SMRT Probe 4000™

User Guide

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The product described in this user guide is SMRT Probe 4000™, part of the Sentinel Power™ product line, by Ridgetop Group.

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1 Introduction to SMRT Probe 4000

About the SMRT Probe 4000

Ridgetop's SMRT Probe (Sample Mode Response Technique™ Probe) 4000, part of the Sentinel Power product line, is a resonant frequency sensor and data acquisition module that is attached to an electrical assembly to extract prognostic degradation signatures. It provides real-time monitoring of an electrical assembly.

SMRT Probe 4000 monitors power systems by measuring the characteristic frequency response to a small, well-controlled load change, enabling prognostic and degradation analysis. The system response will change due to reduction of regulation capability, loss of output buffer (filter) capacitance, changes in the equivalent series resistance (ESR) of the power system being monitored, MOSFET switch degradation, or other electrical degradation. SMRT Probe processes the sampled data and outputs the results to the controlling host (such as a computer or embedded controller).

The SMRT Probe device performs a digital signal processing (DSP) analysis of the induced sensor's frequency response resulting from applying a well-controlled small load change to the power system being monitored, and outputs the frequency expressed in Hz. Data gathered and provided by SMRT Probe can then be subject to further analysis using optional tools such as ARULE™ (Adaptive Remaining Useful Life Estimator) to provide prognostic and health management (PHM) results such as, but not restricted to, actual state of health (SoH) and remaining useful life (RUL).

The SMRT Probe 4000 is shown in Figure 1.

Figure 1: SMRT Probe 4000

Additional information about SMRT Probe 4000 can be found online at www.ridgetopgroup.com/smrt-probe-4000.

SMRT Probe 4000 System Configuration

The block diagram in Figure 2 illustrates SMRT Probe operation.

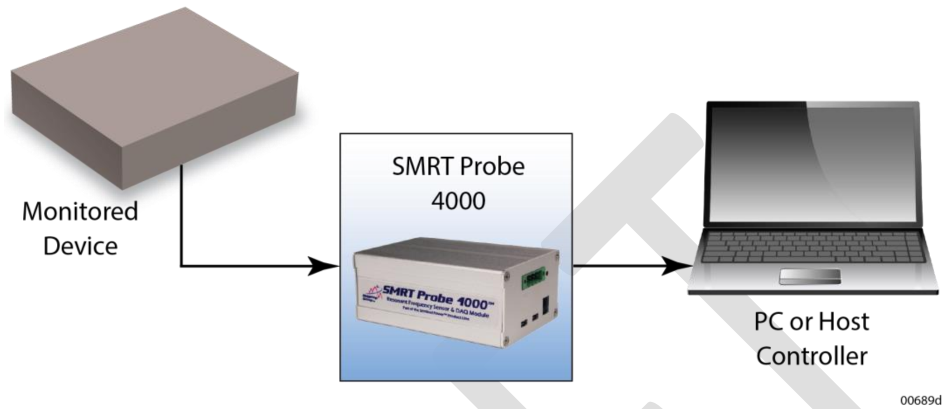


Figure 2: System diagram of SMRT Probe 4000 operation

Component Specifications

The standard SMRT Probe 4000 has the following specifications. However, you can request factory modifications to customize your SMRT Probe 4000 device to your specifications. Please contact Ridgetop for further information.

Capacitance range	132 to 13,200 µF	**Output connector**	Micro USB
Input voltage range	2.5 to 33 V	**Output data protocol**	ASCII
Connectivity	USB	**Temperature range**	0 to 40 °C
ADC sample rate	250 kHz	**Frequency response range**	850 Hz to 4.1 kHz
Dimensions	L = 4.38 in. (11.1 cm) W = 3 in. (7.6 cm) H = 1.75 in. (4.5 cm)	**Characteristic frequency response**	16-bit resolution
Power supply	24 VDC / 1.25 A	**Serial COM port**	115,200 baud N81

About Sentinel Power

The Sentinel Power family comprises features and algorithms to support advanced diagnostics and prognostics. The ARULE algorithm can be included with the SMRT Probe 4000 to calculate SoH and RUL. Ridgetop prognostics are independent of noise effects.

The sensor processing unit (SPU) embedded in the SMRT Probe 4000 unit is controlled by the host Sentinel Power prognostic analysis platform, which processes the data sampled by the probing section of the device.

About Ridgetop Prognostics

Ridgetop Group specializes in the development of prognostic methods that are used to improve the reliability of deployed systems by analyzing components that have high failure rates and critical impact on performance.

Detectors, or sensors, monitor these systems and help isolate failure precursors that indicate when the high-failure-rate components are degrading toward failure. By knowing the progression of failure dynamics for a monitored device, an accurate prediction of RUL can be made and an appropriate evidence-based maintenance action, such as removing and replacing the device, can be initiated only when required, thus reducing the cost of maintenance.

Fault-to-failure progression (FFP) signature detection developed by Ridgetop is an effective method to detect and report a precursor to failure or incipient fault condition of an assembly containing a degraded component. Such detection is the basis for a notification capability, supplied by the Sentinel Power software, to provide a prognostic early warning of impending failure.

Box Contents

Your SMRT Probe 4000 box contains:

- SMRT Probe 4000 device
- One USB cable
- One power cable
- SMRT Probe 4000 CD (or an FTP folder location) containing the SMRT Probe driver software and the User Guide
- Screwdriver specified for the green plugs

If your box contents differ, please contact us at +1 520-742-3300 or by email at info@ridgetopgroup.com.

System Requirements

1. Windows 8.1 or Windows 7 Professional operating system (either 32- or 64-bit) or Windows XP Service Pack 3. Do not use Windows 7 Home Edition.
2. PC with one USB port available (PC is not provided).

3. The latest version of the free Java software run-time environment is required; the steps for Java installation and updating are included in Chapter 3, Installing the SMRT Probe 4000.

2 SMRT Probe 4000 Description

SMRT Probe 4000 Connections

All connections to and from the SMRT Probe 4000 are made at the back panel of the device. Figure 3 provides an overview of the connectors and indicators, and their functionality is explained in the following paragraphs.

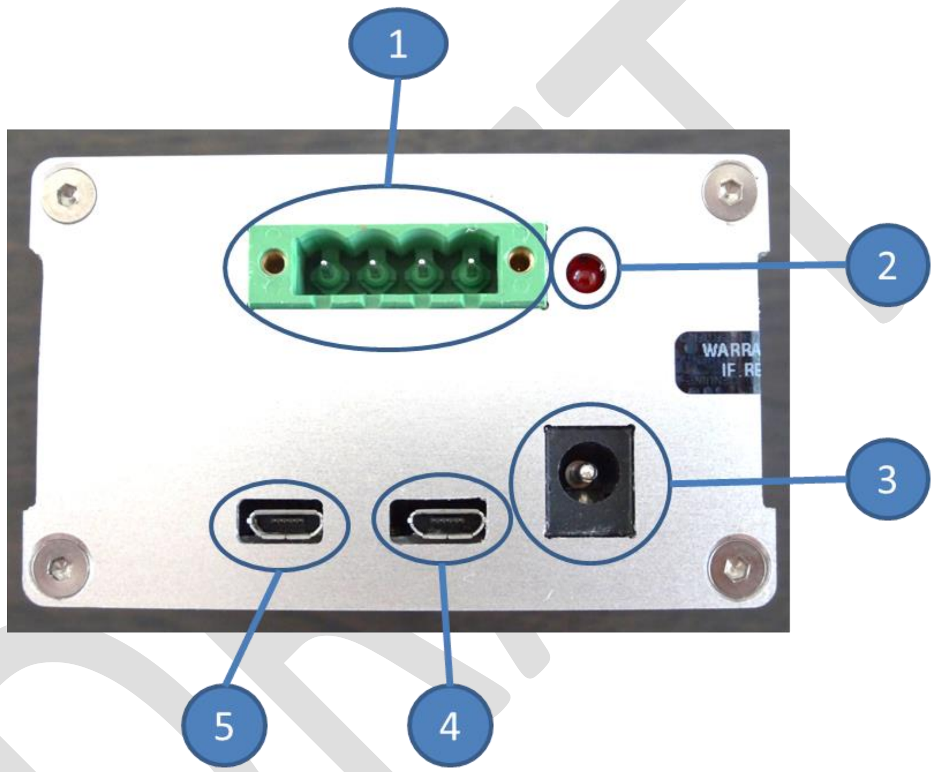


Figure 3: SMRT Probe 4000 connections and indicators

1. Four-pin green connector (**1** in Figure 3): Use the green connector to connect SMRT Probe to the power supply or system that needs to be monitored. The green connector pin assignment is detailed below.

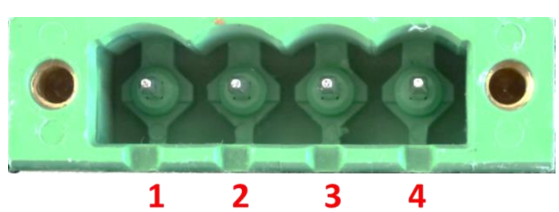


Figure 4: Green connector, pin assignments

The green connector has four terminals that are hooked up internally, two by two. The first two contact points from the left (pins 1 & 2) are reference/ground connections and must be connected to the ground terminal of the supply or system that is to be monitored. The last two contact points (pins 3 & 4) are signal connections and must be connected to the positive terminal of the supply or system that is to be monitored.

2. Power LED (**2** in Figure 3): The power LED indicates that the SMRT Probe is active.
3. Supply connector (**3** in Figure 3): The optional supply connector can be used to supply SMRT Probe from the mains using an appropriate supply adapter. SMRT Probe 4000 takes its power either from the USB bus or from its supply connector.
4. Micro USB connector (**4** in Figure 3): Data and Control Port. Use this connector to hook up SMRT Probe 4000 to its controlling host using an appropriate USB cable.
5. Micro USB connector (**5** in Figure 3): Programming Port. This connector is reserved for system programming and in-field application support, and is to be left unconnected during normal use of SMRT Probe 4000.

SMRT Probe 4000 Application

The application of SMRT Probe 4000 is simple and straightforward. SMRT Probe is to be hooked up to the output terminals of the supply or system to be monitored, basically in parallel to the normal supply or system load, as illustrated in Figure 5.

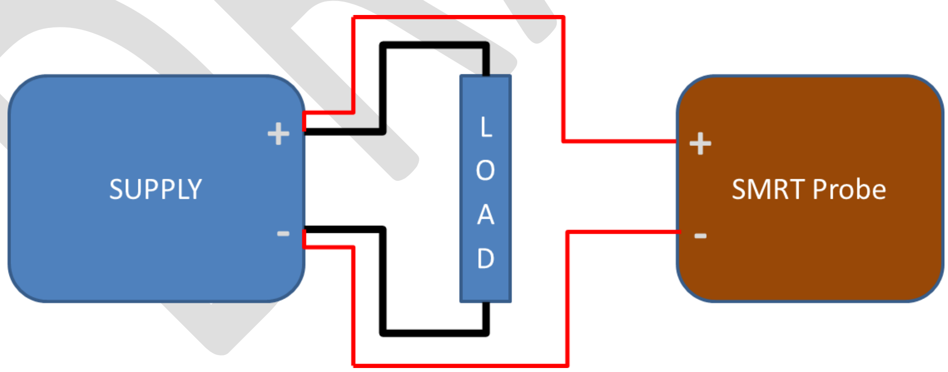


Figure 5: SMRT Probe 4000 application diagram

As such, SMRT Probe 4000 serves as an additional load to the power supply or system that is being monitored. The input of SMRT Probe is of high impedance, and the additional load from SMRT Probe is negligible as a result.

3 Installing the SMRT Probe 4000

Installing the Software

1. The first step is to make sure the PC is running version 8.25 of Java or greater. If the PC is not running the latest version of Java, the Sentinel PowerView user interface may not operate properly. To check your Java version, simply go to the following URL – http://www.java.com/en/download/installed.jsp – then follow the on-screen instructions to update to the most current Java version.
2. Create a folder named "SMRT Probe" on the computer that will control the SMRT Probe 4000 unit.
3. Copy the contents of the SMRT Probe CD (or copy content from the FTP folder) and save all of it into the new SMRT Probe folder you created.
4. Double-click the file in that folder called **setup.exe**, and follow the on-screen instructions.
5. When the installation is complete, click **Finish**.

Installing the Hardware

1. Connect the micro USB cable to the SMRT Probe 4000 micro USB cable socket shown in Figure 6.

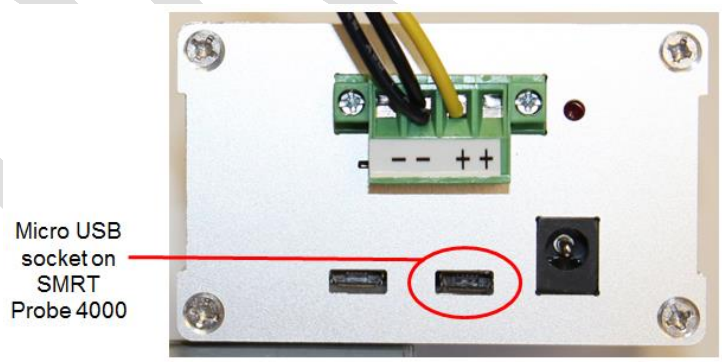


Figure 6: SMRT Probe 4000 micro USB cable socket

2. Connect the other end of the SMRT Probe 4000 USB cable to a USB port on the PC. The device driver automatically installs.
3. Connect SMRT Probe with the included power cable to a locally available power outlet.
4. Connect SMRT Probe to the system to be monitored.

4 Using the SMRT Probe 4000

Before You Begin

Ensure that the following actions have been performed:

- SMRT Probe is plugged into the PC or host controller via USB cable.
- SMRT Probe power cable is connected to the SMRT Probe and plugged into a power outlet.
- SMRT Probe is connected to the device under test (DUT).
- SMRT Probe is turned on; an illuminated power LED indicates that SMRT Probe is turned on.

Running the SMRT Probe 4000

1. Navigate to the folder on the PC that contains the SMRT Probe 4000 installation files.
2. Double-click the file named **rgi-smrtprobe.jar**.
3. The Sentinel PowerView GUI appears (Figure 7).

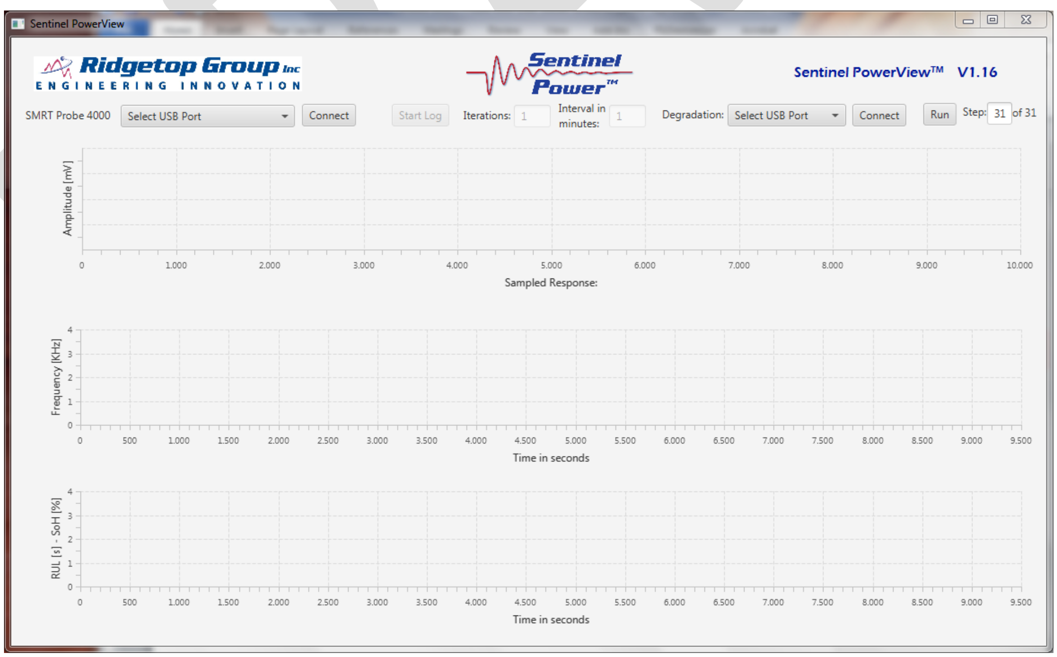


Figure 7: Sentinel PowerView interface before data collection

4. In the Sentinel PowerView interface, click the drop-down list box next to **SMRT Probe 4000** (Figure 8).

Figure 8: The drop-down list box for selecting the COM port

5. Select the COM port associated with the SMRT Probe (Figure 9).

Note: Your COM port number might differ from what is shown in Figure 9.

Figure 9: Selecting the correct COM port

6. Once the COM port is selected, click the **Connect** button (Figure 10).

Figure 10: With the correct COM port selected, click Connect

When the device has connected, the button name changes to Disconnect (Figure 11).

Figure 11: Once connected, the button name changes to Disconnect

Note: The connection might not occur instantly.

7. Once the connection is made, a damped waveform appears and above that, a frequency reading expressed in kHz, as illustrated in Figure 12. Your frequency value will differ from what is shown in the picture.

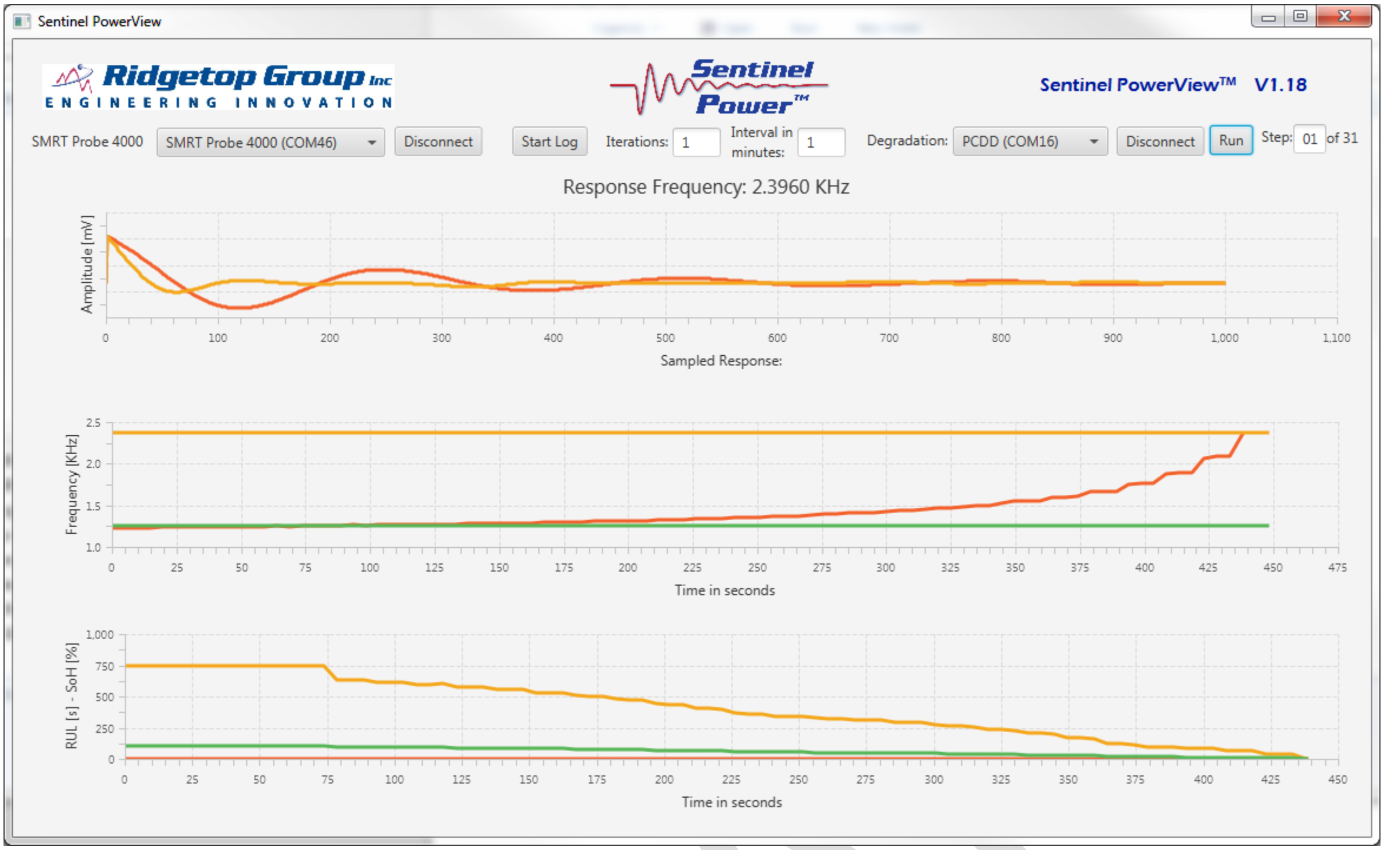


Figure 12: The top graph shows damped waveform and frequency reading; middle graph shows frequency over time; bottom graph shows RUL and SoH over time

- In the top power source probe response graph, the vertical axis titled **Amplitude** indicates mV. The horizontal axis indicates sampled response. The red line shows the nominal response (the healthy state), and the orange line shows probe response (actual response).
- In the second graph, the vertical axis indicates **frequency in kHz**. The horizontal axis indicates time in seconds. The red line represents the probe response at the power supply; when it is below the green line, the power supply is not degraded. The orange line represents the preset Ceiling threshold; if the probe response rises above that point, the power supply is considered failed. In a failed condition the state of the power supply is defined as 0% healthy; and even though the power supply might still be operating, complete failure is imminent. The green line shows the preset Floor threshold; if the probe response rises above that point it means the power supply is considered degraded. In a degraded condition, the health state of the power supply is less than 100% healthy.
- In the third graph, **Remaining Useful Life (RUL)** and **State of Health (SoH)**, the numbers along the vertical axis represent the predicted RUL and SoH in percent. In an actual application, remaining useful life is predicted in months, weeks, and days. The horizontal axis indicates the time in seconds that the test

has run. The red line is the RUL floor, the green line indicates the SoH, and the orange line represents the power source's RUL.

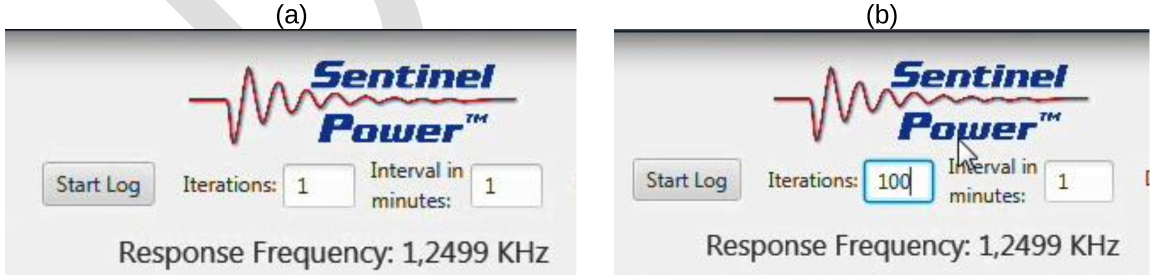
Running a Test and Using the Data Logging Feature

1. In preparation for running a test, set the desired number of iterations (that is, the number of SMRT Probe 4000 assessments to be made over time) and the desired interval time between assessments, in the dialog box shown in Figure 13 (a). The interval time is expressed in minutes. The combination of the number of iterations and the interval time in between assessments determines the overall test execution time.

   In Figure 13 (c), the number of iterations is set to 100 and the interval time is set to 17, meaning that an assessment will be made every 17 minutes and that in total 100 assessments will be made over a time period of 1700 minutes. (Figure 13 (b) shows 100 iterations at one-minute intervals.)

2. To start the test, click the **Start Log** button (Figure 13 (a)). Once the test is started, the name of the Start Log button changes to Stop Log (Figure 13 (d)) and the number of iterations decreases by one, because after you click the Start Log button, a first assessment is made and an output file is created in the directory where the SMRT Probe 4000 software is installed. The output file name has the following naming convention: **sp-mm-dd-yyyy-hh-mm-ss.csv**, where in the actual filename, dd is replaced by the number of the day on which the test is started, mm is replaced by the number of the month, yyyy is replaced by the value of the year, hh by the hour, mm by the minute, and ss by the seconds. For example, a filename of "sp-11-23-2014-10-11-12.csv" means that the file contains data from a test that was started on 23 November 2014 at 10:11:12.

(a) (b)



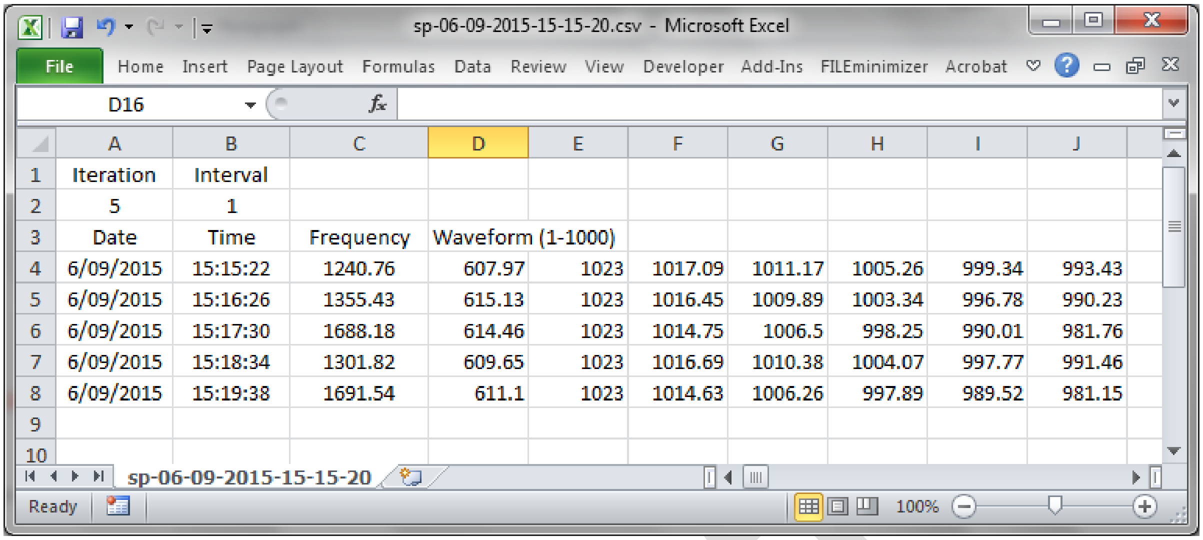
(c) (d)

Figure 13: Examples of logging settings

While the test is running, the Iterations and Interval fields are dimmed (Figure 13 (d)).
When the test is completed, the text on the button will change to “Start Log” again as an indication that the test is finished. You can interrupt an ongoing test at any time by clicking the **Stop Log** button. When the test is finished or aborted, the Iterations and Interval Fields become active (editable) again (Figure 14).

Figure 14: After logging is stopped, the Iterations and Interval Fields are once again editable

3. When the test is finished (upon completion or after aborting), a comma-separated file is available that contains the test results and that can be used as input for further data processing. The content of the file is as illustrated in Figure 15.



	A	B	C	D	E	F	G	H	I	J
1	Iteration	Interval								
2	5	1								
3	Date	Time	Frequency	Waveform (1-1000)						
4	6/09/2015	15:15:22	1240.76	607.97	1023	1017.09	1011.17	1005.26	999.34	993.43
5	6/09/2015	15:16:26	1355.43	615.13	1023	1016.45	1009.89	1003.34	996.78	990.23
6	6/09/2015	15:17:30	1688.18	614.46	1023	1014.75	1006.5	998.25	990.01	981.76
7	6/09/2015	15:18:34	1301.82	609.65	1023	1016.69	1010.38	1004.07	997.77	991.46
8	6/09/2015	15:19:38	1691.54	611.1	1023	1014.63	1006.26	997.89	989.52	981.15
9										
10										

Figure 15: Sample CSV log file content

For the example shown in Figure 15, the number of iterations was set to 5 and the interval time was set to 1. The first column contains the date stamp when the assessment was done, the second column contains the time stamp, the third column contains the frequency (expressed in Hz), and the subsequent columns contain the first 1000 samples of the sampled damped oscillation waveform (as shown in the GUI).