SC11 Automated Survey System

SC11/Auto in use

SC11/Auto in carrying case

- Automated site surveys for SEM and TEM installations
- Full SC11/SI system with
  - 2 x 3-axis DC magnetic field sensors
  - 3 x Wilcoxon 731A accelerometers
  - Brüel & Kjær precision microphone
- Measures
  - Magnetic field at 2 heights
  - Floor vibration in 3 axes
  - Acoustic levels
- SC11 Survey 5.5 software automates multiple unattended site surveys
- Self Test feature checks all the sensors before making measurements
- Templates and a step-by-step guide aid novice users to perform site surveys
- Predefined setup scripts run the spectrum analyser, chart recorder, oscilloscope and plot results.

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Overview

The SC11/Auto is a fully populated configuration of the SC11/SI system. With 2 DC magnetic field sensors, 3 accelerometers and a precision microphone, it provides all the sensors needed for a full automated site survey for an SEM or TEM. All the sensors connect to an SC11 Sensor Interface, which is AC powered and connects to a Windows laptop PC via USB. The whole system including a tripod and laptop fits into a rugged custom carrying case for ease of portability.

The software suite includes "SC11 Survey", which automates a complete survey and "SC11 Wizard", which aids in setting up a single measurement. These call up three virtual instruments, an oscilloscope, a spectrum analyser and a chart recorder that display results graphically on the laptop screen. Also included is "SCplot", a comprehensive results plotting program. There is a video showing how to use this system at: http://youtu.be/82374VhsdAM

SC11/Auto Hardware

Laptop computer

Typically, our customers use their own laptop computer, purchased in their own country to ensure the correct language and type of keyboard and they install the SC11 software themselves. However, if required, Spicer Consulting (or one of our trained agents) can install the system on the customer's computer or supply a suitable laptop with the system.

The requirement for the computer is Windows XP/Vista/7/8/8.1/10, screen pixels at least 1024 x 768, USB and CD/DVD drive. The processor, RAM and hard drive must be as recommended for the operating system.

Sensor Interface

Sensor SC24/DC+AC (two)

Brüel & Kjær 4190 microphone

Wilcoxon 731A accelerometers (three)

Sensor Interface

The Sensor Interface operates from universal AC power (100-240 V ~ 50/60 Hz) which is used to power all the sensors and its embedded Analog Devices Blackfin microcomputer. For long term monitoring applications, where loss of data would not be acceptable, the sensor interface can be powered from an un-interruptible power supply. Our tests with a fully charged 350W UPS from APT provided up to four hours of operation.

There are inputs for two Spicer Consulting 3-axis magnetic field sensors. There are inputs for three Wilcoxon 731A accelerometers. The inputs provide the constant current load and power supply for each Wilcoxon 731A and are suitable for most other types of piezo accelerometers when using the spectrum program.

There is an input for a Brüel & Kjær 4190/2669L precision microphone. The Interface provides the special power supplies for the 2669L microphone pre-amplifier to enable the microphone to operate to its full specification.

There is a general purpose DC coupled auxiliary input via a BNC connector at the back of the interface.

A multi-channel 13 bit ADC controlled by an embedded Analog Devices Blackfin Microcomputer acquires all the signals in digital format inside the Interface. The microcomputer performs extensive signal pre-processing before the signals are sent to the laptop computer through the USB connection.

Sensor SC24/DC+AC

This is the 3-axis magnetic field sensor supplied with the SC11/Auto system. It can measure DC and AC fields, e.g. changing DC fields from trams and elevators and AC power line fields. It has internal bias coils that are used to null the Earth's field. The bias coil currents are reset by clicking an icon on the program screen, each time the sensor is moved. The measurement range is ± 20 mG. The sensor has low noise and when fully warmed up the DC drift is below 20µG/day.

Wilcoxon Research model 731A accelerometer

The Wilcoxon Research model 731A has a measurement range of 200 mg's Pk-Pk and a bandwidth of 0.1 Hz to 500 Hz when used with SC11/Auto system. It is suitable for the measurement of extremely low level vibrations. Its noise limit is 0.03µg/√Hz at 2Hz. The system supports simultaneous measurements by three accelerometers. Each accelerometer measures along one independent axis. With three correctly oriented accelerometers, vibration can be measured in three orthogonal axes.

Brüel & Kjær 4190/2669L microphone

The Brüel & Kjær 4190 microphone with 2669L preamplifier connects directly to the sensor interface. It provides acoustic measurements to acoustic laboratory reference standards. It measures sound levels from 20dB to 110dB and 1.5Hz to 20kHz. It measures infrasound levels (i.e. frequencies below 20Hz) which can limit the performance of transmission electron microscopes by vibrating the sample. (The Sound Level Meter supplied with the SC11/Compact is also supported).

Calibration

The magnetic field sensors are manufactured and calibrated by Spicer Consulting. Their calibration is NAMAS traceable.

The Wilcoxon accelerometers are supplied by Wilcoxon Research Inc. Germantown MD, USA with a calibration certificate traceable to the National Institute of Standards and Technology, Gaithersburg, MD, USA.

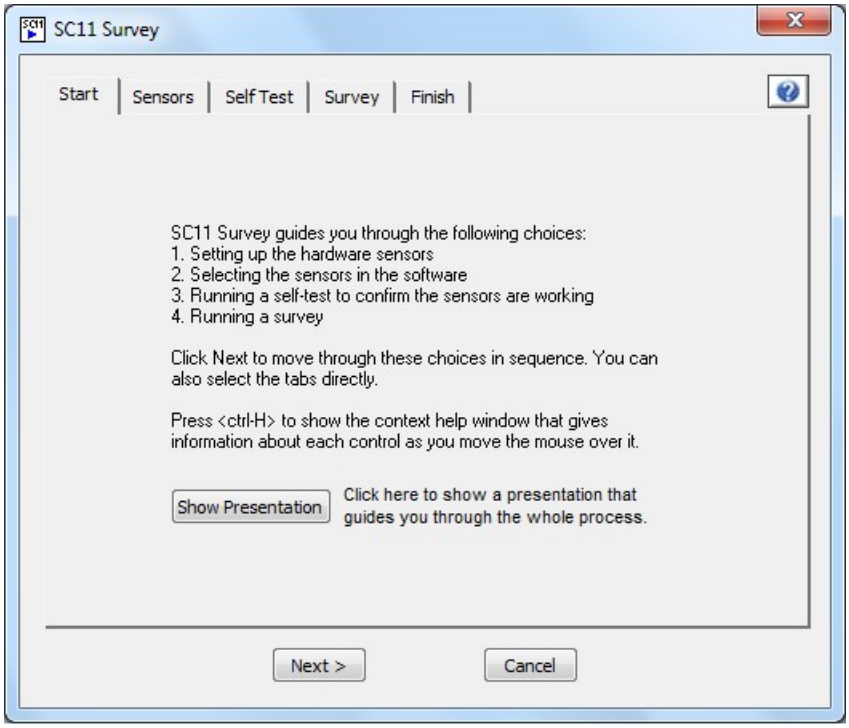
The Brüel & Kjær 4190 microphone is supplied with a calibration certificate traceable to the National Institute of Standards and Technology, Gaithersburg, MD, USA.

Spicer Consulting provides a re-calibration service for the entire system.

SC11 5.5 Software

SC11 Survey

SC11 Survey automates a complete survey by calling other SC11 instruments using Active X technology. It uses a macro that can run several measurements and automatically save the results. Survey guides you through the choice of sensors, a self test to ensure all the sensors are working and then the survey itself. Survey enables first-time users to set up the equipment and run a standard survey using a macro and setup files that have already been created by an expert user.



This program is designed to work with the full SC11/SI system with 2 DC magnetic field sensors, 3 accelerometers and a precision microphone. Self test can be customised to omit magnetic field, or vibration or acoustic tests if required. Survey macros are very flexible, but once written, they require the sensors for which they are designed.

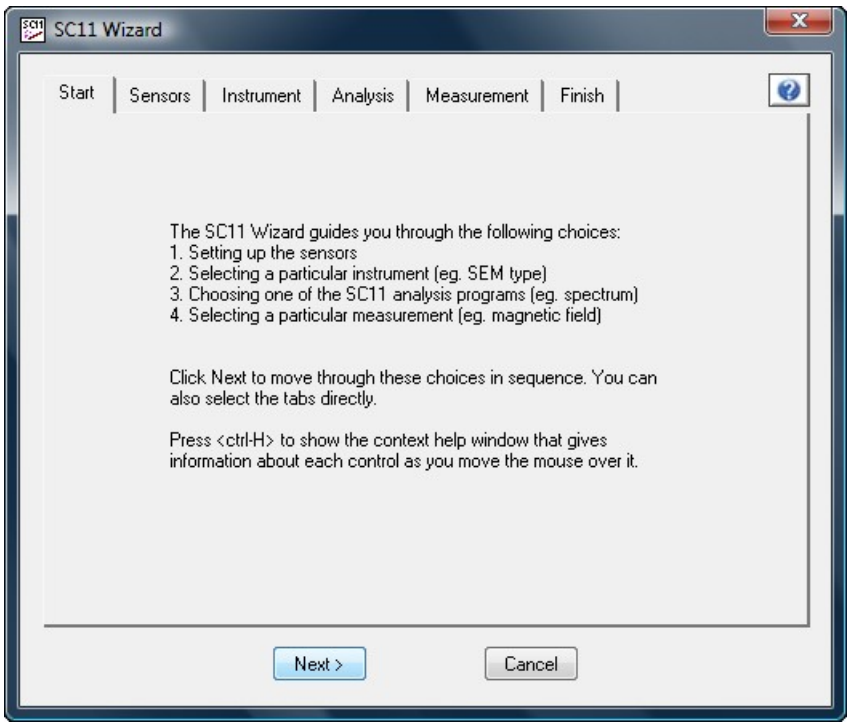
The Show Presentation button on the Start page opens a document that shows in detail how to connect the sensors, run a self test and perform a survey for the full SC11/SI system. It is possible to customise this presentation for other hardware configurations.

Self test works by comparing the output of 2 magnetic field sensors or 3 accelerometers. It also uses the self-test feature of the precision microphone. The self test report includes spectra comparing the sensors and a pass/fail result. If self test fails, it advises the user to ask for support before continuing with the survey. The report can then be sent to an expert user so that they can diagnose whether a sensor is faulty or advise the user how to get it working.

To run a survey, the user follows the instructions in the presentation and then selects the required survey from a predefined list. Surveys may be repeated at fixed intervals to show how the environment changes with time.

Survey macros are written by an expert user as follows: First set up a measurement in the scope program and save the setup file. Then turn on macro recording and run through the process of loading the setup, making the measurement and saving the results. Save the macro. Repeat for the spectrum analyser and chart recorder. Do the same with SCplot to create the graphs required and append them to a survey report in Microsoft Word. Manually edit the recorded macros together, adding Wait and Exit statements to make a complete survey macro. Save the setup files and the macro together in a folder ready for SC11 Survey to use. Macros contain simple statements that run in sequence. However the statements can be directly used in Microsoft Visual Basic if more complicated programming is required.

SC11 Wizard



The SC11 Wizard quickly and easily starts a single pre-defined measurement using the spectrum analyser, chart recorder or oscilloscope program. It guides you through the choice of sensors, the instrument for which the environment is to be checked, the type of analysis and the type of measurement.

The Wizard helps new or occasional users to get started with making measurements as simply as possible, using setup files that have already been created by an expert user. It also helps experienced users to organise their setup files.

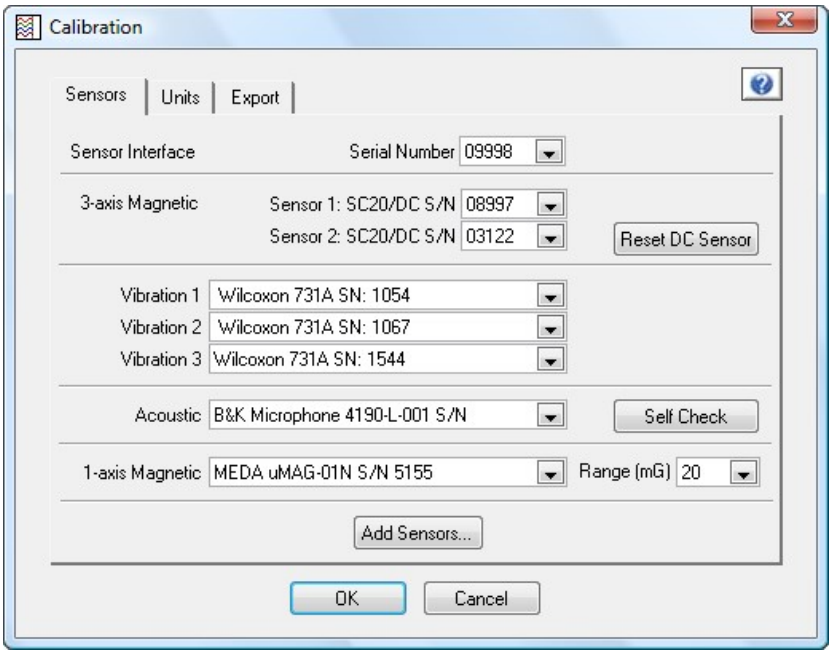
The Wizard can call up individual measurements that are part of a complete survey.

Measurement Programs

The core of the SC11 system are three measurement programs: Oscilloscope, Spectrum Analyser and Chart Recorder.

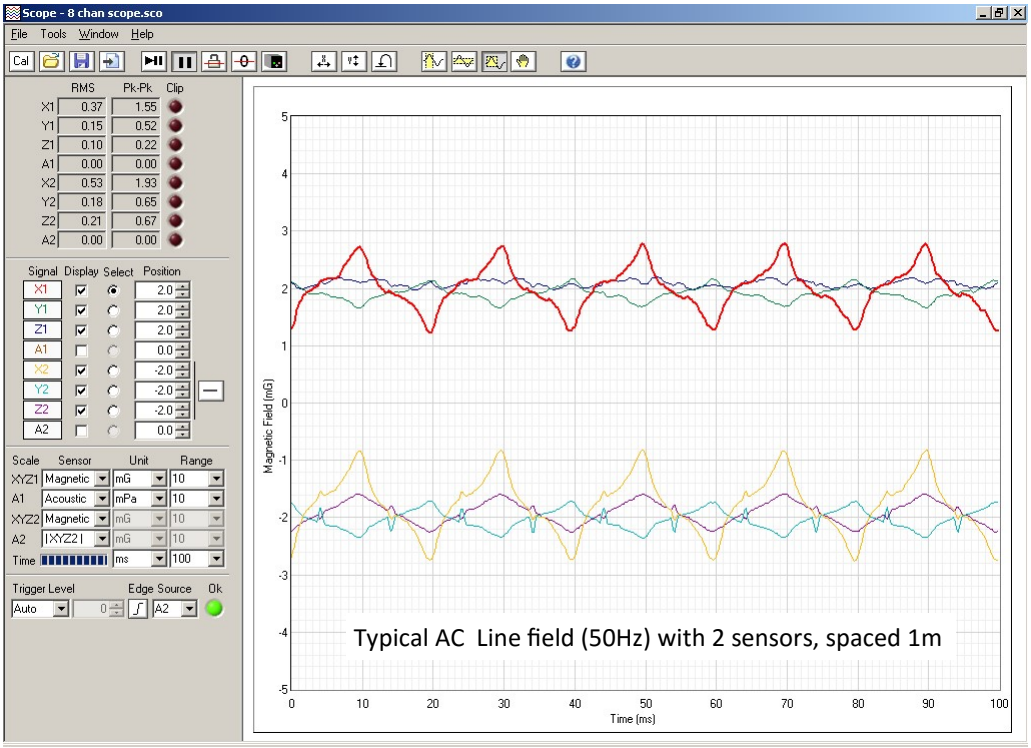
The SC11/SI/USB hardware supports operation in 4 channel or 8 channel modes. In 4 channel mode the channels are called X, Y, Z & A. In 8 channel mode the channels are called X1, Y1, Z1, A1, X2, Y2, Z2 & A2. To make full use of all the sensors, the SC11/Auto typically uses 8 channel mode. The sensors are assigned to the channels in the calibration window. Many combinations are possible. It is not necessary to have sensors assigned to all the channels in either 4 or 8 channel modes. So for example, you can run in 8 channel mode without a second magnetic field sensor plugged into channel 2.

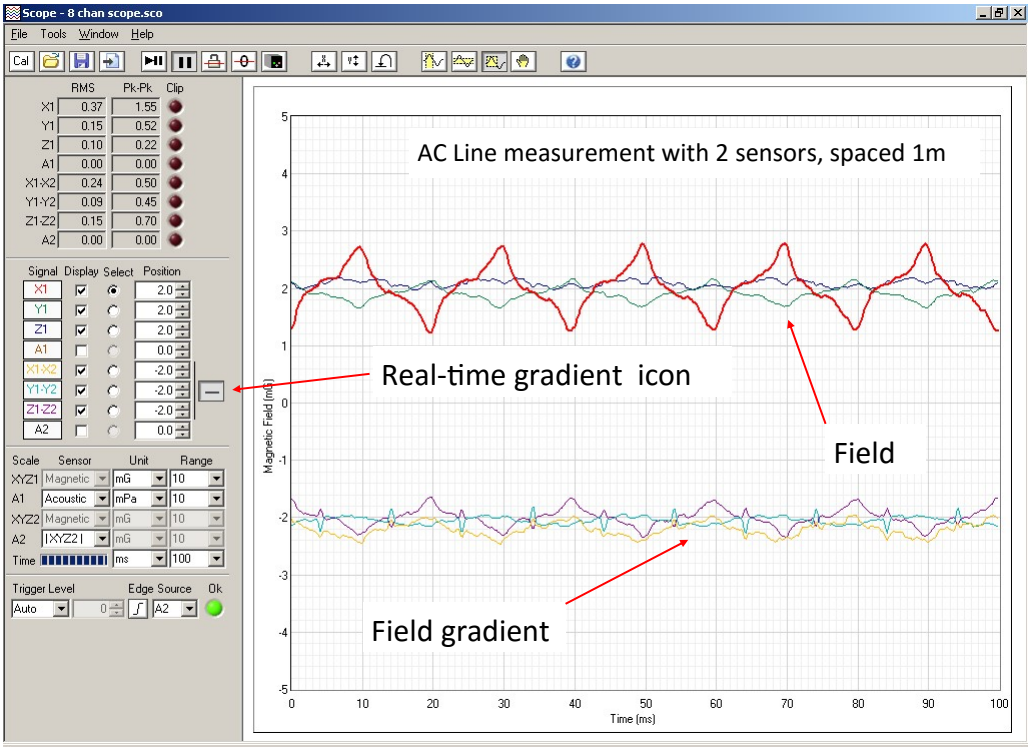
The principal use for 8 channel mode is to measure real time AC and DC magnetic field gradients by using two magnetic field sensors. This is a unique capability of this system. There are some differences in performance between the 4 and 8 channel modes. In 8 channel mode the system is acquiring twice as much data and this causes some bandwidth reduction in the chart recorder, a restriction on the choice of points in the spectrum analyser and poorer anti-aliasing performance.



Oscilloscope

The oscilloscope program is useful for initial investigation of magnetic fields during trouble shooting of electron microscope imaging problems. Examples of oscilloscope screen displays in 8 channel mode are shown below.





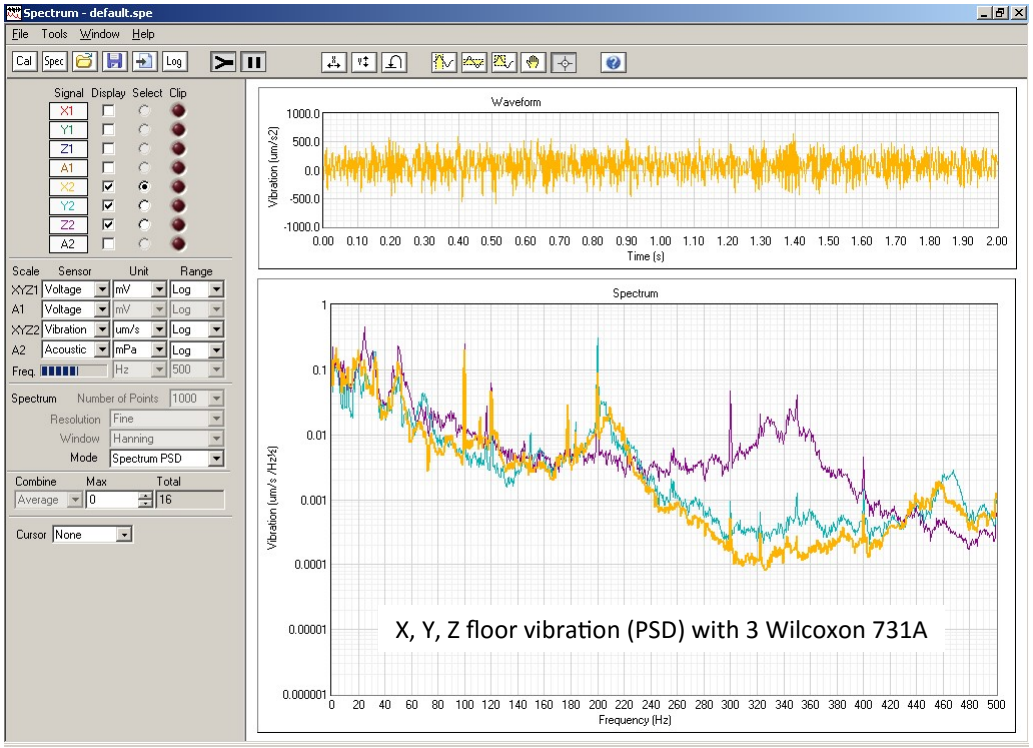
The oscilloscope has a bandwidth of 20kHz on its shorter time ranges. The A input is DC coupled. There are common controls for the time base and the vertical axis ranges. There are independent controls for the auxiliary channel ranges and the vertical position of each channel. The RMS and Pk-Pk values of the waveforms are measured and displayed numerically.

Icons on the top toolbar are used to control operation. These include “pause”, “one-shot”, “reset DC sensors” and “zero position”. The “lock position” icon activates AC coupling that varies with the time base. The effect is to stabilise the vertical position of the traces, which is useful with an AC sensor that is being moved frequently during searches for magnetic field sources.

Files to set-up the controls may be imported and exported for future use. Results may be saved as an image using the windows alt-print-screen function or exported as a text file or Matlab level 5 file for processing by the SCplot program.

Spectrum Analyser

The spectrum analyser program enables in-depth analysis of magnetic field, vibration, sound and other sources such as the video output from an SEM in spot-mode. It displays the waveforms and spectra of up to 8 channels. It highlights the selected channel. It has a wide range of units for use with all the sensors. An example of floor vibration analysis using 3 Wilcoxon 731A accelerometers is shown below. When measuring vibration with the Wilcoxon 731A accelerometer, the software integrates its output to provide velocity and displacement units as well as acceleration.



Tracking cursors are provided to measure features of the spectrum as well as define bands for RMS measurement. Harmonic cursors can be used to recognise harmonics in the spectrum and enable more accurate measurement of the fundamental frequency. Successive spectra can be combined over a period of time, as an average to reduce noise, or to find the worst case peak values. Spectra can be data-logged to a file at a maximum rate of once every minute to trace sources that vary.

The example below is a sound level measurement with comparison to the Electron Microscope manufacturer's specification, in third octave format. The specification line changes colour from grey to magenta if the specification is exceeded, as shown.

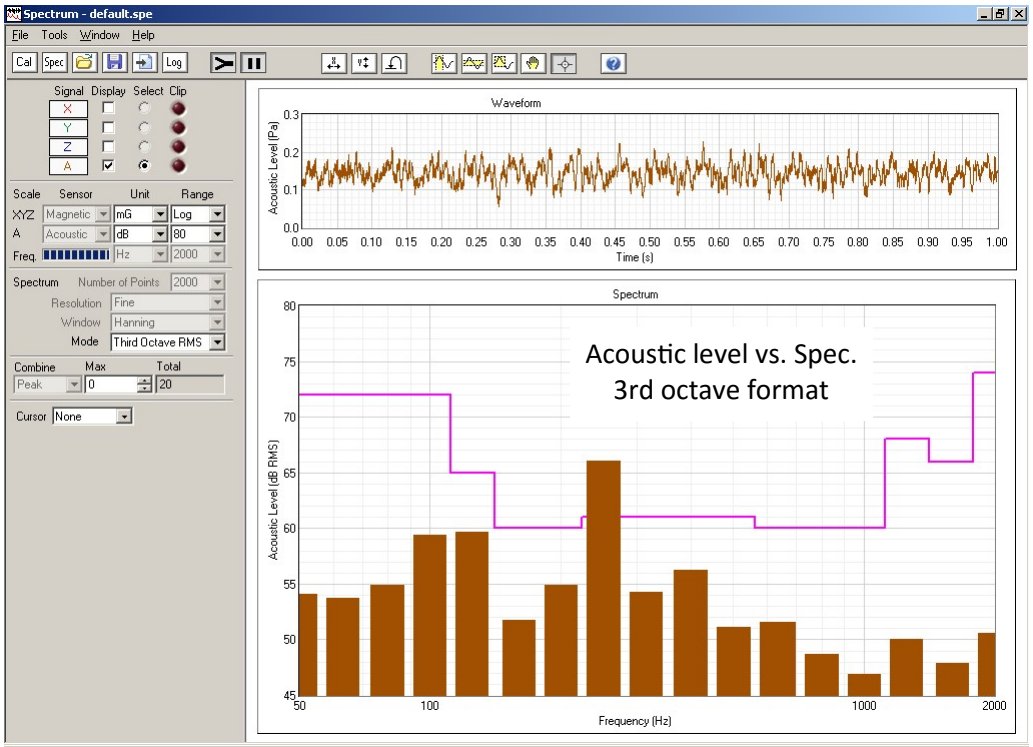
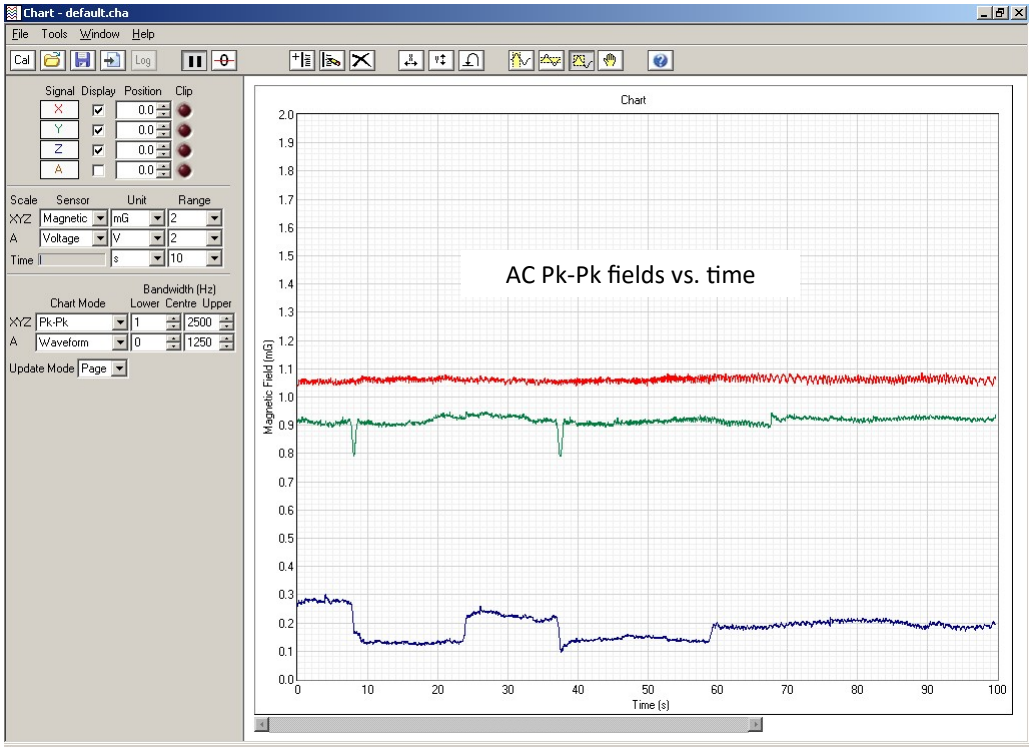


Chart Recorder

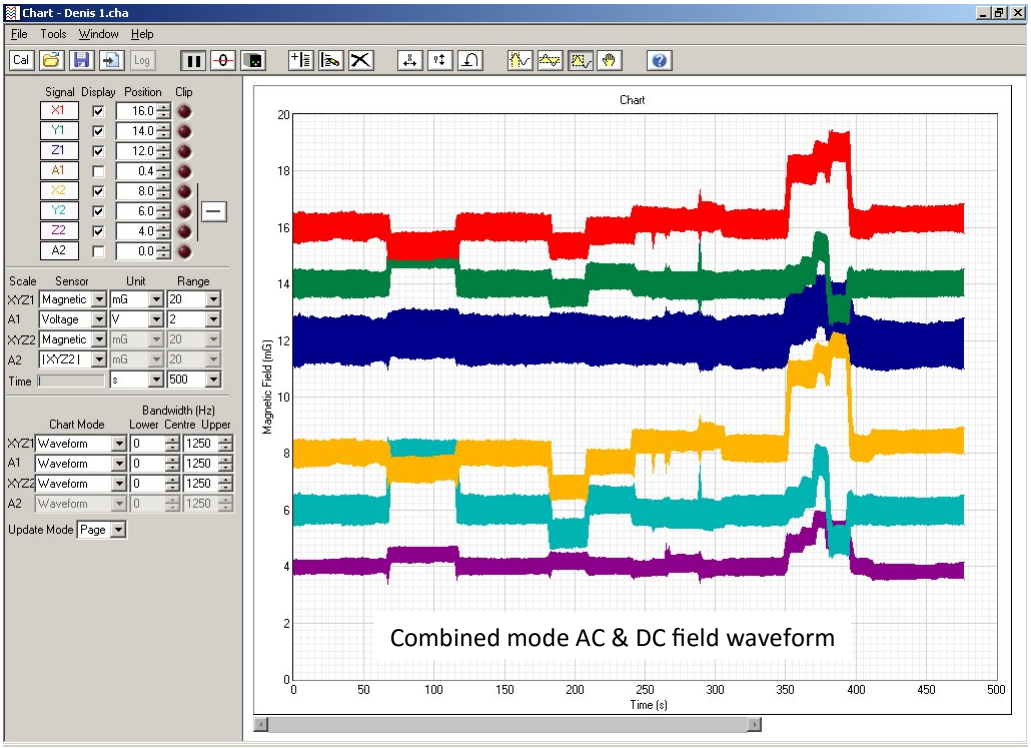
The chart program is used to record events that change relatively slowly. It simulates plotting on a paper chart which is up to 20 screen pages wide. It displays in page mode (one screen width at a time) or as a continuous scroll. The most recent 20 pages of data are retained in memory (2 hours 46 minutes at slowest chart speed). Controls for vertical range, chart speed and bandwidth are provided. Pan and zoom controls enable any section of the plot to be examined. You can mark events that occur during measurement of any chart, such as the movement of trains. The markers are exported with the results.

The example below, in 4 channel mode, is a chart of the total Pk-Pk AC magnetic field in the 1Hz to 2500Hz range. The program is calculating the Pk-Pk values in real time and charting the result. It shows that the X field was steady at 1.05mG Pk-Pk and the Z field varied from 0.1 to 0.3mG Pk-Pk during the 100 second period of the chart. By selecting the narrow band option the program can chart the field at a specified frequency, e.g. 50Hz or 60Hz.

The results of two consecutive acoustic measurements (without moving the microphone) are shown below. First is in the

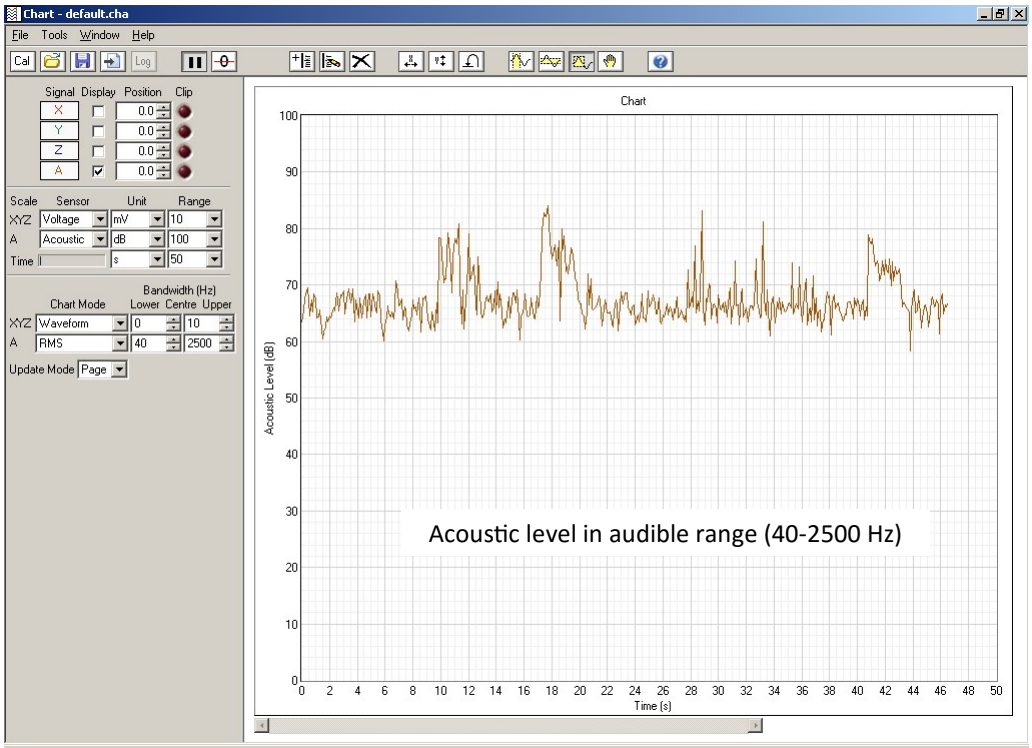


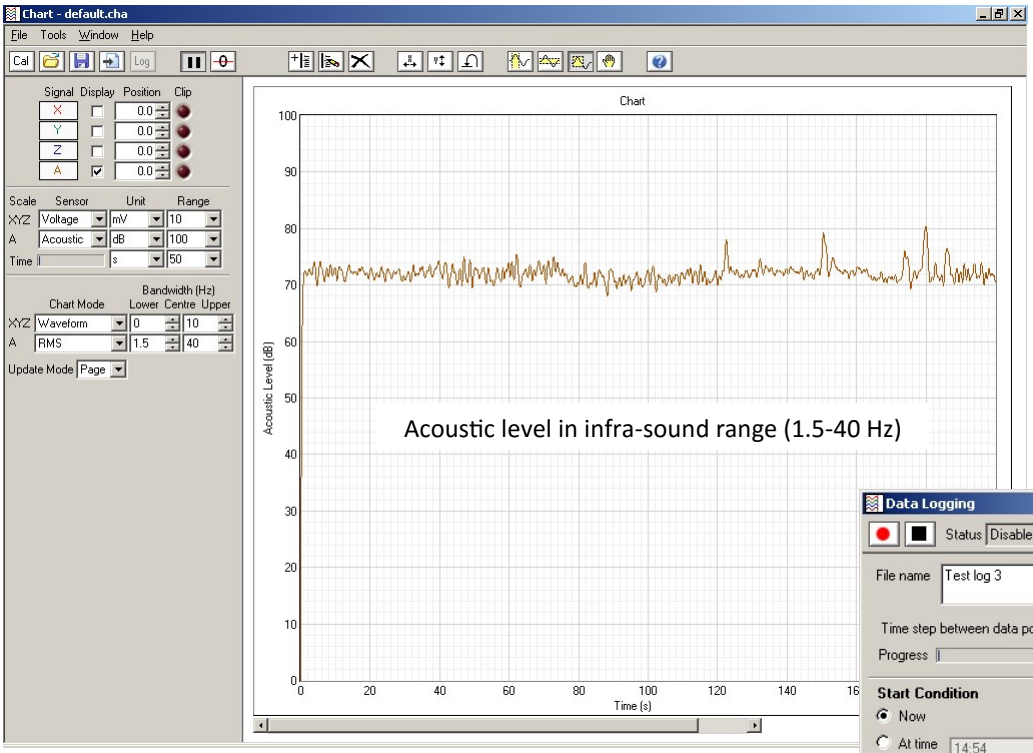
The waveform chart below was recorded in 8 channel mode using two SC20/DCMR sensors and DC-1250Hz bandwidth. The "width" of each trace is the Pk-Pk value of the AC power line fields (50Hz and harmonics), so the X1 axis power line field is 0.8mG Pk-Pk. The step function changes are the DC field caused by to the movement of nearby steel objects, in this case, about 4 mG Pk-Pk in X1. This "combined" charting mode was a new feature in the SC11 software version 5.0.

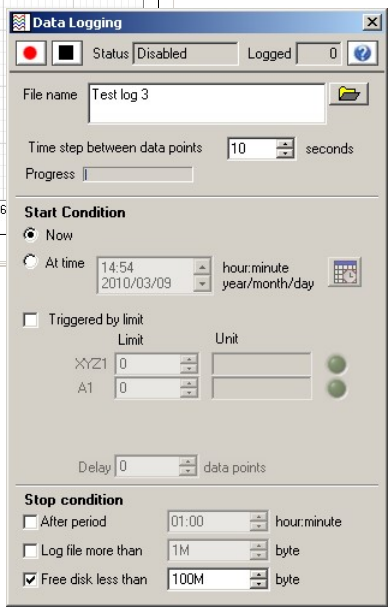


audible range (40-2500 Hz) second in the infra sound range (1.5-40 Hz). Note that the infra-sound level is typically higher. Infra sound can seriously degrade the performance of high end TEMs by moving the sample. The Brüel & Kjær 4190 microphone enables accurate infrasound measurements to below 2 Hz.

When charting vibration using the 731A accelerometers, an integrating filter tailored to the 731A allows direct



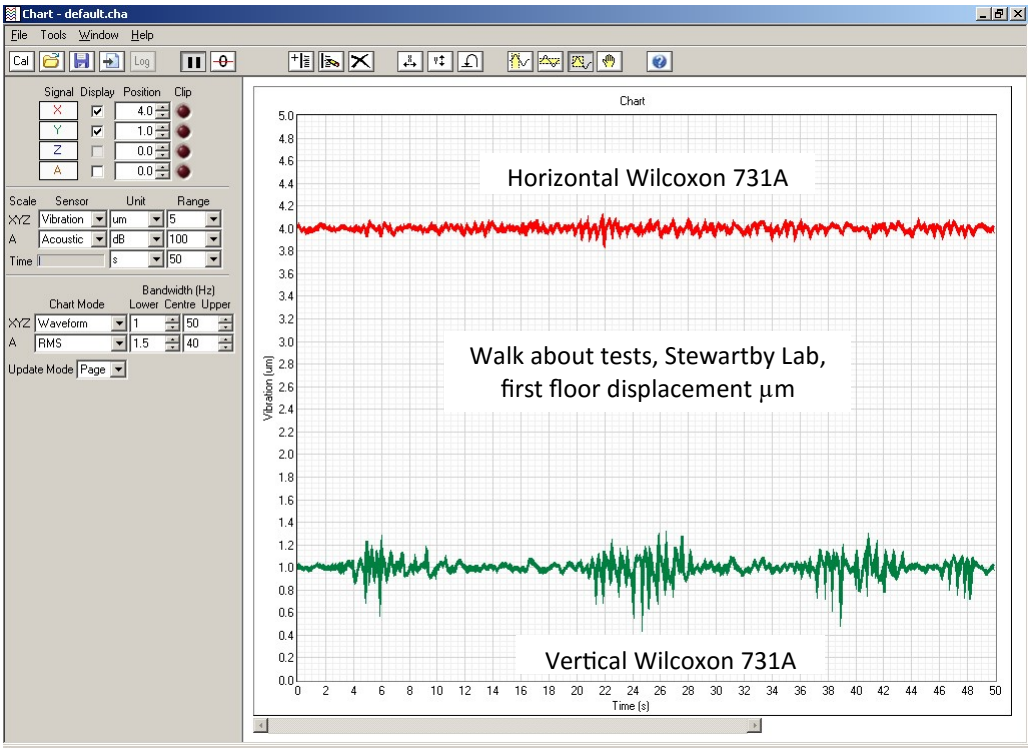




The data logging feature of the chart recorder can be used to write the results to a disc file at a specified rate, as the data is acquired. This is useful for long term recording of disturbances that occur occasionally or overnight. The adjacent screen image shows the comprehensive start and stop controls for data logging.

displacement and velocity charts to be made. This is useful for “walk about” floor vibration tests at proposed electron microscope sites, as in the example below.

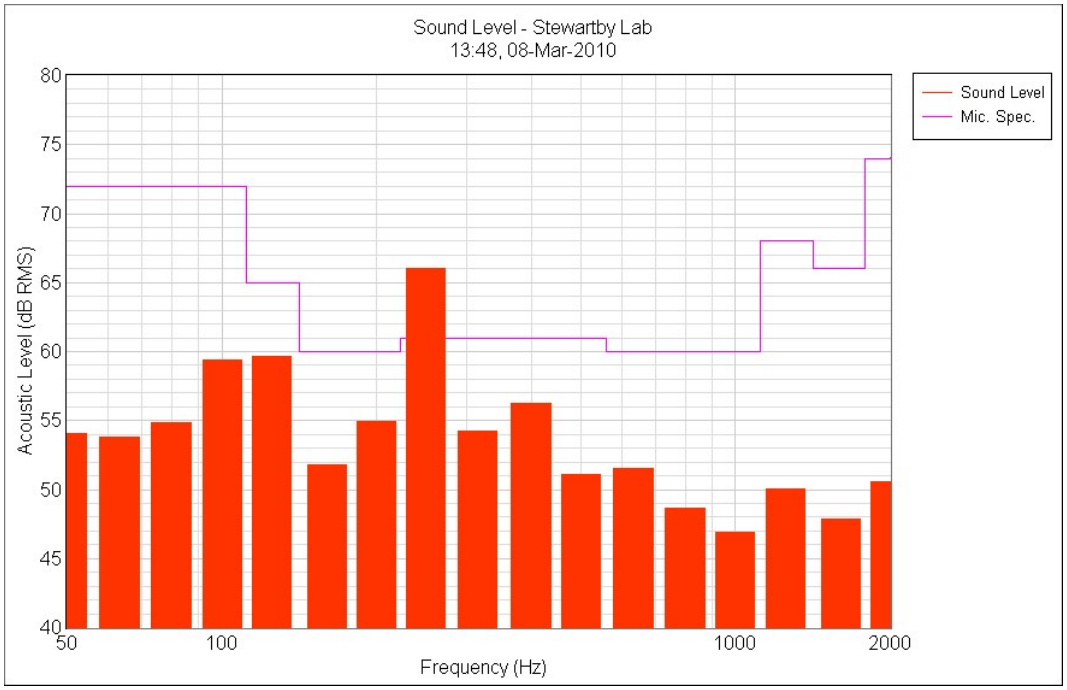
SCplot



SCplot is a comprehensive results editing program that enables results exported as text files or Matlab level 5 files from the Oscilloscope, Spectrum and Chart recorder programs to be formatted for published reports. It is particularly useful for formatting the large text files that result from long term data logging.

It supports all the units and formats that are used in the Oscilloscope, Spectrum and Chart recorder programs. It enables units conversion and can post-process results with user specified formulas. SCplot can show multiple results measured at different times on a 3D waterfall plot and it can append plots to a document in Microsoft Word.

The acoustic measurement shown on page 5 is reproduced below as an image exported from SCplot after formatting.



SC11/Auto - Specification

System

Carrying Case Size	55 x 46 x 23 cm approx. (21.5 x 18 x 8.5 in approx.)
Weight	15 kg (32 lb) approx. including typical laptop.

Laptop Personal Computer

Operating System	Windows XP/Vista/7/8/8.1/10
Display	At least 1024 x 768 pixels
Interface	USB 1.0 or 2.0
Optical Drive	CD/DVD
Processor	As required for operating system
Memory	As required for operating system
Hard Disc	As required for operating system

Sensor Interface: SC11/SI/USB

Inputs	
MAG1, MAG2	3-axis magnetic field sensor (2 x SC24 sensor)
VIB1, VIB2, VIB3	3-axis vibration (3 x Wilcoxon 731A)
MIC	Microphone (B&K 4190/2669L)
AUX	BNC voltage input, DC coupled, ±10 V range 100 kΩ impedance.
Anti-aliasing Filters	20kHz
Power	100-240V AC, 50-60 Hz, 0.25A max

3-axis Magnetic Field Sensor: SC24/DC+AC

Co-ordinate System	X, Y, Z rectangular Cartesian
Bandwidth	DC - 13 kHz (-3 db)
Ambient Field Range	±2000 mG (±200 µT)
Measurement Range	±20 mG (±2.0 µT)
Warm-up drift	±0.1mG (±10 nT) in 2 hours (typ) ±0.25mG (±50 nT) in 2 hours (max)
Long term drift	±20 µG (±2 nT) in 24 hours
Noise Level	7 µG (0.7 nT) RMS (0-10kHz)
Accuracy	±1 % (after >2 hour warm up). (±5 % cold)

Vibration Sensor: Wilcoxon 731A Accelerometer

Type	Wilcoxon Research, model 731A
Bandwidth	0.1 - 500 Hz
Measurement Range	2 m/s^2 (0.2 $g's^{\alpha}$) Pk-Pk (in this system)
Noise Limit	7 $\mu m/s^2$ RMS max. 0.35 µm/s RMS at 1Hz, 0.11 µm/s RMS at 5Hz 0.07 µm RMS at 1Hz, 0.0035 µm RMS at 5Hz
Accuracy	±5 % (with gain calibration file)

Acoustic Sensor: B&K 4190/2669L Microphone

Type	Brüel & Kjær, Condenser microphone 4190, Pre-amplifier 2669L
Bandwidth	1.5 Hz - 20 kHz
Measurement Range	110 dB (in this system)
Noise Limit	20 dB (in this system)
Accuracy	±1 dB 3 Hz - 20 kHz

Programs (General)

Channel modes	4 channel & 8 channel
Channels	4 channel mode X, Y, Z, A 8 channel mode X1, Y1, Z1, A1, X2, Y2, Z2, A2
Clipping	Audio/visual indication
Pause control	Freeze/resume instrument operation
Calibration panel	Set channel mode, add/select sensors, set ranges, calibrate offsets, microphone self check, add/edit user defined units, set export file options.
Setup file	Open/save instrument controls
Export	Export results for SCplot or spreadsheet
Print window	Print current screen display
Help	Context help on controls, online help file

Oscilloscope

Amplitude units	
Magnetic Field	mG, nT, µT, mA/m, A/m
Vibration	µg's$^{\alpha}$, mg's$^{\alpha}$, µm/s^2, mm/s^2
Acoustic	mPa, Pa
Voltage	mV, V, user defined units
Resultant |XYZ|	Magnetic Field, Vibration, Voltage units
Time ranges (ms)	0.5, 1, 2, 5, 10, 20, 50, 100, 200, 500, 1000, 2000 , 5000
Bandwidth (Hz)	20,000 for time ranges 0.5, 1, 2, 5 At least 100,000/(time range) for other time ranges
Digital Meter	RMS, Peak to Peak (all channels)
Trigger	Auto/Manual level, +/- edge, source, one-shot
Capture indicator	Indicates progress of data acquisition

Spectrum Analyser

Displays	Waveform (autoscaling), Spectrum
Select	Highlight and attach cursor to selected signal
Amplitude units	
Magnetic field	mG, nT, uT, mA/m, A/m
Vibration	µg's$^{\alpha}$, mg's$^{\alpha}$, µm/s^2, mm/s^2, µm/s, mm/s, nm, µm
Acoustic	mPa, Pa, dB, dBA, dBC
Voltage	mV, V, user defined units
Resultant |XYZ|	Magnetic Field
Amplitude ranges	1, 2, 5, 10, 20, 50, 100, 200, 500, log full scale.
Frequency ranges	20, 25, 30, 40, 50, 60, 80, 100, 120, 160, 200, 250, 300, 400, 500, 600, 800, 1000, 1200, 1600, 2000, 2500, 3000, 4000, 5000, 6000, 8000, 10000, 12000, 16000$^{\beta}$, 20000, Hz full scale.
Number of points	200, 250$^{\gamma}$, 400, 500$^{\gamma}$, 800, 1000$^{\gamma}$, 1600, 2000$^{\gamma}$, 3200$^{\beta}$, 4000$^{\beta}$
Accuracy	Frequency: ±0.01% ±0.02 div
Waveform windows	None, Hanning, Flat top
Spectrum modes	RMS, 0-Pk, Pk-Pk, PSD, Third Octave (RMS, 0-Pk, Pk-Pk)
Combine spectra	Average/Peak, Max no. spectra
Cursor modes	Total RMS between 2 tracking cursors, 10 harmonic cursors
Capture indicator	Indicates progress of data acquisition
Specification files	Create, edit, add & remove. Compare with measurements.
Data logging	Start: Now, At time, Triggered by flat level, Triggered by spec Stop: Period, File size, Disk space Min. time step: 1 minute

Chart Recorder

Position	Set or zero vertical positions
Amplitude units	
Magnetic Field	mG, nT, µT, mA/m, A/m
Vibration	µg's$^{\alpha}$, mg's$^{\alpha}$, µm/s^2, mm/s^2, µm/s, mm/s, nm, µm
Acoustic	mPa, Pa, dB, dBA, dBC
Voltage	mV, V, user defined units
Resultant |XYZ|	Magnetic Field, Vibration, Voltage units
Page length	5, 10, 25, 50, 100, 250, 500 s
Chart length	20 Pages
Max Bandwidth	(Bandwidth may be reduced by controls)
Magnetic field	DC - 2.5$^{\delta}$ kHz for Sensor SC24/DC+AC 0.1 Hz - 2.5$^{\delta}$ kHz for Sensor SC11/AC
Vibration	0.1 Hz - 500 Hz
Acoustic (B&K mic.)	1.5 Hz - 2.5$^{\delta}$ kHz
Voltage	DC - 2.5$^{\delta}$ kHz
Bandwidth controls	XYZ/A upper/lower - all modes except narrow band
Narrow band filter	Centre frequency, f_0 range: 1 Hz - 1250 Hz Accuracy: ±1% within pass band, (f_0 ± 3%) Attenuation: 60 dB min. in stop band, (f_0 ± 20%)
Chart modes	Waveform, RMS, Peak to Peak, Narrow band RMS, Narrow band Pk-Pk.
Markers	Time, text string
Clear	Clear chart data
Buffer indicator	Indicates state of data acquisition buffer
Update modes	Page, scroll
Chart palette	Pan, zoom, format, reset and clear chart
Data logging	Start: Now, At time, Triggered Stop: Period, File size, Disk space Log rate limit, time step: ≥ (page length)/500

$^{\alpha}$ g's are units of the acceleration due to gravity
$^{\beta}$ 4 Channel mode only
$^{\gamma}$ Not available on 20000 Hz range in 8 channel mode
$^{\delta}$ 1.25 kHz in 8 channel mode