SeTAC

Triaxial Vibration & Collision Monitoring System

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ABSTRACT

Today's manufacturers business is the growing of production with existing machinery, while continuing to cut costs. But the most harmful cost is unplanned equipment and manufacturing process downtime.

This paper is focused on a new strategy to monitor equipment and machinery in order to reduce these harmful costs.

The Sequoia IT SeTAC could be used in several processes in a manufactory plant. Thanks to its innovative technology, it has the ability of detecting impending mechanical failures in working processes at the early stages of fault development and detecting shocks and collisions during the working process, saving these information on the sensor internal memory.

The SeTAC reduces considerably the costs and difficulty of acceleration and vibration monitoring in industrial environment.

The SeTAC is a highly sophisticated sensing device which takes advantage of new technologies and manufacturing techniques, coupled with the in house development of advanced hardware and software solutions, to provide an accurate and reliable monitoring system. It is a smart sensor capable of signal discrimination, conditioning, analysis and digital communication. Moreover, the auto-diagnosis function always ensures measure reliability.

Thanks to the programmability of the device, the SeTAC can be configured to perform different functions. It is enough to install the device in the desired location and supply the required voltage in order to have a reliable monitoring system.

Within this short technical document it will be explain the whole functioning SeTAC system, its application software for process monitoring, how to use it and real case history.

SeTAC GENERAL DESCRIPTION

All the industrial machines utilise working gears and members in motion which produce dynamic forces, vibrations and accelerations on the machine itself and on structures which are connected to the equipment. The ability to obtain an accurate description of the vibration by measurement and analysis can provide an invaluable contribution for gathering reliable information on the behaviour of the machine under different conditions, on the working process and on the quality of the final products. By using this information effectively, it is possible to identify problems and asses their causes, evaluate the effect of proposed changes on the overall process and make meaningful decisions on the production system.

However, despite the growing awareness on the importance of this information, monitoring and detecting these often small variations has not been so far technically or economically easy to obtain. Moreover, existing systems are expensive and complex.

The SeTAC is built on the latest technological innovations and is able to provide a precise and reliable monitoring system. It can work as an autonomous monitoring solution in new, modern systems, be installed on old equipment or structures, replace or be integrated within existing installations. It offers high performance and reliability in a small and robust case. Due to the miniaturisation of the components that build the system, the integration of different functions in a unique device and the measurement accuracy, the SeTAC is surely one of the most advanced vibration monitoring systems available on the market.

Figure 1: SeTAC axis

The Sequoia Triaxial Acceleration Computer (SeTAC) is a device that includes three MEMS accelerometers, one for each of the Cartesian axis. The accelerometer signals are then computed by a microprocessor that is integrated within the SeTAC. This
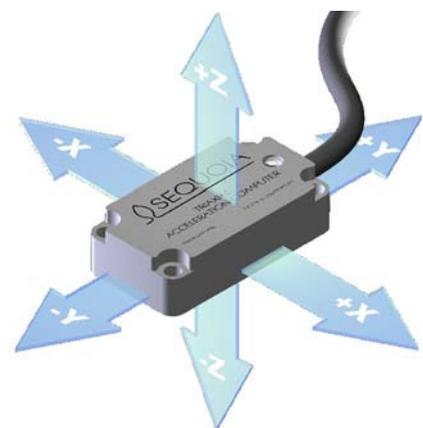
microprocessor performs the signal analysis and data communication functions on the basis of the uploaded application.

It is programmable and fully customisable and is able to supply digital outputs. These outputs can be configured to provide an alarm signal and are logically suitable for being used as input signal by common devices, like PLC, actuators, etc,..

The SeTAC monitoring concept is extremely flexible because it allows to monitor and evaluate a wide range of phenomena by simply changing the installed software. A common notebook or any other computer can be used to upload programs in the SeTAC internal, non-volatile memory. During normal operations, the Personal Computer operate as a graphical-user-interface, providing the ability to display waveform signals, modify filter settings and configure vibration thresholds appropriate to the working process. Once all the configuration parameters required for an application have been set, they are saved in the SeTAC non-volatile memory and the computer can be removed. Indeed, the SeTAC is fully capable of operating utilising only the digital I/O without connection with the PC.

APPLICATIONS

The SeTAC can be used for a wide range of applications, thanks to the programmability of the device. Indeed, it can be easily configured and work differently according to the uploaded software. Typical applications include shock monitoring, vibration measurement and analysis, tilt sensing and centrifugal force measurement in all the environments. A list of the applications in which the SeTAC has already been employed is provided in the figure 2.

SeTAC allows the Real-Time Monitoring of equipments. The competitive advantages of this monitoring activity are:

- ❐ to determine Performance Issues;
- ❐ preventive & predictive maintenance;
- ❐ manufacturing line stability;
- ❐ increased productivity;
- ❐ decrease wastages;
- ❐ protection of manufacturing equipment (Collision detection);
- ❐ faster problem detection / identification;
- ❐ simple and fast Process optimization;
- ❐ longer machine life time;
- ❐ planned Maintenance;
- ❐ reduce scrap and improve quality due to immediate detection of process variations.
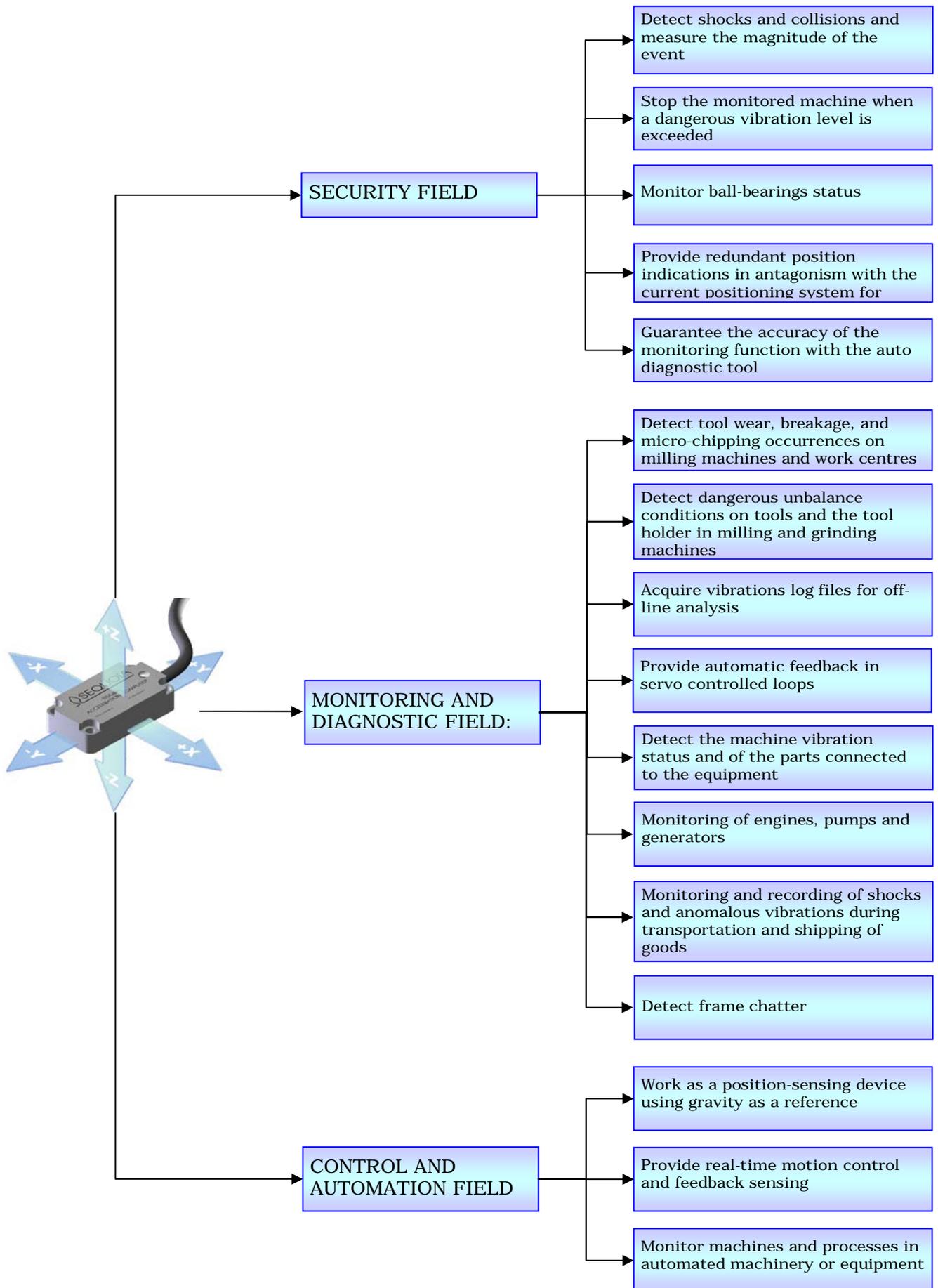
SEQUOIA

SECURITY FIELD
- Detect shocks and collisions and measure the magnitude of the event
- Stop the monitored machine when a dangerous vibration level is exceeded
- Monitor ball-bearings status
- Provide redundant position indications in antagonism with the current positioning system for
- Guarantee the accuracy of the monitoring function with the auto diagnostic tool

MONITORING AND DIAGNOSTIC FIELD:
- Detect tool wear, breakage, and micro-chipping occurrences on milling machines and work centres
- Detect dangerous unbalance conditions on tools and the tool holder in milling and grinding machines
- Acquire vibrations log files for off-line analysis
- Provide automatic feedback in servo controlled loops
- Detect the machine vibration status and of the parts connected to the equipment
- Monitoring of engines, pumps and generators
- Monitoring and recording of shocks and anomalous vibrations during transportation and shipping of goods
- Detect frame chatter

CONTROL AND AUTOMATION FIELD
- Work as a position-sensing device using gravity as a reference
- Provide real-time motion control and feedback sensing
- Monitor machines and processes in automated machinery or equipment

Figure 2: SeTAC application fields

SeTAC TECHNICAL DESCRIPTION

General features

Bandwidth:	linear DC up to 2500 Hz
Configuration	Triaxial accelerometer
Response time:	< 1 ms

Sensor elements

Type:	Capacitive micro-milled silicon MEMS
Bandwidth:	DC from 0 to 2500 Hz
Dynamic range:	85 dB @ 10Hz
Full scale range:	± 18 g full scale

High Linearity

Low hysteresis

Low Cross Axis Sensitivity

Resolution:	1 mg @10Hz
Shock:	Up to 1000 g

Minimum temperature offset drift

Integrated temperature sensor

Electrical characteristics

Supply Voltage:	20÷36 VDC
Supply Current:	200 mA
Communication:	RS232 or USB
Serial communication protocol:	USB/RS232 up to 38 kBaud
Physical Outputs (relay contacts):	Out1 and Out2 = 240Vdc, 6A;
	Out3 =240Vdc, 150mA

Real time clock battery autonomy without power supply: 20 months

Inputs/Outputs:

3 digital outputs

2 digital inputs (maximum voltage to be applied: 24V)

1 Serial RS232 (user interface and remote configuration)

1 Serial USB (user interface and remote configuration)

Power: 20÷36 VDC power supply, 200 mA

Cable: 2 m, polyurethane jacket. PUR shielded. Cable extensions may be used but cable length should not exceed 30m length.

Housing / Environment

Case: Aluminium box, 30 x 55.5 x 15mm (see Fig. 3)

Weight:	55 g
Protection index:	IP67
Temperature Operating:	-20° to 70 °C
Storage:	-40° to 100 °C
Humidity:	0 to 100 %
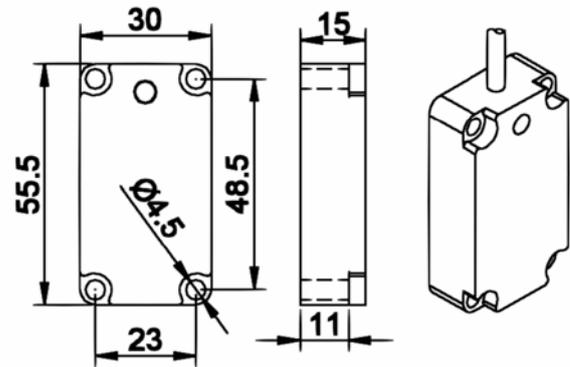
Figure 3: Dimensions of the SeTAC aluminium case

SeTAC INSTALLATION

Due to the variety of the functions that can be performed by the SeTAC, mounting information cannot be specific for all the equipment and applications. Therefore, the guidelines detailed in the following paragraphs are only the general instructions that should be considered for mounting and the electrical connection of the sensor. Installation and service of the SeTAC must be performed either by people who's trained and by Sequoia IT personnel and according to Sequoia IT guidelines and suggestion, or directly by Sequoia personnel.

Positioning

The SeTAC should be mounted in a place where the phenomena to detect can be mechanically transmitted to its box. The closer the sensor is mounted to the source, the more satisfactory will be the monitoring results. Care must be taken in mounting the sensor and attention is required in order to prevent damages to the sensor, to the cable and to the machinery to which the SeTAC is applied.

The SeTAC box must be secured to the equipment that has to be monitored by drilling and screwing (there are 4 holes for mounting), especially if the disturbances to detect are high in frequency. In order to get the best signal measurement and analysis, the SeTAC should be mounted on a flat surface, prepared using the sensor dimensions as guidelines.

Moreover, care must be taken to the fixing devices. These must be securely fastened so that they do not add other vibrations to the monitoring system and do not modify the signal that is measured by the SeTAC. The sensor must be mounted on the most relevant part of the equipment, i.e. the point in which the measured vibration is effectively representative of the overall stress to which the equipment is subject. For example, when the monitored equipment is a metal cutting machine, the recommended location for fixing the sensor is the machine spindle nose.

It is necessary to be cautious not only to the way in which the SeTAC is fixed to the equipment, but also to the cable mounting. Secure the cable with appropriate mechanical fasteners, being careful not to break the insulation or crush the internal wiring. Provide adequate slack in the cable to allow it to flex when moving machine elements are present.

Programming

The SeTAC belongs to the category of the smart sensors. It is a programmable device and can perform different functions according to the uploaded software. By using a personal computer – connected to the SeTAC via RS232 or through the USB port – and the SeTAC Interface board that is provided together with the SeTAC, it is possible to modify the current monitoring parameters. Moreover, a new software can be uploaded into the device at any time. In daily use, the SeTAC is only connected with power supply and a PC only serves as a graphical user interface for displaying waveform signals.

The diagram shown in the following figure provides a quick indication of the connection scheme to be applied for programming the SeTAC.
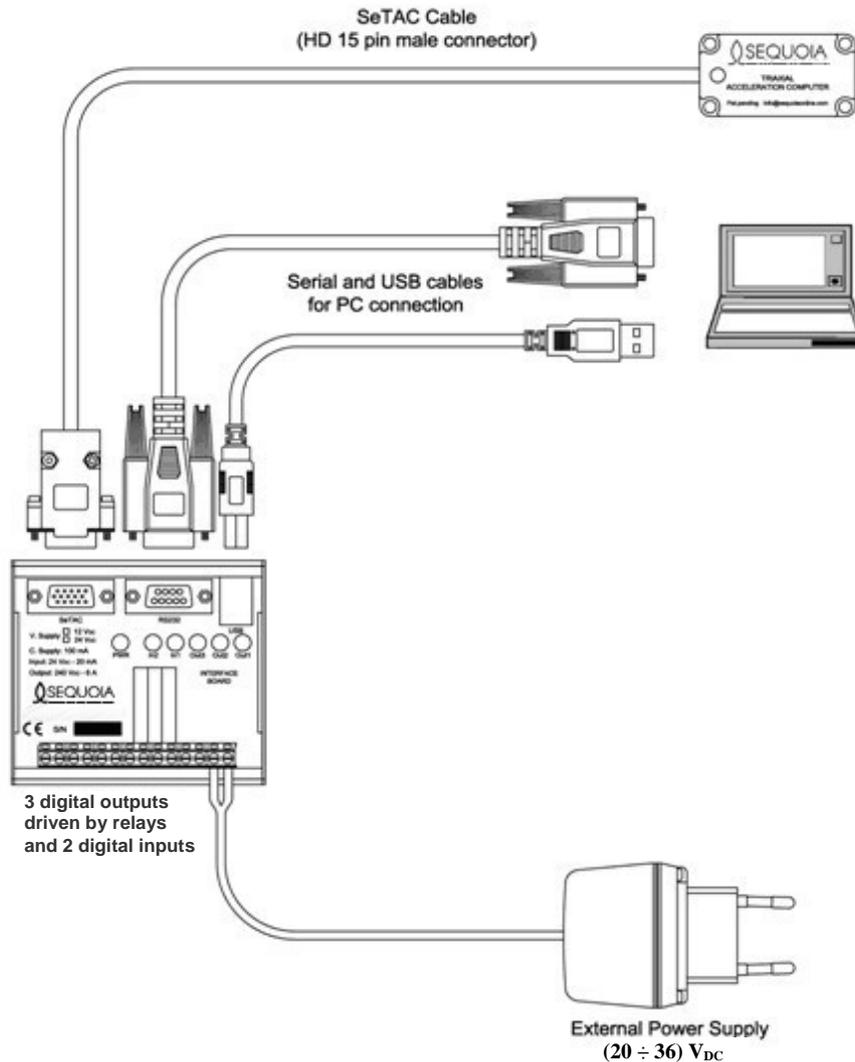

Figure 4: SeTAC programming connection diagram

The SeTAC is provided together with the SeTAC Interface. It is a programmer and signal repeater that makes easy the connection of the sensor with the PC, the PLC, the machine control and any other panel providing input or output signals to the monitored equipment. The major Interface Board components are identified in the photograph and in the table below.

Figure 5: SeTAC Interface

Component	Description
SeTAC	15 pin D-type HD conn. to link the SeTAC Interface
RS232	Serial 9pin D-type conn. to link a PC (in alternative to USB)
USB	USB conn. to link a PC (in alternative to RS232)
PWR	Led power ON: it stays ON as long as power is available
IN/OUT	Led for visual indication of the sensor I/O status
Relays	The relays are used for output electrical de-coupling
Terminal block strip	14 pin strip providing connection for input, outputs and power

Power supply must be provided to the Interface Board by the 24Vdc electrical cabinet line. The programming box should be installed into the cabinet using the DIN rail mounting provided. It is suggested to install the Interface in a protected location (required protection index: IP65).

Wiring for inputs, outputs, power and the monitoring function is provided through the terminal block connector on the Interface Board. A view of the Interface board pin out connector is shown in figure 6:
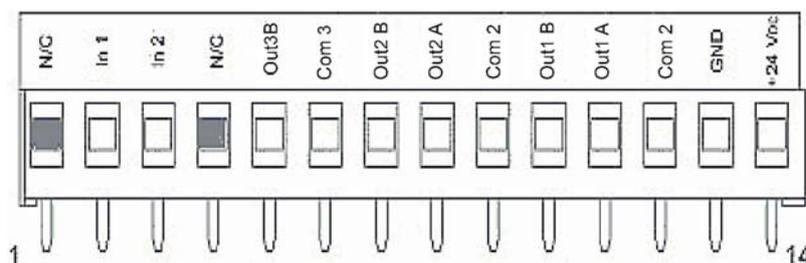
Figure 6: Interface Board terminal block connector

Connection information (including the pin number, label, pin description and function) is provided in the following table.

PIN #	Label	Description	Function
1	N/C	Not Used	Not Connected / Not Used
2	In 1	Input 1	Monitor Active
3	In 2	Input 2	Auxiliary Input
4	N/C	Not Used	Not Connected / Not Used
5	Out3B	Output 3 NC	Normally Closed Output
6	Com 3	Output3 Common	Common 3
7	Out2 B	Output 2 NO	Normally Open Output
8	Out2 A	Output 2 NC	Normally Closed Output
9	Com 2	Output2 Common	Common 2
10	Out1 B	Output 1 NO	Normally Open Output
11	Out1 A	Output 1 NC	Normally Closed Output
12	Com 2	Output 1 Common	Common 1
13	GND	0 V	Ground
14	+ 24 VDC	+ 24 VDC	+ 24 VDC

The main features of the SeTAC Interface board can be described as follows:

- ❏ small footprint (90.5 mm x 82 mm);
- ❏ programmable Logic Controller;
- ❏ serial and USB connection to computer;
- ❏ leds providing a visual indication of the sensor I/O status.

Inputs

Two inputs are available on the Interface Board.

Input 1 is used to control the time rating of the process that the SeTAC is monitoring. It is referred to the term Monitor Active and enables\disables the monitoring operations from SeTAC.

Input 2 is the Auxiliary Input; it is used for different purposes by each application (please, refer to the datasheet of the software you are interested in for connection information).

Outputs

Three outputs are available on the Interface Board. These are identified on the terminal strip by the labels O1, O2 and O3 (please, note: each output comes on the strip with the initials NO and NC). An output signal is provided when the monitored process exceeds the limits set by the user. When such an event occurs, the corresponding led on the Interface Board goes on.

Output 1 & 2 are Relay contacts (240 VDC\ 6 A) that can be Normally Open (NO) or Normally Closed (NC) according to the monitored process and to the user's requirements.

Output 3 (240 VDC \ 150 mA) is a unique output with a high speed of response. It reacts very quickly (less than 1 ms) to abnormal working conditions detected by the SeTAC. Therefore, it is recommended to use this output for the most relevant alarm, such as engine block, machine off and so on.

If power is not applied to the Interface Board or the SeTAC has some problem (for example is disconnected or its power supply is missing or its autodiagnostic routine has failed), Out3_NC is not closed to its Common signal. So Out3 is an indicator of the good health of the whole system.

SeTAC CONFIGURATION CONSOLE

The SeTAC Configuration Console is the Human-Machine Interface software for the SeTAC monitoring system. This application works in the MS Windows operating environment and provides communication with the SeTAC through the RS232 serial port or the USB port. The SeTAC Configuration Console allows the user to:

- ❒ upload the desired application into the SeTAC;
- ❒ configure the limits and many other settings available in the software;
- ❒ visualize a process and monitor the work of any machine;
- ❒ check and download in any PC the event list or other data that the SeTAC has acquired during the monitoring process cycle.
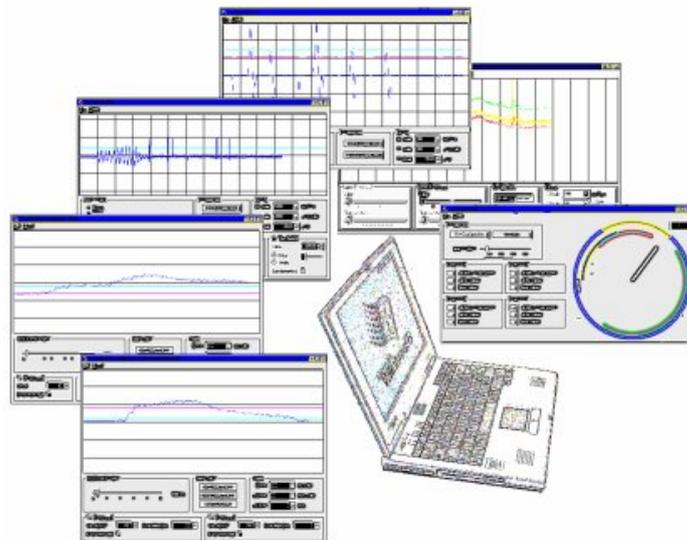
Fig. 7 SeTAC Configuration Console. Some user interfaces

Installation CD-ROM

Once you have successfully completed the installation and you run the application for the first time, it requests the authentication code that is provided together with the CD.

Together with the Help command, for identifying the installed version of the software, other three sections (i.e. Files, Tools and Firmware) make up the main menu. These sections and their submenus will be described in the following pages of this manual.

The Application

When the SeTAC Configuration Console is launched, it detects if a SeTAC is connected to the serial port (or the USB port) of the PC. If a SeTAC is found, the Configuration Console user interface is shown. The last application downloaded into the SeTAC is opened when you re-enter in the Console.

If the SeTAC is connected and powered but the application does not detect it, an incorrect COM Port number is likely to be configured. In the Settings window ('Tools > Settings') the user can set the correct port number (fig. 8).
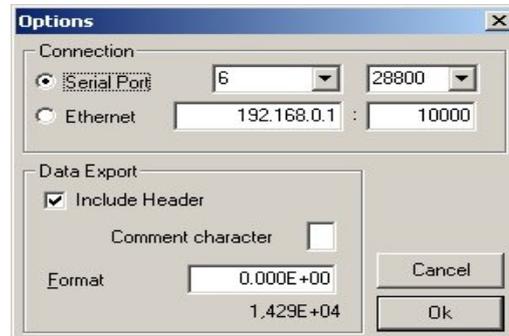

Fig. 8- Options

- ❒ Serial Port: when using a serial port to communicate with the SeTAC, confirm that the Port Number matches the one displayed in the Settings Menu Port Number Box. Serial port numbers are generally 1 or 2.
- ❒ USB Port: when using a USB port to communicate with the sensor, confirm that the virtual serial port number assigned by the USB driver matches the port Number in the Settings Menu Port Number box. USB port numbers can be read in the Windows Control Panel – System – Hardware – Device Manager, in the Ports (COM & LPT) tree.

The Status Bar (shown in Figure 9) is displayed at the bottom of the SeTAC Configuration Console Window.

Fig. 9: The Status Bar

It contains the following information on the device status:

- ❒ On chip software: it is the current application name.
- ❒ Administrator: an "A" is displayed in the panel when the administrator password has been entered.
- ❒ Warnings: this panel shows special messages such as "Output Disabled" or "Autodiagnostic Error".
- ❒ Output status: the three small panels on the right side of the interface contain the output number when the corresponding output is in an alarm state.

Administrator Privileges: many features are not available to common users. To enable these features, you need to log in as administrator by inserting the correct administrator password (Menu File – Administrator Log On). The default password for each SeTAC shipped from the factory is "SEQUOIA". The password is case sensitive.

The password can be changed by the administrator (Menu File – Change Administrator Password). It is recommended to always change the password and record it in a safe place based on each company's policy and procedures.

The system feature available only to the administrator include:

- ❒ changing the application that is running on the SeTAC;
- ❒ modifying global settings, like the Output Disable option or the device clock time;

- ❑ modifying software-specific settings;

- ❑ loading previously stored configuration from a file.

- ❑ Once the application has been configured, the Administrator should log off (Menu File – Administrator Log Off) to avoid that other users can change the system settings.

Choosing the application: the SeTAC performs different tasks according to the software that is running. The user can upload a software simply by selecting it in the Firmware menu (fig. 10).
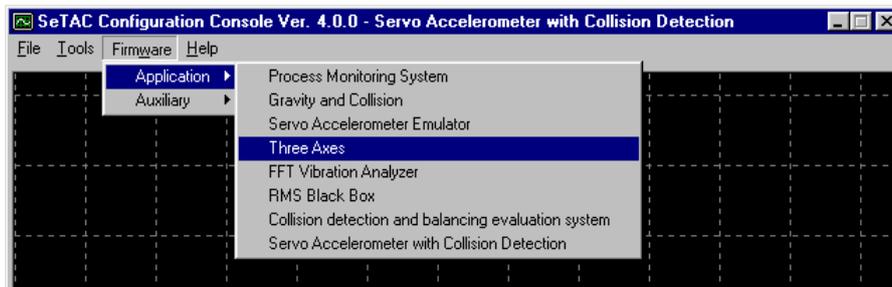

Fig. 10: Firmware menu

The available software are divided into two groups:

- ❑ Application: it contains the algorithms that are used more frequently

- ❑ Auxiliary: it includes the test utility and other software applications useful for diagnostic purposes.

Event Log: the SeTAC stores in its internal, non-volatile, memory all the significant events that have happened during the monitored period. The event log can store up to 12288 entries. The last event to occur in the process will be the first event to be displayed by the SeTAC.

The event log is always active and available to the user. It can be used to rebuild the whole history of the monitored equipment. The content of the list cannot be deleted or modified, making it a reliable black box useful for diagnostic and warranty scopes. Therefore, it is a permanent record associated to the monitored process. When the Event Log is full, the SeTAC overwrites the recorded data starting from the oldest one.

Each event is stored within the SeTAC with the date and time information. The different kinds of events that are logged may be such things as:

- ❑ Power on and off;

- ❑ Configuration changes;

- ❑ Alarms that have taken place.

Fig. 11: Event Log window

You can open the Event Log window (Fig. 11) from the Tools Menu (Tools – Event Log – On Device). The most recent events are shown at the top of the list and are immediately available to the user, whereas the download of the entire list can take some time. The entire list can be saved to a file (Menu Tools – Event Log – Save to File) and browsed later (Menu Tools – Event Log – Load from File) even without the

SeTAC connected. Be careful that only the data downloaded from the SeTAC will be saved to the file: you have to wait the download operation to be completed before saving the list to a destination file.

Settings Archive / Restore: once the SeTAC configuration, the filter cut frequency and the limits have been set, they are permanently saved in the device and automatically reloaded on each power on. In order to program another SeTAC with the same monitoring parameters, or replace a failed unit, the Archive / Restore functionality is provided in the "Tools Menu". Use the Save to File command (Tools – Archive – Save to File) to store in a file all the settings of the device. These settings can then be reloaded in the same SeTAC or in another sensor with the Load from File command (Tools – Archive – Load from File).

Global settings In the Device Settings window (Fig. 8, menu 'Tools – Device settings') the user can visualize and adjust the SeTAC internal clock. Use the "Synchronize with PC" button to synchronize the device clock with a PC or open CNC internal clock). Moreover, the Output Disable function can be selected by clicking within the white check box.

If this mode is selected, no alarm will be provided. No other variation will affect the behavior of the system: the software will work as normal, except for a red blinking box in the status bar. This feature can be useful to set up the application without giving any alarm to the interface. Turn-off delay sets the lenght for the alarm visualization.

Fig. 12: Device Settings

Monitor Active: The Monitor Active input enables the monitoring activity of the SeTAC. When the Monitor Active is not enabled, the limits are not activated even if the user try to select them in the user interface. This can be noted because the limit boxes remain white even if they have been checked (please, refer to the paragraph "Common Features of the User Interface" for further information on the limit setting function). Without the MA, no alarm will be raised and no alarm entry will be written in the Log Book.

Continuous Autodiagnostic: the SeTAC is able to perform a self test procedure to check the functionality of the system components. If the test fails, an alarm is issued on output 3 and the event is added to the log. This feature always ensures the reliability of the monitoring function and makes the SeTAC the most appropriate application for all the tasks that require guaranteed uninterrupted control.

Common Features of the User Interface

The oscilloscope: Most applications utilizing

a signal with a time domain, that can be displayed by

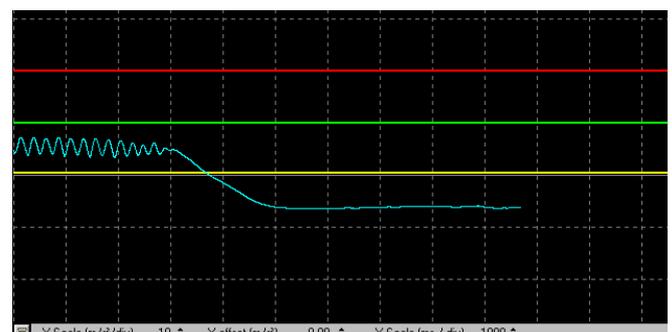the Oscilloscope function (fig. 13) in the user

interface.

Fig. 13 The oscilloscope

It is a useful tool for visualizing in real time the signal that is processed by the SeTAC and the associated limits. Moreover, the Oscilloscope can be used to check the limits and filters settings for the downloaded software.

The Oscilloscope function works like a true oscilloscope. Each track displayed has the following parameters:

❐ Y Scale : it is the amplitude scale

❐ Y Offset : it is the offset of each track

❐ X Scale: it is the time scale of the visualisation and is the same for all the tracks.

Moreover, each track can have one or more limits to which the same parameters set for the track itself.

The oscilloscope is fully configurable with the tools provided at the bottom of the oscilloscope itself (simply use the arrows) or through the Control Panel (Fig. 10). To open the Control Panel window you can:

❐ use the button on the left side; it shows a menu with the Autoset command and the Control Panel item that opens the Control Panel window.

❐ double-click with the left mouse key.

❐ select the 'Control Panel' item from the popup menu that is shown when you right-click on the oscilloscope screen.
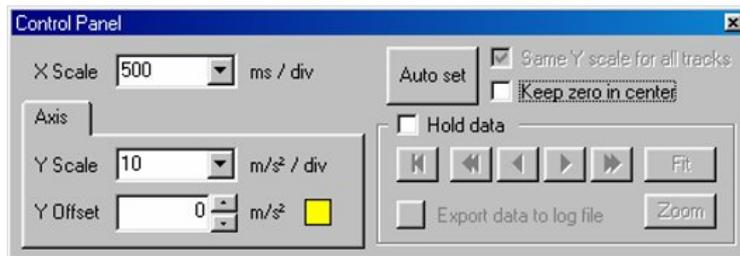

Fig. 14 Control Panel Window

With the Control Panel window, the user can set the X Scale, the Y Scale and the Y Offset of each track. The Autoset command finds the best settings for the signal visualisation.

Two options are available in the Autoset function:

❐ keep zero in centre: selecting this option results in a zero Y Offset for all the tracks.

❐ same Y Scale for all tracks: selecting this options results in all the tracks having the same Y Scale value. This option is useful when comparing two or more signals.

The additional tools available in the control panel will be described in the 'Data Analysis' section.

Serial Communication: the SeTAC communicates with the external world through a RS232 serial line. The protocol has the following settings:

❐ baud rate: 28800 bit/s (In some application it can be 19200 bit/s, please see the instruction section of the specific application you're using);

❐ 1 start bit - 1 stop bit;

❐ 8 data bits.

Configuration: in each application, the user can set the working parameters used in the data analysis function and define the limits. In many applications, three limit levels - corresponding to the three digital outputs - can be set. A typical window for setting the limits is shown in figure 15.
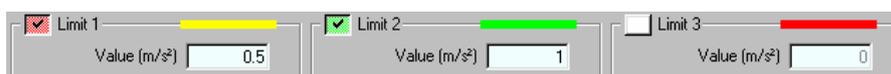

Fig. 15 Limit settings

Each limit can be activated by clicking the Check Box near the limit number; an active limit has a mark inside the box.

The limit value is written in the Text Box and can be changed by placing the cursor in the text box and using the keypad to type the number. Alternatively, the Up/Down arrow keys (change by 1) or the PageUp/ PageDown buttons (change by 10) can be used to increase or decrease the limit value.

The color of the box is also used to describe the limit status:

❑   White: the limit is not currently active. It may not be selected by the user or the Monitor Active input may be inactive.

❑   Green: the limit is active and no alarm is detected.

❑   Red: the limit is active and an alarm is issued.

Another feature of the SeTAC is the ability to modify frequency cut settings for the digital filters (fig. 16). Select the filter to be modified and move the cursor of the slider left or right to decrease or increase the filter frequency. The label to the right of the slider indicates the current frequency setting.
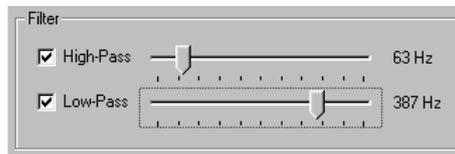

Fig. 16 Filter configuration

When a parameter is changed in the user interface, the new value is acquired in real time by the SeTAC and immediately applied in the monitoring function. In this way, by looking at the results obtained while changing the system settings, the user is able to observe the result of each action and find the best setting for each parameter and the best combination for each application.

These settings are saved in the non-volatile memory of the SeTAC and applied in the monitoring process until the user changes them or another software is uploaded into the SeTAC. In this case, the default settings for that software are loaded.

N.B. Every time you change some parameters in the configuration the data inside the SeTAC are converted in its internal discrete numeric system with an obvious approximation error. The same inverse conversion is utilized when the SeTAC sends the data from its internal memory to the PC in order to plot the thresholds value on the screen. In some cases (mainly for low values) is possible that this double approximation can show a value with a little differences between its original value and the following times the SeTAC would be connected to PC

Data Analysis with PC

Stop Acquisition and Analysis: in the Control Panel window (see Oscilloscope section) the user can stop the data acquisition by selecting "Hold Data".

When the user clicks on the "Hold data" command, he stops the data acquisition and the control panel window enlarges itself (Fig. 17) to show the "Data analysis" frame.

Use the arrow commands to scroll through the values of the stored data and the "Fit" button to visualize all the acquired values.
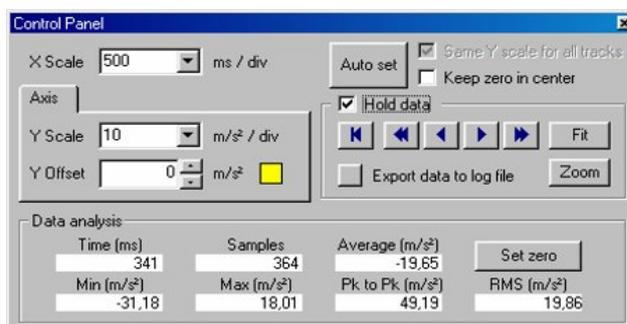

Fig. 17 Control Panel Window (Hold data mode)

By clicking on the oscilloscope two cursors can be used to define a window and select a range of data to be reviewed. The "Zoom" command sets the best X Scale value to visualize the data between the cursors.

These data are analyzed to evaluate the following items:

❒ Time: it shows the time interval in milliseconds.

❒ Samples: the number of analysed samples

❒ Average: $Avg = \dfrac{\sum Samples}{N}$

❒ Min: the minimum value in the range

❒ Max: the maximum value in the range

❒ Pk to Pk: it is the difference between the minimum value and maximum value in the range

❒ RMS: $RMS = \sqrt{\dfrac{1}{N} \sum \left(Samples^2 \right)}$

The computation of the parameters listed above takes place on the basis of a Y-Offset value set to zero. The "Set zero" command sets the current average value as the Y Offset.

Exporting Data: The program allows saving the data that are visualized on the oscilloscope by clicking on the button "Export data to log file" in the Control Panel window. The saved values are in ASCII format and are displayed in a matrix where each column contains the data from one track. The user can personalize the data file format in the "Data Export" section of the "Options" dialog box (menu Tools - Options):

❒ Include Header: if this option is selected, the data file will include a header with the date, the application that generated the file, the sampling rate and the name of each column.

❒ Comment Character: here the user can enter a character that will be used to mark the header lines. This is useful when the data are imported automatically through a third part software (e.g. when using Matlab the comment character will be the '%' sign).

❒ Format: it is the format used to save numeric values. A sample data is shown under the TextBox.

In most cases, the user can save the acquired data in a log file. Exported data can be analyzed by using various software packages, such as Matlab, LabView, Excel etc.

REAL CASE HISTORY

In this application the Sequoia Triaxial Acceleration Computer emulates the functions that are normally performed by a servo accelerometer combined to an extremely fast collision detector. By this powerful combination the Servo Accelerometer Emulator and Collision Detection System provides high performance measurement:

❒ a very sensitive reading of acceleration to which a body is subject on one of the three Cartesian axes;

❒ the triaxial module of acceleration to fast reaction and Logbook recording of collisions.

By adopting a sophisticated filtering system, the Servo Accelerometer Emulator is able to discriminate the signal from frequencies which are not relevant to the analysis. In this way, it achieves low noise

and provides common servo accelerometer high precision signal analysis capabilities coupled with the digital signal processing offered by the built in microcontroller and algorithms.

In the Collision Detection System the triaxial module of acceleration is filtered by a sophisticated band pass filter (built up by a low pass and a high pass filter) in order to discriminate between the collision and every other vibration source. A real-time alarm is provided when the threshold is exceeded.

The SeTAC can store in its internal memory all the relevant events which have taken place during the monitored period by recording the date and time information. Therefore, it works as a triaxial servo accelerometer emulator, that is able to detect collision in every space direction and to display the vibration story of the machine. The list containing all the events can be viewed at any time with a PC; this function can make an invaluable contribution to diagnostics, maintenance and warranty.
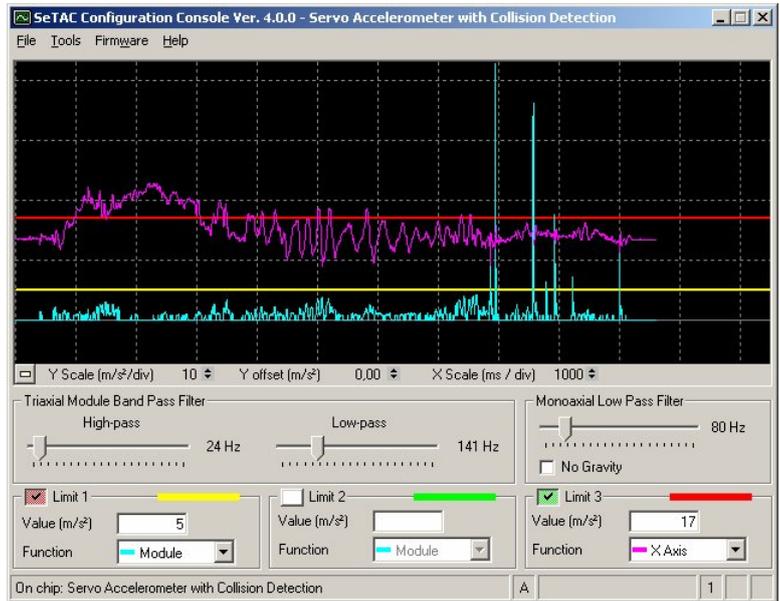

Fig. 19 Servo accelerometer with collision detection window

The application history

In this example we can see how easy can be set thresholds and filtering in a SeTAC applications in order to perform perfect real time monitoring and avoid erroneous and/or dangerous behaviours. The first target of this project was to create the right settings in a customer machining center in order to discriminate collisions from axes rapid movement avoiding false alarms and permit a conforming collision detection and reaction. Afterwards we were called to set a threshold in vibration level in order to stop machine when a chatter (very problematic on the customer site) happened.

Collision detection settings

In order to define right settings in the collision detection system, we made, by helping of Sequoia Vibration Analyzer FastTracer Analyzer, the analysis of machine, discriminating the differences between rapid movements and collision simulation in order to classify the machine dynamic features and choose the specific set of monitoring parameters.

On both the machines monitored to perform this analysis we recorded the dynamic vibrational response due to a rectangular movement in air on plane XY and simulating a collision by a hammer test on the machine spindle. The two machine shown identical vibration; besides the effects induced by rapid movements of machine axes excited typical machine frequencies in a very low way, impossible to be confused with the huge collision effects. By this responses we were able to fix the right threshold settings.

By the Sequoia Vibration Analyzer FastTracer we were able to perform simultaneously analysis on three axis and by this feature we could analyze both the rapid movements (X and Y) and the structural response (on Z axis not interested by movements) comparing them and immediately discriminating the possibility to exclude, by digital filters the effect due to movements, from the signal for the collision detection.

The frequency analysis of rapid movement showed that the acceleration creates only components at low frequency range. For instance, in the next figures we can see how the acceleration on machine vertical axes (Y) generates a component at 23 m/s2 at low frequency (less than 40 Hz).
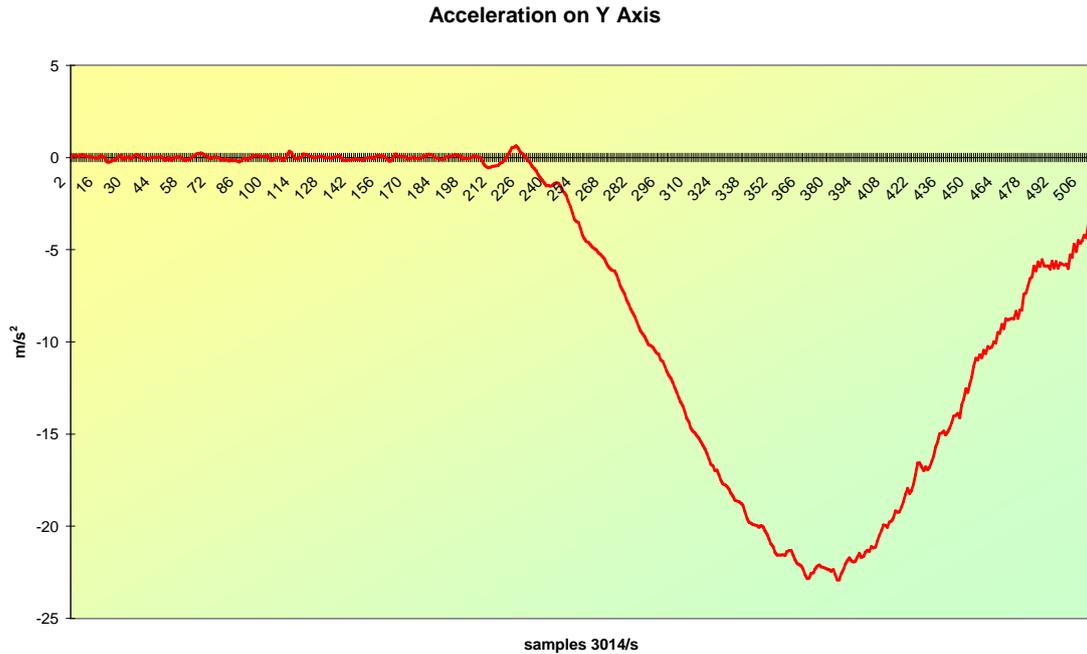
Acceleration on Y Axis

Fig. 20 – Rapid movement: acceleration on Y axis

Obviously the same results have been obtained by analysis on X axis. If we look at the effect on Z axis (excited by rapid on Y) we can see the structural frequency response of the machine and it's really evident a component around 200 Hz that we can associate to one typical machine frequency.
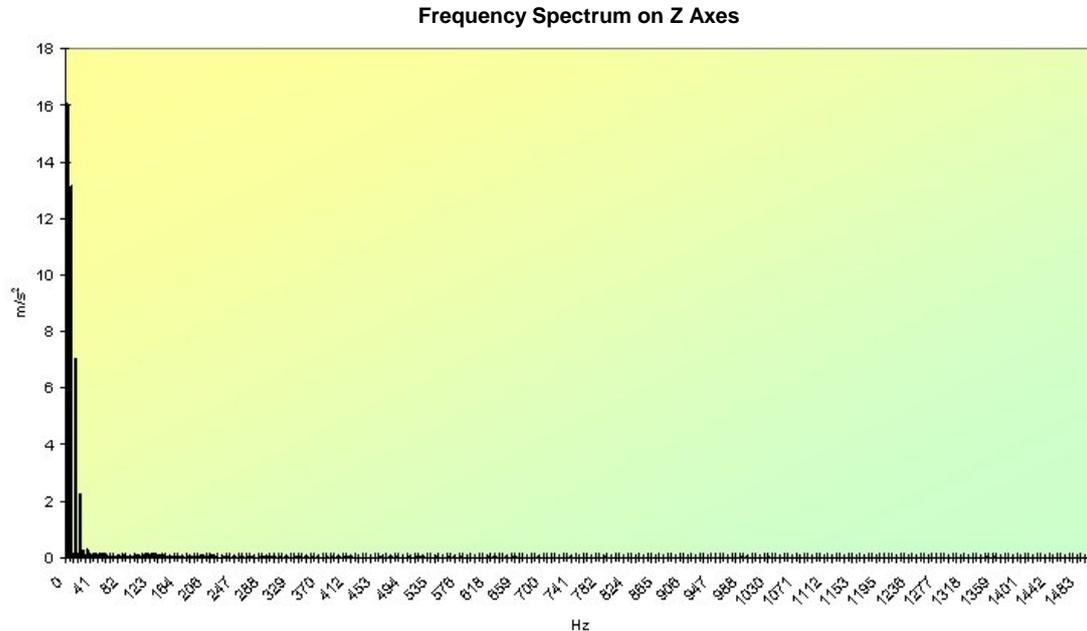
Frequency Spectrum on Z Axes

Fig. 21– Rapid Movement: frequency spectrum of acceleration on Z axis by movement on Y

Obviously also by the collision simulation (by a hammer shock) on the Y axis we can obtain also a spectrum very similar to the previous one. The most important component is between 160 and 280 Hz with a maximum value read is around 1.8 m/s2 (but a real collision is sure to be bigger).

Making some tests during working operations we obtained that no vibration overcome the level of 23 m/s2 (which was the maximum level in rapid movements), so we decide to fix a threshold level at 25 m/s2. Moreover, inserting a digital band pass filters only in the range where we want to amplify the collision effect (from 160 to 280 Hz) we reduced the effect of normal working vibration avoiding any kind of false alarms. That was the final setting:

□   OUT 3 (the fastest one) at 25 m/s2 on the Triaxial Module of Acceleration

□   Band Pass Filter (chosen around the bigger component):

  ➢   Low Pass at 280 Hz;

  ➢   High Pass at 160 Hz.
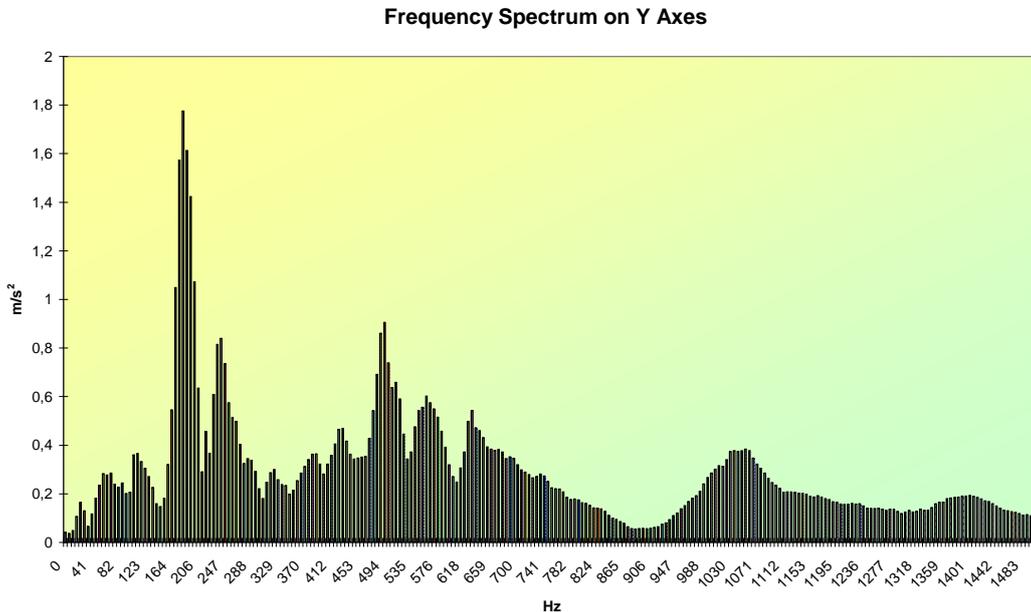
Frequency Spectrum on Y Axes

Fig. 22 – Collision Simulation

CHATTER ALARMS

After we have started to mount Collisions Detection on this machine typology we have been contacted to investigate in the chatter behaviour which the customer complained in some specific working operations (basically with extremely strong steel).

The chatter is a progressive accumulation of energy due to a too low level of stiffness in part-tool coupling.

This time, using the SeTAC on board of the customer machine, we used the FFT Vibration Analyzer application to make the machine frequency analysis and we saw that when we have Chatter behaviour (that we could easily recognize by environment high noise), a very high frequency component at 45 Hz appeared.
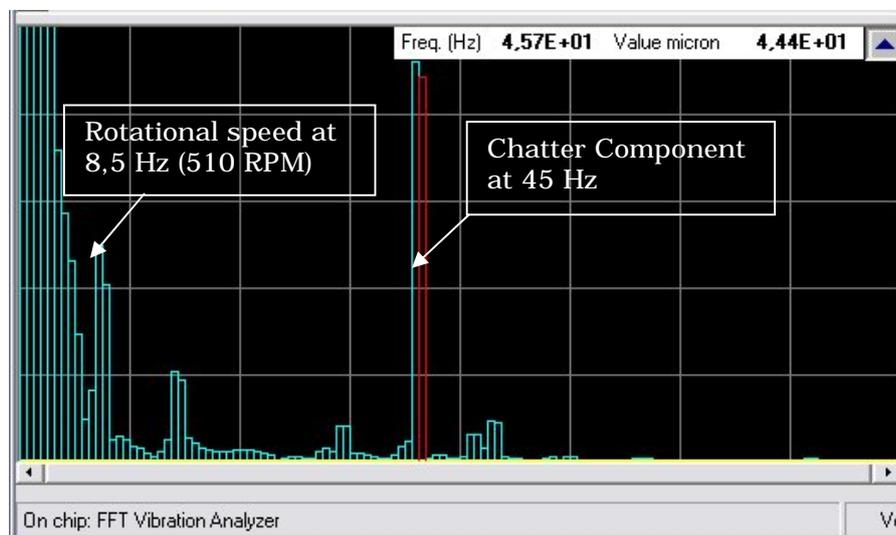

Fig. 23 – FFT Vibration Analyzer

By the servo accelerometer application we could see that during some kind of specific working operations the chatter behaviour suddenly happened and quickly explode.
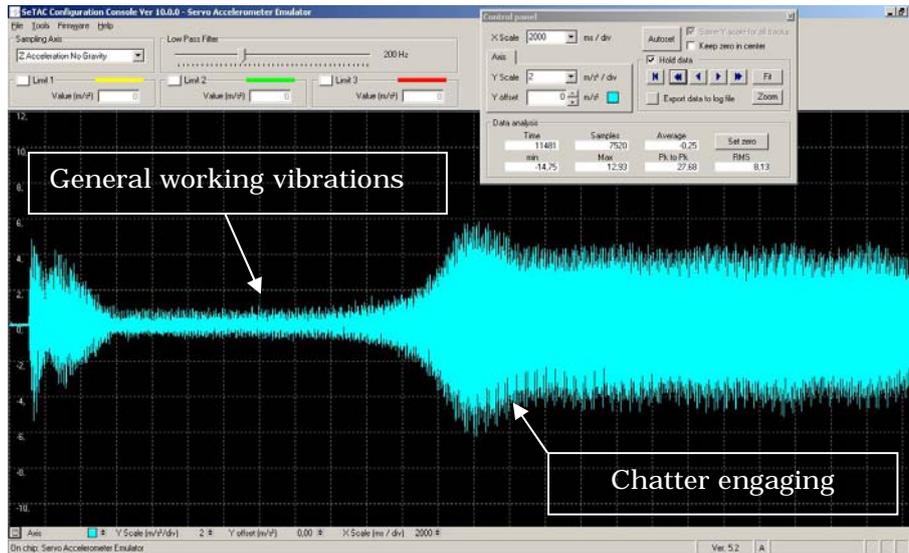

Fig. 24 – Chattering phenomena

The chatter was all concentrated in the Z direction (the spindle axes) so it was very easy to set a monoaxial threshold at 4 m/s2 (in order to be far from normal vibration level) that associated on a Low Pass Filter at 60 Hz (in order to include the chatter frequency and limit the effect of the working vibrations increasing the gap between the normal working vibration level and the threshold) was an optimal settings to have chatter identification without any kind of false alarms. That was the final setting:

❏   OUT 1: at 4 m/s2 on the Z Axes (with no gravity) at 4 m/s2 ;
❏   Monoaxial Low Pass Filter: 60 Hz.

CONCLUSION

Please visit our website at www.sequoia.it to run through our company and products details and to learn more about all the possible applications of our devices.

For any kink of further requests or additional information don't hesitate to contact us directly at info@sequoia.it