SPICER CONSULTING   SYSTEM SC28

SC28 Monitoring System

SC28/SI with sensors

SC28 in use

- Long term monitoring of the room environment for electron beam instruments, including Scanning Electron Microscopes (SEM), Transmission Electron Microscopes (TEM) , Electron Beam Lithography tools and SEM-based metrology and inspection tools

- Continuously measures Magnetic fields in 3 axes, Floor vibration in 3 axes and Acoustic levels all at 2kHz, and Temperature/Humidity at 1Hz

- Inputs for 1 x 3-axis magnetic field sensor, 3 x Wilcoxon 731A accelerometers, Brüel & Kjær precision microphone, Temperature/Humidity sensor, and one BNC AUX

- Up to 14 different graphs may be displayed giving simultaneous display of the data as it is acquired

- Acquires sensor data and logs spectra and charts to date-stamped files

- Headless - Can run without user interface open

- Compares environment to specifications with PASS/FAIL indication. Sends signal to a traffic light or sends email if offline or out-of-spec

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Overview

The SC28 monitoring system is purpose-designed to monitor the environment for electron beam instruments, including Scanning Electron Microscopes (SEM), Transmission Electron Microscopes (TEM), Electron Beam Lithography tools and SEM-based metrology and inspection tools. It can log the spectrum and charts of ambient magnetic fields, vibrations, acoustic levels, temperature and relative humidity. It measures the magnetic fields, vibrations and acoustic levels at a sample frequency of 2 kHz and temperature/humidity at 1Hz. Measurements are taken continuously, with no gaps, so that no event is missed.

The SC28 software runs on a Windows PC that is connected to the same Local Area Network as the SC28/SI. It automatically detects the SC28/SI hardware without needing to know its IP address in advance. The SCplot program is included with the SC28 software and allows you to view and print results as well as save graphs for use in reports.

SC28 Hardware

The SC28/SI supports 1 x 3-axis magnetic field sensor, 3 x Wilcoxon 731A accelerometers, Brüel & Kjær precision microphone and 1 x Temperature/Humidity sensor. It samples the magnetic fields, vibrations and acoustic levels at 2 kHz and temperature/humidity at 1Hz. The SC28 monitoring system is provided without a PC. The requirement for the personal computer is Windows 7/8.1/10, screen pixels at least 1280 x 960, and Ethernet Interface at least 100Mbps. The processor, RAM and hard Disc must be as recommended for the operating system.

SC28/SI	Sensor SC24/DC+AC	Sensor SC11/AC

Brüel & Kjær 4190 microphone	Sensor SC28/TH	Wilcoxon 731A accelerometers (three)

SC28/SI-Sensor Interface (Ethernet-based)

The SC28/SI operates from DC power (9-36V, 12 W max). A universal AC power adaptor is supplied.

There is an input for one Spicer Consulting 3-axis magnetic field sensor. Sensor SC24/DC+AC and Sensor SC11/AC are compatible.

There are inputs for three Wilcoxon 731A accelerometers. The inputs provide the constant current power supply for each Wilcoxon 731A and are suitable for most other types of piezo accelerometers.

There is an input for a Brüel & Kjær 4190/2669L precision microphone. The SC28/SI-Sensor Interface provides the special power supplies for the 2669L microphone pre-amplifier to enable the microphone to operate to its full specification.

There is an input for a SC28/TH Temperature/Humidity sensor. The sample rate is 1Hz max.

In addition, one AUX input is available for a user-defined channel as required.

Sensor SC24/DC+AC

This is the 3-axis magnetic field sensor supplied with the SC28 monitoring 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 when the sensor is moved. The measurement range is ± 20 mG. The sensor has low noise and is accurate to within 1% when completely warmed up.

Sensor SC11/AC

This is a 3-axis AC magnetic field sensor with a lower bandwidth of 1 Hz and a dynamic range of 80 mG (8 mT) Pk-Pk.

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 the SC28 monitoring system. It can be used to measure 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 500Hz when used with the SC28 monitoring system. It measures infrasound levels (i.e. frequencies below 20Hz) which can limit the performance of transmission electron microscopes by vibrating the sample.

Sensor SC28/TH
This is a combined temperature and relative humidity sensor supplied with the SC28 monitoring system, with a temperature accuracy of ±0.2 °C and humidity accuracy of ±2 %RH.

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.

The temperature and relative humidity sensor is manufactured and calibrated by Spicer Consulting.

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

SC28 Monitor Software

While data logging, the SC28 software runs as a small window that shows the current status of logging, whether the environment is within specification and the number or emails sent. The software uses very little CPU in this state.

The SC28 Monitor window is provided for setting up the sensors, analysis, logging, environmental specifications and email parameters. When everything is configured, you can close this window and data logging will continue in the background.

The SC28 provides 10 channels of data acquisition. In the SC28 Monitor, these signals can be displayed on 6 scales and in 3 display formats (Scope, Spectrum and Chart). Up to 14 different graphs can be viewed at the same time, allowing you to see the data as it is collected.
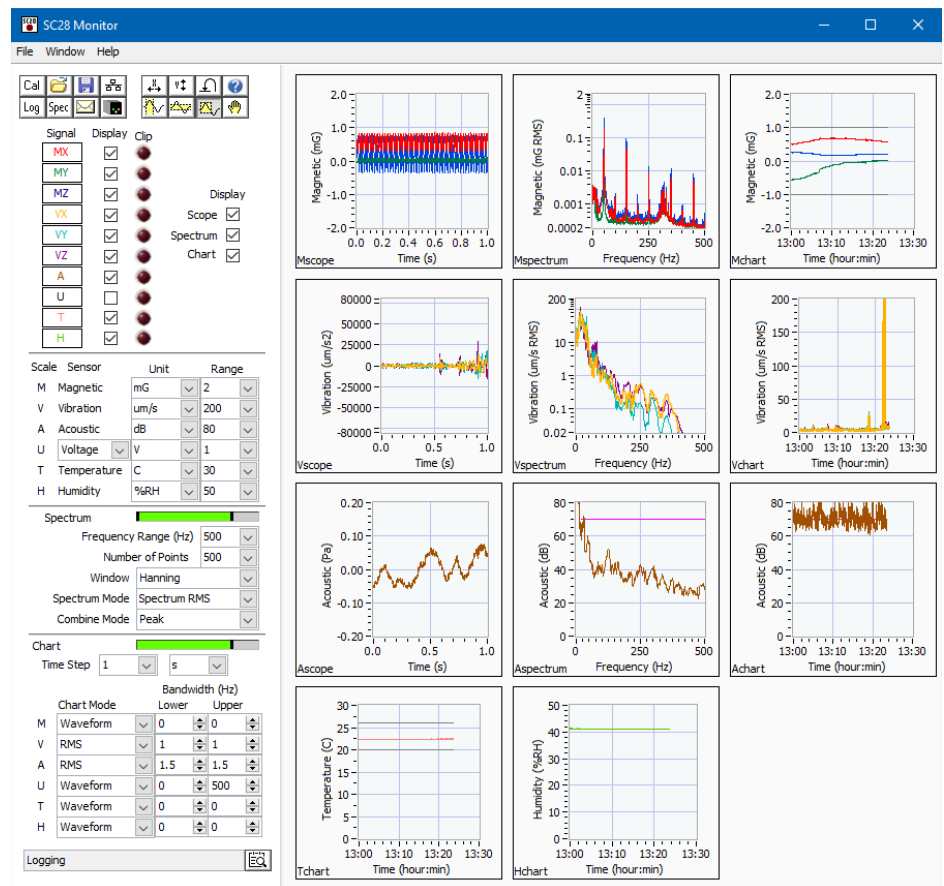
Signals and Scales
In the SC28 Monitor, you can select the signals you want to measure according to the instrument specifications and the sensors that you have available. You can choose the Scope/Spectrum/Chart view based on the way the specification is written and the way in which you want to analyse or present the results. The units and ranges can be set to match the units and specified levels for each quantity in the instrument specifications.

The Display tick boxes affect which signals and graphs are on display. The Signal Display tick boxes also control which signals are data logged. The Scope, Spectrum and Chart Display tick boxes do not affect data logging.

The Spectrum and Chart graphs are controlled by the Spectrum and Chart controls. The Scope graphs do not have their own controls – they are controlled by the Spectrum settings. The graph area re-formats depending on the settings of the Display tick boxes. The Clip indicators show when the incoming signals exceed the analog to digital converter range. If this happens on any channel selected for Display, the program turns on the Clip light for that channel. This warns you that data for that channel will show waveform limiting, harmonic distortion and inaccurate RMS and Pk-Pk levels.

The SC28 provides unit and range settings for each scale. The User scale has a selectable sensor, depending on the user defined units available.

Spectrum Analyser Controls

The Spectrum controls set the Frequency Range, Number of points in the spectrum, the Window function, the Spectrum Mode and the Combine Mode.

The frequency range sets the upper frequency on display.

Spectrum Frequency Ranges		
Unit		Ranges
Hz	Hertz	25, 50, 100, 250, 500

The available numbers of points in the spectrum are as follows:

Spectrum Number of Points
250, 500, 1000, 2000, 4000

The Spectrum Analyser uses a Discrete Fourier Transform (DFT) algorithm to calculate the spectra of captured waveforms. You can apply a Window function to the waveforms of all channels before the DFT is calculated. The following windows are available: None, Hanning or Flat top.

Using the Spectrum Mode control, you can select one of the following modes:
Spectrum RMS, Spectrum 0-Pk and Spectrum Pk-Pk display the magnitudes of the component sine waves that make up the captured signal.
Spectrum PSD displays the RMS power spectral density in amplitude units per root Hertz.
Third Octave RMS, Third Octave 0-Pk and Third Octave Pk-Pk display the spectrum in Third Octave bands on a logarithmic frequency axis.

The Combine Mode controls how the Spectrum Analyser combines spectra from multiple acquisitions. Average mode computes the mean of the acquired spectra, in order to reduce noise levels. On a log scale, you can watch the noise reducing as each successive spectrum is included in the average. Peak mode keeps the largest value seen at each point on the spectra, in order to hold the peaks of any unusually high activity.

Chart Recorder Controls

The Chart controls set the size and unit of the Time Step for the chart and the Lower and Upper bandwidths for each signal. The following time steps between chart points are available. Setting this is a compromise between the time resolution and the size of the data files produced.

Chart Time Steps		
Unit		Ranges
s	second	1, 2, 3, 4, 5, 6, 10, 12, 15, 20, 30

You can select from 3 different Chart Modes for each Scale. The Lower and Upper Bandwidth controls set the 3dB frequency ranges that contribute to the display. The bandwidths available depend on the data acquisition hardware, the number of channels, the Sensor, Unit and Chart Mode. The limits are summarised in the table below:

| Chart Recorder Bandwidth Limits			
Software		*Minimum (Hz)*	*Maximum (Hz)*
SC28 1.0		0	500
Sensor Bandwidths			
Magnetic	SC11/AC	1*	-
	SC24/DC+AC	-	-
Vibration	Wilcoxon 731A	0.1	500
Acoustic	B&K 4190/2669L	1.5	-
Voltage	BNC input	-	-
Temperature	SC11/TH	-	1
Humidity	SC11/TH	-	1
Integrating Units			
um/s, mm/s, nm, um		1	-
Chart Mode			
RMS, Pk-Pk		0.2	-

* 0.1 Hz in Waveform mode, using extended low frequency filter

Chart waveform mode charts the waveform directly. Each trace shows the mean of the maximum and minimum value of the signal that was seen during the time step for each point.

Chart RMS and Pk-Pk modes are useful for charting the variation of AC magnetic fields, vibrations or sound levels over a period of time.

Data Logging Controls

The SC28 provides two types of data logging files Chart and Spectrum. Each have their own folder, file name and file interval settings. In addition, the SC28 can automatically delete old log files to save disc space.
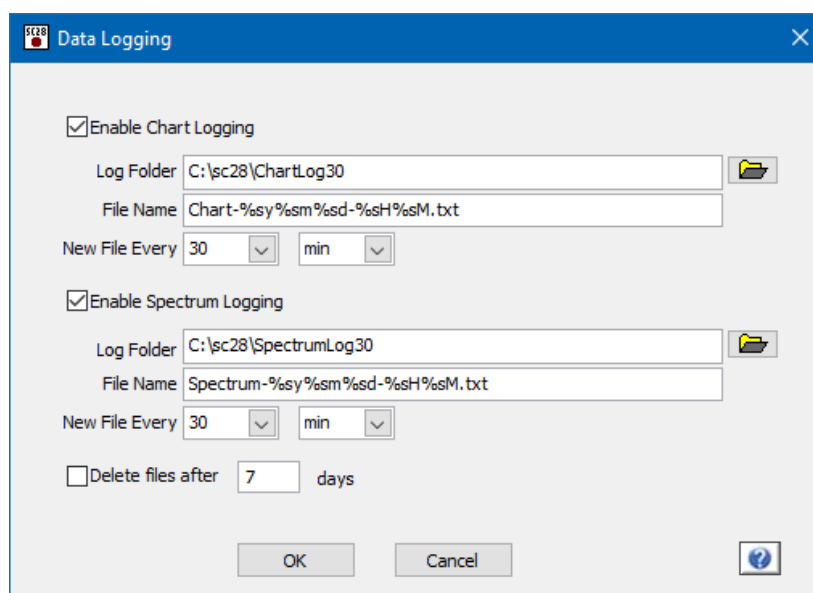
File names can embed date and time information so that they are unique and can show the time period that they cover. The following date/time codes are available:

Code	Description
%sS	Start seconds (00-59)
%sM	Start minutes (00-59)
%sH	Start hour on 24-hour clock (00-23)
%sd	Start day (01-31)
%sm	Start month (01-12)
%sy	Start year (four digits)
%fS	Finish seconds (00-59)
%fM	Finish minutes (00-59)
%fH	Finish hour on 24-hour clock (00-23)
%fd	Finish day (01-31)
%fm	Finish month (01-12)
%fy	Finish year (four digits)
%zM	Time zone minutes (00|30)
%zH	Time zone hour (+|-)(00-12)

Start and Finish refer to the start and finish times of the data in the file. All date and time information, including the time zone, is derived from the PC running the SC28 program.

The SC28 starts a new file at the file interval that you set. The following are available:

Unit		Ranges
min	minute	1, 2, 3, 4, 5, 6, 10, 12, 15, 20, 30
hour	hour	1, 2, 3, 4, 5, 6, 8, 12
day	Day (24 hours)	1, 2, 3, 4, 5, 6, 7

Each file starts on a whole multiple of its file interval. The available lengths are designed so that whole multiples of the file interval always fit into the next unit above. Therefore, files with lengths set in minutes always fit neatly into each hour and files with lengths set in hours always fit neatly into each day.

When you start the SC28, or after you change the file interval, the SC28 waits until the next whole interval is reached before it starts logging. While in this state, data on the Charts start part way through the interval.

When Chart Logging is enabled, the SC28 includes a point for each signal on display for each Chart Time Step during the file interval.

When Spectrum Logging is enabled, the SC28 combines spectra during the file interval and writes the resulting spectrum to the file for each signal on display.

If Delete Files After is enabled, whenever the SC28 creates a new log file, it checks the folder to see if any files are older than the limit set and deletes them. The Chart and Spectrum folders are handled separately. If logging is not enabled for a folder, files are not deleted from it.

Environmental Specifications

You can use the Specifications feature to check whether the site meets the environmental specifications of an electron beam instrument or other equipment. You can load in multiple specification files to show on the Spectrum and Chart displays for direct comparison with the measured results.

A specification editor is included so that you can create specifications for the chart recorder or the spectrum analyser. Chart specifications have a minimum and maximum value. Spectrum specifications are piece-wise linear graphs of maximum amplitude versus frequency

.
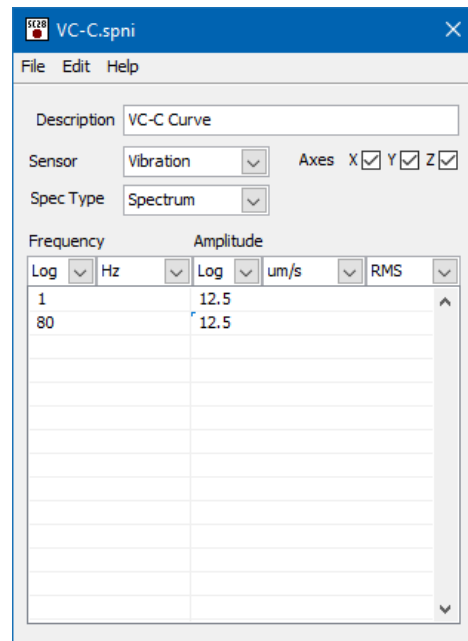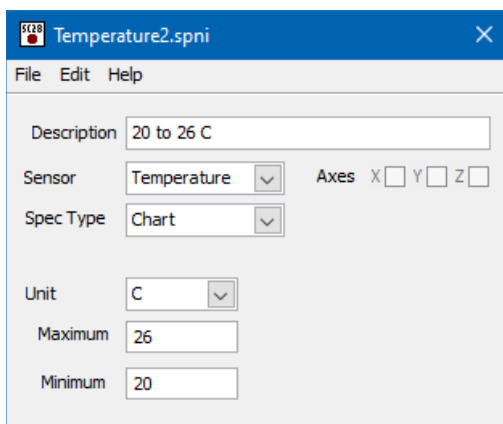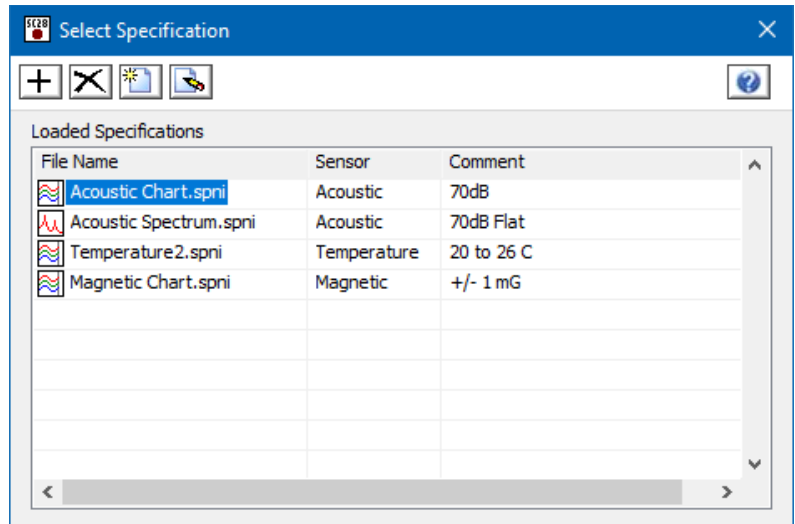
Email

The Email panel controls how and when emails are sent by the SC28 Monitor. Emails are only sent if Enable Email is ticked. You enter the details of your email server, user id and password similar to setting up an email client. The SC28 can then send emails whenever the environment goes out of specification, or if the SC28/SI goes off line for any reason. You can limit the number of emails sent. The emails include a single line for each event, giving the serial number of the SC28, the date time and type of event.
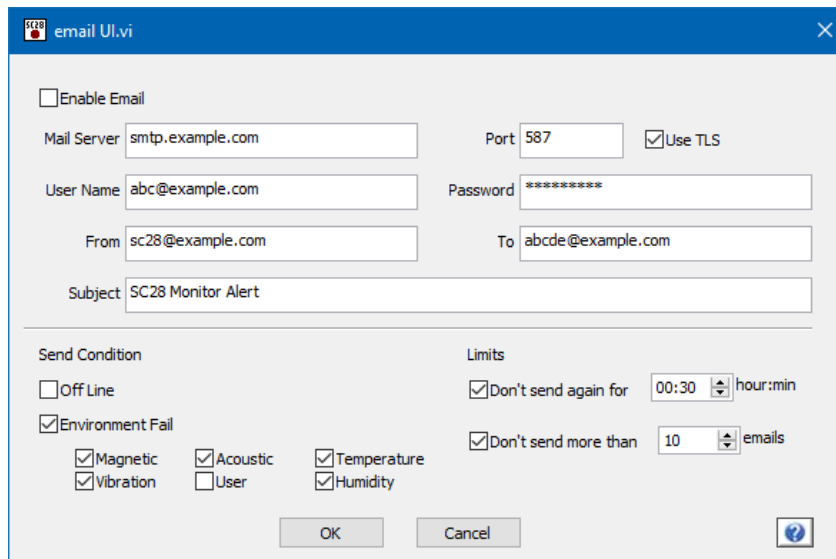
SCplot

SCplot is a comprehensive results editing program that enables results logged from the SC28 Monitor to be formatted for viewing or adding to reports. It can stitch together multiple chart data logging files to make a continuous plot.

SCplot can handle large amounts of data. For example the plot below shows a weeks worth of magnetic field data. The data was extracted from nearly 70 Mbytes of data in 335 files each containing 30 minutes logging at one point per second of 3-axis magnetic field, 3-axis vibration, acoustics, temperature and humidity.
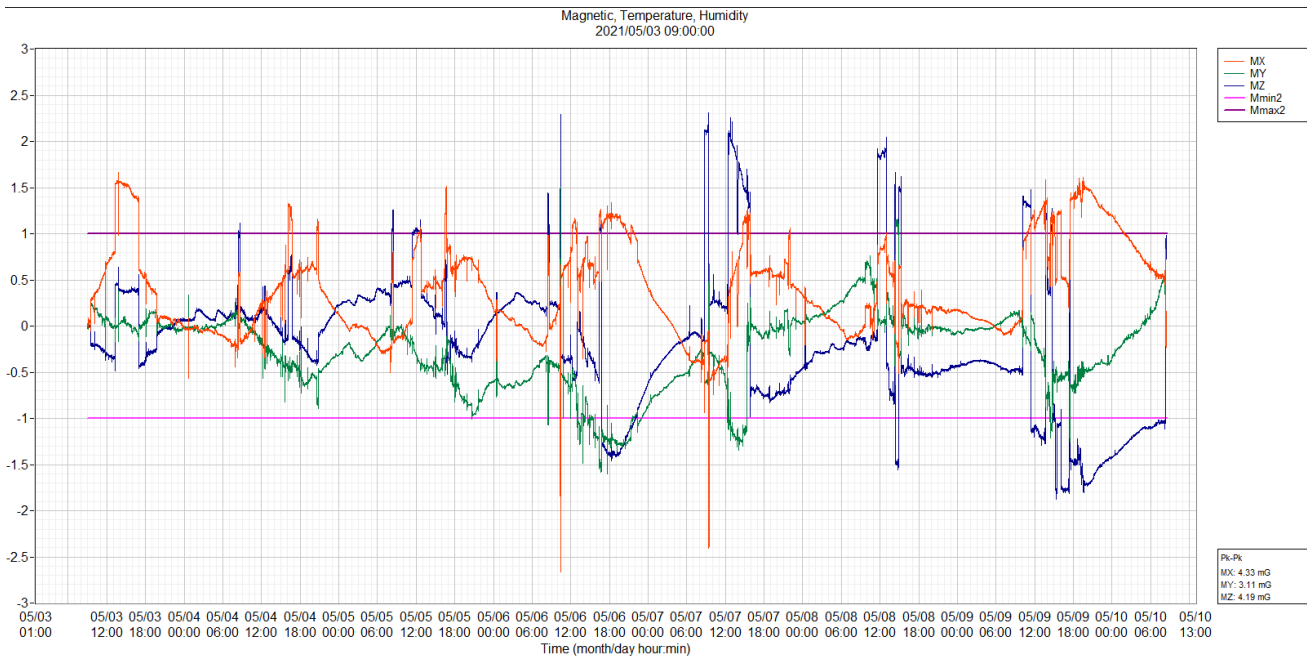
The next plot shows a waterfall plot of the acoustic spectrum for a week.
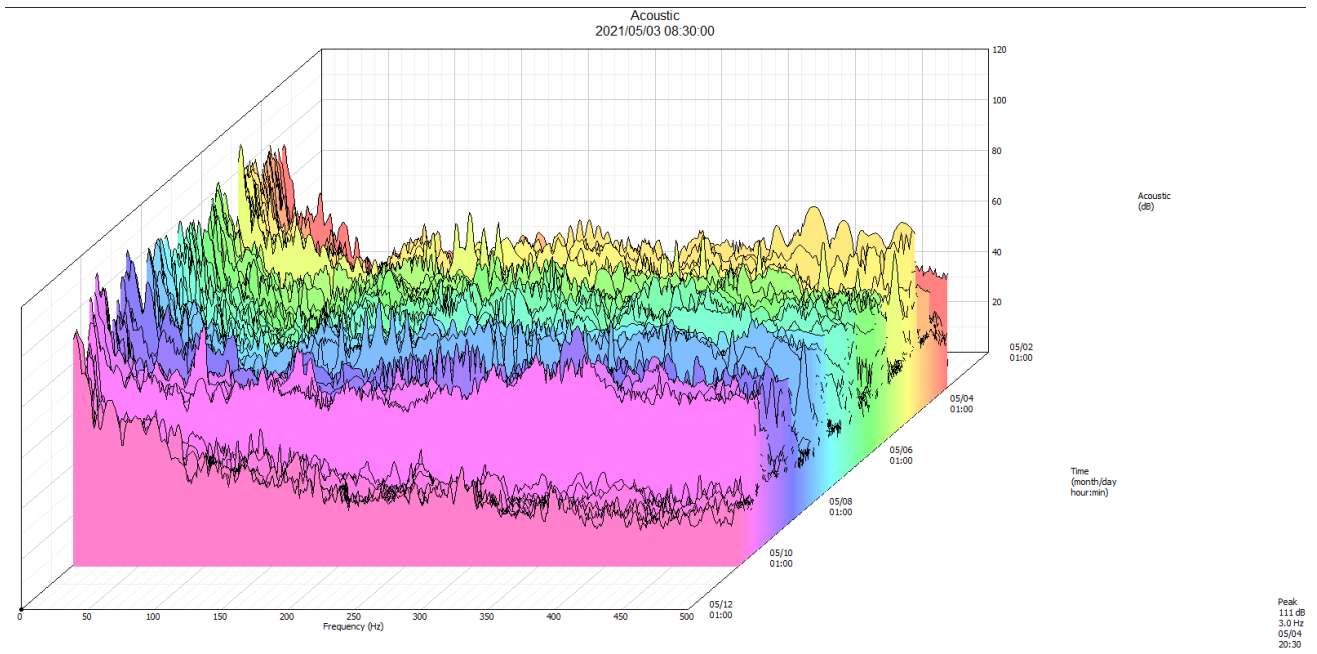
SCplot supports all the units that are used in the SC28. It can convert units and post-process results with user-specified formulas. It can save plots as images, copy them to the paste buffer or append them to a word document. SCplot also provides macro scripting so that command sequences can be captured, saved and re-played.

SC28 - Specification

System

Box Size	58 x 36 x 19 cm approx. (23 x 14 x 7.5 in approx.)
Weight	11 kg (24 lb) approx.

Personal Computer Requirements

Operating System	Windows 7/8.1/10
Display	At least 1280 x 960 pixels
Ethernet Interface	At least 100 Mbps
Processor	As required for operating system.
Memory	As required for operating system.
Hard Disc	As required for operating system.

Core System: SC28/SI - Sensor Interface

Inputs	
MAG	3-axis magnetic field sensor
VIBX, VIBY, VIBZ	3-axis vibration (3 x Wilcoxon 731A)
MIC	Microphone (B&K 4190/2669L)
AUX	BNC voltage input, DC coupled, ±10 V range, 100 kW input impedance.
TEMP/RH	SC28/TH Temperature/Humidity Sensor

DAQ Resolution/Range	Bits	Input Range	Resolution
	13	±10V	2.44 mV

Anti-aliasing Filters	20kHz
Sampling rate	200 kHz x 8 channels + 1 Hz x 2 channels continuous
Data transfer rate	2 kHz x 8 channels + 1 Hz x 2 channels continuous
Communications	USB port for Patlite signal tower Ethernet port for PC/LAN connection
Power	9-36V DC, 12 W max

AC Power Adaptor

Type	Meanwell GST90A24
Input	100-240V AC, 50/60 Hz, 1.3A
Output	24V DC, 3.75 A, 90 W max.

3-axis AC Magnetic Field Sensor: SC11/AC

Co-ordinate System	X, Y, Z rectangular Cartesian
Bandwidth	1 - 20 kHz
Dynamic Range	80 mG (8 µT) Pk-Pk
Noise Limit	3µG RMS max
Accuracy	±1 %

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

Co-ordinate System	X, Y, Z rectangular Cartesian
Bandwidth	DC - 10 kHz
Ambient Field Range	±2 G (±200 µT)
Dynamic Range	±20 mG (±2 µT) Pk-Pk
Noise Limit	DC: 5 µG (0.5 nT) Pk-Pk typ. (0.0001 – 0.01 Hz) AC: 0.1 µG/√Hz (10 pT/√Hz) RMS typ. at 50 Hz
Accuracy	±1 % (after >2hour warm up). (±15 % cold)

Vibration Sensor: Wilcoxon 731A Accelerometer

Type	Wilcoxon Research, model 731A
Bandwidth	0.1 - 500 Hz
Dynamic Range	2 m/s2 (0.2 g's*) Pk-Pk (in this system)
Noise Limit	7 µm/s2 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 Precision Microphone

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

Temperature/Humidity Sensor: SC28/TH

Sample rate	1 Hz max

Performance	Temperature	Relative Humidity
Dynamic Range	0 - 100 °C	0 - 100 %RH
Resolution	0.01 °C	0.01 %RH
Accuracy	±0.2 °C	±2 %RH
Drift (max)	0.03 °C/Year	0.25 %RH/Year

Signal Tower

Type	Patlite LR6-3USBW-RYG
Power	USB Bus powered, 5V, 500mA max
Colours	Red, Green
Dimensions	60mm dia, 199mm height

Software

Channels	10: MX, MY, MZ, VX, VY, VZ, A, U, T, H
Clipping	Visual indication
Display modes	Scope, Spectrum, Chart (simultaneous)
Selection	Individual Channels, Display modes
Scales	6: Magnetic, Vibration, Acoustic, User-defined, Temperature, Humidity
Amplitude units	
Magnetic field	mG, nT, µT, mA/m, A/m
Vibration	µg's[α], mg's[α], µm/s2, mm/s2, µm/s, mm/s, nm, µm
Acoustic	mPa, Pa, dB
User-defined	mV, V, user defined units
Temperature	°C, °F
Humidity	%RH
Amplitude ranges	
General	1, 2, 5, 10, 20, 50, 100, 200, 500
dB	50, 60, 70, 80, 90, 100, 110, 120
°C, %RH	30, 40, 50, 60, 70, 80, 90, 100
°F	60, 80, 100, 120, 140, 160, 180, 200
Spectrum Analyser	
Frequency ranges	25, 50, 100, 250, 500 Hz full scale.
Number of points	250, 500, 1000, 2000, 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
Specification files	Create, edit, add & remove. Compare with measurements.
Chart Recorder	
Time step	1, 2, 3, 4, 5, 6, 10, 12, 15, 20, 30 s/point
Chart modes	Waveform, RMS, Peak to Peak,
Bandwidth controls	Lower and Upper - individual for each scale
Data Logging	
Logging	Chart Logging, Spectrum Logging, Folder, Filename, File interval
Deletion	File age
Calibration panel	Add/select sensors, reset DC sensor, microphone self check, add/edit user defined units.
Setup file	Open/save control settings
Help	Context help on controls, online help file

[α] g's are units of the acceleration due to gravity