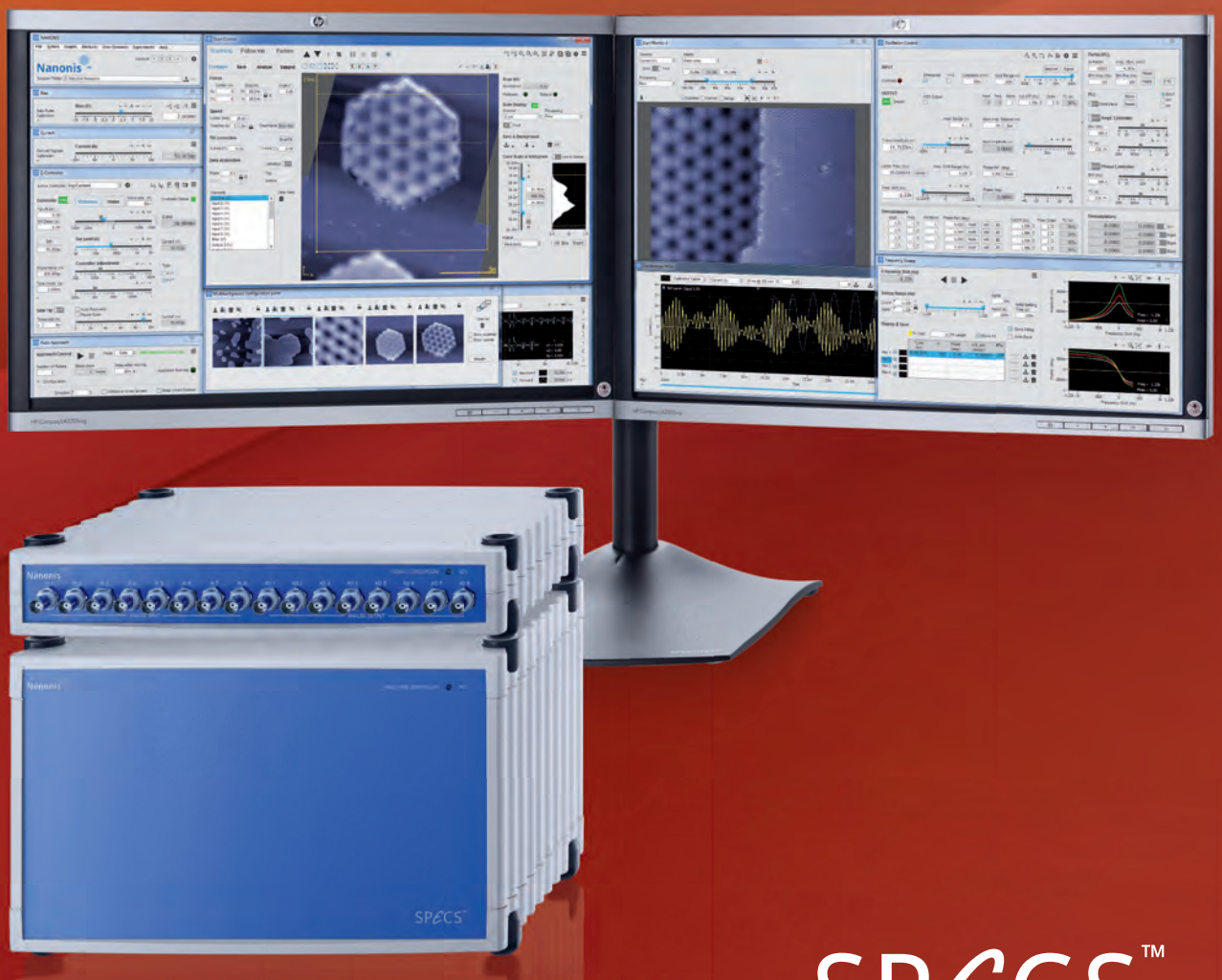
Nanonis™ BP5

SPM CONTROL SYSTEM BASE PACKAGE 5

KEY FEATURES

- Operation-Optimized User Interface
- Full Flexibility for most Advanced Measurement Techniques
- Uncompromising Signal Quality
- Works with any SPM in any Mode
- Future-proof state-of-the-art Hardware



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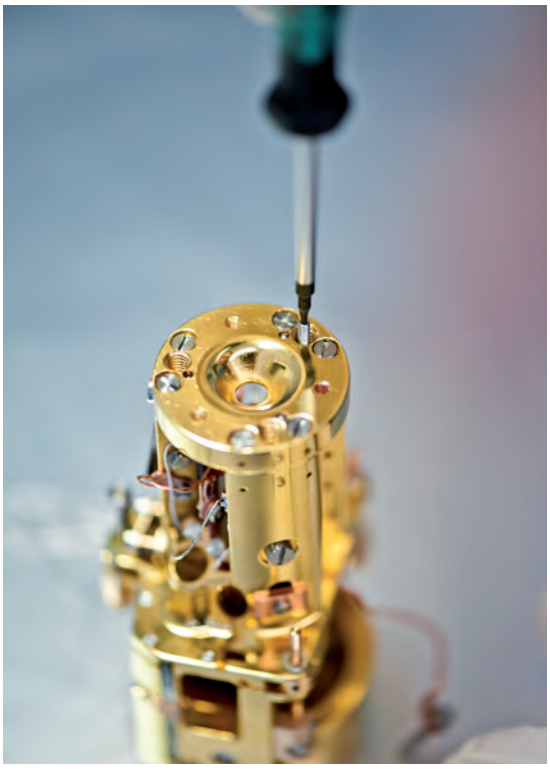
INNOVATION IN SURFACE SPECTROSCOPY
AND MICROSCOPY SYSTEMS

SPECS leads the way in state-of-the-art technology for electron spectroscopy and scanning probe microscopy.

Development of
Nanonis version 5

SPECS Surface Nano Analysis GmbH

SPECS has more than 150 employees at its headquarters in Berlin and its subsidiaries in Switzerland, the USA and China. The company also has liaison offices in Spain and BeNeLux, supported by international sales channels in sixteen countries. A team of scientists and engineers is involved in developing and producing scientific instruments for surface analysis, materials science and nanotechnology. Since the company was founded in 1983, its success is based on a continuous gain in experience. SPECS scientists are in close contact with a large number of customers and scientists around the world. SPECS is your essential partner in scientific instrumentation due to our focus on customer support, know-how and international contacts. Scientists all over the world can rely on SPECS product quality and be inspired by the continuous development of new products.



Assembly of a scanning
probe microscope

SPM Control System Base Package 5

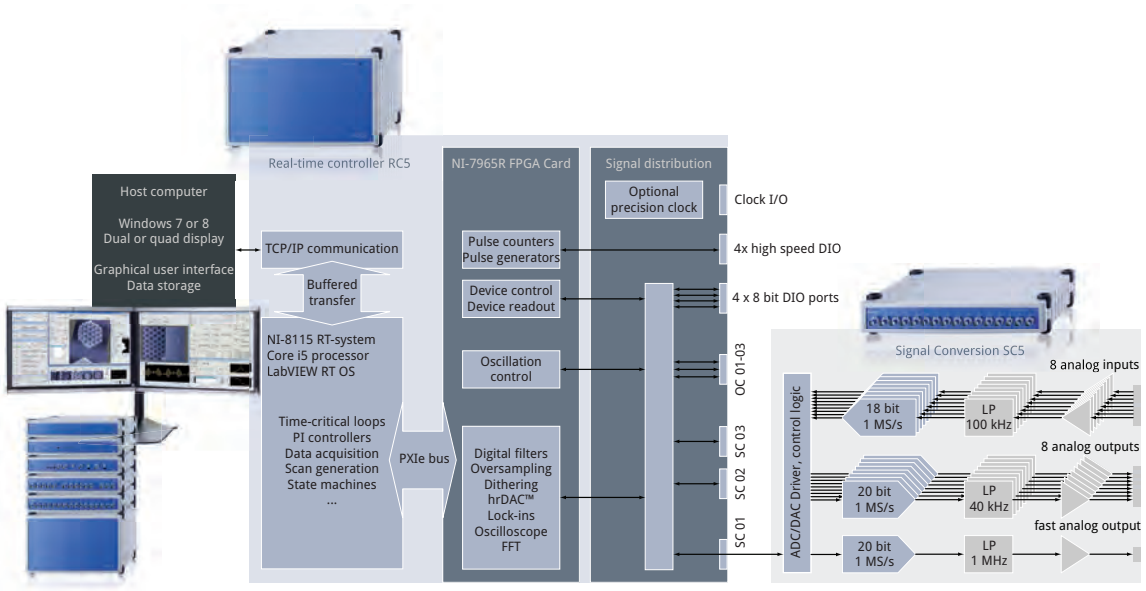
Nanonis BP5

THE EXPANDABLE ENGINE FOR YOUR SPM PROJECT

The Base Package 5 of the Nanonis Control System combines exceptional signal quality and a flexible, powerful, and user-friendly software interface making it the ideal choice for the most demanding SPM applications. Nanonis BP5: the standard for SPM control systems in its latest version.

Nanonis SPM Control System

The Nanonis SPM Control System Base Package 5 answers the demand for cutting edge performance: It combines uncompromising signal quality owing to the most advanced hardware with responsive and reliable control software. 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 Z-control, scan control, data acquisition, data monitoring, 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 streamlined user interface, offering all necessary functionalities in an efficient workflow for demanding SPM experiments.



Simplified block diagram of the Nanonis BP5

Highest signal performance

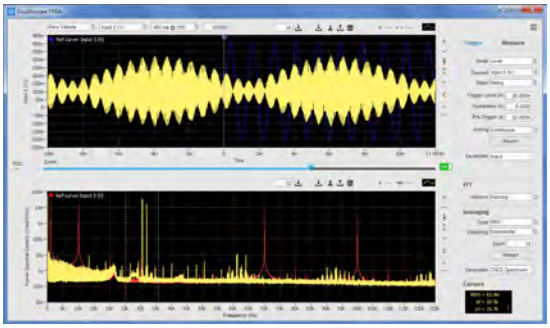
Fully Digital System

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 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.

Plenty of Channels

The generic analog interface provides 48 live signals: 8 inputs, 8 outputs and 32 internal signals, with up to 24 signals that can be acquired simultaneously. This allows the connection of signals including bias voltage, current, scan signals, lock-in signals, etc., and combination of different signals in the digital domain. The hardware is designed to support up to 24 inputs and 24 outputs, plus multiple PLLs for AFM operation, thus allowing operation of even the most complex measurement set-ups. This 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 high resolution oscilloscope and spectrum analyser add-on module make monitoring, analysing and recording signals an easy task

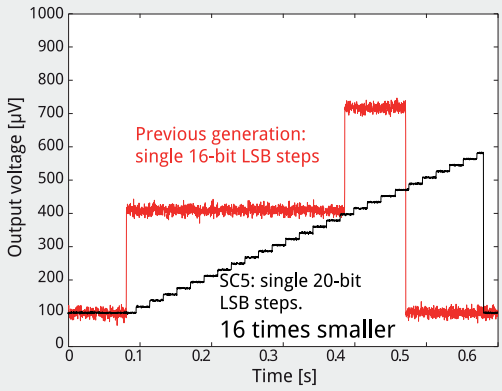
All signals can be inspected with the FFT spectrum analyzer, dual-channel oscilloscope, signal charts, and history panels. Such fully digital and integrated software instruments are much more efficient in use, less invasive, better in performance, and lower in cost than their external counterparts. The 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.

High Resolution AD/DA Conversion

“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, oversampling, and dithering techniques, to provide the highest resolution.

22-bit Resolution with Patented hrDAC™ Technology

All outputs of the SC5 use 20-bit resolution with 1-ppm precision DACs, 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.

Lowest Drift with Temperature Stabilization

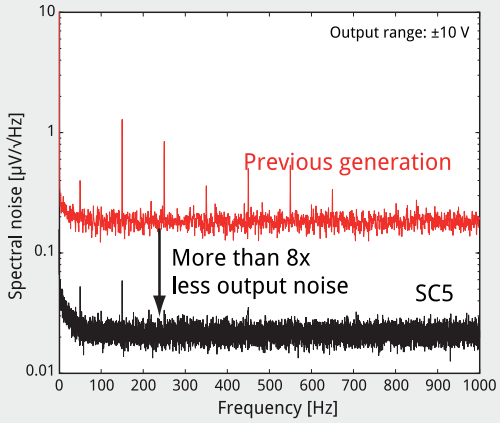
Scanning probe microscopes require very stable signals over long measurement times. For this reason, the SC5 is equipped with a custom temperature-stabilized, high precision voltage reference. The reference has a very low inherent noise and drift. Temperature stabilization combined with thermal decoupling 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.

State-of-the-art Optional Digital Lock-In Amplifier with 40 kHz Bandwidth

DC signals are not the only strength of the SC5: Each output has a bandwidth of 40 kHz, and measurement schemes requiring a lock-in amplifier (e.g. dI/dV spectroscopy) can be realized very easily. With 1 MS/s sample rate, a THD+N larger than 93 dB (18 V_{p-p} at 1 kHz), linearity down to below -120 dB, up to 22-bit resolution, and multiple demodulators, the lock-in module of the SC5 is a powerful measurement tool also for the most demanding AC experiments requiring low harmonic distortion and multiple harmonic demodulation.

Lowest Output Noise Floor

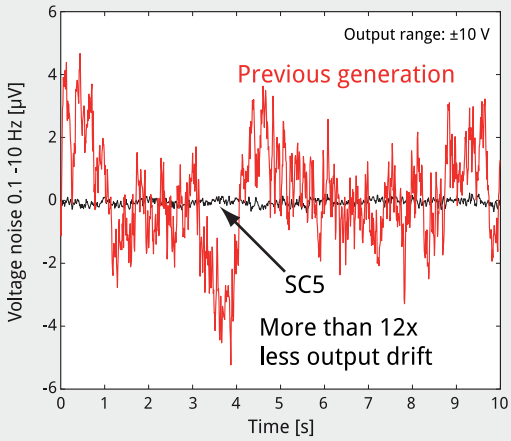
When experiments involve energies of a few µeV, high resolution alone is not the only prerequisite for a measurement interface: Low noise is of utmost importance, and the SC5 delivers impressive performance on both inputs and outputs. The noise floor of the SC5 lies below 25 nV/√Hz with an output voltage 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 requiring signals to be very stable. The outputs of the SC5 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 2^{23} times smaller than the maximum output signal.



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

High-Speed Analog Output

Designed for providing sawtooth waveforms for coarse positioning applications, the 9th analog output of the SC 5 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 Version 5

Most Advanced User Interface for SPM

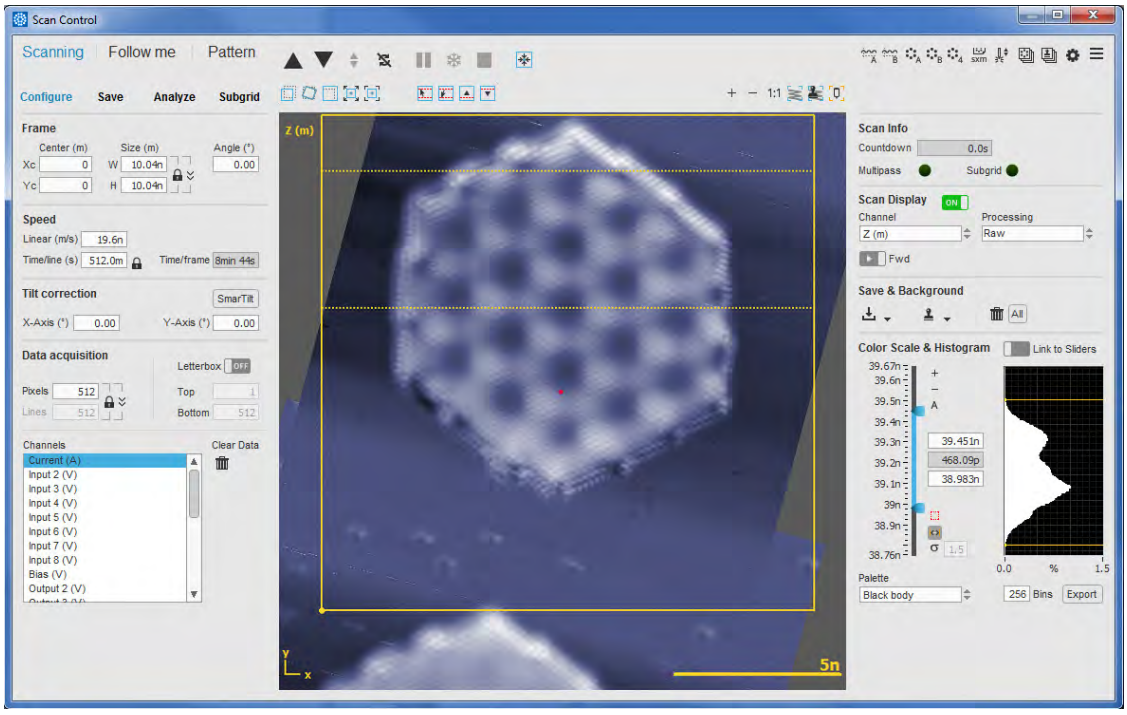
The user interface, or in aviatic terms the cockpit, is the crucial part of the measurement system when recording of high quality data in a short time is required. The growing complexitiy of modern SPM experiments requires control of a large number of parameters. The BP5 user interface has been streamlined. 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.

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 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.



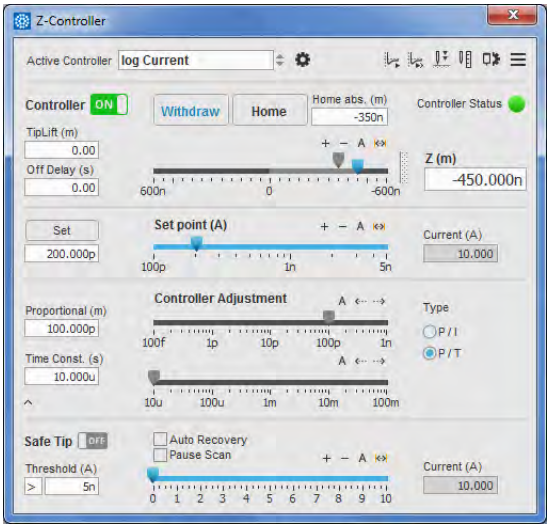
The scan control module gives the user full control of the SPM tip at any time and a complete overview of the acquired images

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. In addition to the already implemented modules, any user-defined experiment written in LabVIEW can be integrated into the spectroscopy functionality of the Nanonis SPM Control System, by using the Programming Interface.

Versatile Z-Controller

The distance between tip and sample can be controlled by any signal or combination of signals. Quantitative parameters allow the application of control theory models and yield a further understanding of the tip-sample interaction. The user-configurable Z-controller allows on-the-fly switching between settings such as input signal and feedback parameters. And 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.



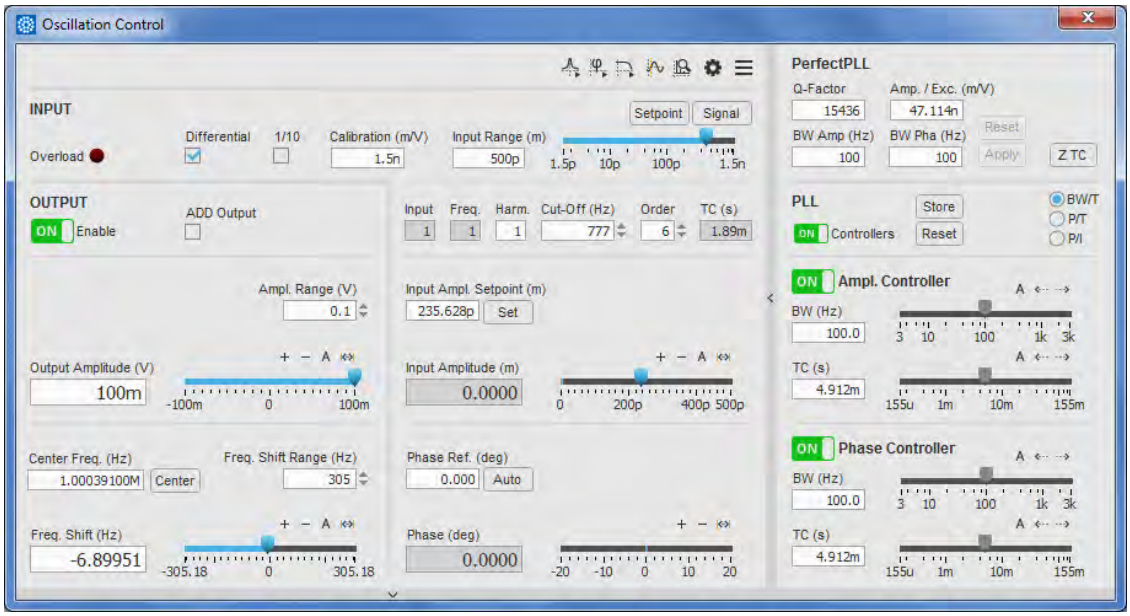
User Interface Z-Controller

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: A new 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 AFM cockpit has been redesigned, offering a more logical approach and a better overview. 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.

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.

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 improved filtering techniques with even better amplitude and phase accuracy, better noise rejection, user-selectable slopes, individual configuration for each harmonic, and all of this is compatible with the existing OC4 hardware.

Add-On Module: LabVIEW Programming Interface

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 LabVIEW Programming Interface steps in: to give you the building blocks to design your own experiment. 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. Instead of using a simple scripting language, or a dedicated language, 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.

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. A new 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.

Add-On Module: Scripting

For experiments where exact timing is crucial, the scripting module becomes the ideal companion for the Nanonis Programming Interface: Scripts are executed on the real-time system in a time-deterministic manner, improving the time response by a factor of 100. Scripting can be fully integrated with time consuming measurements like Kelvin Probe and multipass-techniques, thus reducing dwell times and improving measurement precision.

Further Add-On Modules for Special Applications

A variety of other modules are available. These include Atom Tracking, Kelvin Controller, Interferometer Controller, Function Generator, PI Controller. 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.

Development of further Functionalitites

A large number of other new functions and improvements, ranging from improved data display to subgrid spectroscopy have been implemented with the goal to give researchers an even more powerful and effective tool for cutting edge scientific research. 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 BP5, new add-on modules will be developed in the next years to come.

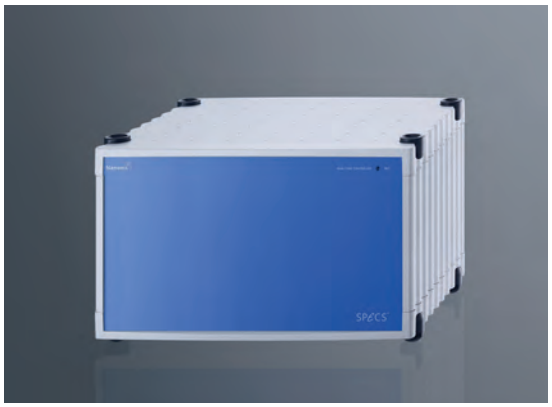
Future-proof state-of-the-art hardware Base Package 5

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 RC5

The “brain” of the Nanonis Base Package is the real-time controller RC5. 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 RC5. The addition of one or more Nanonis Oscillation Controllers (OC4), which extends the frequency range to 5 MHz, is straightforward, should a larger signal bandwidth be required. Communication, triggering and control of additional external instruments is an easy task thanks to the various digital communication options of the RC5.



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.

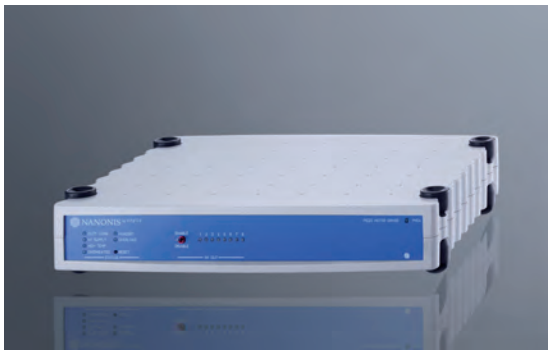
High Voltage Amplifiers Nanonis HVA4

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.



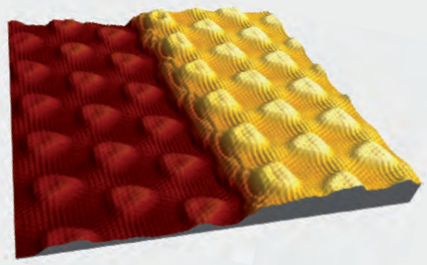
Piezo Drivers Nanonis PD5

The Nanonis PD5 combines the functionality of the HVA4 and of the PMD4 into a single enclosure. Five low-noise high voltage channels with the same specifications as the HVA4 are combined with eight outputs for driving low-capacitance piezo motors with software or handset control.

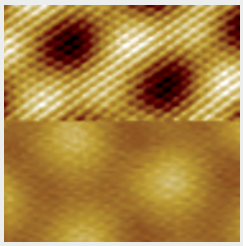
Adaptation Kits for use with Commercial Microscopes

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.

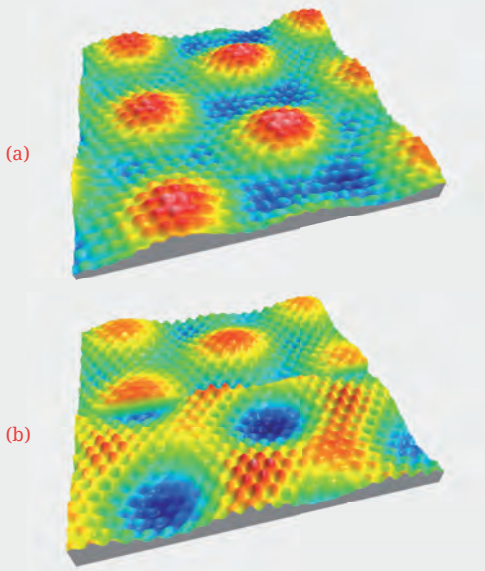
High Resolution Images measured with the Nanonis BP5



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.



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 RC5, 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

RC5	
Dimensions	32.5 x 28 x 21 cm
Weight	7.8 kg
Power Supply	Built-in universal power supply, max. 200 W, 100 – 240 V, 50 - 60 Hz
Real-time System	NI PXIe-8115 real-time system with Intel Core i5 CPU 2.5 GHz, 2 GB RAM
Operating System	NI LabVIEW Real-Time OS
FPGA Card	NI PXIe-7965R
Connectivity	3 x SC5 max., 3 x 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 RC5

Analog Inputs (all specifications for ±10 V input range)	
Hardware Interface	8 x BNC connectors, differential
Differential Input Voltage Range	±10 V
Differential Input Impedance	2 MΩ
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
Measurement Noise	< 100 µVrms @ 1 MS/s, < 25 µVrms @ 60 kS/s, < 6.5 µVrms @ 240 S/s
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

Analog Outputs (all specifications for ±10 V output range)	
Hardware Interface	8 x BNC connectors, referenced to AGND
Output Voltage Range	±10 V into 1 kΩ or larger (0 to +10 V with internal jumper 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

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

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
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 XP/Vista/7/8 Windows 7 64-bit recommended
Min. Requirements	Intel Core Duo 1.5 GHz or equiv., 2 GB RAM, 100 GB HD, two 19" screens with at least 1280 x 1024 pixels
Recommended Configuration	Intel Core i5 2.5 GHz or equiv., 4 GB RAM, 1 TB HD, two 21" screens with 1600 x 1200 or 1920 x 1200 pixels
License	Unlimited in time, bound to RC5
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	48 signals (inputs, outputs and internal signals), up to 24 simulteneous signals for data display and acquisition
Data Transfer	Via TCP/IP, 2 kS/s default, up to 20 kS/s
Representation	32-bit floating point, real world physical units

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