Vibration Sentry RT

Shipment Monitoring Applications

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1   Introduction

The *Vibration Sentry* series datalogger can be used to monitor shipments in transit and record adverse events such as shocks, high vibration levels and/or tilt. In order to do that properly, careful attention must be paid to the instrument's configuration and installation. This document discusses the dos and don'ts of shipment monitoring.

2   Long Term Monitoring

In order to monitor shipments in transit the *Vibration Sentry* must record data for very long periods of time, ranging from a few days to a few weeks or months. Two parameters affect the length of the recording and must be watched closely:

2.1   Power Consumption

The power consumption must be low enough that the instrument will not run out of battery before the end of the trip. Power consumption is roughly proportional to the accelerometer's sampling rate. So in order to have battery times ranging in the weeks and months the sampling rate must be low enough. For instance a sampling rate of 400 Hz will provide a battery time in excess of 50 days. A sampling rate of 100 Hz will give approximately 120 days of battery time. The sampling rate must not be so low however that it won't allow the detection of short transients.

> *Hint: After adjusting the sampling rate, the total number of battery hours is calculated automatically and reflected in the scale to the left of the battery gauge in Vibration Sentry RT Manager (see Figure 1).*
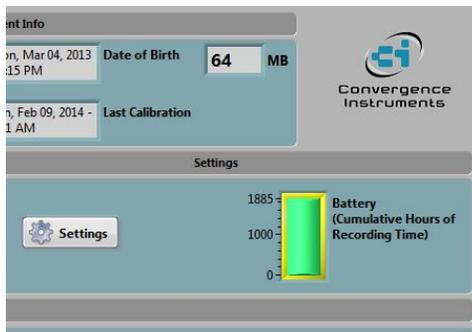
Figure 1   Battery Gauge

2.2   Memory Consumption

The memory must not be exhausted before the end of the trip. So the type of values that are being recorded and the log interval must be adjusted appropriately. Recording the raw signal is not recommended. Even at low sampling rates, recording the raw signal continuously will fill-up the memory in no-time. The only way to record raw signal in a shipment monitoring application is to use the *Auto-Rec* function. However that function is not recommended as the primary source of information. If the *Auto-Rec* threshold is adjusted too low, this can lead to hundreds, even thousands, of records over the course of the trip. If the threshold is too high, relevant events may be missed altogether.

There are two types of statistics that can be recorded as the main source of information:

- **Acceleration Statistics:**   The min, max and average of the acceleration signal over each log interval.

- **Vibration Level Statistics:** The min, max and average of the RMS vibration level over each log interval.

These two types of statistics will monitor the signal on a sample-by-sample basis, and will not miss anything. However they will preprocess the signal at the instrument level and only store one statistical value at every log interval. This allows the recording to properly reflect any adverse event that occurred during the trip, but will not fill-up the memory prematurely.

Hint: After adjusting the values to be recorded and the log interval, the total memory size is calculated automatically in Days/Hours/Min of recording time, and reflected in the scale of the Memory-Depth bar in Vibration Sentry RT Manager (see Figure 2).
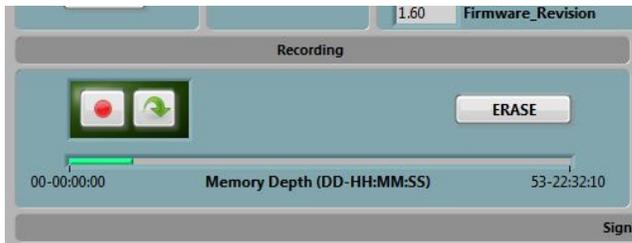
Figure 2   **Memory Gauge**

3   Bandwidth Issues and Instrument Mounting

When measuring accelerations due to shocks the accelerometer's bandwidth can have a dramatic effect on the measured waveform. A shock, or an impact, is essentially a very sharp and short pulse with a very high acceleration value. Only measuring the height of the shock pulse without consideration for the measurement bandwidth can be very misleading. For instance a very benign glass-on-glass impact, measured with a 100 kHz-bandwidth accelerometer can easily show acceleration impulses in the hundreds, or even thousands of g!

A very wide-bandwidth shock, such as a glass-on-glass impact, has an acceleration impulse that is extremely high in amplitude, but also extremely short in duration. It carries a very small amount of energy. As the measurement bandwidth is reduced the pulse is spread-out in time, and lowered in amplitude.

To properly measure and compare shocks it is imperative to limit the measurement bandwidth to reasonable values. This is achieved by:

1. **Selecting a low-enough sampling rate:** A sampling rate in the range of 100Hz to 400 Hz is usually appropriate)

2. **Properly mounting the instrument**: The best way to mount the instrument is to attach it to the transported equipment or goods, inside the packing. The layers of packing material will insulate the instrument from wide-bandwidth very high-g transients and lower the acceleration signal bandwidth to reasonable levels. In addition, the accelerations measured will then be those that the transported equipment is subjected to, rather than those that the external framework is subjected to. The worst place to mount the instrument is onto an external container. Metal-on-metal shocks can create very high-g events that are not always representative of the accelerations that the transported goods are subjected to.

4 What to Record

Even at a low sampling frequency such as 100 Hz or 400 Hz it is not possible to record raw acceleration signals continuously for more than a few hours. In order to detect and record adverse events over longer periods of time one of the strategies discussed below must be used.

4.1 Primary Information

We recommend measuring either of the following two types of data as the primary source of information:

4.1.1 Acceleration Statistics

The min, max and average of the raw acceleration signals are captured over each log interval. With a log interval of 1 to 10 seconds the instrument can record for a few days, up to a month, on all three axes. This setup is often chosen when the tilt of the shipment is of interest. In this case, no high-pass filtering is applied, which preserves the static 1g acceleration of the earth's gravity. The min and max of the acceleration signals represent the envelope of the acceleration signal over each log interval and properly reflect the amplitude of the largest event (shock or vibration) during each log interval (see *Figure 3*).
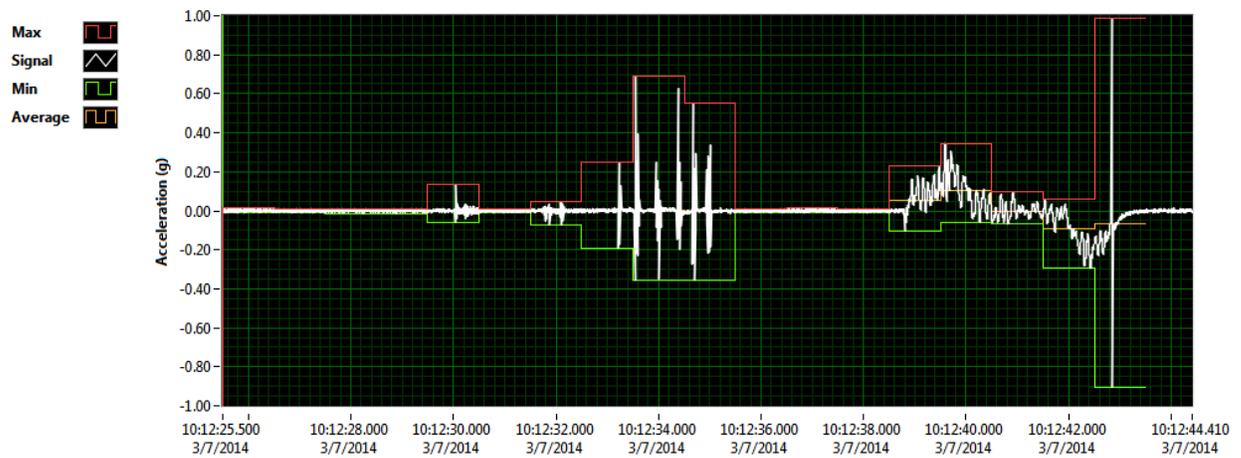
Figure 3   **Acceleration signal, min max and average values captured over 1s log intervals.**

4.1.1.1 Typical Settings
Figure 4 shows a typical setup for measuring acceleration statistics. In this case no high-pass filter is applied and the acceleration average is recorded. That static acceleration average over each log interval will be used to measure the tilt of the shipment in both axes. The *Vibration Sentry RT Manager* application will be used to display acceleration averages as tilt angles as a function of time.

The min and max values of the acceleration signals will be used to reflect the amplitude (or envelope) of the acceleration signal. The *Vibration Sentry RT Manager* application will be used to display acceleration extremes as a function of time.
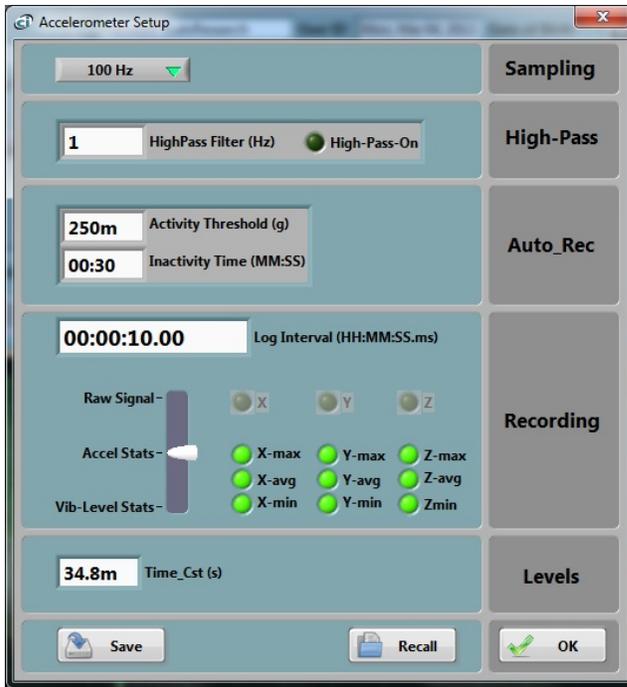
Figure 4   Typical Setup for measuring Acceleration Statistics

4.1.2   RMS Level Statistics

The Root Mean Square amplitude of the acceleration signal is calculated as a function of time. Then the min, the max and the average of the RMS levels can be captured over the length of each log interval. With a log interval of 1 to 10 seconds the instrument can record for a few days, up to a month, on all three axes. This setup is often chosen when only the vibration levels or shock levels are of interest. In this case, a high-pass filter must be applied to center the acceleration signals around zero, and avoid having the DC value bias the RMS calculation. A cutoff between 1 Hz and 5 Hz is usually a good compromise. The max of the RMS level is representative of the peak amplitude of the acceleration signal over each log interval and reflects the amplitude of the largest event during each log interval (see *Figure 5*). The min of the RMS level is indicative of the quietest level during the log interval and is often not relevant to shipment monitoring applications. The average of the RMS level over the log interval has only limited value. When the difference between the max and the average is high that indicates the presence of very short isolated events. On the other hand, when the max is close to the average that is indicative of a fairly constant vibration level over the whole log interval.

In order for the instrument to react quickly and properly capture very short transients the time constant for the RMS estimator needs to be set to a small value. A value between 25 ms and 125 ms is often appropriate.
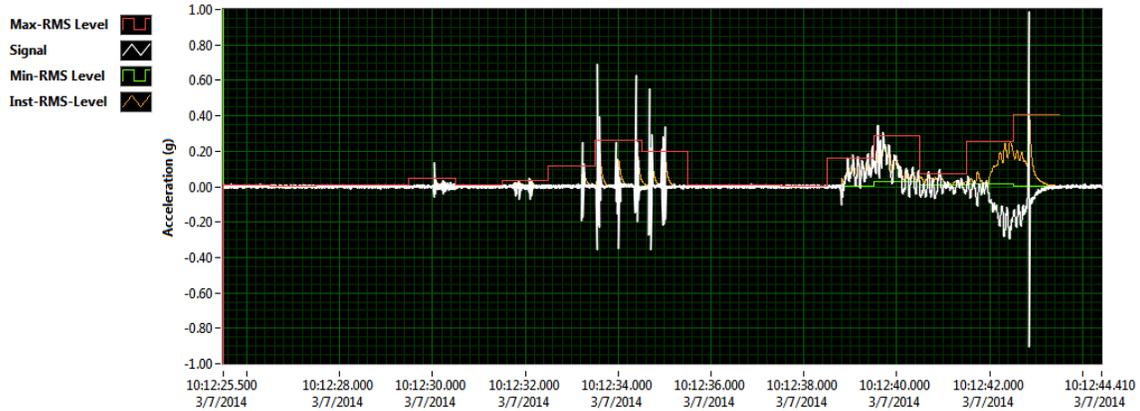
Figure 5   Acceleration Signal, Instantaneous, Min and Max RMS Levels
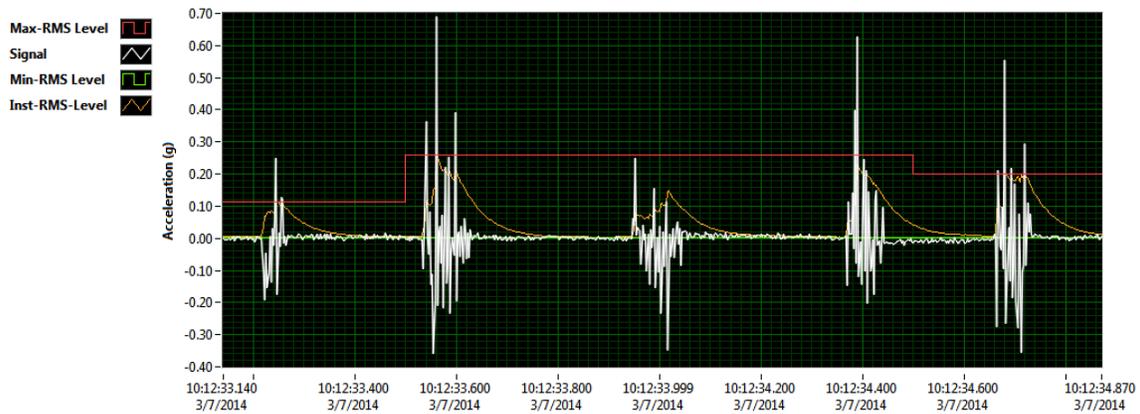
Figure 6   Zoom on Figure 5 showing the continuous evolution of the RMS Level as a function of time. The time constant of the RMS estimator is set to 25 ms (very short).

4.1.2.1   Typical Settings

Figure 7 shows a typical setup for measuring vibration level statistics. In this case a high-pass filter is applied with a cutoff at 1 Hz in order to eliminate the DC component from the RMS calculation. Only the max and average levels are recorded. The min RMS level, which represents the quietest level during the log interval is usually of no concern in shipment monitoring applications. The *Vibration Sentry RT Manager* application will be used to display max and average RMS levels, either in linear scale or decibel scale (dB) as a function of time.

Note that the *Time_Cst* value is adjusted to a very short value (34.8 ms). This is required for the RMS estimator to react quickly to sharp transients and properly capture shock events.
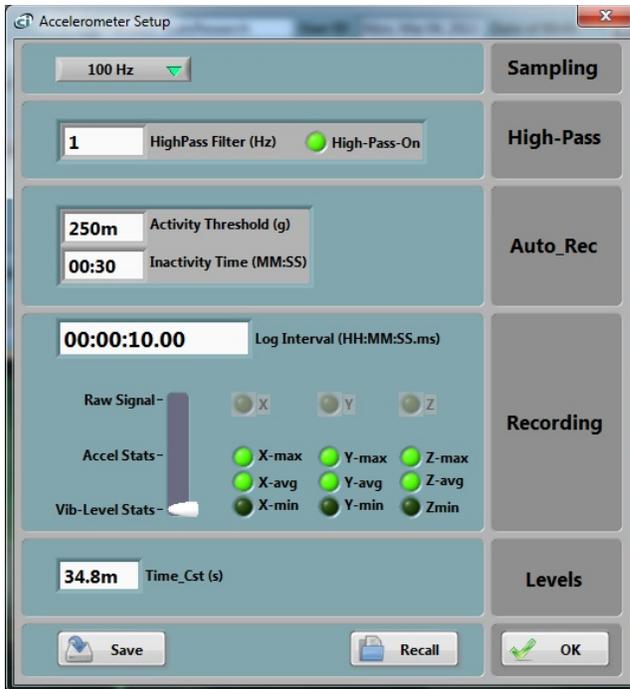
Figure 7   Typical Setup for measuring Vibration Level Statistics

4.2   Secondary Information

It is possible to record short segments of raw signal over long periods of time. However that entails using the *Auto-Rec* function. When using the *Auto-Rec* function the instrument is mostly asleep. It only wakes up and starts recording whenever the acceleration signal passes a pre-adjusted threshold, and will keep recording until the acceleration signal stays under the threshold for a pre-adjusted length of time.

We do not recommend using this mode of operation as the primary source of information because it presents the following difficulties:

- The trigger is detected in hardware and cannot be adjusted as finely and as precisely as the recorded data itself. More importantly it cannot be adjusted to a level lower than 125 mg.

- When the instrument is asleep the sampling rate is only 8 Hz in order to preserve battery. This sampling rate can be low enough to sometimes miss very fast transients such as sharp shocks.

- For a particular setting of the threshold it is notoriously difficult to predict how many events will be detected during the whole trip. This can lead to hundreds or even thousands of events being detected if the threshold is set slightly too low, or can lead to some events being missed if the threshold is set slightly too high.

Nevertheless the *Auto-Rec* mode can be used as an additional source of information, running on a separate *Vibration Sentry RT*. That information may complement the acceleration statistics, or the vibration level statistics, with complete waveforms for later analysis.

4.2.1.1   Typical Settings
Figure 8 shows a typical setup for measuring raw signals. In this case a high-pass filter is not applied. Since the signals are raw it will always be possible to apply a filter in post-processing (using the *Wave-*

Analysis application for instance). The sampling frequency can be kept high. The trade-off here is that the total number and duration of the recordings during the whole trip must not exhaust the memory before the end of the trip. The activity threshold is kept at a high value in order to avoid triggering on trivial events. The inactivity time is kept to a short value to allow the recording to stop quickly after the acceleration level falls back below the threshold.
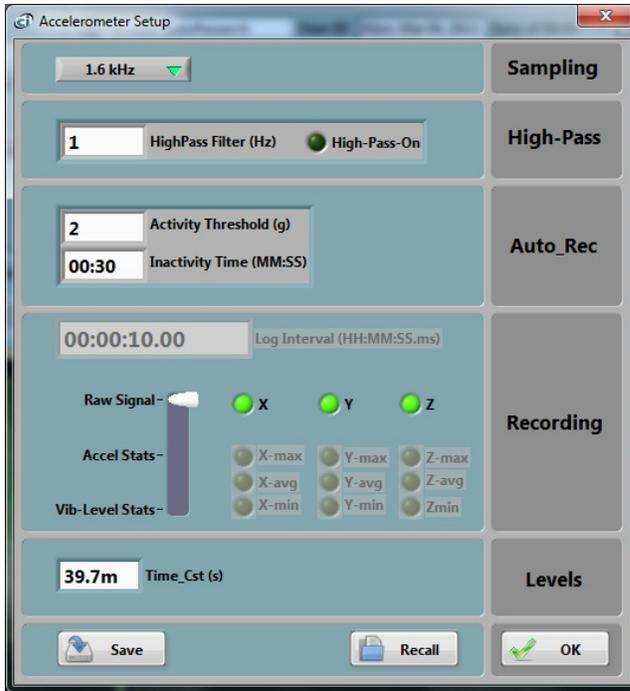
Figure 8   Typical Setup for measuring Raw Signals

5   Off-Site Start

In many shipment monitoring applications someone has to start the recording at the departure point. Often, this is not the same person who will be analyzing the data after arrival. In order to simplify the task of the person who must start the recording, the *VSRT_SimpleStart* application has been developed. That application allows the user to start the recording in a very simple manner, either using the present setting of the instrument, or using a setting file that has been prepared in advance by someone else who knows and understands the instrument. All of the instrument setup, as well as the verifications and checks that should be performed at startup (such as verifying that there is enough memory and battery for the trip) are completely automated by the application.