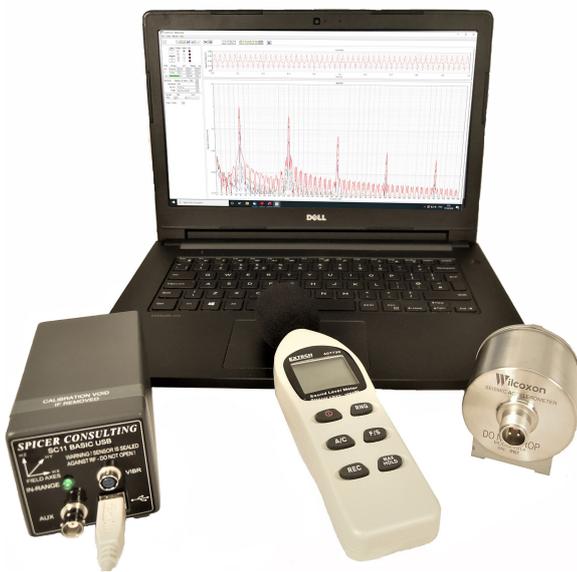# SC11 Compact Analysis System

SC11 System in carrying case

- Windows laptop powered measurement and analysis system
- Data acquired and pre-processed in sensor with universal USB sensor connection
- Measures environmental magnetic fields, vibrations and sound levels
- 20 kHz Bandwidth in Scope and Spectrum programs
- Measures 9kHz magnetic fields from wafer transport robots and 0.1 Hz field from trams
- Ultra low noise seismic accelerometer for vibration measurements
- Narrow-band and third octave spectrum analysis
- Chart recorder with data logging for long term measurements

The SC11/Compact is the latest version of our popular site survey equipment. It features data acquisition and pre-processing by an embedded microcomputer in the magnetic field sensor, for enhanced performance. The separate data acquisition card (DaqCard) used by our earlier systems is not required. The computer interface is through an industry standard USB connection, which enables the system to be used with most modern laptops running Microsoft Windows.

The Compact Analysis System includes the SC11/Compact three axis AC magnetic field sensor, an accelerometer and a sound level meter. An optional flux gate magnetometer can be added to measure DC magnetic fields. The system is powered from the laptop except for the sound level meter and magnetometer which have their own batteries. It is supplied in a rugged custom carrying case. The software suite includes three virtual instruments, an oscilloscope, a spectrum analyser and a chart recorder that display results graphically on the laptop screen. Also included are "SCplot", a comprehensive results plotting program, "SC11 Wizard", which aids in setting up a single measurement, and "SC11 Survey", which automates a complete survey.

SC11/Compact - 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.

Magnetic field sensor	Wilcoxon 731A accelerometer	Sound level meter	MEDA µMAG-01N magnetometer

Magnetic Field Sensor

The SC11/Compact three axis magnetic field sensor is derived from sensors used in the Spicer Consulting range of magnetic field cancelling systems. It contains a three-axis inductive pick up coil (X, Y, & Z) connected to precision analog integrators, to measure AC magnetic fields. The measurement range is 80 mG pk-pk with a bandwidth of 1 Hz to 20 kHz and the total noise limit in the band is 3µG RMS. Post-processing in the laptop computer enables the low frequency limit to be extended to 0.1Hz with minor increase in the 1/f noise limit. The measurement accuracy is ± 1%.

The sensor has two inputs for connecting external signals. The first input is specifically for the Wilcoxon 731A accelerometer. It provides the constant current load & power supply for the 731A. The second "Aux" input has a BNC connector. It is used with the sound level meter and the Meda magnetometer and other sources such as the video output from an SEM in spot mode. These two inputs can only be used one at a time. The software selects which is used.

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

Accelerometer

The accelerometer supplied is a Wilcoxon Research model 731A, with a measurement range of 200 mg's pk-pk and a bandwidth of 0.1 Hz to 500 Hz. It is suitable for the measurement of extremely low level vibrations. Its noise limit is 0.03µg/√Hz at 2Hz. The accelerometer measures along one independent axis. It can be rotated to measure three orthogonal axes (one at a time) while standing on a horizontal plane.

Digital Sound Level Meter

The sound level meter supplied is an Extech 407730 for general purpose sound measurements. It can measure from 40 to 130 dB on its internal meter. The sound level meter connects to the Magnetic Field Sensor Aux input through a coax cable.

Flux Gate Magnetometer

The optional flux gate magnetometer is a µMAG-01N from MEDA. It measures one axis magnetic fields from DC to 400 Hz, with a maximum range of ±2000 mG and a meter resolution of 0.01 mG on the most sensitive 20 mG range. The Meda meter connects to the Magnetic Field Sensor Aux input through a coax cable.
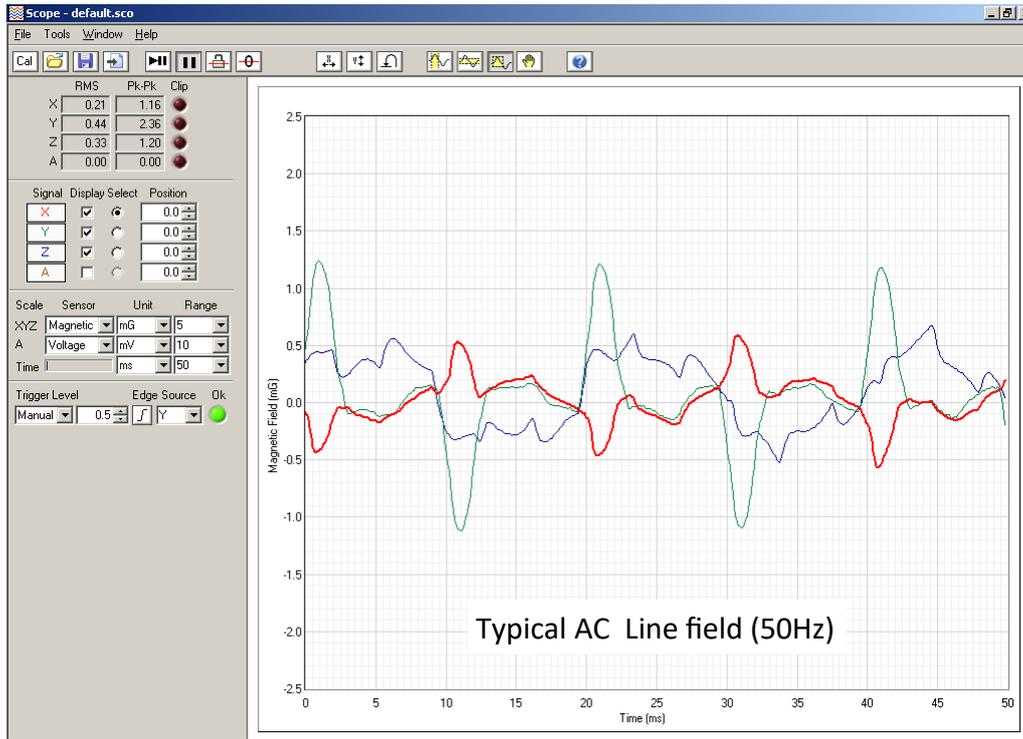
Calibration

The calibration of the magnetic field sensor is NAMAS traceable. The Wilcoxon accelerometer 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.
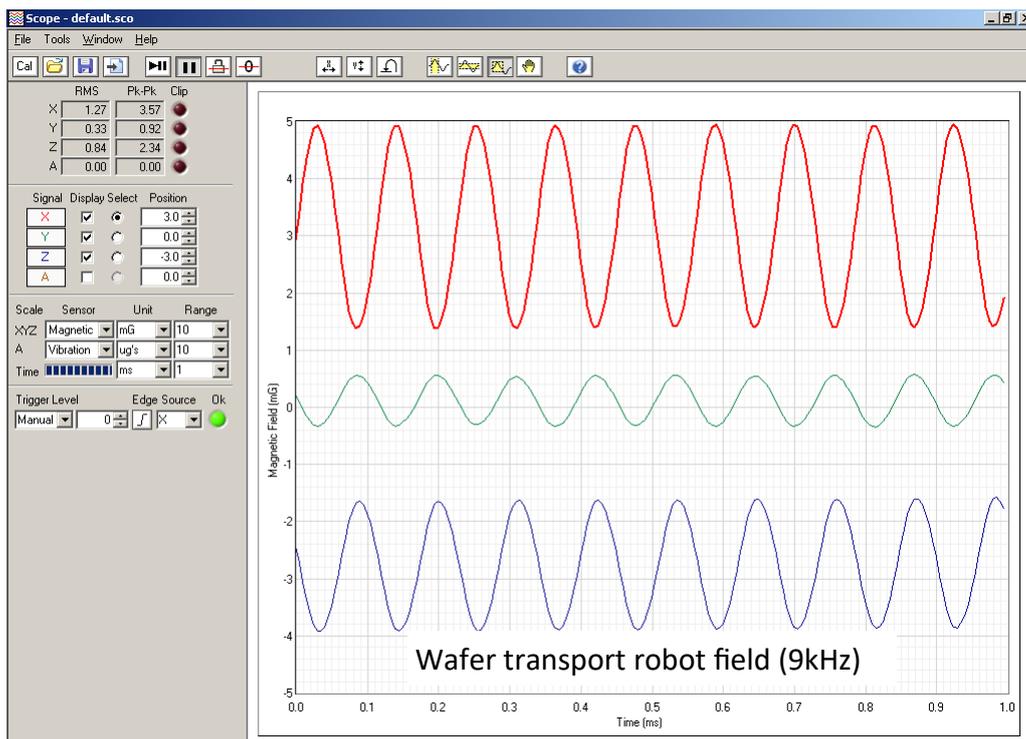
SC11 5.5 Software

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 are shown below.

Typical AC Line field (50Hz)

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 magnetic field axis ranges. There are independent controls for the auxiliary channel range and the vertical position of each channel. The RMS and Pk-Pk values of the waveforms are measured and displayed numerically.
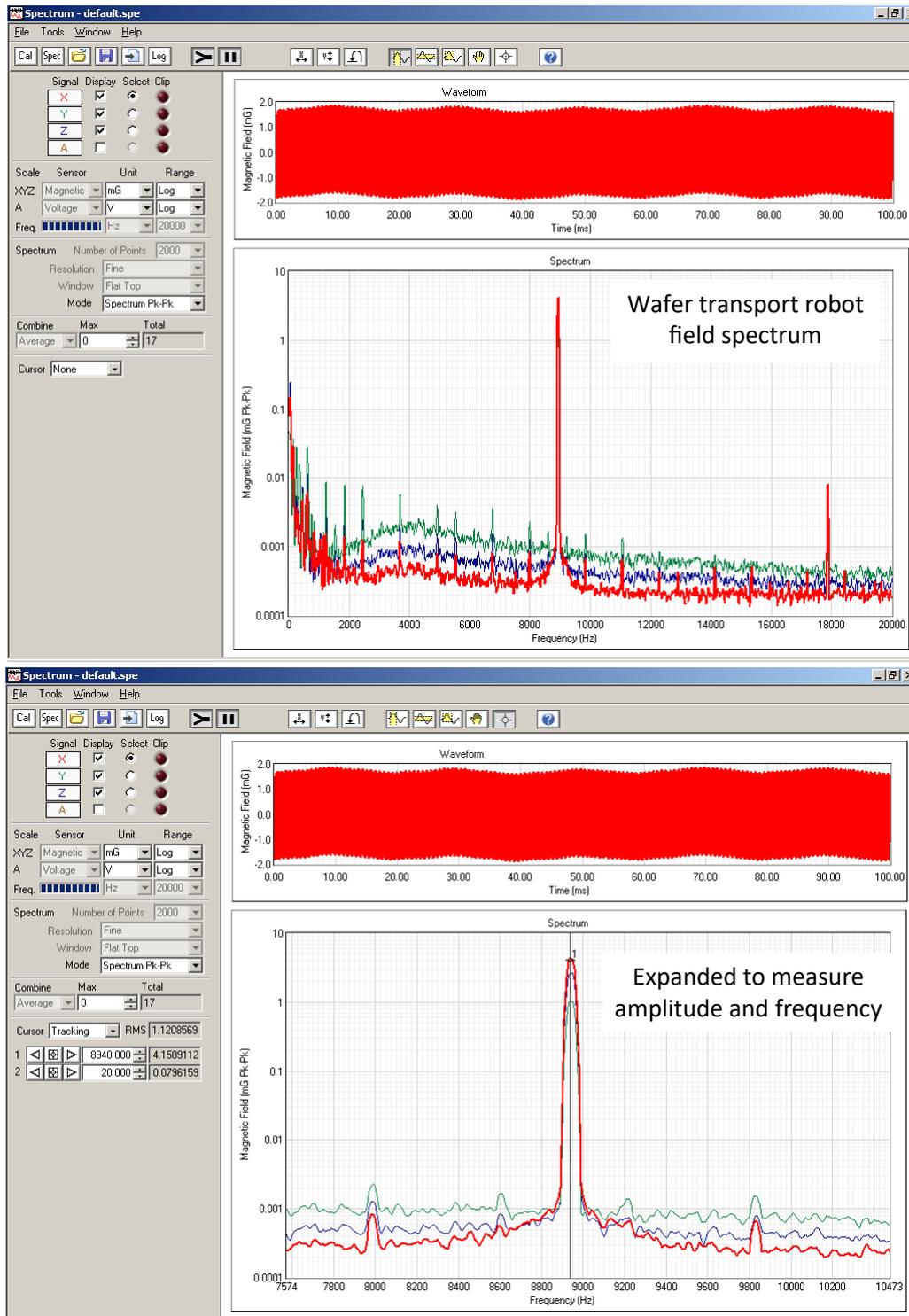
Icons on the top toolbar are used to control operation. These include "pause" and "one-shot" and "zero position". The "lock position" icon activates AC coupling that varies with the time base. The effect is to stabilise the vertical position of the traces, which is useful if the sensor is being moved 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.
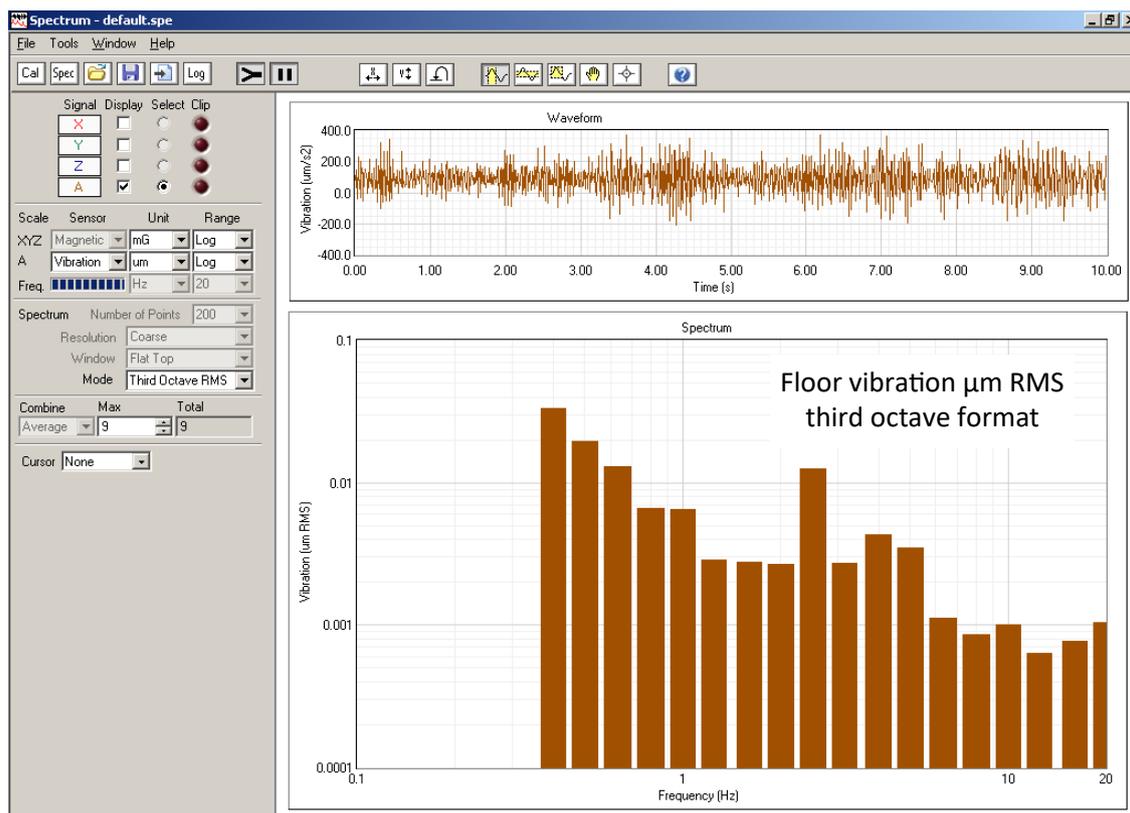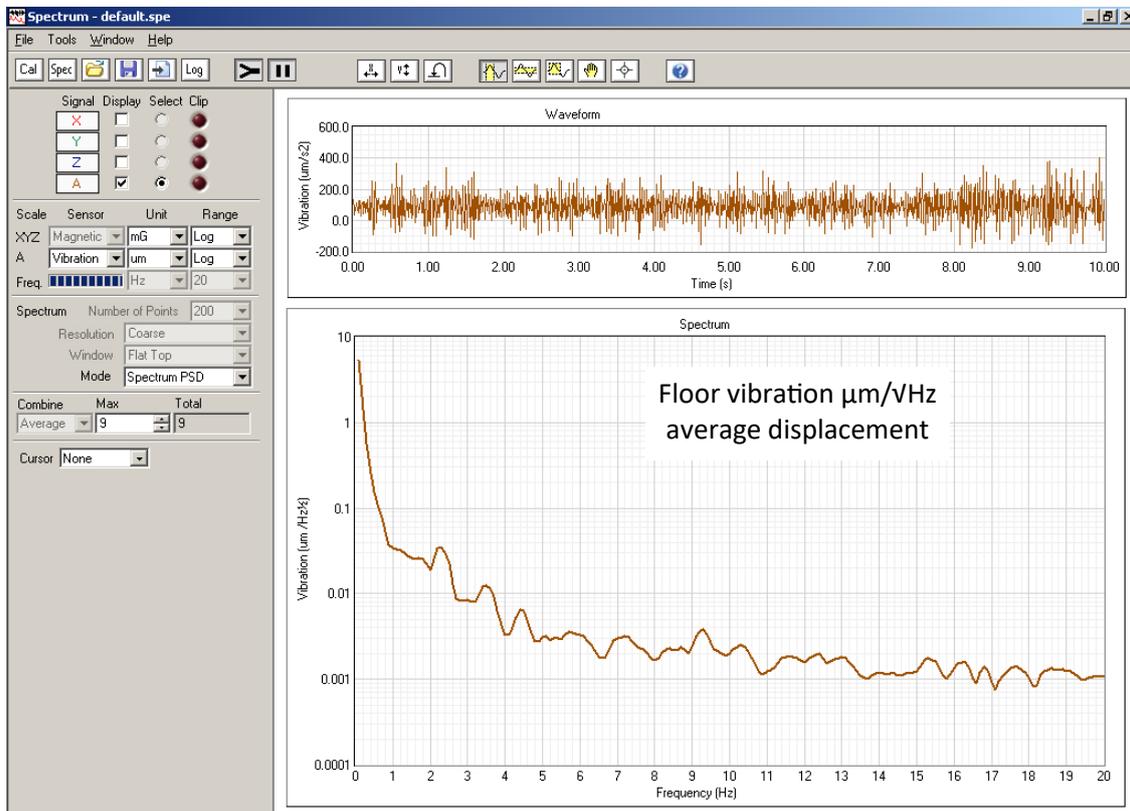

Wafer transport robot field (9kHz)

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 4 channels (3 Magnetic Field and one other). It highlights the selected channel. It has a wide range of units for use with all the sensors. An example of magnetic field analysis is shown below.

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.

When measuring vibration with the Wicoxon 731A accelerometer, the software integrates its output to provide velocity and displacement units as well as acceleration. Two examples of floor vibration in the critical low frequency range below 20Hz follow. The first measurement is in industry standard "power spectrum density" (PSD) units. These units have the advantage that the measured vibrations are independent of the number of points in the spectrum. The second is in 1/3 octave bands.

4

Floor vibration µm/√Hz average displacement

Floor vibration µm RMS third octave format

Examples of Acoustic level spectra made using the sound level meter follow. The 20kHz bandwidth of the SC11/Compact/ USB "A" input allows measurements over the full 20Hz –20kHz audio band when required. (For infrasound measurements i.e. below 20Hz, the SC11/SI system should be used with the Bruel & Kjaer 4190/2669L precision microphone.)

The third octave format is commonly used to specify the acoustic environment for electron microscopes. This enables simple comparison with the microscope manufacturers acoustic specification. The SC11 software enables the specification to be entered and compared during the acoustic measurement. This is a typical example. The line defining the specification changes colour when the specification is exceeded.
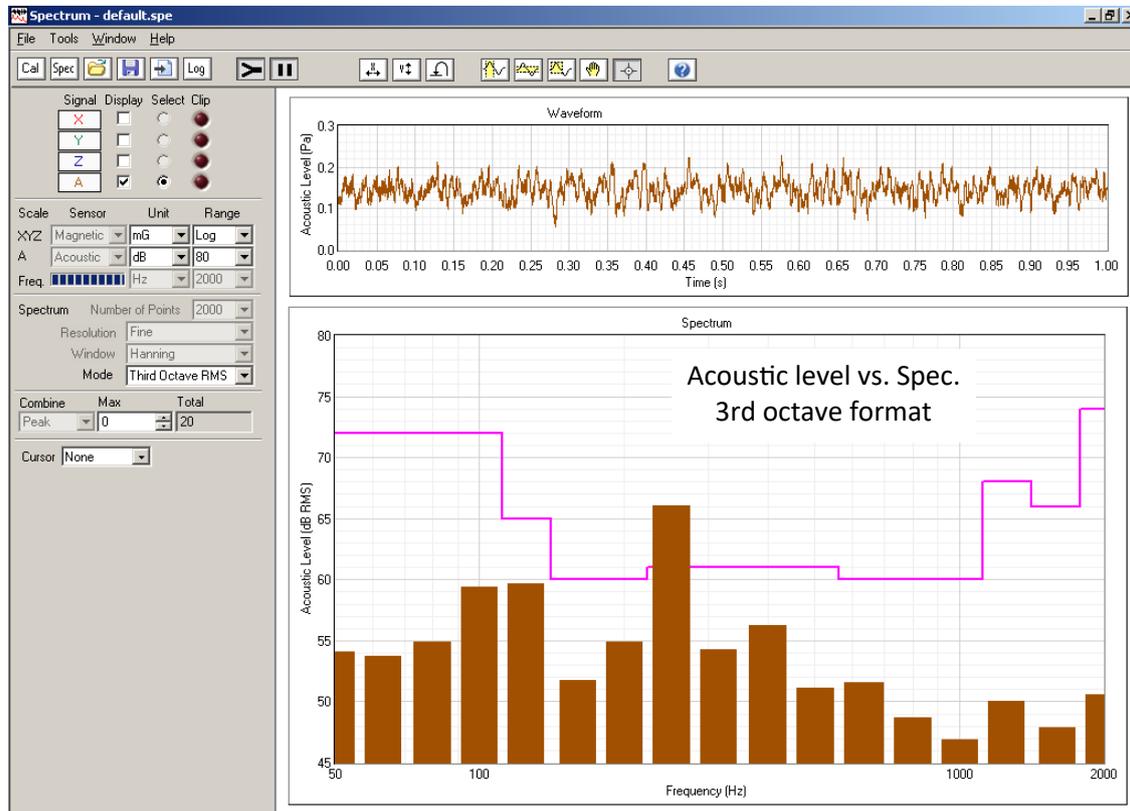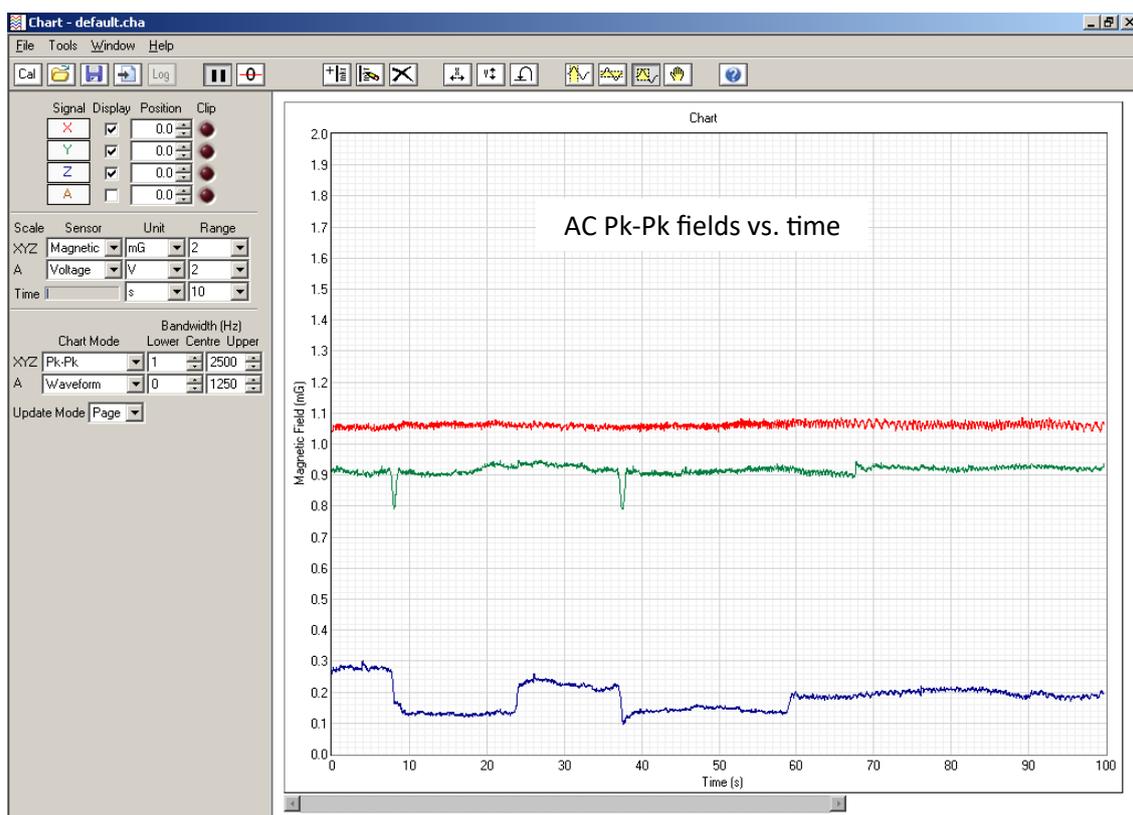
Acoustic level vs. Spec.
3rd octave format

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. There are many options.
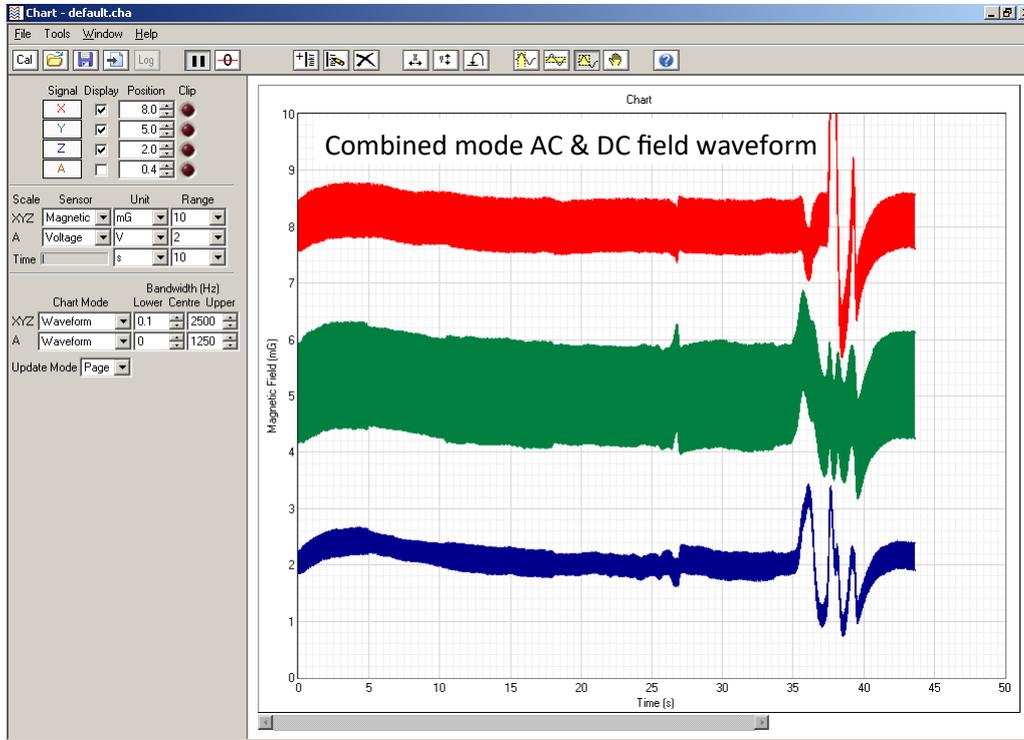
The example below is a chart of the total pk-pk AC magnetic field in the 1Hz to 2500Hz range. The program is calculating the Pk-Pk values in real time and charting the result. It shows that the X field was steady at 1.05mG Pk-Pk and the Z field varied from 0.1 to 0.3mG Pk-Pk during the 100 second period of the chart.

By selecting the narrow band option the program can chart the field at a specified frequency, e.g. 50Hz or 60Hz.
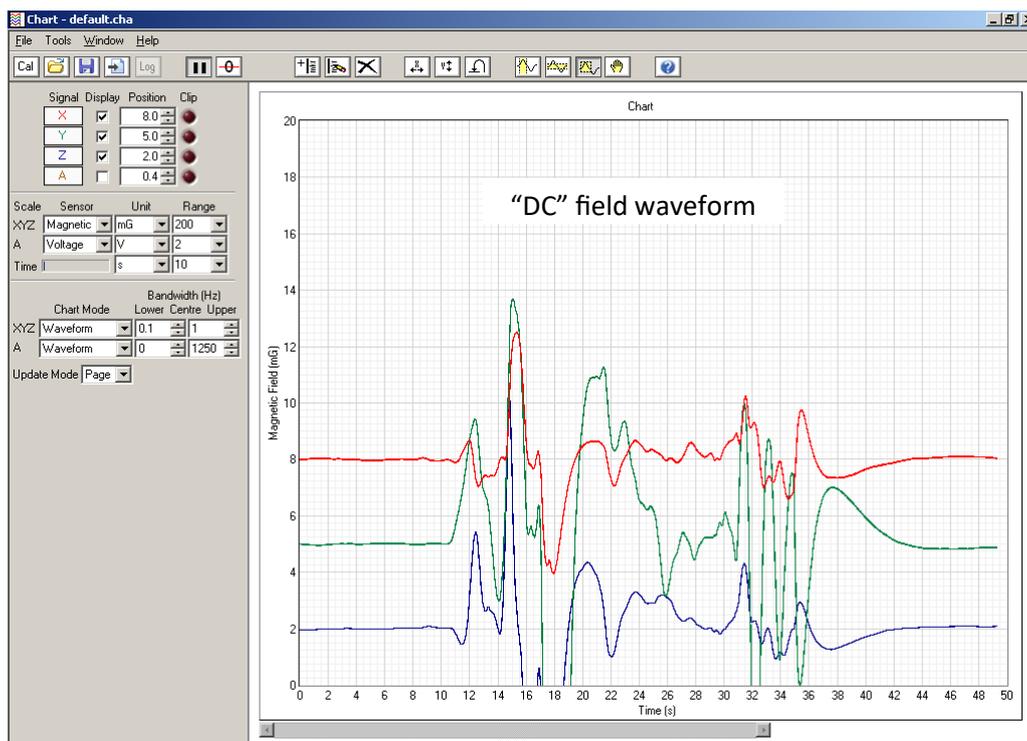

AC Pk-Pk fields vs. time

When charting the magnetic field waveform, the program is able to extend the low frequency limit of the AC magnetic field sensor by post-processing its output with a digital filter that boosts the low frequencies. The 1/f noise of the sensor is also boosted by the same amount and this sets a limit to the usefulness of this feature. With the low frequency set to 0.1Hz the 1/f noise is about 0.2mG Pk-Pk which is small enough to distinguish typical tram fields from the noise.

The following waveform chart was recorded with the bandwidth set to 0.1Hz - 2500Hz. The "width" of each trace is the pk-pk value of the AC power line fields (50Hz and harmonics). The Y axis power line field is 1.8mG Pk-Pk. The "wiggles" in the trace are changes in the DC field caused by to the movement of nearby steel objects, in this case, about 4 mG Pk-Pk. This "combined" charting mode was a new feature in the SC11 software version 5.0.
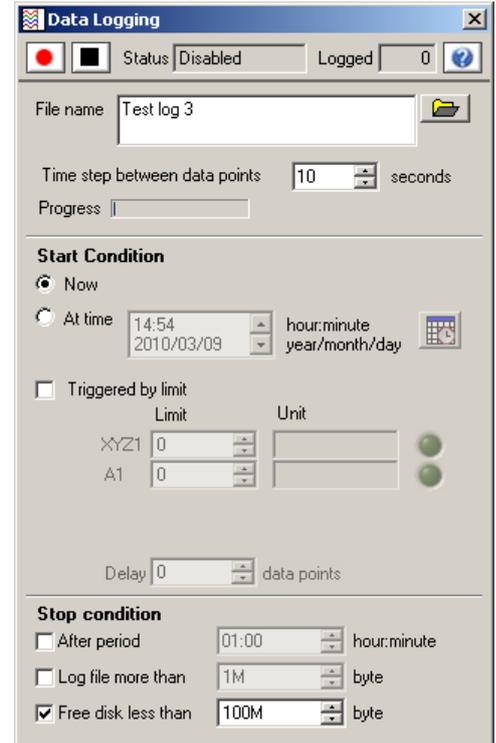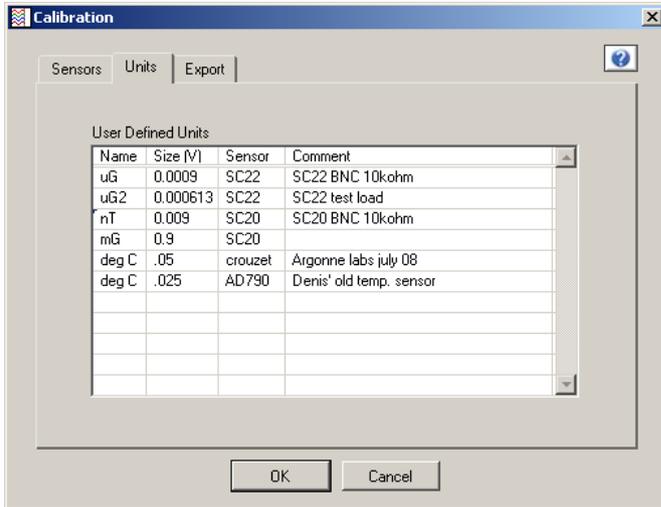

The waveform chart below has the bandwidth set to 0.1Hz –1.0Hz to show only the slowly changing field from trams.

If true DC field measurement is required the optional MEDA µMAG-01N magnetometer should be used.

When charting vibration using the 731A accelerometer, an integrating filter tailored to the 731A allows direct displacement and velocity charts to be made. This is useful for "walk about" floor vibration tests at proposed electron microscope sites.

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 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.
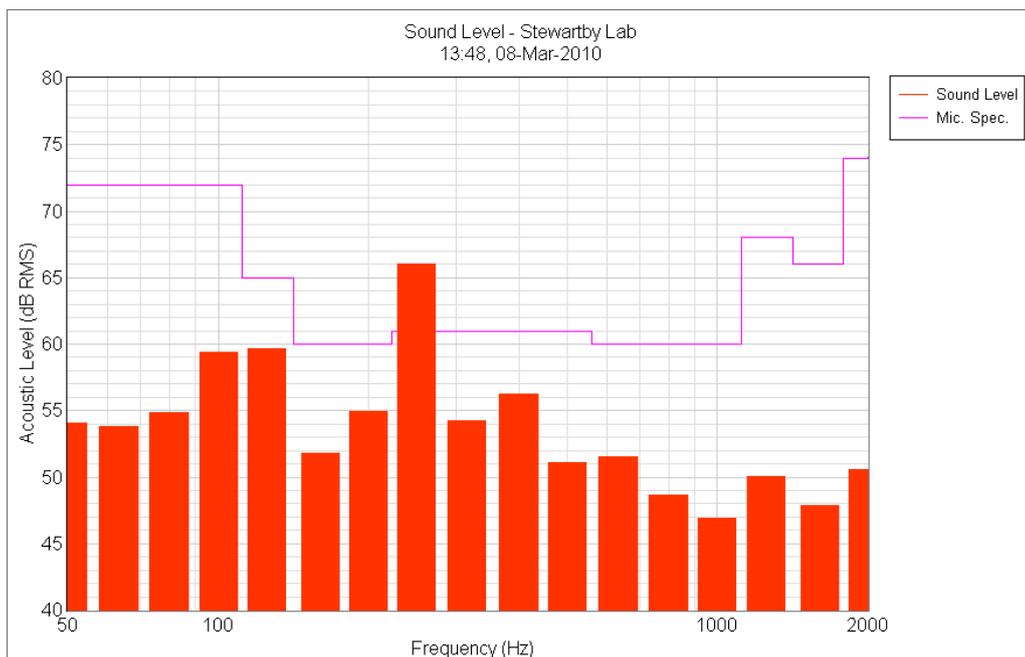
The chart recorder can be used with other external sensors connected to the "A" input. Click on the "Cal" icon then select "Units" to access the window above where custom units can be defined for external sensors as shown.

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.
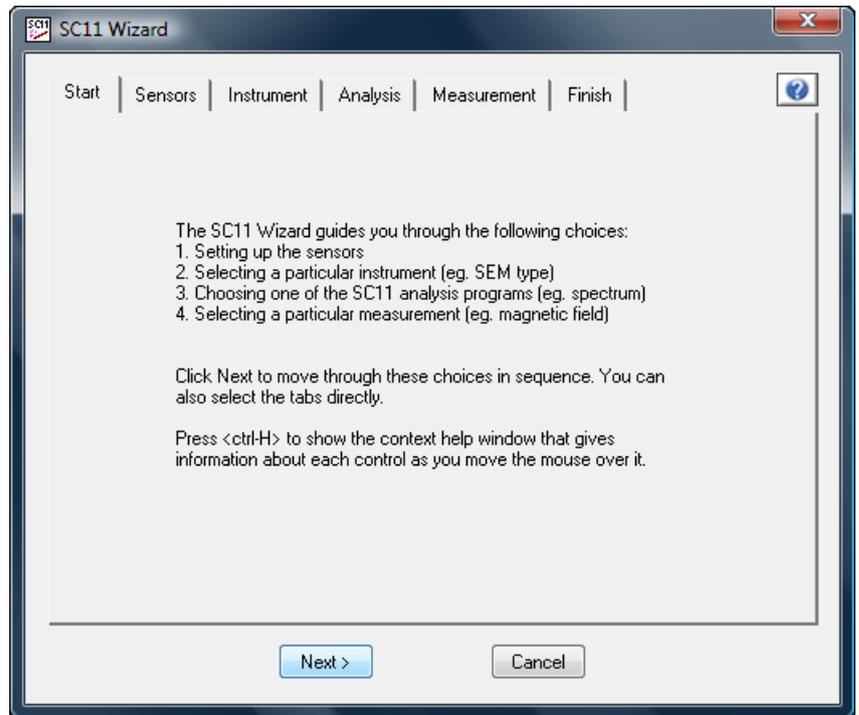
The acoustic measurement shown on page 6 is reproduced below as an image exported from SCplot after formatting.

SC11 Wizard

The SC11 Wizard quickly and easily starts pre-defined measurements using one of the three measurement programs. 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.
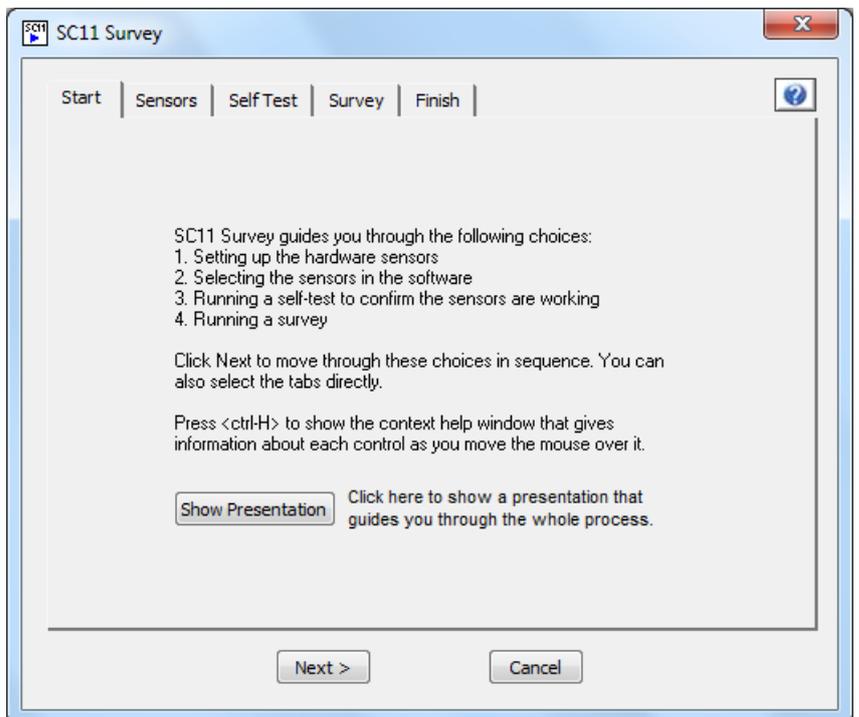
SC11 Survey

SC11 Survey automates a complete survey by calling the SC11 instruments using Active X technology. It is like the SC11 Wizard except that it uses a macro that can run several measurements and automatically save the results. Survey guides you through the choice of sensors and the survey itself. The SC11/ Compact does not support the self test feature. 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 works best with the full SC11/SI system with 2 DC magnetic field sensors, 3 accelerometers and a precision microphone, but survey macros can be written to work with the SC11/Compact system.

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.

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. SCplot can show this in a waterfall plot.

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/Compact - Specification

System

Carrying Case Size	58 x 36 x 19 cm approx.
	(23 x 14 x 7.5 in approx.)
Weight	11 kg (24 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
Processor	As required for operating system
Memory	As required for operating system
Hard Disc	As required for operating system

Core System: SC11/Compact AC Magnetic Field Sensor

Co-ordinate System	X, Y, Z rectangular Cartesian
Bandwidth	1 Hz - 20 kHz
Measurement Range	80 mG (8 µT) Pk-Pk
Noise Limit	3 µG (0.3 nT) RMS max.
Accuracy	±1 %
A channel Inputs	
VIBR	1-axis vibration (Wilcoxon 731A)
AUX	BNC voltage input, DC coupled, ±10 V range, 100 kΩ input impedance
Anti-aliasing Filters	20kHz

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 µm/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: Sound Level Meter

Type	Extech, Model 407730
Bandwidth	300 Hz - 8 kHz
Measurement Range	40 to 130 dB (A wtg), 45 to 130dB (C wtg)
Accuracy	±2 dB @ 1kHz
Meter Response	Fast: 125 milliseconds, Slow: 1 second

1-Axis Magnetic Field Sensor: Flux gate Magnetometer

Type	MEDA µMAG-01N flux gate magnetometer
Bandwidth	0 - 400 Hz
Ranges	±20.00, ±200.0, ±2000 mG full scale
Accuracy	±0.5% of full scale
Linearity	±0.05% of full scale
Signal Output	±2 V full scale

Programs (General)

Channels	4 (X, Y, Z, A)
Display	Show or hide individual channels
Clipping	Audio/visual indication
Pause control	Freeze/resume instrument operation
Pan & Zoom	Examine any section of the plot
Calibration panel	Add/select sensors, set ranges, calibrate offsets, 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

Position	Set, zero or lock vertical positions
Select	Highlight or trigger from selected signal
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, 20000 Hz full scale.
Number of points	200, 250, 400, 500, 800, 1000, 1600, 2000, 3200, 4000
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	0.1 Hz - 2.5 kHz (DC - 2.5 kHz for magnetometer)
Vibration	0.1 Hz - 500 Hz
Acoustic (SLM)	32 Hz - 2.5 kHz
Voltage	DC - 2.5 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, ($f_0 \pm 3\%$)
	Attenuation: 60 dB min. in stop band, ($f_0 \pm 20\%$)
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 buffer
Update modes	Page, scroll
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