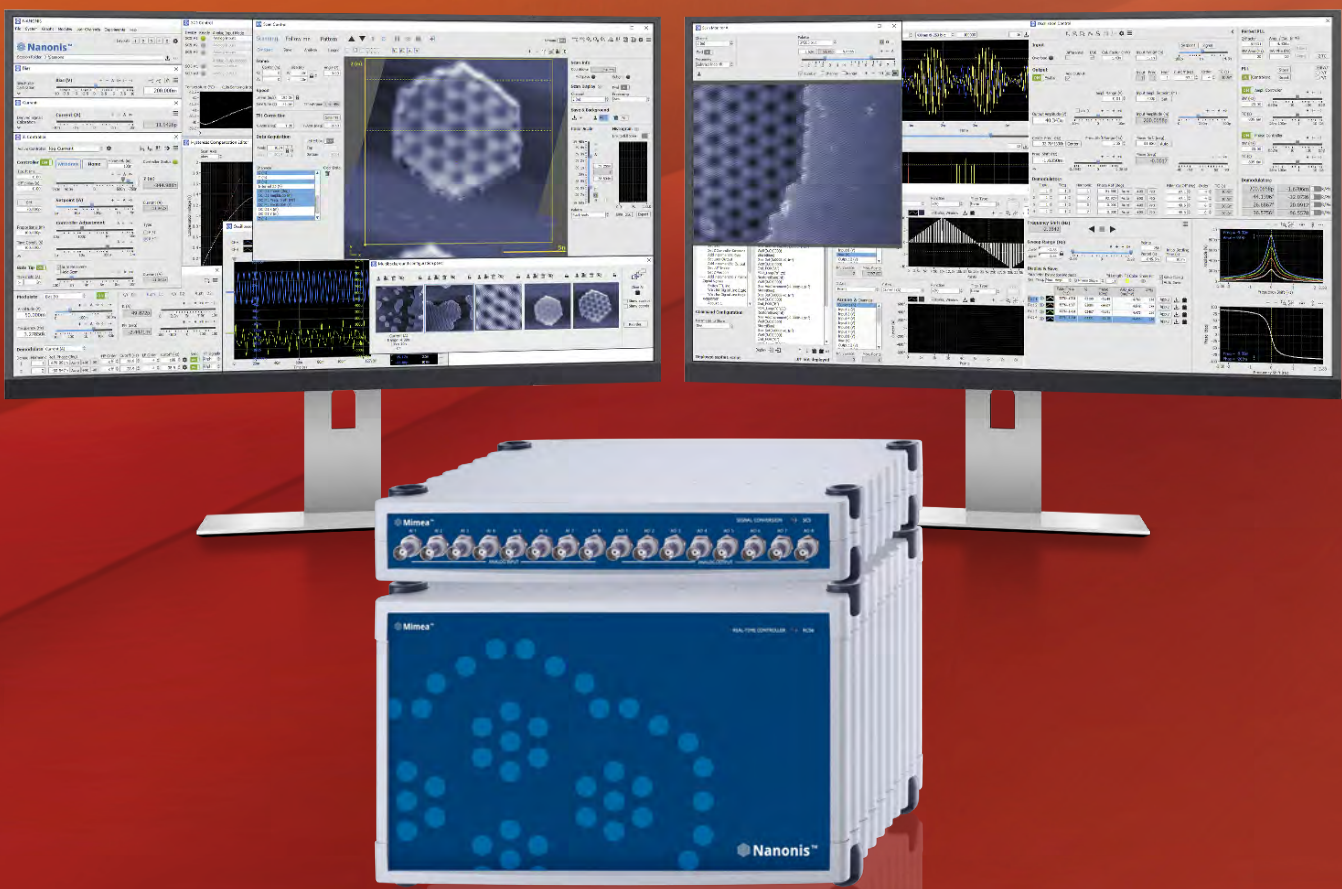
Mimea BP5e

ENHANCED SPM CONTROL SYSTEM
BASE PACKAGE 5E

KEY FEATURES

- Fast scanning and spectroscopy
- Uncompromising signal quality
- Full flexibility for most advanced measurement techniques
- Works with any SPM in any mode
- Future-proof state-of-the-art hardware



Nanonis™
A member of SPECS Group

Nanonis™

INNOVATION IN CONTROL SYSTEMS FOR SPM AND QUANTUM TRANSPORT

Defining the benchmark in Microscopy and Quantum Transport Measurement Systems for over a decade, Nanonis, in true Swiss quality, continues to deliver innovative and powerful solutions for all your measurement needs.

SPM measurements performed with Nanonis Mimea

Nanonis

Driven by their experience in Scanning Probe Microscopy and their revolutionary ideas on how such measurements could be realized, a small team of research scientists turned entrepreneurs founded Nanonis in 2002. By applying utmost care to both the hardware component selection and the software algorithms employed, ensuring optimum data quality has always been at the core of the Nanonis mind-set. The graphical user interface with its "Cockpit" approach allowed presenting the myriad of functionalities in a clearly arranged design. Continuous investment into the platform produces a steadily growing feature-set available to the user.

In 2009 Nanonis became part of the SPECS group as SPECS Zurich, benefitting from an established infrastructure and international network. During this time, Nanonis products have continuously re-defined the standard in SPM control systems. Customer- and community feedback, including leading figures in academic and industrial research, ensures that Nanonis innovation and development continues to serve researchers' needs. Take CONTROL.

Nanonis Mimea setup taylored for a SPECS Aarhus 150 NAP Scanning Probe Microscope

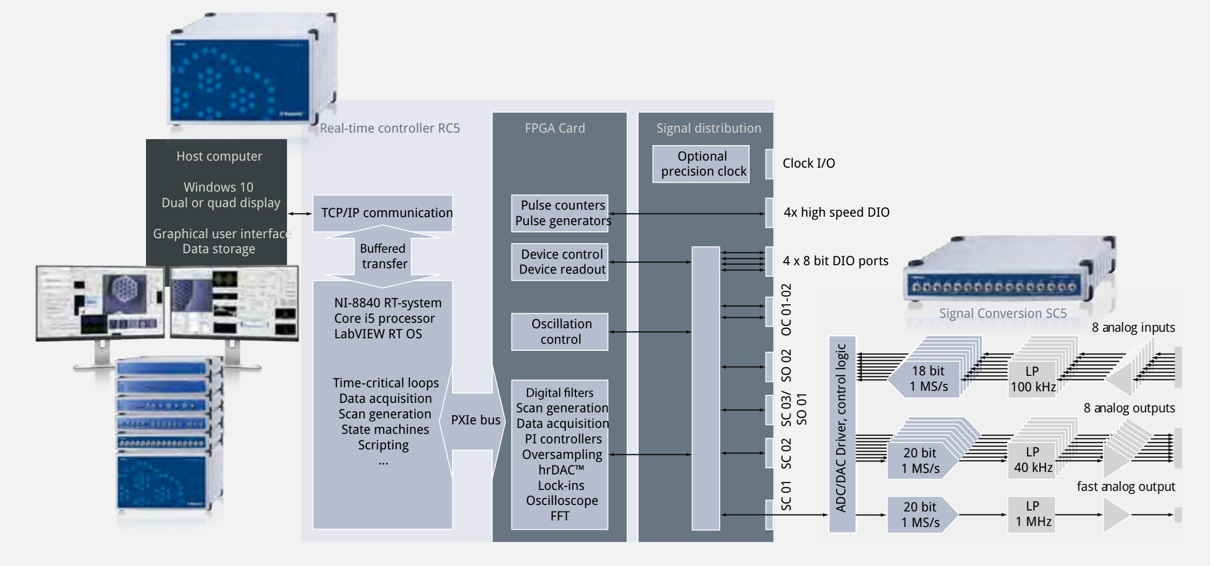
Mimea BP5e

THE EXPANDABLE ENGINE FOR YOUR SPM PROJECT

The Mimea Base Package BP5e is the latest evolution of the Nanonis SPM Control System. It combines exceptional signal quality, high speed and a flexible, powerful and user-friendly software interface. It's the logical choice for the most demanding SPM applications.

Nanonis SPM Control System

With over 400 units in operation, the Nanonis SPM Control System base package 5 is the result-producing workhorse for demanding SPM experiment. The enhanced BP5e builds on the exceptional performance and signal quality of the BP5 and offers higher speed and even more functionality and flexibility. From signal conditioning and AD/DA conversion to fast signal processing via a comprehensive and operation-optimized graphical user interface, the Nanonis SPM Control System provides a powerful framework that can be further adapted and extended with a wide range of add-on modules. All basic processes such as scan control, spectroscopy, Z-control, fast data acquisition, data monitoring and logging, spectroscopy, atomic manipulation and lithography are included, allowing easy control of most STM and AFM operations. The software provides measurement methods and complete signal processing combined with a modern and easy to use graphical interface, offering all necessary functionalities and an efficient workflow for demanding SPM experiments.



Simplified block diagram of the Nanonis Mimea BP5e

Mimea BP5e

THE EXPANDABLE ENGINE FOR YOUR SPM PROJECT

Fast Scanning and Spectroscopy: SPM goes Big Data

The BP5e can perform scanning and spectroscopy measurements up to 50x faster than with the previous generation. Up to 1,000,000 pixels per second can be generated and acquired on up to 8 channels. This makes it possible to acquire extremely highly resolved topography or spectroscopy maps in a significantly shorter time. Scanning can also be much faster than before up to the point where it is no longer a matter of lines per second but of frames per second. With a 64-bit software where memory is no longer a limitation, the only barrier is given by disk space. Spectroscopy is not limited to specific output signals thereby making electrical transport measurements, as an example, much faster and easier to perform. Even time can be a spectroscopy channel, allowing continuous acquisition of raw data at ADC sampling rates.

Simple Extension to a Multiprobe Control System

While in the past multiprobe-SPMs required multiple SPM controllers to operate more than one SPM tip, the BP5e can be upgraded at any time to operate multiple tips: A single SO5 added to the BP5e provides a total of 24 outputs, which are enough to control 4 independent tips leaving 8 outputs available for any other purpose. Everything else is handled by the software: Multiple Z-controllers and a switchable scan engine ensure that any tip can be used for scanning while the others are kept at a constant distance to the sample.

Highest Signal Performance

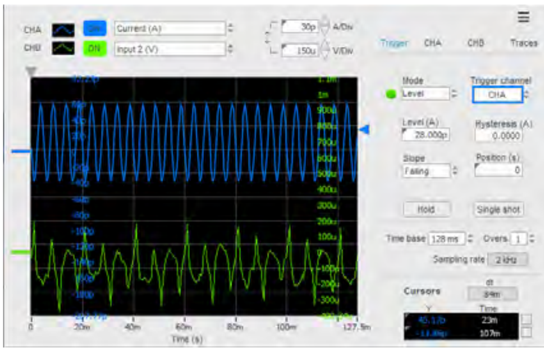
Fully Digital System

All analog signals are converted immediately into the digital domain, where all signal processing is performed, making them essentially immune to external noise and crosstalk and ensuring the best possible signal quality, which is crucial for SPM applications. In combination with the powerful software package, signal routing, signal monitoring and any operation between signals can be adapted and optimized on the fly with the press of a button instead of adjusting external hardware cabling. A fully digital system is also flexible and scalable, since software adaptations are all that is needed for rapid custom developments of the system. Even adding more signal interfaces, should more connectors become necessary, is a plug and play procedure as all corresponding signals become immediately available in the existing user interface.

Plenty of Channels

The system handles 128 live signals in real-time: Up to 40 outputs, up to 24 inputs with the remaining signals being user configurable internal signals. Up to 24 signals can be acquired simultaneously with up to 8 additional signals streamed to disk at up to full ADC speed. The base package offers 8 inputs and 8 outputs which allow the connection of signals including bias voltage, current, scan signals, lock-in signals, etc., and any combination of different signals in the digital domain. The hardware also supports multiple PLLs for AFM operation, thus allowing operation of even the most complex measurement set-ups. This very large number of live signals can not only be monitored, but also all signals are displayed as real world numbers in floating-point representation, with assigned SI units for immediate quantitative results, without the need of additional calibrations during data analysis.

Signal Analysis and Monitoring



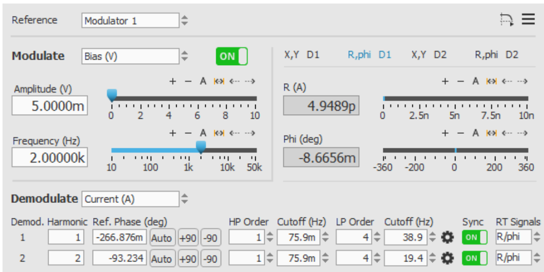
The dual trace oscilloscope is one of the many signal analysis tools.

All signals can be inspected with the FFT spectrum analyzer, dual-channel oscilloscope, signal charts, and history panels. Such fully digital and integrated software instruments are much more efficient in use, less invasive, better in performance, and lower in cost than their external counterparts. The ability to digitally route live signals to software instruments during active measurements without any negative impact on signal quality is truly invaluable when optimizing the experimental set-up, eliminating disturbances and thus improving the quality of scientific results.

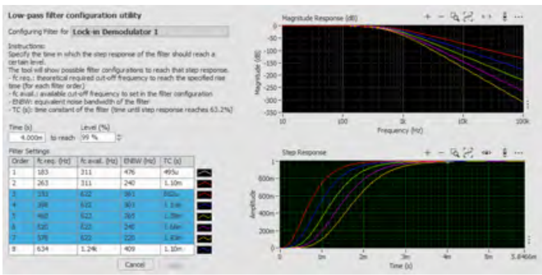
State-of-the-art Optional Digital Lock-In Amplifiers

With up to 8 optional fully user-configurable lock-in amplifier modules, measurement schemes requiring AC modulation (e.g. dI/dV spectroscopy, IETS, electrical transport) can be realized very easily. 1 MS/s sample rate, 40 kHz bandwidth, a THD+N larger than 93 dB (18 Vp-p at 1 kHz), linearity down to below -120 dB, and up to 22-bit resolution ensure sufficient bandwidth and high signal purity. Advanced filtering with user configurable time constants and filter orders for each demodulator result in over 100 dB dynamic reserve for isolating the measured signal from any noise source. AC-coupling with adjustable parameters can be added to keep DC or low-frequency components from adversely affecting the demodulators. Up to 8 independent frequency generators and demodulators offer ample flexibility for multi-frequency measurements. The clear signal handling of the Nanonis software facilitates configuring complex signal schemes and allows for parallel and series (tandem) demodulation. A filter configuration utility guides the user towards the optimal filter order and time constant choice, preventing smeared features due to insufficient integration time.

High Resolution AD/DA Conversion



Front panel of the lock-in module

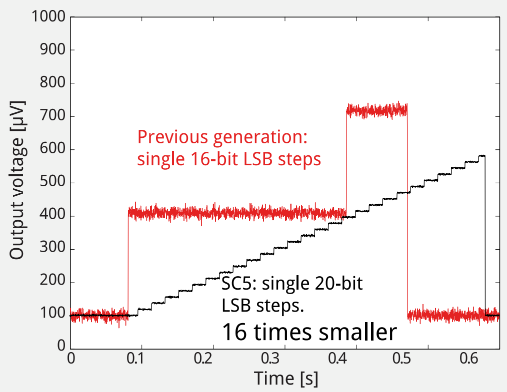


The filter configuration tool helps setting correct time constants and filter orders

“There is plenty of room at the bottom”, Richard Feynman said, when he described his vision of the science that led to nanotechnology. Enormous resolution is required to reveal the smallest features, while maintaining a large dynamic range. The signal frontend of the Base Package, the Nanonis SC5, uses the latest advances in AD/DA conversion technology, in combination with sophisticated digital filtering, over-sampling, and dithering techniques, to provide the highest resolution.

22-bit Resolution with patented hrDAC™ Technology

All outputs of the SC5 and SO5 use 20-bit resolution DACs with 1-ppm precision, the best available on the market. Just a few years ago, similar performance on multiple outputs would have been impossible to realize. The patented hrDAC ™ technology turns these state-of-the-art converters into real 22-bit devices, which in a traditional approach would fill a rack with single-channel instruments and cost ten times as much. Measurements requiring very small modulations with large offsets are thus possible without the need for drift- and error-inducing analog circuits or external mixers or attenuators. The impressive dynamic range also eliminates the need for switching gains, therefore coordinates are absolute over the full signal and scan range.



A 500 μV sweep measured under equal conditions: The SC5 shows a 16x higher resolution, higher precision, stability and lower noise compared to the previous generation

Adaptive Oversampling High Resolution Data Acquisition

A custom-designed input stage allows acquisition of the weakest analog signals, without compromises in dynamic range. The signals are digitized at an early stage with 18-bit AD converters running at 1 MS/s and then processed in the digital domain. Adaptive oversampling is used to always obtain the best signal-to-noise ratio for a given data acquisition rate. The user does not need to care about adjusting time constants, as the data acquisition automatically provides the best setting.

Optional Ultra-High Impedance, Low Noise Frontend: MCVA5

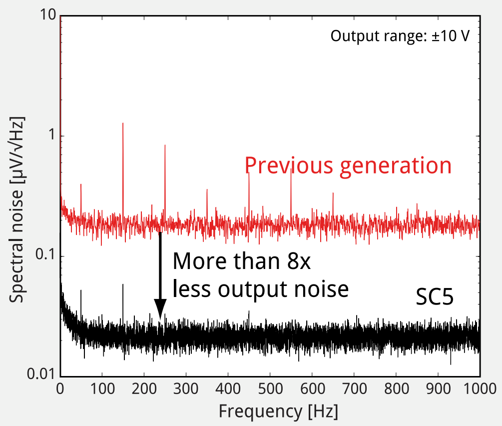
For direct measurements of high-resistance samples, for true differential measurements or simply for extremely small signals, the newly developed MCVA5 voltage amplifier is the ideal frontend to the SC5. It provides staggering 10 TΩ input impedance (to GND), an input spectral noise below 4 nV/√Hz (single-ended at 1 kHz and gain 100), over 120 dB of common-mode rejection and over 500 kHz bandwidth at any gain setting. Remote control is provided for gain (1, 10, 100, 1000), coupling (DC, AC) and input mode (A, A-B). The amplifier is seamlessly integrated into the Nanonis software meaning that all calibrations are automatically adjusted when the gain is switched. The design ensures exceptional low-frequency performance resulting in a noise density below 11 nV/√Hz at 1 Hz and 0.1-10 Hz noise of only 25 nV rms (gain 100, single-ended).

Lowest Drift with Temperature Stabilization

Scanning probe microscopes require very stable signals over long measurement times. For this reason, the SC5 and SO5 are equipped with a custom temperature-stabilized, high precision voltage reference. The reference has a very low inherent noise and drift. Temperature stabilization combined with thermal decoupling allows reduction of the temperature coefficient to below 3 µV/°C and output drift to below 1.5 µV in 12 hours at 0 V.

Lowest Output Noise Floor

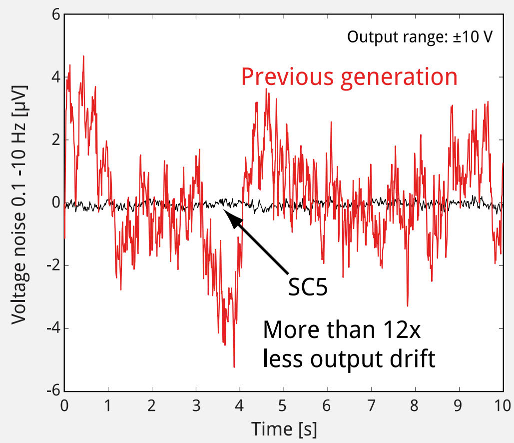
When experiments involve energies of a few µeV, high resolution alone is not the only pre-requisite for a measurement interface: Low noise is of utmost importance, and the SC5 de-livers impressive performance on both inputs and outputs. The noise floor of the SC5 and SO5 lies below 25 nV/√Hz with an output volt-age range of ±10 V. Despite its large bandwidth of 40 kHz, the output noise does not exceed 10 µV RMS at a measurement bandwidth of 300 kHz, meaning that the noise contribution of the SC5 is irrelevant in experimental situations.



A massive reduction in output noise ensures the best possible measurement results

Lowest 1/f Noise Outputs

In contrast to broadband noise, which can be easily filtered, 1/f noise cannot be eliminated and becomes an issue for experiments requir-ing signals to be very stable. The outputs of the SC5 and SO5 have been designed keeping this in mind, leading to a noise level below 750 nV peak-peak (0.1 – 10 Hz, ±10 V range), or about 223 times smaller than the maximum output signal.



Stability at its best: More than a one order of magnitu-de improvement over the previous generation

High-Speed Analog Output

Designed for providing sawtooth waveforms for coarse positioning applications, the 9th analog output of the SC5 has a bandwidth of 500 kHz. With the flexible software function generator, the operator can use this additional channel to output arbitrary periodic waveforms.

Digital Inputs and Output

32 bidirectional digital lines give sufficient flexibility for read-out and control of both Nanonis and external instruments. For high speed counting applications, four dedicated lines allow counting rates of up to 100 Mc/s.

Nanonis Software

Most Advanced User Interface for SPM

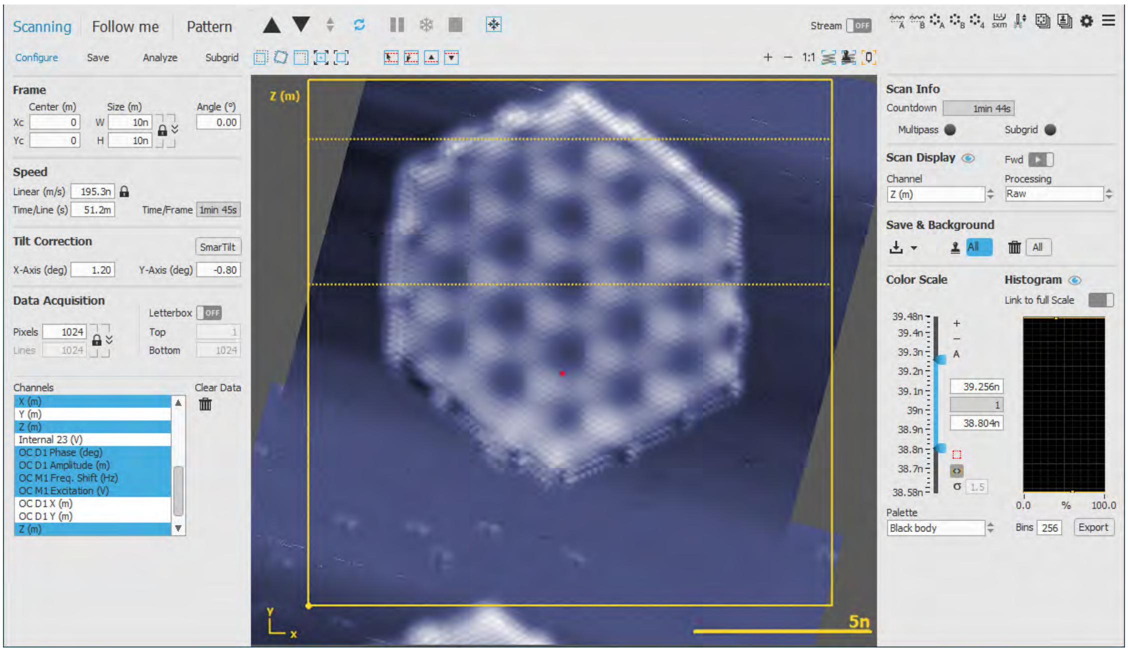
The user interface, or in aeronautical terms the cockpit, is the crucial part of the measurement system when recording of high quality data in a short time is required. The growing complexity of modern SPM experiments requires control of a large number of parameters. To ensure that the user is not overwhelmed by the resulting experimental complexity, the user interface is designed based on the typical workflow of SPM measurements, with all functions accessible but with the option to only display the relevant ones. A streamlined design ensures that the software is easy to use and that even inexperienced users can work more productively and safely.

Interactive Scan Control

The scan control module is interactive and dynamic, allowing instantaneous control of the SPM tip in real-time and in any situation. Mouse button and scroll wheel control allows on the fly adjustments and data visualization optimization. By this, it is possible to zoom in, adapt scan frame parameters and paste multiple scanned images to the background for reference. With up to seven scan windows it is easy to keep an overview over all acquired data. In the newly introduced stream mode the scan engine is able to generate scan patterns at video rate with up to 30 frames per second with a 128x128 pixel image.

Advanced Multipass Techniques with Scripting Functions

Many experimental techniques require the tip to be scanned multiple times on the same line while acquiring a scan image. The Nanonis multi-pass function allows multiple passes with different setpoints, speeds, bias voltages, at constant tip-to-sample distance, constant Z or with any other parameter recorded during the previous pass. Multiple passes can be time consuming when taking high resolution images, therefore optimizing the time for each scanned image



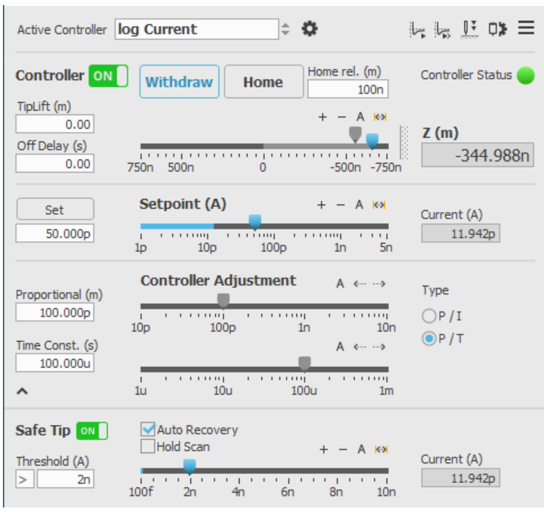
The scan control module gives the user full control of the SPM tip at any time and a complete overview of the acquired images can become crucial. The multipass function can therefore be combined with the scripting function, which makes it possible to run experiments like KPFM in real-time and deterministic speed just with a few script entries. This reduces time losses without the need for complex programming.

Advanced 2D and 3D spectroscopy

Advanced spectroscopy modules provide a set of flexible routines for experiments on a point, line, grid, or a cloud of points. Additionally, a “point and shoot” mode, where the user can interactively perform any experiment at a mouse click, and a fast spectroscopy mode allow precise and time-efficient spectroscopic measurements while scanning an image. Spectroscopy modules include bias spectroscopy, Z-spectroscopy, and generic sweep where any output or parameter can be swept while any number of other selected channels can be recorded. Each module is designed to optimize precision and time requirements of the experiments. In the case of bias spectroscopy, a bias-dependent measurement resolution reduces the required measurement time per acquired spectroscopy curve, while disabling of the dI/dV AC modulation signal when in feedback improves reliability when determining the exact Z-position. In the same way, in the Z-spectroscopy module, a dedicated safety loop reduces the risk of tip crashes. A dual-step retract condition allows for atomic resolution on non-planar molecules and also of the substrate next to the molecule, and therefore full imaging of force fields even when constant-dF measurements are not possible. In addition to the already implemented modules, any user-defined experiment can be integrated into the spectroscopy functionality by using the LabVIEW programming interface, the generic TCP interface or real-time scripting.

Versatile Z-Controller

The distance between tip and sample can be controlled by any signal or combination of signals. The user-configurable Z-controller allows on-the-fly switching between settings such as input signals and feedback parameters. And with the BP5e the Z-controller also gains a factor of 5 in usable control bandwidth. When it takes days to get the first high quality image, a tip crash is the last thing a researcher wants to happen. The SafeTip™ function takes care of retracting the tip should a potentially harmful event be detected. Not only is this function very fast, and designed to reduce creep-induced drift, but it also gives the user a variety of choices what to do in such an event, ranging from engaging coarse motion to retract the tip further, to a scan resume function which limits data losses while scanning.



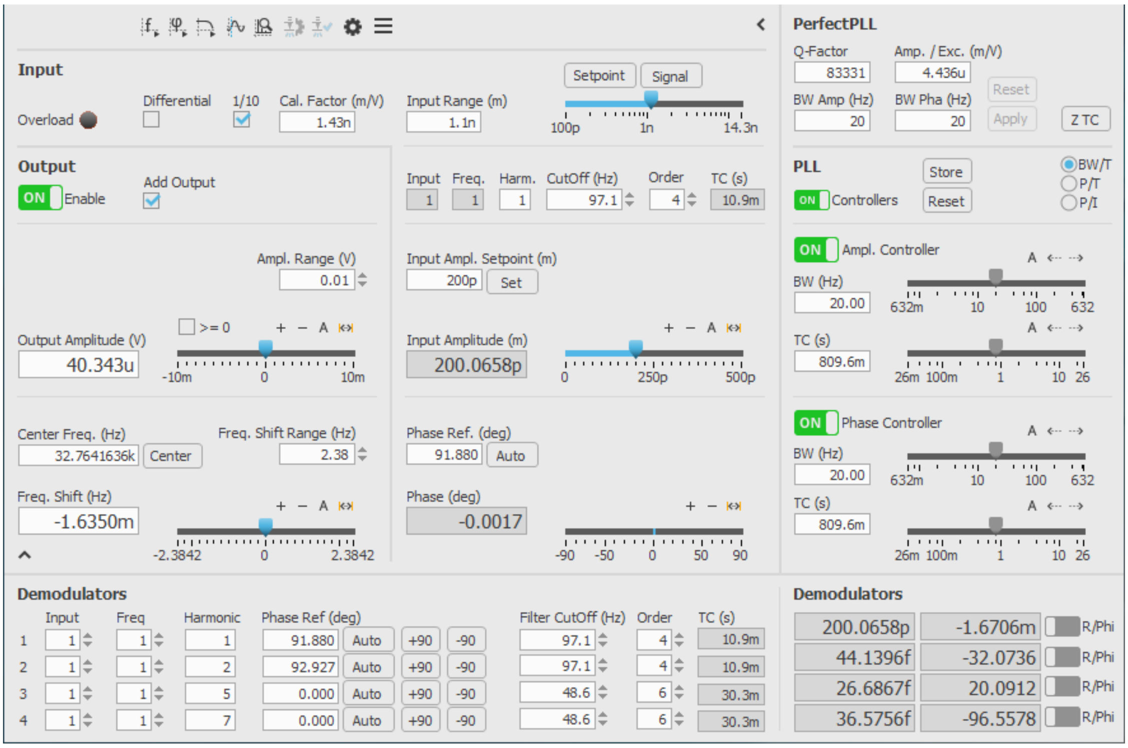
User Interface Z-Controller

Easy Expansion through Add-On Modules

The modularity of the software is a key advantage in cost optimization: Additional software modules can be added when experimental needs require them. The addition of new modules does not require any hardware or software installation, and can be performed in a very short time.

Oscillation Control: The Modern Cockpit for AFM experiments

Nowadays new measurement environments and techniques ask for a plethora of new AFM modes. The control center for all this is the Oscillation Control. Growing sophistication requires more effective user guidance, therefore the oscillation control offers a streamlined, logically organized user interface which still gives full authority to the user over all parameters to the user. The oscillation control can be transformed from a simple high-performance lock-in for intermittent contact mode measurements to a full-featured controller for multi-excitation and multi-frequency FM-AFM. Multiple resonance-fitting methods ensure that the resonance frequency is exactly determined independently from the Q-factor or damping of the sensor. With the BP5e, Q-control is integrated into the oscillation control module giving direct access to faster scanning with sensors having a high Q-factor.

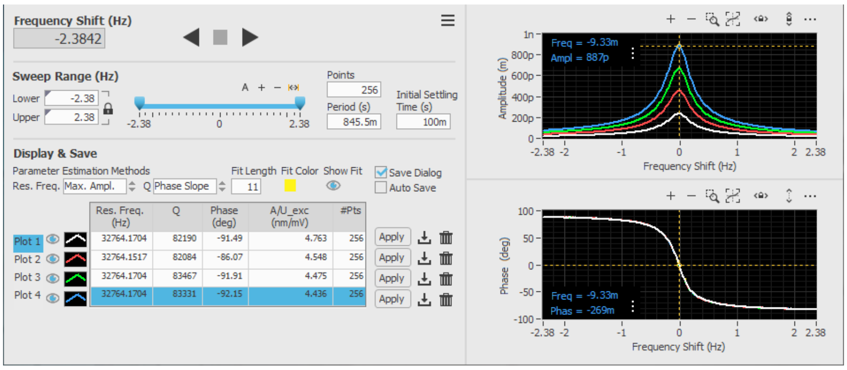


User interface
Oscillation Control

Advanced Signal Processing: Multifrequency and Multidemodulator Filtering

Multifrequency techniques have shown that significant physical information can be extracted from an apparently simple-looking AFM probe oscillation signal. The new Oscillation Control offers multiple independently configurable demodulators, all seamlessly integrated into the Nanonis signal handling. Performing complex multifrequency measurements is now possible with just a few clicks, and without requiring additional hardware. Small amplitudes of harmonics or noisy signals due to difficult environments demand high performance signal recovery capabilities. The Oscillation Control offers highly configurable filtering techniques with optimal amplitude and phase accuracy, large noise rejection, user-selectable slopes, individual configuration for each harmonic, and all of this is compatible with the existing OC4 hardware.

Frequency sweep module with resonance fitting options



Add-On Module: TrueDissipation™

FM-AFM measurements allow discerning between conservative and nonconservative tip-surface interaction forces, the latter being determined by recording the excitation signal of the AFM probe. In many cases, however, the resulting dissipation data show artefacts, which cannot be related to tip-sample interaction. Most of these artefacts, are attributed to “apparent damping”, which mainly originates from energy dissipated into the measurement system, thus making quantitative and therefore scientifically meaningful dissipation measurements impossible. The fully automated TrueDissipation™ algorithm (developed at McGill University) determines the amount of apparent damping, and corrects measured dissipation data accordingly, allowing for a much more precise determination of non-conservative interaction forces.

Add-On Module: Multi-Excitation

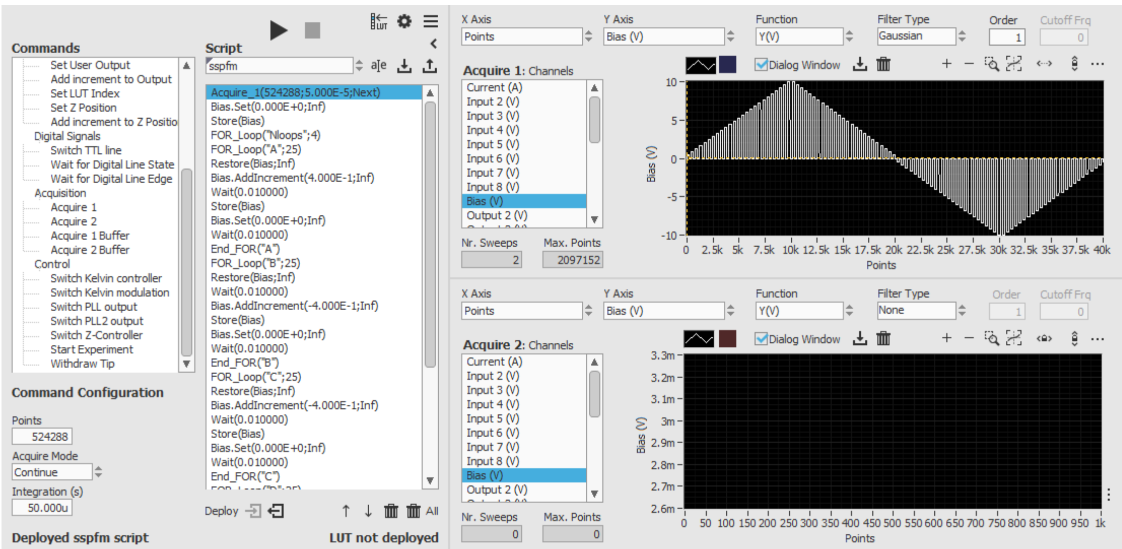
Multifrequency techniques might require multiple excitation frequencies, and the Multi-excitation add-on module extends the capabilities of a single OC4 instrument when a second physical output (as required for AM-KPFM) is not required. The module offers a fully flexible configuration of amplitude, frequency, phase, phase references and signal routing, for example for amplitude modulation or Q-control. It also offers two predefined configurations for dual-excitation techniques and for sideband detection.

Add-On Module: Programming Interface for LabVIEW, Python, Matlab, C++ and many more

Competitive advantage in research is often based on the modification of an instrument that allows the researcher to perform experiments in a way nobody else has done before. This is where the Programming Interface steps in: to give you the building blocks to design your own experiment. The user can either program in LabVIEW or in Python, Matlab, C++ or any other programming language able to write to and read from a TCP port on the host PC. The LabVIEW Programming Interface consists of libraries to access the controls and functions of the graphical user interface. It is used to automate experiments, sequences, calibration routines and experimental procedures. Polling of parameters and signals at high rates allows for supervision and alarm settings, and many other features. With the LabVIEW interface the Nanonis SPM Control System provides full access to all the features provided with LabVIEW: graphs, database access, convenient data handling, TCP/IP, GPIB, RS232, USB access to other instruments, signal analysis functions and much more. The generic TCP interface offers all functionality of the LabVIEW interface but with the commands sent to and received from a TCP port of the Nanonis software on the host PC in a generic script format. It lacks the ease of use and debugging options of LabVIEW, but is not bound to a specific programming language and grants a simple integration of the SPM Control System if existing software routines are not available in LabVIEW.

Add-On Module: Scripting

For experiments where exact timing is crucial, the scripting module becomes the ideal tool for customization: Scripts are executed on the real-time system in a time-deterministic manner, improving the time response by a factor of 100 compared to the programming interface. Logic functions can be implemented with the use of FOR loops and IF conditions. Triggering over TTL lines directly from the real-time system is ideal for fast synchronization and optical experiments. Scripting is fully integrated into the spectroscopy options of scan control and is ideally suited for time consuming measurements like Kelvin Probe and multipass techniques, reducing dwell times and improving measurement precision. It can also be combined with the Programming Interface offering the best of both worlds: speed and flexibility.



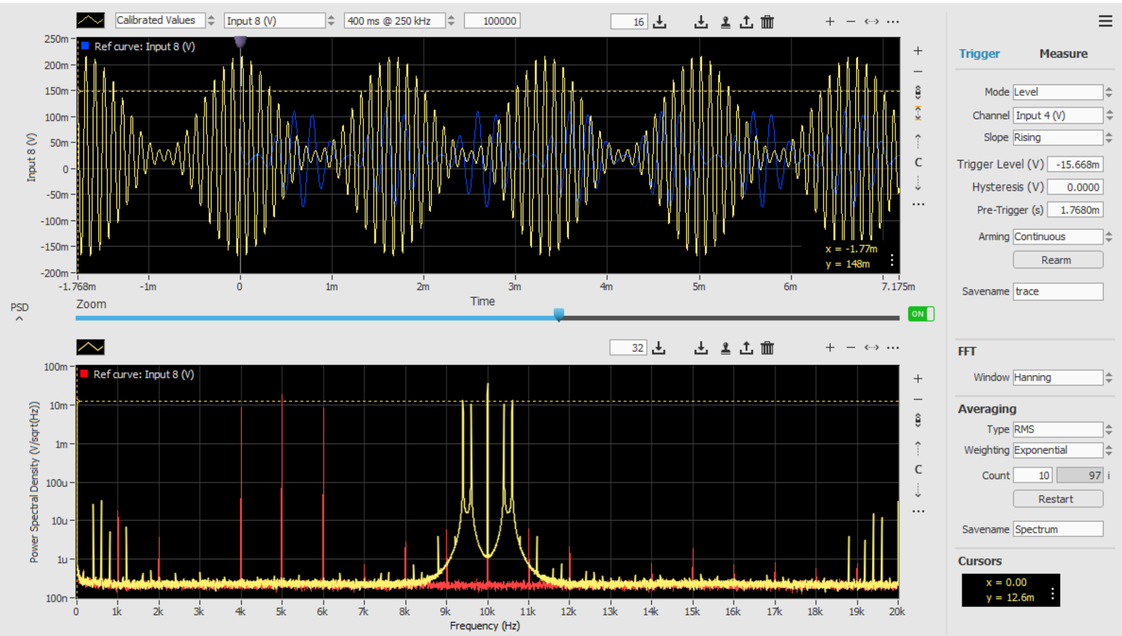
Scripting module with script for fast switching spectroscopy PFM (Script: courtesy of I. Gaponenko...)

Add-On Module: High Resolution Oscilloscope and FFT

SPM experiments often require acquisition of time-dependent signals, with typical time scales ranging from microseconds to several minutes. The high-resolution oscilloscope and FFT module gives access to data acquisition with up to 1 MS/s, variable acquisition time, and trace lengths of up to 1 million points. The high precision and low noise inputs of the SC5 allow acquisition of high dynamic range signals without the need of gain switching, while exact timing is guaranteed by a fully configurable triggering system (with pre-triggering option). In parallel to precise time-resolved measurements, the FFT function offers very high frequency resolution down to the mHz range.

Further Add-On Modules for Special Applications

A variety of other modules are available. These include Atom Tracking, Kelvin Controller, Interferometer Controller, Dual-channel Function Generator, PI Controllers. In addition to the add-on modules listed above, pulse counters, a large number of coarse approach motor control modules for commercial and home-built microscopes and other dedicated modules are available on request. And as demonstrated in the last decade, the Nanonis SPM Control System has continuously evolved, giving researchers access to new functionality and features. Also for the BP5e, new add-on modules will be developed in the next years to come.



High resolution oscilloscope and FFT

Future-proof state-of-the-art hardware of the BP5e

Signal Conversion SC5

The electronic mainboard of the SC5 is a showcase for the best available active digital and analog electronic components on the market. Cheaper solutions leading to compromises have been discarded from the beginning, since only by meticulously choosing the best suitable components down to each single resistor, can the exceptional performance of the SC5 be achieved. The SC5 is powered by a linear power supply. Switching power supplies or DC/DC converters are not used anywhere in the instrument. Despite being equipped with a linear power supply, there is no need to manually adjust the line voltage to local circumstances: An intelligent circuit detects the line voltage and automatically configures the power transformer inputs. An auxiliary power supply is available for powering external instruments like e.g. preamplifiers. With its low-noise, pre-regulated ±15 V voltage with up to 300 mA current delivery capability, it makes external power supplies unnecessary.

Real-Time Controller RC5e

The “brain” of the Nanonis Base Package is the real-time controller RC5e. By using the latest FPGA and CPU technology, the RC5 provides enough speed, connectivity and processing power for the most demanding tasks. Modularity doesn’t stop there either: Both FPGA and real-time modules are easily exchangeable, and can be updated should significantly faster modules be available in the future. When a new experiment is started, often not all requirements are already known in detail. This is no problem with the SC5 and its real-time controller RC5e. The addition of one or more Nanonis Oscillation Controllers (OC4) which extends the frequency range to 5 MHz, or more SC5 and SO5 is straightforward, should a larger signal bandwidth or more channels be required. Communication, triggering and control of additional external instruments is an easy task thanks to the various digital communication options of the RC5e.

Hardware add-ons for a modular control system

Modularity of the Nanonis SPM control system means that the hardware required for a given experimental situation can be tailored to the user's needs. This is the most flexible and at the same time cost-effective solution, and offers the best performance since each instrument is highly optimized. Hardware add-ons include the Oscillation Controller, high-voltage amplifiers, piezo drivers, and adaptation kits for commercial microscopes.

Oscillation Controller with PLL Nanonis OC4 and OC4 Dual

The Oscillation Controller (OC4) with digitally integrated PLL adds dynamic AFM capabilities to the Nanonis Control System. The Z-feedback can regulate on any signal coming from the mechanical resonator with any predefined SafeTip™ conditions. Imaging modes include: non-contact AFM, intermittent contact mode, phase imaging, dissipation as well, as many more. With an input bandwidth of 5 MHz, the OC4 can operate any type of cantilever, tuning fork, needle sensors, etc. and their harmonics. It can also be used as a powerful digital lock-in amplifier.

Signal Output SO5

The SO5 shares the same output architecture with the SC5, but replaces the 8 inputs with 8 additional outputs. It is ideally used with multiprobe SPMs or for measurements of multiterminal nanodevices where a large number of low-noise ultrastable outputs are required. The SO5 uses the same linear power supply wit automatic line voltage detection and thus also offers a pre-regulated ±15 V preamplifier power supply.

High Voltage Amplifiers Nanonis HVA4

The Nanonis HVA4 is a low noise, six-channel high-voltage amplifier specifically designed for nanopositioning applications using piezo elements. Three different models with maximum output voltages of ±140 V, ±220 V or ±400 V let the user choose an optimal setup for his application. With differential inputs and a noise spectrum density below 1 µV/√Hz at 300 Hz at gain 40 (input shorted), the HVA4 sets the standard for low-noise HV applications. The SNR of the HVA4 is so large that even with a 10 µm Z-range piezo tube, the noise level in Z corresponds to less than 2 pm (RMS), far below the corrugation of the sample.

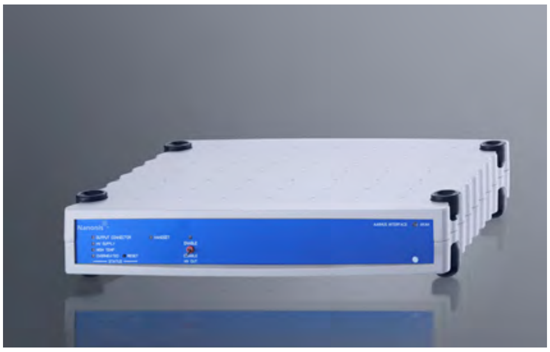
Piezo Drivers Nanonis PMD4

The Nanonis PMD4 is a high performance piezo motor driver, designed to drive piezo positioners with a very wide range of specifications. Owing to its patented output drive technology, the PMD4 is perfectly suited for driving piezo positioners in SPM applications, even under the most difficult conditions, e.g. at very low temperatures or with large capacitance piezo motors. The PMD4 is available with eight or sixteen output channels and a single waveform generator, or with eight output channels and two waveform generators. It can be remotely controlled in combination with a Nanonis SPM control system over its digital interface, or with the included handset. The amplitude of the output waveform can be varied continuously between 0 and ±400 V, and its frequency continuously between 1 Hz and 20 kHz.

Piezo motor driver PMD4 (left image)

Adaptation Kits for Use with Commercial Microscopes

Numerous adaptation kits are available to interface the Nanonis SPM Control System with most types of commercial microscopes including Omicron, Veeco (Bruker), JEOL, Createc, RHK and Unisoku. The original SPM cables connect directly to the pin-compatible interfaces, making a change of the control system extremely simple.

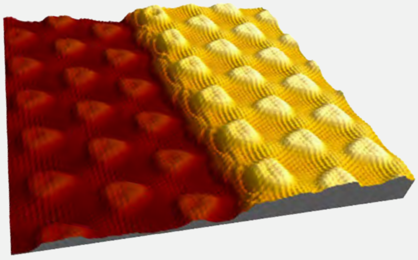


Aarhus Adaptation Kit

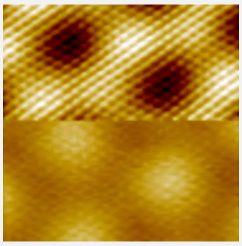
Omicron Adaptation Kit

Veeco Adaptation Kit

High Resolution Images Measured with the Mimea BP5e

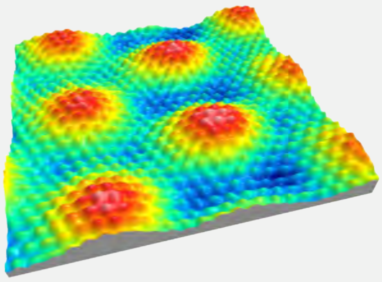


Atomically resolved 3D STM image of graphene moiré on Ru(0001). Scan size: 16.5×16.5 nm². Tunneling parameters: I_T=1 nA, U_T=0.5 V.

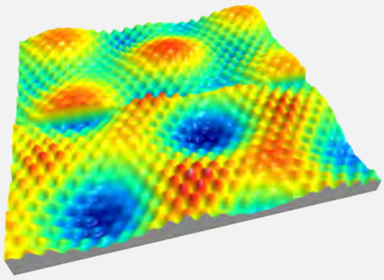


Graphene/Ir(111): Switch between STM (top) and nc-AFM (bottom) modes "on-the-fly". Scan size: 5×5 nm². Scanning parameters: U_T=+30 mV, I_T=1 nA, Δf=-475 mHz.

(a)



(b)



Constant height SPM images of graphene/Ir(111). (a) Δf channel, range: -2.66 Hz ... -2.46 Hz; (b) I_T channel, range: -1.88 nA ... +2.43 nA. Scan size: 4.3 × 4.3 nm². Bias voltage was changed from +50 mV to -50 mV in the middle of the scan area.

Specifications

Technical data

General	
Content of Delivery	Real-time controller RC5e, Signal conversion SC5, software and license, unlimited updates and support for one year, host computer (Option)
Cases	Stackable benchtop cases, full metal enclosure
Operating Temperature	+5° C to +35° C
Compliance	CE
Warranty	One year parts and labor (EU: two years) on defects in material and workmanship
Documentation	User manual describing hardware and installation, online user manual for graphical user interface

RC5e	
Dimensions	32.5 x 28 x 21 cm
Weight	7.8 kg
Power Supply	Built-in universal power supply, max. 220 W, 100 – 230 V, 50 - 60 Hz
Real-time System	NI PXIe-8840 real-time system with Intel Corei5 CPU 2.7 GHz, 4 GB RAM
Operating System	NI LabVIEW Real-Time OS
FPGA Card	NI PXIe FlexRIO
Connectivity	3x SC5 max., 2x SO5 max., 2x OC4 max. Total of max. 4 frontends

SC5	
Dimensions	R 32.5 x 28 x 7 cm
Weight	4.2 kg
Power Supply	Built-in linearly regulated power supply, toroidal transformer, automatic line voltage detection. Max. 51 W, 100 – 240 V, 50 - 60 Hz
Electrical GND	10 kΩ AGND to chassis, decoupled from RC5e

Analog Inputs (all specifications for ±10 V input range)	
Hardware Interface	8 x BNC connectors, differential
Differential Input Voltage Range	±10 V, ±1 V*, ±100 mV*, ±10 mV*
Differential Input Impedance	2 MΩ
Input Impedance*	>10 TΩ to GND, >50 GΩ differential
Input Bias Current*	<2 pA typ.
Analog Bandwidth	DC – 100 kHz (-3 dB), 5th-order Butterworth low-pass filter
AD-Converter	18-bit, no missing codes, 1 MS/s
Effective Resolution	20-bit @ 60 kS/s, 22-bit @ 1 kS/s (oversampling)
INL	±2 LSB typical
DNL	±1 LSB typical
Input Noise Density	< 150 nV/√Hz @ 10 kHz, < 650 nV/√Hz @ 10 Hz <4 nV/√Hz (<5.5 nV/√Hz) @10 kHz SE (differential)* < 5 nV/√Hz (<6 nV/√Hz) @ 10 Hz (differential)* <11 nV//√Hz (<15 nV/√Hz) @ 1 Hz (differential)* With gain 100
Measurement Noise	< 100 µVrms @ 1 MS/s, < 25 µVrms @ 60 kS/s, < 6.5 µVrms @ 240 S/s
0.1-10 Hz noise*	<25 nVrms (< 32 nVrms) SE (differential) With gain 100
12 h-Drift	< 80 µV (< 100 µV) @ 0 V (@ 9.9 V)
THD+N, 9 V Input Signal	> 120 dB @ 100 Hz, > 95 dB @ 1 kHz, > 70 dB @ 10 kHz
CMRR*	>125 dB @ 10 Hz >120 dB @ 100 Hz >100 dB @ 1 kHz

* With optional MCVA5 multichannel preamplifier

Analog Outputs (all specifications for ±10 V output range)

Hardware Interface	8 x BNC connectors (SO5: 16x BNC connectors) Referenced to AGND
Output Voltage Range	±10 V into 1 kΩ or larger (0 to +10 V with internal jum-per per channel)
Output Impedance	<1 Ω, short circuit safe
Analog Bandwidth	DC – 40 kHz (-3 dB), 5th – order Butterworth low-pass filter
DA Converter	20-bit, 1-ppm precision, 1 MS/s
Effective Resolution	22-bit, patented hrDAC™ technology with active glitch compensation
INL	< ±2 LSB max. < ±1 LSB typical
DNL	< ±1 LSB max. < 0.5 LSB typical
Output Noise Density	< 25 nV/√Hz @ 100 Hz, < 75 nV/√Hz @ 1 Hz
Output Noise	< 200 nVrms (0.1 – 10 Hz), < 10 µVrms (10 Hz – 300 kHz)
12h-Drift	< 1.5 µV (< 25 µV) @ 0 V (@ 9.9 V)
THD+N, 9 V Output Signal	> 93 dB @ 100 Hz, > 93 dB @ 1 kHz, > 79 dB @ 10 kHz

Digital Lines

Ports	4 x 8 lines on four D-sub 9 female connectors
Direction	Input or output for each line
Signal	3.3 V TTL, max. 25 mA per line
Maximum Sampling Frequency	500 kHz

High Speed Digital Lines

Ports	4 x inputs and 4 x outputs on SMB male connectors
Ports	4 x inputs and 4 x outputs on SMB male connectors
Signal	3.3 V TTL, max. 33 mA per line
Maximum Sampling Frequency	200 MHz

Clock

Ports	1 x input, 1 x output for active clock source
Frequency	10 MHz, square wave, 3.3 V
Accuracy	± 50 ppm (standard clock), ± 4 ppm (optional OCXO)

Graphical User Interface

Operating System	Windows 10 64-bit
Min. Requirements	Intel Core i3-4XXX 3 GHz or equiv. or better, 4 GB RAM, 500 GB HD, two 22" screens with at least 1680 x 1050 pixels
Recommended Configuration	Intel Core i5-7XXX 3 GHz or equiv. or better, 16 GB RAM, 500 GB SSD + 2 TB HD or better, two 24" screens with 1920 x 1200 or 2560 x 1440 or pixels
License	Unlimited in time, bound to RC5e
Documentation	Online help, F1 for context sensitive help, tip strips for each control element, printed hardware user manuals with operation instructions for related software modules
Settings Configuration	For every session directory/ user, settings, parameters and screen layouts

Signals

Signals	128 signals (inputs, outputs and internal signals), up to 24 simulteneous signals for data display and acquisition, 8 simultaneous signals for data streaming
Data Transfer	Via TCP/IP, 2 kS/s default, up to 20 kS/s, 1 MS/s x 8 channels for data streaming
Representation	32-bit floating point, real world physical units

c/o **SPECS** Surface Nano Analysis GmbH
Voltastrasse 5
13355 Berlin / Germany
www.specs-group.com

T +49 30 46 78 24-0
F +49 30 46 42 083
E info@specs.com

Version 02.04

SPECSGROUP™