SC28 Monitor for Magnetic Fields, Vibrations, Acoustics, Temperature and Humidity

Version 1.0 Beta 1 for Windows 7, 8.1, 10

User Manual

SPICER CONSULTING Electron Beams & Electronic Systems

Acknowledgement

The SC28 software includes programs created by Spicer Consulting using LabVIEW from National Instruments.

Copyrights

Trademarks

SPICER CONSULTING
Eden Laboratory, Broadmead Road, Stewartby, Bedfordshire, MK43 9ND, England.
Telephone: +44 1234 765773, Fax: +44 1234 765778
E-mail: enq@spicerconsulting.com
Web site: http://www.spicerconsulting.com

Contents

About this Manual

This manual describes the SC28 Monitor for Magnetic Fields, Vibrations, Acoustics, Temperature and Humidity and explains how to use it.

Organisation of this Manual

Chapter 1 - Introduction to the SC28 System, describes the system components and applications. It explains how to get started, how to use the sensors, how to run the programs and how to get help.

Chapter 2 – Environmental Disturbances, describes the environmental factors that can disturb an electron beam instrument.

Chapter 3 – Setting up Monitoring, explains how to use the electron beam instrument's environmental specifications to guide the setting of the SC28 controls.

Chapter 4 – Signals and Scales, is a detailed reference on the SC28 signals and scales settings.

Chapter 5 – Spectrum Analyser Controls, is a detailed reference on the SC28 spectrum analyser settings.

Chapter 6 – Chart Recorder Controls, is a detailed reference on the SC28 chart recorder settings.

Chapter 7 – Data Logging Controls, is a detailed reference on the SC28 datalogging settings.

Chapter 8 – Environmental Specifications, explains how to load a microscope's environmental specifications into the SC28 for direct comparison with measured results.

Chapter 9 – SC28 Calibration, explains how to load calibration files, reset a DC sensor, self-check a microphone and add user-defined units.

Chapter 10 - Menu and Toolbar functions, explains how to use all the Menu and Toolbar functions of the SC28.

Appendices 1-4 give details of SC28 specifications, file formats, units and window functions.

Conventions used in this Manual

The following conventions are used in this manual:

bold — Bold text denotes control names, menu items, dialog box buttons or options that appear on the screen.

italic — Italic text denotes emphasis, a cross reference, or an introduction to a key concept.

bold italic — Bold italic text denotes a note, caution, or warning.

< > — Angle brackets enclose the name of a key on the keyboard.

\+ — A plus between two or more key names enclosed in angle brackets denotes that you hold down the first key while you press the next key(s) - for example, <ctrl+P>.

🔔 **Warning:** ***This symbol to the left of bold italic text denotes a warning, which alerts you to the possibility of damage to your equipment.***

! Caution: ***This symbol to the left of bold italic text denotes a caution, which alerts you to the possibility of data loss or a system crash.***

✍ **Note:** ***This symbol to the left of bold italic text denotes a note, which alerts you to important information.***

Chapter 1 - Introduction to the SC28 System

Hardware

The SC28 monitor is a designed for long term monitoring of the room environment for electron microscopes and similar equipment. It can log the spectra and charts of ambient magnetic fields, vibrations, acoustic levels, temperature and relative humidity. It measures the magnetic fields, vibrations and acoustic levels at 2 kHz and temperature/humidity at 1Hz or below. Measurements are taken continuously, with no gaps, so that no event is missed. It supports the following hardware:

Model	*Number of Inputs*				
	3-axis Magnetic Field	*Vibration*	*Precision Microphone*	*Temperature/ Humidity*	*AUX BNC*
SC28/SI	1	3	1	1	1

The SC28/SI supports a wired Ethernet connection.

Software

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. Included with the SC28 software is the SCplot program, which views and prints results or saves graphs that you can use in reports.

Sensors

The following sensors are available for the SC28 system:

Sensor	*Description*
Sensor SC11/AC	A 3-axis AC magnetic field sensor with a lower bandwidth of 1 Hz and a dynamic range of 80 mG (8 µT) Pk-Pk.
Sensor SC24/DC+AC	A 3-axis DC magnetic field sensor using magneto-resisitive technology with a lower bandwidth down to DC a dynamic range of 40 mG (4 µT) Pk-Pk.
Wilcoxon 731A	A Seismic Accelerometer, with bandwidth of 0.1 Hz to 500 Hz and max range of 200 mg's (20 mm/s^2) Pk-Pk in this system.
B&K 4190/2669L	A Brüel and Kjær precision microphone type 4190 with preamplifier type 2669L can measure from 20 dB to 100 dB with a lower bandwidth of 1.5 Hz.
SC28/TH	A combined Temperature and Relative Humidity Sensor.
AUX	One input is available for a user-defined channel as required.

Connecting the SC28/SI

Connect an Ethernet cable from the sensor interface to the Local Area Network (LAN) that your PC is connected to. (If there is no LAN, you may connect the PC and SC28/SI together directly. In this case, both devices should use a link local IP address of the form 169.254.x.x). Connect the supplied power supply to the DC IN input and to an AC outlet of 100-240V, 50-60Hz.

When you run the SC28 software, it automatically detects the SC28/SI hardware and connects to it. If no SC28/SI is detected the software will wait until one is connected to the LAN. If more than one SC28/SI is detected on the LAN, the software asks which you wish to connect to. Once connected, the SC28/SI's serial number is automatically selected on the Calibration panel.

Connecting a 3-axis Magnetic Field Sensor

Mount a **Sensor SC11/AC** or **Sensor SC24/DC+AC** magnetic field sensor onto the tripod provided and connect it to the **MAG** input. Select the serial number of the sensor on the Calibration panel. The magnetic field sensors have three axes, oriented as shown on the label. They display on the **MX**, **MY** and **MZ** channels in the SC28 Monitor. DC sensors must be reset after they are moved, using the software **Reset DC** button.

✍ **Note:** ***Plug in the AC or DC sensor before you start the SC28 program, because the software detects the sensor at start up.***

Connecting Accelerometers

Each accelerometer measures 1-axis vibration, oriented along the axis of its cylindrical case. It is supplied with a stand, allowing it to be placed on the floor in each of the X, Y and Z directions.

On the SC28/SI there are three four-pin accelerometer connectors: **VIBX**, **VIBY**, **VIBZ**. They display on the **VX**, **VY** and **VZ** channels in the SC28 Monitor.

Select the accelerometer(s) on the Calibration panel. You can connect or disconnect an accelerometer at any time.

🔔 **Warning:** ***Do not drop the accelerometers. They are fragile and must be handled gently.***

✍ **Note:** ***Allow 2 minutes for the DC operating level of an accelerometer to stabilise after turning it on or moving it. Moving it more gently reduces the settling time.***

Connecting a Precision Microphone

Insert a Brüel and Kjær precision microphone type 4190 with preamplifier type 2669L into one of the holders on the tripod provided and gently tighten the holding screw. Connect the cable to the **MIC** input of the SC28/SI.

Select the microphone's serial number on the Calibration panel. The signal then displays on the **A** channel in the SC28 Monitor.

You can run a quick self-check on the microphone from the Calibration panel. See the <u>*Microphone Self Check*</u> section of *Chapter 9 – Calibration* for details.

🔔 **Warning:** ***Do not drop the microphone. It is fragile and must be handled gently***

Connecting a Temperature/Humidity Sensor

Insert a **Sensor SC28/TH** Temperature/Humidity sensor into one of the holders on the tripod provided and gently tighten the holding screw. Connect the cable to the **TEMP/RH** input of the SC28/SI.

Select the sensors serial number on the Calibration panel. The signals then display on the **T** and **H** channels in the SC28 Monitor.

Connecting a Voltage Signal (or User-defined Sensor)

Connect the signal to the BNC **AUX** input. This input displays on the **U** channel of the SC28 Monitor.

You can connect or disconnect the BNC input at any time. See the <u>*User Defined Units*</u> section of *Chapter 9 – Calibration* for how to add user-defined units.

🔔 **Warning:** ***Connecting a voltage greater than ±30V to the AUX input could damage it.***

Install the Software

The SC28 system is provided without a PC. First install the software on your computer using the separate instructions in the release notes.

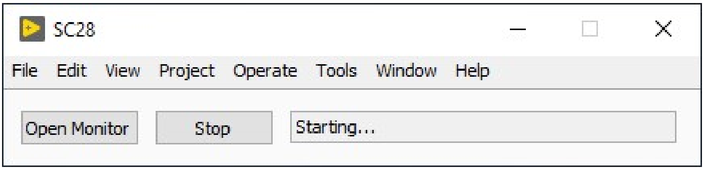
Adding Sensor Calibration Files

At installation time, you are prompted to install the sensor calibration files. You can add them at any other time by clicking the **Cal** button in the **Monitor** window then using **Add Sensors** on the Calibration panel. For full details, see the <u>*Add Sensors*</u> section in *Chapter 9 - Calibration*.

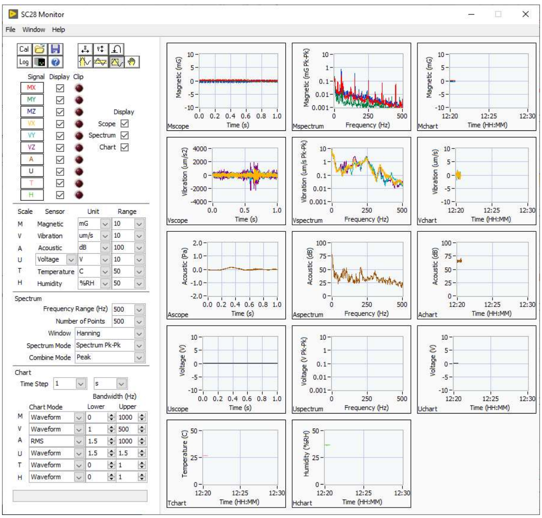
How to Run the Programs

To run the SC28 programs, select one of the following from:
Start Menu > All Programs > Spicer Consulting > SC28 1.0 >
SC28 1.0
SCplot 5.6

SC28 is the main monitoring program that performs measurements and logs results to files on the PC.



Click **OpenMonitor** to show the Monitor window that allows you to configure the settings and view the current measurements.



SCplot is for viewing, formatting, printing and saving graphs of results from the virtual instruments. For full details see the *SCPlot User Manual*.

Getting Started

Start the SC28. The SC28 should start up in the task bar. Click the **SC28** task bar icon to open the SC28 main window. The status should show **Starting…** and then **Connected to SC28/SI** with its serial number, firmware version and IP address. Click **Open Monitor** to show the user interface where you can change the settings and view the current measurements. When data log files have been written, use SCplot to view them.

How to Exit SC28

Close the SC28 Monitor window using the close button at the top right corner of the window. You may do this any time without affecting the data capture and logging function of the SC28 main window. If you have changed any settings, it will ask you to save the setup. When the SC28 starts up it automatically loads the setup file `setup.sc28`. Normally this is all that is needed. However, you can save the settings to a different file name if you need to keep alternative setups.

To shut down data logging and close the whole program, click the **Stop** button on the SC28 main window.

Getting Help

Help is available in the following ways:

 Help `<F1>`

• To get help, click the **Help** button or select **Help for SC28** from the **Help** menu.

• Tip strips appear when you move the pointer over the icons and sensor controls, providing additional information.

• To turn on the *help window*, click on **Show Context Help** from the **Help** menu in any of the programs. When you move the cursor onto any control of the instrument, the help window shows information about that control. You can drag the help window to any location on the screen. To close the help window, click on its close button. Alternatively, you can use <ctrl-H> to toggle the help window on and off.

• To see brief information about the program, click on **About...** from the **Help** menu.

Chapter 2 – Environmental Disturbances

Electron Beam Instruments

The SC28 Monitor is purposed-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. These instruments are sensitive to magnetic fields, floor vibrations, acoustic levels, temperature and humidity. Manufacturers specify the maximum changes of these quantities that can be tolerated before movement of the electron beam prevents the instrument from reaching its optimum performance. The methods and units of the specifications vary between manufacturers, but the SC28 is flexible enough to measure the parameters found in all mainstream manufacturers' specifications.

Magnetic Field Sources

Power Frequency (50 or 60 Hz) magnetic fields are often produced by current-carrying power cables. Problem fields may come from well-installed cables carrying very large currents or from moderate but unintentional currents flowing in loops made by protective ground conductors and structural steel frames. Equipment such as lighting and air conditioning may make a field, but there are many examples of well-installed units that cause no problem at all. Power distribution panels and transformers make very local fields and may therefore cause severe difficulties if they are close, but none at all if they are distant.

Slowly varying magnetic fields are often called DC fields. They require a DC sensor to measure them accurately. They may be produced by large ferromagnetic objects moving in the earth's magnetic field, including nearby doors, road traffic and lifts/elevators.

Electric trains, trams or trolley buses may make fields at DC, 16.67, 50 or 60 Hz depending on the power used. Much of the field comes from currents flowing in the overhead wires, tracks or associated wiring, rather than passing vehicles themselves. The field is usually vertical and may extend hundreds of metres away from the track.

Some equipment associated with electron beam instruments makes local fields. These fields are not usually a problem for the instrument, but they may cause confusion if the sensor is placed near to them.

Power frequency magnetic fields often cause regular fine "tearing" of an SEM image that makes small "teeth" in any vertical edges. Other things may cause the same effect are ground loop currents in the external cables or pipes supplying the electron beam instrument, electrostatic hum on detectors or probes in the chamber or other microscope faults. Power frequency fields may simply blur a TEM image. They may cause peaks in electron energy analysers to broaden or even split into two.

DC magnetic fields may make an SEM image look wavy or cause stitching errors in electron beam lithography.

Vibration Sources

Vibrations may be caused by a wide variety of sources. Random vibration sources include people walking by, lifts/elevators, road traffic, trains and ocean waves. Regular vibrations may be caused by rotating machinery, including rotary pumps associated with the electron beam instrument. Synchronous motors rotate at slightly below the power frequency. Transformers may vibrate at harmonics of the power frequency.

The severity of the vibrations depends strongly on the construction of the building and floor. Often concrete blocks and other isolation structures are placed under electron beam instruments to reduce vibration. Vibrations tend to be broadband, but with peaks at resonant frequencies that are characteristic of the instrument and its environment.

Random vibrations may cause “tearing” of an SEM image, similar to power frequency magnetic fields, but much less regular and with varying amplitude.

Acoustic Sources

Acoustic sound levels are pressure waves in the air. They may be made by a wide variety of sources, which are readily identified by ear. However, many audible sounds are not a problem, but some instruments, particularly TEMs, are affected by inaudible low-level infra-sound. Acoustic problems are often caused by air conditioning systems, which need to be carefully designed to avoid them.

Acoustic levels may translate into vibrations of some part of the instrument, such as the specimen stage in a TEM. As a result, the effect on the image may look similar to that of vibration.

Temperature

Changes in room temperature can cause drift of the image as different parts of the microscope expand or contract slightly. Air conditioning systems must be designed to keep temperature changes below a specified limit.

Humidity

For microscopes where the stage is cooled by liquid nitrogen, the humidity in the room must be kept low to avoid water from the air condensing and forming frost and ice.

Chapter 3 – Setting up Monitoring

Setup Steps

The following steps are needed to set up the SC28 to monitor the environment of an electron beam instrument:

1. Check the Specifications
2. Define Position and Orientation
3. Set up Signals and Scales
4. Set up Spectrum Analyser
5. Set up Chart Recorder
6. Set up Data logging

Check the Specifications

Manufacturers provide environmental specifications for their instruments. Some are very clear and precise, but others require interpretation.

Magnetic fields are usually specified in mG or nT, but it is not always specified whether these are RMS, 0-Pk or Pk-Pk values. It is conservative to assume it means Pk-Pk. Sometimes a distinction is made between fields that are synchronous or asynchronous with the power frequency because the instrument is designed to tolerate higher levels of synchronous fields. All instruments are sensitive to DC fields, but they are not always specified. If in doubt, assume a similar level of sensitivity as to asynchronous fields.

Vibrations are usually specified in the frequency domain for measurement by spectrum analyser, but in many different ways. They may use displacement, velocity or acceleration units, RMS or Pk-Pk. They may use well-defined power spectral density units or third octave spectra, which are independent of the number of points setting of the spectrum analyser. However, they may be specified in straight vibration units, in which case the number of points affects the results, but it may not be specified. If in doubt, a rule of thumb is to assume that there is one point per Hz.

Acoustic levels are usually specified in third octave dB bands. Common sound level weightings are dBA for human hearing, which is less sensitive to low frequencies, and dBC which is much flatter. Unless otherwise specified, use the B&K microphone with dB units (un-weighted response.

Temperatures may be specified in degrees Celsius (Centigrade) or Fahrenheit. Humidity is usually specified as percent relative humidity.

Specifications in the frequency domain may be entered into the Specification Editor and loaded into the spectrum for direct comparison with the measurements.

Define Position and Orientation

Fix your measurement location at convenient place near to the column of the electron beam instrument, preferably where the sensors will not be in the way during operation or maintenance of the instrument. Place the magnetic field sensor, microphone and temperature/humidity sensor on the tripod roughly mid height of the column. Measure the vibration on the floor at the same location.

The conventional orientation is X left-to-right, Y front-to-back, Z upwards relative to the electron beam instrument. Make a plan of the room showing the position and orientation of the measurements.

Set up Signals and Scales

In the SC28 Monitor, select the signals you want to measure according to the microscope specifications and the sensors that you have available. Select 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. Set the units and ranges to match the units and specified levels for each quantity in the microscope specifications. See *Chapter 4 – Scales and Ranges* for more details.

Set up Spectrum Analyser

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

Where possible, be guided by the microscope specification. In the SC28, all the signals share the same spectrum analyser settings, so compromises may have to be made. The frequency range can be set to the largest required. The number of points can be set to give the minimum required point bandwidth. See *Chapter 5 - Spectrum Analyser Controls* for more details.

Set up Chart Recorder

The **Chart** controls set the size and **Unit** of the **Time Step** for the chart and the **Lower** and **Upper** bandwidths for each signal.

Where possible, be guided by the microscope specification. The maximum upper bandwidth in the SC28 is 1 kHz. Bandwidths are also limited by the sensors in some cases. See *Chapter 6 – Chart Recorder Controls* for more details.

Set up Data Logging

Data Logging <F6>

Click the **Data Logging** tool or select **Data Logging** from the **File** menu to open the Data Logging control panel.

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. See *Chapter 7 - Data Logging Controls* for more details.

Chapter 4 – Signals and Scales

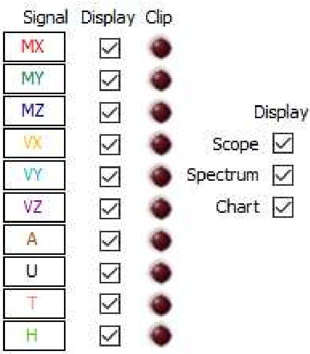
The SC28 provides 10 channels of data acquisition. In the SC28 Monitor, these signals may be displayed on 6 scales and in 3 display formats (Scope, Spectrum and Chart). Up to 14 different graphs may be displayed giving simultaneous display of the data as it is acquired.

Scale	*Signal*		*Display*		
			Scope	*Spectrum*	*Chart*
M	MX	Magnetic X axis	Mscope	Mspectrum	Mchart
	MY	Magnetic Y axis			
	MZ	Magnetic Z axis			
V	VX	Vibration X axis	Vscope	Vspectrum	Vchart
	VY	Vibration Y axis			
	VZ	Vibration Z axis			
A	A	Acoustic	Ascope	Aspectrum	Achart
U	U	User defined	Uscope	Uspectrum	Uchart
T	T	Temperature	-	-	Tchart
H	H	Humidity	-	-	Hchart

Magnetic field signals MX, MY and MZ are displayed together on the M scale. Vibration signals VX, VY and VZ are displayed together on the V scale. Temperature T and humidity H appear only on charts because they change too slowly to display on the Scope and Spectrum graphs.

Signal Display and Clipping

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 following can cause clipping to occur:
• Moving any magnetic field sensor in the Earth's magnetic field
• Placing an SC11/AC sensor in an AC magnetic field greater than 80 mG pk-pk.
• Placing a SC24/DC+AC sensor in an AC field greater than 40 mG pk-pk or where the DC level fluctuates more than ±20 mG after reset.
• Connecting a voltage greater than 10V to the AUX input.
• Moving an accelerometer or turning it over. Wait 2 minutes for it to recover.
• Placing an accelerometer where it vibrates at greater than 200 mg's peak to peak.
• Using a precision microphone at sound levels more than 103 dB.
• It is not likely to find temperature or humidity out of range of the sensor.

Scales and Ranges

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

Scale	Sensor	Unit	Range
M	Magnetic	mG	10
V	Vibration	mm/s2	10
A	Acoustic	dB	100
U	Voltage	V	10
T	Temperature	C	50
H	Humidity	%RH	50

The SC28 provides the following units and ranges by default. User-defined units may be added. See the <u>*User Defined Units*</u> section of *Chapter 9 – Calibration* for how to add user-defined units.

SC28 *Amplitude Ranges*				
Scale	*Sensor*	*Unit*		*Ranges*
M	Magnetic	mG	milliGauss	1, 2, 5, 10, 20, 50, 100, 200, 500
		nT	nanoTesla	1, 2, 5, 10, 20, 50, 100, 200, 500
		uT	microTesla	1, 2, 5, 10, 20, 50, 100, 200, 500
		mA/m	milliAmp per metre	1, 2, 5, 10, 20, 50, 100, 200, 500
		A/m	Amp per metre	1, 2, 5, 10, 20, 50, 100, 200, 500
V	Vibration	ug's	micro g's *	1, 2, 5, 10, 20, 50, 100, 200, 500
		mg's	milli g's *	1, 2, 5, 10, 20, 50, 100, 200, 500
		um/s^2	micron per second squared	1, 2, 5, 10, 20, 50, 100, 200, 500
		mm/s^2	millimetre per second squared	1, 2, 5, 10, 20, 50, 100, 200, 500
		um/s	micron per second	1, 2, 5, 10, 20, 50, 100, 200, 500
		mm/s	millimetre per second	1, 2, 5, 10, 20, 50, 100, 200, 500
		nm	nanometre	1, 2, 5, 10, 20, 50, 100, 200, 500
		um	micron	1, 2, 5, 10, 20, 50, 100, 200, 500
A	Acoustic	mPa	milliPascal	1, 2, 5, 10, 20, 50, 100, 200, 500
		Pa	Pascal	1, 2, 5, 10, 20, 50, 100, 200, 500
		dB[‡]	decibel (no weighting)	50, 60, 70, 80, 90, 100, 110, 120
U	Voltage	mV	milliVolt	1, 2, 5, 10, 20, 50, 100, 200, 500
		V	Volt	1, 2, 5, 10, 20, 50, 100, 200, 500
T	Temperature	C	Degrees Celcius	30, 40, 50, 60, 70, 80, 90, 100
		F	Degrees Fahrenheit	60, 80, 100, 120, 140, 160, 180, 200
H	Humidity	%RH	Percent relative humidity	30, 40, 50, 60, 70, 80, 90, 100

* g is the acceleration due to gravity.
‡ dB units force the Chart Mode to be RMS

Integrating Units

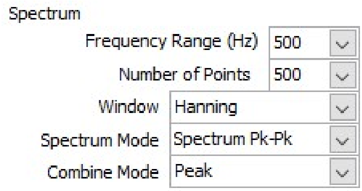
Velocity (um/s, mm/s) and displacement (nm, um) units require integration of the acceleration spectrum. The spectrum analyser integrates the acceleration spectrum by dividing it by ω to get velocity and by ω^2 to get displacement, where $\omega = 2\pi f$ and f is the frequency. The chart recorder has filters to perform the integration, but the scope display always uses acceleration units for accelerometers. See *Appendix 3 - Units* for more details of *integrating units*. The integration process boosts the low frequency end of the velocity and displacement spectra, making it easy to see the noise floor of the accelerometer at low frequencies.

Decibel Units

Acoustic decibel units (dB) are logarithmic units, requiring different ranges from other units. The Scope display uses Pa for dB units. See *Appendix 3 - Units* for more details of dB units. When you select dB units the Acoustic spectrum is forced to be RMS even if the Spectrum Mode is set to 0-Pk or Pk-Pk. The Chart mode for Acoustic is always set to RMS.

Chapter 5 – Spectrum Analyser Controls

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



Frequency Range

The frequency range sets the upper frequency on display.

Spectrum Frequency Ranges		
Unit		*Ranges*
Hz	Hertz	25, 50, 100, 250, 500, 1000

Number of Points

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

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

The **Frequency Range** and **Number of points** affect (1) the frequency resolution, (2) the sweep time, and (3) the noise level.

1. If you increase the number of points, you can distinguish frequency peaks more clearly, because this reduces the frequency step between points is δf. δf is simply the frequency range f_r divided by the number of points n.

$$\delta f = f_r / n$$

2. The sweep time is the time taken to acquire one scope waveform, which is then converted into a spectrum. The sweep time is the reciprocal of the frequency step, and so can be found by dividing the number of points by the frequency range:

$$t_s = 1 / \delta f = n / f_r$$

Therefore, it increases in proportion to the number of points. The shortest available time is 0.25 s for 1000 Hz and 250 points and the longest is 160 s for 25 Hz and 4000 points. You can see the length of the time sample from the **Scope** displays.

3. Johnson noise is proportional to the square root of the frequency step, so it reduces as you increase the number of points.

$$V_{noise} \propto \sqrt{\delta f} \propto \sqrt{(f_r / n)}$$

This affects measurements that contain wide-band noise, such as vibration. If you increase the number of points, the vibration spectrum reduces, because there is reduced signal in each point. Therefore, it is important to set the correct number of points when making comparisons with specifications. See *below* for third octave and power spectral density measurements, which do not suffer from this effect.

Window Function

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**. The windows apply the transformations found in *Appendix 4 – Window Functions*

Selecting **None** applies no window, but is not generally recommended, because of the spectral leakage that occurs when an incomplete number of cycles of the waveform are input to the DFT algorithm. This creates a broad skirt around each large peak in the spectrum.

The **Hanning Window** is a general-purpose window to reduce the spectral leakage. It may allow you to see small amplitude frequency components that are otherwise hidden by the broad skirts around large peaks. However, it broadens each narrow peak from one point to three points wide.

The **Flat Top Window** is for accurate measurement of the height of individual peaks. It broadens each narrow peak from one point to five points, but the height of the peak is accurate, even if the true peak falls mid-way between two points of the spectrum.

Spectrum Mode

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. They are scaled as the root mean square, amplitude or peak to peak of these component sine waves, respectively.

Spectrum PSD displays the RMS power spectral density in amplitude units per root Hertz. In this mode the level is divided by $\sqrt{\delta f}$, the square root of the frequency step between points. This produces a detailed spectrum in which the level of wide band signals is independent of δf.

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 frequency range sets the frequency of the upper band. The number of points in the spectrum determines the number of bands and hence the frequency of the lowest band. The frequency axis is logarithmic in these modes and the spectrum is stepped to show the third octave bands.

Third Octave Frequency Bands (Hz) repeated in decades									
1	1.25	1.6	2	2.5	3.15	4	5	6.3	8

Number of Bands depends on Number of Points					
Points	250	500	1000	2000	4000
Bands	19	22	25	28	31

The RMS level of each band is constructed by summing the squares of the magnitudes of the spectrum points within the frequency limits of the band. The 0-Pk and Pk-Pk values are $\sqrt{2}$ and $2\sqrt{2}$ times the RMS value respectively. Use the **Hanning** window for the most accurate results. There is a certain amount of overlap between the lowest frequency bands because they are derived from very few DFT points. With the Hanning window, the lower 4 bands may share up to 33% of their energy with the two adjacent bands. This effect is less than 1% between all other bands.

Combine Mode

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.

The **Combine Mode** function operates on the spectra acquired during the capture period of the Spectrum data log file. The total number of spectra combined is the Spectrum log file duration divided by the Spectrum Analyser period. If clipping occurs while combining, the clipped results are included. The clip light indicates that the results may not be accurate. Clipping information is included in the log file.

Chapter 6 – 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.

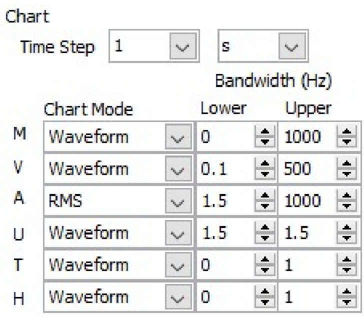


Chart Time Step

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
min	minute	1, 2, 3, 4, 5, 6, 10, 12, 15, 20, 30

In the SC28 Monitor, the maximum chart length is 3600 points, so it is always at least 1 hour. The chart display normally shows the current chart data log file as it is being built up. However, it is possible to set data log file intervals so that only some of the file can be shown in 3600 points. In this case, once the chart is full, the oldest data on the chart is discarded as new data is acquired. This does not affect the data logged to the file.

Chart Mode Controls

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	1000
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

Where more than one limit applies, the strictest one is used. These values then affect what you can set in the bandwidth controls:

Control	*Minimum Setting*	*Maximum Setting*
Lower Bandwidth	Minimum	Maximum/2
Upper Bandwidth	Minimum*2	Maximum

In addition, you cannot set the Lower Bandwidth higher than the Upper Bandwidth.

! Caution: ***The chart recorder automatically limits the Bandwidth controls to available values when you change the Sensor, Unit or Chart Mode. Set these before adjusting the Bandwidths.***

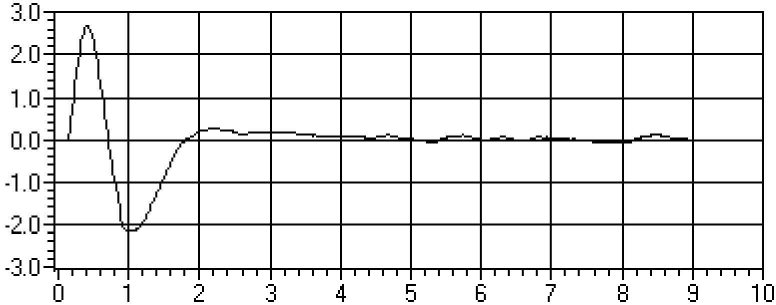
Chart Waveform mode

This 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.

Displacement and velocity waveforms

It is sometimes useful to chart position or velocity. The chart recorder provides this feature by integrating the accelerometer signal. This sets the lower 3dB Bandwidth to 1 Hz.

The displacement and velocity waveforms are derived from an integrating filter with a sharp cut-off below 0.7 Hz. The sharp cut-off is necessary to reduce 1/f noise from the accelerometer, but it causes the filter to have the step response shown below. This means that you need to take care in interpreting the results. If you see this response, then discount the results for about 5 seconds until it has died away. It may occur when you start a chart with units um/s, mm/s, nm or um, or if a very large peak signal occurs whilst measuring floor vibration. You may also see sinusoidal 1/f noise with a period of 1.4 s and amplitude up to 0.2 μm Pk-Pk.



Extended low frequency

If you need to chart low frequency magnetic fields and only an SC11/AC sensor is available, it is possible to extend the lower bandwidth in **Waveform** mode down to 0.1 Hz. If you set lower bandwidth below 1 Hz, the Chart Recorder applies a digital filter to the magnetic field channels, boosting the gain below 1 Hz to compensate for the low frequency cut-off point of the sensor.

There is a trade-off for the extra bandwidth. The digital filter is very sensitive to any offset voltages from the sensor amplifiers and the ADC. These cause an initial transient lasting up to 10 seconds. The filter also boosts the 1/f noise of the sensor, which causes the DC level of the trace to drift slowly up and down. When the lower bandwidth is set to 0.1 Hz, there is typically 0.15 mG Pk-Pk of 1/f noise at 0.1 Hz.

Chart RMS and Pk-Pk modes

These modes are useful for charting the variation of AC magnetic fields, vibrations or sound levels over a period of time.

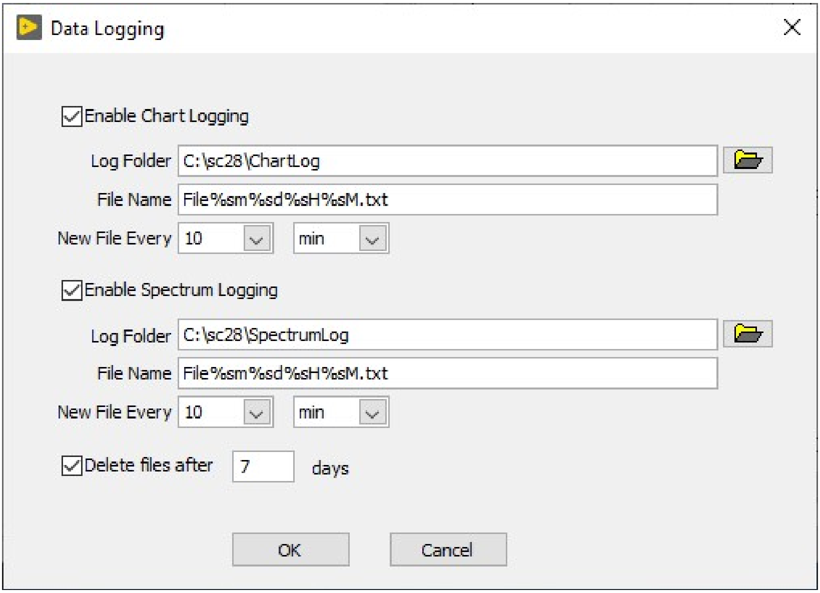
The **RMS** mode charts the Root Mean Square and the **Pk-Pk** mode charts the Peak to Peak value of the signals on display. **RMS** mode uses high-pass and low-pass filters to select the bandwidth of interest followed by a function that squares, low-pass filters and square-roots the signal to obtain the RMS. **Pk-Pk** mode uses an algorithm that finds the peaks and valleys of the signal over a rolling period of time.

At frequencies just below the minimum bandwidth, there is some unavoidable breakthrough of a rectified version of the signal. For smooth results, it is therefore best to set the lower bandwidth to a frequency where there is little activity.

Chapter 7 – Data Logging Controls

Data Logging <F6>

Click the **Data Logging** tool or select **Data Logging** from the **File** menu to open the Data Logging control panel.



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)

<table>
<tr><td>%fM</td><td>Finish minutes (00-59)</td></tr>
<tr><td>%fH</td><td>Finish hour on 24-hour clock (00-23)</td></tr>
<tr><td>%fd</td><td>Finish day (01-31)</td></tr>
<tr><td>%fm</td><td>Finish month (01-12)</td></tr>
<tr><td>%fy</td><td>Finish year (four digits)</td></tr>
<tr><td>%zM</td><td>Time zone minutes (00|30)</td></tr>
<tr><td>%zH</td><td>Time zone hour (+|-)(00-12)</td></tr>
</table>

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.

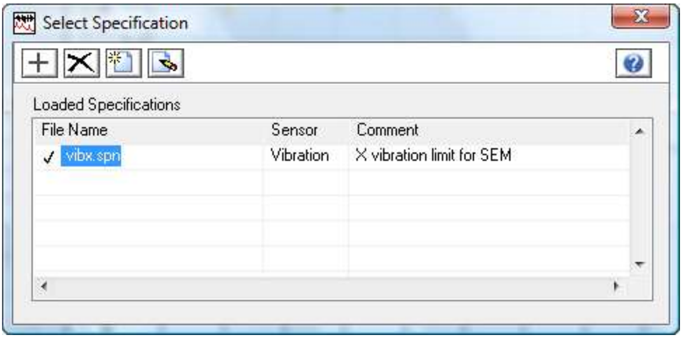
If **Delete Files After** is enabled, whenever the SC28 creates a new log file, it checks the folder to see if any files are older than the limit set and deletes them. The Chart and Spectrum folders are handled separately. If logging is not enabled for a folder, files are not deleted from it.

Chapter 8 – Environmental Specifications

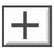
Specifications

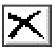
You can use the **Specifications** feature to quickly check whether a particular site meets the environmental specifications of an electron beam instrument or other equipment. You can load in *specification files* to show on the **Spectrum** display for direct comparison with your measured results. You may load more than one specification file at a time. The specification is normally shown as a thick grey line, but if the **Select**ed spectrum at any point exceeds the specification, then the specification is displayed as thick magenta line.

Specifications <F9>



The **Select Specification** panel lists the specification files that you have loaded.


Add


Remove

Use the **Add** tool to add a file and the **Remove** tool to remove the selected file from the list.


New


Edit

Use the **New** tool to create a new file and the **Edit** tool to edit the selected file. These tools both open the Specification Editor. See <u>*below*</u> for details. When you close the Specification Editor, you return to the Select Specifications panel. If you did not change the name of the file, it will be automatically updated. If you create or rename files, then you have to load them explicitly.

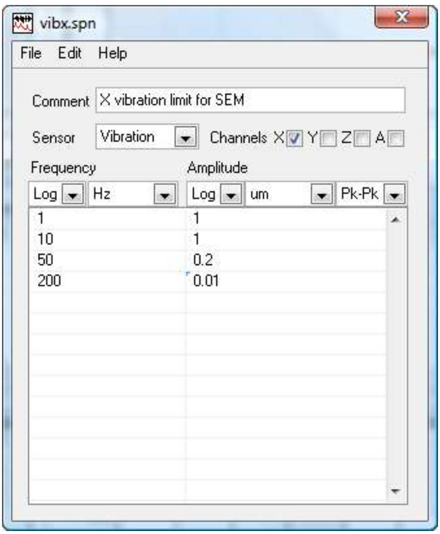
If the sensor or channel of the selected signal matches the specification file, then a tick ✓ appears by the filename and the specification is displayed on the spectrum. If they do not match, the *forbidden* symbol Ø appears by the filename. The specification remains on the list, but is not displayed until you select a signal with the same sensor and channel as in the file.

When the Spectrum Analyser displays the specification, it takes into account the units, Spectrum Mode and linear or logarithmic scales. For example, if you display a specification in nT RMS alongside measurements in mG Pk-Pk, then the program converts the specification into mG Pk-Pk for direct comparison. If you use different choices for log or linear scales, then straight lines on the specification may appear curved. Therefore, to avoid confusion, it is best to use the same units and scales for your measurements as the specification.

When the Spectrum Analyser exports or data logs results, it also outputs the specifications that are on display. When you save a Spectrum Analyser setup file, it contains references to any specification files that are loaded. These specification files are re-loaded when you re-open that setup file.

Specification Editor

You can use the Specification Editor to create and edit specification files. See *above* for how to open the Specification Editor.



<u>Specification Editor menus</u>

File	
New	Create a new specification file
Open	Open an existing specification file
Import Spectrum	Import a Spectrum Analyser results file as a specification
Save	Save the current file
Save As	Save the file with a different name
Edit	
Check Table	Display any errors found in the data
Help	
Show Context Help <Ctrl+H>	Open the Help window
Help on Edit Specification	Open the Help file

Once within the Specification Editor, you can use the **File** menu to start a **New** file, **Open** an existing file or **Save** the current specification to a file. You can also **Import** one channel's spectrum from a result file. This enables you to compare the current spectra with previously saved ones.

You can add a **Comment** that will appear on the Specifications panel when the file is loaded. Typically the comment identifies the instrument that the specification belongs to, and gives the direction of the measurement and whether it is magnetic field, vibration or sound level.

When you have selected the **Sensor**, you can then select from the **Amplitude Unit**s available for that sensor. Select a **Mode** (RMS, 0-Pk or Pk-Pk) and tick the **Channels** that this specification works with (the default is all channels).

The Specification Editor does not allow you to select acoustic units dBA or dBC, because the Spectrum Analyser does not convert the dB weighting of specifications. Use dB and ensure the correct weighting is used for measurements. When dB is selected the **Mode** is always RMS.

Enter the data points of the specification into the table. Click the right mouse button on the table to show the pop-up menu that contains some options to help you to edit the table. Put the frequency in Hz in the left column. Put the amplitude in the units shown in the right column. Frequency values must be greater than or equal to zero and increase as you move down the table. Amplitude values for all except dB units must be greater than zero. You can check the data in the table using **Check Table** on the **Edit** menu. If there are errors, a window appears, listing the errors. If there are no errors, nothing happens. You cannot save a specification that has errors.

The program interpolates straight lines between your frequency points, so you only need to enter the turning points of the specification. If the specification has a step change in level, then repeat the frequency value at that point and enter different amplitude values in the two cells in the right column. There is no need to enter values for frequencies outside the range of the specification.

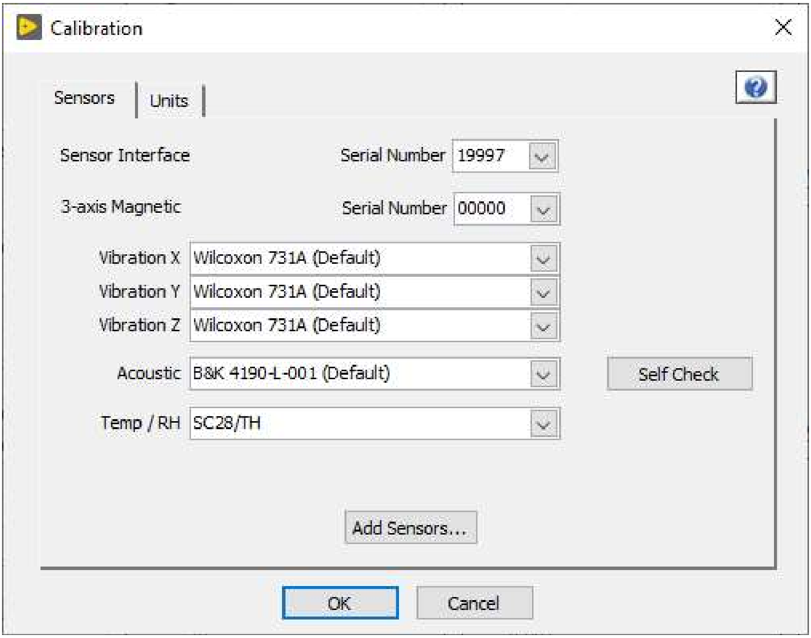
Set the **Frequency Mapping** and **Amplitude Mapping** to **Log** or **Lin** (logarithmic or linear). The program uses this information to interpolate lines between the points you enter. When the scales on the Spectrum Analyser match the settings here the interpolated lines are straight. If you see curved lines, then either the settings here are wrong, or you are viewing the data with different log/lin settings or different displacement/velocity/acceleration units from the original specification. The vertical mapping for dB units is always linear.

The *Specification file format* is shown in *Appendix 2 - File Formats*.

Chapter 9 – SC28 Calibration

Calibration Panel

Calibration <F2>



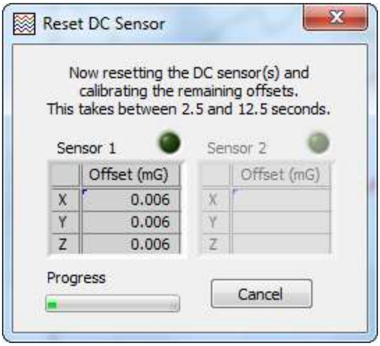
On the **Sensors** tab of the Calibration panel, you can select the sensors you are using.

All Spicer Consulting sensors and interfaces are identified by their serial numbers. Other sensors are identified by their manufacturer, type and serial number. SC28/SI units set the serial number automatically.

On the SC128/SI, there are three Vibration sensors. The acoustic sensor is a precision microphone. The Temp / RH sensor is an SC28/TH.

Reset DC Sensor

The **Reset DC Sensor** button is available on the Sensors tab only when a DC sensor is connected to the SC28/SI. If you move a DC sensor, you must reset it by clicking either this button or the **Reset DC** button in the tool bar of the SC28 Monitor. The following window appears:



Initially the DC sensor outputs are zero, while it internally zeros its output to the nearest 1 mG at the current X, Y and Z magnetic field levels. After that, the DC sensor outputs turn on and the software uses low-pass filtering to compensate for any residual offset. The green light comes on if the DC sensor has successfully reset to within ±2 mG and the window closes automatically. This process takes 2.5s for newer “1s reset” DC sensors and 12.5 seconds for older DC sensors.

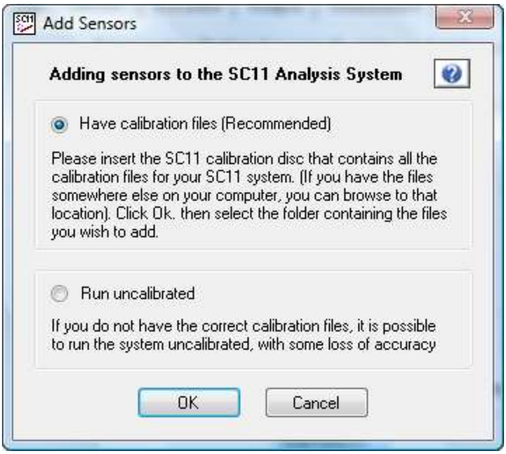
If either DC sensor failed to reset properly, then its green light goes out and a warning dialog appears. In this case, check the red LED on the DC sensor, which flashes if it is too close to any permanent magnets that put the DC field out of range of the reset (±2 G). Also ensure that there are no deliberate field generators turned on that could be changing the field level at frequencies around 0.1 to 1 Hz. Then try again.

Microphone Self Check

The Brüel & Kjær precision microphone has a delicate diaphragm that is biased to 200 V in operation and requires careful handling. To check that the microphone is in good condition, click the **Self Check** box that appears when a precision microphone is selected. The check takes 2 seconds and gives a pass/fail result. The microphone self check uses Brüel & Kjær's patented charge-injection calibration technique to test the microphone and the whole signal chain. To make the check reasonably independent of ambient sounds, the system generates a 70 Hz sine wave test signal and ignores all other frequencies. If the check passes, the microphone is working. If it fails, check that it is connected properly.

Add Sensors

Sensors are made available for selection in the Calibration panel by adding their calibration files to the SC28 system. Click the **Add Sensors…** button.



Have Calibration Files

Spicer Consulting provides calibration files for sensors on a USB memory stick. The calibration files are named as follows, where * represents the serial number:

Sensor interface	**si*.cal**
3-axis magnetic field sensor	**sen*.cal**
Accelerometer	**acc*.cal**
Acoustic sensor	**mic*.cal**
Temperature/Humidity sensor	th***.cal**

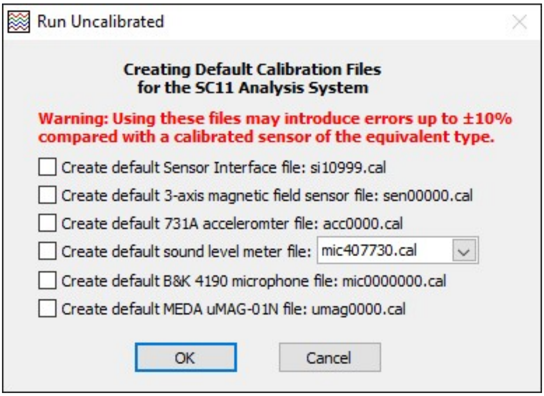
Insert the calibration memory stick, select **Have calibration files** and click **OK**. The file dialog appears. Browse to the location of your calibration files, select the files you wish to add to the SC28 system and click **OK**. You can select all the files using <ctrl-A> (recommended), individual files using <ctrl-click> or a range of files using <shift-click>. A pop-up window confirms the number of files added.

Next select the sensors you are using on the **Sensors** tab of the Wizard.

Run Uncalibrated

If you do not have the calibration files, then as a last resort, you can select **Run uncalibrated** to get started. There may be some loss of accuracy for 3-axis magnetic field sensors, 731A accelerometers or precision microphones. However there is typically no loss of accuracy for Sensor Interfaces or Temperature/Humidity sensors, since these are independently calibrated.

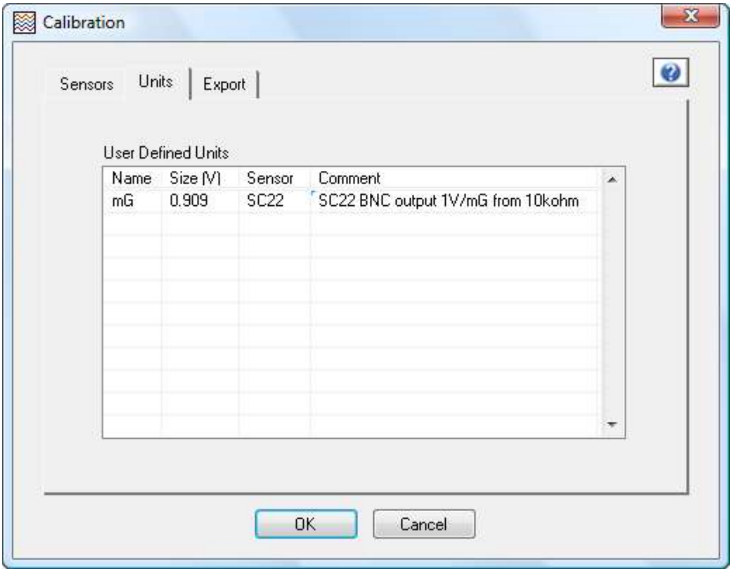
Select only the sensors that you need and click **OK**. The system adds default calibration files that you can select on the **Sensors** tab of the Calibration panel, SC11 Wizard or SC11 Survey.



✍ **Note:** ***After using the default files, it is recommended that you take steps to obtain the correct calibration files as soon as possible. You should then delete the default files to avoid confusion.***

User Defined Units

Under the **Units** tab, you can enter user-defined units for use with the **AUX** input (or the **MAG** or **MIC** input of the Sensor Interface). For example, you might connect a Spicer Consulting SC22 Magnetic Field Cancelling System BNC output to the **AUX** input. The SC22 measures magnetic field and outputs 1.0 Volts per milliGauss with 10 kΩ output impedance. The input impedance of the AUX input is 100 kΩ, so the result is that a 1mG field produces a voltage of 1.0 * 100/110 V = 0.909 V.



To add a unit for this situation, you would enter its details into a row of the table:
· Name of the unit – in this case, **mG** the abbreviation for milliGauss.
· Size of the unit in Volts – in this case 0.909
· Name of the sensor – in this case SC22
· Comment identifying the signal source.
There is a special case for user sound level meters. If the name of the unit is **dB**, then the size of the unit is in Pa. dB user defined units appear only in the Spectrum Analyser and Chart Recorder. See *Appendix 3 – Units* for more information about *sound level units*.

The sensor name for a user unit may not be the same as any of the built-in sensors: **Magnetic, Vibration, Acoustic, Voltage**, **Temperature** or **Humidity**.

To delete a unit, delete all characters in both the Name and the Size. Any blank lines you leave in the table are ignored.

When you have defined units, the sensor names are added to all Sensor controls that list the **Voltage** sensor. It is possible to use the **AUX** or **MAG** inputs. In the software, select the sensor and unit you have defined.

The program displays and data logs the signal in the selected unit by dividing the input voltage by the size of the unit.

Chapter 10 - Menu and Toolbar Functions

Menu

This section lists all the menu functions of the Oscilloscope, Spectrum Analyser and Chart Recorder. Their operation is described in the following sections.

File	
Calibrate…	Open the Calibration panel.
Specifications…	Open the Specification panel.
Open Setup…	Load control settings from a file.
Save Setup…	Save control settings to a file.
Data Logging…	Open the Data Logging panel.
Exit <Ctrl+Q>	Exit the program.
Window	
Full Size <Ctrl+/>	Maximise the instrument window to fill the screen or restore the window to its previous size. See *Resizing the Window*, below.
Help	
Show Context Help <Ctrl+H>	Show the *help window.*
Help for SC28	Show the SC28 help file.
About…	Show brief information about the program.

Calibration Tool

Calibration <F2>

Calibration is described in Chapter 9, SC28 Calibration.

Specification Tool

Specifications <F9>

Specifications are described in Chapter 8, Environmental Specifications.

Setup Files


Open Setup <F3>


Save Setup <F4>

A setup file saves all the control settings including data logging. The default setup file `setup.sc28` is loaded automatically when the program starts. You can also save and load named setup files using the **Open** and **Save** tools or **Open Setup…** and **Save Setup…** from the **File** menu.

Data Logging Tool

Data Logging <F6>

This opens a dialog to set the Data Logging controls. For details see *Chapter 7 – Data Logging Controls*

Exiting the Program

You can exit the Monitor window using the **X** button at the top right of the window or using **Exit** from the **File** menu. The menu option also asks if you want to replace the default file. See *Setup Files* above.

Resizing the Window

You can re-size the window of the SC28 Monitor by dragging the edges or corners, by clicking on the **Maximise** button near the top right or by using **Full Size** on the **Window** menu. The graph areas expand to give a more detailed view of your results. It remembers the size and position that was last used.

Help Tool


Help <F1>

The **Help** tool opens the sc11 help file at the page relevant to the current panel.

Reset DC Sensor Tool


Reset DC Sensor <F8>

This tool is available only when one or two DC sensors are connected to the SC11/SI. It resets the DC sensor(s) and calibrates their offsets. This function is also available on the Sensors tab of the Calibration panel. See *above* for details.

Autoscaling

 Autoscale X
 Autoscale Y
 Reset scale

Autoscale X and **Autoscale Y** scale the plot to fit all the data in the horizontal and vertical directions respectively. **Reset scale** resets the plot to the values set on the control panel scales.

Plot Tools

 Zoom X
 Zoom Y
 Zoom Area
 Pan

Zoom X, Zoom Y and **Zoom Area** select different ways of zooming in by dragging the mouse over the plot. **Pan** allows you to drag the data around the plot area.

Appendix 1 – 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.

Data Acquisition

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

Core System: SC28/SI - Sensor Interface (Ethernet-based)

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 kΩ input impedance.
TEMP/RH	SC28/TH Temperature/Humidity Sensor
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
Power	9-36V DC, 12 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 uT)
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/s^2 (0.2 g's*) 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 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

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, 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
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, 1000 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 1, 2, 3, 4, 5, 6, 10, 12, 15, 20, 30 min/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

$^{\alpha}$ g's are units of the acceleration due to gravity

Appendix 2 - File Formats

Export File Text Format

[Header]
Version="*Version*"
Program="*Program*"
Mode="*FileMode*"
Date="*Date*"
Time="*Time*"
Setup="*SetupFile*"
Title="*GraphTitle*"
Sensors=*NumSensors*
for (i=0; i<NumSensors; i++){
Sensors*i*="Channel=*Channel*,Sensor=*SensorType*,BWlower=*BWlower*,
BWupper=*BWupper*,Name=*SensorName*"*}*
Controls=*NumControls*
ProgControls
Stats="*ProgStats*"
Axes=*NumAxes*
for (i=0; i<NumAxes; i++){
Axes*i*="Name=*AxisName*,Min=*Min*,Max=*Max*,Major=*Major*,
Minor=*Minor*,Format=*Format*,Precision=*Precision*,
Map=*AxisMap*"*}*
Markers=*NumMarkers*
for (i=0; i<NumMarkers; i++){
Marker*i*="Time=*MarkerTime*,Text=*MarkerText*"*}*
Cursors=*NumCursors*
for (i=0; i<NumCursors; i++){
Cursor*i*="Name=*CursorName*,X=*X*,Y=*Y*,Signal=*CursorSignal*"*}*
Horiz="Name=*HorizName*,Unit=*HorizUnit*,Map=*HorizMap*,Start=*Start*,
Step=*Step*,Points=*NumPoints*"
Signals=*NumSignals*
for (i=0; i<NumSignals; i++){
Signals*i*="Name=*SigName,*Unit=*SigUnit*,Range=*SigRange*,Display=*SigDisplay*,
Position=*SigPosition*,Axis=*SigAxis*"*}*
[Data]

H_0	$S_{0,0}$	..	$S_{NumSignals,0}$
:	:	:	:
Hnp	$S_{0,NumPoints-1}$	..	$S_{NumSignals-1,NumPoints-1}$

[End]

Normal type appears in the file. C-style for loops make repeated lines. Data values are separated by tabs. *Italics* are substituted as follows:

Version	Current version of SC28
Program	Program that created the file (SC28)
FileMode	How the file was output (Logged)
Date & Time	Date and time data logging started
SetupFile	Name of program setup file (setup.sc28)
Title	Graph title (SC28 Chart, SC28 Spectrum)
NumSensors	Number of sensors
Channel	Sensor channel (MX, MY, MZ, VX, VY, VZ, A, U, T, H)
SensorType	Sensor type (Magnetic, Vibration, Acoustic, Voltage, *User-defined*, Temperature, Humidity)
BWlower	Sensor lower bandwidth
BWupper	Sensor upper bandwidth
SensorName	Sensor name (eg. SC24/DC Sensor S/N 12345)
NumControls	Number of program-specific control setting lines (see below)
ProgControls	Program-specific control settings (see below)
ProgStats	Program-specific statistics (see below)
NumAxes	Number of axes
AxisName	Axis name (eg. Frequency (Hz))
Min & Max	Axis minimum and maximum
Major	Axis major tick size
Minor	Axis minor tick size
Format	Axis format (Dec, Sci)
Precision	Axis precision (0 .. 6)
AxisMap	Axis mapping mode (Lin, Log)
NumMarkers	Number of markers
MarkerTime	Marker time
MarkerText	Marker text
NumCursors	Number of cursors
CursorName	Cursor name
X & Y	Cursor X & Y position
CursorSignal	Signal cursor is attached to
HorizName	Horizontal axis name (eg. Frequency)
HorizUnit	Horizontal axis unit (eg. Hz)
HorizMap	Horizontal axis mapping mode (Lin, Log)
Start	Horizontal start point
Step	Horizontal step between points (add for Lin, multiply for Log)
NumPoints	Number of points
NumSignals	Number of signals
SigName	Signal name (eg. VX)
SigUnit	Signal unit (eg. um/s2 RMS)
SigRange	Range control associated with signal
SigDisplay	1=Show signal, 0=Hide signal

SigPosition Signal position
SigAxis Axis signal assigned to (1 .. 4)
Only displayed signals are output to the file.

The program-specific *ProgControls* and *ProgStats* are as follows:

<u>Spectrum Analyser</u>

Controls0="NumPoints=*NumPoints*,Resolution=*Resolution*,Window=*Window*,
Mode=*SpecMode*,CombineMode=*CombMode*,
MaxSpectra=*MaxSpectra*"
Stats="Combined=*NumComb*, MXclip=*MXclip*,MYclip=*MYclip*,MZclip=*MZclip*,
VXclip=*VXclip*,VYclip=*VYclip*,VZclip=*VZclip*,Aclip=*Aclip*,Uclip=*Uclip*"

Italics are substituted as follows:

NumPoints Number of points in spectrum
Resolution ADC resolution (Fine, Coarse)
Window Window function (None, Hanning, Flat Top)
SpecMode Spectrum mode (Spectrum RMS, Spectrum 0-Pk, Spectrum Pk-Pk, PSD, Third Octave RMS, Third Octave 0-Pk, Third Octave Pk-Pk)
CombMode Combine mode (Average, Peak)
MaxSpectra Maximum number of spectra to combine
NumComb Number of spectra combined
MXclip..Aclip Clipping indicators for all channels (0=not clipping, 1=clipping)

The Spectrum Analyser adds signals for displayed specifications, named **Spec*i***, where *i* goes from 0 to NumSpecs-1. Data values are set to **NaN** for frequencies outside the range of the specification.

Chart Recorder

Controls*0..5*="Scale=*Scale*,Mode=*ScaleMode*,BWlower=*BWlower*,
BWupper=*BWupper*"
Stats="MXclip=*MXclip*,MYclip=*MYclip*,MZclip=*MZclip*,VXclip=*VXclip*,
VYclip=*VYclip*,VZclip=*VZclip*,Aclip=*Aclip*,Uclip=*Uclip*,Tclip=*Tclip*,
Hclip=*Hclip*"

C-style for loops and if statements make repeated and alternative lines. *Italics* are substituted as follows:

Scale	Scale (MX, MY, MZ, VX, VY, VZ, A, U, T, H)
ScaleMode	Scale mode (Waveform, RMS, Pk-Pk)
BWlower	Scale lower bandwidth
BWupper	Scale upper bandwidth
MXclip..Hclip	Clipping indicators for all channels (0=not clipping, 1=clipping)

The SC28 Chart Datalog may format the horizontal signal data H0 to Hnp as an ISO 8601 compliant time stamp of the form: yyyy-mm-ddTHH:MM:SS+/-ZZ:zz where:

Yyyy-mm-dd	Date with 4-digit year, 2-digit month and 2-digit day of month
HH:MM:SS	Time on 24-hour clock, with 2-digit hour, minute and seconds
+/-ZZ:zz	Time zone difference from GMT with either + or – and 2-digit hour and minute.

Other programs use a floating-point number.

Specification File Format

Version	*version*	
comment		
Sensor	*sensor*	
freqscale	*ampscale*	
frequnit	*ampunit*	*mode*
f_0	S_0	
:	:	
f_{n-1}	S_{n-1}	

All fields are separated by tabs. Words in *italics* are substituted as follows:

version	the version of the program that created the file
comment	comment describing the specification
sensor	sensor type (**Magnetic**, **Vibration**, **Acoustic**, **Voltage**)
freqscale	frequency scale of the specification (**lin, log**)
ampscale	amplitude scale of the specification (**lin**, **log**)
frequnit	frequency unit of the specification (always **Hz**)
ampunit	amplitude unit of the specification
mode	mode of amplitude unit (**RMS**, **0-Pk**, **Pk-Pk**)
f_0 & f_{n-1}	first and last frequency values
S_0 & S_{n-1}	first and last amplitude values

Default Folders

By default, all executables, dynamic link libraries and originals of default setup files for SC28 1.0 are installed in one of the following folders. These files should not be altered.

C:\Program Files\Spicer Consulting\SC28 1.0 (32-bit Windows)
C:\Program Files (x86)\Spicer Consulting\SC28 1.0 (64-bit Windows)

By default, all calibration files, setup files and specification files for SC28 1.0 are stored in the following folder. These files are created and modified by the SC11 programs.

C:\Users*user*\AppData\Local\Spicer Consulting\SC28 1.0

Where *user* is the username of the user running the SC28 program.

Appendix 3 - Units

This appendix gives some general information about the units used in the SC28 software.

Magnetic Field Units

The SI unit for magnetic flux density, B is T (Tesla).
1 T is a strong magnetic field. The older unit G (Gauss) is often used.1 G = 10^{-4} T.
mG (milliGauss), μT (microTesla) and nT (nanoTesla) are used for typical environmental fields.

The SI unit for magnetic field strength, H is A/m (Amp/metre).
In free space, 1 A/m = $4\pi \times 10^{-7}$ T.
Oe (Oersted) is sometimes used for magnetic field strength.
1 Oe = $1/4\pi$ kA/m. In free space, 1 Oe = 1 G.
A/m and Oe are not often used for environmental field measurements.

The following table gives some conversions derived from the above:

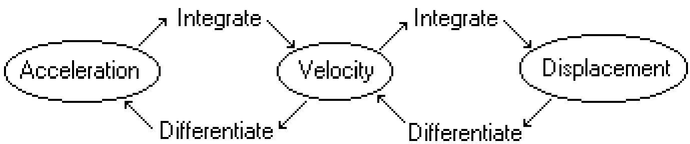
Gauss	*Tesla*	*A/m*
1 G	100 μT	79.6 A/m
100 mG	10 μT	7.96 A/m
12.6 mG	1.26 μT	1 A/m
10 mG	1 μT	0.796 A/m
1 mG	100 nT	79.6 mA/m
0.1 mG	10 nT	7.96 mA/m
12.6 μG	1.26 nT	1 mA/m
10 μG	1 nT	0.796 mA/m
1 μG	100 pT	79.6 μA/m

Vibration Units

Vibration may be measured in displacement, velocity or acceleration units. The SI units for these quantities are m (metre), m/s (metre per second) and m/s^2 (metre per second squared) respectively. g's (the acceleration due to gravity) are also used. The acceleration due to gravity varies from place to place, but for the purpose of defining the units, 1 g's = 9.80665 m/s^2.

µm (micron), µm/s (micron per second), mm/s^2 (millimetre per second squared) and µg's (microgees) are suitable for environmental measurements. There are various standards for vibration measurements, but no industry-wide agreement over which standards to use.

Displacement, velocity and acceleration are related by integration.



Integration and differentiation are straightforward in the frequency domain. For example, the velocity spectrum is simply the acceleration spectrum divided by ω and the displacement spectrum is the acceleration spectrum divided by ω^2, where $\omega = 2\pi f$ and f is the frequency.

The following table gives some conversions between vibration units at different frequencies.

Frequency	*Displacement*	*Velocity*	*Acceleration*	
Hz	*µm*	*µm/s*	*µm/s²*	*µg's*
0.159	1	1	1	0.102
1	0.159	1	6.28	0.641
1.59	0.1	1	10	1.02
10	0.0159	1	62.8	6.41
15.9	0.01	1	100	10.2
100	0.00159	1	628	64.1
159	0.001	1	1000	102
1000	0.000159	1	6280	641

Sound Level Units

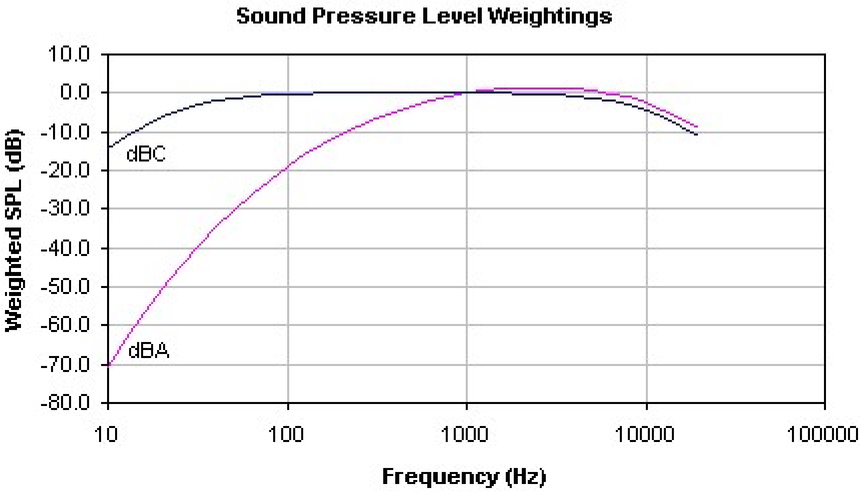
The Sound Pressure Level (*SPL*) in dB (deciBel) is referenced to the softest pure tone audible to normal human ears at 1 kHz. This is an intensity of 10^{-12} W/m^2, which in air at 20 °C is a pressure, P_0 = 20 μPa (microPascal) RMS. The sound pressure level in dB is given by:

$$SPL = 20 \log_{10}(P/P_0)$$

Two commonly used frequency weightings are:

dBA This has reduced sensitivity to low frequencies and is tailored for measuring the effect of the sound on the human ear.

dBC This has a much flatter response and is suitable for measuring the effect on equipment.



The following table shows some example levels for the Radio Shack analogue sound level meters.

Range (dB)	*Meter Reading*	*SPL (dB)*	*Pressure (Pa RMS)*
70	0	70	0.063
80	-6	74	0.1
80	0	80	0.2
80	+6	86	0.4
90	0	90	0.63
90	+4	94	1.0

Appendix 4 - Window Functions

The windows apply the following transformations to the waveform:

Hanning $y_i = a_0 \, x_i \, [\, 1 - \cos(2\pi i / n)]$ $i = 0, 1, 2, ..., n\text{-}1$

Flat Top $y_i = b_0 \, x_i \, [\, 1 - b_1 \cos(2\pi i / n) + b_2 \cos(4\pi i / n)$
$- b_3 \cos(6\pi i / n) + b_4 \cos(8\pi i / n)]$ $i = 0, 1, 2, ..., n\text{-}1$

where x_i is the i^{th} point of the original waveform
y_i is the i^{th} point of the transformed waveform
n is the number of points in the waveform
a_0 is 0.5
b_0 is 0.215578948
b_1 is 1.932617187
b_2 is 1.286132809
b_3 is 0.38769531
b_4 is 0.03222656

Index