ProCAT Users Manual.

Software Versions 7.0 & 7.0D
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The ProCAT is an 8 channel general purpose spectrum analyzer system for mechanical testing analysis. It fully supports HALT-HASS-AST test chambers and other applications that require standard spectrum analysis functions in addition to comparative fatigue estimates.

I. INTRODUCTION

The ProCAT product includes a Windows compatible executive program and PCI Bus data capture/anti-alias hardware. The software is auto-installed from a CD-ROM. The included hardware is user installed in PCI slots. ProCAT can captured 8 channels of data in a fast channel-by-channel multiplexed mode. The digitizing rate is 25 KHz/channel. The system grabs 32,768 digitized samples per capture and performs FFT's based on that number of input points. This results in available spectra of 16,000 lines, however, due to AA filter roll-off, 12,500 are useable.

The hardware system is comprised or two PCI cards. The first is the 8 channel gain setting, and digitizer and interface card . The second is a combination eight channel input voltage mode signal conditioning and eight channel sharp cutoff low pass Chebyshev anti-alias filter card..

See Section 'IV. Specifications.'

II. ProCAT TASK-BAR MENUS

Operation of the ProCAT is controlled from Windows Task Bar MENUS. These menus and their functions are described in this section.

A. File   This menu includes Windows file management functions such as:

A.1.	New
A.2.	Open
A.3.	Save
A.4.	Save As
A.5.	Export
A.6.	Delete Stream
A.7.	Print
A.8.	Print Preview
A.9.	Print Setup
A.10.	Recent File
A.11.	Exit

A description of the functioning menu items is given below.   Those that lack a description are redundant or not used.

A.2. Open This function is used to open previously saved single channel PSD, FFT, averaged FFT, Damage Potential, or quad PSD, and DP(f) spectrum files. After Recall, the file may be edited as a current analysis screen.

Zoom, grids, smoothing, print or graphics output may be used. Acquiring a new spectral file will replace the old data in PC memory, but will not destroy the previously Saved File on the hard disk.

   A.3. Save   This function saves the results from single channel PSD, FFT, averaged FFT, PSD, or DP(f), or quad PSD and DP(f) analysis. The user may recall the file and perform the functions listed in A.2. Open.

   A.4. Save As   This function is identical to A.3 except that Windows boxes allow naming the file. It is automatically saved with the correct extension.

   A.5. Export This function creates an ASCII file of analysis results in engineering units listed as amplitude and frequency pairs. Exports can be executed for both single spectrum PSD, FFT, averaged FFT, or DP(f) plots and quad plots of PSD and DP(f). A Windows type BROWSE screen is presented to select a folder into which to save the converted file. The exported files may also be saved to floppy or other media, in order to allow the data to be uploaded to third party software for further analysis.   Export may also be used on previously saved FFT, averaged FFT, PSD, and DP(f) plots after they are recalled.

The data is exported in the smoothed status for the PSD or DP(f) spectra. Other files will be saved in the status in which they appear on the ProCAT screen. It should be noted that the exported files will be more correct than the screen image since they are taken from the spectrum arrays and do not suffer from plot pixel decimation aliases. Screen plots are sampled in order to obtain fewer plot points than the spectrum array, and hence are prone to minor errors due to interpolation.

   A.6. Delete Stream   This function deletes streamed file sets that were previously saved to the hard disk during a Stream to Disk function. When called, a directory is presented that has been used to load streamed files. Follow the prompts to remove the streamed files from the hard disk. MANUAL ADDENDUM VIII to this manual describes Streamed File Management.

   A.7. Print   This function prints the active spectrum to the installed system printer. If the printer may be Color or B&W, the plot is optimized for either.

   A.8. Print Preview   This function provides a view of the intended printout.

   A.9. Print Setup   This function links to your installed printer driver in order to optimize the printout.

A.10. Recent Files This function is a Windows function.

B. View   This menu provides selections for 1) Toolbar, 2) Status Bar, 3) Grid, 4) and Smoothing.

 B.1. Toolbar.   No Toolbar is used in this software.

 B.2. Status Bar. No. Status Bar is used in this software.

 B.3. Grid. This choice installs appropriate grids on analysis screens as well as the waveform screen. Each grid is scaled in user entered amplitude engineering units, and time or frequency scales. The waveform plot sensitivity and recording parameters are shown with each waveform plot along with the computed Grms. Time graduations on the Waveform presentation is 100 msec/division.

 B.4. Smoothing.   This function is a low pass averaging data filter that reduces the high frequency components of an analytical plot to enhance the underlying low frequency structure to improve analysis. It is applied only to the spectral plot data, not to the raw data. For this reason, it may be turned ON or OFF at any time.

 B.5. Set Zoom   In addition to the standard paint-to-zoom function provided by the mouse pointer, this software version also includes a zoom present. This function is used for multiple captures and analysis of spectrums. It can be used in the single screen as will as the quad plot spectrum modes. To use this function, click on the View Menu and then Set Zoom. A Dialog box appears with windows to set both lower and upper spectrum plot limits (zoom).
 Enter the desired values using the keyboard. When set, click OK, this setting will remain till canceled. To cancel the mode, lick on Restore on the Menu Bar.

C. Setup   The setup menu activates a Screen Box that includes system setup choices. This screen is seen in Figure 1.

 C.1. Channel Number. Select which channel will be assigned for analysis, or for the Recording Parameters which will be used when a spectrum analysis process is selected. Alternately, select a channel for analysis from the Waveform presentation by simply clicking within the desired channel box.

 C.2. **Recording Parameters**.   Enter the engineering units for the sensor on the selected channel, such as acceleration magnitude g**'s.**

If metric units are desired, enter the magnitude sensitivity (g's) as above. Data presented will be in metric units.

C.2.a. Volts per Unit. Enter the calibration sensitivity of the sensor for each channel here. Scroll through the channel numbers using the spinner. Entry is made in Volts per Engineering Unit.

C.2.b. Sensitivity (full Scale). Select one of six (6) full scale values that will not clip the expected signal. The displayed values are computed from the sensor sensitivity value entered above. <u>In the event that a full scale value selected is too low and any clipping occurs, the ProCAT will automatically adjust the gain for the affected channel.</u> For acceleration loading, such as a 6DOF machine, the time data may contain peaks much higher than anticipated. This process takes at least one recording cycle. Since gain is sequentially stepped, the automatic reset may take several cycles.

C.3. Transfer Function- response channel. Computation of a Transfer function requires input from two channels, 1) the primary or reference channel, and 2) the response channel. Select the response channel to be used from any of the channels recorded. The primary channel may be selected as per C.1.

C.4. Averaging for PSD or Damage Potential. This sets the number of recordings to be averaged when computing the spectra for PSD or Damage Potential, DP(f). Note, when it is desired to overlay DP(f) spectra from different channels for direct comparison, use the Damage Potential Setup screen. The value you enter will become the Default value until changed again.

C.5. Weighting Filters.   Alternate waveform weighting windows may be selected on this screen. Choices are: 1) Default, 2) Hamming, 3) Hann, and 4) Rectangular.

C.5.a. Default. The ProCAT system automatically uses the weighting window that is considered most appropriate for the type of analysis you select. If you choose one of the other weighting windows below, the software will use that weighting window.

C.5.b. Hamming. This choice selects the Hamming weighting window.

C.5.c. Hann. This choice selects the Hann weighting window.

C.5.d. Rectangular. This choice selects the rectangular weighting window.
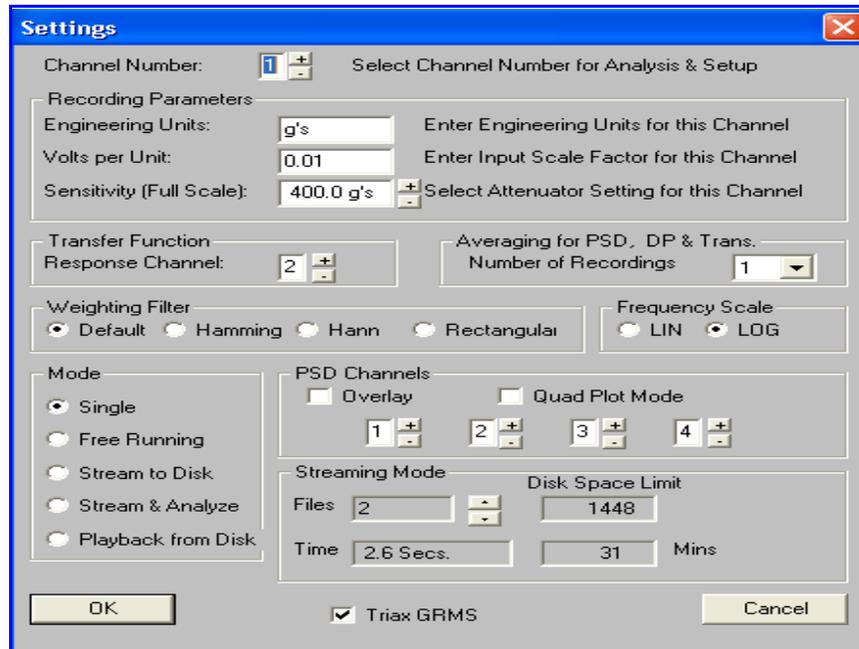
Figure 1. ProCAT V7.0 Setup Screen.

A weighting window must be selected prior to data capture. In general, the ProCAT will select the Hann or Hamming window.

   C.6.   Frequency Scale, Lin or Log. This choice selects the frequency scale format of spectrum plots as either linear or log progression. This mode may be changed after an analysis has been performed.

   C.7. Modes This block contains choices between the various data acquisition modes available.

   C.7.a. Single Capture Mode.   This choice selects the single block data capture and analysis mode.

   C.7.b. Free Running Mode. In this mode, the system continuously triggers and captures data blocks and instantly performs the selected analysis function until the mode is terminated. To terminate the Free Running Mode, press the escape [ESC] key. The mode will be terminated following the current

operation.

  C.7.c. Stream to Disk.   When large numbers of spectral averages are required, (extend the capture time) the user may pick this mode to capture and save time domain files to the hard disk. Setup for this mode is made in the adjacent Streaming Mode block. Block total is limited by HG capacity.

  C.7.d. Stream & Analyze. This function also streams data to the hard disk. In addition, the user may select an analysis function to be performed on the files at the same time, thus shortening some analysis tasks.

  C.7.e. Playback from Disk. This function recalls the streamed files sequentially. At the same time they are being recalled, the user may select a spectrum analysis mode.
Each recalled file will be processed with the selected analysis mode.

Any available mode offered on the ProCAT can thus be post-processed any number of times regardless of any analysis performed when the files were streamed. Post-processing includes averaged spectra. However, in this mode, only the final averages of the selection will be displayed.

  C.8 PSD Channels for Quad screen display.   The ProCAT can plot four simultaneous PSD plots when this function is active. Set the four channels to be plotted on a single screen. Click on the Check Box to turn ON the feature for the next data capture and analysis. If the user wishes to overlay quad plots, it is suggested that the base data file be saved and then recalled. Also see **Section V.**

  C.9 Streaming Mode Settings This box includes settings for number of files to be streamed (Files), the time duration of these files (Time), what total disk space is available for files (Disk Space Limit), and what the total time limit is if all available disk space is used (Min.).

  C.10 Grms Resultant Magnitude Plot Mode Check box. When this box is checked, the system will playback streamed files recorded with triaxial accelerometers and compute the root of the sum of the squares from each of he three input channels. The resulting plot will show the Grms magnitude from each channel, as well as the resultant, on a special screen with active cursor for readout. The triaxial mode is initiated by checking this box. If the box has not been checked when the Resultant Grms mode is commanded from the Menu bar, the plot will show a single channel Grms versus time plot. Select the channel number is the usual manner from the Setup Menu. An illustration of the triaxial Grms plot is shown in the addendum to this manual. The resultant plot is autoscaled in time to match the length of the streamed file set saved.

D. Waveform   This menu triggers a recording of all eight channels and displays the time waveforms. This is seen in Figure 2.

The display is from parallel 130 msec data block captures. The vertical scale in engineering units per division of the recording is shown along with the computed RMS value, also in engineering units.

D.1. Zoom. The Paint-to-Zoom function may be used on any channel, down to the limit of the process resolution, in order to validate the data to be analyzed. When a Zoom is done on the Waveform Screen, all channels are zoomed to the same degree and over the same time span. See Section L.

D.2. Select Channel.   Select the channel for analysis by clicking on the waveform plot of the desired channel. When selected, an asterisk will appear adjacent to the channel number. Alternately, the channel may be selected from the Setup Menu. This is required if a Transfer Function is to be computed.

D.3. Restore.   After zooming, to return the display to full length (1.3 sec.), click on the Restore Menu selection on the Task Bar.

E. FFT Menu   This menu controls the single FFT, and FFT filtering functions. These are: 1) Calc & Display FFT, 2) Low Pass Filter, 3) High Pass Filter, and 4) Display Inverse FFT.

E.1. Calc & Display FFT.   This selection initiates a new recording and plots a standard FFT. The recording loads 32,768 digitized samples from the sensor signal into the FFT processor to produce a 16,384 line spectrum. This spectrum is limited to the lower 12,500 lines because lines above this number have been attenuated by the roll-off knee of the anti-alias filter. After computing, a 12,500 line spectrum is plotted. If Smoothing (Section B.) has been implemented, the plot will be smoothed using a low frequency averaging filter. The plot may be zoomed, and restored.

E.2. Low Pass Filter.   After a new FFT plot has been computed, move the cursor to the frequency to serve as the low pass filter roll-off point and click 'Low Pass Filter' on this menu. This process is illustrated in Figure 3.

E.3.   High Pass Filter.   This function operates the same as E.2. Either can be selected first, but must be logically located to be correct. This process is illustrated in Figure 4.
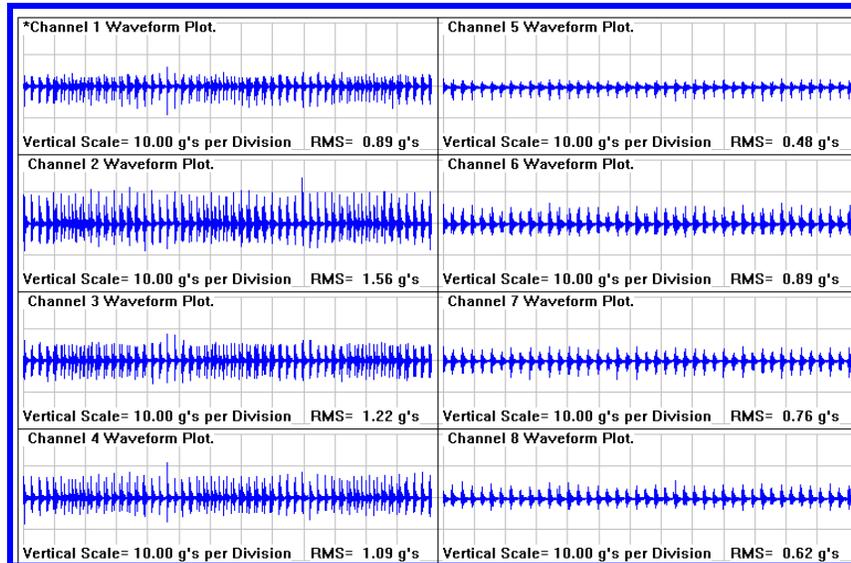
Figure 2. Waveform Screen, showing eight channels of captured data. The Grms value for each channel is computed and listed along with each signal. The time per division is listed at the bottom of the Waveform Screen. If the plot is zoomed, the Grms of the data shown is listed.

  E.4. Display Inverse FFT.   The Inverse FFT function performs a reversed FFT on the data that remains after applying high, or low filter functions. This reconstructs a time waveform from the amplitude and phase data after filtering. The 'slope' of the filters is sharp, narrow passbands are possible.

Figure 4 shows a filtered FFT with a pass band of less than 200 Hz. When the Inverse FFT has been performed, the resulting waveform is plotted on the waveform screen automatically. Figure 5 shows an example in which a 1 KHz sine on random has been filtered out from a random background.

F. Averaged FFT   ProCAT can perform averaged FFTs, (3, 5, 10 and 50 averages per plot), as well as single FFTs. Averaged FFTs are used to extract weak stationary signals, such as response resonances out of high noise backgrounds, like those encountered with by Repetitive Shock Machines. A major use of averaged FFTs is to isolate coherent signals that may be below the noise level of random vibration. In theory, when a random function such as white noise, is averaged, it will be reduced to it's mean value. A sine function, imbedded in the random data, will be "averaged-up" to it's RMS value. The

Averaged FFT is a tool for isolation of resonances from fixtures, products, etc.
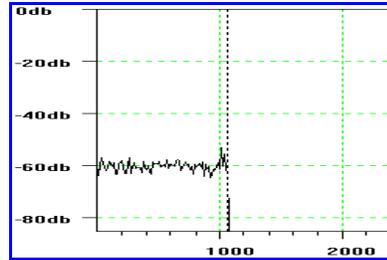
Figure 3. FFT of sine on random signal after setting Low Pass Filter.
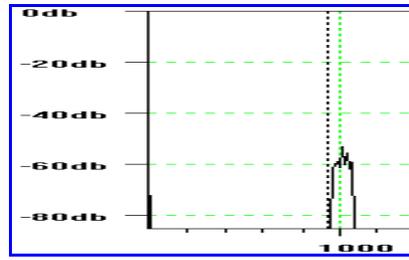
Figure 4. Remaining FFT amplitude data after both high and low pass filter.
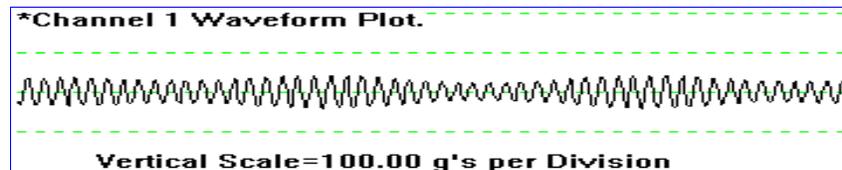
Figure 5. Resulting time waveform of filtered waveform from this example.

G. PSD   Perhaps the tool most used in evaluating vibration loading is the classic autospectral density function ASD, more commonly known as Power Spectral Density, PSD. This tool provides a measure of vibration power per cycle of analysis bandwidth. The computed result is plotted as a spectrum.

The root of the area under the PSD curve is defined as the Root of the Mean Squared, or Standard Deviation of the vibration excitation. For acceleration signals, this becomes the Grms.   Full or partial spectrum Grms values may be obtained using zooming of the PSD spectrum. The Grms value giving at the bottom of the PSD data box after a zoom is for the portion of the spectrum shown on the plot. In this way, expansion can be used to obtain partial Grms values from portions of the entire spectrum to compare with band limited panel meters.

The PSD curve gives a graphic picture of the relative power of an excitation at

various frequencies and *is the correct gauge* to measure the spectral power uniformity of vibration on non-Gaussian 6DOF tables, fixtures, etc.. Figure 6 shows a smoothed, non-Zoomed PSD from a 6DOF machine table product fixture point. This PSD is the result of five averages. The number of PSD's to average is selected on the Setup Screen.

The resulting PSD was plotted using the Log Amplitude/Frequency scales and smoothed plot modes. These options are intended to enhance the underlying basic structure of the PSD. The ProCAT provides a special Quad Plot Mode for PSD. Details of operation of this mode are found in section **V. Quad Plot Mode**
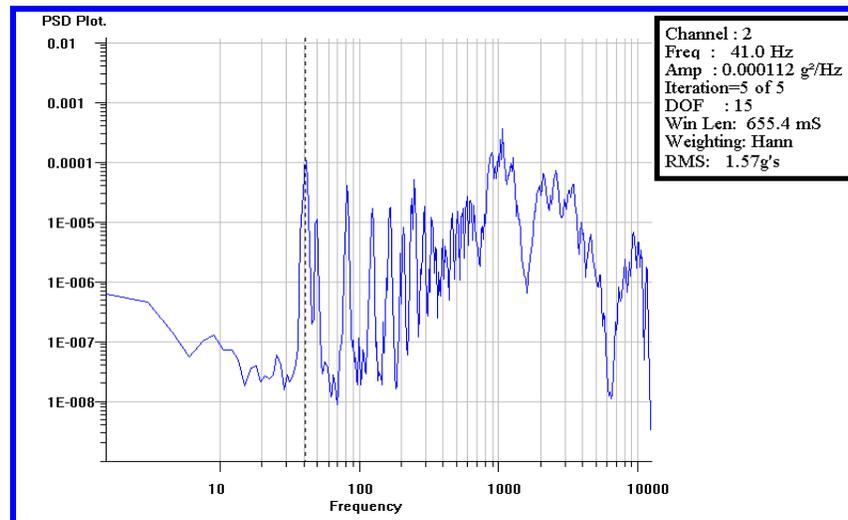
Figure 6   PSD from five averages of a 6DOF machine table point. Note that the cursor readout shows that the first strong spectral line is at 41 Hz, which is the fundamental hammer frequency average.

H. Transfer Function - Frequency Response Function.   Transfer functions and coherence are key tools when adjusting spectral energy balance, such as between multiple product fixture points

 In practice, you may find average power differences of 10:1 between input and response channels at a certain frequency. The TF is also know as a Frequency Response Function, or FRF. Also, Transmissibility is another termed used. Figure 7, below, shows a TF Plot. Specific frequency "gain" ratios at the

position of the cursor are read-out on the data box (upper right).
In addition, the Coherence is also plotted.
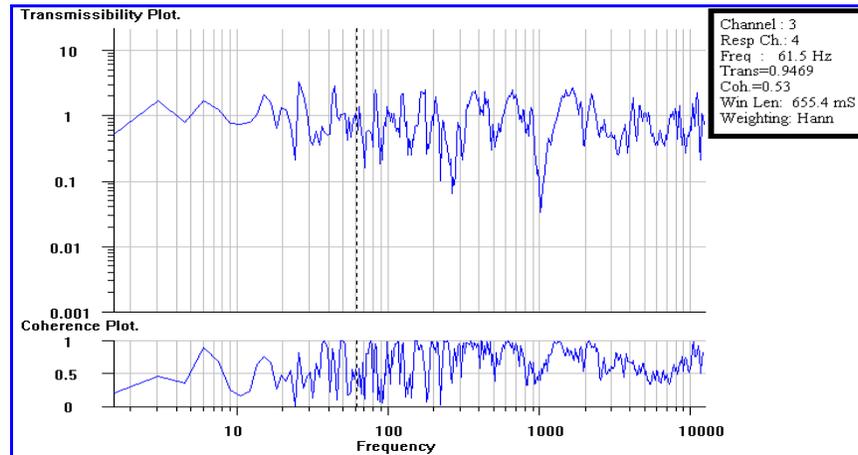
Figure 7. Transfer function Plot of amplitude vs frequency ration between two channels.

Low coherence, less than 0.5, indicates the source signal is not statistically present in the response channel. This usually is caused by local resonances from fixtures and products. The TF may be averaged using the setting on the Setup Table, Section C.

The Transfer Function is similar to the high fidelity system input/output response curve. It shows the 'fidelity" gains or losses in response at specific frequencies that may be caused by the system.

If all spectral amplitudes at their respective frequencies were equal and no gain or loss occurred, then the value of the TF would be continuous at a value of 1. If gains or losses caused by local resonances or damping occur, the spectral magnitude difference will be shown. This is an important tool for troubleshooting product fixtures.

The Coherence plot tells if the signals are phase related. High coherence indicates that the response signal probably originated from the source, and is unaffected by the transmission.

I. Damage Potential   One major Feature that ProCAT provides, the Damage Potential Spectrum, DP(f)[1], that gives the user a new analytic tool for superior inter-channel comparisons of fatigue accumulation.   Figure 9 shows the setup

menu for the DP(f), Figure 10 shows overlaid DP(f) plots.

This tool, based on the spectrum of the velocity of the first bending mode of a resonating component, is vastly superior to the AFDF/PPDF, which was based on acceleration peaks. **IT IS NOT INTENDED TO REPLACE THE PSD**, but to augment it as a tool.

> *Fatigue is directly related to velocity of the vibration modes and not to their acceleration.*

In addition to single channel plots, DP(f) analysis can produce two channel comparative (overlaid) plots when in the Quad Plot Mode.

The analysis format of relative fatigue magnitude is easy to understand. Since the system has eight channels, there are over 64 different channel to channel selections with which to compute comparisons. In addition, prior status files saved to the hard disk may be compared by overlay with current status files. This is signature tracking, which is invaluable in validating machine performance and if test setups used previously are being correctly duplicated.

Since the DP(f) spectrum is essentially a prediction of the velocity of resonant motion a product with given damping and fatigue S/N characteristics experiences due to a particular excitation, the measuring sensors should be located at or very near the location of the component being analyzed.

  I.1. DP(f) Setup.   This selection is called from the Damage Potential Menu Icon. This pull-down menu is described below.   The setup parameters are shown in Figure 9.   Figure 10 shows a DP(f) plot.

  I.1.a. Channel Number.   This selects a single channel to be analyzed and plotted. It is usually a response channel, or can be a channel that is to be compared with a previously computed DP(f). This setting overrides any channel numbers that appear in the Quad Plot Ch selection spinner windows.

  I.1.b. Number of Recordings to Average.   Like other functions that allow averaging of spectra in order to reduce non-stationary noise, the user may enter a number of averages for the DP(f).

  I.1.c. Overlay. This check box sets the ProCAT to overlay the next DP(f)

Figure 9.   Damage Potential Setup Box. It controls both the Quad display mode and

spectrum on the prior spectrum on the screen.
 It is only possible to plot one overlay (original plus one additional spectrum),

Figure 9. Damage Potential Setup Box. It controls both the Quad display mode and overlays for fatigue comparison.

since the cursor readout box is only active for one pair of plots.

   I.1.d. Duration. The data captured by the system should be reasonably stationary in time. With this assumption, the DP(f) that results from a short recording at time A will be the same as another recorded at time B. With this degree of stationality, to obtain the total DP(f) for a complete test, it is only necessary to capture a short record and adjust the fatigue accumulation for the total duration of the test. Enter here the total time of the test.   Time is entered in minutes. An alternative to this, is to use the streaming mode which can capture the entire length of a screen.

   I.1.e. Damping.   The DP(f) calculation depends on a realistic value of resonator damping ζ. A default damping of 5% is suggested. Refer to Mil-STD 810 section covering vibration testing for discussions of damping.

   I.1.f. Slope (S/N curve). This value is an estimate of the average fatigue slope of the materials from which the product is fabricated, known as the S/N value. The slope is negative for most materials used in electronic components fabrication ranges between 8 to 14. Undamaged copper is 10. For comparative

purposes, various test specification relating to vibration testing recommend that a S/N β between 4 and 8 be used.   The default is 4, the sign of the slope is not used. The magnitude of the DP(f) spectrum will change for different values of
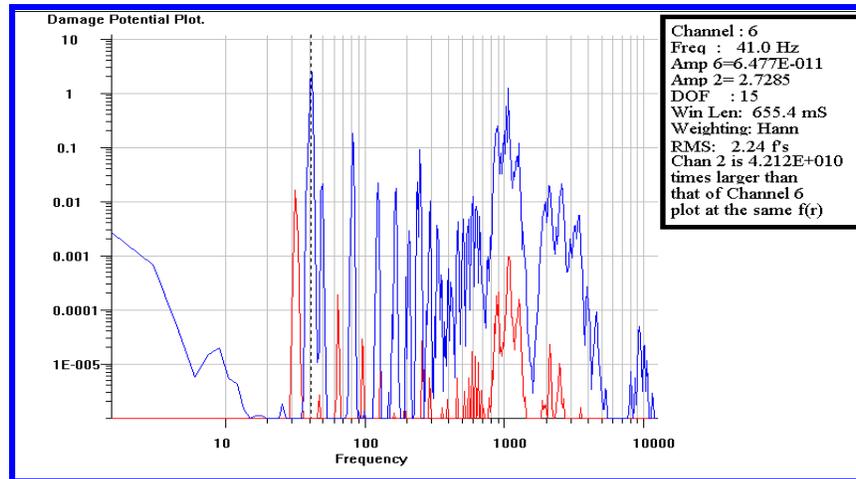
Figure 10. Two DP(f) spectra overlaid. This is used to show variability in fatigue between two points such as a table and fixture, or machine to machine. The ratio of fatigue exceeds 4.21E+10 at 41Hz.

beta, it is therefore important when doing comparative tests to use the same beta for all analysis. Since the results of the DP(f) are "relative", this is allowable. Even if an incorrect value is used, the *ratio of comparative DP(f) spectra* will be valid as beta cancels out in the process. Figure 10 is an example of overlaid DP(f) plots. For this example, duration was 60 min., damping was 5%, and beta was 8. The Data Box indicates that at 41 Hz, the ratio of fatigue accumulation between the two recordings is approximately 4.21 E+10, A very large amount. Ratios greater than E-12 or more have been experienced. The DP(f) plot may be Zoomed, and Smoothed. For the comparative plot shown in Figure 10, the Zoom could be used to better resolve the spectrum.

In addition, the degree of overall fatigue can be obtained from the **DP(Ave)** value which when zoomed indicates the magnitude of fatigue accumulation, expressed in terms of the MEAN value of the DP over a specified bandwidth. For long term exposures, such as from end-use environments, as long as the data is reasonably stationary, the user may enter very long exposure time values in the Setup Window. Values approaching end of life in particular environments have been tested, such as thousands of hours.

While Grms is only meaningful if used in conjunction with it's source spectrum, DP(Ave) can act alone, as it is a function of the source DP(f), which is a spectrum. However, if a comparison is being made between two spectra in terms of which can produce the most overall fatigue, one spectrum must completely envelope the other in order to compare the DP(Ave) values.
It is obvious that the DP(Ave) spectrum which is higher overall in magnitude, for the same given time, damping and S/N Slope, will have more damage potential than one that is overall lower. However, caution should be used on narrow band peaks that may exceed a generally higher spectrum. This indicates that at the frequencies of the peaks, that there can be more comparable damage potential.

J. Waterfall Analysis. This selection produces a three dimensional display of either averaged FFT or PSD spectra versus time plane. It is a powerful tool to detect and define events that vary with time. The user may select a total time to bracket the plot, as short as two minutes to as long as an hour. Data is periodically captured and spectra computed during this time. Each spectral plot becomes an increment in the time plane of the presentation, i.e., if twenty spectra are produced, the time scale of the plot will have 20 spectral planes. A waterfall plot is seen in Figure 11. Amplitude is scaled in colors and the different spectra become the components of rectangular areas bounded by adjacent spectra, forming a surface. This surface defines the spectral power during the analysis interval. The Waterfall provides a very graphic presentation of "events" that occur during a test.
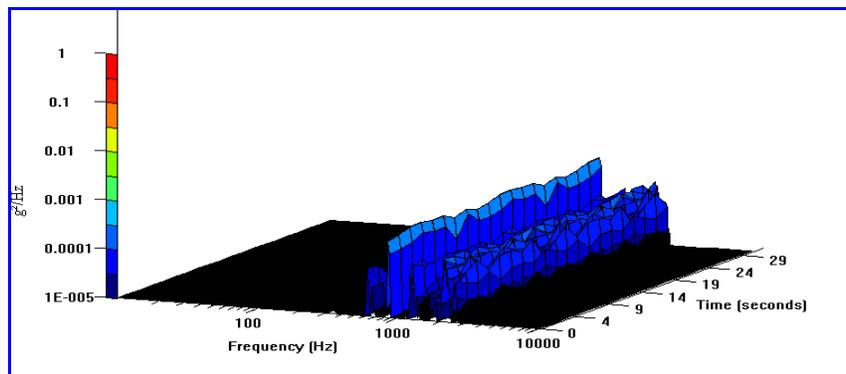
Figure 11.   Typical Waterfall Plot.

The appearance of the Waterfall plot is effected by the analysis mode chosen. In addition, the duration of the test will cause extension of the plot into the axis of the screen. The time scale will indicate the total time of the waterfall plot analysis. When using PSD's the plots are shown as area zones of amplitude bounded by the color key at the left.

For FFT's the plots are shown as line maxima. The Waterfall plot will commence after selection of one of the various spectral modes.

J.1. Setup. This submenu is presented when the Waterfall Menu Icon is clicked and is used to select desired spectrum and number of averages to use for the Waterfall analysis.

J.2. PSD. This selects the PSD as the analytical spectrum method to use for the Waterfall plot. The number of averages is selected on the Standard Setup Screen.

J.3. Average FFT (number of averages). These choices select different totals for averaging FFTs for the analysis. The averaging is described in the previous section on Averaged FFTs.

K. Grms vs Time Plot Mode This function plots the root of the sum of the squares of the Grms values as measured during a Streaming Mode recording from a triaxial accelerometer. The accelerometer must be mounted such that its three axis are orthogonally aligned with the table's primary 3DOF directions: Z - vertical to the table, X and Y - horizontal in the plane of the table but at 90 degrees to each other.

The triax resultant Grms magnitude mode must first be set by clicking on the check box at the bottom of the Setup Menu and then clicking on this Menu Icon. If the check box is not checked, then the resultant plot will show only a single channel Grms vs time plot. The desired channel must first have been selected by clicking on that channel on the Waveform Screen, or selecting the channel using the Setup Screen. The full triaxial Grms resultant can only be initiated if the check box on the Setup Menu is first clicked.

The Grms vs Time plot screen has an active cursor and data read-out box to provide analysis.

L. Restore. This function is used to restore the waveform or any of the analysis screens to their original unexpanded bandwidth that was in effect prior to zooming. It restores the plot without having to input new data.

M. Zoom Function. A Paint-to-Zoom function is provided. The zoom is initiated by pointing the mouse to the lower frequency of the expanded bandwidth desired then click and hold the left button while dragging the pointer to the upper frequency. A red box, or line, will appear on the screen plot to indicate the portion of the spectrum that will be zoomed.   When the mouse button is released, the zoomed spectra will be re-plotted. Figures 12 and 13 illustrate pre and post zoom spectra.

In Figure 12, the red box represents the mouse painted frequency span to be zoomed. The result is shown in Figure 13.
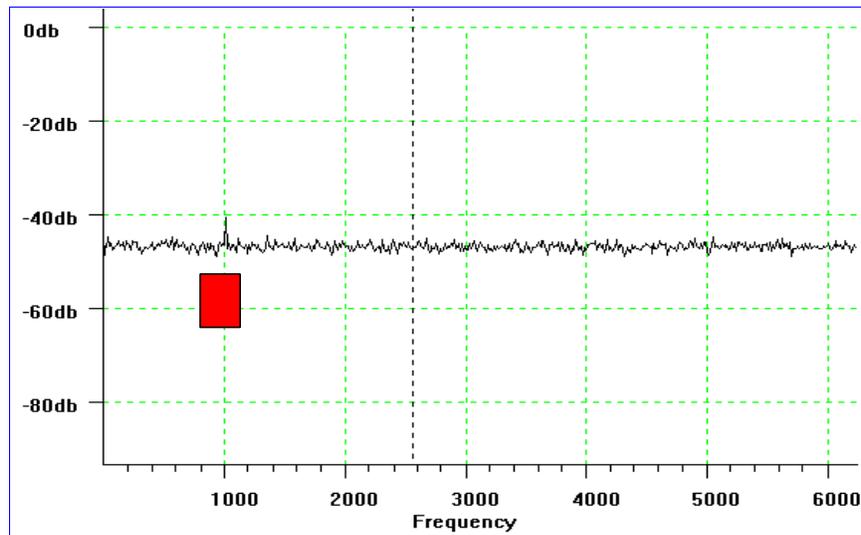
Figure 12. This figure illustrates the process of zooming a spectrum display. The mouse was clicked at 800 Hz and then drug to 1200 Hz.

Please note that only the width of the box is relevant. It defines the frequency band over which the zoom will be applied. The height of the zoom box has no meaning.   Once a spectrum is zoomed, subsequent captured spectra on that channel will be displayed at the same degree of Zoom. Zooms may be repeated up to the resolution limit of the screen or spectrum.

An alternate method of setting exact zoom frequencies is described in another section of this manual. Please refer to section **B. View 5.**
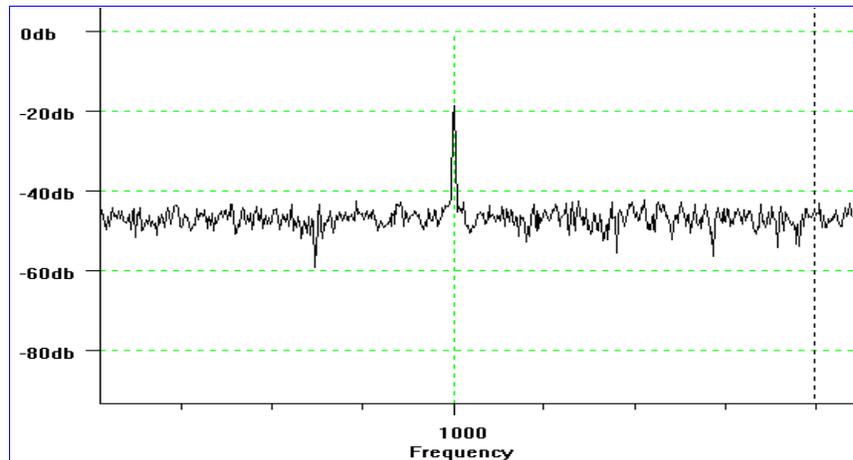
Figure 13. Zoomed spectra from Figure 12. The frequency scale is 50Hz/division.

IV. SINGLE OR FREE RUNNING SPECTRA MODES

The system also features both single and free running data capture for all
modes with the exclusion of the Waterfall Plot. In this mode, the system will
continuously capture and display spectra at the rate of one per 1.3 seconds,
depending on PC Processor. If averaging spectra analysis has been selected, the
mode captures and computes each individual spectra but does not display them
separately. Only the resulting average spectra are displayed. Example, if the
Averaged FFT mode is selected with a setting of N=10, only the average of ten
FFTs will be plotted sequentially. During this time, the applicable data box at
the upper right will display the iteration number of the individual spectra being
captured and computed.

The Free Running Mode provides a fast spectral display of data that may be
changing or is not stationary. In addition, the combination of Averaging modes
with Free Running provide additional analysis power.

V. QUAD PLOT MODE

A special Quad Plot Mode with overlay s is available for both the PSD and
DP(f) functions. It is initiated on the Setup Menu in the case of the PSD, and on
the Damage Potential Setup Menu for the DP(f) spectrum.

There are four channel selection spinners on each of these respective setup screens to set the desired channels to process and display. Once a channel number is set in the left-most spinner, the mode is activated and will be used for succeeding spectra till canceled. To cancel the mode, either remove the click on the selection box, or reset the default channel number 0 on the same spinner.

While in the Quad Plot Mode, each spectra displayed may be independently Zoomed and Smoothed. They may also be Restored. If a Zoom has been set on any channel, subsequent spectra will be displayed at the same degree of Zoom. Overlays in the Quad Plot Mode of PSDs and DP(f) can both be made. FFT, Averaged FFT, Transfer Function, and Waterfall modes are not supported in the Quad Plot Mode. Quad Plot is shown in Figure 14.
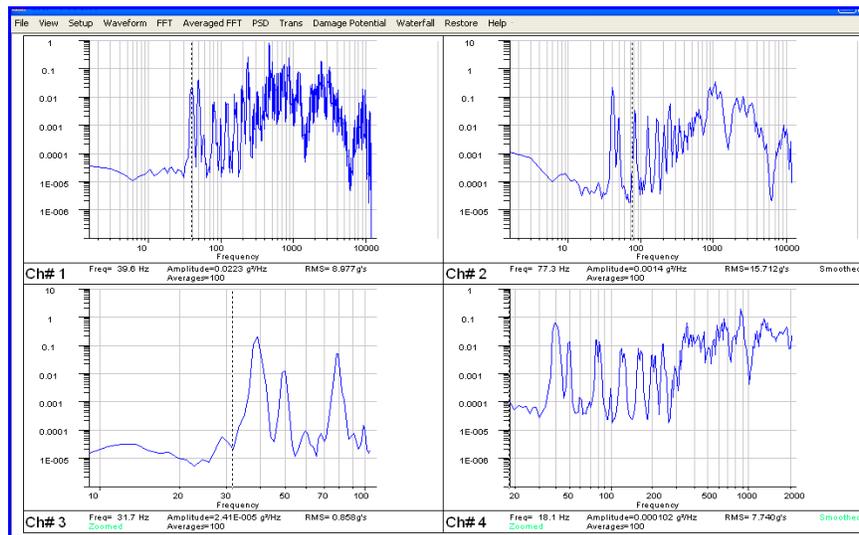
Figure 14. Quad Plot display mode. Showing 4 of 8 channels recorded. Data is in form of PSDs. Note: each plot can independently be zoomed, smoothed, or measured. In addition, Overlays of other recording data can provide many benefits ,including before and after product modification, data from different machines, tables, etc., or old versus new machine screen setup performance.

This illustrates that the spectra shown in each window may be individually tailored for a specific use. Channel #1 is shown non-zoomed and not smoothed. Different zoom settings, and smoothed plots are seen, Each active cursor shows the amplitude and frequency at it's position.

VI. HARDWARE

ProCAT hardware includes two PCI cards, I/O Cables and an Input Box with eight BNC connectors. The Input card has eight channels of parallel instrumentation amplifiers with software adjustable gain, fast A/D conversion, and the needed interface circuitry to communicate with the PCI bus.

The ProCAT Hardware Installation Kit is shown below in Figure 14. The second card has eight channels of ICP sensor signal conditioning (typically accelerometer) and sharp cut-off anti-alias filters. These filters are passive and have minimal phase shifting.

Installation is simple and involves plugging ProCAT's two cards into PCI bus slots and loading the software and drivers from the install CDROM. All
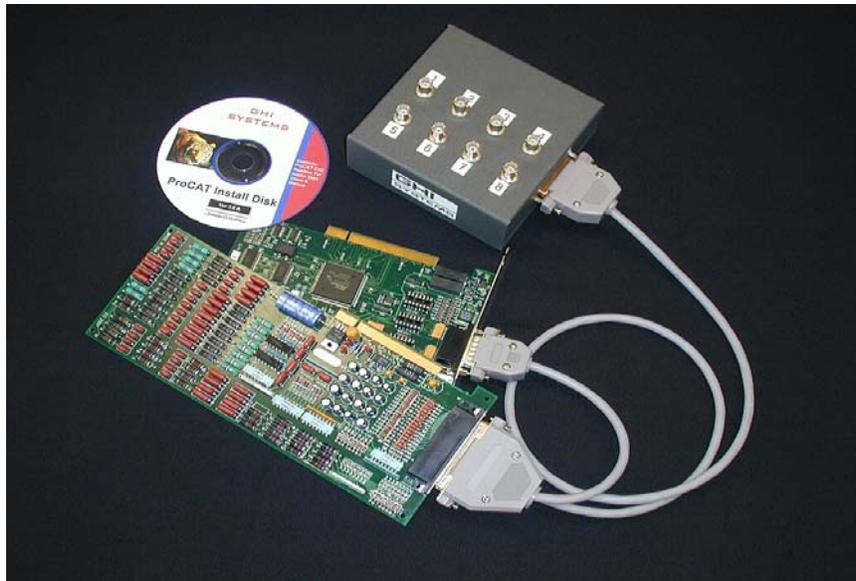
Figure 14. ProCAT System Installation Kit.

Windows Operating Systems are supported, however, some may require a driver available from GHI Systems.
As an alternate, the ProCAT is available in a portable version. The Portable version relies on a Notebook PC for operation and analysis and support for PCI Bridge operation. There is a special requirement for this Notebook. This is the

correct chip set to support PCI Bridge operation.

The ProCAT desktop version requires a PC with processor speed greater than 160MHz, 2 PCI bus slots, and Windows 98, NT, 2000 or XP.   The ProCAT card kit is shown in Figure 14. ProCAT provides simplified operation. Everything is pre-programmed. Default weighting windows for the type of analysis selected, digitizing rates and time data block lengths are all set by software.

When a spectral analysis mode is selected, the system takes 1.3 second blocks of data from 8 channels in parallel. The waveforms from all channels can be displayed on the Waveform screen for signal validity checks. After validity has been established a new recording resulting in the selected analysis mode is plotted. The waveform screen becomes redundant.

Each data capture block inputs 32,768 binary samples/Ch. For most spectrum this is then converted into an FFT array with 16, 384 "real" and "imaginary" components. This results FFTs with 16,384 spectral lines.
Of this total, 12,500 spectral lines are displayed. Spectral lines above the cut-off frequency are invalid. The plots may be displayed in smoothed or high resolution formats. Maximum zoom results in a high resolution display with interpolated 1.5 or 0.7Hz resolution.

IV. ProCAT SPECIFICATIONS:

A/D Converter:	1MHz throughput, 12bits/sample
A/D Sample Rate/Ch	25KHz each channel, parallel
Block Size:	32,768 Samples
Block Time:	1.31 sec
AA Filter Type:	Chebyshev
AA Filter Attenuation,	
@ 25KHz:	70 dB, (70dB/Oct).
Spectrum Plot Array Lines:	12,500
Screen Plot Resolution:	512 Pixels

Spectrum Analysis Modes, any of all channels.

Final Zoom Resolution:	512 lines @ 0.7Hz/line non-interpolated
Linear FFT:	12,500 lines, zoomable to 512 lines.
Averaged FFT	3, 5, 10 and 50 averages, 12,500 lines zoomable to 512.
PSD:	Single 12,500 line Power Spectrum, zoomable to 512 lines. Averages 2-100X.
Transfer Function FRF:	12,500 lines, between any two channels, log amplitude ratio with phase coherence,
Coherence:	12,500 lines, zoomable to 512 lines.
Waterfall Plot:	User selected spectral lines, plots averaged FFTs or

	PSDs, analysis duration up to 1 Hour. Three Dimensional surface plot of amplitude vs frequency spectra vs time.
Damage Potential, DP(f):	12,500 lines, Zoomable. User inputs: "Beta," damping and test duration. Two Overlays of multiple plots with computed DP(f) magnitude ratio at frequency line. DP(f) = Damage Potential at specific F(r) DP(Ave) = Mean value of DP values over bandwidth Analyzed..
Resultant Grms Data	Triax from Channels 1m 2, and 3, of 8 streamed channels. Single from any of 8 channels of streamed data.

ProCAT requires a PC with processor speed greater than 160MHz, 2 PCI Standard 2.1 or 2.2 PCI bus slots, and Windows 95-98-2000, ME, NT, or XP.

Note: Because of design differences between some PC's that make them non-compatible with PCI standards, GHI Systems does not guarantee that it's cards will operated in any specific computer that is supplied by the buyer. Contact GHI Systems about purchasing a turn-key system.

VI. CUSTOMER SUPPORT

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References:

1. Henderson, G.R., and Piersol, A.G., "Fatigue Damage Related Descriptor for Random Vibration Test Environments," Shock and Vibration, October 1995, pp 20-24.

2. Henderson, G.R., and Piersol, A.G., "Evaluating Fatigue Producing Vibration Environments Using the Shock Response Spectrum," Proceedings of the CPMT, IEEE, Accelerated Stress Testing Conference, Denver, Colorado, October 2.4, 2000, pp 271-280.
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VII. MANUAL ADDENDUM Example of Resultant Grms plot

See Next Page.

gRMS vs Time Plot.

Time: 99 Seconds
Ch 1 (Z) : 44.28 Grms
Ch 2 (X) : 32.13 Grms
Ch 3 (Y) : 41.42 Grms
Resultant: 68.62 Grms
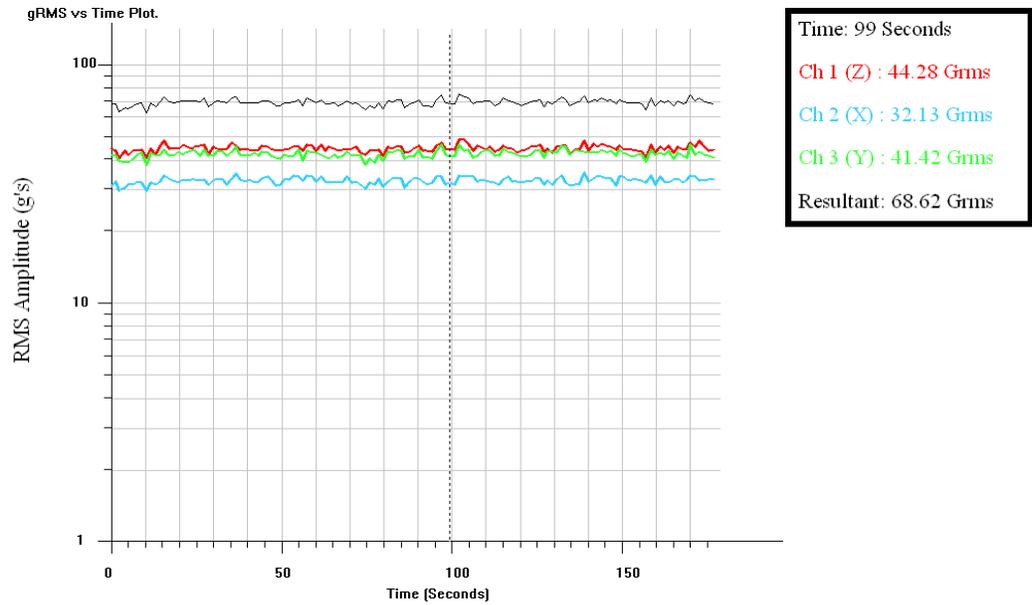
VIII. MANUAL ADDENDUM Management of Streamed Files

The ProCAT system utilizes data block files that are 1.3 seconds in realtime duration. Each file is digitized at 25 KHz and includes input from all 8 channels. These files are used in several applications such as averaging and other functions where multiple successive spectra must be computed. This includes the Streaming To Disk Function.

When a streamed file sequence is initiated, you will be prompted for a sequence name. This name will be attached to each 1.3 second data block file of the stream with an appended sequence number. A typical file name sequence, as it would appear in a directory, would appear as below:

Name .Str	Name 4.Stn
Name 2.Stn	Name n.Stn
Name 3.Stn	

Etc until n = the selected total of files.

Notice that the file *.Str has no sequence number. It is considered to be the first file of the sequence. i. e. #1. There will as many files as the total number set by the user on the Streaming control panel in Setup.

It is important to know that when naming the streamed file sequence, as soon as the name is entered (all other functions including total number of files to stream have been set), the first occurrence of data level exceeding the ProCAT amplitude trigger will cause the sequence count to begin and files to be saved to the selected directory.   This process will continue until the count set by the user reaches 0.

Any time after completion, the streamed data may be recalled and processed with any of the library of functions ProCAT provides with one or two exceptions. Following are special instructions on how to archive the streamed file sequences to other media, for file retention or transfer to another ProCAT systems. The data files may be re-installed for reprocessing on the original ProCAT from an archive media device such as a CD-ROM or DVD.

Archiving Streamed Files. Downloading streamed files to other media is a simple Windows Explorer function. Use highlighting to select the file sequence and then Copy and Paste. The important thing is that all files of the sequence must be included, otherwise they will not function later. Use the same method to writing the stream onto a CD-ROM or DVD.

Re-installing Streamed Files. Use the identical procedure described above for archiving after selecting a directory into which to place the files. Remember that when you recall the stream using ProCAT, that you must direct it to the proper directory. Suggestion: Perhaps name a directory "Streamed Files."