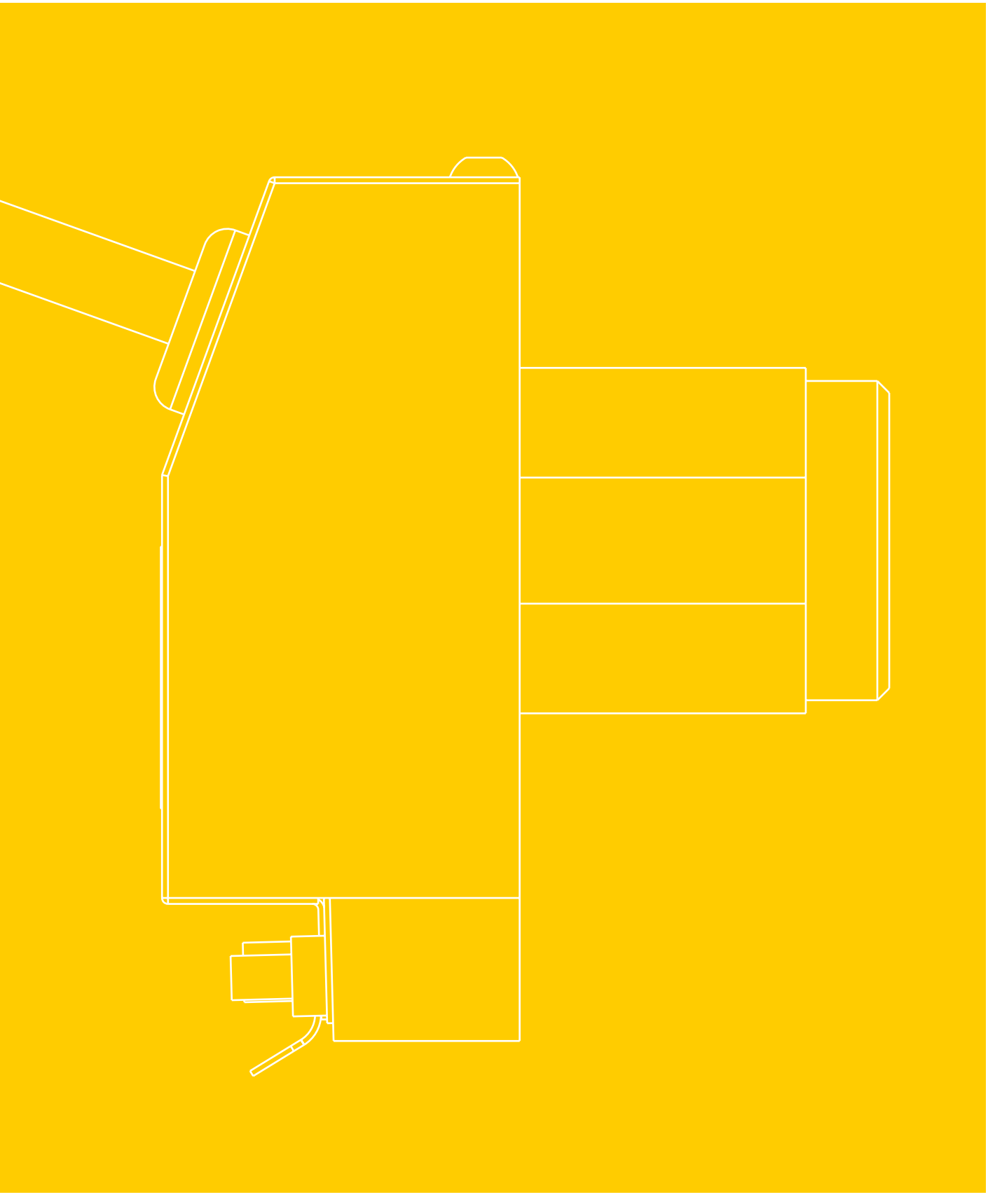
The preamplifier and the front end electronics are matched to the spectrometer module. With the exception of the MCS FLEX, the preamplifier is integrated into the spectrometer module. Its task is the amplification of the low output signals of the detector array and the minimization of possible interference of analog signal.

The front end electronics device is the connection point between the spectral sensor and the interface. The sensor clock signals are generated and the analog video signal digitized via the control electronics unit and an ADC. High dynamics and signal stability in the used configurations are achieved thanks to quartz-precision timing and integrated filtering of supply voltages. Depending on the interface, the front end electronics device features a 40-pin (PCI) or 36-pin (USB) connector.

PCI and high speed USB are the standard interfaces for operation with a desktop PC. The PCI interface board is inserted into the PC, while in the case of the USB interface board the front end electronics unit is directly plugged onto the sensor. An Ethernet interface electronics is currently in preparation and will be available soon.

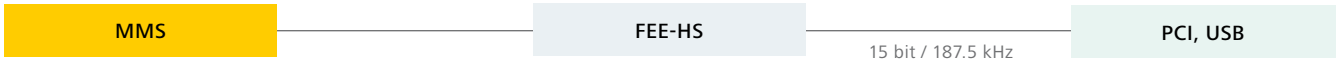
*All operating electronics are manufactured by tec5 AG.





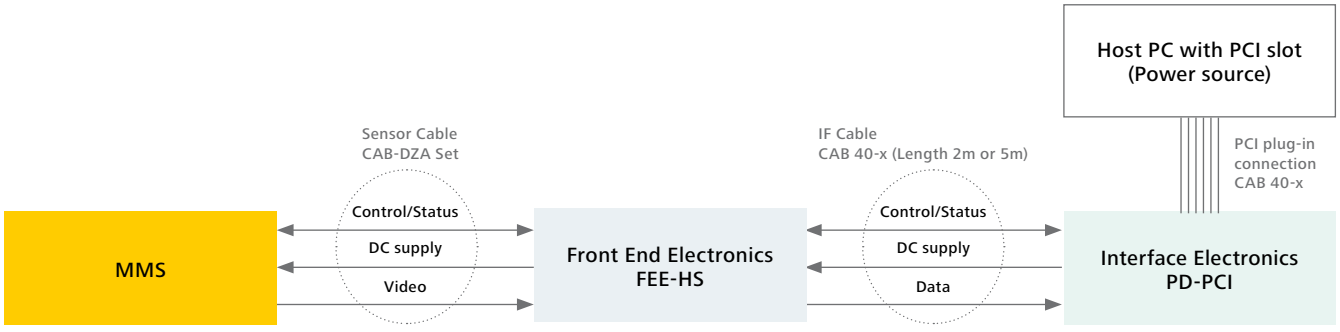
Operating electronics for MMS

Configurations overview



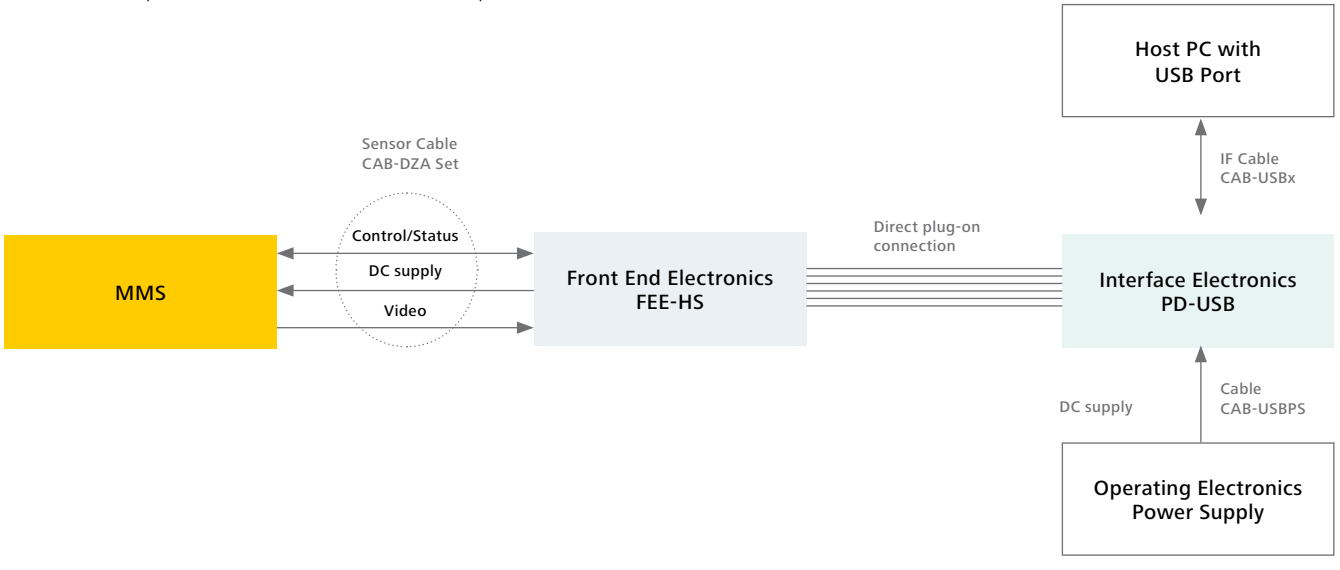
PCI Configuration (Order numbers ➔ Page 27)

A dedicated interface electronics board is plugged into a PC with PCI slot. The other boards and the sensor are designed for being included into a customer's housing connected to the PC by a 40-pin interface cable available in standard lengths of 2 m or 5 m. All signal electronics modules are supplied from the PC's internal power supply.

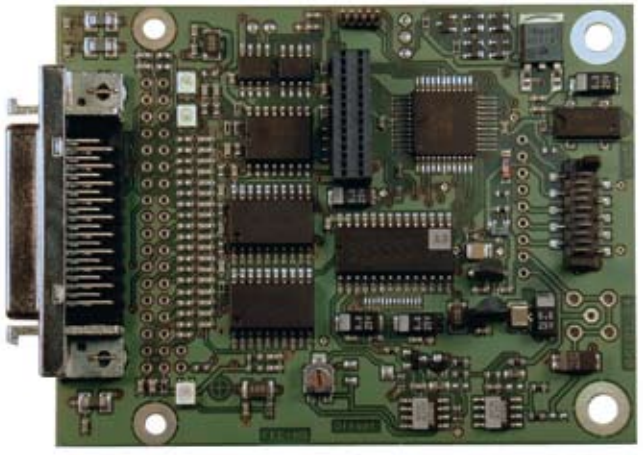


USB Configuration (Order numbers ➔ Page 27)

The signal electronics is supplied externally by an additional power supply (self-powered USB device). The electronics is connected to the PC by a standard USB interconnection cable. We recommend to use a Hi-Speed USB 2.0 port (compatible to USB 1.1) and a Hi-Speed certified USB cable for best performance. For highest speed versions FEE-1M, Hi-Speed USB communication is mandatory. All electronics boards are designed for integration into a customer's housing. External +-12 VDC and +5 VDC supply voltages have to be provided by the user.



Front End Electronics for MMS
FEE-HS



For operation of a MMS module, a FEE-HS and one of the interface boards are required. This standard configuration results in 15 bit A/D conversion and readout time below 1.5 ms.

Short Description

- High speed readout control logic with ADC for digitization of the sensors's analog video signal
- Readout rate: 187.5 kpixel per second (1.4 ms readout time for 256 pixels)
- Resolution: 15 bits A/D conversion
- Dynamic range: approx. 1:23.000 with MMS Spectral Sensor, gain 1
- Input from device: preamplifier with PDA or Spectral Sensor
- Output to device: PCI bus or USB Interface Electronics
- PCB dimensions 87 mm x 67 mm (FEE standard)

Features / Specifications

Functional Properties
- Provision of all supply voltages for the PDA
- Autonomous single scan control:
  - generation of all control signals for the PDA
  - analog video signal preprocessing
  - 15 bit A/D conversion of the intensity values
  - provision of the digital intensity values for acquisition by the Interface Electronics
- Prepared for controlling tec5's Electronic Spectral Sensor Multiplexer units
- Local non-volatile memory, 256 Bytes capacity
- (e.g. for identification data of the sensor(s), calibration coefficients or customer specific information)

Specifications
- ADC: 16 bits signed, type AD976A
- Resolution: 15 bits
- Conversion rate: approx. 187.5 kSps, crystal clock controlled
- Readout time: 1.4 ms for 256 pixels
- Spectra rate: approx. 700 spectra/s
- Input sensitivity: approx. 23.000 counts/V
- Offset adj. range: approx. ± 900 counts
- Standard deviation: typically 1.4 counts with MMS sensor, gain = 1 (20 dark spectra at 10 ms)
- Dynamic range: approx. 1 : 23.000 (215 / 1.4)
- Non-linearity: typ. ±2 counts, max. ±4 counts
- Temperature drift: < ±1,5 counts / °C

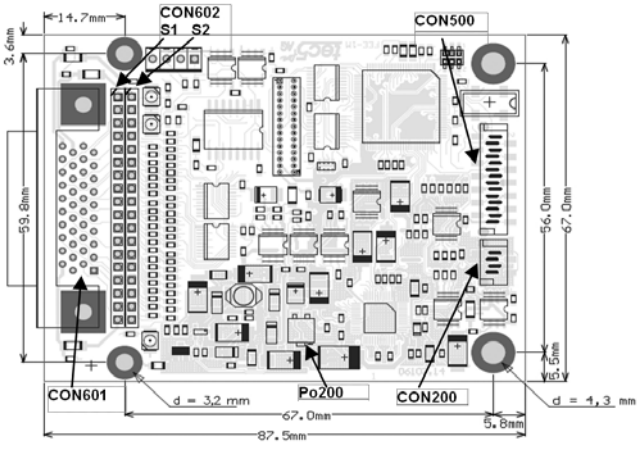
Interfaces
- Interface type ‚Sensor_1A' to sensor unit
- Interface type ‚Interface_40' or 'Interface_2*18' to Interface Electronics
- Connector for Spectral Sensor Multiplexer

Power consumption (from Interface Electronics)
- - 12 V: approx. 30 mA
- +12 V: approx. 120 mA

with additional supply on +5 V external supply input:
- + 5 V ext.: approx. 70 mA
- +12 V: approx. 50 mA

Environmental conditions
- Temperature range operating: 0 °C – 60 °C
- Temperature range storage: -40 °C – +70 °C
- Humidity (@25°C, non condensing): 10 % – 90 %

PCB Design



Assembly Versions

Version ‚Standard' (FEE-HS /STD)
with 40 pin Mini-Delta connector for connection to the Interface Electronics via cable. The 36 pin connector array S1/S2 may be assembled with socket contacts (not used).

Version ‚Embedded' (FEE-HS /EMB)
is prepared to be directly plugged on top of the Interface Electronics (typically USB Interface Electronics). The 36 pin connector array S1/S2 is assembled with pins on the solder side, the 40-pin Mini-Delta connector is not assembled.

Interfaces

Sensor interface connector type / specs / pinout
ST2: MICS 10 and SMB, 'Sensor_1A' compatible
ST3: 9 pin socket connector array

ST2 Pin or SMB	SL3 Pin	Description
1	1	not connected
2	7	Sensor StartScan
3	3	Ground
4	6	Sensor Clock
5	3	Ground
6	5	Sensor EndOfScan
7	3	Ground
8	2	-5 V Power supply for sensor module
9	3	Ground
10	1	+5 V Power supply for sensor module
SMB	9	Ground
SMB	8	Sensor Video signal (center contact)
---	4	Mode for Sensor Multiplexer (MUX-4A)

Interface Electronics

Depending on the preferred type of connection to the host PC, a PCI plug-in Interface Electronics or a USB-type Interface Electronics may be used.

The interface electronics modules retrieve digitized data from the Front End Electronics and forward the data to a host PC. The electronics circuitry contains the readout scan cycle control logic with precise integration timing and hardware sequencing of all functions with real-time requirements. A FIFO buffer memory is used to assure consistent data transfer to the computer's main memory.

The Interface Electronics modules offer peripheral control and synchronization with digital I/O lines, e.g. flash trigger output, external trigger input and general purpose digital I/O lines.

Detailed information and order numbers ➔ Page 44/46

Software

Software is required to enable control of the module via the electronics unit. It is available either as a complete package (Aspect Plus) or as libraries and drivers enabling the development of customized software.

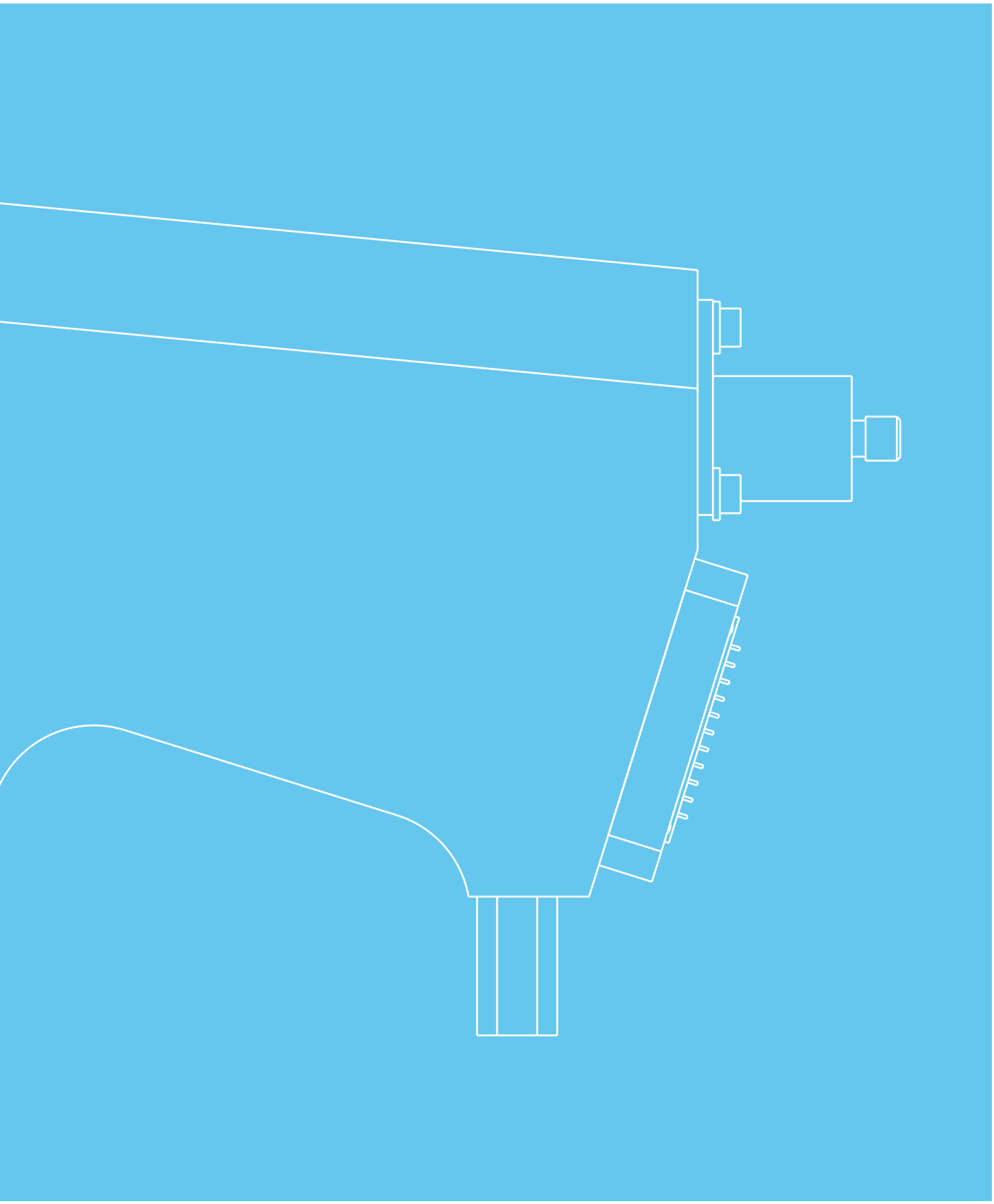
Detailed information and order numbers ➔ Page 49

USB Configuration

Order No.	Designation		Description
000000-0464.008	tec5-Operating Electronics MMS BE-USB HS 15-Bit	15-Bit	Front End-Electronic (FEE) SDACQ32 Admin test software for Windows 2000, XP and Vista (32bit) Front End-Electronic USB (Power supply and USB cable required)
226001-8390.000	Cable		Coaxial cable with SMB – flange
226001-8391.000	Cable		Flat ribbon cable with 10-pin-knife plug, length 50 cm
000000-0465.486	Power supply for USB electronic		Power supply for USB electronic ((+-12VDC, +5VDC), 115/230VAC)

PCI Configuration

Order No.	Designation		Description
000000-0450.148	tec5-Operating Electronics MMS BE-PCI HS 15-Bit	15-Bit	Front End-Electronic (FEE) SDACQ32 Admin test software for Windows 2000, XP and Vista (32bit) Front End-Electronic Flat ribbon cable with 25-pin SUB D plug, length 2 m
226001-8390.000	Cable		Coaxial cable with SMB – flange
226001-8391.000	Cable		Flat ribbon cable with 10-pin-knife plug, length 50 cm

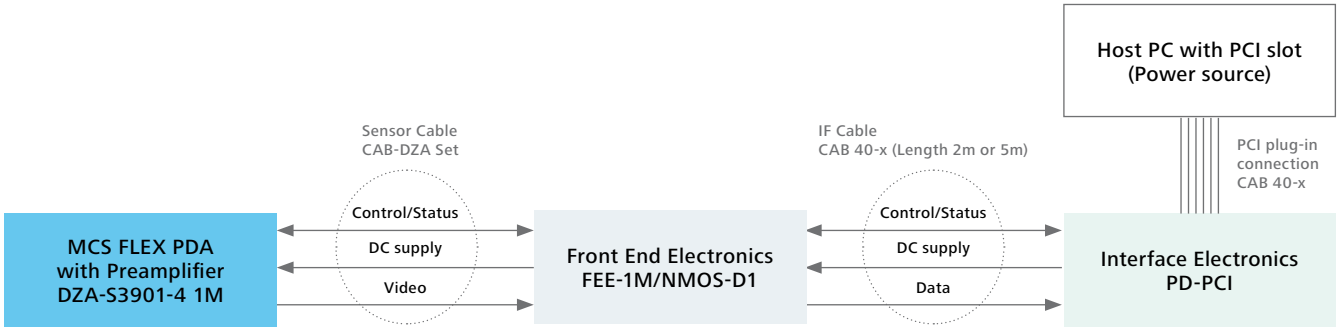


Operating electronics for MCS FLEX PDA

Configurations overview

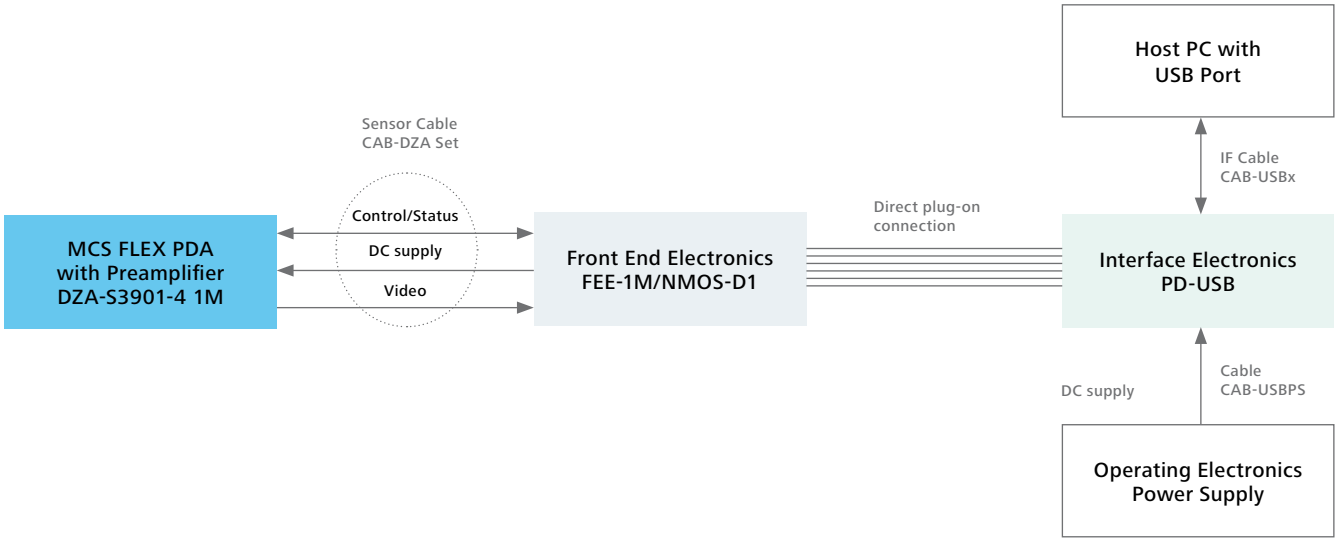
PCI Configuration (Order numbers ➔ Page 33)

A dedicated interface electronics board is plugged into a PC with PCI slot. The other boards and the sensor are designed for being included into a customer's housing, connected to the PC by a 40-pin interface cable available in standard lengths of 2 m or 5 m. All signal electronics modules are supplied from the PC's internal power supply.



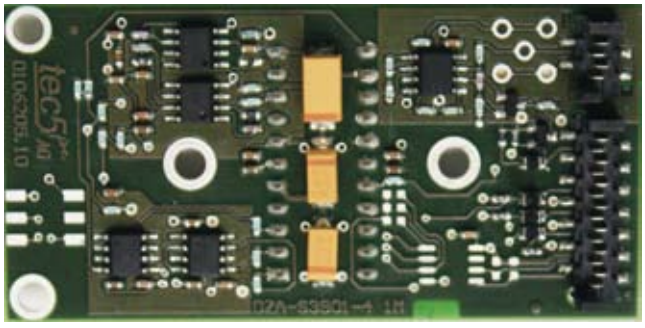
USB Configuration (Order numbers ➔ Page 33)

The signal electronics is supplied externally by an additional power supply (self-powered USB device). The electronics is connected to the PC by a standard USB interconnection cable. We recommend to use a Hi-Speed USB 2.0 port (compatible to USB 1.1) and a Hi-Speed certified USB cable for best performance. For highest speed versions FEE-1M, Hi-Speed USB communication is mandatory. All electronics boards are designed for integration into a customer's housing. External +5 VDC supply voltage has to be provided by the user.



Preamplifier Electronics for MCS FLEX PDA

DZA-S3901-4 1M/D04



Short Description

- Fast preamplifier electronics for MCS FLEX PDA N-MOS Linear Image Sensors S3904
- Pixel frequency up to 1 MPixel per second
- For 16 bit readout
- Sensor chip socket for direct insertion on PCB
- Device input: sensor chip
- Device output: tec5 16 bit Front End Electronics with sensor interface ‚Sensor_U3' (FEE-1M /NMOS-1)
- PCB dimensions: 73 mm x 37 mm
- Low-speed version /Dxx available, reduced readout noise for 100 kPixel per second readout

General

The preamplifier electronics DZA-S3901-4 1M serves as an interfacing component between the Hamamatsu N-MOS Linear Image Sensors of series S3904 on the Carl Zeiss MCS FLEX PDA and the Front End Electronics board of a tec5 operating electronics. Typically the PDA is plugged directly into the DIL-22 socket mounted to the soldering side of the PCB. The electronics is designed for a readout rate of up to 1 MPixel per second. Using the product version /Dxx at a clock rate of 100 kPixel per second results in lower detection noise, but longer minimum integration time and slower achievable measurement rate. Both versions are supported by corresponding versions of the FEE-1M /NMOS-1 or FEE-1M /NMOS-D1. The interface to the Front End Electronics complies to the specification ‚Sensor_U3' (MICS-14, MICS-4 and SMB.

Description of Operation

Based on the CLK and START input signals the preamplifier board generates all signals required to read out the sensor chip. The analog signal from the sensor array is preamplified, integrated, and forwarded differentially for further processing (video signal).

Technical Data

- Diode arrays: Hamamatsu N-MOS PDAs of types S3901 to S3904
- Number of pixels: depending of the sensor
- CLK frequency: max. 1 MHz (100 kHz)*
- Readout time (512): 0.52 ms at 1 MHz Clock
- Min. integration time: 0.6 ms (5.2 ms)*

* 100 kPixel/s version /Dxx

Analog Range:

- Output signal: 0 – 8 V (differential)

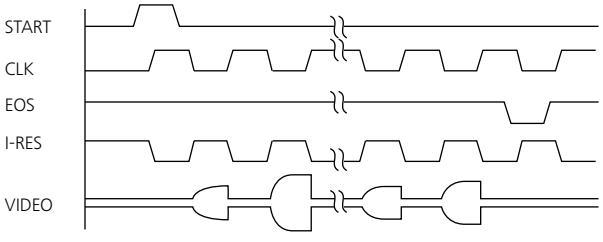
Digital Input Control Signals (HC level):

- START: Start of readout cycle, if signal 'START' is HIGH and 'CLK' has a rising slope.
- CLK: Master Clock signal for the array. The pixel frequency is equal the CLK frequency.
- I-RES: Reset signal for the integrator.

Digital Output Control Signals (HC level):

- /EOS: EndOfScan, Signal /EOS is HIGH during readout procedure. At the end of the scan the Sensor produces an EndOf-Scan LOW pulse.

Signal Behavior:



Current consumption:

- +5 V: typically < 35 mA
- –5 V: typically < 30 mA

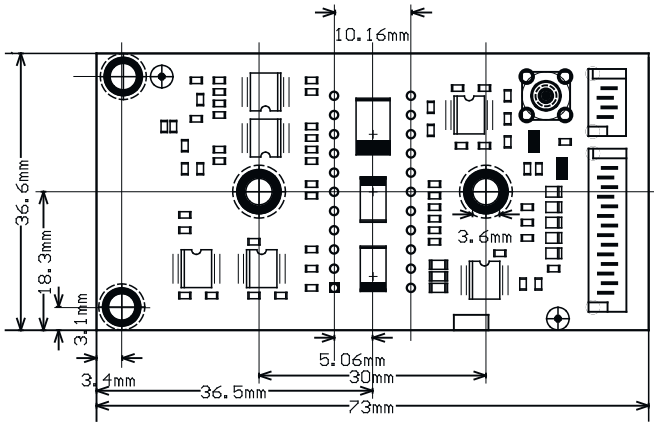
Ambient Conditions (DZA-S3901-4 1M board only):

- Operating temperature range: 0 °C – 65 °C
- Storage temperature range: -40 °C – +70 °C
- Humidity (@25°C, non condensing): 10 % – 90 %

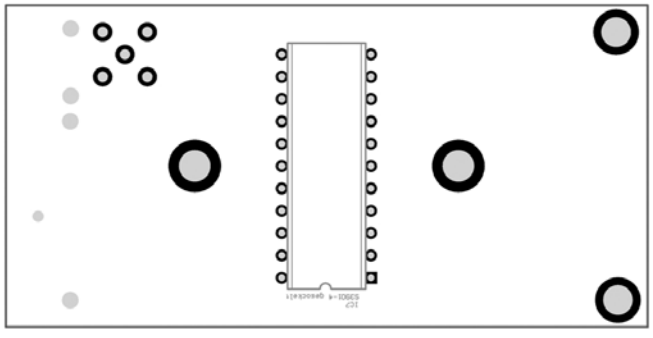
Product Versions

For operation of the various linear image sensors supported, the following product versions are available:
DZA-S3901-4 1M /STD for S3904, 1 MHz
DZA-S3901-4 1M /D04 for S3904, 100 kHz
Note: 1 MHz versions can be operated at pixel rates up to 1 MHz. For slower readout at max. 100 kPixel/s, 100 kHz versions are recommended resulting in lower detection noise. These versions cannot be operated at readout rates faster than specified.

Board Layout



DZA-S3901-4 1M, component side



DZA-S3901-4 1M, soldering / sensor side

Mechanical Interfacing

- Board dimensions: 73 mm x 35 mm
- Connector for PDA: DIL socket on soldering side of the board
- Mounting of board: 4 mounting holes as shown on drawing

Electronic Interfaces

- Type: tec5 specification ‚Sensor_U3'
- Video output: MICS-4 (alt. SMB socket)
- Digital control: MICS-14

Pin Assignment MICS-14 Connector:

Pin	Designation	Pin	Designation
1	TRIGGER (not used)	2	START – Start of Scan
3	PHI2 (not used)	4	CLK - Master Clock
5	I_RES (Integrator Reset)	6	/EOS - End of Scan
7	0V - Digital Ground	8	-5 V – Supply
9	0V - Digital Ground	10	+5 V – Supply
11	DOUT1 (not used)	12	DOUT2 (not used)
13	I2C-SDA	14	I2C-SCL

Pin Assignment MICS-14 (and SMB) Connector:

Pin	Designation
1	0V – Analog Ground
4	0V – Analog Ground
2 (= SMB Center Contact)	Video Out (inverted)
3 (= SMB Outer Contact)	Video Out (non inverted)

System Data

System data, realized with tec5 16 bit Operating Electronics FEE-1M /NMOS-1 and sensor type S3904:

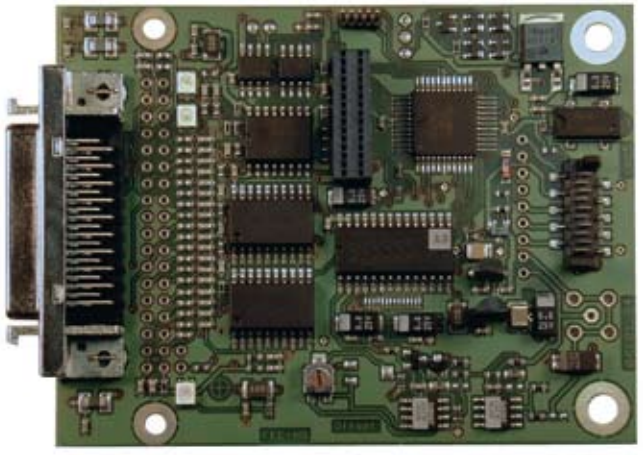
- Integration time: 1 ms
- Clock frequency: 1 MHz
- Intensity resolution: 16 bits
- Ambient temperature: +25 °C
- Resulting single pixel dark noise: < 4.5 counts rms

For product version /Dxx:

- Integration time: 8 ms
- Clock frequency: 100 kHz
- Intensity resolution: 16 bits
- Ambient temperature: +25 °C
- Resulting single pixel dark noise: < 2 counts rms

Front End Electronics for MCS FLEX PDA

FEE-1M/NMOS-D1



For operation of a MCS FLEX PDA module, a FEE-1M and one of the interface boards are required. This standard configuration results in 16 bit A/D conversion and readout time below 1.5 ms.

Short Description

- Fast readout control logic with ADC for digitization of the sensors's analog video signal
- Readout rate: 100 kpixel/second
- High resolution: 16 bits A/D conversion
- Dynamic range: up to > 15 bits (with PDA)
- On-board generation of stabilized ±5 V for the sensors from a single supply voltage (5 V ±1V)
- Input from device:
  Preamplifier with PDA or Spectral Sensor
- Output to device: Interface Electronics
  PD-USB01V2 or PD-PCI01V1
- PCB dimensions 87 mm x 67 mm (FEE standard)

Features / Specifications

Functional Properties

- Generation of supply voltages for sensors and pre-amplifiers (not used by self powered DZA-S7030-4)
- PDA readout clock sequencing
- analog video signal preprocessing, A/D conversion
- data transfer to the Interface Electronics
- Local non-volatile memory, 256 Bytes capacity (e.g. for identification data of the sensor(s), calibration coefficients or customer specific information)

Specifications

- ADC 16 bits, type AD7677
- Conversion rate (100), 500 or 1000 kSps
- Electrical Non-linearity < ±2 counts
- Temperature drift < ±1.0 count / °C
- Offset adj. range approx. ± 2000 counts

Basic Version	NMOS-D1
Standard deviation [counts] typically	4.0
Pixel frequency	100 kHz or 1 MHz
Readout time [min.]	10.3 ms or 1.2 ms
Sensor (example) [number pixels]	1024

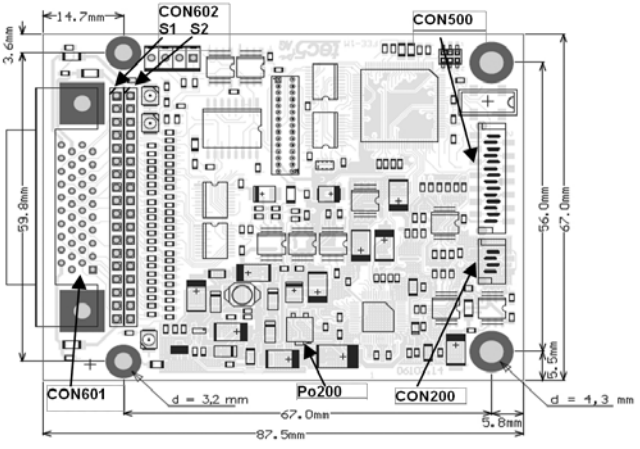
Interfaces

- Interface type ‚Sensor_Ux' to sensor preamplifier (MICS4 connector for analog input signal only)
- Interface type ‚Interface_40' or 'Interface_2*18' to Interface Electronics
- Power consumption (from Interface Electronics)
- + 5 V: approx. 150 – 350 mA depending on configuration and readout frequency.

Environmental conditions

- Temperature range operating 0 °C – 60 °C
- Temperature range storage -40 °C – +70 °C
- Humidity (@25°C, non condensing) 10 % – 90 %

PCB Design



Assembly Versions

Assembly Version ‚Standard' (extension /STD)
with 40 pin Mini-Delta connector for cable connection to the tec5 PCI Interface Electronics. The 36 pin connector array CON602 may be assembled with socket contacts (not used).

Assembly Version ‚Embedded' (extension /EMB)
is prepared to be directly plugged on top of the Interface Electronics (typically USB Interface Electronics). The 36 pin connector array CON602 is assembled with pins on the solder side, the 40-pin Mini-Delta connector is not assembled.

Interfaces

Sensor interface connector type / specs / pinout
MICS 14 and MICS 4 'Sensor_Ux' compatible

Pin	In/Out	Description
CON500		
1	Input	DI1 Sensor Trigger (*)
2	Output	DO1 Sensor StartScan
3	Output	DO2 Sensor Integrator Reset (*)
4	Output	DO3 Sensor Master Clock
5	Output	DO4 Sensor Clock2 (/Master Clock) (*)
6	Input	DI2 Sensor EndOfScan
7, 9	Power	Ground
8	Power	-5 V Power supply for sensor module
10	Power	+5 V Power supply for sensor module
11	Input	DI3 currently unused
12	Input	DI4 currently unused
13	Bidirect.	I2C_SDA currently unused
14	Bidirect.	I2C_SCL currently unused
CON200		
1, 4		GND
2	Input	Analog In-
3	Input	Analog In+

(*) Sensor technology specific signals

Interface Electronics

Depending on the preferred type of connection to the host PC, a PCI plug-in Interface Electronics or a USB-type Interface Electronics may be used.

The interface electronics modules retrieve digitized data from the Front End Electronics and forward the data to a host PC. The electronics circuitry contains the readout scan cycle control logic with precise integration timing and hardware sequencing of all functions with real-time requirements. A FIFO buffer memory is used to assure consistent data transfer to the computer's main memory.

The Interface Electronics modules offer peripheral control and synchronization with digital I/O lines, e.g. flash trigger output, external trigger input and general purpose digital I/O lines.

Detailed information and order numbers ➔ Page 44/46

Software

Software is required to enable control of the module via the electronics unit. It is available either as a complete package (Aspect Plus) or as libraries and drivers enabling the development of customized software.

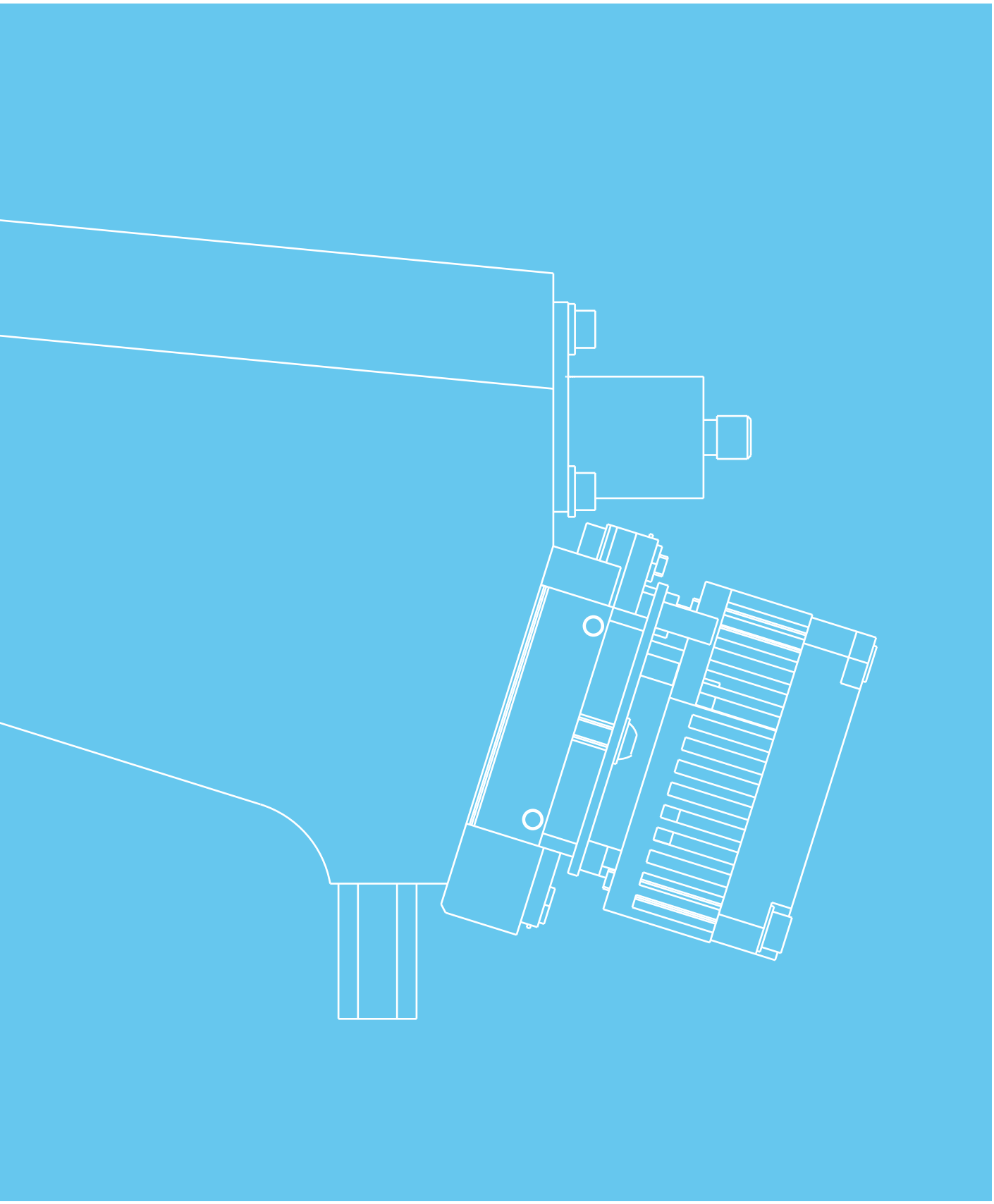
Detailed information and order numbers ➔ Page 49

USB Configuration

Order No.	Designation		Description
000000-0514.726	tec5-Operating electronic MCS FLEX PDA USB interface for MCS FLEX PDA UV-NIR	16-Bit	Front End-Electronic (FEE-1M), Preamplifier electronic mounted on MCS (cables included, external power supply required) USB interface card for MCS FLEX PDA UV-NIR

PCI Configuration

Order No.	Designation		Description
000000-0514.727	tec5-Operating electronic MCS FLEX PDA PCI interface for MCS FLEX PDA UV-NIR	16-Bit	Front End-Electronic (FEE-1M), Preamplifier electronic mounted on MCS (cables included) PCI interface card for MCS FLEX PDA UV-NIR

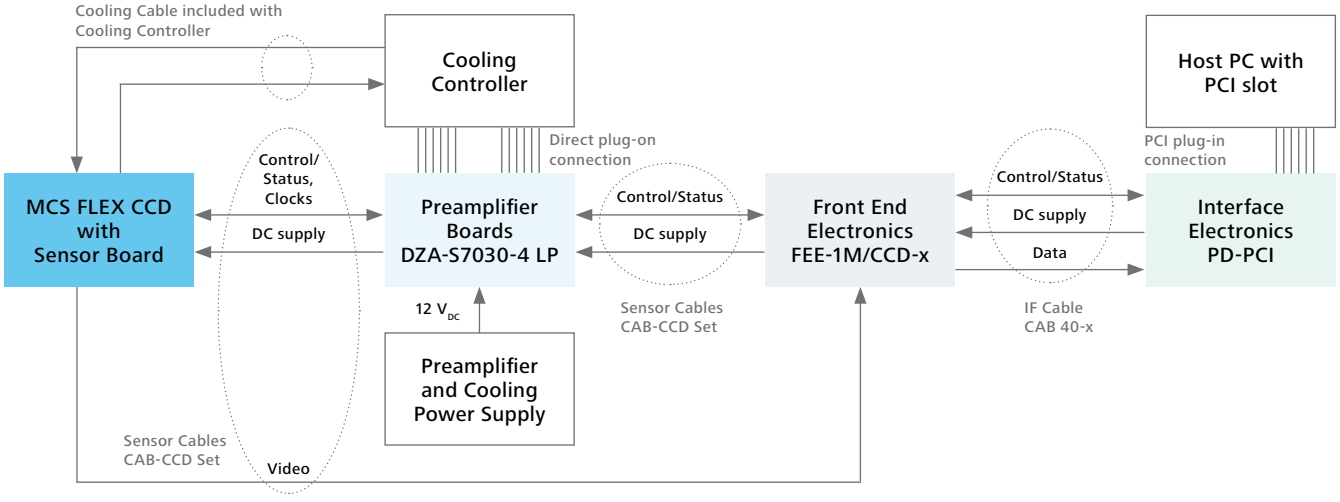


Operating electronics for MCS FLEX CCD

Configurations overview

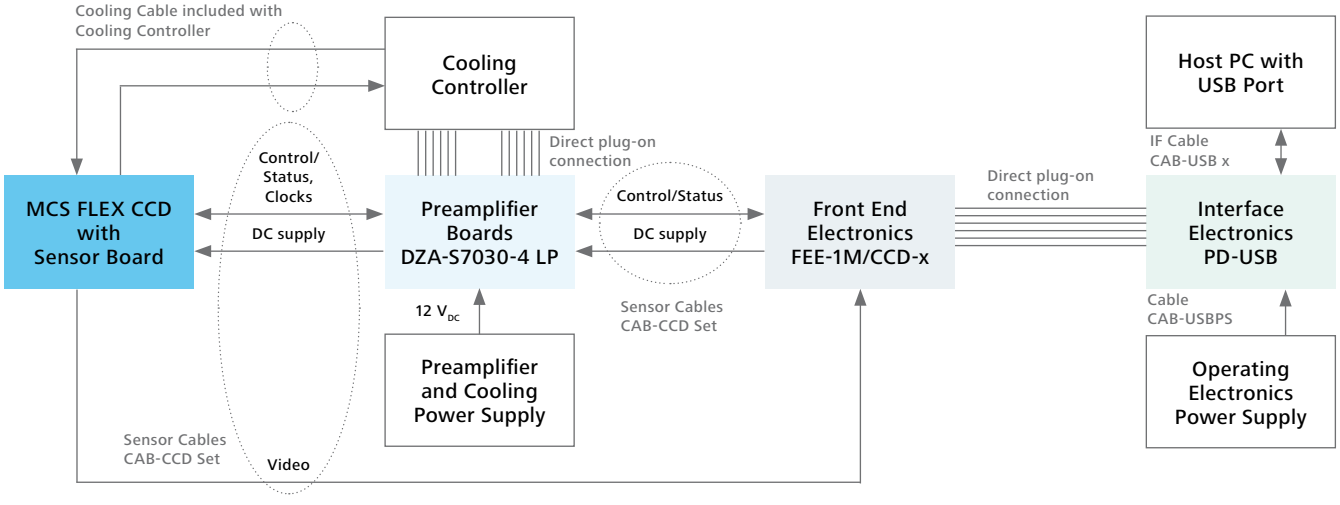
PCI Configuration (Order numbers ➔ Page 39)

A dedicated interface electronics board is plugged into a PC with PCI slot. The other boards and the sensor are designed for being in-cluded into a cus-tomer's housing, connected to the PC by a 40-pin interface cable available in standard lengths of 2 m. The Front End Electronics and Interface are supplied from the PC's internal power supply. For the preamplifier board and the cooling controller, an external 12 VDC supply voltage has to be provided by the user.



USB Configuration (Order numbers ➔ Page 39)

The USB-based interface electronics with the Front End Electron-ics are supplied externally by an additional power supply (self-powered USB device), the preamplifier and cooling controller requires a 12 VDC supply. The electronics is connected to the PC by a standard USB interconnection cable. We recommend to use a Hi-Speed USB 2.0 port (compatible to USB 1.1). All electronics boards are designed for integration into a customer's housing.



Preamplifier Sensor Electronics for MCS FLEX CCD

DZA-S7030-4 LP

Short Description

- Preamplifier sensor board set for MCS FLEX CCD with back-thinned/ back-illuminated CCD Sensors series S7031
- Optional Peltier cooling controller
- Single supply +12 V operation
- Input from device: CCD sensor
- Output to device: Front End Electronics with sensor interface ‚Sensor_U2'

General

The Preamplifier Sensor Electronics DZA-S7030-4 serves as an adaptation subassembly matching the Hamamatsu back-thinned / back illuminated CCDs series S7031 to a Front End Electronics unit of a tec5 Operating Electronics (i.e. FEE-1M).

The unit consists of the following printed circuit boards:

- a Sensor PCB (DZA-S7030-4-S)
- a Logic PCB (DZA-S7030-4-L)
- a Power Supply PCB (DZA-S7030-4-P)
- an optional Cooling Controller PCB (DZA-S7030-4-tc)

The Logic and Power Supply PCBs may be combined mechanically to a board format of 135 mm x 100 mm for easier mounting into standard housings or frames. In most applications, the CCD array is directly plugged into the 24 pin DIL socket mounted to the soldering side of the Sensor PCB. The interface for the Front End Electronics complies to tec5 specification ‚Sensor_U2' (14 pin header connector for PDA control signals and SMB flange socket with pin contact or 4 pin MICS-4 connector for differential video signal) for direct interconnection to FEE-1M.

DZA-S7030-4 for Carl Zeiss MCS FLEX Spectral Sensors

For use with MCS FLEX spectral sensors from Carl Zeiss, equipped with a compatible CCD sensor, the Sensor PCB can be plugged directly onto the CCD array integrated in the spectrometer and is fastened to the spectrometer housing by means of two screws.

Features

Modes of operation

- Standard mode "line binning" (summing the vertical pixels), reading the array like a linear array
- Various alternative modes are supported by the DZA-S7030-4 (binning and imaging), depending on system configuration. Please contact for details.

Signal processing

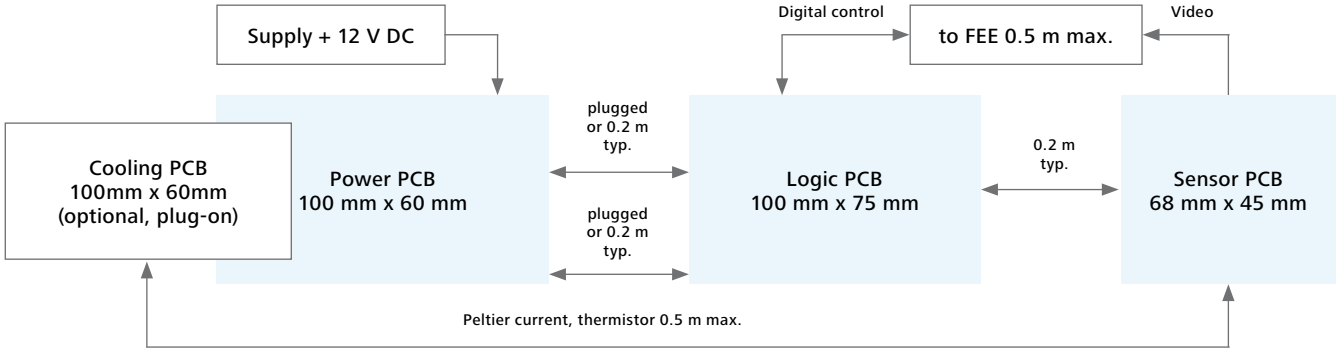
- Operation in MPP-mode defined by Hamamatsu, optimizing dynamic range
- Correlated Double Sampling
- Differential video output

Cooling (optional)

- Four quadrant PI cooling possible with optional cooling board
- Automatic detection of excess detector temperature and disabling of cooling
- Analog setpoint input and monitor output

Configuration and monitoring

- Configuration and mode selection alternatively via I2C bus or solder gaps
- Error monitoring via I2C bus or LED's
- Fast hardware error signal available



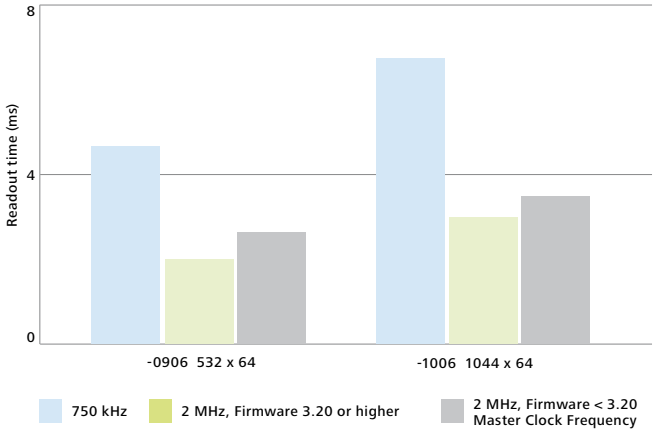
Technical Specifications

Supported CCD sensors
Hamamatsu back thinned / back illuminated CCDs series S7031

Type	Cooling	Pixel count
S7031-0906	One-stage TE-cooled	532 x 64
S7031-1006	One-stage TE-cooled	1044 x 64

Master clock (f_m): 200 kHz – 2 MHz
(two preselected ranges)
Resulting readout time: see diagram

CCD readout time (line binning operation)



Readout time calculated for two selected master clock frequencies f_m in standard line binning operation (preliminary)

Analog output:
Output range: 0 .. 20 V (differential)
Maximum load: 600 Ohm / 1 nF
Pixel readout clock: f_m / 4

Digital control inputs (TTL level):
START: Initiates a read-out cycle for the CCD (active high, minimum length: one MCLOCK period).
MCLOCK: Master clock for CCD readout (fm), should be applied continuously. Used to derive all internal clocking and the output pixel rate.

Digital control outputs (TTL level)
EOS: EndOfScan, returns a pulse (active low, duration: one MCLOCK pulse) to indicate the end of the array.
TRIGGER: Pulse chain, indicating the sampling instant (the value is valid throughout the duration of the pulse) for the video signal per pixel during readout (active high, duration: one MCLOCK pulse).

I²C Interface
The DZA-S7030-4 is equipped with an I²C interface addressing on-board EEPROM and digital I/O circuitry. This interface is used by new-generation tec5 Interface Electronics for retrieval of characteristic data, automatic detection and setting of configuration details and error determination purposes.

Cooling Controller (optional)
Function: Four quadrant PI-controller
Power supply: From +12 V supply input
Max. current: 1.5 A (optional: 3 A)
Temperature sensor supported: Thermistor (NTC)
Setpoint range: 5 kOhm – 100 kOhm

Power consumption
+12 V: typically < 300 mA (no cooling)

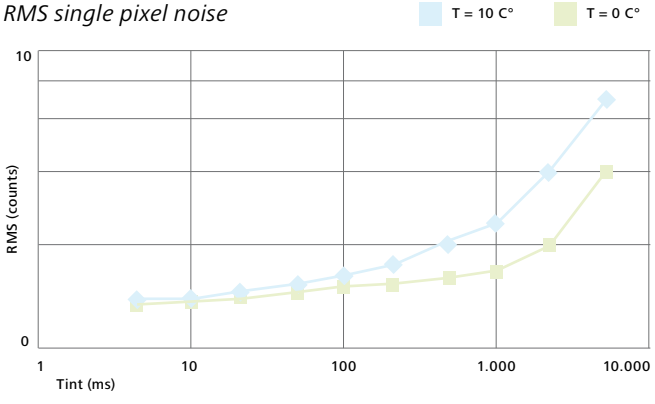
Environmental conditions
Temperature range operating: 0 °C – 30 °C[1]
Temperature range storage: -40 °C – +50 °C[1]
Humidity (@25°C, non condensing):10 % – 90 %
[1] limited by operating / storage temperature ratings of the CCD sensor

System Operational Specifications

Example data obtained using the tec5 PC Operating Electronics, 'CCD' version, and a Hamamatsu CCD Sensor type S7034-0907 (cooled operation):

Pixel clock rate: 500 kHz
Intensity resolution: 16 bits
Dynamic range: typically 15 bits (line binning)
Electronics thermal drift: typically < 2 counts/°C

RMS single pixel noise



RMS single pixel noise data obtained with S-7034 0907 sensor in line binning operation with tec5 16-bit CCD operating electronics at 0 °C and 10 °C detector temperatures.

Front End Electronics for MCS FLEX CCD

FEE-1M/CCD-2

If ordered as OEM spectrometer modules, the MCS FLEX CCD is supplied with a mounted sensor board. For operation, additional preamplifier components (logic, power and cooling boards), Front End and Interface Electronics are required.

Short Description

- Fast readout control logic with ADC for digitization of the sensors's analog video signal
- Readout rate: (100), 500 or 1000 kpixel/second
- High resolution: 16 bits A/D conversion
- Dynamic range: up to > 15 bits (with PDA)
- On-board generation of stabilized ±5 V for the sensors from a single supply voltage (5 V ± 1 V)
- Input from device:
  Preamplifier with PDA or Spectral Sensor
- Output to device: tec5 Interface Electronics
  PD-USB01V2 or PD-PCI01V1
- PCB dimensions 87 mm x 67 mm (FEE standard)

Features / Specifications

Functional Properties

- Generation of supply voltages for sensors and pre-amplifiers (not used by self powered DZA-S7030-4)
- PDA readout clock sequencing
- analog video signal preprocessing, A/D conversion
- data transfer to the Interface Electronics
- Local non-volatile memory, 256 Bytes capacity (e.g. for identification data of the sensor(s), calibration coefficients or customer specific information)

Specifications

- ADC 16 bits, type AD7677
- Conversion rate (100), 500 or 1000 kSps
- Electrical Non-linearity < ±2 counts
- Temperature drift < ±1.0 count / °C
- Offset adj. range approx. ± 2000 counts

Basic Version	CCD-2
Standard deviation [counts] typically	3.1 (cooled)
Pixel frequency	500 kHz
Readout time [ms]	1.9 or 2.9
Sensor (example) [number pixels]	(532 or 1044 x 64)

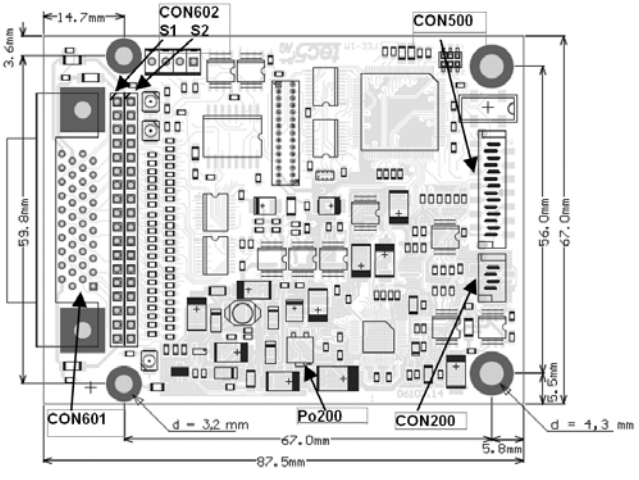
Interfaces

- Interface type ‚Sensor_Ux' to sensor preamplifier (MICS4 connector for analog input signal only)
- Interface type ‚Interface_40' or 'Interface_2*18' to Interface Electronics
- Power consumption (from Interface Electronics)
- + 5 V: approx. 150 – 350 mA depending on configuration and readout frequency.

Environmental conditions

- Temperature range operating 0 °C – 60 °C
- Temperature range storage -40 °C – +70 °C
- Humidity (@25°C, non condensing) 10 % – 90 %

PCB Design



Assembly Versions

Assembly Version ‚Standard' (extension /STD)
with 40 pin Mini-Delta connector for cable connection to the tec5 PCI Interface Electronics. The 36 pin connector array CON602 may be assembled with socket contacts (not used).

Assembly Version ‚Embedded' (extension /EMB)
is prepared to be directly plugged on top of the Interface Electronics (typically USB Interface Electronics). The 36 pin connector array CON602 is assembled with pins on the solder side, the 40-pin Mini-Delta connector is not assembled.

Interfaces

Sensor interface connector type / specs / pinout
MICS 14 and MICS 4 'Sensor_Ux' compatible

Pin	In/Out	Description	
CON500			
1	Input	DI1 Sensor Trigger (*)	
2	Output	DO1 Sensor StartScan	
3	Output	DO2 Sensor Integrator Reset (*)	
4	Output	DO3 Sensor Master Clock	
5	Output	DO4 Sensor Clock2 (/Master Clock) (*)	
6	Input	DI2 Sensor EndOfScan	
7, 9	Power	Ground	
8	Power	-5 V Power supply for sensor module	
10	Power	+5 V Power supply for sensor module	
11	Input	DI3	currently unused
12	Input	DI4	currently unused
13	Bidirect.	I2C_SDA	currently unused
14	Bidirect.	I2C_SCL	currently unused
CON200			
1, 4		GND	
2	Input	Analog In-	
3	Input	Analog In+	

(*) Sensor technology specific signals

Interface Electronics

Depending on the preferred type of connection to the host PC, a PCI plug-in Interface Electronics or a USB-type Interface Electronics may be used.

The interface electronics modules retrieve digitized data from the Front End Electronics and forward the data to a host PC. The electronics circuitry contains the readout scan cycle control logic with precise inte-gration timing and hardware sequencing of all func-tions with real-time requirements. A FIFO buffer memory is used to assure consistent data transfer to the computer's main memory.

Detailed information and order numbers ➔ Page 44/46

Software

Software is required to enable control of the module via the electronics unit. It is available either as a complete package (Aspect Plus) or as libraries and drivers enabling the development of customized software.

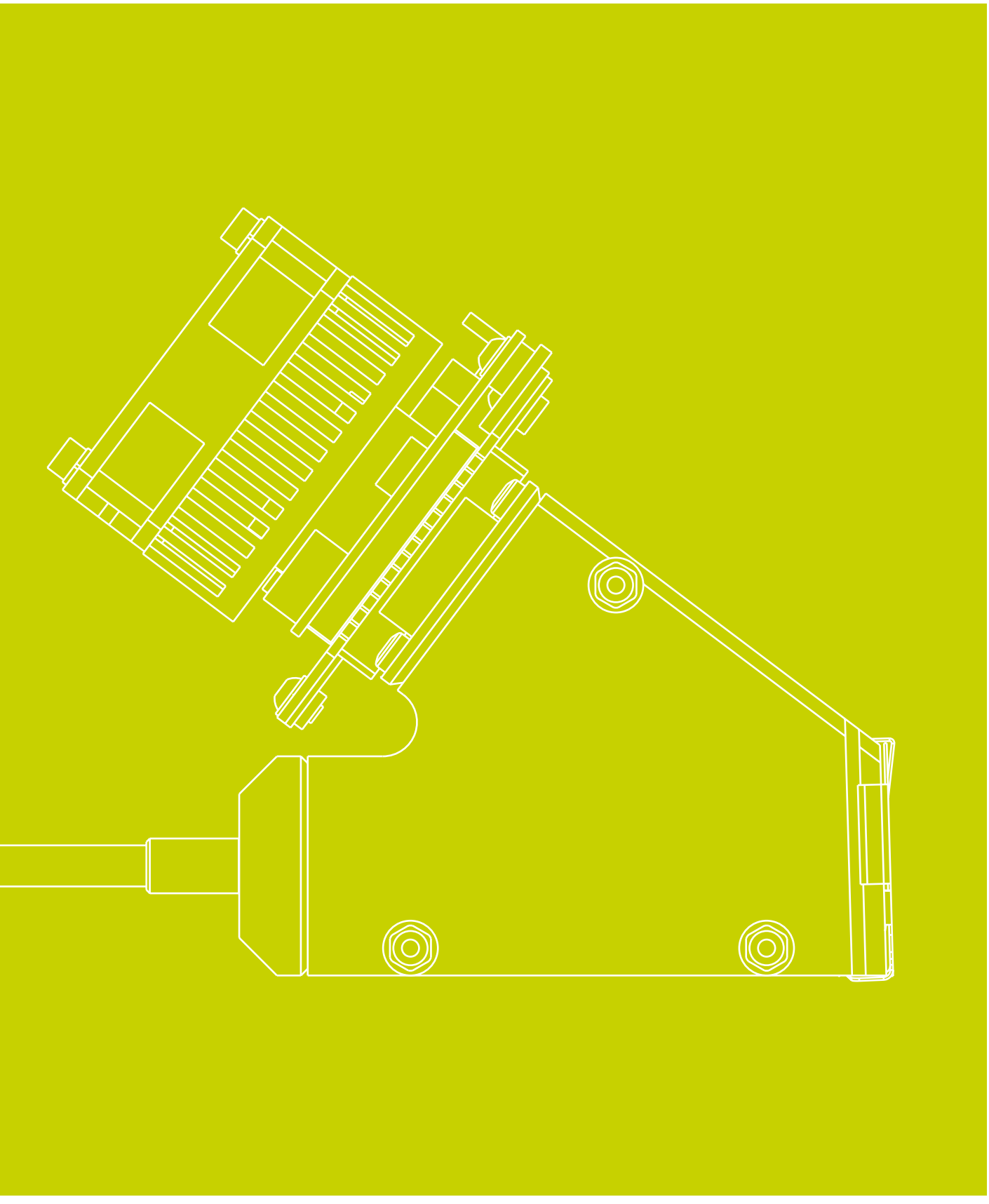
Detailed information and order numbers ➔ Page 49

USB Configuration

Order No.	Designation		Description
000000-1434.006	tec5-Operating electronic MCS FLEX CCD USB interface for MCS FLEX CCD UV-NIR	16-Bit	Front End-Electronic (FEE-CCD), Sensor electronic mounted on MCS, Logic Electronic, power supply (internal) and cooling electronics, cables (external 12 V and 5 V power supply required) USB interface card and 3 A cooling for MCS FLEX CCD UV-NIR

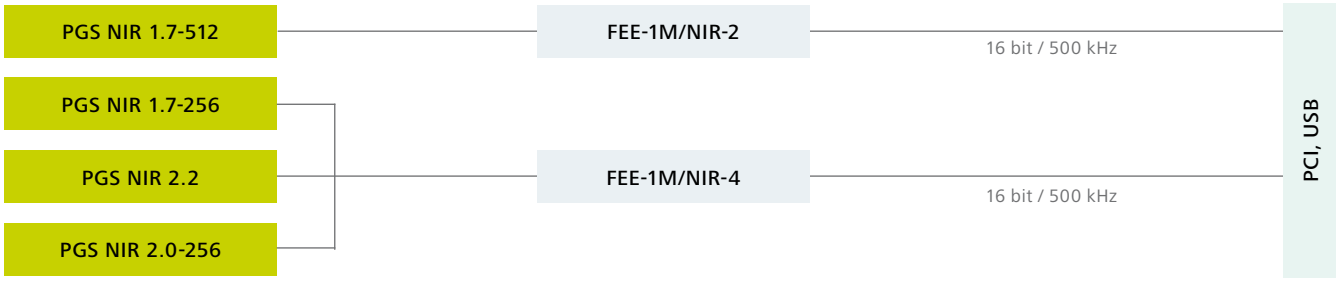
PCI Configuration

Order No.	Designation		Description
000000-1434.018	tec5-Operating electronic MCS FLEX CCD PCI interface for MCS FLEX CCD UV-NIR	16-Bit	Front End-Electronic (FEE-CCD), Sensor electronic mounted on, Logic Electronic, power supply (internal) and cooling electronics, cables (external 12 V power supply required) PCI interface card and 3 A cooling for MCS FLEX CCD UV-NIR



Operating electronics for PGS

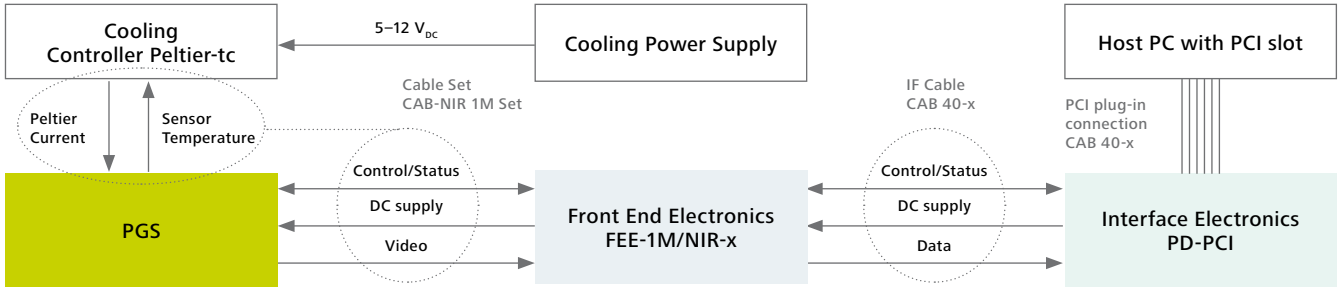
Configurations overview



PCI Configuration (Order numbers ➔ Page 43)

A dedicated interface electronics board is plugged into a PC with PCI slot. The other boards and the sensor are designed for being included into a customer's housing, connected to the PC by a 40-pin interface cable available in standard lengths of 2 m or 5 m.

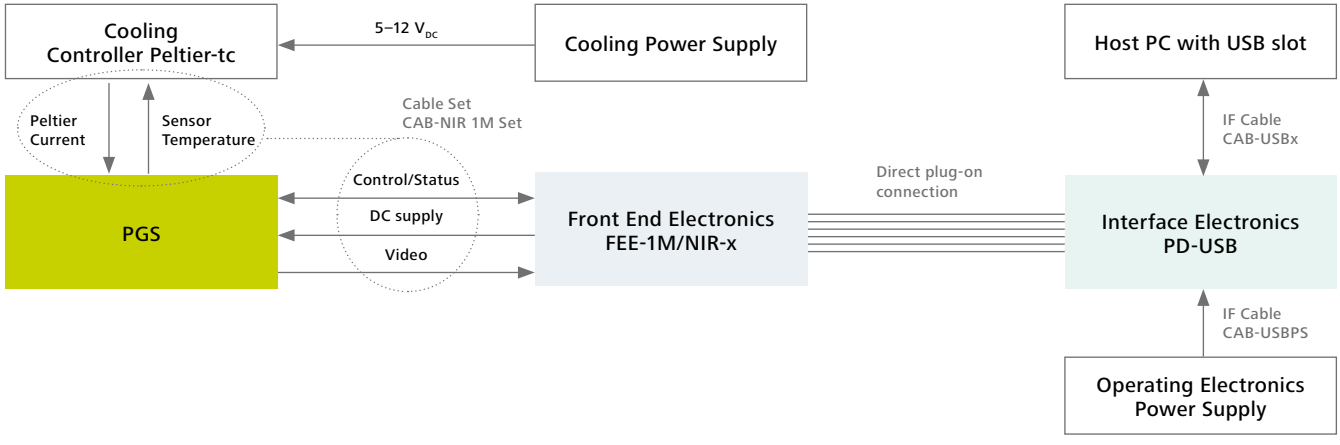
All signal electronics are supplied from the PC's internal power supply. Only the DC supply voltage required for Peltier cooling has to be provided externally.



USB Configuration (Order numbers ➔ Page 43)

The USB-based signal electronics is supplied externally by an additional power supply (self-powered USB device). The electronics is connected to the PC by a standard USB interconnection cable.

we recommend to use a Hi-Speed USB 2.0 port (compatible to standard USB 1.1) All electronics boards are designed for integration into a customer's housing.



Front End Electronics for PGS

FEE-1M/NIR-2 and NIR-4

If ordered as OEM spectrometer modules, the PGS-NIR series are supplied with sensor preamplifier electronics. For operation, a Front End and Interface Electronics and a cooling controller are required.

Short Description

- Fast readout control logic with ADC for digitization of the sensors's analog video signal
- Readout rate: (100), 500 or 1000 kpixel/second
- High resolution: 16 bits A/D conversion
- Dynamic range: up to > 15 bits (with PDA)
- On-board generation of stabilized ±5 V for the sensors from a single supply voltage (5 V ±1 V)
- Output to device: tec5 Interface Electronics PD-USB01V2 or PD-PCI01V1
- PCB dimensions 87 mm x 67 mm (FEE standard)

Features / Specifications

Functional Properties

- Generation of supply voltages for sensors and pre-amplifiers
- PDA readout clock sequencing
- analog video signal preprocessing, A/D conversion
- data transfer to the Interface Electronics
- Local non-volatile memory, 256 Bytes capacity (e.g. for identification data of the sensor(s), calibration coefficients or customer specific information)

Specifications

- ADC 16 bits, type AD7677
- Conversion rate (100), 500 or 1000 kSps
- Electrical Non-linearity < ±2 counts
- Temperature drift < ±1.0 count / °C
- Offset adj. range approx. ± 2000 counts

Basic Version	NIR-2
Standard deviation [counts] typically	4.0
Pixel frequency	500 kHz
Readout time [ms]	1.1
Sensor (example) [number pixels]	(512)

Basic Version	NIR-4
Standard deviation [counts] typically	4.0
Pixel frequency	500 kHz
Readout time [ms]	0.6
Sensor (example) [number pixels]	(256)

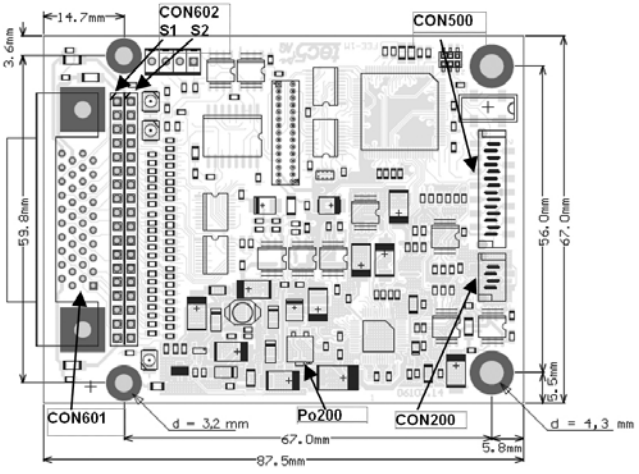
Interfaces

- Interface type ‚Sensor_Ux' to sensor preamplifier (MICS4 connector for analog input signal only)
- Interface type ‚Interface_40' or 'Interface_2*18' to Interface Electronics
- Power consumption (from Interface Electronics)
- + 5 V: approx. 150 – 350 mA depending on configuration and readout frequency.

Environmental conditions

- Temperature range operating 0 °C – 60 °C
- Temperature range storage -40 °C – +70 °C
- Humidity (@25°C, non condensing) 10 % – 90 %

PCB Design



Cooling Controller

The electronics module Peltier-tc is a universal cooling controller unit, which has been specifically designed to operate cooled photodiode arrays. Containing a linear PI-type control circuit, possible interactions and cross-talk to the weak optical signal are minimized. Depending on the system configuration, a temperature stability of less than 0.1 K can be achieved.

All important parameters for control loop operation are selectable on the board. For known temperature sensor and Peltier element parameters, factory preconfiguration of the module is possible. In addition, the electronics board allows to connect heatsink thermistors or remote switches to shut down cooling in cases of failure. Relay contacts are available allowing to disrupt the power supply of attached electronics (e.g. the sensor preamplifier) if the sensor temperature is out of its control limit.

The module offers a maximum cooling current of 3 A with adjustable current limit. It is supplied by a DC voltage in the range between 5 V and 12 V. For specifications and configuration details please refer to the technical data sheet of the module.

Interface Electronics

Depending on the preferred type of connection to the host PC, a PCI plug-in Interface Electronics or a USB-type Interface Electronics may be used. Other alternatives for interfacing are available, please contact tec5 for additional details.

The interface electronics modules retrieve digitized data from the Frontend Electronics and forward the data to a host PC. The electronics circuitry contains the readout scan cycle control logic with precise integration timing and hardware sequencing of all functions with real-time requirements. A FIFO buffer memory is used to assure consistent data transfer to the computer's main memory.

The Interface Electronics modules offer peripheral control and synchronisation with digital I/O lines, e.g. flash trigger output, external trigger input and general purpose digital I/O lines.

Detailed information and order numbers ➔ Page 44/46

Software

Software is required to enable control of the module via the electronics unit. It is available either as a complete package (Aspect Plus) or as libraries and drivers enabling the development of customized software.

Detailed information and order numbers ➔ Page 49

USB Configuration

Order No.	Designation		Description
	tec5-Operating Electronics PGS (Cable set not included)	15-Bit	Front End-Electronic (FEE) SDACQ32 Admin test software for Windows 2000, XP and Vista (32bit)
000000-1433.999	BE USB NIR for PGS NIR 1.7-512		Front end electronic: Type FEE NIR (Power supply and USB cabel required)
000000-1434.001	BE USB NIR for PGS NIR 1.7-256, 2.0 and 2.2		Front end electronic: Type FEE NIR (Power supply and USB cabel required)
000000-0465.486	Power supply for USB electronic		Power supply for USB electronic ((+-12VDC, +5VDC), 115/230VAC)
000000-0483.864	Peltier-tc 1.7		Peltier cooler controller for PGS 1.7
000000-0483.915	Peltier-tc 2.0 and 2.2		Peltier cooler controller for PGS 2.0 and 2.2
000000-0473.454	Cable set for PGS		Cable set for connecting of operating electronic to preamplifier board of PGS NIR 1.7 and 2.2 (Peltier cooler cable, signal cable and control cable)

PCI Configuration

Order No.	Designation		Description
	tec5-Operating Electronics PGS (Cable set not included)	15-Bit	Front End-Electronic (FEE) SDACQ32 Admin test software for Windows 2000, XP and Vista (32bit)
000000-1434.002	BE PCI NIR for PGS NIR 1.7-512		Front end electronic: Type FEE NIR
000000-1434.003	BE PCI NIR for PGS NIR 1.7-256, 2.0 and 2.2		Front end electronic: Type FEE NIR
000000-0483.864	Peltier-tc 1.7		Peltier cooler controller for PGS 1.7
000000-0483.915	Peltier-tc 2.0 and 2.2		Peltier cooler controller for PGS 2.0 and 2.2
000000-0473.454	Cable set for PGS		Cable set for connecting of operating electronic to preamplifier board of PGS NIR 1.7 and 2.2 (Peltier cooler cable, signal cable and control cable)

PCI Bus Interface Electronics
PD-PCI01V1

General

The OEM Interface Electronics PD-PCI01V1 is a digital spectral data acquisition controller and data buffer with a PCI bus interface. The board is directly compatible to all Front End Electronics (FEE) which comply to tec5 specification 'Interface_40' (e.g. FEE-HS and FEE-1M).

The PCI Bus Inter-face Electronics supports photodiode arrays and Spectral Sensors based on NMOS, CCD or InGaAs diode array technology. In this way, the UV-VIS to NIR spectral ranges (190 nm – 2150 nm) can be covered by ready-to-use subunits. Once parameterized and started by the PC, the board's data acquisition controller provides a fully autonomous management of the photodiode array readout cycle. During spectral data acquisition the PC is able to perform other jobs. The state of data acquisition is accessible at any time by reading the status of the spectra data buffer. An integrated I_C bus allows additional information exchange between attached electronics modules (e.g. parameters or coefficients, identification / version).

PC-Requirements

For operation, a PC with Windows 2000 / XP / Vista operating system with a free PCI slot is needed.

Power requirements (supplied from PCI bus)
- +5 V: < 500 mA (without external electronics)
- ±12 V: depending on external electronics (FEE, DZA, sensor)

Features / Specifications

Data Acquisition
- Software selectable sensor operating modes (Single Scan, Single Cycle, Continuous Scan, Burst Scan, Sync To Cont Scan, etc.)
- Crystal clock controlled integration time
- 4 K or 64 K words on-board FIFO buffer for spectral data, readout of FIFO data during measurement, allowing continuous data acquisition.

Periphery I/O
- Integrated illumination control output for triggering flash lamps
- Trigger input for synchronization of spectral data acquisition (e.g. when using a chopper wheel)
- Universal digital I/O signals available: 2 outputs and 2 inputs at External I/O-connector, 3 outputs and 3 inputs at connector to Front End Electronics

Miscellaneous
- Plug & Play: configuration by software
- I2C Bus controller for configuration data exchange
- Non volatile memory for configuration data storage

Interfaces

- Interface to Front End Electronics
- External interface for trigger and digital I/O
- PC interface: PCI bus, 32 Bit

Environmental conditions

- Temperature range operating: 0 °C – +60 °C
- Temperature range storage: -40 °C – +70 °C
- Humidity (@25°C, non condensing): 10 % – 90 %

Design

The PCI Bus Interface Electronics is a plug-in board for the PC PCI bus with the format 130 mm x 107 mm. The current basic version '/52' with PCI controller type PCI9052 replaces the older standard basic version '/STD'. An assembly version '/52-64K' with an extended FIFO buffer of 64 K words is available.

Interfaces

The slot bracket contains a 40 pin Mini Delta connector and a 9 pin Sub-D connector. The 40 pin connector is used for linking the FEE to the Interface Electronics. The 9 pin External I/O-connector provides control signals for triggering additional devices like flash lamps or synchronization of the readout procedure. Most signals of the External I/O-connector can be also accessed at the 40 pin connector (for simplifying system cable connections).

External I/O-connector type
9 pin Sub-D connector (pin type)

Pin	In/Out	Comment
1	Input	Digital input 1, TTL
2	Input	Illumination control voltage input (ICVI)
3	Input	External scan trigger input (ESTI), TTL
4	Input	Digital input 2, TTL
5	Output	Illumination control output (ICO)
6	Output	Supply voltage output +5 V / <500 mA
7	Output	Digital output 1, TTL
8	Output	Digital output 2, TTL
9	-	Ground

Illumination control

The PCI Bus Interface Electronics provides two connections for activating a light source (e.g. a flash lamp):

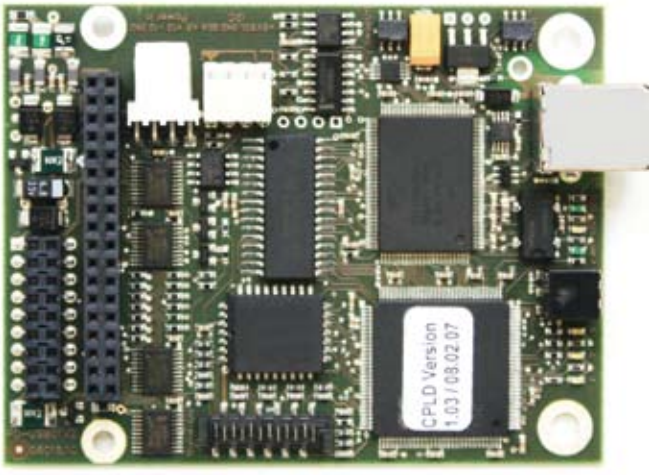
- ICVI: illumination control voltage input and
- ICO: illumination control output.

The voltage range of the ICO signal can be software programmed to either GND to +5 V or GND to ICVI-voltage.
ICO can be locked (0) or released (1) by software. In case of output released, a negative pulse is generated right after the start of the integration time window of each data readout scan. The pulse appears directly after the EndOfScan pulse of the previous "dummy" scan with a pulse width of 45 µs, timed by a monoflop.

External Trigger Capabilities

In many standard applications, a sensor scan cycle is triggered internally by the PC. The External Scan Trigger Input (ESTI) can be used to synchronize the sensor readout to an external event. Two different modes are available: pulse mode (active low, falling edge) and slope mode (both edges). The external trigger functions can be controlled by software.

USB Interface Electronics
PD-USB01V2



General

The PD-USB01V2 Interface Electronics is a powerful and compact digital spectral data acquisition controller with a Hi-Speed USB interface. The product is directly compatible to all Front End Electronics (FEE) which comply to tec5 specification 'Interface_18*2' (FEEs in version /EMB = 'Embedded').

Using theUSB Interface Electronics, the PC is able to control the Frond End Electronics and the spectral sensor connected to it. Once parameterized and started by the PC, the data acquisition controller provides a fully autonomous management of the selected readout cycle. During spectral data acquisition the PC is able to perform other tasks.
An integrated I_C bus allows additional information transfer between connected electronics (e.g. parameters or coefficients, identification / version).

PC and Power Requirements

For operation, a PC with a free USB2.0 (recommended) or USB1.1 port and Windows Vista, XP or 2000 is required.

The PD-USB01V2 Interface Electronics is a 'self powered USB device'. Thus, a supply voltage of +5 VDC (-5%, +10%, typically < 300 mA for PD-USB01V2 board only) has to be provided by an external supply for the Interface Electronics.

Hint: The ±12 VDC supply voltage is not used by the PD-USB01V2 itself but it is only forwarded from the Power connector to the Front End Electronics connector. It has to be applied for configurations with Front End Electronics of type FEE-HS (FEE-CCD), it is not required for FEE-1M (FEE-1M generates all voltages required for it's internal use and the sensor electronics from +5 VDC). For power consumption of Front End Electronics and sensor units / preamplifiers refer to the components data sheets.

Features / Specifications

Data Acquisition
- Software selectable sensor readout cycles (Single Scan, Single Cycle, Continuous Scan, Burst Scan, Sync To Cont Scan)
- Timer controlled integration time
- Continuous data stream via USB during measurement, therefore, continuous data acquisition possible
- Additional spectra data buffer (FIFO 8 or 16 KByte) (16 KByte starting with serial number 379)

Periphery I/O
- Integrated illumination control: trigger output for triggering of flash lamps
- Trigger input for external synchronization of spectral data acquisition (e.g. when using a chopper wheel)
- Universal digital I/O: 3 outputs, 3 (latched) inputs

Miscellaneous
- Plug & Play: configuration by software
- On board I2C Bus for configuration data exchange
- Non volatile memory for configuration data storage

Interfaces
- Interface to Front End Electronics ('Interface_18*2' for FEEs in version 'Embedded')
- USB Series 'B' Receptacle Interface
- External I/O interface for trigger and digital I/O
- Power connector
- I2C Bus connector
- Auxiliary connector

Environmental conditions
- Temperature range operating: 0 °C – +60 °C
- Temperature range storage: -40 °C – +70 °C
- Humidity (@25°C, non condensing): 10 % – 90 %

Design

The USB Interface Electronics is a PCB with the dimensions 87.5 mm x 67 mm (same as FEE).

Interfaces

On the PCB, there is a 36 pin header connector for direct attachment of the FEE on top of the USB Inter-face Electronics. The 12 pin MICS 12 External I/O-connector provides control signals for triggering addi-tional devices like flash lamps or synchronization of the readout procedure. Most signals of the External I/O connector can be accessed at the 36 pin connector alternatively (for simplifying system cable connections). The pinout of the first 9 pins of the External I/O connector allows easy conversion to the tec5 standard 9 pin SUB-D connector using a 1:1 ribbon cable.

External I/O connector type
MICS 12

Pin	In/Out	Signal, Comment
1	Input	Digital Input 1, CMOS
2	Output	Supply voltage output +5 V / <500 mA (fused)
3	Input	Illumination control voltage input (ICVI)
4	Output	Digital Output 1, CMOS
5	Input	External Scan Trigger Input (ESTI)
6	Output	Digital Output 2, CMOS
7	Input	Digital Input 2, CMOS
8	-	Ground
9	Output	Illumination control output (ICO)
10	-	Ground
11	Output	Digital Output 3, CMOS
12	Input	Digital Input 3, CMOS

Power connector type
Molex KK 7395-4 (Plug type: KK 6471-4)

Pin	Signaltype	Signal, Comment
1	Power-I/O	+5 VDC, Standard Power Input
2	Power-I/O	+12 VDC, Standard Power Input
3	Power-I/O	-12 VDC, Standard Power Input
4	Return	Ground

I2C Bus connector type
AMP Quick 0-828549-4 (90°)

Pin	Signaltype	Signal, Comment
1	I2C-Bidirect.	I2C-SDA, Serial data
2	-	Ground
3	I2C-Bidirect.	SCL, Serial clock
4	Power-Output	+5 VDC (*)

Auxiliary connector type
BCS-109-L-D-PE-BE)

This connector may be used for connecting to additional electronics modules, which are prepared to be mounted under the PD-USB01V2 (i.e. PSU2). In this case, a socket connector is plugged into the auxiliary connector from the PCBs bottom side.

Pin	Signaltype	Signal, Comment
1	Power-Output	VUSB, +5 V USB bus voltage (*)
2	-	Reserved (PWR_SW)
3	-	Ground
4	Power-Output	+5 V_INTERN (typically +5 VDC from power connector (*)
5	-	Ground
6	Power-I/O	+5 VDC, Alternat. Power Input
7	Power-I/O	+12 VDC, Alternat. Power Input
8	Power-I/O	-12 VDC, Alternat. Power Input
9	Input	Digital Input 1, CMOS
10	Output	Digital Output 1, CMOS
11	Input	Digital Input 2, CMOS
12	Output	Digital Output 2, CMOS
13	Input	Digital Input 3, CMOS
14	Output	Digital Output 3, CMOS
15	Output	IO_FLASH, internal illumination control, CMOS
16	Input	Illumination control voltage input (ICVI)
17	Output	Illumination control output (ICO)
18	Input	External Scan Trigger Input (ESTI)

(*) No separate current limitation

Hint: The source for Input Signals (External-I/O / FEE-interface / Auxiliary connector) can be selected by software (Default: FEE-interface).

Illumination control

The USB Interface Electronics provides two connections for activating a light source (e.g. a flash lamp):

- ICVI: illumination control voltage input and
- ICO: illumination control output.

The voltage range of the ICO signal is either GND to +5 V (internal) or GND to ICVI-voltage, if an external source > +6V (24V max) is connected to ICVI. Its output resistance is 500R (internal) or 1000R (external).

The ICO's pulse polarity and operation mode can be controlled by software. In case of output released, alternatively a scan-synchronized pulse (pulse width approx. 60 µs) is generated at the beginning of the integration time window of each data scan directly after the EndOfScanPulse of the previous scan or after the StartScanPulse.

External Trigger Capabilities

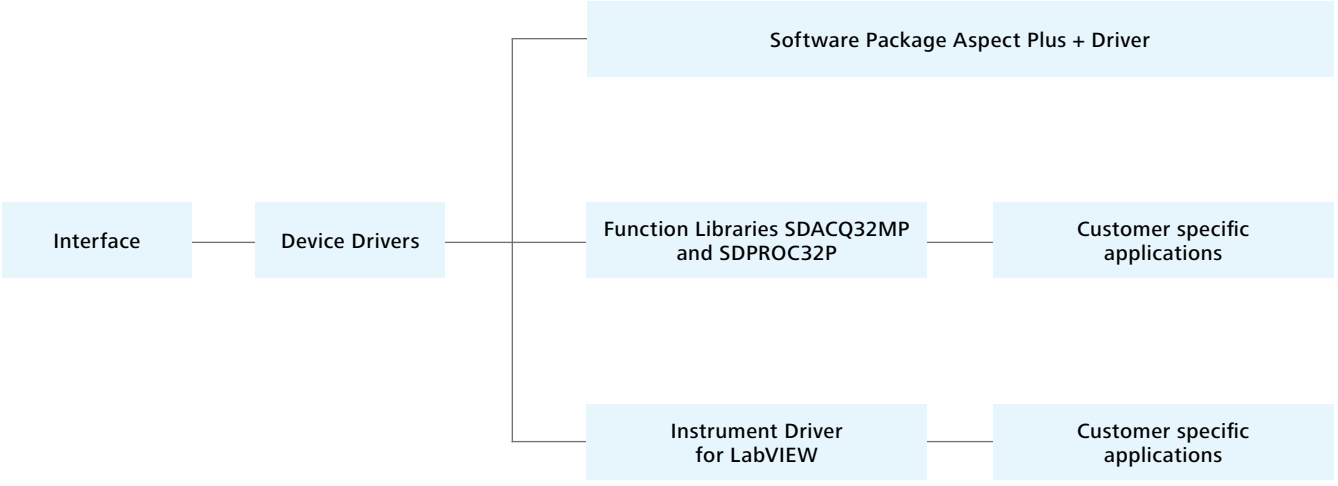
Normally, a sensor scan cycle is triggered by the PC. For synchronizing the sensor readout to an external event the External Scan Trigger Input (ESTI) can be used. Two different modes are available: pulse (active low, falling edge) and slope mode (each slope). The external trigger functions can be controlled by software.

Software Products
Inside the process

The architecture of the software products for acquisition and processing of spectral data is based on a modular structure. Therefore, the software meets versatile, customer-specific requirements and allows adaptation to different hardware configurations. For the various operating electronics units, instrument drivers are available for Windows 2000, XP and Vista.

The universal Aspect Plus program package featuring numerous functions is available in addition to the instrument drivers for the PC Bus interface. Also offered for easy integration into customer-specific applications: a programming interface for the SDACQ 32 MP function library that directly supports C/C++/Visual Basic and Delphi, and a LabVIEW driver that enables programming in a LabVIEW environment. Furthermore, the SDPROC32 function library allows programming with finished menu structures for data acquisition, configuration and parameter entry.

The SDACQ32MP function library directly addresses these instrument drivers and delivers a hardware-independent collection of functions that enable the configuration of the operating electronic units and the acquisition of spectral data.



Modular spectral analysis software package
Aspect Plus

General

Aspect Plus is a flexible, modular spectral analysis software package that runs under MS Windows. Extensions are available to support specific applications and to implement standard diagnostic tests. Using Aspect Plus, spectral measurements and processing can be carried out for the Zeiss spectrometer systems. An extensive set of functions are available both by menu and macro to perform measurements, process data and format displays and printout.

File

The File menu contains operations that are used for managing files that have been created using Aspect Plus or other compatible programs. Aspect Plus supports the import/export of GRAMS (spc) ASCII (csv) and JCAMP format files.

Edit

The Edit menu contains operations that are useful for inter-program transfer of data. A Copy command allows a spectrum to be easily inserted into Windows-based programs such as word processors.

View

The View menu contains operations that can be used to alter the visual display of spectra and the set-up of the screen.

Measurement

The Measurement menu contains the commands that are used to operate the spectrometer. Sample, reference and dark spectra can be measured, saved and restored. Parameter files can be created, loaded and edited. Kinetic data measurements can be defined and started.

Data Handling

The Data Handling menu allows the user to process saved spectra using different arithmetic operations. Standard available options include:

- Multiplication by or addition of a constant
- Conversion, e.g.% T - Abs, nm - cm-1
- 1st – 4th derivative
- Smoothing
- Interpolation
- Normalization
- Addition, subtraction, multiplication, division of two spectra

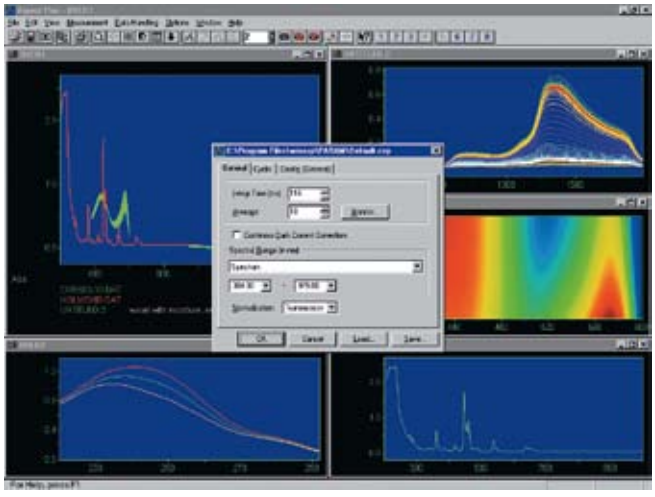
In addition to providing for manipulation and analysis of spectra, the Data Handling menu provides a log record of the operations performed.

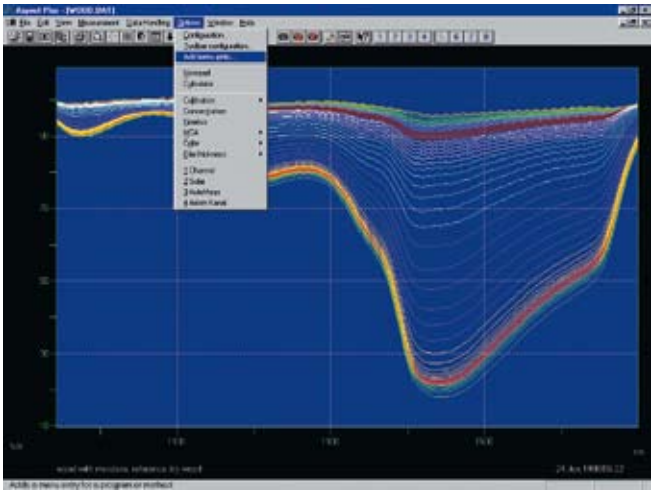
Options

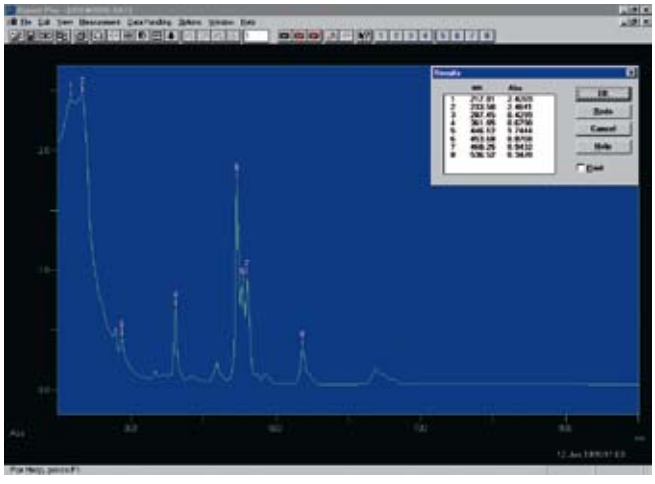
The Options Menu provides access to a variety of useful external programs and methods. These include the creation of calibration files, the estimation of concentrations and the measurement and evaluation of the kinetics of reactions. A Windows Notepad editor and Calculator can be accessed from this menu.

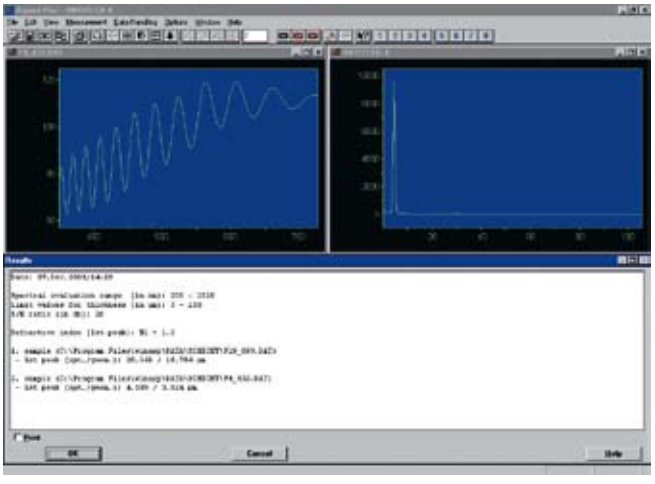
The kinetics software module includes the ability to calculate kinetic constants from spectra using the following models:

- S
- $y=bx$
- $y=a+bx$
- $y=a+bx+cx^2$
- $y=a+be-kx$
- $y=a+bx+ce-kx$
- $y=a+b(1-e-kx)$
- $y=a+bx+cx^2+dx^3$
- $y=a+bx+cx^2+dx^3+ex^4$









Order No.	Designation	Description
263259-5020.026	Aspect Plus	WINDOWS spectrometer software
000000-1242.401	Driver Aspect Plus for PCI-card and USB	Aspect Plus driver for tec5 electronic for Windows 2000 and XP

Software Products for Spectral Data Acquisition*

Device Drivers, Function Libraries SDACQ32MP and SDPROC32

Device Drivers

All Operating Electronics with PC Bus Interface (PCI, USB) are supported by special device drivers. As an extension of the operating system these interrupt controlled drivers interact with the hardware, e.g. to set parameters and acquire pixel related data. These drivers cannot be accessed directly by users due to the complexity of hardware parameters and sensor operating modes. However, the drivers can be accessed by the user-friendly function library SDACQ32MP.

Function Library SDACQ32MP

As a base for all tec5 software products the function library SDACQ32MP (*.DLL) provides many functions for setting the hardware parameters, acquiring spectral data and supporting additional hardware functions (e.g. digital I/O). The pixel related data is transferred to the application for further processing.

The function library interacts with the hardware related device drivers. The different features of the individual electronic devices in use are taken into account. The function library allows a hardware version independent acquisition of spectral data. With just one software interface, all different hardware configurations can be managed. Therefore, the application software is independent of the hardware type.

The function library can handle several Operating Electronics of the same type simultaneously (up to 6, depending on type). This allows the acquisition of spectral data from different sensors at the same time.

Each individual board of the tec5 Operating Electronics contains a memory chip (EEPROM) that stores various identification information and the calibration coefficients of the spectrometers in use. The function library can read and use this information e.g. for automatic configuration of the software.

Function Library SDPROC32 for Spectral Data Acquisition and Processing

Based upon the SDACQ32MP module the SDPROC32 library implements an interface, which provides further abstraction from the actual hardware, and a basic data processing functionality required in most spectroscopy applications.

The hardware configuration is stored in a human-readable INI file, which is created by using the integrated hardware configuration wizard. Standard processing features such as interpolation, calculation of transmittance and absorbance, channel joining are implemented as well as data preprocessing functionality (i.e. base line correction).

Overview

Feature	SDACQ32MP	SDPROC32
Abstraction	low	high
Direct access to hardware	R	∑
Channel assignment	physical	logical
Configuration file	∑	R
Hardware transparent for application	∑	R
Ready-to-use configuration dialogue	∑	R
Control of light sources	R	R
Dark current correction	R	R
Wavelength related data	∑	R
Calculation of transmission/absorption	∑	R
DLL interface	R	R

Test Software AdminTool

The AdminTool is a test program for tec5 Operating Electronics and spectrometer systems. It allows the acquisition and display of pixel related data as well as the setting of the sensor parameters (calibration coefficients, number of pixels, sensor type) and their storage to the hardware. The acquired data can be exported as an ASCII file for further data processing.

Software Development Kits for SDACQ32MP / SDPROC32

The Software Development Kits provide files and documentation in order to develop applications based upon the respective library. Specifically the programming languages C, C++, Visual Basic, Delphi (SDACQ32MP only) are supported by the SDKs including prepared files for function and constants definition. In general most common programming environments able to handle standard windows DLLs can be used. In addition, some program examples in MSVC, MSVB, Delphi (SDACQ32MP only) and C#.NET are included.

Instrument Driver for LabVIEW

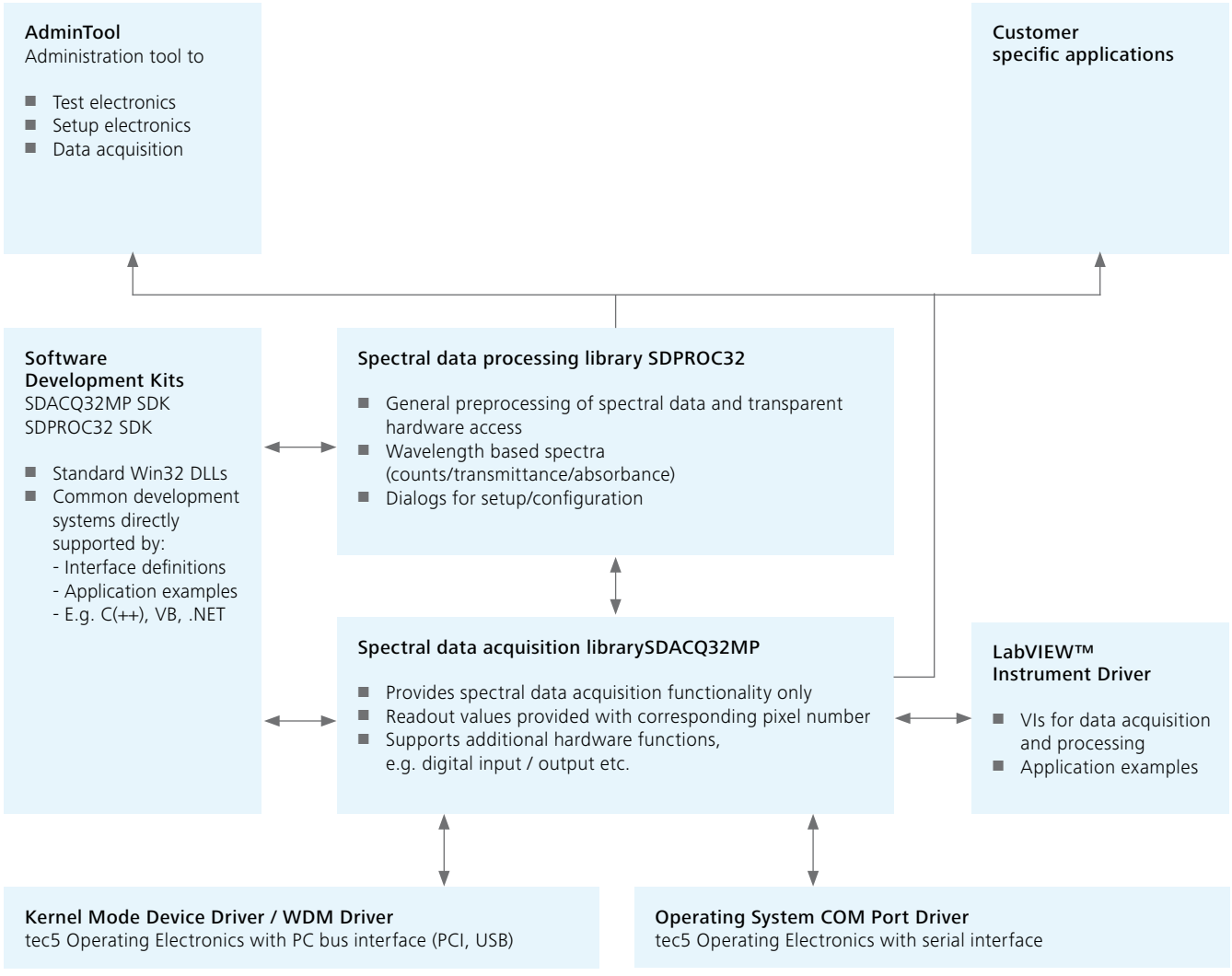
The programmer language LabVIEW™ from National Instruments is a graphical user interface for developing process application software. For the direct integration of tec5 hardware, LabVIEW™ instrument drivers are available. These instrument drivers consist of various Sub-VIs providing most of the functions of the library. In addition to these basic functions, tec5 offers a variety of Sub-VIs for processing of spectral data, e.g.:

- calculation of the wavelengths based on the calibration coefficients
- interpolation of spectral data
- determination of absorption and transmission values
- export of spectral data as ASCII and JCAMP files

Specific application examples are provided for the USB Operating Electronics. The setting of hardware parameters as well as the acquisition and processing of spectral data is shown.

* Software products are developed by tec5 AG.

Overview



Order No.	Designation	Description
000000-1277.426	SDACQ32MP Programmer-Interface for tec5 electronic	Basic function library for C++, Visual Basic and Delphi for Windows 2000 and XP
000000-0483.921	SDPROC32 Programmer-Interface for tec5 electronic	Advanced function library for C++, Visual Basic and Delphi for Windows 2000 and XP
000000-1277.424	LabVIEW Instruments driver for tec5 electronic SDACQ32	Spectral Data Acquisition Library for 32-Bit Environment (included as DLL) Sub-VIs for spectral data handling

Applications
Nothing is impossible

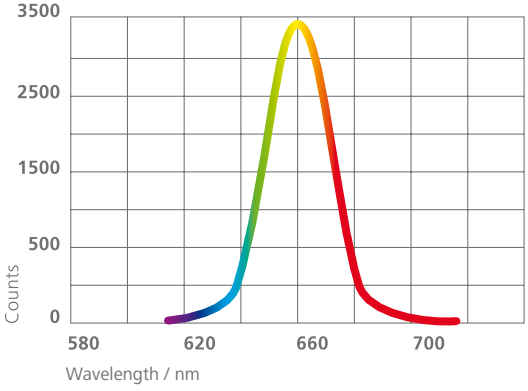
The flexible design of the Carl Zeiss spectrometer modules makes them suitable for use in many applications. They can be classified according to the measurement principles used, the fields of use or the materials to be analyzed. However, the most important benefit is the compactness and the insensitivity to external influences. This allows them to be directly integrated into processes. In most of the applications mentioned below, on-line inspection possibility is possibile.

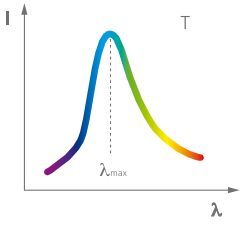
Measurement principles:
1. Emission
2. Diffuse reflection
3. Reflection
4. Transmission – absorption
5. White Light interference

Emission

To determine the spectral emission of a light source, part of the light is directed to the spectrometer module. In view of the high light sensitivity, it is in many cases sufficient to bring the coupling fiber bundle close to the light source. For optimization, an achromatic collecting lens can be used.

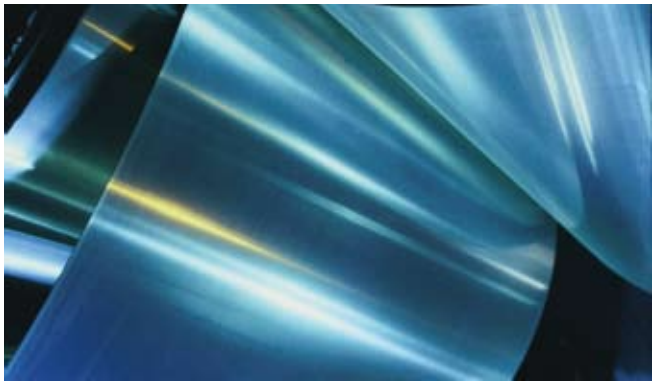
Examples
- Checking illuminators (aging)
- Determining the wavelength of LEDs or (tunable) lasers
- Luminescence, fluorescence
- Monitoring the solar spectrum, burns, discharges or plasma
- Determining the temperature T in accordance with the Wien displacement law, e.g.: 3000 K ⟷ 966 nm





$\lambda_{max} \times T = 2.8978 \times 10^3 \text{ m} \times \text{K}$

Requirements
The wavelength accuracy, which is very high considering the size of the module, allows an exact determination of the wavelength of light sources which emit a single line, such as LEDs (calibration), using the sub-pixel resolution procedure. The spectrometer modules are not suitable for the analysis of emission radiation containing spectrally adjacent lines which are too close together.



Diffuse reflection

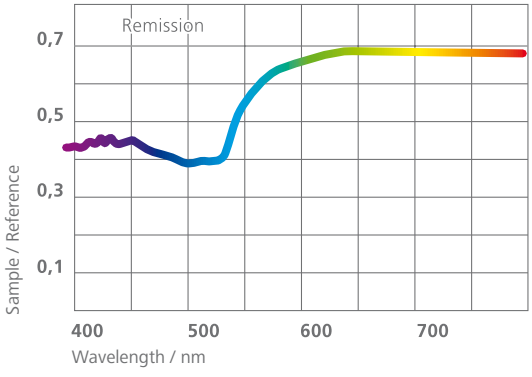
The diffuse reflection of scattered light (from rough surfaces) supplies information on the color of the surface. Important for this procedure (in addition to the spectrometer used) are the light source and the position of the detector (angle with surface normal). In most cases, a light source with a wide-band emission, e.g. a halogen lamp, is used. Here, too, it is often sufficient to bring the input of the cross section converter close to the colored surface to be measured without using additional optics.

Examples

- Color measurement of different surfaces (materials)
- Condition of coatings
- Analysis of paper quality

Requirements

The spectrometer modules have been specially designed for color measurement. Its high repeatability and light intensity, combined with moderate spectral resolution, exactly meet the demands made in this field.



Reflection

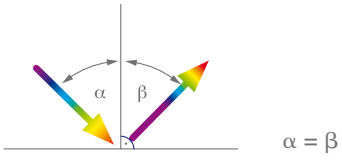
Reflection is a special case of diffuse backscatter and refers to the directionally reflected light thrown back from low-scatter, smooth surfaces. In addition to the sensor, a light source is needed. It should be noted that reflectivity is strongly dependent on the angle α. The most simple setup for measurements at $\alpha = 0°$ can be obtained using a special light guide which supplies the light and also directs it to the detector.

Examples

- Coatings in general
- Antireflection coatings of surfaces using metals or dielectric coatings
- Ellipsometry
- Determining the fat content of meat and sausages
- Determining the humidity content in cereals, food and cellulose
- Plastic identification for recycling and disposal

Requirements

Many reflection spectra do not display any marked structures. For this reason, high absolute wavelength accuracy is considerably more important in many cases than good spectral resolution.



$\alpha = \beta$

White light interference

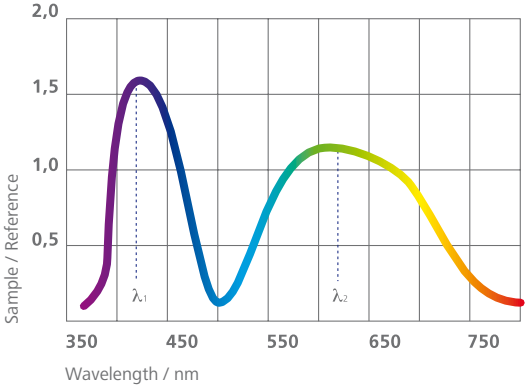
When white light is incident on optically (partially) transparent layers, interference occurs, as the path difference between specific wavelengths is exactly a multiple of the optical layer thickness n x d (λ_1, λ_2: position of the extrema, spaced at a cycle). If the refractive index n is known, the geometric layer thickness d can be calculated. The fiber Interface ensures easy coupling to microscopes or the flanging to coating systems. If the layer thickness d is known, dispersion n (λ) can be determined.

Examples

- Layer thickness measurements of photoresists, films and dielectric layers

Requirements

To ensure exact thickness measurements, high absolute accuracy of the wavelength is again required. The maximum measurable thickness is linked to the spectral resolving power (separation of two interference maxima), the minimum thickness to the spectral range to be covered (recording of at least one half-cycle). The measurement of even thinner layers (evaluation of less than a half-cycle) requires that absolute intensity values be known.



E.g. MMS 1, n = 1.5
d_{max}, ≈ 25 µm, d_{min}, ≤ 0.2 µm

$2 n x d = \lambda_1 x \lambda_2 / (\lambda_1 - \lambda_2)$

Transmission

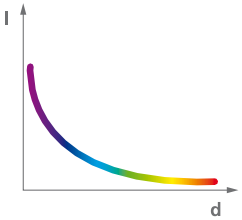
The transmission of material with a thickness d supplies information on the spectral dependence of the absorption constant $\alpha(\lambda)$ (I_0: incident intensity, I(d): transmitted intensity). Immersion probes connected to a light source and a spectrometer module using fibers is the simplest system for measuring the concentration c of liquids. The concentration is related to the absorption constant via the absorbance coefficient ε. In other cases it is advisable to set up a collimated beam path. Measurements where the input of the cross-section converter is in direct contact with the object to be measured can also be performed.

Examples

- Measurement of filters (color filters, interference filters)
- Measurement of the concentrations of liquids
- Thickness measurement if absorption coefficient is constant
- Determination of the sugar and alcohol contents in beverages
- Quality control in the petrochemical industry

Requirements

Here, too, very high spectral resolution is less important than a very good wavelength accuracy and high dynamic resolution – as provided by the spectrometer modules.



Lambert-Beer-Law
$I = I_0 x e^{-a x d}$
$\alpha = \varepsilon x c$

The most important criterion when selecting a spectrometer is the spectral range which must be covered by the spectrometer. In most cases, this range is clearly defined. The other two important criteria of a spectrometer – the spectral and the intensity related (dynamic) resolution – are, however, very rarely clearly defined.

Spectral resolution

The following three terms are often used to describe "spectral" resolution:

1. Line width, mostly full width at half maximum – $\Delta\lambda_{FWHM}$
2. Sub-pixel-resolution (also termed "software resolution")
3. Mean spectral pixel pitch – $\Delta\lambda_{Pixel}$

It is the actual application which provides a useful definition in this respect. There are mainly three different purposes for which a spectrometer is used (these can also occur in combination, of course):

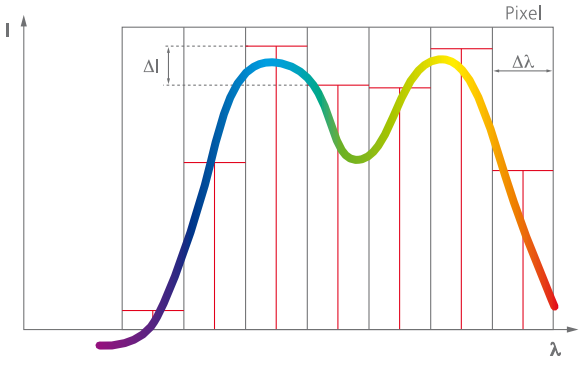
1. Separation of two or more lines within a spectrum – analysis of compositions
2. Determining the line shape mostly determining the width of a line or band (FWHM or $1/e^2$-width)
3. Measurement of a line with respect to its peak wavelength and intensity at the maximum.

Spectral resolving power
According to DIN, the Rayleigh criterion is relevant to the separation of spectral lines. The criterion indicates how wide the spectral distance between two lines $\Delta\lambda_{Rayleigh}$ must be to allow their recognition as separate lines. Here, the spectral width of the individual lines $\Delta\lambda_{Line}$, (see above) must be markedly smaller than their spacing. This is the only significant definition of spectral resolving power.

2 lines with $I_{max},1 = I_{max},2$ are separated if
$\Delta I_{decrease} \geq 19\ \%$

Width of spectral lines
To enable the measurement of the width of a spectral line $\Delta\lambda_{Linie}$, the expansion of this line by the spectrometer must be smaller than the spectral width of the line itself. To ensure this, it is important to know the expansion $\Delta\lambda_{FWHM}$ produced by the spectrometer. This property is related to the Rayleigh criterion.

$\Delta\lambda_{FWHM} = \lambda_2(I_{max}/2) - \lambda_1(I_{max}/2)$
$\Delta\lambda_{FWHM} \approx 0.8 \times \Delta I_{Rayleigh}$



Wavelength accuracy
To determine the spectral position λ – with a specific accuracy $\Delta\lambda_{\pm}$ – of a single line, a spectrometer with at least this absolute wavelength accuracy $\Delta\lambda_{\pm}$ is required. This parameter is dependent on the accuracy of the positions of the readout elements (pixels or slit/detector) or the stability of these positions characterized by repeatability. Contrary to this, the absolute wavelength accuracy only depends indirectly on the dispersive and focal properties of the spectrometer and is not "resolution" in the classic sense. The stability (or repeatability) of a spectral sensor is dependent on the mechanical stability of the module and the temperature-related wavelength drift. The former is completely uncritical in the spectrometer modules, and the drift can be more or less neglected.

Dispersion
The term $\Delta\lambda$ / Pixel (= $\Delta\lambda_{Pixel}$) has nothing to do with spectral resolution; it is merely the linear dispersion of a diode array spectrometer. The pixel dispersion and the spectral resolution are related to each other via the width of the entrance slit and the imaging properties of the spectrometer. If the entrance slit is imaged on approx. 3 pixels, the triple of the pixel dispersion approximately corresponds to $\Delta\lambda_{Rayleigh}$.

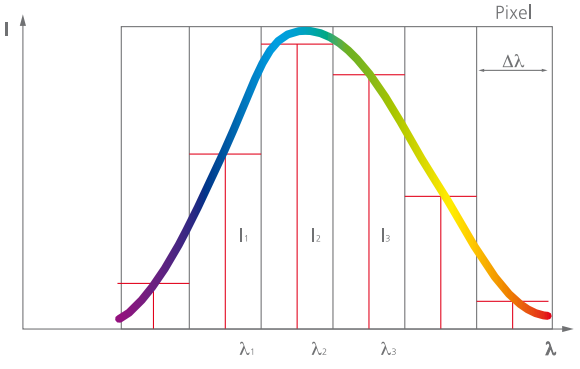
$\Delta\lambda_{Rayleigh} \approx 3 \times \Delta\lambda_{Pixel}$

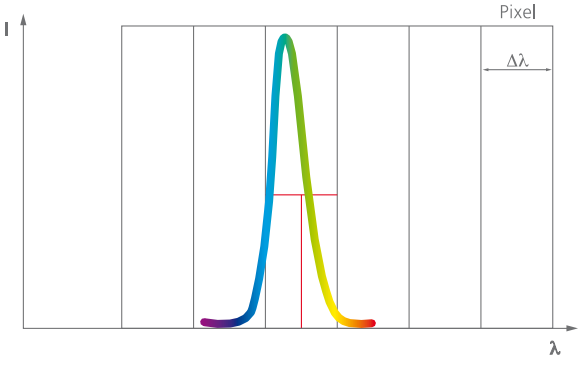
Special features of diode array spectrometers (AS)

Spectral resolution
Due to the fixed position of the pixels with respect to the wavelength of the incident light, the resolution provided by AS differs from that provided by monochromators/spectrometers with moving components: resolution defined as the "separation of two adjacent lines" is dependent on the relative position of these lines with respect to the pixels:

If two adjacent lines are imaged on the pixels in such a way that the minimum falls on the central pixel (I_2) and the maxima on the adjacent pixels (I_1, I_3) the lines can be separated if the intensity displayed is $I_2 < 0.81 \times I_1$ (I_3), $\Delta\lambda$ is then exactly two pixels ($2 \times \Delta\lambda_{Pixel}$). In this case, it is sufficient to evaluate a total of 3 pixels; the locations of the maxima correspond almost exactly to the central wavelengths of the pixels displayed.

If the maximum of a line is imaged on the separating line between two pixels (I_1,I_2) however, a total of 4 pixels is required to be able to detect a clear reduction in the pixel intensities. Both pixels record about the same intensity, with the result that a reduction to 81 % is not displayed until in the next pixel (I_3) Here, the actual maxima are separated by fewer than 3 pixels; the AS displays a spectral spacing of $3 \times \Delta\lambda_{Pixel}$ as a diode array can only detect discrete values using the step width of the pixel dispersion. A total of 4 pixels are needed for processing.





Sub-pixel resolution or the parabola fit
To determine the peak wavelength λ_{max} (and/or peak intensity I_m) the spectral line to be measured must be imaged on at least 3 pixels (see below). Three pairs of values (intensity per pixel $I_{1,2,3}$ and the related central wavelength of the pixel $\lambda_{1,2,3}$ allow relatively easy fitting of the line to a parabola. The equation for the parabola then gives the peak of the curve including the data for the peak wavelength and peak intensity. The accuracy of this method largely depends on the absolute accuracy of the central wavelength. In a diode array spectrometer, this wavelength can be determined, in principle, to almost any accuracy required. If necessary, each pixel can be individually calibrated. However, this will only make sense if the module features the necessary stability. Otherwise, the wavelength specification will only remain valid until the next shock or temperature change.

If the imaging performance (and the dispersion) of a AS has been chosen such that fewer than 3 pixels are illuminated, no extrema can be determined, resulting in a parodox: an apparently ideal situation – a line is very narrow at the output – leads to considerably increased inaccuracy. If, for example, a line is only imaged on a single pixel, the spectral inaccuracy is $\Delta\lambda_{Pixel}$ in this case.

Parabola equation
$I(\lambda) = a \times \lambda^2 + b \times \lambda + c$

Coefficients
$a = (I_3 + I_1 - 2\,I_2) / 2\,\Delta\lambda^2$
$b = (I_3 - I_1) / 2\,\Delta\lambda - 2a \times \lambda^2$
$c = I2 - a \times I22 - b \times I2$

Maximum at $\lambda_{max} = -b / 2a$

Determining the half-width
The parabola fit also supplies qualitative data on the half-width. For this, Imax/2 must only be inserted in the parabola equation. There are only minor differences between the half-width of a parabola fit and that of a Gaussian fit (see below).

The half-width which is displayed by a AS is also dependent on the position of a line relative to the individual pixels. Our specifications are valid for worst-case values.

More adequate, but more complex, are fits to Gaussian or Lorentz curves which better correspond to the actual spectral distributions. These fits also have the advantage that the half-width calculated from them is not dependent on its position relative to the pixels.

$$\Delta\lambda_{FWHM} = 2[(b/2a)^2 - (c - I_{max})/a]^{1/2}$$

Intensity resolution

To measure intensity, the following properties which are dependent on each other are of interest:

Relative:
- smallest detectable change
- signal stability
- detection or dynamic range
- linearity

Absolute:
- lowest detectable amount of light or sensitivity.

Accuracy
Measurements of minimal changes and stability are directly dependent on each other and are mainly limited by the noise present in the electronics, as the stability of the „light path" is ensured in most spectrometers. As with all parameters, it is important how a value – here in the true sense of the word – is determined. For the data provided by the MMS, for example, an integration time of 10 ms is set and the standard deviation $\Delta\sigma$ is computed using 20 recordings. This supplies a measure of the accuracy $\Delta\lambda$ with which an intensity value can be determined.

$$\Delta I = I_{noise} = \Delta\sigma$$

Dynamic range and intensity changes
The dynamic response is defined as the ratio of the saturation value I_{sat} and the noise $I_{noise} \longleftrightarrow \Delta\sigma$ and thus corresponds to the signal-to-noise ratio S/N. (The usable range is reduced by the dark current.) $\Delta\sigma$ does not only depend on the detector, but also on the digitization determining the smallest step width into which a measured signal can be decomposed.

$$\text{Dynamic range} = S/N = I_{sat} / I_{noise}$$

The weakest link in the chain, of course, determines the signal to-noise ratio to be achieved. For instance, when using a 14 bit converter – this corresponds to 16,384 steps or increments and a noise of $\Delta\sigma$ = 1 count, a signal (full-scale display) can really be divided into 16,384 increments. Hence, the lowest measurable change is 1/16,384 of the saturation signal. At a noise of 4 counts an uncertainty of 4 counts also exists, i.e. a change of 4/16,384 of the saturation signal can only be definitively measured or the signal divided into 4,096 increments.

It should be noted here that a wide dynamic range is only obtainable if the PDA (photodiode array) is near the saturation limit. The aim is always to reach high light intensity – here, the high sensitivity of the spectrometer modules is beneficial.

$$\text{Dynamic range} = \text{range ADC}/\Delta\sigma$$

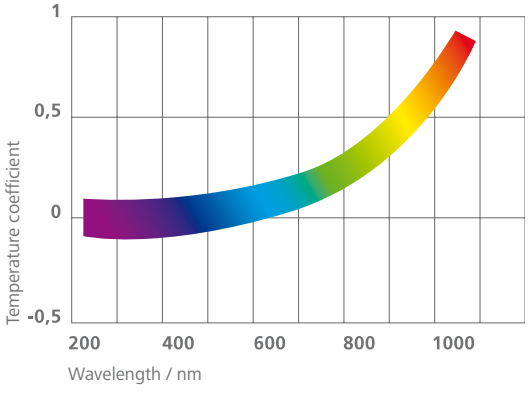
Linearity
The previous remarks will be completely accurate only if the detector and the post-detector electronics provide ideal linearity, i.e. if the dependence of the measured charge on the irradiated intensity is exactly linear. For quantification, the admissible deviation must be specified. Fortunately, the behavior of modern semiconductor detectors is almost perfectly linear within a wide range. Before saturation (the extreme case of non-linearity) is reached, however, the increase of the current (carrier of the intensity information) supplied is no longer linear to the number of photons striking the photosensitive material. For this reason, the range of linearity is smaller than the dynamic range.

External influences
As the graphic shows, a change of the temperature T does not cause any change in sensitivity of silicon, the sensitivity in fact increases slightly in the range of up to 1100 nm when the temperature is raised. In the case of InGaAs photodiode arrays, the sensitivity also changes by less than 1 % in the range of 1 to 1.55 µm with temperatures ranging from -50 and +50 °C. Only outside the specified range, does the different coating lead to an increased influence of temperature. (Falling temperatures lead to reduced sensitivity on the band edge).

In addition, the signal-to-noise ratio of the photodiode array used does not degrade with increasing T. It is only the dark current Idark which increases with rising temperature, resulting in a reduction of the dynamic range. Therefore, detectors, in particular InGaAs diode arrays, are often cooled.

In this context it should be mentioned that the amounts of light to be measured are also subject to fluctuations. The instability of the light source is often the limiting factor.

$$I_{dark}\,(T+7K) = 2I_{dark}(T)$$



Sensitivity
The smallest detectable change is a relative specification. Much more difficult to specify is the lowest detectable amount of light or: how many photons are needed for the detection electronics to record a change. The difficulties result from determining the light intensity of a light source and the coupling efficiency. Furthermore, these parameters are wavelength-dependent. There is, on the one hand, a direct dependence, as all components feature wavelength dependent efficiencies – including the coupling – in device; on the other, there is a dependence, as the bandwidth is of decisive importance for sensitivity measurements. The simplest case is a light source with a very narrow band, as displayed by most of the lasers. If the bandwidth of the light source used is markedly smaller than the bandwidth of the spectrometer used, the situation is clear. The MMS value of more than 10^{13} counts / Ws has been measured with a red HeNe laser.

Scattered light

The specification of scattered light data is only useful in connection with the measuring instructions. Scattered light data for the spectrometer modules are determined using three different light sources to measure the different spectral components of scattered light: a deuterium lamp for UV, a xenon lamp for VIS and a halogen lamp for VIS-NIR.

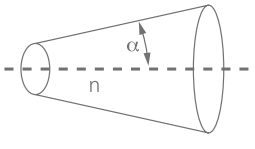
The level of scattered light is defined as the ratio of the respective measurement using Schott GG495 and KG3 filters to the maximum useful signal and is therefore specified for the short wavelength range. This reveals that the main components of scattered light in the spectrometer modules come from the NIR range. These spectral components are easy to filter out as they are far away from the spectral range of interest. The scattered light value for the PGS NIR is reduced to 0.1 % (measured at 1450 nm, halogen lamp, Schott RG 850 filter and 10 mm water absorption).

Scattered light influences the dynamic range as the full range is no longer available. However, changes in the radiation used only affect the dynamic range in proportion to the scattered light present: for example, a change pf 10 % in the radiation used causes a change of 10^{-4} if the scattered light component is 0.1 %. If the radiation causing the scattered light is not used, the amount of scattered light can be further reduced by filtering this radiation. A blocking of 103 results in a change of 10^{-7} in the case described. Thus, the measurement of minimal changes is only impaired to a very limited extent, as noise is the bigger problem in most cases. In addition, if the signal causing the scattered light is known, the scattered light component can be eliminated by computation.

Optical interface

Interfaces must be mechanically and optically defined. A useful mechanical interface for optical systems is the SMA connector as used in the modules. Together with the well-defined light guidance factor of a fiber bundle, this results in a unique interface.

Light guidance factor
The light guidance factor G is the product of the light entrance area F and the aperture angle Ω of the light beam, with the refractive index n also having to be taken into account. The first factor corresponds to the cross-section of the fiber bundle, the second factor is derived fro m the numerical aperture NA. In the case of the e.g. MMS 1 family, the fiber optical light value is calculated at G = 0.157 mm^2sr.



$G = F \times \Omega \times n^2$
$\Omega = 2\pi \times (1-\cos \alpha)$
$\alpha = \arcsin NA$

For the optimum adaptation of an existing light source (whether fiber, illuminator, imaging system) it is recommended to determine the respective light guidance factor. A comparison of the

factor obtained for the light source with the MMS light guidance factor permits an estimate to be made of the possible coupling efficiency. In addition, Fresnel losses of 4 % (index jump at glass fiber) must also be taken into account.

Increase in transmission
If round light spots are assumed, the use of a cross-section converter (CSC) results in increased transmission $\eta_{FF, QSW}$ / $\eta_{FF, slit}$ compared with the classic slit. This increased transmission can be calculated from the ratio of the amount of light transmitted by the CSC to the amount of light transmitted by a rectangular slit.

In the CSC, the transmitted amount of light is given by the fill factor $\eta_{FF, QSW}$. The fill factor is defined as the quotient of the optically effective surface A_{eff} and the overall illuminated are a_{Apt}.

In the CSC, A_{eff} is the product of the fiber core cross-section and the diameter d_{fiber} and the number of fibers N; in the slit, A_{eff} is the area obtained from the slit width b and slit height h. The total area is the circular area with the diameter d_{slit} = h.

$$\eta_{FF, QSW} = N \times d_{fiber}^2 / d_{Apt}^2$$
$$\eta_{FF, sli}t = 4\ b/(p \times d_{slit})$$
$$\eta_{FF, QSW} / \eta_{FF, slit} = 16 \text{ (MMS)}$$

Optimization of an array spectrometer

In addition to the selection of the most efficient components possible (blazed grating, cross-section converter, sensitive diode array), dispersion, imaging properties, entrance slit and pixel size must be matched to each other. To obtain maximum light sensitivity it is important that – with monochromatic light – only just a little more than the 2 pixels are illuminated which are required for spectral resolution. In a first approximation, the grating provides a 1:1 ratio image, i.e. the entrance slit should be 2 to 3 pixels wide. If more pixels are illuminated, the signal-to noise ratio and the sensitivity will worsen (1 pixel does not cover the optimal bandwidth). If fewer than 3 pixels are illuminated, the wavelength accuracy will worsen. The selection of 70 µm individual fibers (effective slit width approx. 60 µm) for the MMS 1 CSC, for example, is thus ideal for a pixel width of 25 µm. The number of fibers is obtained by dividing the pixel height by the outer diameter of the individual fibers.

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