Operator's Manual
SD385 NOMAD Portable Signal Analyzer
Part Six

Legacy Manual

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Function Group - POWER

This Function Group is a "cross channel" Function Group and is available only with the two channel option. The term "cross channel" refers to those functions using a quantity called "Cross Spectrum". Cross Spectrum is the complex product of the complex spectrum (real and imaginary) of Channel A and the complex spectrum of the response channel (Channel B).

There are, basically, four calculations that comprise this Function Group. These calculations are: Coherent Output Power (COP), Coherence (COH), Magnitude Cross-Spectrum (|XSPT|) and the Real and Imaginary components (XSP RE & IM) of the Magnitude Cross-Spectrum calculation.

For Transfer Function measurements, a qualifying factor as to the total validity of the Transfer Function can be established by means of the Coherence function. However, there are applications where the operator is not interested in the Transfer Function between two points, but rather in isolating a source of noise and vibration. For these situations it might be desired to measure both the total power present at a measurement location and the amount of power at the location which is coherent with some reference point. For example, the total noise measured in the vicinity of an operating machine might be caused by the operation of a compressor section, gearbox or blower. Measurements of the individual noise or vibration associated with these three subassemblies does not necessarily indicate which of the subassemblies makes the greatest contribution to the monitored location. Factors such as transmission paths and signal interaction could modify data interpretations. This is where the Coherent Output Power measurement can be used. The Coherent Output measurement takes a total power spectrum measurement at a monitor location and multiplies this by the Coherence function between the monitor point and some reference location. Using a spectrum averaging process, any signals which are not related to, or Coherent with the reference spectrum, effectively average down. The resulting function is Coherent Output Power.

The Coherence measurement that accompanies the Coherent Output Power calculation is calculated the same as the Coherence measurement that accompanies the Transfer Function calculation. In both cases, it is used to qualify the validity of the calculation in question. The coherence function provides a check as to whether a single input/single output situation or multiple input/single output or a multiple input/multiple output situation has been encountered. Since the coherence function is the ratio of the absolute value of Cross spectrum "squared" to the input/output power spectra product, it is a real valued quantity. The magnitude of the coherence function can vary from 0 to 1, with 0 indicating no coherence, and a unity value (1) indicating perfect coherence.

Cross-Spectrum is similar to a Power Spectrum analysis in that it involves forming the product between two functions. However, this is where the similarity ends. In the Power Spectrum case, a single signal is used. Usually the Power Spectrum is calculated by multiplying the FFT of a signal by the complex conjugate of the same FFT. In the case of the Cross-Spectrum, two different signals are used in the calculation by taking the product of the FFT on one signal and the complex conjugate of the FFT of the other signal. Using the Cross-Spectrum calculation, a certain amount of signal-to-noise enhancement is achieved, and at the same time, signals which are not contained mutually in both channel inputs tend to be discarded. While the Cross-Spectrum calculation does not give a complete causal relationship between two signals, it can serve as an excellent first indication as to whether or not two signals are, in fact, related.

The first selection on the POWER FUNCTION menu, COP & COH (Coherent Output Power and Coherence), is a scroll-dual type display. The lower, larger, display is Coherent Output Power. The upper trace is Coherence. Coherent Output Power is always the lower trace data and Coherence is always the upper trace data. However, if either trace is selected for a single trace display, the outside dimensions of either display grid will be the same.

Selection 2, |XSPT| & ϕ (Cross-Spectrum and Phase), is also a scroll-dual type display. The lower, larger, display is the Magnitude Cross-Spectrum measurement. The upper trace is a display of the Phase relationship between the reference input (Channel A) and the response output (Channel B). Magnitude Cross-Spectrum is always the lower trace data and Phase is always the upper trace data. If either trace is selected for a single trace display, the outside dimensions of either display grid will be the same.

Selection 3, XSP RE & IM, is a dual display of the Real and Imaginary components of the Magnitude Cross-Spectrum calculation. The upper trace is always the Real component and the lower trace is always the Imaginary component.

If you look at the DISPLAY MEM MENU, you will notice that memory selection, for all the Power Function selections, is limited to the Average and Storage Memories. There is a very good reason for this. When dealing with any of the Cross Spectrum functions, the quantities that make up the Cross Spectrum calculation, and the Power Function calculations, are averaged separately and then the functions to be displayed are calculated from these averaged quantities.

Figures 3-DSP/SEL-39 through 3-DSP/SEL-41 are examples of each POWER FUNCTION menu item.

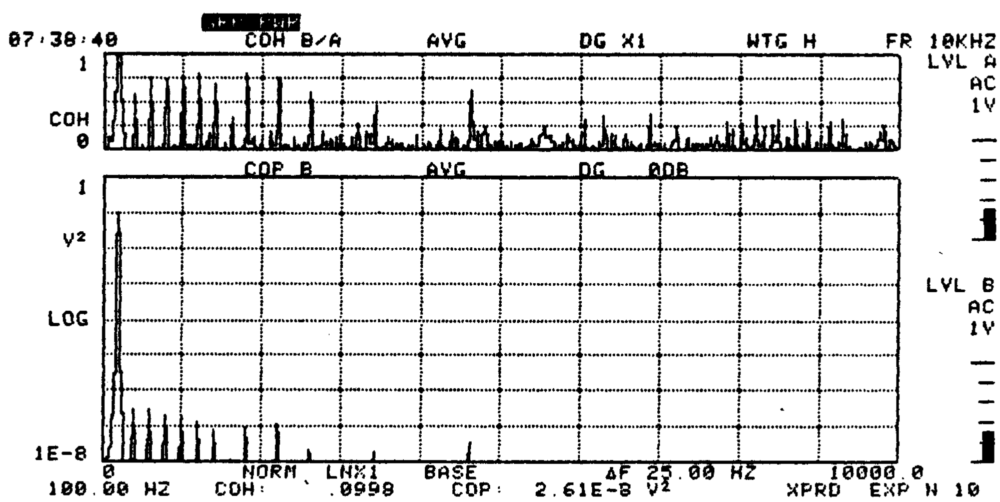


Figure 3-DSP/SEL-39. POWER FUNCTION Menu Selection 1, COP & COH

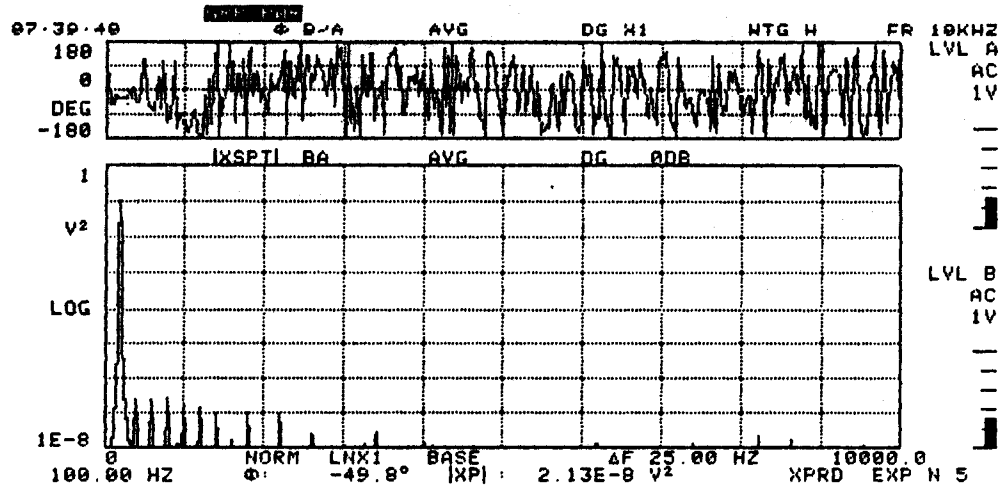


Figure 3-DSP/SEL-40. POWER FUNCTION Menu Selection 2, |XSPT| & ϕ

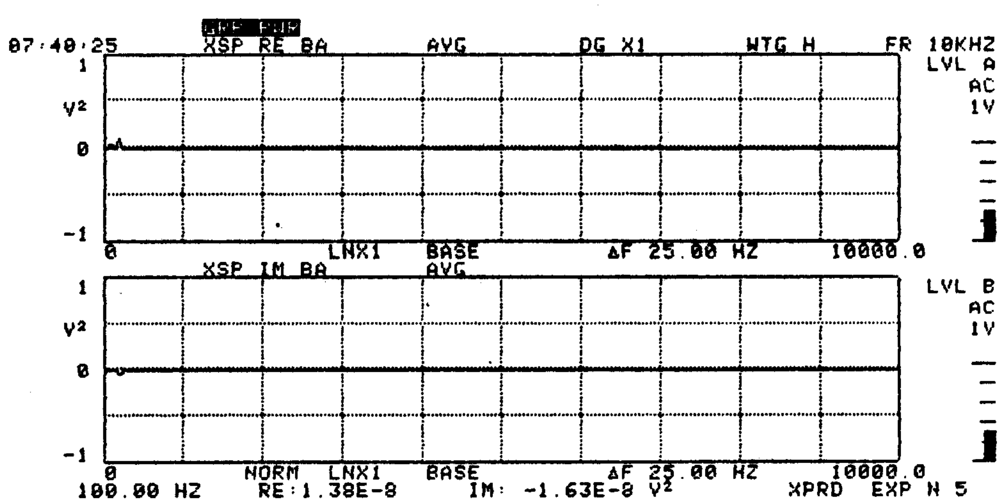


Figure 3-DSP/SEL-41. POWER FUNCTION Menu Selection 3, XSP RE & IM

Function Group - IFFT

This Function Group is a "cross channel" Function Group and is available only with the two channel option. The term "cross channel" refers to those functions using a quantity called "Cross Spectrum". Cross Spectrum is the complex product of the complex spectrum (real and imaginary) of Channel A and the complex spectrum of the response channel (Channel B).

There are, basically, four calculations that comprise this Function Group. These calculations are: Auto-Correlation (R AA), Cross-Correlation (R BA), Impulse Response (IR) and Output Response (OR).

Auto-Correlation is a single channel function obtained by comparing a signal with itself and displaying it in terms of plus and minus time with respect to a zero time delay. Perfect correlation is displayed as unity or one. An Auto-Correlation function of any complex signal will have perfect correlation at time = 0 (a given signal is always equal to itself).

In the SD385, the **Auto-Correlation function** is determined by first calculating the Power-Spectrum and then performing an Inverse FFT on the Power Spectrum calculation.

The Auto-Correlation function can be used to check for the existence and nature of periodicities and to provide some signal-to-noise enhancement. Note that the Auto-Correlation function is a bipolar result having both positive and negative values. It is normalized by its maximum value to provide a function which varies between + 1 and -1. It is this normalized coefficient which is displayed by the SD385.

Cross-Correlation is a two channel function obtained by comparing two signals from separate sources. If these signals are independent, there will be no correlation. However, if these signals or part of the signals originate from a common source but travel different paths, or are delayed by different times, the correlations will be measured at a time equal to the delay.

The calculation for Cross-Correlation is similar to Auto-correlation, the difference being that Cross-Correlation is calculated using two separate channels. In the SD385, the Cross-Correlation function is determined by first calculating the Magnitude Cross-Spectrum, and then performing an Inverse FFT on the Magnitude Cross-Spectrum calculation.

Impulse-Response is a two channel function that can be defined as the response of a Transfer Function to an impulse. The Impulse-Response measurement can be used to characterize electronic filters, determine noise transmission paths, identify structural modes and to predict system outputs.

In the SD385, Impulse-Response is determined by first calculating the complex Transfer Function and then performing an Inverse FFT on the complex Transfer Function calculation.

Output-Response is calculated as follows: Transfer Function is the Frequency Domain ratio of a system output to a system input. If the input (Channel A), and the Transfer Function are known, then the output can be predicted based on and Inverse FFT of the product of the complex Spectrum calculation from Channel A and the complex Transfer Function calculation. The result is the predicted Time-Domain Output-Response.

The first selection on the IFFT FUNCTION menu, AUTO-CORR, is a dual trace display. Even though this is a single channel function, it is available only with the two channel option. Channel A (R AA) is always upper trace and Channel B (R BB) is always lower trace.

Selection 2, CROSS-CORR, is a cross-channel function resulting in a single trace display; i.e., Cross-Correlation is the Inverse FFT of the Magnitude Cross-Spectrum calculation. The resultant calculation is R BA.

Section 3, IMPULSE-RES, is a cross-channel function resulting in a single trace display; e.g., Impulse-Response is the Inverse FFT of the complex Transfer Function calculation. The resultant calculation is IR B/A.

Selection 4, TIME & OUTRES, is a dual trace display of Time Domain data from Channel A Input Memory (upper trace always) and the predicted Time Domain Output Response (lower trace always). If you look at the DISPLAY MEM menu selections for this function, you will notice that Display Memory selection is somewhat different that it is for the other IFFT FUNCTION selections. The upper trace will always be Time Domain data from the Channel A Input Memory. The lower trace Display Memory can be either the Average or Storage Memories. This isn't entirely true. The lower trace data is actually the result of a calculation that takes place between the complex Transfer Function contained in the Average (or Storage) Memory and the complex Spectrum data contained in the Channel A Input Memory. If you select TIME & OUTRES for display, and the **SOURCE MEMORY IS: ERASED"** message appears on the lower display, pressing the AVERAGE group START button won't do a thing (except beep). The reason for this is that an average cannot be performed while displaying this function selection because the calculation for the lower trace data requires a Transfer Function or Impulse Response calculation to be performed first, before the Output Response can be calculated. The proper Display Memory selection for the lower trace data might be "INP X AVG" (Input Memory time the Average Memory), but that would probably be more confusing than this description.

If you look at the DISPLAY MEM MENU, you will notice that memory selection, for almost all the IFFT Function modes, is limited to the Average and Storage Memories. There is a very good reason for this. When dealing with any of the Cross Spectrum functions, the quantities that make up the Cross Spectrum calculation are averaged separately and then the functions the selected IFFT calculations are to be performed on (Complex Power Spectrum, Complex Cross Spectrum, Complex Transfer Function) are calculated from these averaged quantities.

Figures 3-DSP/SEL-42 thorough 3-DSP/SEL-45 are basic examples of each IFFT FUNCTION menu item.

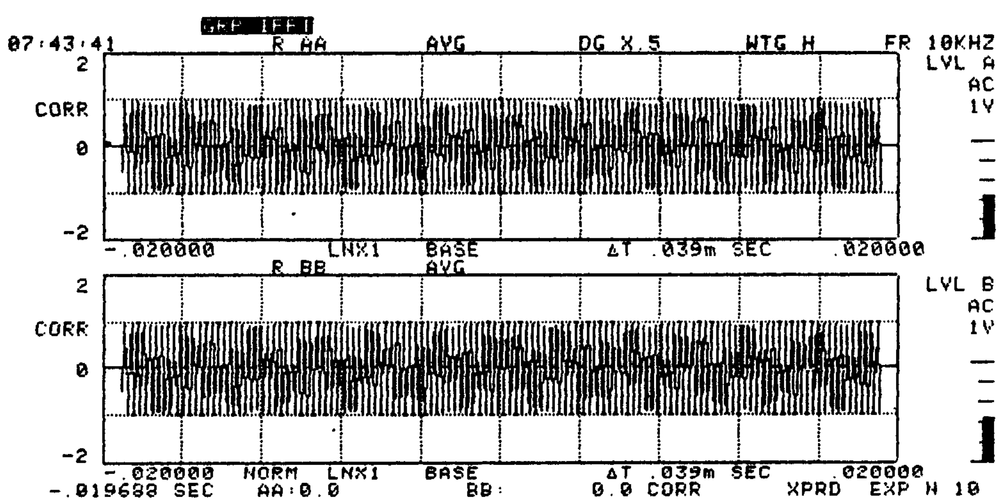


Figure 3-DSP/SEL-42. IFFT FUNCTION Selection 1, AUTO-CORR

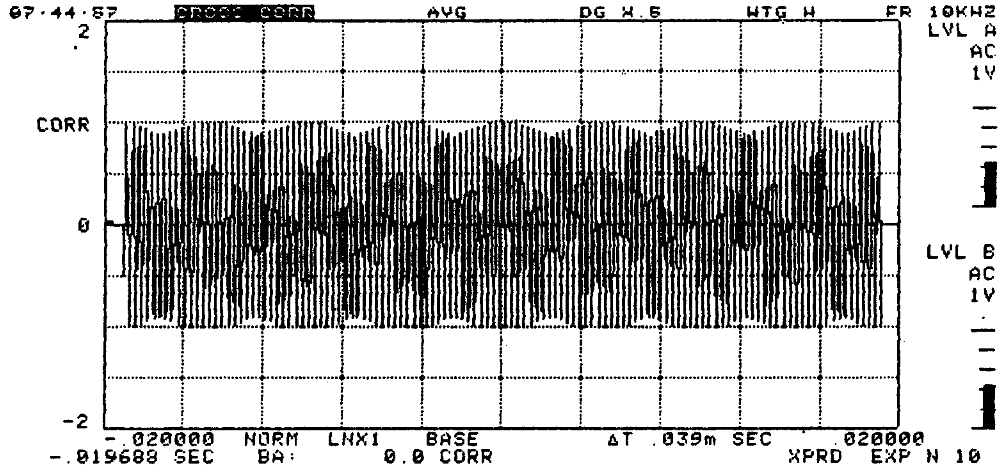


Figure 3-DSP/SEL-43. IFFT FUNCTION Selection 2, CROSS-CORR

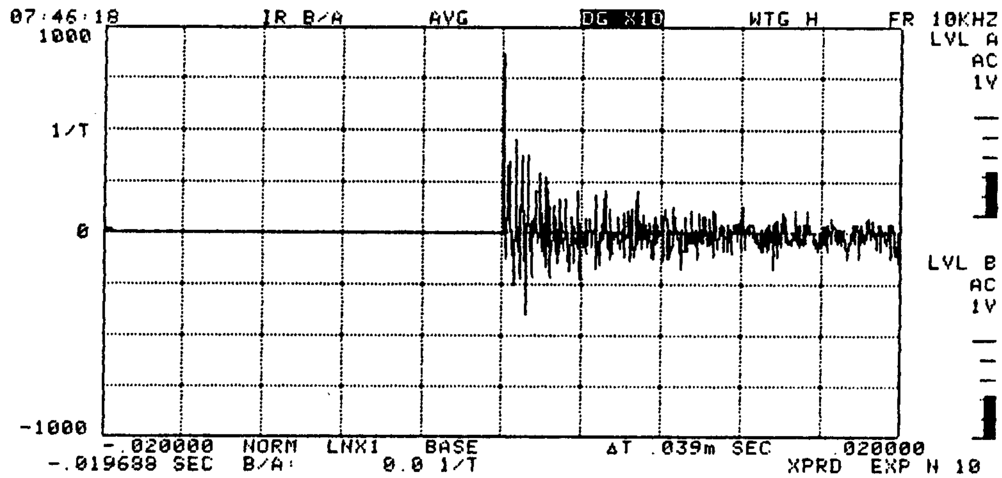


Figure 3-DSP/SEL-44. IFFT FUNCTION Selection 3, IMPULSE-RES

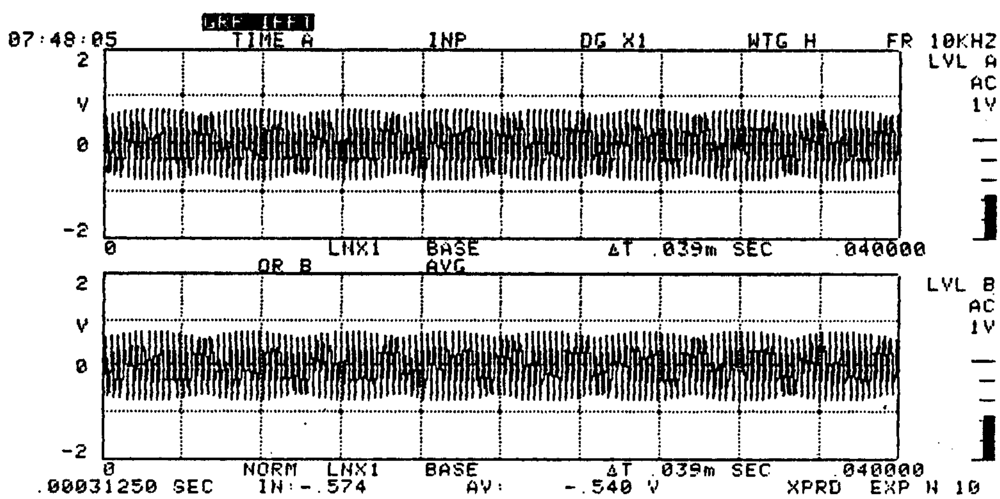


Figure 3-DSP/SEL-45. IFFT FUNCTION Selection 4, TIME & OUTRES

Table 3-DSP/SEL-2. Definitions of Functions and Symbols

All formulae are expressed in terms of G_{AA}, G_{BB}, T_A, T_B, CO, QUAD and their averages.

G_{AA} — MAG^2 or Power Spectrum, Channel A
G_{BB} — MAG^2 or Power Spectrum, Channel B

$\sqrt{G_{AA}}$ — MAG or Spectrum, Channel A
$\sqrt{G_{BB}}$ — MAG or Spectrum, Channel B

T_A — Time Domain data, Channel A
T_B — Time Domain data, Channel B

$\overline{G_{BA}}$ — Cross Spectrum

$\overline{CO}$ — $\overline{G_{BA}}_{REAL}$

$\overline{QUAD}$ — $\overline{G_{BA}}_{IMAG}$

Φ — Phase angle of the FFT

$\mathcal{F}^{-1}[\,]$ — Inverse FFT (IFFT) of whatever's inside the brackets

INP — Contents of the Input Memory (Time Domain Data)

RT — FFT'd contents of the Input Memory (Real Time Spectrum Data)

AVG — Contents of the Averager Memory (Averaged Data)

STO — Contents of the Storage Memory (Stored Averaged Data)

SYNC — Time Averaged Data (Data Averaged in the Time Domain, *before* the FFT)

ZOOM — Zoomed or Translated Data

Any quantities with an "overbar" are averaged quantities. For example:

$\overline{G_{AA}}$ = Average of G_{AA}; $\overline{GBA}$ = Average of G_{BA} = $\overline{CO}$ + j$\overline{QUAD}$
(CO and QUAD are averaged separately)

$\overline{T_A}$ = Average of Time Domain Data, Channel A, etc.

3-3.3.1 Function Calculations

In order to provide a comprehensive description of the FUNCTION GROUPS and each Function-menu item, the formulae for the calculations performed by each Function and Function-menu item are included with the tables and the following descriptions. While it is not required to have a complete knowledge of the mathematics performed by the instrument, the formulae can be used for comparison purposes to give you an idea as to what is actually happening to the data for each function.

This description used Channel A as the reference to describe the single channel calculations, and Channels A and B to describe the Cross-Spectrum calculations. If you have the two channel option, the descriptions of the single channel calculations apply to both Channels A and B. FUNCTION GROUPS 4, 5 AND 6 (TRANSFER FUNCTION, POWER and IFFT) work with a quantity called "Cross Spectrum" requiring two channels. These functions use Channel A as the reference.

The SD385 deals with Frequency Domain data resulting from an FFT (Fast Fourier Transform) on Time Domain samples taken. While this statement is true, it really doesn't mean much unless you have intimate knowledge of the FFT. The following formulae will help clarify how the many functions performed by the SD385 are calculated, and what quantities these calculations are based on.

The pure Fourier transform of a time varying waveform is typically calculated in terms of sine and cosine vector components, referred to as Real and Imaginary components. A simplified version of the formula can be expressed as follows:

$$\mathcal{F}[a(t)] = A(j\omega)$$

$$\mathcal{F}[b(t)] = B(j\omega)$$

Where $\mathcal{F}$ indicates Fourier Transform, $a(t)$ and $b(t)$ are the Time Domain inputs to Channels A and B, and $A(j\omega)$ and $B(j\omega)$ are complex numbers that can be expressed in Real and Imaginary parts so that for any particular "cell" (which corresponds to the ω or radian frequency value; the value of ω being $2\pi f$),

$$A(j\omega) = a + jb$$

$$B(j\omega) = c + jd$$

A complete spectrum presentation would require a 3-dimensional display with a Real axis (a or c), and Imaginary axis (b or d) and an ω or frequency axis.

However, in order to perform spectrum averaging, or to observe the spectrum of a signal in a readily recognizable form, it is the spectrum magnitude (|A|,|B|) which is most often used. This magnitude is obtained by combining the sine and cosine vector components using a square root of the sum of the squares calculation as follows:

$$|A|^2 = a^2 + b^2 \leftrightarrow |A| = \sqrt{a^2 + b^2} \quad \text{hence, } \sqrt{G_{AA}}$$
$$|B|^2 = c^2 + d^2 \leftrightarrow |B| = \sqrt{c^2 + d^2} \quad \text{hence, } \sqrt{G_{BB}}$$

The SD385 also handles the data in MAG^2. This results in the Power or Magnitude spectrum and are the quantities:

$$G_{AA} = a^2 + b^2$$
$$G_{BB} = c^2 + d^2$$

The phase relationship between A and B is important and is an integral part of the Cross Spectrum calculation. The value of the Cross Spectrum can be seen by attempting the Complex Transfer Function calculation, $H(j\omega)$.

$$H(j\omega) = \frac{B(j\omega)}{A(j\omega)} = \frac{c + jd}{a + jb}$$

By resolving the Imaginary component out of the denominator (the Imaginary component is the symbol "j", the $\sqrt{-1}$ complex operator that allows the inclusion of the phase relationship in the transform) of the Transfer Function calculation using the complex conjugate of the denominator as follows:

$$\frac{c + jd}{a + jb} \leftrightarrow \frac{c + jd}{a + jb} \times \frac{a - jb}{a - jb} = \frac{(ac + bd) + j(ad - bc)}{a^2 + b^2}$$

We find the resultant denominator ($a^2 + b^2$) is G_{AA} (Magnitude Spectrum). The numerator as it turns out, is the Cross Spectrum, or G_{BA}. The SD385 stores G_{BA} in rectangular coordinates (Real and Imaginary) where:

$$\overline{ac + bd} = \overline{G_{BA}}_{\ REAL} = \overline{CO}$$

and

$$\overline{j(ad - bc)} = \overline{G_{BA}}_{\ IMAG} = \overline{QUAD}$$

When you display transfer function and phase, you are displaying the magnitude of the transfer function with the phase in the upper-scroll display. The following formulae show how this is achieved:

$$TF = \frac{\overline{G_{BA}}}{\overline{G_{AA}}} = \frac{\overline{G_{BA}}_{\ REAL} + j\overline{G_{BA}}_{\ IMAG}}{\overline{G_{AA}}}$$

hence phase

$$\Phi = \tan^{-1}\left(\frac{\overline{G_{BA}}_{\ IMAG}}{\overline{G_{BA}}_{\ REAL}}\right) = \tan^{-1}\left(\frac{\overline{QUAD}}{\overline{CO}}\right)$$

and

$$|TF| = \sqrt{\left(\frac{\overline{G_{BA}}_{\ REAL}}{\overline{G_{AA}}}\right)^2 + \left(\frac{\overline{G_{BA}}_{\ IMAG}}{\overline{G_{AA}}}\right)^2} = \sqrt{\frac{\overline{CO}^2 + \overline{QUAD}^2}{\overline{G_{AA}}}}$$

One important factor must be noted in these formulae. When dealing with Transfer Function, Power or the IFFT functions, the SD385 is always displaying Average Memory data. The Averaged quantities are denoted by an "overbar"; i.e., $\overline{G_{AA}}$, $\overline{G_{BB}}$, $\overline{G_{BA}}$ REAL, $\overline{G_{BA}}$ IMAG. Each quantity is averaged separately, then the functions to be displayed are calculated from these averaged quantities.

Coherence

Coherence, a dimensionless scaler quantity, is an important function for determining the quality of a Transfer Function measurement. Coherence can be any value from 0 to 1. A totally coherent measurement would yield a value of 1; whereas, a totally incoherent measurement would show a value of 0. A value of 1 indicates that 100% of the measured output response from a system is directly related to the reference input. For example, if a specimen is "excited" by a random noise of some energy to A (refer to Figure 3-DSP/SEL-46), the output B will also be random noise, but the relationship between A and B will be consistent if the specimen has a consistent Transfer Function. A "noisy" phase and invalid gain will show up when there is no consistent relationship between A and B. Coherence is a measure of this.

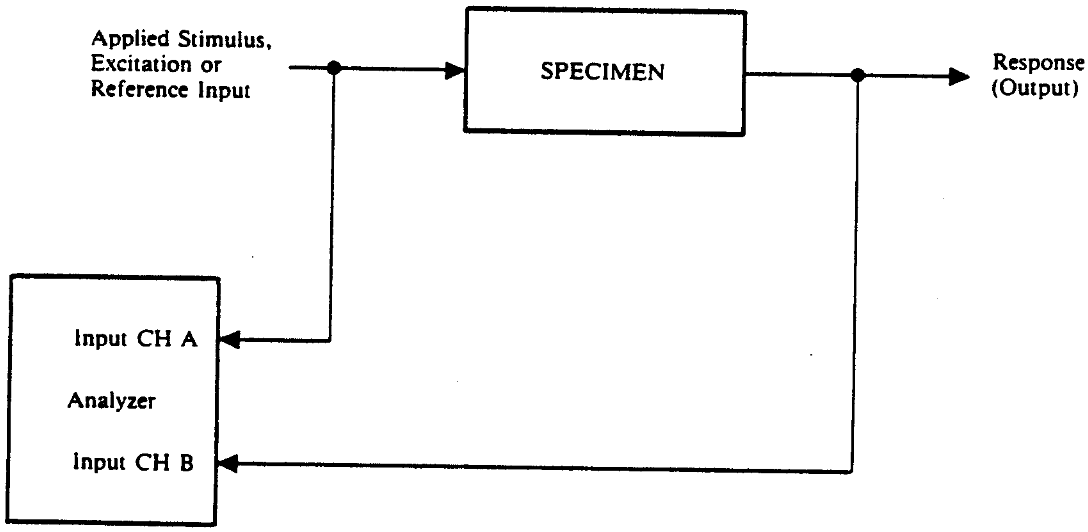


Figure 3-DSP/SEL-46. Basic Transfer Function Interconnect

Coherence is calculated as follows:

As already noted, the quantity G_{BA} is averaged separately from G_{AA} and G_{BB}. G_{AA} and G_{BB} are the MAG^2 of A and B spectra; therefore their values are always positive. G_{BA} is a signed quantity. A series of random, unrelated values averaged as MAG^2 will result in a much larger quantity than a series of random values averaged as signed quantities. This happens because a random phase relationship produces both positive and negative values which will cancel each other out. If the relationship is totally random, the result will

MAG^2. If a consistent relationship does exist, the phase will be consistent, yielding no "positive on this pass, or negative on the next" to cancel.

Hence, if we render G_{BA} to a form compatible with G_{AA} and G_{BB}, the ratio between the two should be a value from 0 to 1 indicating the validity, or "Coherence" of the value averaged.

NOTE

There is always a relationship between A and B. Coherence tells you whether or not that relationship is a characteristic of the specimen or the random universe we live in.

The formula for Coherence is:

$$COH = \gamma^2 = \frac{|\overline{G_{BA}}|^2}{\overline{G_{AA}} \bullet \overline{G_{BB}}}$$

since (ignoring the average characteristics)

$$G_{BA} = |B|\,|A|_{REAL} + |B|\,|A|_{IMAG}$$

and

$$G_{AA} = |A|^2; G_{BB} = |B|^2$$

then

$$\frac{|\overline{G_{BA}}|^2}{\overline{G_{AA}} \bullet \overline{G_{BB}}} = \frac{(|B|\,|A|)^2}{|A|^2\,|B|^2} = 1$$

excepting, of course, where the A-B relationship is random, in which case $|G_{BA}|^2$ will approach zero in relationship to $G_{AA} \cdot G_{BB}$. Thus we achieve our measurement of Coherence.

Coherent Output Power

Coherent Output Power is the amount of response coherent with the measured input. It is the product of the power spectrum (G_{BB}) and Coherence; i.e., that part of output power actually generated by input power.

Coherent Output Power is calculated as follows:

$$COP = \gamma^2 \bullet G_{BB} \text{ or, more precisely, } COP = \frac{|\overline{G_{BA}}|^2}{\overline{G_{AA}} \bullet \overline{G_{BB}}} \times \overline{G_{BB}}$$

Since GBB will "cancel out" in the previous calculation, we find that:

$$COP = \frac{|\overline{G_{BA}}|^2}{\overline{G_{AA}}} \qquad \frac{\overline{CO}^2 + \overline{QUAD}^2}{\overline{G_{AA}}}$$

Auto-Correlation (R AA)

Auto-correlation is a single channel function obtained by comparing a signal with itself and displaying it in terms of plus and minus time with respect to a zero time delay. Perfect correlation is displayed as unity or one. An Auto-Correlation function of any complex signal will have perfect correlation at time = 0 (a given signal is always equal to itself).

In the SD385, the Auto-Correlation function is determined by first calculating the power spectrum ($\overline{G_{AA}}$) and then performing an Inverse FFT:

$$R_{AA} = \mathscr{F}^{-1}[\overline{G_{AA}}]$$

The Auto-Correlation function can be used to check for the existence and nature of periodicities and provide some signal-to-noise enhancement. Note that the Auto-Correlation function is a bipolar result having both positive and negative values. It can also be normalized by its maximum value to provide a function which varies between +1 and -1. It is this normalized coefficient which is displayed by the SD385.

Cross-Correlation (R BA)

Cross-Correlation is a two channel function obtained by comparing two signals from separate sources. If these signals are independent, there will be no correlation. However, if these signals or part of the signals originate from a common source but travel different paths, or are delayed by different times, then correlation will be measured at a time equal to the delay.

The calculation for Cross-Correlation is similar to Auto-Correlation, the difference being that Cross-Correlation is calculated using two separate channels, hence Cross-correlation is an Inverse FFT of the Cross-Spectrum, ($\overline{G_{BA}}$):

$$R_{BA} = \mathcal{F}^{-1}[\overline{G_{BA}}]$$

Impulse Response (IR)

The Impulse Response, a Time Domain function, is defined as an Inverse FFT of the Complex Transfer Function, $H(j\omega)$, a Frequency Domain function. Impulse Response can be used to characterize electronic filters, determine noise transmission paths, identify structural modes and to predict system outputs.

$$IR = \mathcal{F}^{-1}[H(j\omega)]$$

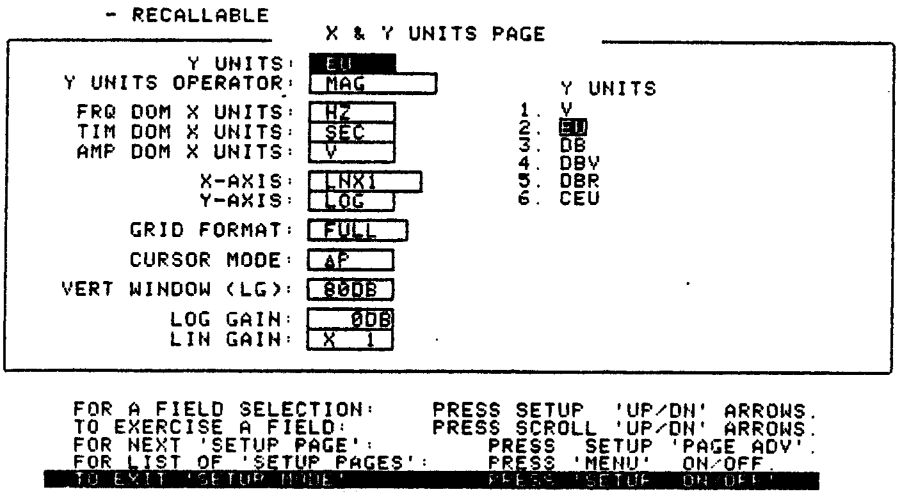
Output Response (OR)

Transfer Function is the Frequency Domain ratio of a system output to a system input. If the input, and the Transfer Function are known, then the output can be predicted based on an Inverse FFT of the product of the complex Spectrum, $A(j\omega)$, and the Complex Transfer Function, $H(j\omega)$. The result is the predicted Time-Domain Output Response:

$$OR = \mathcal{F}^{-1}[A(j\omega) \bullet H(j\omega)]$$

X & Y UNITS CONTROL
(Setup Page 4)

3-3.4 Setup Page 4 -- X & Y UNITS PAGE



To access this Setup Page (from the data display), press the SETUP group SETUP ON/OFF button. This displays the Setup Page listing. Next, place the RV on selection 4, X & Y UNITS CONTROL. Now, press the SCROLL group MENU button and Setup Page 4 will appear on the display. If a Setup Page appears instead of the Setup Page listing when SETUP ON/OFF is pressed, or if Setup Page 3 is already on the display, the PAGE ADV button can be used to access Setup Page 4.

Most of the X & Y Units Controls can be accessed directly from the data display without accessing Setup Page 4. Figure 3-XYUNITS-1 shows the location of each of the X & Y UNITS Controls that can be accessed in this manner.

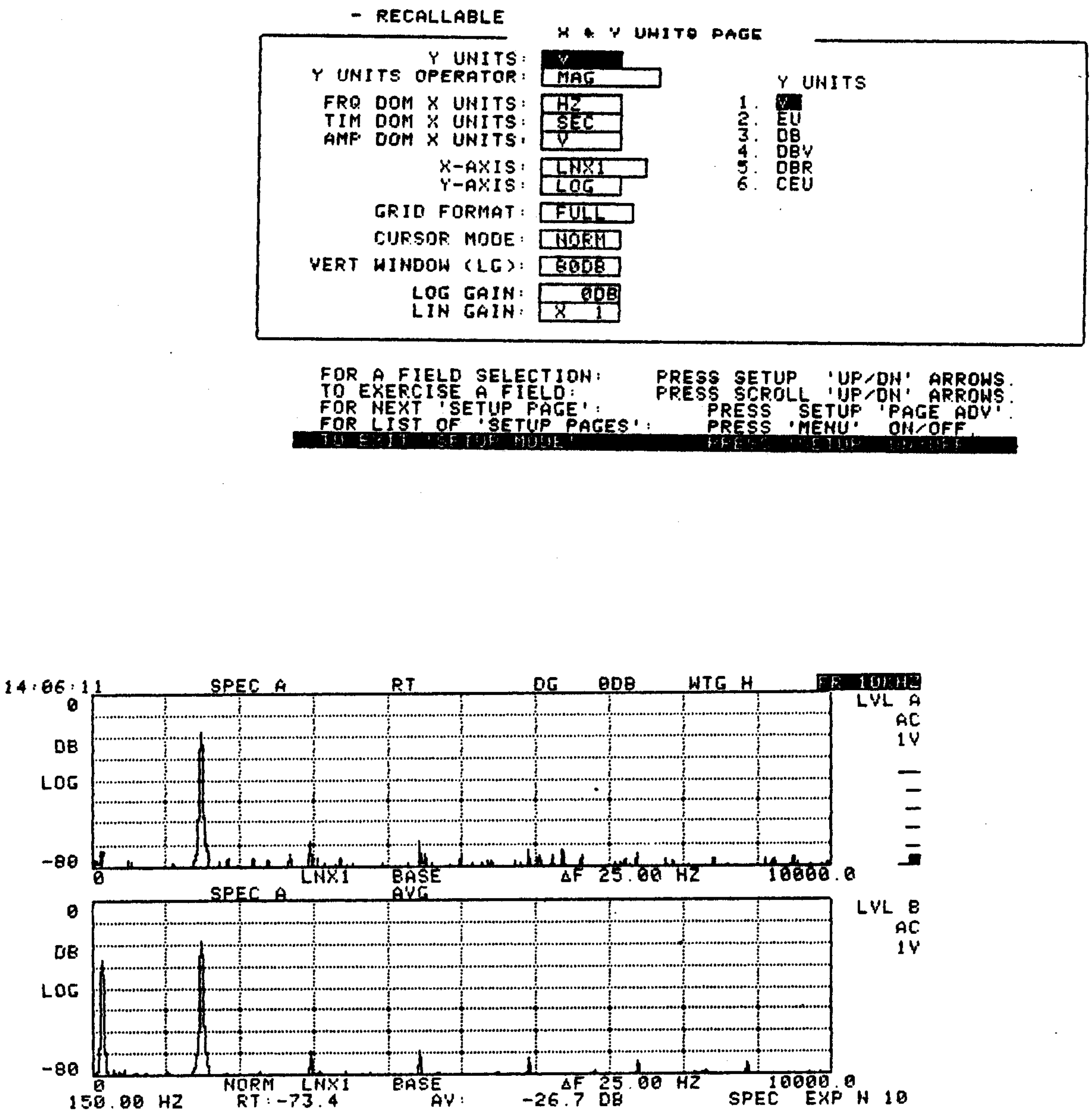
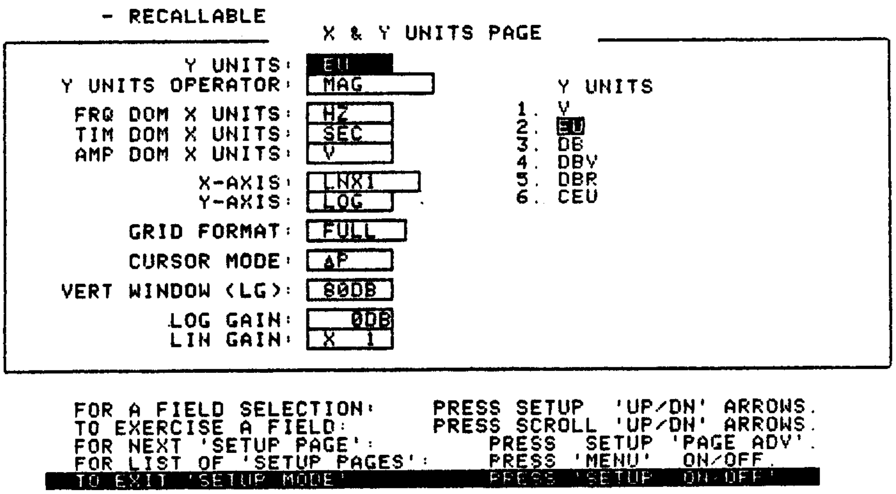


Figure 3-XYUNITS-1. X & Y UNITS Controls Accessed Directly From the Data Display

Y UNITS:



Control Menu for Selecting Units of Measurement for the Y-Axis.

1. V When this selection is made, the Y-axis scaling and cursor amplitude readouts will be in volts. This scaling will vary depending upon the selected primary function and the Y UNITS OPERATOR (next menu).

2. EU When this selection is made, Y-axis scaling and cursor amplitude readouts will be in Engineering Units. Engineering Units are a user-entered value (Setup Page 5) representing the probe relationship between voltage and a measured quantity, or a linear reference value designated by the operator. The probe can be an accelerometer, displacement-type, velocity pickup, or any one of several types of dynamic motion, or audio measuring devices (transducers). Since this value is voltage-related, Y-axis scaling for Engineering units will have the same scaling variations as Volts.

3. DB When this selection is made, Y-axis scaling and cursor amplitude readouts will be in dB. With the exception of transfer function and ratio type displays , the full scale level on the display will be 0 dB. Of course, this will not be the case if any Y-axis LOG GAIN is selected (ninth menu on this Setup Page). Also, dB cannot be selected for the Time and IFFT displays as the analyzer is forced to LOG when DB is selected.

4. DBV When this selection is made, Y-axis scaling and cursor amplitude readouts will be in dBV. DBV is a factory-set dB/Voltage reference where 0 dB = 1V.

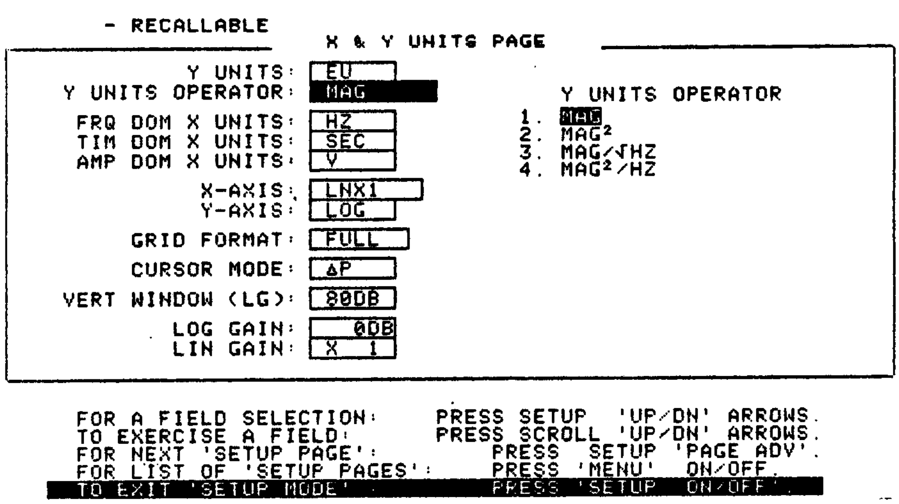
5. DBR This selection is the same as dBV except, dB reference and Voltage reference are selected by the operator via Setup Page 5.

6. CEU This selection means "Compensated Engineering Units" and is used to enable the Artificial Integration feature located on Setup Page 5. When this selection is made, Y-axis scaling will reflect the selections made on the three related Artificial Integration Menus from Setup Page 5. These menus are:

ENGLISH/METRIC UNITS,
DISPLAY TYPE, and
TRANSDUCER TYPE.

Some of the primary functions from Setup Page 3 have dedicated Y-axis scaling and are not affected by any of these selections; e.g., Statistics Y-axis scaling is either occurrences or % or total occurrences, IFFT Y-axis scaling is Correlation, 1/T and Volts.

Y UNITS OPERATOR:



Control Menu for Modifying Y-Axis Units.

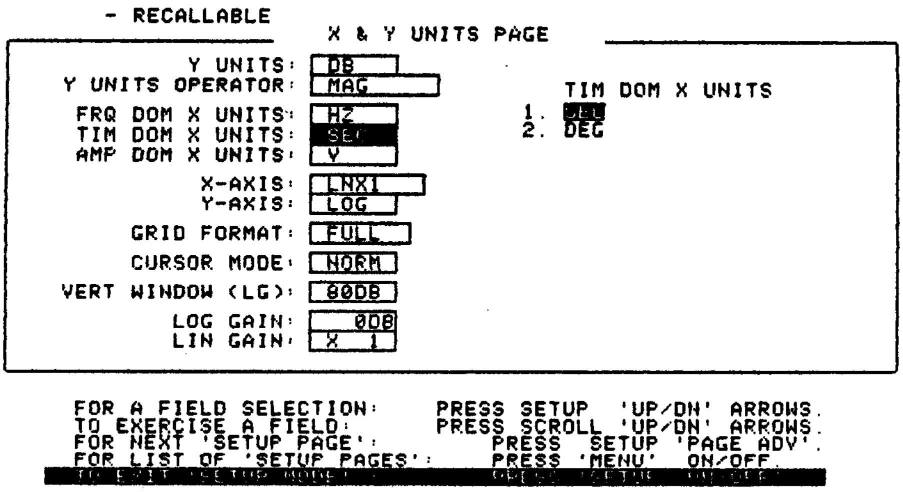
The selections on this menu are directly related to the Y UNITS menu. Rather than describe each menu item separately, the following table is provided to illustrate the effect the Y UNITS OPERATOR has on the Y UNITS.

Table 3-XYUNITS-1. Y-UNITS vs Y-UNITS OPERATOR

Y UNITS	Y-UNITS OPERATOR	RESULTANT Y-UNITS (DISPLAYED)
V	MAG MAG^2 $MAG/\sqrt{Hz}$ (MSD) MAG^2/Hz (PSD)	V V^2 $V/\sqrt{Hz}$ V^2/Hz
EU	MAG MAG^2 $MAG/\sqrt{Hz}$ (MSD) MAG^2/Hz (PSD)	EU EU^2 $EU/\sqrt{Hz}$ EU^2/Hz
DB	MAG MAG^2 $MAG/\sqrt{Hz}$ (MSD) MAG^2/Hz (PSD)	DB (MAG) DB (MAG^2) $DB/\sqrt{Hz}$ DB (MAG^2)/Hz
DBV	MAG MAG^2 $MAG/\sqrt{Hz}$ (MSD) MAG^2/Hz (PSD)	DBV (MAG) DBV (MAG^2) $DBV/\sqrt{Hz}$ DBV (MAG^2)/Hz
DBR	MAG MAG^2 $MAG/\sqrt{Hz}$ (MSD) MAG^2/Hz (PSD)	DBR (MAG) DBR (MAG^2) $DBR/\sqrt{Hz}$ DBR (MAG^2)/Hz

The selections on the Y-UNITS OPERATOR menu affects only the Spectrum Functions. Each of the other functions (TIME, STAT, TF, PWR, and IFFT) has its own, specialized Y UNITS OPERATOR.

TIM DOM X UNITS:

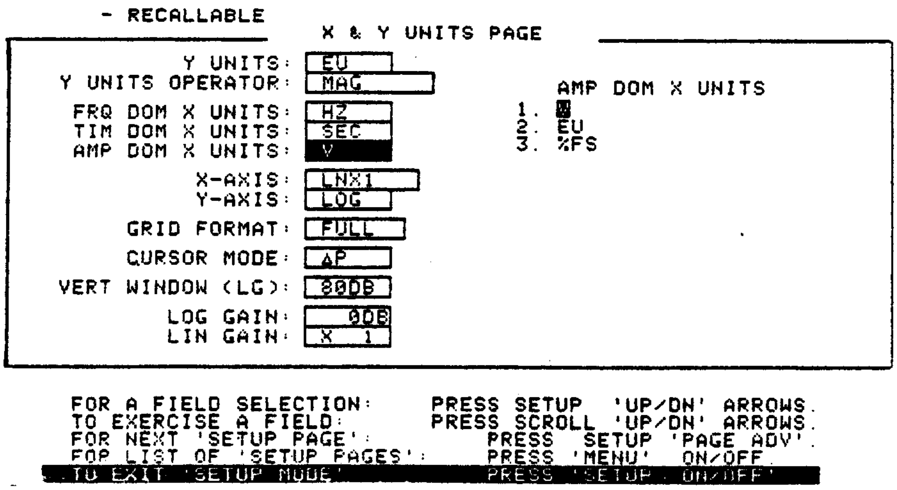


Control Menu for Selecting Units of Measurement for the X-Axis in the Time Domain (Time, IFFT).

1. SEC When this selection is made, X-axis full scale and cursor readout values will be the corresponding memory period (in seconds and milliseconds) that relates to the selected full-scale analysis range (in Hz). Memory period will vary depending upon the selected Resolution (RESOLUTION menu on Setup Page 2; e.g., Resolution/Frequency Range = Full Scale Memory Period).

2. DEG When this selection is made, X-axis scaling and cursor readout annotation will be in degrees in relation to the Tach input and RPM readout, when a Tach input is present.

AMP DOM X UNITS:



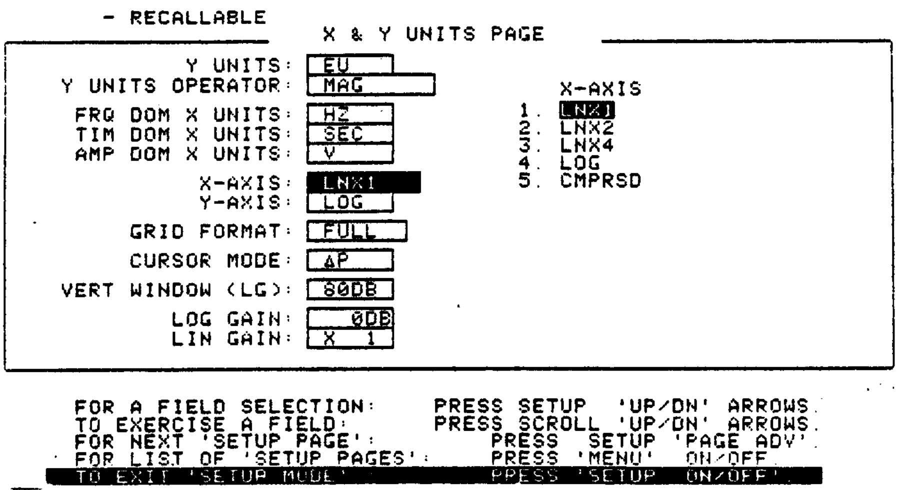
Control Menu for Selecting Units of Measurement for the X-Axis in the Amplitude Domain (Statistics).

1. **V** — **When this selection is made, X-axis scaling and cursor readout values will be +/- p-p Volts.**

2. **EU** — **When this selection is made, X-axis scaling and cursor readout values will be +/- p-p Engineering Units.**

3. **%FS** — **When this selection is made, X-axis scaling and cursor readout values will be +/- percentage of Full Scale. The center of the display represents 0%.**

X-AXIS:



Control Menu for Selecting X-Axis Display-Data Distribution, X-Axis Expansion and X-Axis Compressed Time.

1. LNX1 This selection provides linear X-axis data distribution with no X-axis expansion.

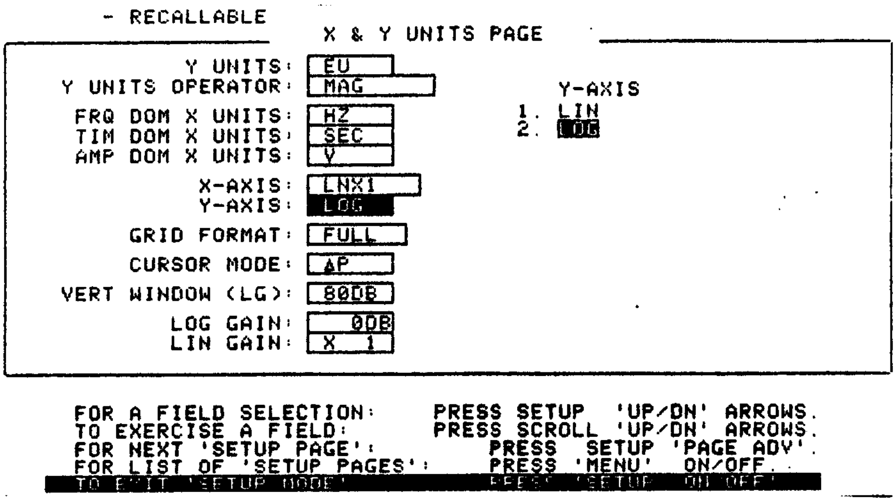
2. LNX2 This selection provides linear X-axis expansion centered on the cursor location. For example, a frequency domain display containing 400 data points (400 lines of resolution selected), yields a resolution of 1/400 of the selected frequency range. X2 X-axis expansion does not increase the measured resolution of the data, it simply displays less data (200 data points for X2) in the same display area causing the data to be expanded.

3. LNX4 This selection provides twice the linear X-axis expansion as LNX2; i.e., LNX4 selected for a 400 line display will yield a resultant display of 100 lines of data in the same area causing the data to be expanded.

4. LOG This selection provides **logarithmic** X-axis scaling distribution and grid scaling. This selection is not allowed for Time Domain, Statistical or Zoom displays.

5. CMPRSD This selection is used with the Time Domain functions. When this selection is made, displayed X-axis data will be the entire contents of the Input Memory (Compressed Time).

Y-AXIS:



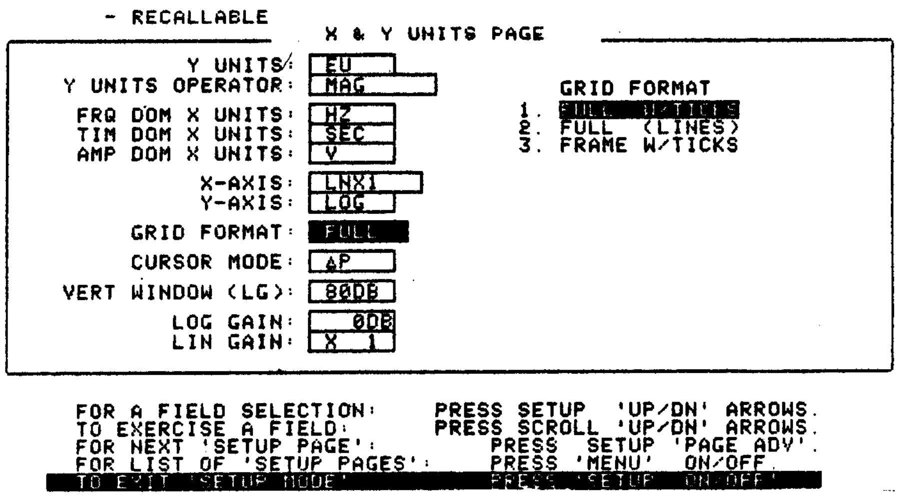
Control Menu for Selecting Y-Axis Display-Data Distribution.

1. LIN — This selection provides linear Y-axis display data distribution. Automatically selected for Time Domain functions. If any of the dB Y-units are selected, Y-axis display data distribution will be forced to LOG.

2. LOG — This selection provides logarithmic Y-axis display-data distribution. Automatically selected if any of the dB Y-units are selected. Cannot be selected for Time Domain displays.

   Neither of these selections has any affect on the Amplitude Domain (Statistics) functions.

GRID FORMAT:



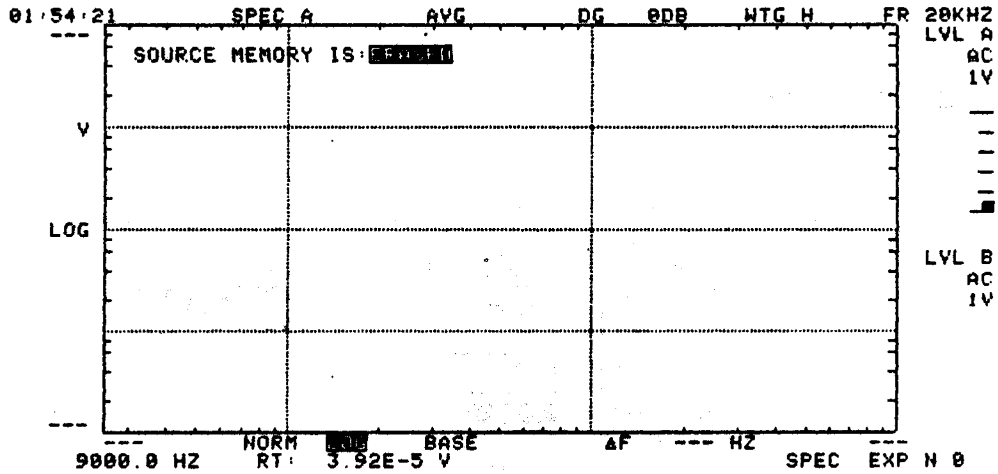
Control Menu for Selecting Display Grid Format.

1. FULL W/TICKS — When this selection is made, the display grid will include the grid frame, vertical and horizontal grid lines and, where the X and Y axis distribution is logarithmic (either or both), the appropriate calibration ticks.

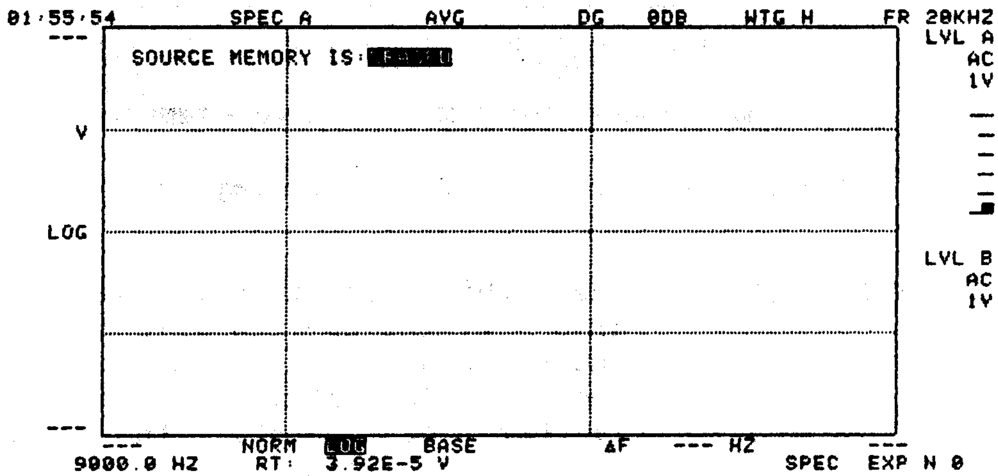
2. FULL (LINES) — When this selection is made, the display grid will include the grid frame and the appropriate vertical and horizontal grid lines.

3. FRAME W/TICKS — When this selection is made, the display grid will have calibration ticks with no horizontal or vertical grid lines.

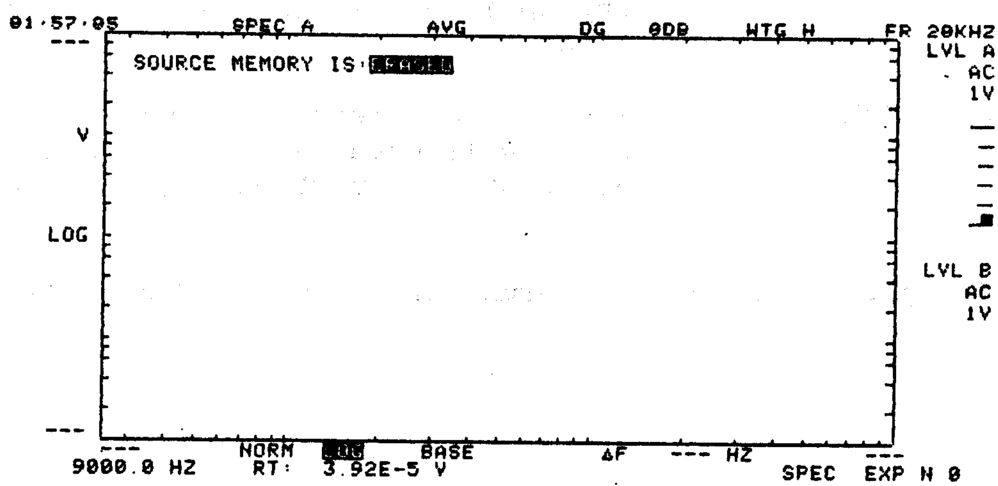
Examples of each grid format are shown in Figure 3-XYUNITS-2.



FULL W/TICKS



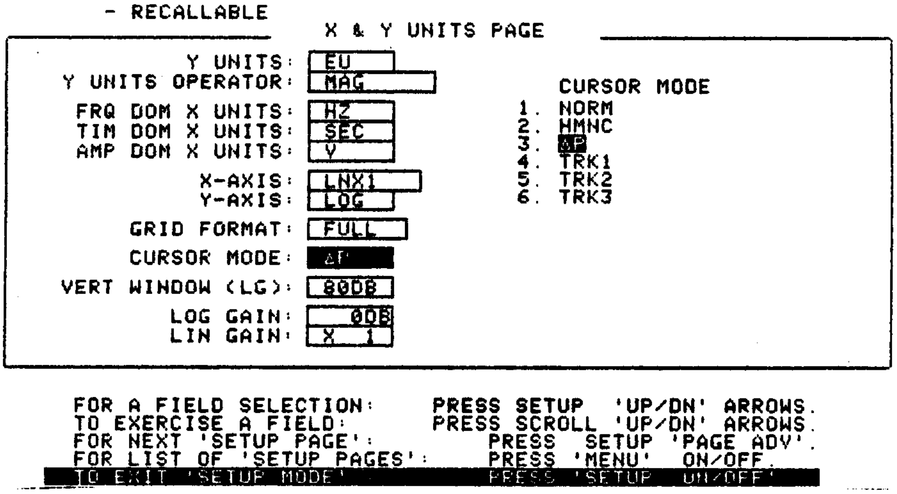
FULL (LINES)



FRAME W/TICKS

Figure 3-XYUNITS-2. Examples of Each Grid Format Selection

CURSOR MODE:



Control Menu for Selecting the Various Cursor Functions.

1. NORM — This selection is the Normal cursor mode, and is the cursor mode used most often. The Normal cursor consists of a single intensified dot that can be moved to any location on the display, regardless of the type of display.

2. HMNC — When displaying signals containing harmonic components, selecting the HMNC (Harmonic) cursor mode places multiple cursors (intensified dots) at each harmonic multiple of the fundamental cursor location. In addition, once the HMNC cursor mode is selected, the fundamental cursor will have a resolution that is 1/256 of the normal resolution allowing true fine-tune alignment of the multiple cursors.

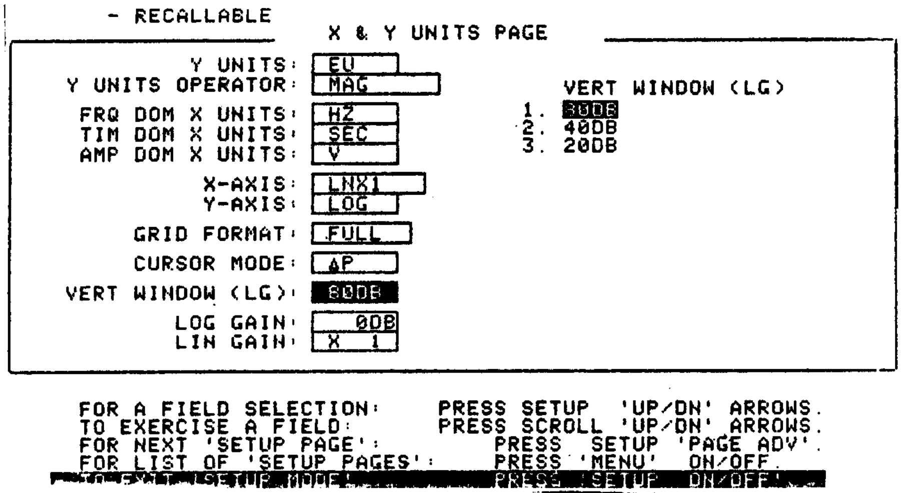
3. ΔP — The ΔP cursor mode, when selected, provides a summation of the rms value of the power level of all the displayed information to the left of the cursor, regardless of its position on the display. Changing position of the cursor will vary the indicated power level. The ΔP mode also operates in conjunction with the SET function to indicate the rms level between two selected frequencies. The Y-axis cursor value in this mode will be designated ΔP representing the rms value of the display spectrum data.

4. TRK1 Tracking Cursor Mode One. This Tracking Cursor will track any frequency shift as long as there is no amplitude variation. Cursor should be placed on tonal of interest before selecting this mode.

5. TRK2 Tracking Cursor Mode Two. This Tracking Cursor will track any amplitude variation as long as frequency shift does not exceed 10%. Cursor should be place on tonal of interest before selecting this mode.

6. TRK3 Tracking Cursor Mode Three. This Tracking Cursor will acquire the highest amplitude signal in the display trace and track it any where in the selected analysis band.

VERT WINDOW (LG):



Control Menu for Selecting the Full-Scale Vertical Window for LOG Y Displays.

1. 80DB With Y-axis LOG display-data distribution and dB Y-units selected (and 0 dB gain), Y-axis scaling will be (for this selection) from 0 dB (top of the display) to -80 dB (bottom of the display) full scale.

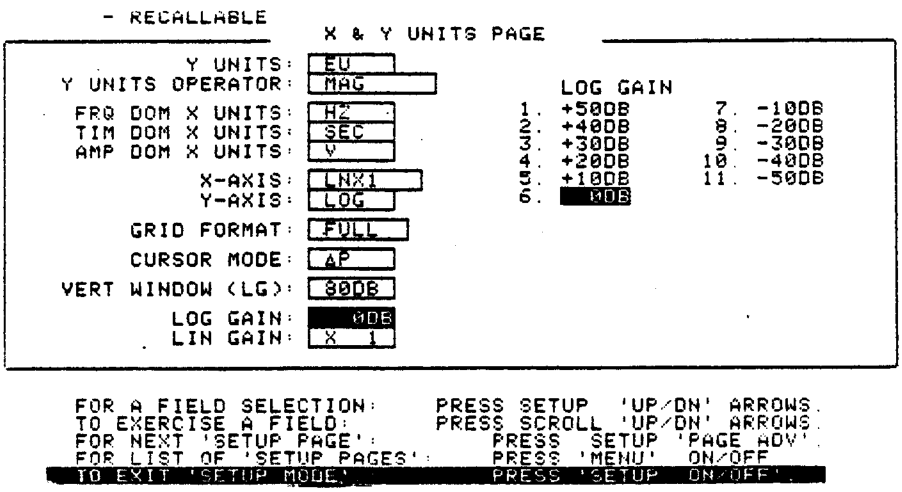
2. 40DB With the same conditions as the previous selection, Y-axis scaling will be (for this selection) from 0 dB (top of the display) to -40 dB (bottom of the display) full scale.

3. 20DB With the same conditions as the first selection Y-axis scaling will be (for this selection) from 0 dB top of the display) to -20 dB (bottom of the display) full scale.

When Transfer Function is selected (and the Y-axis is dB and LOG), the middle of the grid represents 0 dB, the top 40 dB, and the bottom -40 dB (with an 80DB Vertical Window). With a 40DB Vertical Window the top of the grid will be 20 dB, the middle 0 dB, and the bottom -20 dB. With a 20DB Vertical Window the top of the grid will be 10 dB, the middle 0 dB, and the bottom -10dB.

Time functions, Statistical function, IFFT functions, Transfer Function Real and Imaginary displays and Cross Product (Power) Real and Imaginary displays are not affected by the Vertical Window selections. Log window has no effect on a Linear Y-axis display.

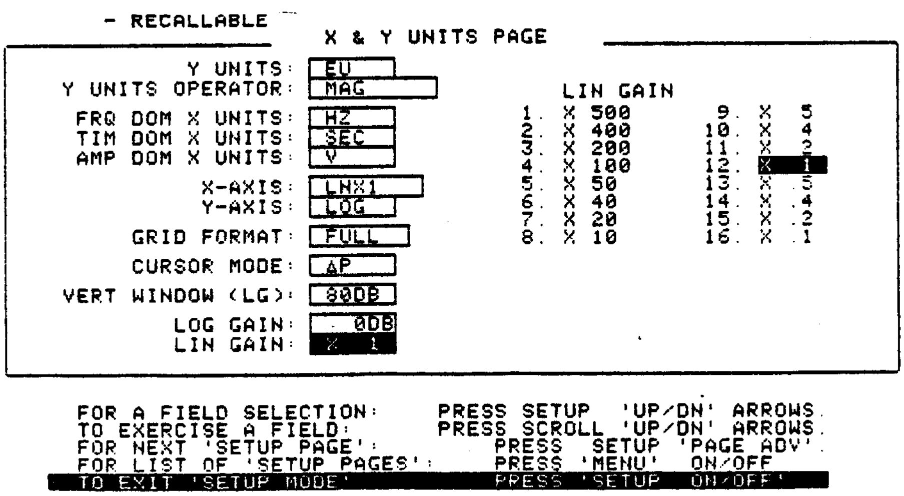
LOG GAIN:



Control Menu for Selecting Logarithmic Y-Axis Display-Data Gain.

If LOG Y-axis display-data distribution is selected, this menu is used to select Log Gain, in dB, on the Y-axis. The LOG GAIN range (display range is still 80, 40 or 20 dB depending upon the Vertical Window selection) is 100 dB in 10 DB steps, from +50 dB to -50dB.

LIN GAIN:



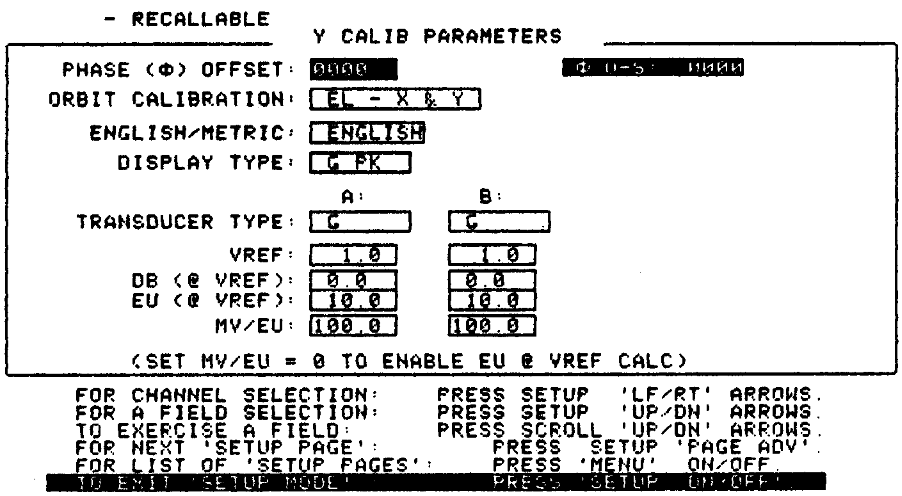
Control Menu for Selecting Linear Y-Axis Display-Data Gain.

If LIN Y-axis display-data distribution is selected, this menu is used to select linear gain on the Y-axis. There are 16 selections available ranging from X .1 to X 500 in a 1, 2, 4, 5 sequence.

Y CALIBRATION PARAMETERS CONTROL (Setup Page 5)

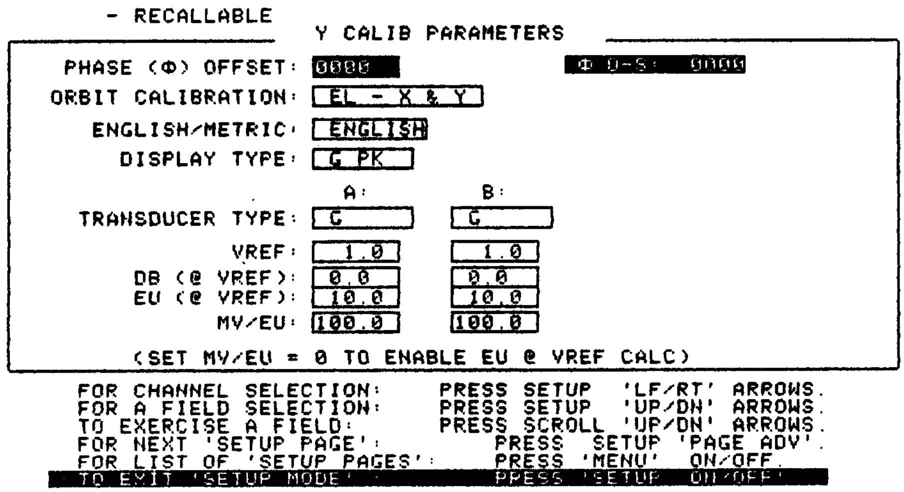
3-3.5 Setup Page 5 - Y CALIB PARAMETERS

To access this Setup Page (from the data display), press the SETUP group SETUP ON/OFF button. This displays the Setup Page listing. Next, place the RV on selection 5, Y CALIB PARAMETERS. Now, press the SCROLL group MENU button and Setup Page 5 will appear on the display. If a Setup Page appears instead of the Setup Page listing when SETUP ON/OFF is pressed, or if Setup Page 4 is already on the display, the PAGE ADV button can be used to access Setup Page 5.



The following three selections, ENGLISH/METRIC, DISPLAY TYPE and TRANSDUCER TYPE, are the Control Menus for the Artificial Integration feature and are described at the end of this Setup Page description rather than in the order they appear on the Setup Page.

PHASE (ϕ) OFFSET:



Numerical Entry Field for Entering the Amount of Phase Offset.

This Numerical Entry Field is for control of the Power and Transfer Function phase displays. When a phase pattern is such that it crosses the upper or lower boundary of the display, the transition will appear as a vertical line. Figure 3-YCALIB-1 illustrates a display with 90 degree phase shifts from 0 degrees to +90 degrees. However, if this same 90 degree shift occurs at a point that causes the signal to extend beyond the upper or lower limits of the display, the extended position will "wrap around" (Figure 3-YCALIB-2). This is a visual effect of the transition from +180 degrees to -180 degrees. This effect can be eliminated by entering the amount of offset necessary to display the phase pattern with no transitions (Figure 3-YCALIB-3). The phase offset value is selectable via the front panel ENTRY keypad. Values from +180 to -180 degrees, in one degree increments can be entered.

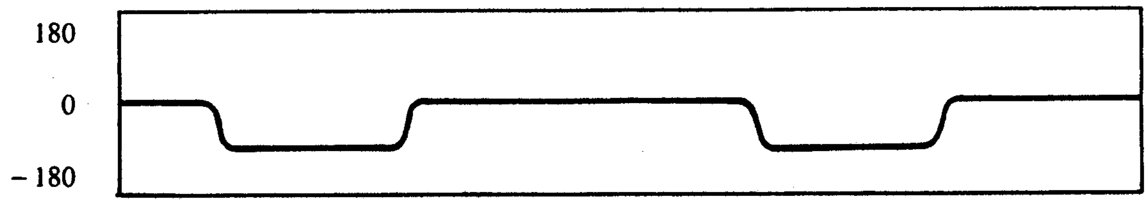


Figure 3-YCALIB-1. Phase Pattern With 90 Degree Phase Shifts

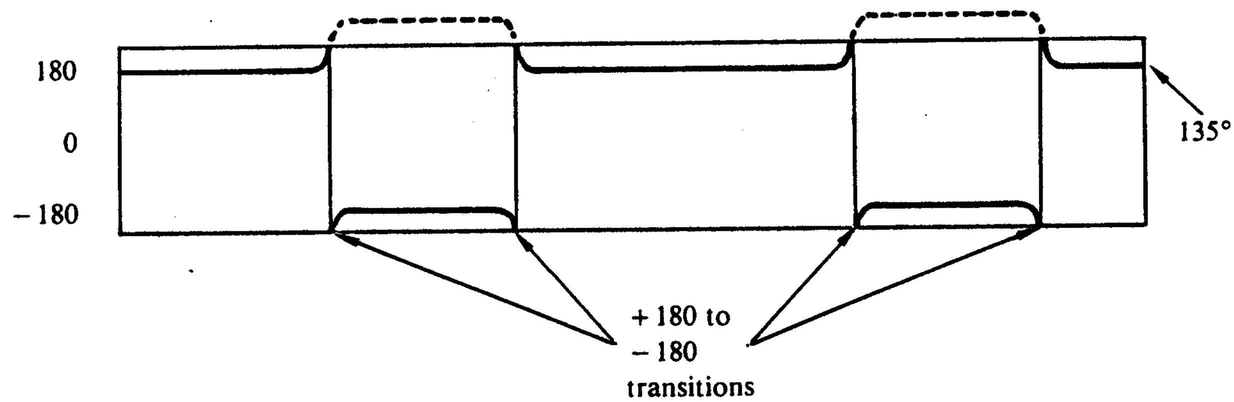


Figure 3-YCALIB-2. Phase Pattern with 90 Degree Phase Shifts Showing Transitions

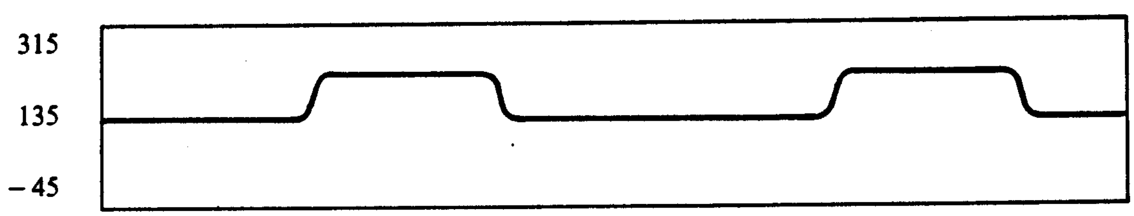
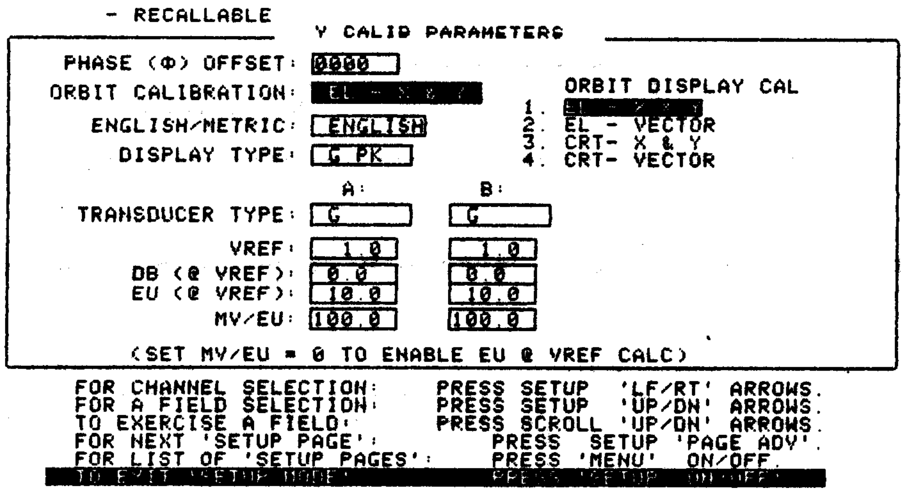


Figure 3-YCALIB-3. Phase Pattern of Signal Shown in Figure 3-YCALIB-2 with 135 Degrees of Offset

ORBIT CALIBRATION:



- RECALLABLE

Y CALIB PARAMETERS

PHASE (Φ) OFFSET: 0000

ORBIT CALIBRATION: EL - X & Y

ENGLISH/METRIC: ENGLISH

DISPLAY TYPE: G PK

ORBIT DISPLAY CAL
1. EL - X & Y
2. EL - VECTOR
3. CRT- X & Y
4. CRT- VECTOR

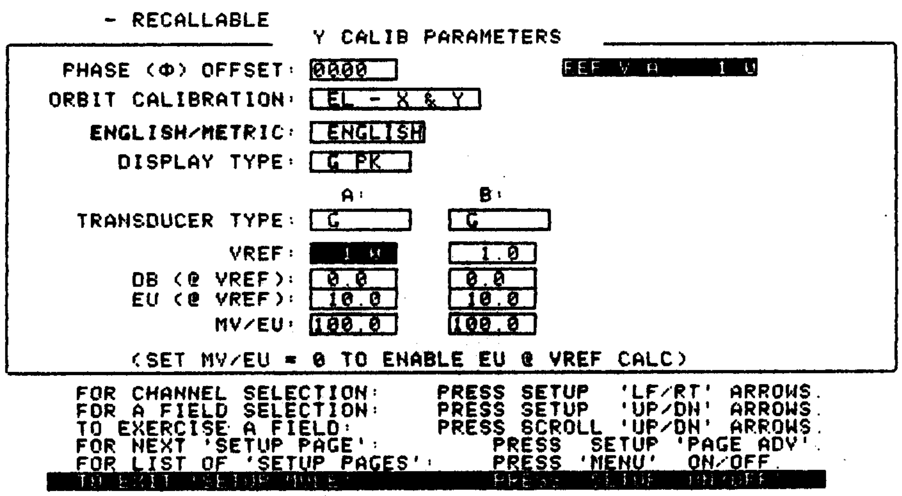
	A:	B:
TRANSDUCER TYPE:	G	G
VREF:	1.0	1.0
DB (@ VREF):	0.0	0.0
EU (@ VREF):	10.0	10.0
MV/EU:	100.0	100.0

(SET MV/EU = 0 TO ENABLE EU @ VREF CALC)

FOR CHANNEL SELECTION: PRESS SETUP 'LF/RT' ARROWS.
FOR A FIELD SELECTION: PRESS SETUP 'UP/DN' ARROWS.
TO EXERCISE A FIELD: PRESS SCROLL 'UP/DN' ARROWS.
FOR NEXT 'SETUP PAGE': PRESS SETUP 'PAGE ADV'.
FOR LIST OF 'SETUP PAGES': PRESS 'MENU' ON/OFF.
TO EXIT 'SETUP MODE': PRESS 'SETUP' ON/OFF.

Control Menu for Selecting Orbit Display Calibration

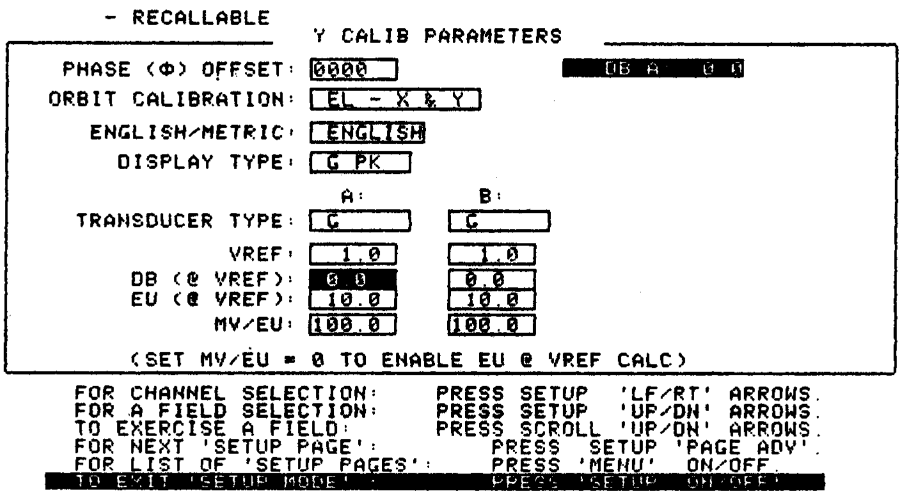
VREF:



Numerical Entry Field for Entering a Voltage Reference.

This Numerical Entry Field is for entering the voltage reference level used with the DB (@ VREF) and EU (@ VREF) Numerical Entry Fields. The reference value is selectable via the ENTRY keypad. Values from +/- 0.002 to +/- 9,999 can be entered.

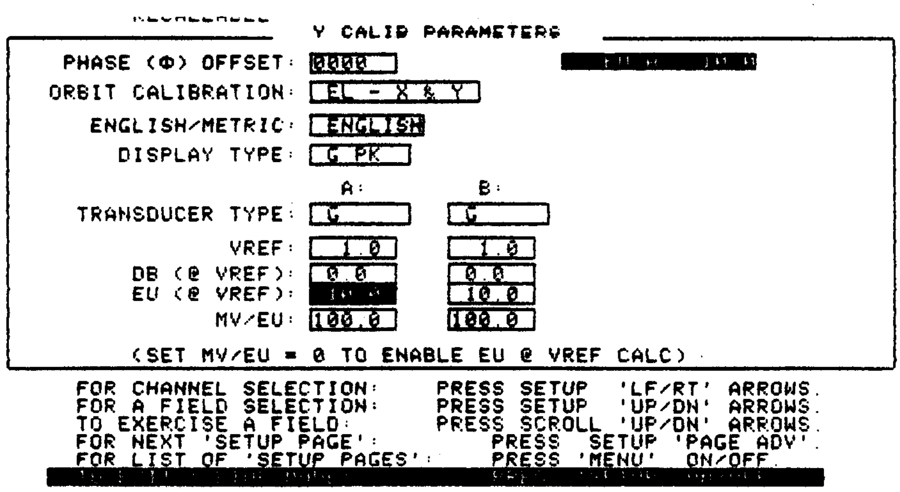
DB (@ VREF):



Numerical Entry Field for Referencing Y-Axis dB to a Voltage Level.

This Numerical Entry Field works in conjunction with the VREF Numerical Entry Field. This feature can be utilized only when menu item 5, DBR (dB Reference), is selected on the Y UNITS Control Menu located on Setup Page 4. DBR allows the operator to select dB readouts calibrated in X dB at Y Volts (VREF). The dB value is selectable via the front panel ENTRY keypad. Values from +/- 0.001 to +/- 200 dB can be entered. For some applications, the value is known and can be entered directly; e.g., 151 dB @ 3 V. Other applications may require measuring signal levels in relation to a "reference" signal. This is accomplished by entering the reference signal voltage level as the VREF.

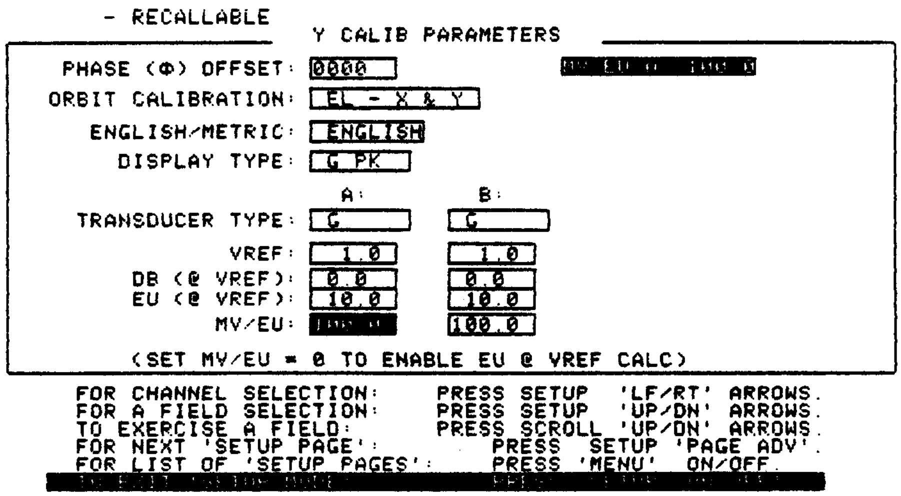
EU (@ VREF):



Numerical Entry Field for Referencing Y-Axis Engineering Units to a Signal Level.

This Numerical Entry Field works on conjunction with the VREF Numerical Entry Field. This feature can be utilized only when Control Menu item 2, EU, is selected on the Y UNITS Control Menu located on Setup Page 4, and allows the operator to select EU readouts calibrated in X EU at Y VOLTS (VREF). This references all signal amplitude measurements to the entered signal value (VREF). For example, if a signal with an amplitude of .67 V is desired as the reference signal, enter an MV/EU value of zero for the appropriate channel. Next, enter 1.0 for EU @ VREF and .67 for VREF. The display is now calibrated to the signal amplitude (.67 V); i.e., a signal with an amplitude of 0.335 V will read out as 0.5 EU, one of 1.34 V will read 2.0 EU, etc. The EU value is selectable via the front panel ENTRY keypad. Values from 0.01 to 9,999 can be entered.

MV/EU:



Numerical Entry Field for Entering Millivolts per Engineering Unit.

This Control allows the Y-Units to be calibrated to an external probe. This enables the operator to view the analysis results in probe calibration units. These units are related to transducer sensitivity. For example, the display and cursor can be calibrated for a displacement probe that generates 130 mV per mil of displacement by selecting and entering 130 as the MV/EU and selecting menu item 2, EU, on the Y-UNITS Control Menu located on Setup Page 4. A one Volt signal will read 7.70 EU. This Control requires a numerical value to be entered via the front-panel ENTRY keypad. Values from 0.0001 to 9,999 can be entered.

Artificial Integration

The SD385 Artificial Integration feature includes the ability to selectively perform different artificial integration functions on different channels; on Spectrum or Transfer Function displays in either Base Band or Zoom analysis.

This feature is enabled on the SD385 by selecting "CEU" (Compensated Engineering Units) on the Y-Units menu (Setup Page 4). This selection can also be made via the Y UNITS button in the FIELD LOCATOR group. If CEU is not selected, any selections made on the three menus associated with Artificial Integration (ENGLISH/METRIC, DISPLAY TYPE, TRANSDUCER TYPE) will be ignored.

The resultant display is determined by the Artificial Integration control menus. These are:

English/Metric Units:

1. ENGLISH
2. METRIC

The setting on the ENGLISH/METRIC UNITS menu have a direct effect on the next two control menus and tell the analyzer which type of units to use for CEU displays.

Display Type:

ENGLISH		METRIC
1. G PK	Acceleration	1. G PK
2. IN/SEC	Velocity	2. MM/SEC
3. MIL	Displacement	3. MIC

Transducer Type:

ENGLISH		METRIC
1. G	Acceleration	1. G
2. IN/SEC	Velocity	2. MM/SEC
3. MIL	Displacement	3. MIC
4. LB	*Force	4. NT

*Channel A Transducer only.

Results:

This approach to controlling the Artificial Integration feature relieves the operator from having to figure out what operation to use.

The operator answers three questions:

1. English or Metric units (ENGLISH/METRIC)?
2. Signal type (TRANSDUCER TYPE)?
3. Type of units to display (DISPLAY TYPE)?

The SD385 figures out the rest. For example, going from g's to mils, the operator selects G for the TRANSDUCER TYPE and MIL for the DISPLAY TYPE. The SD385 automatically conducts the necessary double integration and applies constants to go from the mV/EU (mVrms/g rms) transducer sensitivity to get to the MIL p-p display.

MATH

The Artificial Integration feature is based on the relationships between acceleration, velocity and displacement (a, v, s).

$$a = dv/dt = d(ds/dt)/dt$$
$$v = ds/dt$$
$$s = \int v\, dt = \int\int a\, dt$$
$$v = \int a\, dt$$

This yields a set of operations for transducer-to-display calculus.

Transducer Type	Display Type	Operation
1. G	G PK	None
	IN/SEC(MM/SEC)	$\int$
	MIL(MIC)	$\int\int$
2. IN/SEC(MM/SEC)	G PK	$\dot{Y}$
	IN/SEC(MM/SEC)	None
	MIL(MIC)	$\int$
3. MIL(MIC)	G PK	$\ddot{Y}$
	IN/SEC(MM/SEC)	$\dot{Y}$
	MIL(MIC)	None

Calibration

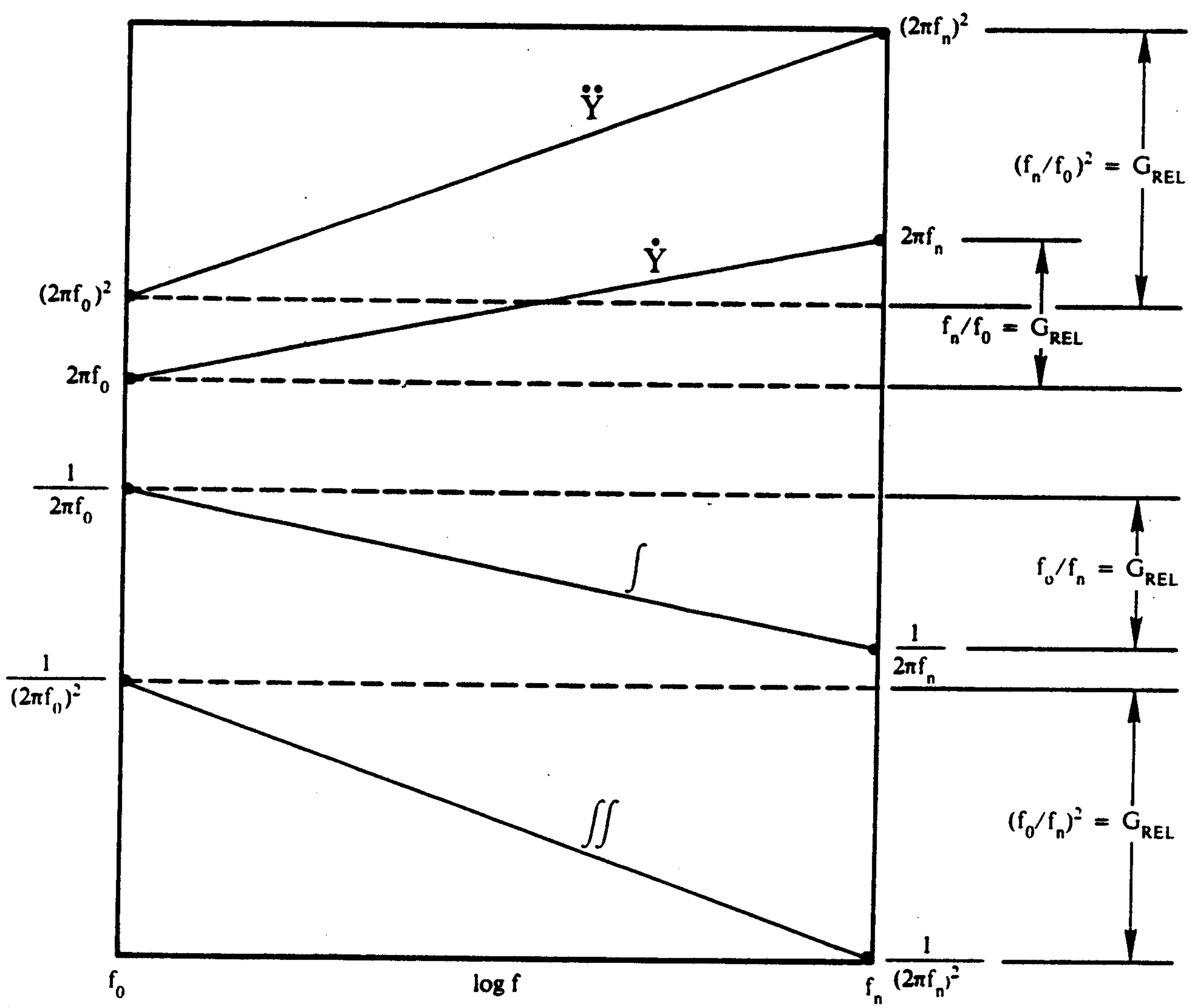
The analyzer assumes the following when calibrating the display.

Accelerometer mV/EU is rms
Velocity mV/EU is 0-p
Displacement mV/EU is p-p

The operation in the frequency domain is achieved with a "slope" applied to the data as a function of frequency (f):

Double integration ($\int\int$):	value = data × $1/2\pi f^2$
Single integration ($\int$):	value = data × $1/2\pi f$
Single differentiation ($\dot{Y}$):	value = data × $2\pi f$
Double differentiation ($\ddot{Y}$):	value = data × $2\pi f^2$
Where f = frequency	

Hence, on a log frequency plot, the applied slope factor is linear. This is shown in the following example.



f_0 = Frequency of first data point
f_n = Frequency of last data point
G_{REL} = Total amplitude difference of slope factor from f_0 to f_N

Note that G_{REL} can be up to 800^2 $(1/800^2)$ = 58 dB. On an 80 dB display, this leaves only 22 dB for signal data. Hence, when G_{REL} is in this range, the analyzer will double the log window in effect for the display; i.e.,

80 dB --> 160 dB
40 dB --> 80 dB
20 dB --> 40 dB

Note also that the data will tend to arrange itself around different ranges of amplitudes. The analyzer will automatically position the display so a full scale signal with 0 dB of display gain at f_N will appear at the full-scale position of the trace. There's more to the performance of the SD385 Artificial Integration feature:

Functions Available:

SPECT

It is entirely possible to set up the same units for display and transducer. what will happen is the units annotation will be specific (MIL, IPS, G, etc) and compensated to p-p in displacement, 0-p for velocity and acceleration. Since (see TF) TF CEU units are assumed to be "per-force," force units are available on Channel A (LB or NT). In this case the transducer type supercedes the display and the user will obtain LB or NT units (in rms).

TIME

The selected transducer units are displayed, no artificial integration operation is performed. For example, Channel A transducer is g and display is mil, TIME A & SPECT A will display g in the TIME trace, mils in the SPECT trace.

TF

Units are assumed to be per-force, hence the Channel A transducer is assumed to be a force transducer regardless of what the Channel A setting is. The result will be G/LB, IPS/LB, IN/LB, etc. (acceleration, velocity, displacement per force). For example, G for Channel B transducer, MIL on display. TF B/A will be double integrated to achieve IN/LB units. Note that units are IN/LB, not MIL/LB.

PHASE

Phase shift due to to the integration operation on channels involved will be accounted for. Units remain degrees. If a function other than the listed available functions is selected, the analyzer will default CEU to EU.

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