

FFT (Optional)

The FFT option gives the 824 the ability to do narrow band frequency analysis using the Fast Fourier Transform. This chapter describes the features and functions of this option.

Features

The FFT option has the following features:

- 400 line FFT (1 Hz to 20 kHz)
- Hanning, Flat-Top or Rectangular window
- Bandwidths of 200Hz, 500Hz, 1kHz, 2kHz, 5kHz, 10kHz, and 20kHz
- Count averaging (1 to 16384)
- Snapshot data storage (no ByTime autostore)
- Display zoom with a factor of 2, 4, or 8
- Total Harmonic Distortion
- User defined Linear Units

Settings Menu

The Settings menu for the FFT instrument is accessed from the SETUP  key.

To select the FFT instrument, press the SETUP  key, scroll down to the FFT instrument and press the Check  key. The FFT display will appear. Press the SETUP  key again to return to the SETUP menu. At the top of the Setup menu “Edit Settings” will be highlighted. Press the Check  key or the right  arrow key to edit the FFT settings menu.

NOTE: See "System 824 Virtual Instruments" on page 6-1 for a more detailed explanation on selecting instrument definitions.

The menu layout of the FFT settings is shown in the table below:

Menu Items	Available Settings Options
Title	User customized text entry
Gain (dB)	-20 -10 +0 +10 +20 +30 +40 +50
Bandwidth (Hz)	200 500 1k 2k 5k 10k 20k
Avg Count	1 to 16384
Repeat	No Yes
Window	Rectngl Hanning Fit-top
Overload Skip	No Yes
Transducer	Condnsr Elctret Direct
Random Corr	No Yes
Linear Units	4 characters of text
Linear Scale	-128.99 to 127.99
Auto Snapshot	No Yes

Settings Descriptions

Title Setting

Use the title setting to create a title or heading for printed reports. This title will be placed at the top of each FFT report you print. You are allotted 30 characters. Printing of FFT reports is not currently available.

Gain Setting

-20 & -10 dB gain are achieved by desensitizing the microphone by reducing its polarization voltage from 200 volts to 20 volts. See "Gain Setting - (SSA)" on page 7-6 for more details.

The gain setting sets the measuring range of the instrument in 10 dB steps by adjusting the amplification of the microphone signal. This setting provides the following options:

-20, -10, 0, +10, +20, +30, +40, +50

Bandwidth

The frequency resolution for each line is the bandwidth divided by the lines setting. With the bandwidth set to 20kHz and 400 lines, the frequency resolution is 50 Hz/line.

The frequency range of a baseband FFT analysis extends upwards from zero to a selected maximum frequency. Thus, the bandwidth, or the frequency range covered by the analysis, can range from a maximum of 20kHz to a minimum of 200Hz. This setting provides the following options:

200Hz, 500Hz, 1kHz, 2kHz, 5kHz, 10kHz, 20kHz

The following table shows resolution and FFT calculation times as a function of the frequency bandwidth.

Bandwidth, Hz	200	500	1k	2k	5k	10k	20k
Resolution, Hz/line	0.5	1.25	2.5	5	12.5	25	50
Calculation Time, Seconds	0.50	0.20	0.10	0.05	0.02	0.01	0.05

Avg Count

The 824 FFT is guaranteed to have no more than 75% overlap.

The average count is the number of FFTs taken and averaged together.

- 1 to 16384

FFT Repeat

Once the average count is completed you can choose to continue repeating the FFT or have the FFT stop.

- No - Stops the count when the average count has been reached.
- Yes - Repeats the count continuously.

Window

The Hanning window is typically used for most measurements.

The time weighting window can be the following:

- Rectangular; provides finest frequency resolution.
- Hanning; good compromise between amplitude accuracy and frequency resolution. Most commonly used for general measurements.
- Flat-top; provides best amplitude accuracy. Often used for calibration.

The Rectangular window provides the best frequency discrimination but can have significant filter leakage or effects of a truncated series. The Hanning window minimizes the filter leakage with the cost of a wider main lobe. The Flat-top window gives better amplitude accuracy in the passband.

Overload Skip

Overload skip allows you to throw away or keep spectra that contain overloaded data.

- No - Averages in spectra with overload data.
- Yes - Does not average spectra in that contains overloaded data.

When a condenser microphone is used, the 824 requires a stabilization time of approximately 45 seconds before a measurement can be taken.

Gains of -20 and -10 dB are only available for condenser microphones.

See "Random Incidence Microphone Correction" on page C-24 for the random incidence correction filter's response.

If this field is left blank then no linear value will be displayed. See the section "Displaying Amplitude in Linear Units" on page 12-14 for more details.

Transducer

- Condenser - This indicates that the microphone being used is an air condenser type and the 824 will generate the appropriate polarization voltage.
- Electret - This indicates that the microphone being used is an "Electret" (pre-polarized) microphone. The 824 will not generate any polarization voltage.
- Direct - This indicates that no microphone is being used and electrical signals are being injected directly into the preamplifier. No polarization voltage is generated. This is the choice when using an accelerometer as the transducer

Random Correction

The Random Corr setting gives you the option of turning on a digital filter to provide the correction necessary to provide a random incidence response when measuring with a free-field microphone.

No - Random incidence correction is turned off.

Yes - Random incidence correction is turned on.

NOTE: Random incidence correction can be used with the 2540, 377B41 and 2551 microphones.

Linear Units

Four characters of text are provided so the user can enter the type of units being used for the measurement. It accepts any alphanumeric character that can be found by scrolling with the up  and down  arrow keys.

Linear Scale

Allows you to enter the sensitivity of a transducer in decibels relative to volts.

- -128.99 to 127.99

Auto Snapshot

This feature allows you to automatically capture an FFT Snapshot on the completion of each FFT. If Repeat is set to “Yes”, then it creates a pseudo Time History. The time interval between spectra Snapshots will equal the FFT calculation time (see "Bandwidth" on page 12-3) multiplied by the number of counts selected for Count Averaging. For more detail on Snapshots, see "Snapshot" on page 12-11.

FFT Display

The FFT data displays are accessed through the View  key. To select the FFT displays press the View  key. The following menu will appear:

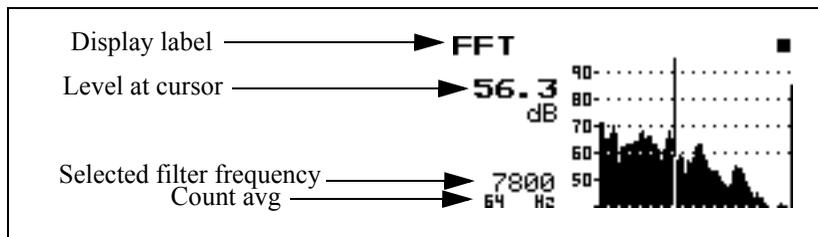


“FFT” accesses the live FFT spectrum and “Snapshot” displays the FFT snapshot data.

With “FFT” highlighted, press the Check  key to enter the FFT display.

FFT

The FFT display shows a live FFT spectrum.



The left ◀ and right ▶ arrow keys move the cursor to change the frequency and level displayed.

FFT Zoom

You can view approximately 80 bars of the FFT at once. When you are zoomed out you will notice that each bar represents several frequencies or lines. Pressing the right ▶ arrow key moves to the next line. The cursor will not move to the next bar until it shows all of the lines represented by that bar of the graph.

The FFT zoom on the 824 allows you to view a representation of all 400 lines or a portion of the 400 lines on the display. This is called a display zoom.

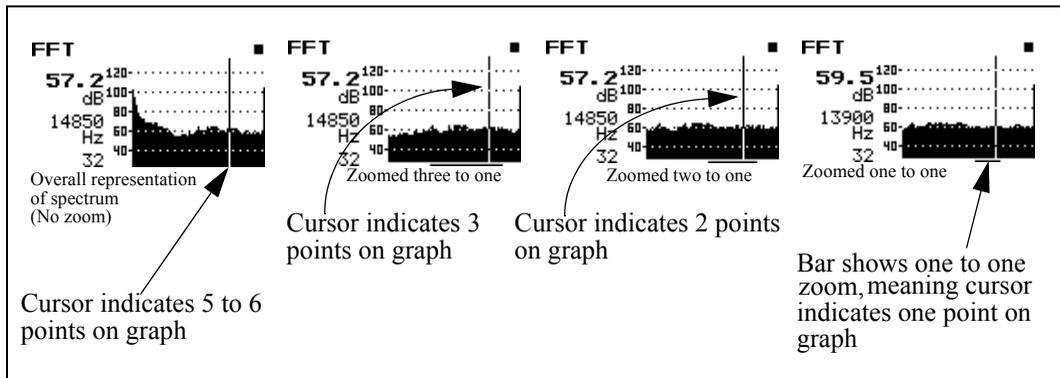
The up ▲ arrow key will zoom in the display by a factor of 2 to 8. This means that a zoom factor of 2 shows one half of the 400 lines on the display. A zoom factor of 8 would show one eighth of the 400 lines on the display. The down ▼ arrow key zooms out to a full screen display of the FFT.

The zoom factor is shown graphically as a horizontal bar at the bottom of the bar graph. The shorter the bar, the greater the zoom.

The location of the zoom bar indicates the position of the displayed area of the spectrum.

NOTE: When more than one frequency is represented by a single bar, the largest bar is represented on the display. As you press the right and left arrow keys to move the cursor across the display, you will notice that the cursor does not move until all of the frequencies represented by that bar have been displayed.

Some examples of zoomed displays are shown below:



While zoomed, the display will scroll when the cursor nears either the left or right edge of the display.

FFT Check Menu

Pressing the Check (✓) key while in the “FFT” display puts you in the check menu shown below:



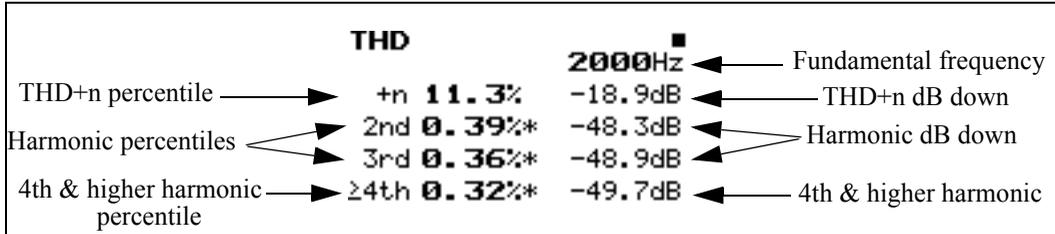
The check menu offers the following options:

- Store Snapshot - Stores the current FFT spectrum at that moment in time.
- THD - Activates the THD display which shows the calculated THD.
- Settings - Activates the FFT settings menu.
- Graph - Adjusts the vertical graph scale and offset (See 824 Reference Manual)
 - *Graph Level* - Allows numerical entry of graph level in dB.
 - *Graph Scale* - Allows numerical entry of graph scale

The THD as calculated in the 824 satisfies all of the requirements for ANSI S3.6.

THD (Total Harmonic Distortion)

The THD display shows the results of the THD calculations.



THD information is only available on screen at the time of the measurement and is not stored with a file or printed to a report.

Entering the THD display will auto-position the cursor to the fundamental frequency on the FFT screen.

Results are reported in dB down difference and units of percentile. The dB down difference is calculated by subtracting the harmonic level from the fundamental level. The percentage is equal to one hundred times ten raised to the power of the result of the dB down difference divided by twenty.

THD is calculated by scanning the full spectrum to find the fundamental frequency and selecting the highest peak. The actual frequency is extrapolated from the fundamental bin frequency and the highest sideband bin frequency. The second harmonic is found by doubling the fundamental frequency, then finding the nearest bin frequency and summing its level with its side-band levels. The third harmonic is found by tripling the fundamental frequency, then finding the nearest bin frequency and summing its level with its side-band levels. The fourth and higher harmonics are found by the process described above for the second and third harmonics.

THD+n is calculated by summing the energy of the fundamental bin with the five bins on each side, then subtracting the energy sum of all the other levels.

For THD to be calculated, the following criteria must be met:

- The window must be in Hanning mode after an overall reset. If not, “Available only in Hanning Window” is shown.
- The fundamental must be above the 4th bin or 10 Hz whichever is higher. In the case where the fundamental frequency is near the 5th bin and it’s skirt extends into some or all of the first four bins, the fundamental energy sum calculation will include only the 3rd and/or 4th bins but not the 1st or 2nd bin. In any case the noise energy sum calculation will never include the first four bins.
- The fundamental must be higher than any of the first four bins. There must not be excessive DC or near DC levels.
- THD+n must be at least 10 dB below the fundamental level. There must be an identifiable tone.
- The fundamental frequency will be displayed whether there is an identifiable tone or not.
- If a harmonic is less than 10 dB above the noise floor, the level of the harmonic is marked with an asterisk. The noise floor is calculated as the maximum of the minimum in the two adjacent valleys.
- If one of the harmonic’s side-bands is higher than the harmonic then the harmonic is marked with an asterisk.

THD Check Menu

Pressing the Check (✓) key while in the “THD” display puts you in the check menu. The check menu is shown below:



The check menu offers the following options:

- View FFT - Takes you back to the FFT display

The bandwidth for each line is the bandwidth setting divided by the lines setting.

- Bandwidth - Allows you to reduce the frequency bandwidth from 20kHz to 200Hz. This setting provides the following options:

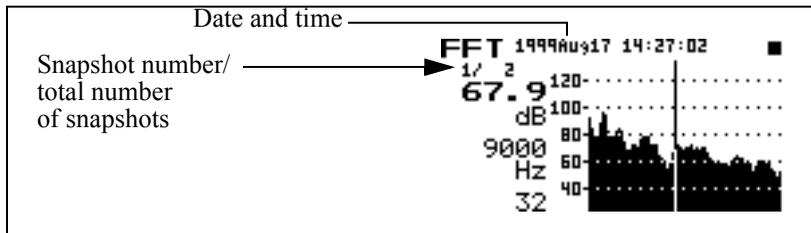
200Hz, 500Hz, 1kHz, 2kHz, 5kHz, 10kHz, 20kHz

Snapshot

Once you have stored an FFT snapshot by accessing “Store Snapshot” from the FFT check menu, you can view the snapshot data by pressing the View  key. The following menu appears:



Highlight “Snapshot” and press the Check  key to access the snapshot data.



Use the up  and down  arrow keys to scroll through each record.

Use the check menu to control the HORIZONTAL SCALE.

The **date** and **time** records when the snapshot was taken.

Snapshot Check Menu

To access the snapshot check menu, press the Check (Ⓢ) key while viewing the snapshot data. The following menu appears:



The check menu offers the following options:

- Locate - Locate Snapshot record
 - *First* - The first Snapshot record
 - *Last* - The last Snapshot record
 - *Find* - Finds the specified Snapshot record
- Graph - Adjusts the graph scale and offset (See 824 Reference Manual)
 - *Graph Level* - Allows numerical entry of graph level in dB.
 - *Graph Scale* - Allows numerical entry of graph scale.
- Zoom in - Allows you to see FFT spectrum with more detail. (See page 6 for more information)
- Zoom out - Allows you to see FFT spectrum with less detail. (See page 6 for more information)

FFT Calibration

The FFT spectrum always displays the measured level in decibels on a logarithmic scale. In fact, the use of the term “level” implies a decibel value relative to a defined reference value.

Acoustic measurements are in dB relative to 20 µPa

When the System 824 has been calibrated using an acoustic calibrator, whether from the ISM, SSA, LOG or FFT instrument, the decibel levels are relative to 20 µPa (20 micro-Pascal).

Note, however, that it is possible to provide a digital readout of the amplitude at the cursor position in linear units as shown below in the section “Displaying Amplitude in Linear Units” on page 12-14

Calibrating dB to a Different Reference

For measurements of non-acoustical parameters such as acceleration, it is more appropriate to express the measurement in decibels relative to a different reference using units typical for that parameter. This is easily done using a calibrator to excite the transducer to a known value.

The decibel level of a measured parameter is calculated as follows:

$$L_V = 20 \text{Log}_{10} [V/V_{\text{ref}}]$$

where V = measured parameter

and V_{ref} = reference value, same units as the measured parameter

Calibrating to measure acceleration in decibel units relative to an acceleration unit (e.g. g, m/s², ft/s², etc.)

For example, if we prefer to express acceleration in units of “g”, we may select to represent the “acceleration level” in decibels relative to 1 µg. Using an accelerometer calibrator which excites the accelerometer at an rms amplitude of 1 g, such as the PCB 394C06 Portable 1g Handheld Shaker, we

will perform a calibration and calculate that the level we measure should be

$$L_v = 20\text{Log}_{10}[1.0/(1.0 \times 10^{-6})] = 120 \text{ dB.}$$

Thus, prior to performing the calibration using the calibration item in the Tools menu, we set the **Cal. Level** to 120.

Similarly, should we wish to use the same calibrator to measure in units of dB relative to 1 μm , we would set the **Cal. Level** to

$$L_v = 20\text{Log}_{10}[9.86/(1.0 \times 10^{-6})] = 139.9 \text{ dB}$$

Displaying Amplitude in Linear Units

Providing a digital readout of the measured amplitude at the cursor position in linear units.

Although the measured level is always displayed in decibels on a logarithmic scale with a digital readout at the cursor position in dB, a second digital readout can be created which will show the amplitude in linear units. This is particularly useful when using an accelerometer and desiring to readout the amplitude in units such as g, m/s², ft/s², etc. The accuracy of the linear units value will be +/- 5 % of the true value.

This procedure requires evaluating the sensitivity of the transducer in decibels relative to volts. The sensitivity of the transducer is usually provided in the manufacturers specifications. To convert sensitivity to decibels use the following formula:

When the linear scale is set to zero the 824 will read the rms input voltage.

$$\text{Linear Scale (dB)} = 20\text{Log} (\mathbf{1 \text{ volt} / \text{sensitivity}})$$

Obtaining a readout in units of “g”.

Example: The sensitivity of an accelerometer is typically provided in units of V/g. Using an accelerometer having a sensitivity of 50 mV/g, the Linear Scale would be calculated as follows:

$$+26.0 \text{ dB} = 20\text{Log} [\mathbf{1 \text{ volt} / 0.05V}]$$

The following table gives some examples of some typical Linear Scale values for common accelerometer sensitivities.:

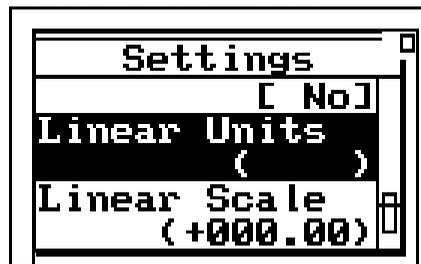
Sensitivity	Linear Scale (dB)	Units
100 mV/g	20 dB	g
50 mV/g	26 dB	g
25 mV/g	32 dB	g
10 mV/g	40 dB	g
5 mV/g	46 dB	g
14.0 mV/Pa	37.08 dB	Pa (2540)
44.5 mV/Pa	27.03 dB	Pa (377B41)
11.7 mV/Pa	38.64 dB	Pa (2559)
47.5 mV/Pa	26.47dB	Pa (377A60)

Obtaining a readout in units other than “g”.

If the desired linear units are different from those provided by the manufacturer, m/s^2 for example, calculate the sensitivity in those units, Volt/ m/s^2 , and use that value in the equation for Linear Scale.

Setup of Linear Units Readout.

The items to be defined to implement this feature are “Linear Units” and “Linear Scale” which appear in the FFT Edit Settings menu as shown in “Settings Menu” on page 12-1 and on the screen as shown below.



Linear Units

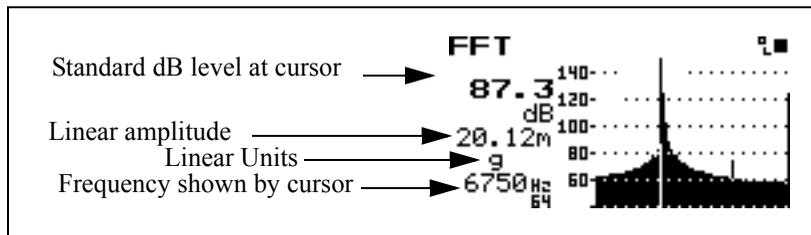
Linear Units is simply 4 alphanumeric characters defining the units name as it will appear on the screen.

Linear Scale

Linear Scale is the value of Linear Scale calculated as shown in the preceding sections.

Input the desired values for both Linear Units and Linear Scale by highlighting the item, pressing the Check (✓) key, entering the values and pressing the Check (✓) key again to close the menu.

Below is an example of the FFT live display with linear units:



The following explains each of the display's components:

In this case it shows 20.12 milli-g acceleration.

Standard dB level at cursor - This is the dB display which appears whether or not the linear amplitude is displayed.

Read out at cursor - This is the linear units level at the cursor.

NOTE: The units level is displayed in engineering exponential notation.

Linear Units - This is the unit entered by the user in the menu for "Linear Units". In this particular case we have entered "g" for acceleration.

Frequency shown by cursor - This is the frequency as shown by the cursor.

NOTE: The linear units level is displayed in engineering exponential notation. This notation expresses the exponent with a single character: “n” for nano (10^{-9}), “μ” for micro (10^{-6}), “m” for milli (10^{-3}), a space for no exponent, “k” for kilo (10^3), “M” for mega (10^6) and “G” for giga (10^9).

Frequently Asked Questions Concerning FFT

What is the reference level for decibels (dB) levels in the FFT option of the 824?

The decibel levels displayed by the FFT option of the 824 are the same as those for SPL in other instruments such as SSA or ISM and is 20 micro-Pascal (set during your microphone calibration process). Now, that may not mean much if you are viewing the output of an accelerometer rather than a microphone. The linear units are available to view the output of the accelerometer but the dB level may be of use.

To calibrate the dB level to some usable value for acceleration requires the use of an accelerometer calibrator. We use the PCB 394C06 Portable 1g Handheld Shaker. Set the calibration level to something like 140dB and run through the calibration procedure. Then the 824 FFT will read 140 dB when it is excited with 1g. This provides a reference of 0.1 micro-g (also 1 micrometer per second squared).

How do I get the DNA software to read FFT data in linear units.

To get DNA to read FFT data in a linear unit such a g or m/s the data must be converted from the decibel numbers that DNA receives from the 824 to that linear units value. To do this you need to know a reference level for the decibel reading that the 824 provides. It will change depending on the current calibration offset in the 824. The answers to the next two questions will help you accomplish this calculation.

How can I convert decibels (dB) levels from the FFT option of the 824 into linear units in my spreadsheet?

There are two ways to calculate the linear units from decibels.

Method 1:

With the FFT instrument in the 824 the data can be outputted to the display in linear values such as 'g' (gravity), or meters/second, volts or Pascal. The 824 makes this calibration using a setting that the user enters. This setting is the sensitivity of the unit relative to 1 volt and entered in dB into the Linear Scale setting (for example a 50mv/g accelerometer would have a Linear Scale of 20 LOG(1/0.05) or +26.02dB). The Linear Unit setting is a text field so that the units may be announced as desired.

The Linear Value is calculated in this way:

1. Take the dB reading
2. Subtract off the calibration offset (this makes the number bigger since the cal. offset is negative)
3. Subtract 167 dB from the previous result and the number is now in dB volts
4. Add the Linear Scale setting
5. Divide by 20
6. Take 10 to this power, this is the Linear Value

Here is an example:

The calibration offset is -45.41dB

The Linear Scale is +26dB (for a 50mV/g accelerometer)

The FFT displays a level of 121.7dB and 20.17g linear value

1. 121.7dB Take the dB reading
2. $121.7 - (-45.41) = 167.11$ dB Subtract calibration offset

3. $167.11 - 167 = 0.11$ dBV subtract 167 dB (180-13, dB volts)
4. $0.11 + 26 = 26.11$ dBg Add the Linear Scale setting
5. $-26.11 / 20 = 1.3055$ divide by 20
6. $10^{1.3055} = 20.21$ take 10 to this power (result will be close to the FFT display)

The difference (+0.2%) between the 824 display and this calculation are primarily due to the precision of math done in the 824 versus precision of the math functions in the calculator.

Method 2:

Take any FFT display reading that shows a dB and a linear level directly from the 824 display.

Calculate the linear reference level (what linear level gives 0dB) using this formula:

$$R = L / (10^{(D/20)})$$

where R is the linear reference level for the current calibration settings of the measurement,

where L is the linear level displayed (i.e. g or m/s), and

where D is the decibel level displayed.

Here's an example. I have an 824 connected to a signal generator supplying 0.5 volts RMS, the Linear Units setting is "g" and the Linear Scale setting is "-26.00" dB. I run the 824 FFT for a while and press stop, the display now shows a dB level of 121.7dB and a linear level of 50.87 milli-g.

$$R = L / (10^{(D/20)})$$

$$R = .05087g / (10^{(121.7dB/20)})$$

$$R = .05087g / 10^{(6.085)}$$

$$R = .05087g / 1216186$$

$$R = 4.182748 \times 10^{-8}$$

now use this R as the reference to get the readings in linear units from dB like this:

$$L = R * 10^{(D/20)}$$

$$L = 4.182748g \times 10^{-8} * 10^{(121.7dB/20)}$$

$$L = 4.182748g \times 10^{-8} * 10^{(6.085)}$$

$$L = 4.182748g \times 10^{-8} * 1216186$$

$$L = 0.05087g$$

Another example, this time down 20 dB:

$$L = 4.182748g \times 10^{-8} * 10^{(101.7dB/20)} = 5.087 \times 10^{-3} = .005087g$$

How can I manually enter a calibration offset so that the decibel levels (dB) from the FFT option of the 824 are relative to 1 micro-meter per second squared?

The calibration offset is calculated with this formula ($\pm 5\%$ accurate):

$$LCAL = 20 \log(4.467 \text{ nanovolts} / V_{ref})$$

Where LCAL is the calibration offset being calculated, V_{ref} is the desired reference voltage (the voltage that would read 0 dB) and 4.467 nanovolts is a constant set by the 824's electronic design (4.467×10^{-9}).

Example: It is desirable to display 140dB for 1 g due to the relationship that 1 g is 10 meters per second squared (m/s^2) and 1 micrometer per second squared (mm/s^2) is a common reference level. Given that an accelerometer with a sensitivity of 0.1V/g has a sensitivity of 0.01 volts per meter per second squared (10 mV/ m/s^2). The voltage at 1 mm/s^2 would be 0.01 microvolt (calculated ratio-metrically since

1m/s² outputs 0.01V then 1m m/s² will have an output of 0.01mV).

$$\text{LCAL} = 20 \log(4.467 \text{ nV} / 0.01\text{mV}) = 20 \log(0.4467) = -7.00\text{dB}$$

LCAL is stored with these steps for instruments that have firmware version 4.065 or newer:

Press the TOOLS key

Highlight Calibration and press the right arrow key

On the Calibration menu scroll to the bottom of the list and highlight Advanced

Press the right arrow key to open the Advanced calibration menu

Highlight the ----Secure---- line and press the check key, this will change the Cal Level value setting to a special key value of 224.48 that allow the calibration settings to be entered directly (the key is to prevent accidental calibration alteration)

Highlight the CAL Offset setting line and press the check key

Enter the LCAL value calculated above and press the check key

Highlight the ----Secure---- line again and press the check key, this will change the Cal Level value setting back to 114.00 and secure the calibration settings.

Exit the menu by pressing the power key, pressing the left arrow or pressing TOOLS

For firmware versions prior to 4.065 the calibration offset (LCAL) is entered using a computer and the following steps.

LCAL is then entered via computer by these I/O commands using HyperTerminal:

Command: "S1,1"Response: ""// Overall Reset

Command: "S 41,225.48"Response: ""// Key, unlock the S227 command

Command: "S227,-7"Response: ""// Send LCAL, enter your LCAL value

Command: "Q227"Response: " -7.00"// Verify LCAL, verify your LCAL value

Command: "S 41,114"Response: ""// Restore Calibrator Level

Here are typical Calibration Offset Levels (dB) for several accelerometer sensitivities (re. 1mm/s²):

Sensitivity 1mV/g 10 mV/g 100 mV/g 1 V/g 10 V/g

Cal. Offset 23.00 dB 13.00 dB -7.00 dB -27.00 dB -47.00 dB