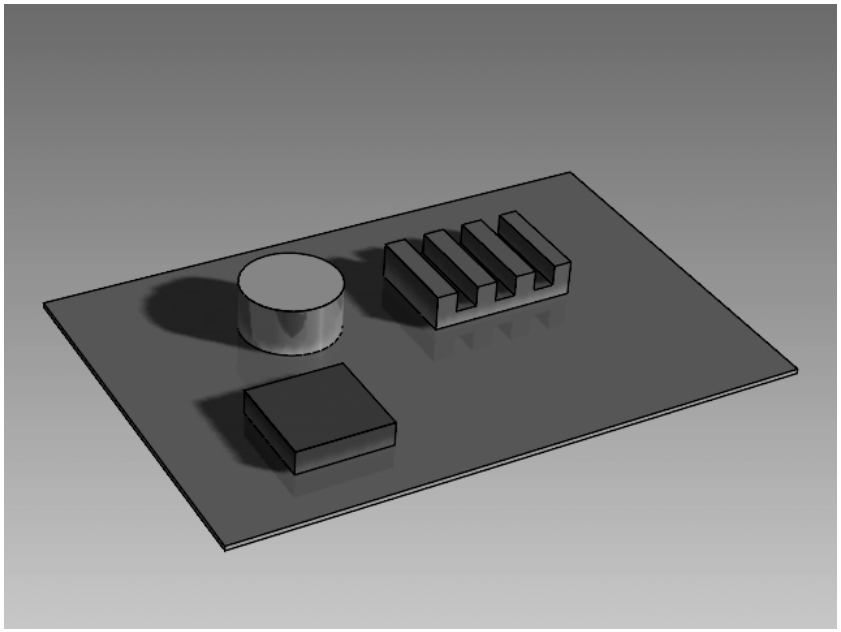
Random Vibration Analysis of a Circuit Board



Sean Harvey

August 2000

CSI Tip of the Week

Random Vibrations

- Outline
  - Introduction
  - Sample Problem
    - Description
    - Pre Processing Steps Omitted
    - Interactive steps
      - **Specify Modal Analysis**
      - **Specify Modal Analysis Options**
      - **Constrain Board**
      - **Solve Modal**
      - **Specify Spectrum Analysis**
      - **Specify Analysis Options**
      - **Specify PSD Settings**
      - **Specify PSD vs. Frequency**
- (Continued)
  - **Plot Input PSD**
  - **Specify Damping**
  - **Flag Nodes to get PSD Input**
  - **Solve for Participation Factors**
  - **Set PSD Calculation Controls**
  - **Solve Random Vibration Solution**
  - **Set Mode Combination**
  - **Calculate mode combinations and 1 sigma response**
  - **Post Processing Results Summary**
  - **1 sigma Results**
  - **Post Processing 1 sigma Displacements**
  - **Post Processing 1 sigma Stresses**
  - **Plotting Response PSD in Post 26**

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Introduction

What is a Random Vibration Analysis?

- A Random Vibration Analysis is a form of Spectrum Analysis.
- The *spectrum* is a graph of spectral value versus frequency that captures the intensity and frequency content of time-history loads.
- Random vibration analysis is *probabilistic* in nature, because both input and output quantities represent only the *probability* that they take on certain values.

Introduction

What is a Random Vibration Analysis (continued)?

•Random Vibration Analysis uses Power spectral density to quantify the loading.

• (PSD) is a statistical measure defined as the limiting mean-square value of a random variable. It is used in *random vibration analyses* in which the instantaneous magnitudes of the response can be specified only by probability distribution functions that show the probability of the magnitude taking a particular value.

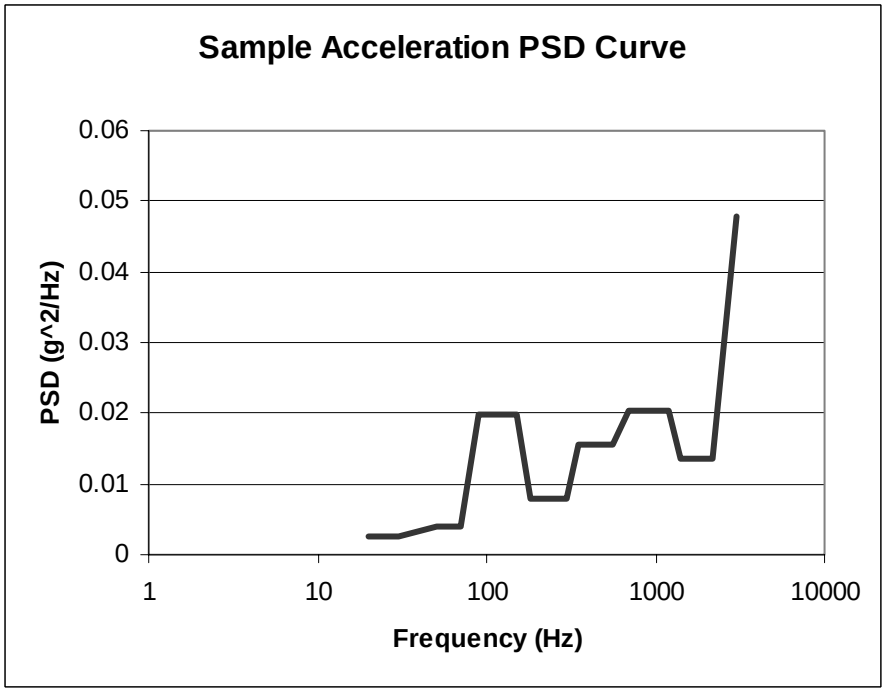
Introduction

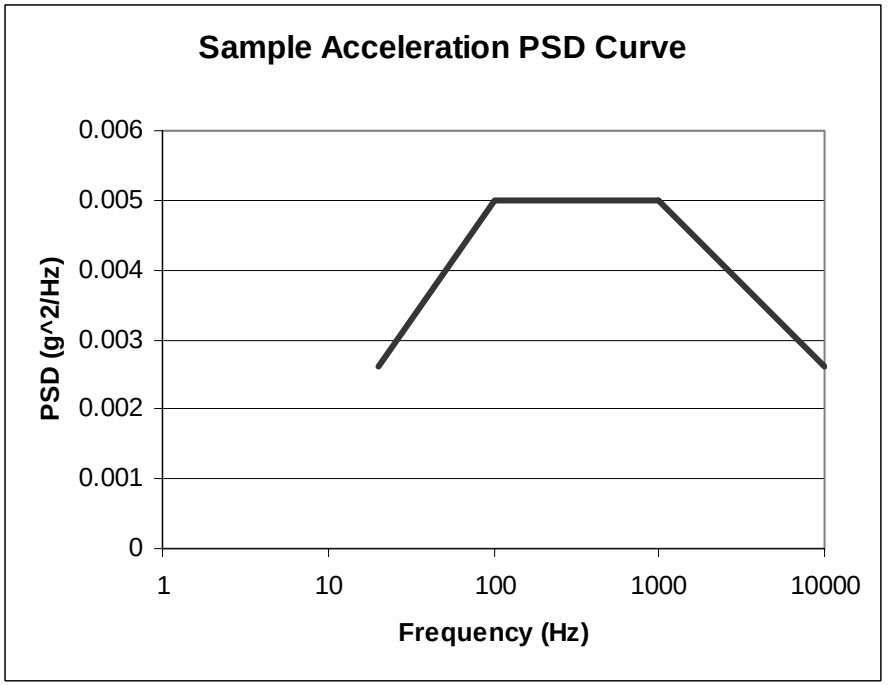
What is a PSD Spectrum?

•A *PSD spectrum* is a statistical measure of the response of a structure to random dynamic loading conditions. It is a graph of the PSD value versus frequency, where the PSD may be a displacement PSD, velocity PSD, acceleration PSD, or force PSD. Mathematically, the area under a PSD-versus-frequency curve is equal to the variance (square of the standard deviation of the response).

Introduction

Sample PSD Curves





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Introduction

How does one obtain a PSD Spectrum?

- *PSD spectrum* curves are generally supplied as a spec., or are measured and calculated using vibration analysis equipment.

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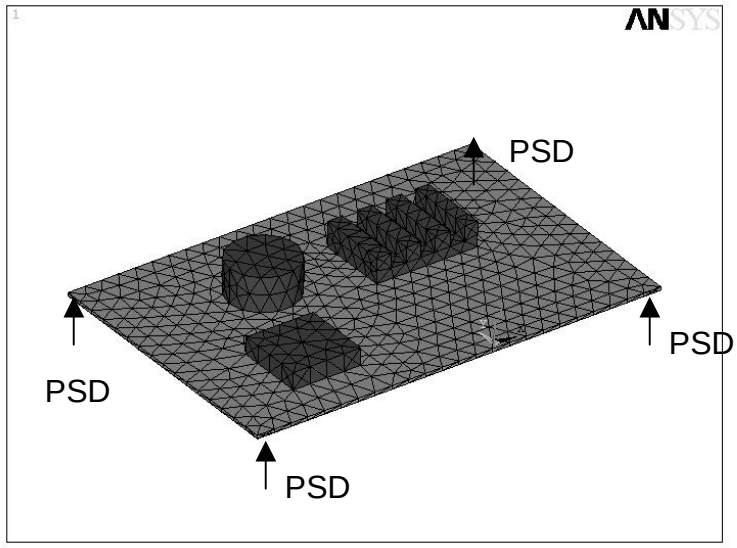
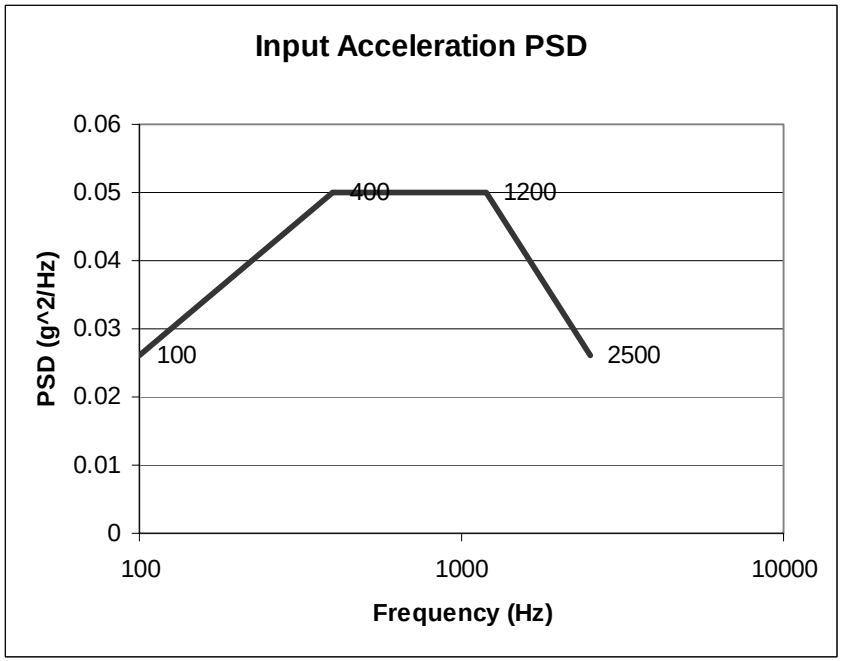
Sample Problem

The following steps will detail running through a simple PSD analysis using the GUI. An input file with every command is included at the end of this document...

Sample Problem Description

•Circuit Board exposed to a Base Acceleration Power Spectral Density (g^2/Hz) input in the global Z direction (normal to board) on 4 corners as show below;





Sample Problem Description

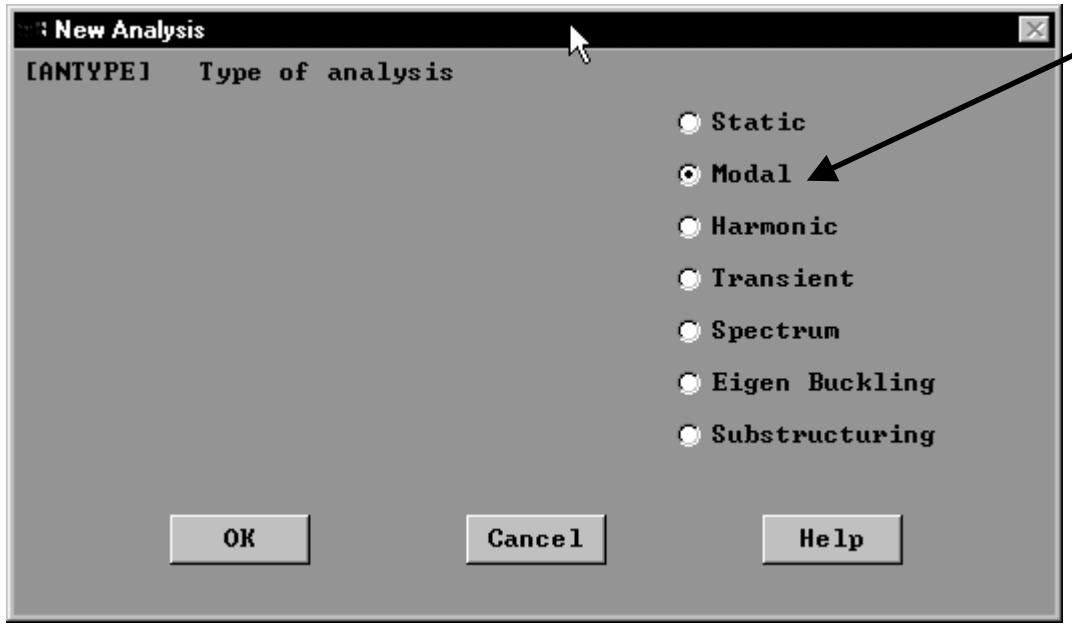
- Circuit Board with 3 components
- Board Constrained at 4 corners in all DOF
- Damping Ratio = 2%
- Model meshed with Solid92 10 noded tetrahedrons

Sample Problem Description

- Preprocessing steps - Details omitted
  - Import Geometry, Glue Volumes, Define Material Properties, Assign Material Attributes, Set Element Type, Mesh Model.
- Solution steps - Step by Step starting on next slide...

Specify Modal Analysis

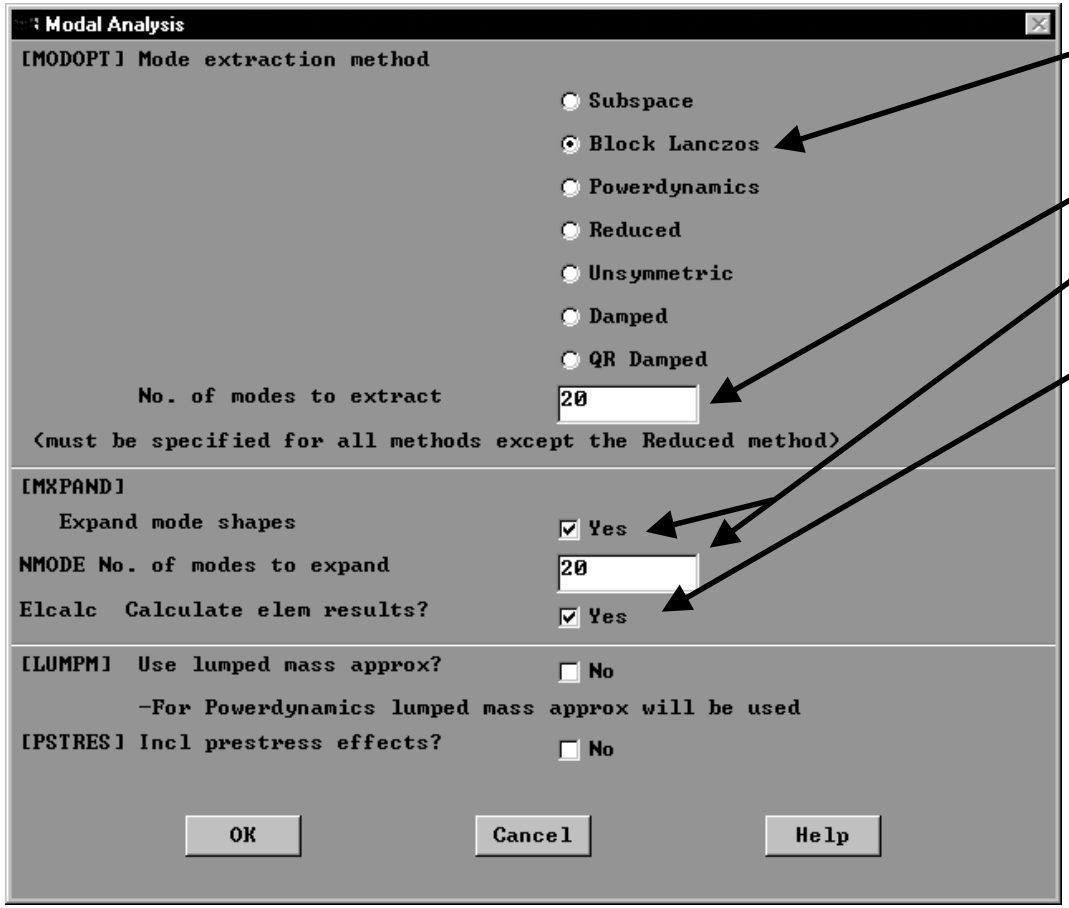
ANSYS Main Menu> Solution > New Analysis



•Pick Modal

Specify Modal Analysis Options

ANSYS Main Menu> Solution > Analysis Options



- Pick Modal Extraction Method (Block Lanczos a good choice)
- Specify 20 modes to extract
- Expand all modes
- Calculate Element results

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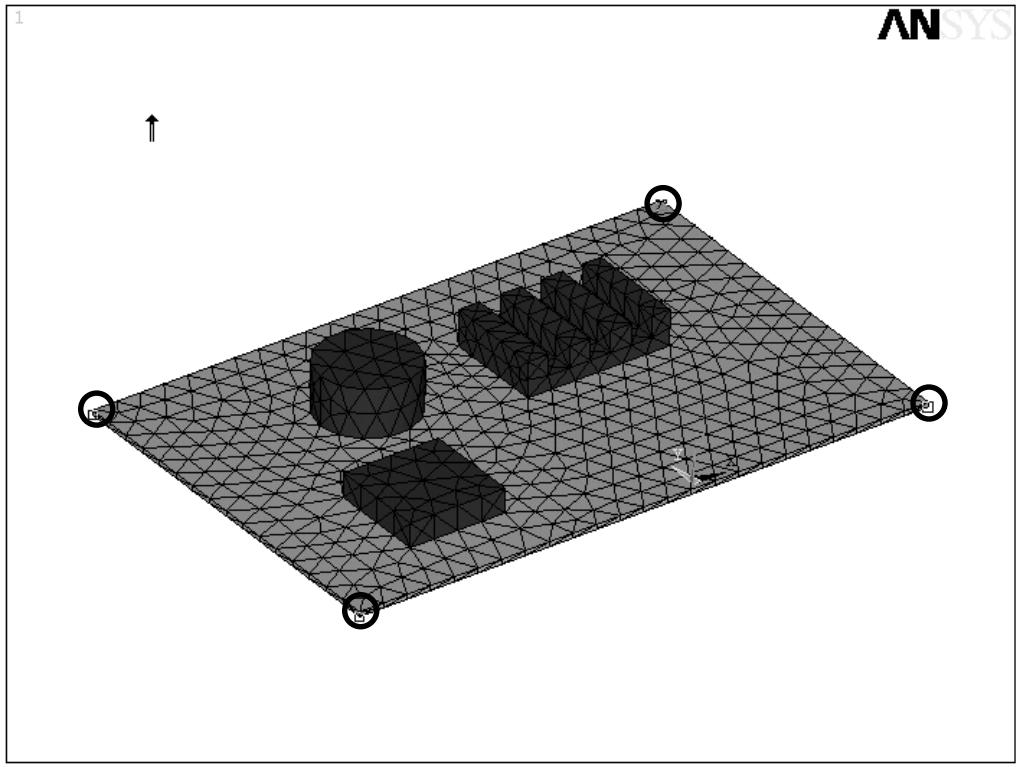
Constrain Board

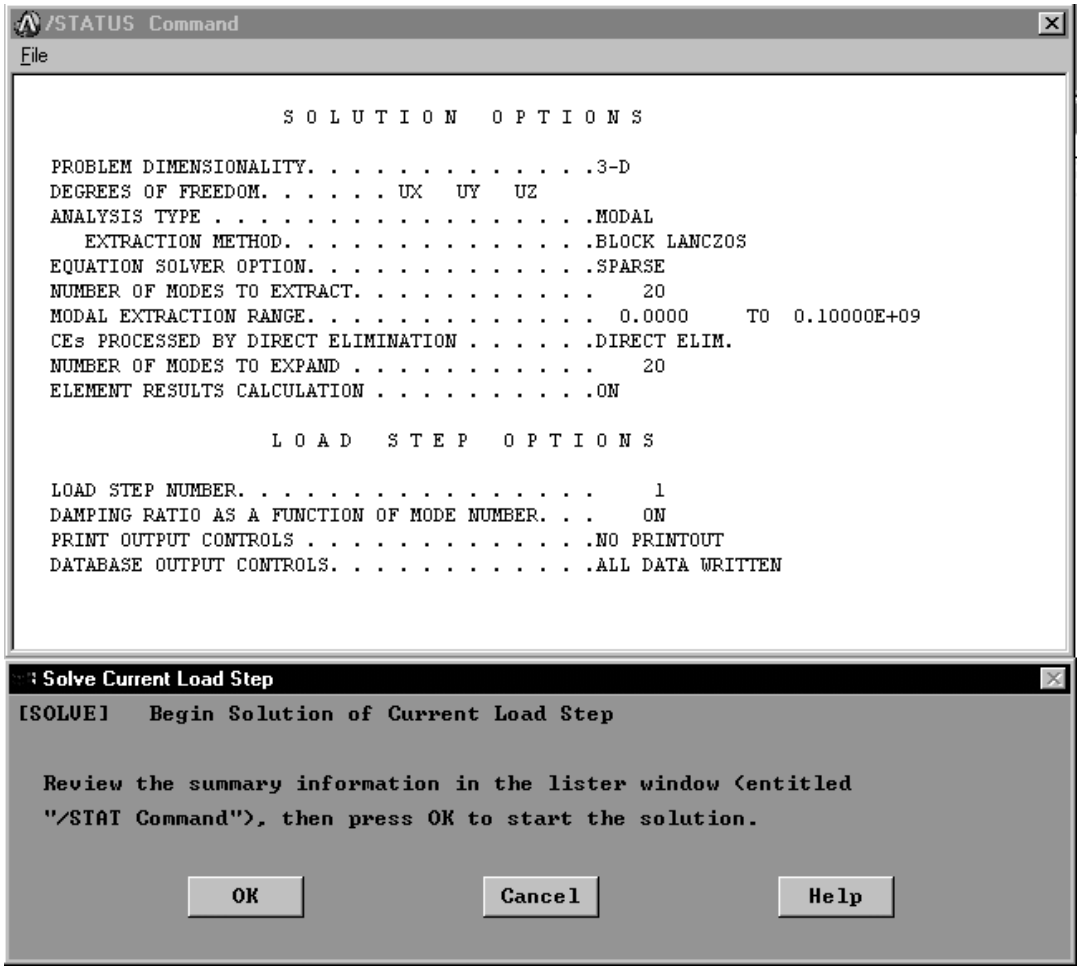
ANSYS Main Menu> Solution > Apply > Displacement > On Nodes



- Pick the 4 corner nodes on the bottom side of the board
  - 1748
  - 1782
  - 1902
  - 2038
- Constrain All DOF (UX,UY,UZ)

Solve Modal

ANSYS Main Menu> Solution > Solve



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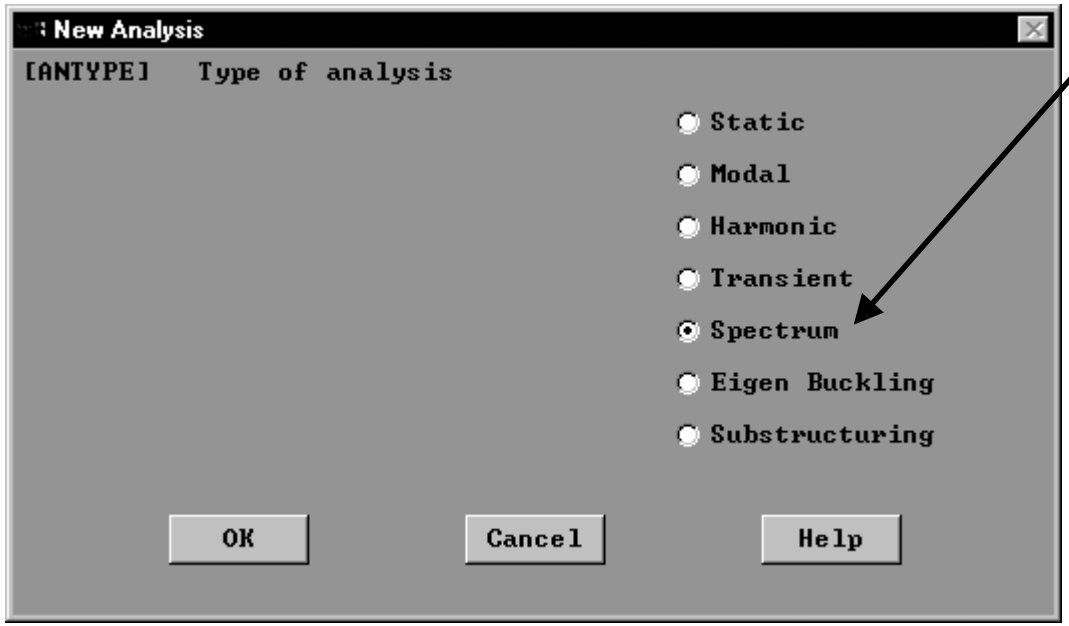
Specify Spectrum Analysis

ANSYS Main Menu> Finish

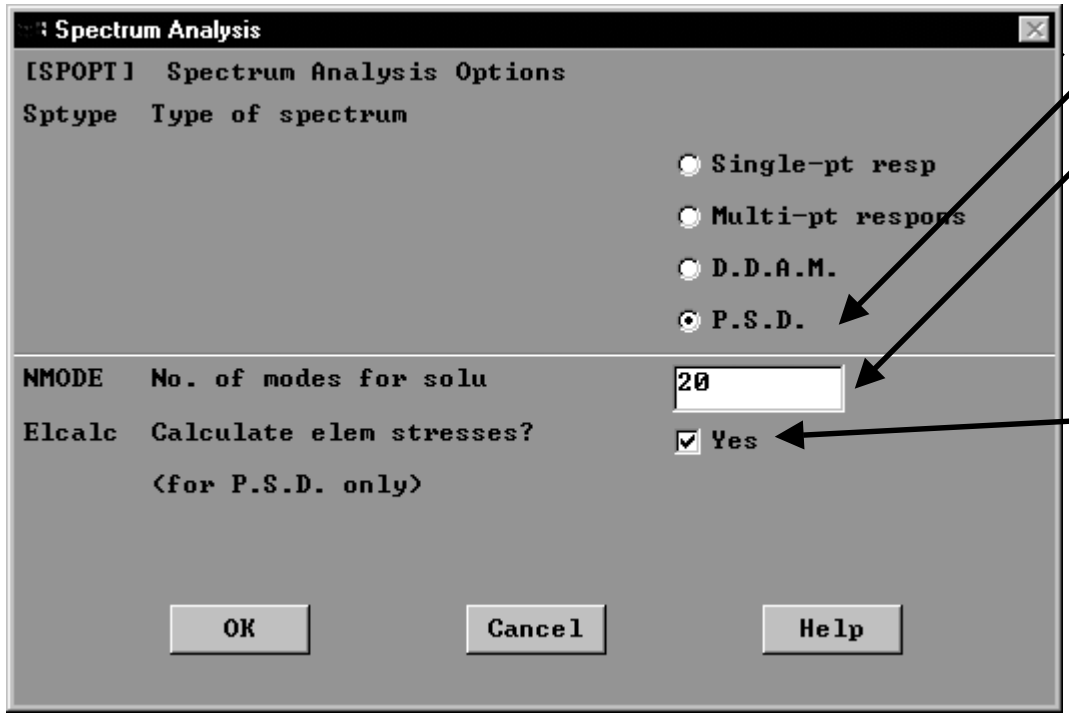
ANSYS Main Menu> Solution > New Analysis



•Pick Spectrum

Specify Analysis Options

ANSYS Main Menu> Solution > Analysis Options



- Specify P.S.D
- Specify the number of modes from the modal to include in the PSD analysis.
- Specify to Calculate Element Results (stresses, strains,etc.)

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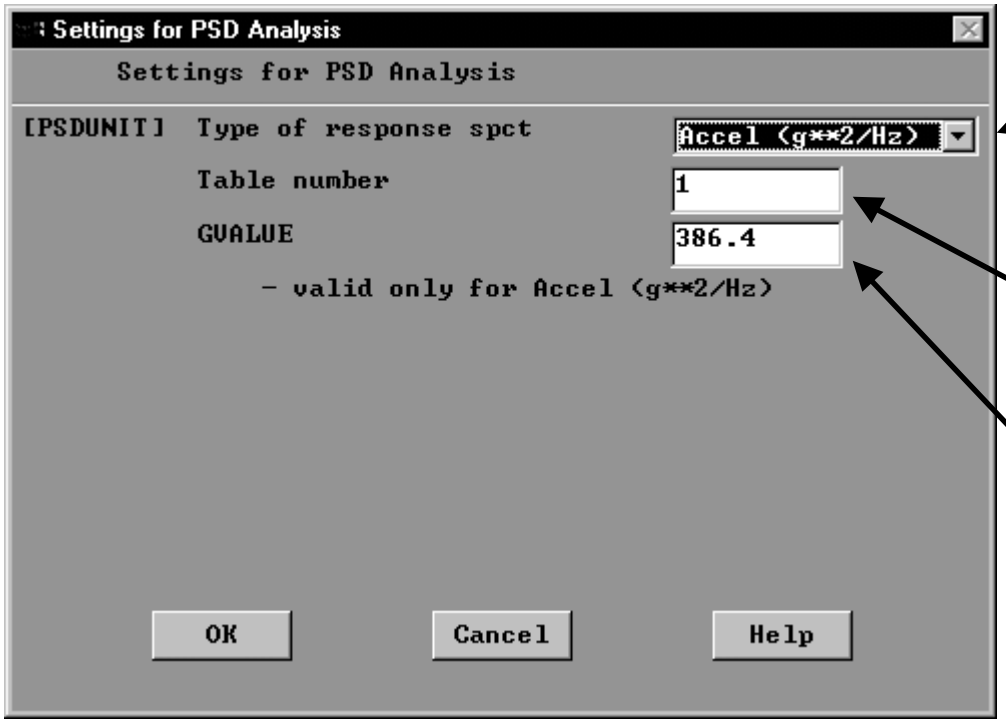
Specify PSD Settings

ANSYS Main Menu> Solution > Spectrum > PSD > Settings



- Input data will be in terms of g^2/Hz, therefore specify this setting
- Analysis has one PSD table, therefore leave table number to 1
- Specify Value of acceleration due to gravity (g)

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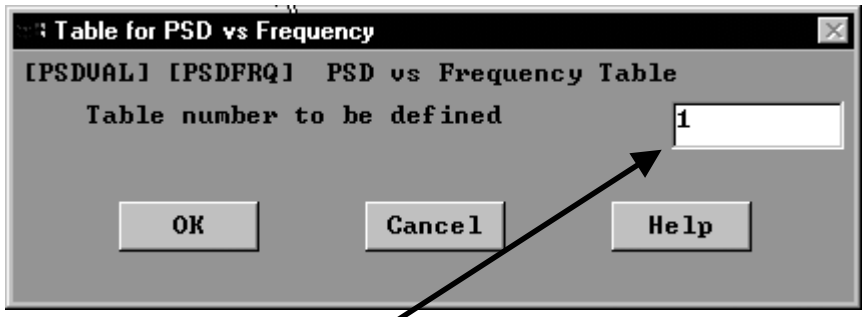
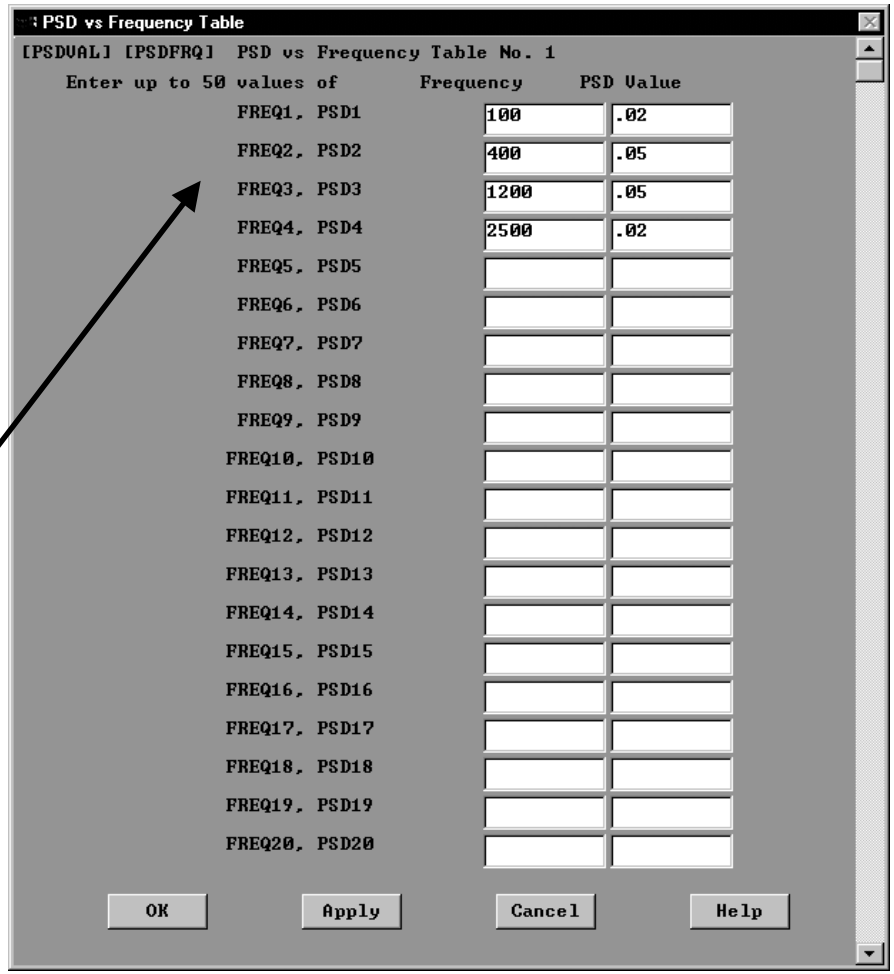
Specify PSD vs. Frequency

ANSYS Main Menu> Solution > Spectrum > PSD > PSD vs. Freq





- Specify 1 for the PSD Table (only one table in this analysis)
- Enter Frequency and Value data

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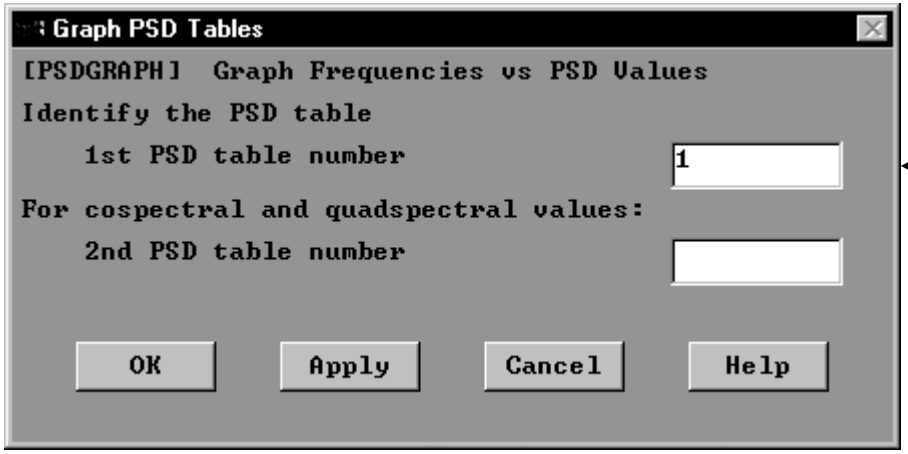
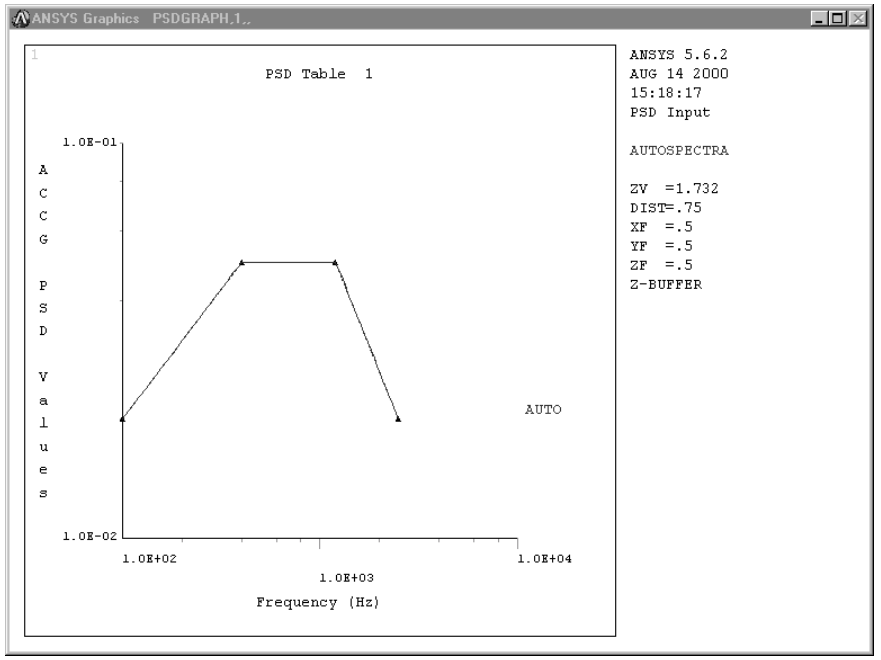
Plot Input PSD

ANSYS Main Menu> Solution > Spectrum > PSD > Plot



•Set table to 1



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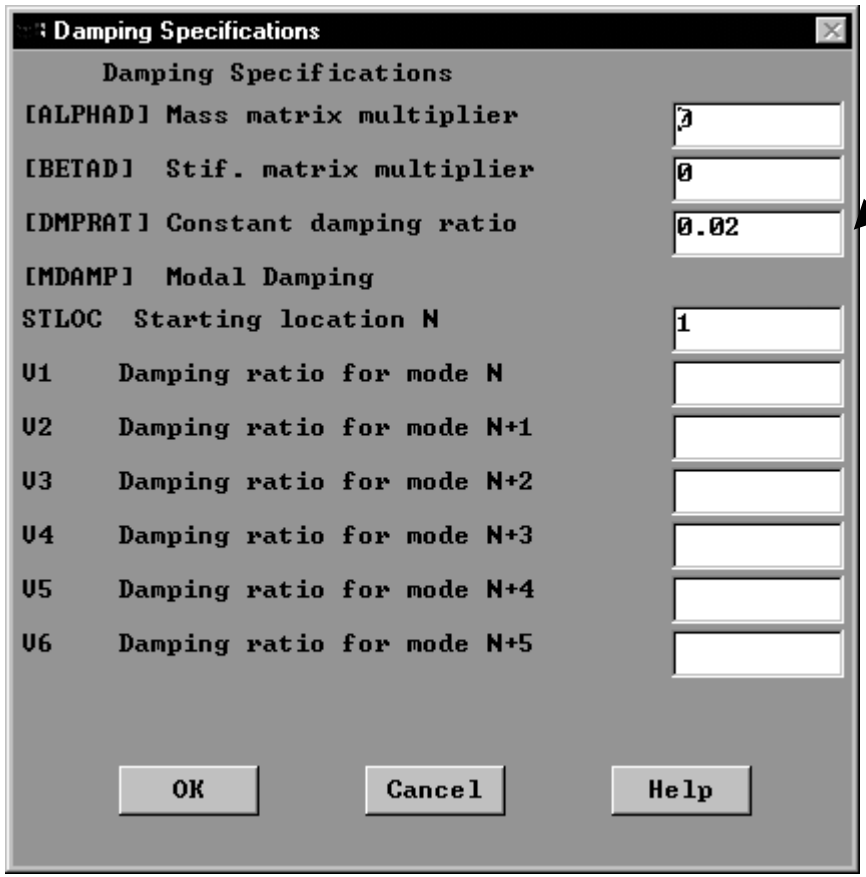
Specify Damping

ANSYS Main Menu> Solution > Time/Frequency > Damping



- Specify 2% Constant Damping Ratio

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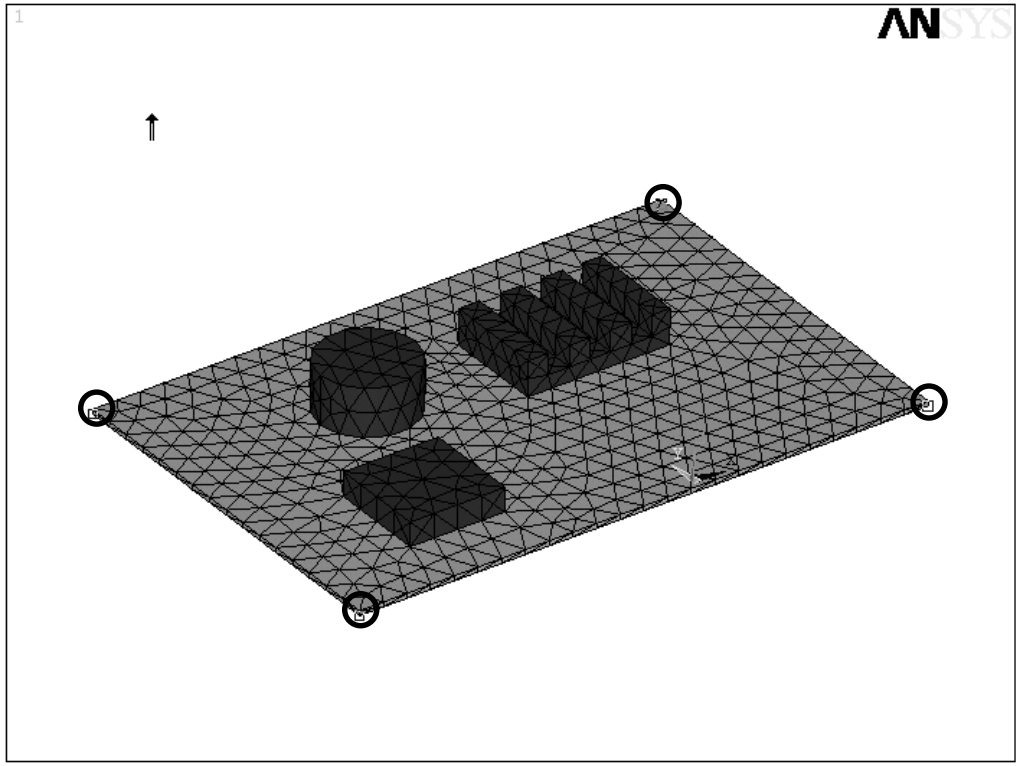
Flag Nodes to get PSD Input

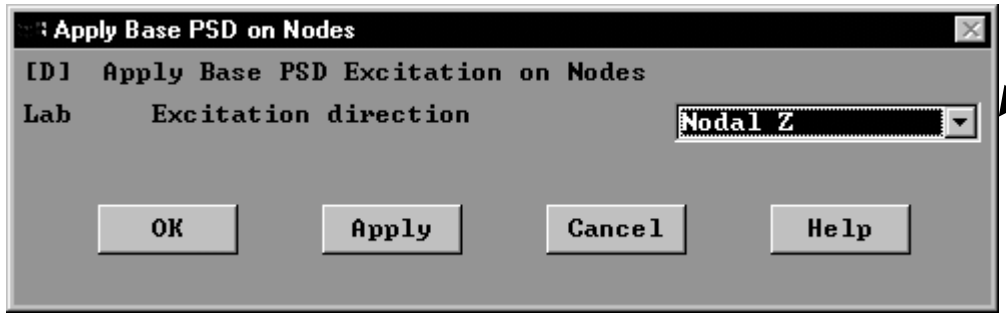
ANSYS Main Menu> Solution > Apply > Spectrum > Base PSD Excit > On Nodes



- Pick the 4 corner nodes on the bottom side of the board
  - 1748
  - 1782
  - 1902
  - 2038

Flag Nodes to get PSD Input

ANSYS Main Menu> Solution > Apply > Spectrum > Base PSD Excit > On Nodes



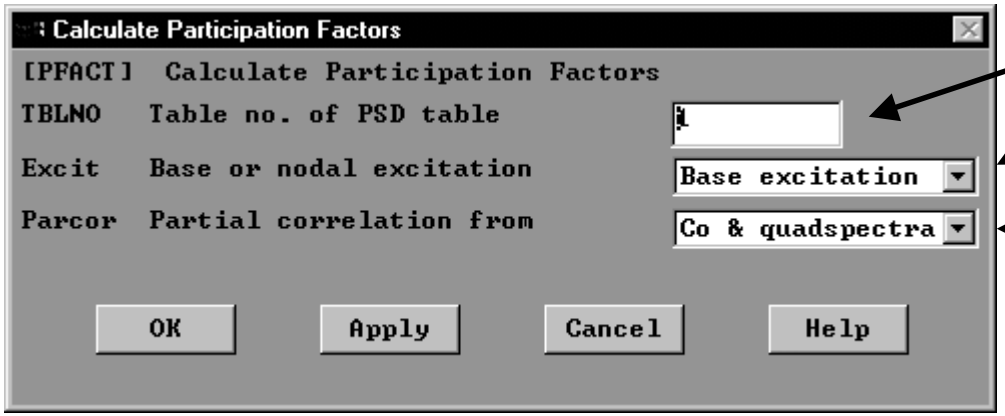
- Specify Excitation direction to Z

Note: This will flag a 1 displacement on the node telling ANSYS the previously defined PSD table is to be applied. You can apply base excitations only at nodes that were constrained in the modal analysis.

- UX,UY =0 Constraints on these 4 nodes are left over from Modal Analysis, and remain through PSD Analysis. No need to re-specify them.

Solve for Participation Factors

ANSYS Main Menu> Solution > Apply > Spectrum > Calculate PF …

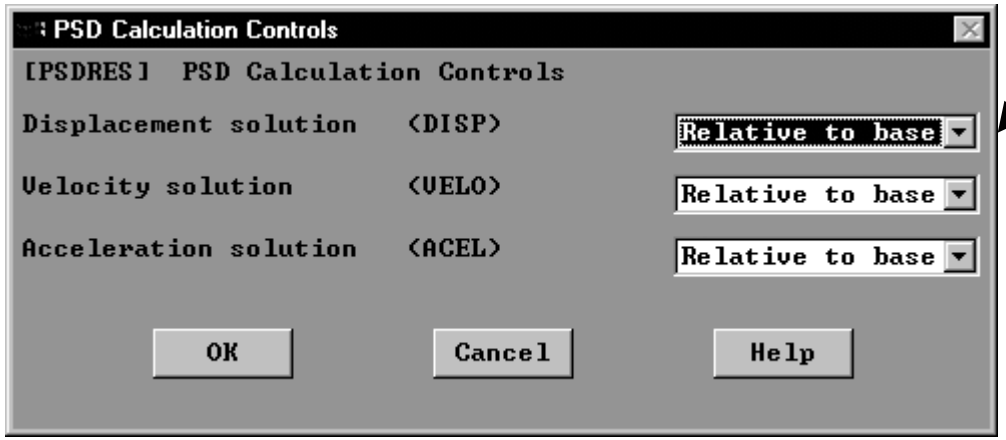


- Specify 1 for table
- Specify Base excitation Problem
- Leave parcor to default. Not required for single PSD excitation

Note: This step Calculates the participation factors for the specified PSD table

Set PSD Calculation Controls

ANSYS Main Menu> Solution > Spectrum > PSD > Calc Controls



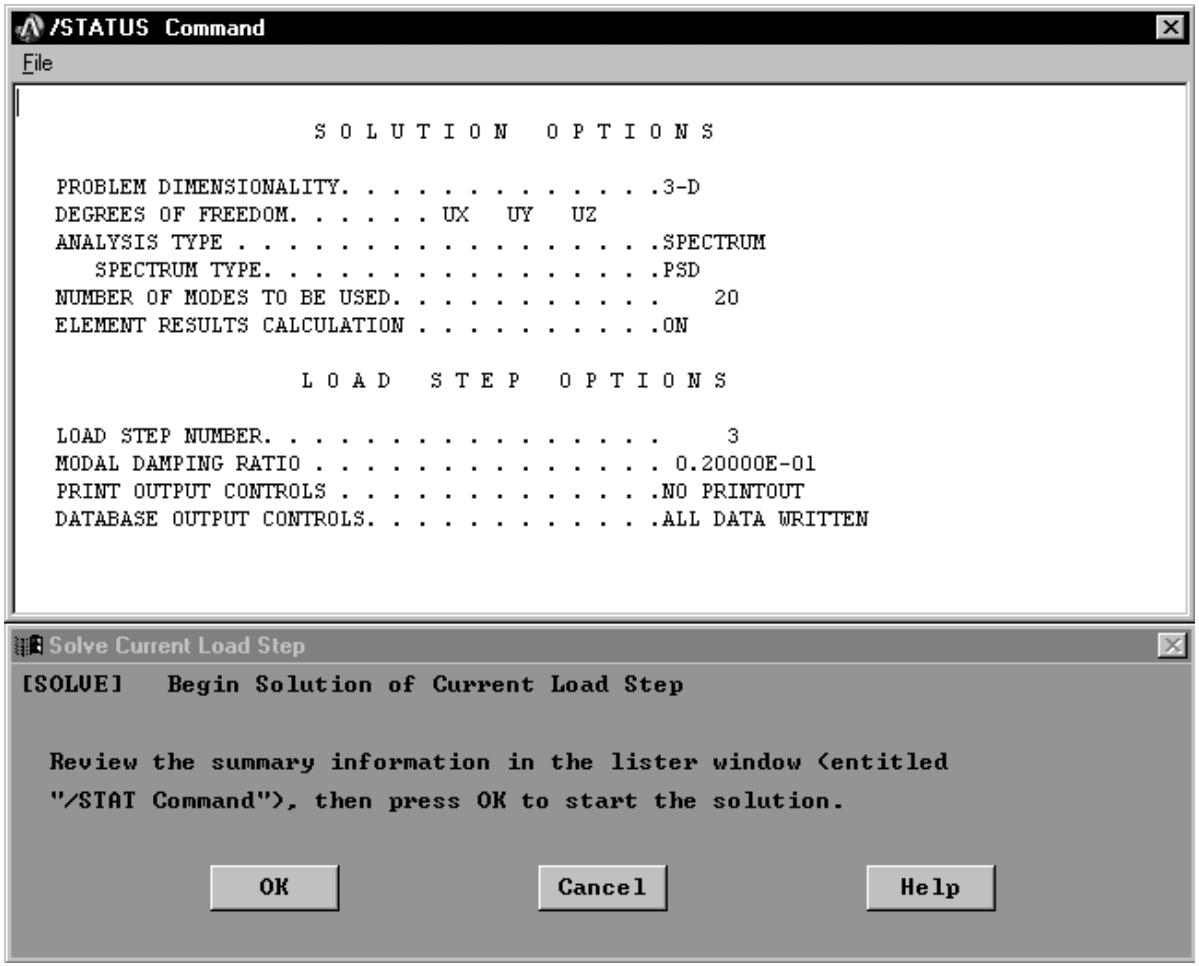
- Specify all Solution items are to be calculated Relative to Base. This means the input excitation is subtracted out. Input nodes have their results reported as zero.

Note:

These specifications are for the general postprocessor results, not the time history postprocessor.

Solve Random Vibration Solution

ANSYS Main Menu> Solution > Solve > Current LS



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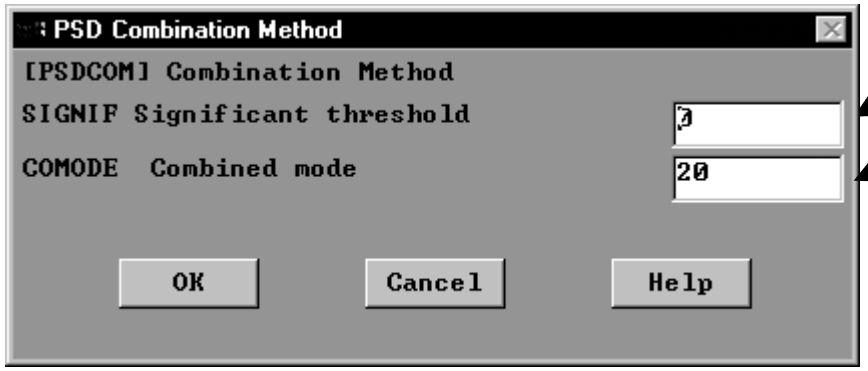
Set Mode Combination

ANSYS Main Menu> Finish

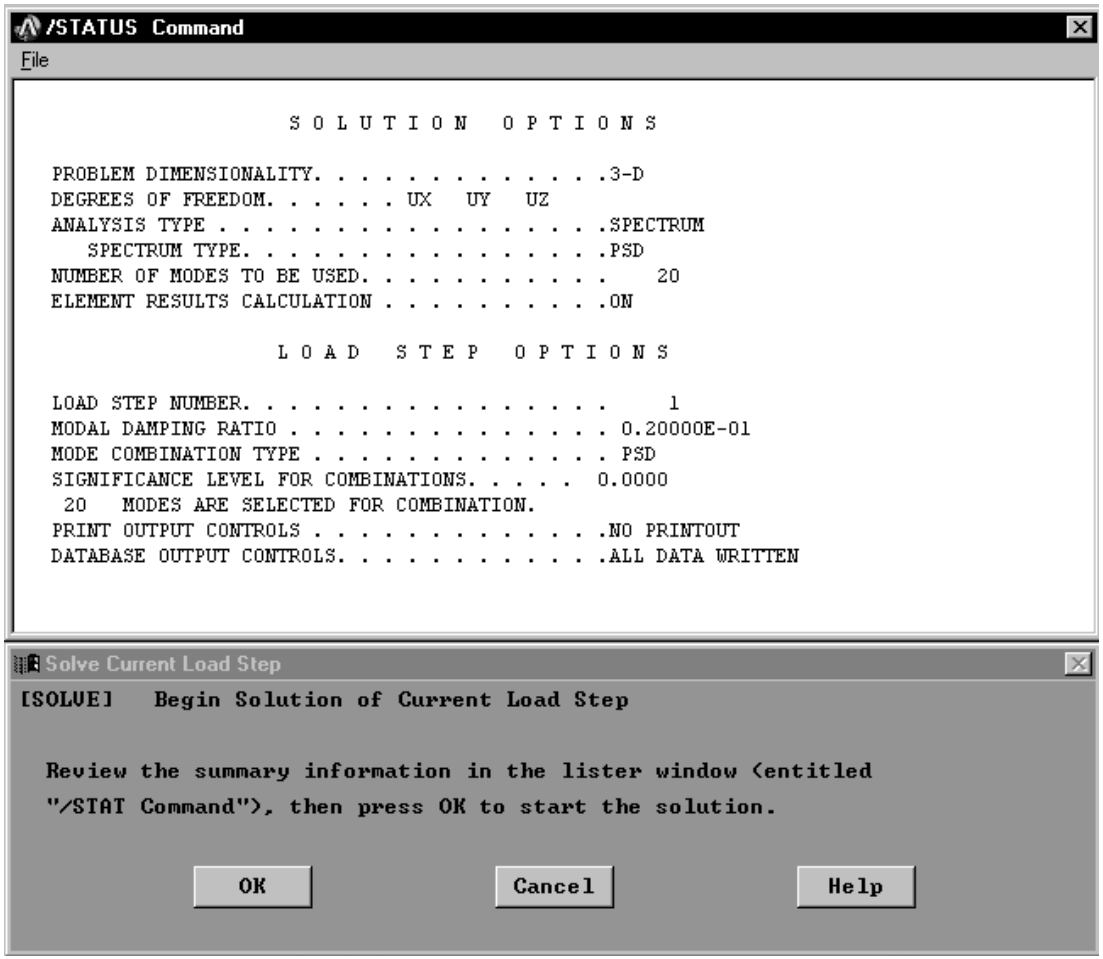
ANSYS Main Menu> Solution > Spectrum > PSD > Mode Combine …



- Leave significance at 0.
- All 20 modes will be used in mode combination

Calculate mode combinations and 1 sigma response

ANSYS Main Menu> Solution > Solve > Current LS

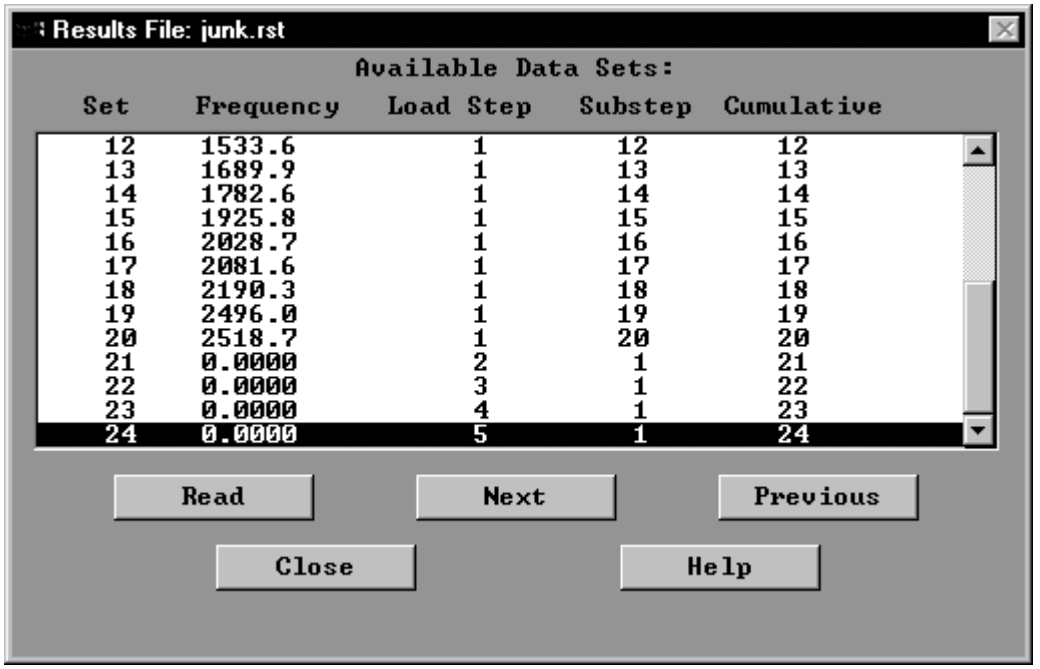


CSI ANSYS Tip of the Week

Post Processing Results Summary

ANSYS Main Menu> General Post Processor > Results Summary

- Load step 1 - modal results
- Load step 2 - unit static solutions
- Load step 3 - 1 sigma displacements, strains, stresses
- Load step 4 - 1 sigma velocities
- Load step 5 - 1 sigma accelerations



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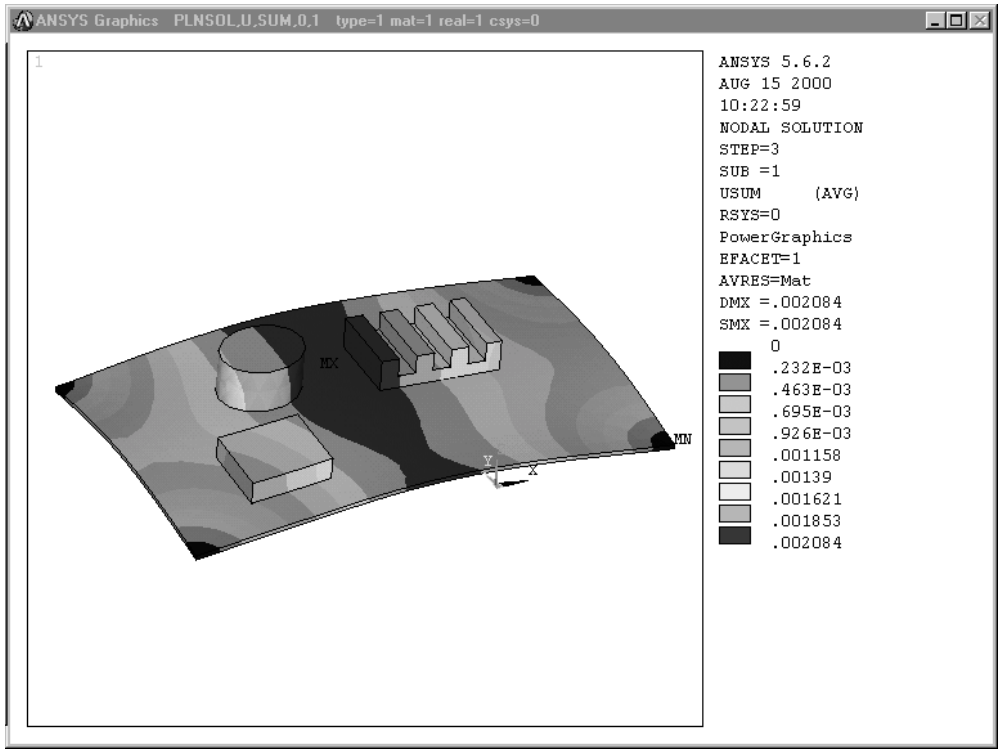
1 sigma Results

1σ results are typically used for:

- First passage failure calculations
  - What is the probability that the displacement at a DOF will exceed a displacement limit in a given time period?
- Fatigue calculations
  - Based on the premise that the stress level is at or below 1σ 68.2% of the time, between 1σ and 2σ 27.2% of the time (95.4-68.2), and between 2σ and 3σ 4.3% of the time (99.7-95.4), and above 3σ less than .3% of the time.

Post Processing 1 sigma Displacements

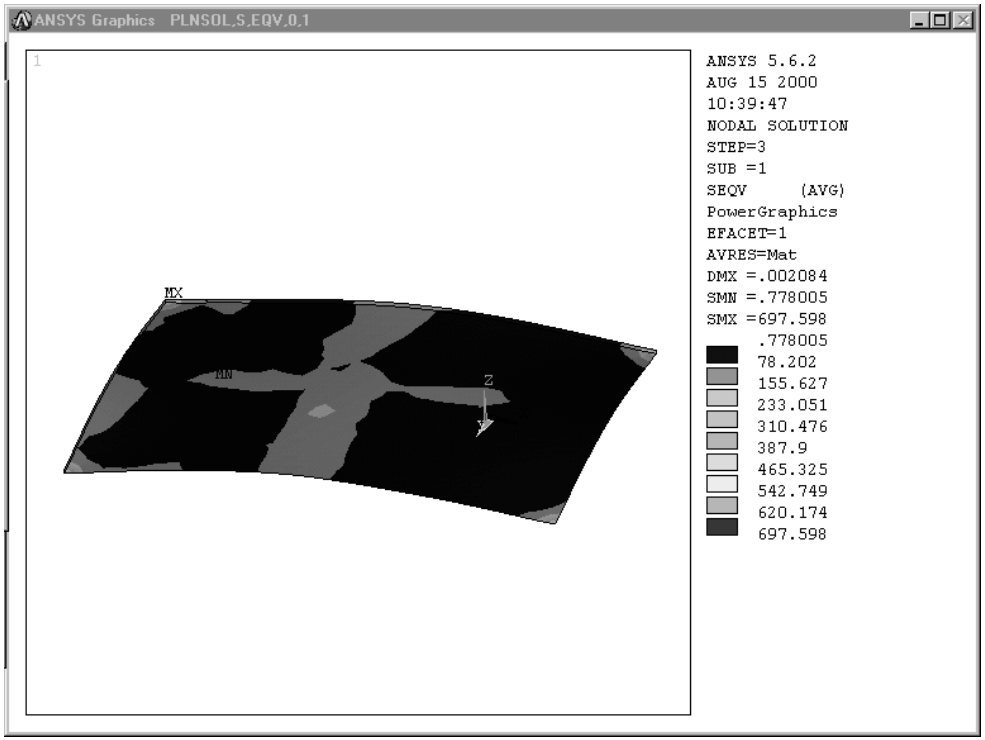
ANSYS Main Menu> General Post Processor > Plot Results > Nodal Solution >DOF Solution > USUM



- 1 sigma board deflection = .002”
- 3 sigma board deflection = 3 *.002” = .006”
- Therefore, only .3% of the time, board deflection will exceed .006”

Post Processing 1 sigma Stresses

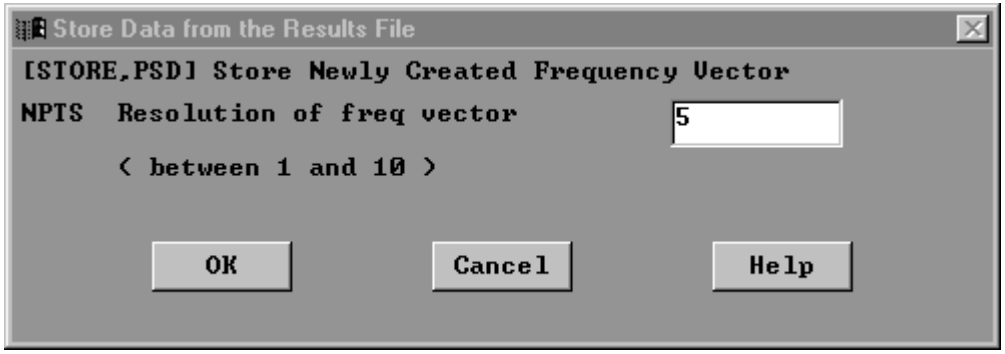
ANSYS Main Menu> General Post Processor > Plot Results > Nodal Solution >Stress > SEQV



- 1 sigma corner stress = 698 psi
- 3 sigma corner stress = 3 *. 698 psi= 2094 psi
- Therefore, only .3% of the time, board corner stress will exceed 2094 psi
- Note: For simplicity in this model, the corner nodes are constrained. This creates singular stress results. In reality, modeling and holding the actual mounting hold would provide more accurate results.

Plotting Response PSD in Post 26

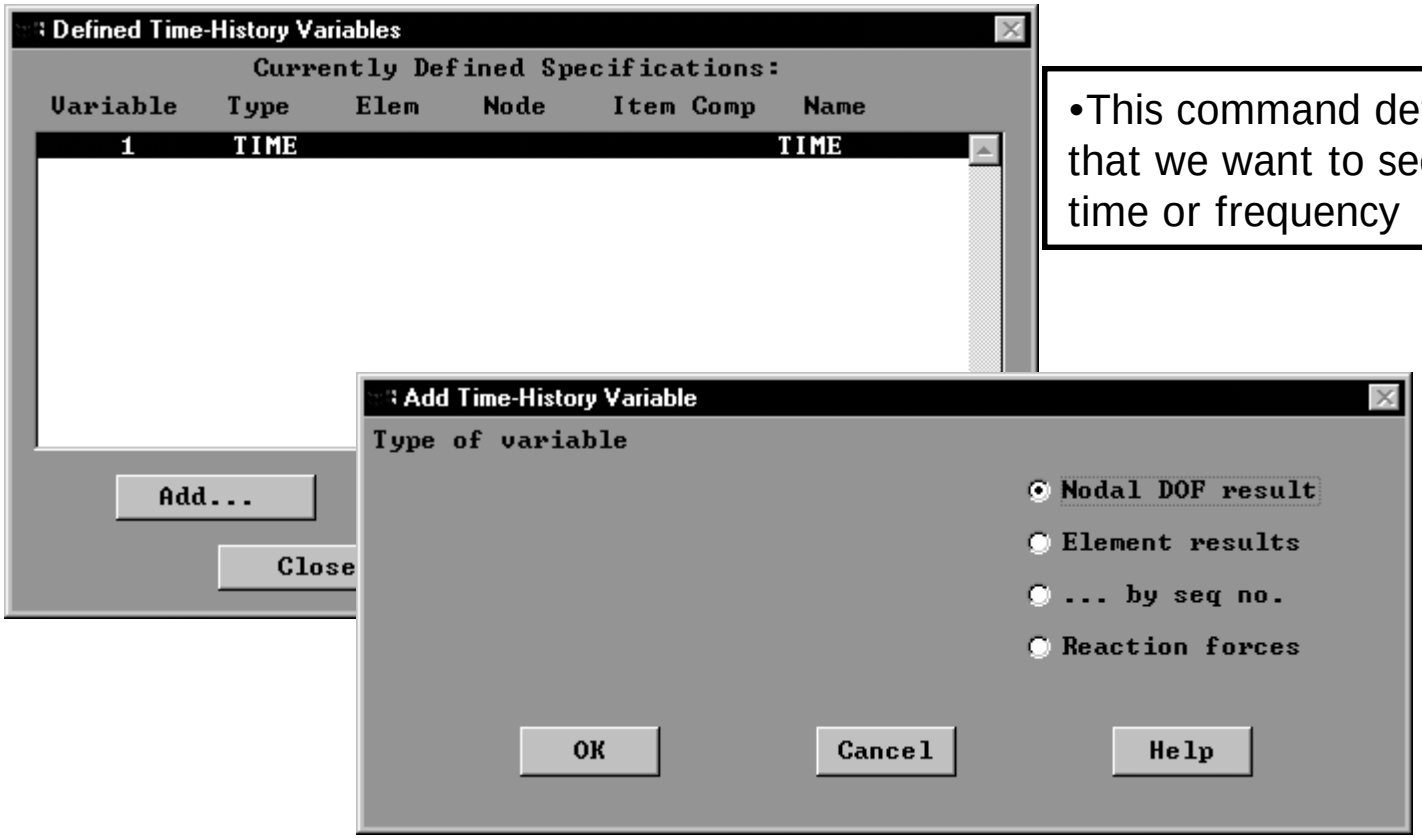
ANSYS Main Menu> Time History Post Processor > Store Data



- This command sets the resolution of the frequency vector for the PSD curve. 10 gives finer results 1 gives coarser results. 5 is the default.

Plotting Response PSD in Post 26

ANSYS Main Menu> Time History Post Processor > Define Variables



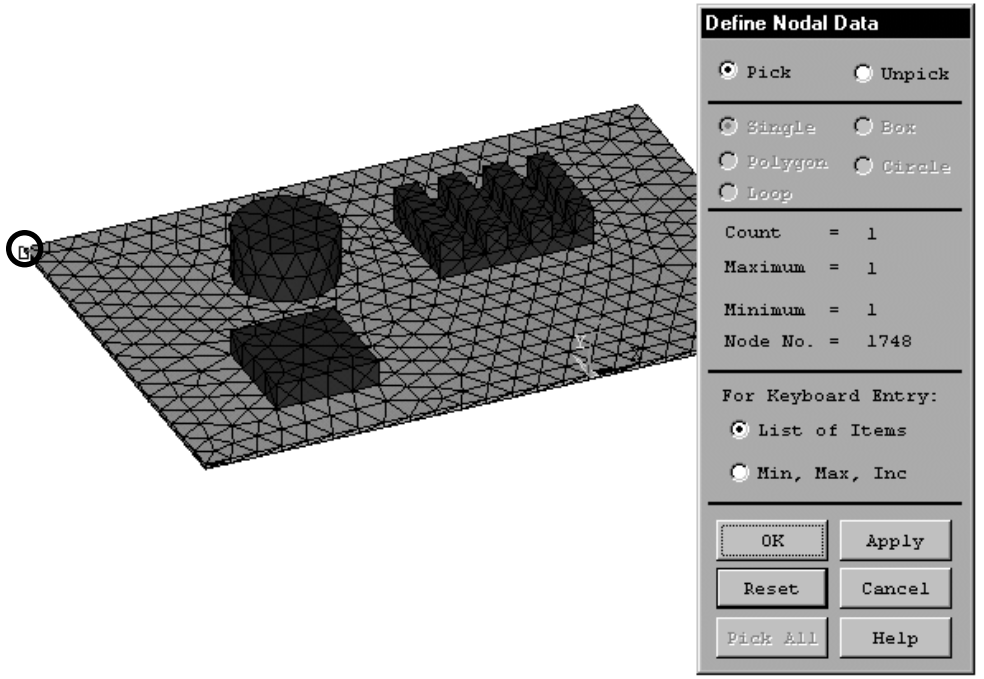
- This command defines the variables that we want to see as a function of time or frequency

CSI ANSYS Tip of the Week

Plotting Response PSD in Post 26

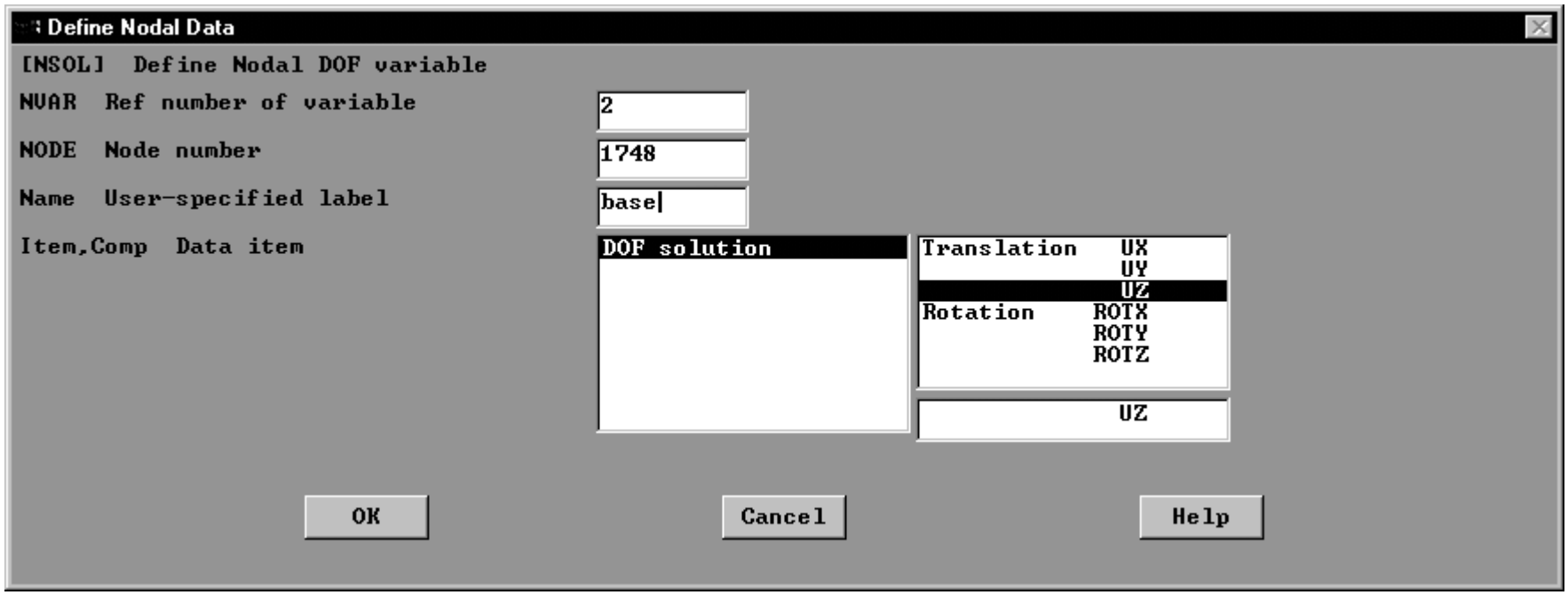
ANSYS Main Menu> Time History Post Processor > Define Variables

Pick one corner node that was constrained. 1748 is picked in this case.



Plotting Response PSD in Post 26

ANSYS Main Menu> Time History Post Processor > Define Variables



Specify UZ DOF and specify a label, in this case label is called base.

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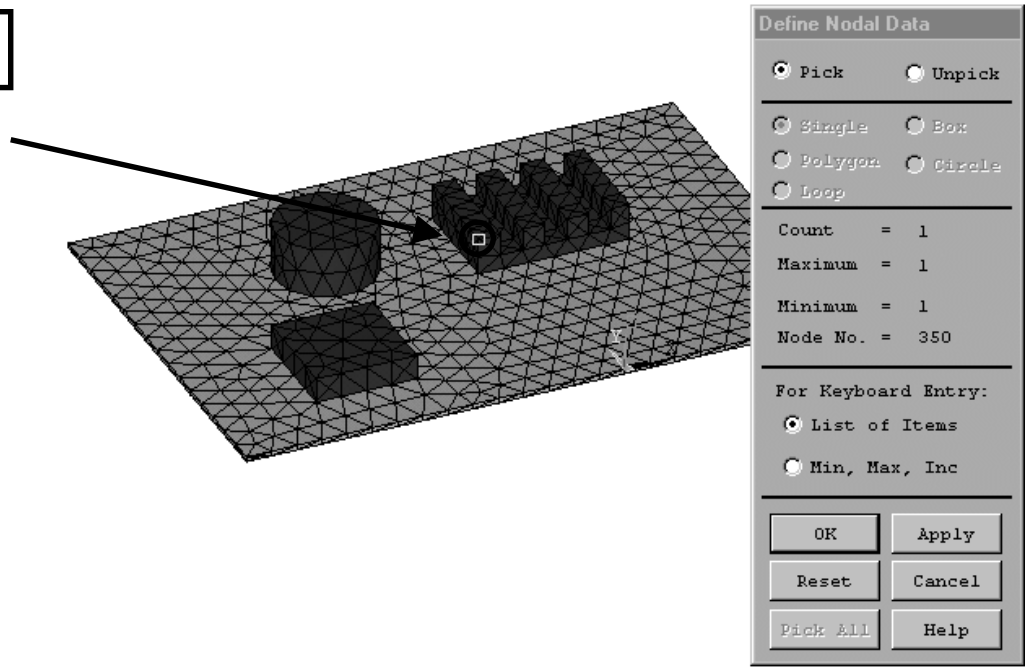
Plotting Response PSD in Post 26

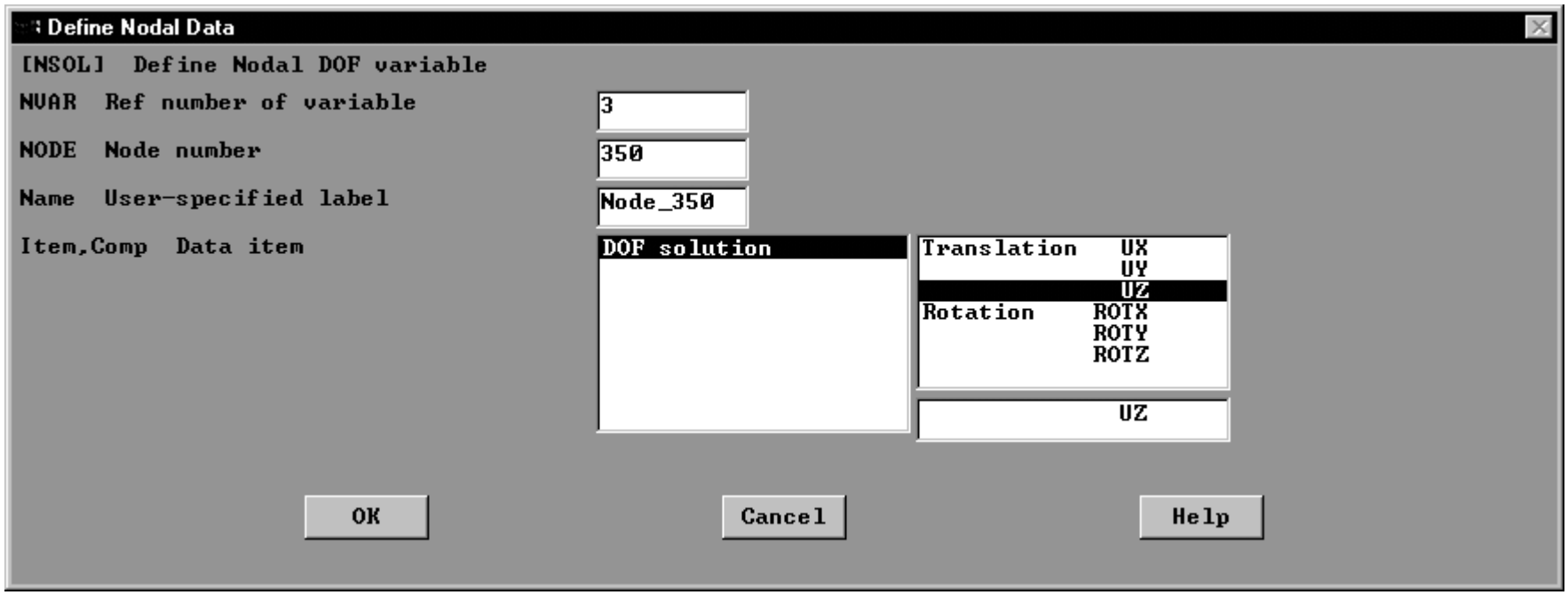
ANSYS Main Menu> Time History Post Processor > Define Variables

Pick node 350 on top of component



Plotting Response PSD in Post 26

ANSYS Main Menu> Time History Post Processor > Define Variables



Specify UZ DOF and specify a label, in this case label is called Node_350.

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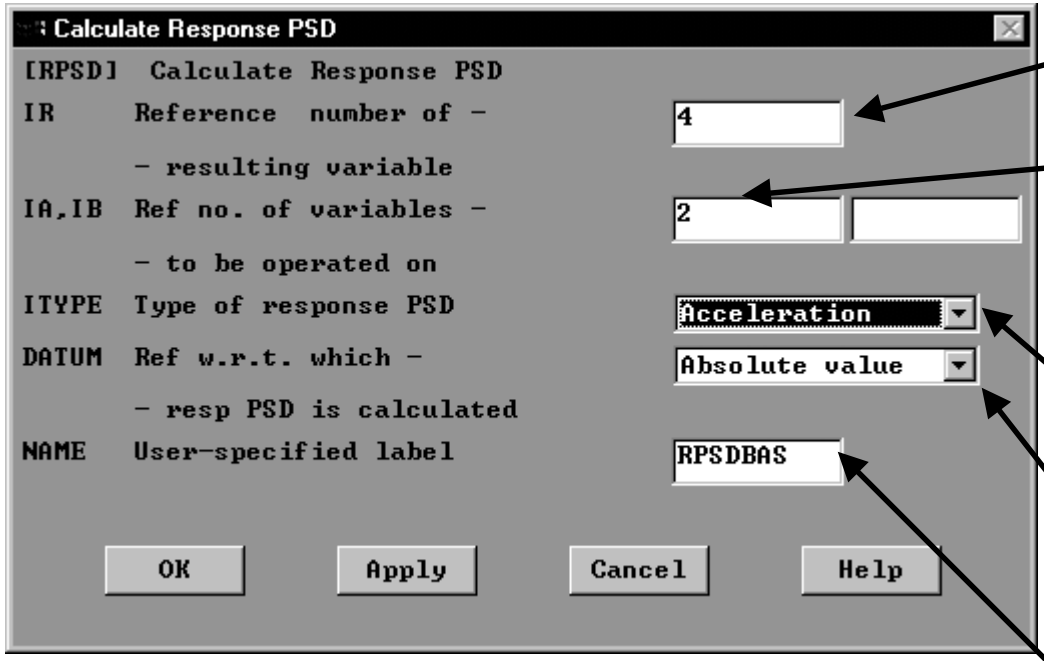
Plotting Response PSD in Post 26

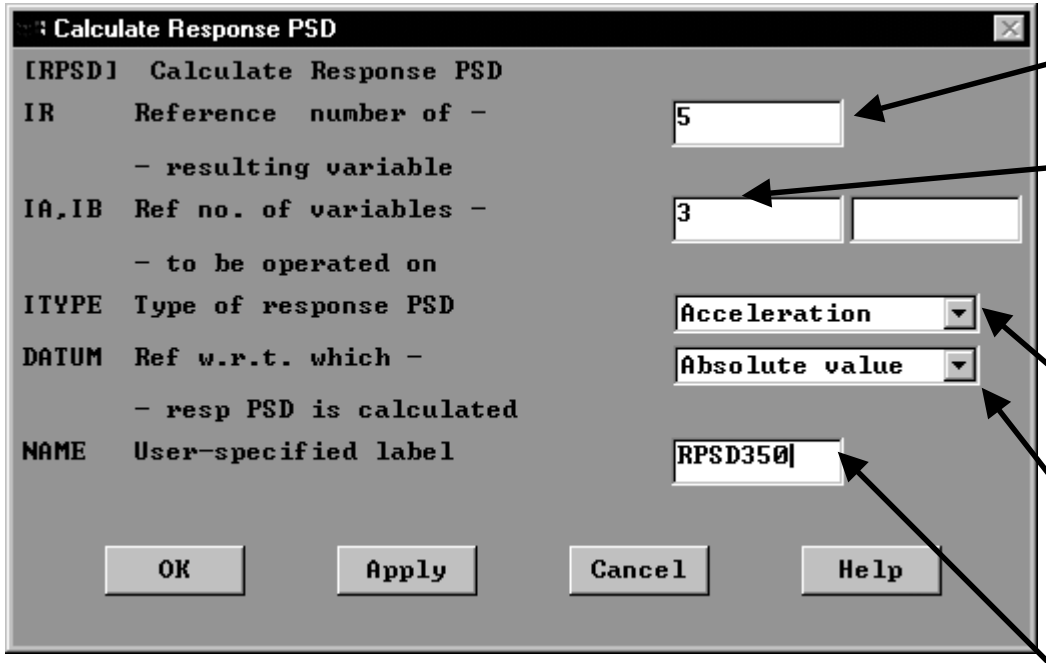
ANSYS Main Menu> Time History Post Processor > Calculate Resp PSD



- Specify new variable number to store PSD in
- Specify existing variable number that has DOF solution. In this case 2 is the corner node base excitation.
- Specify the response to be acceleration.
- Specify absolute in order to plot input PSD and response PSD together
- Give new variable a label

Plotting Response PSD in Post 26

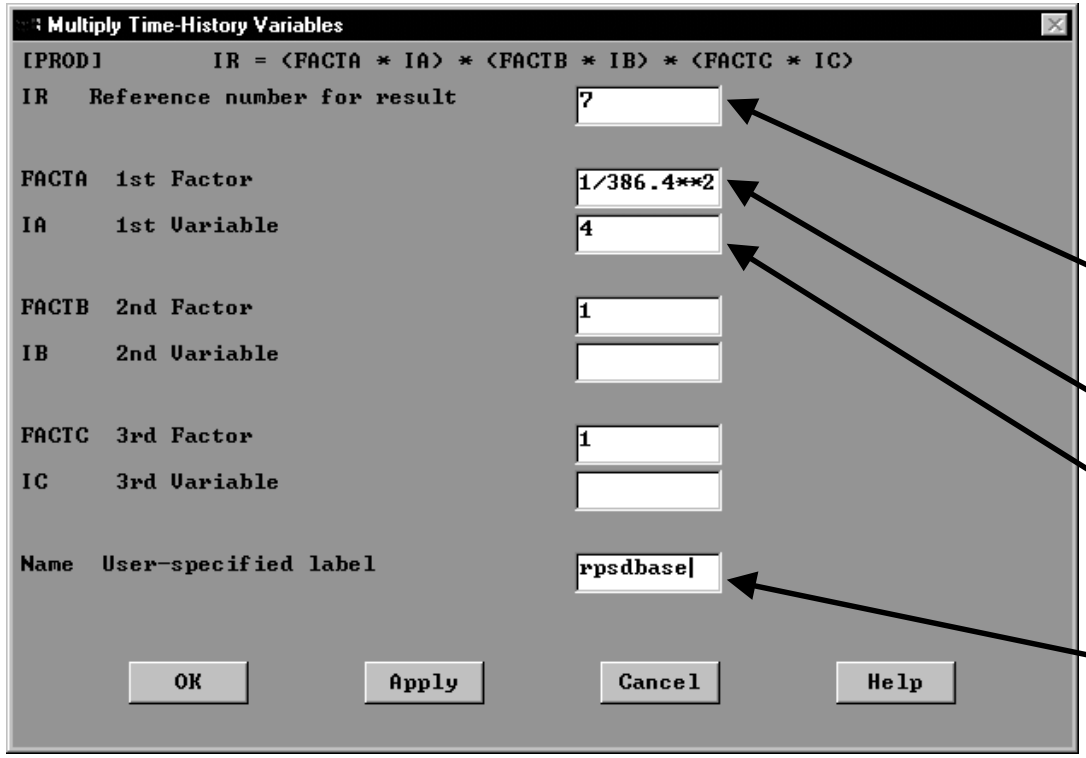
ANSYS Main Menu> Time History Post Processor > Calculate Resp PSD



- Specify new variable number to store PSD in
- Specify existing variable number that has DOF solution. In this case 3 is the node on top of a component
- Specify the response to be acceleration.
- Specify absolute in order to plot input PSD and response PSD together
- Give new variable a label

Plotting Response PSD in Post 26

ANSYS Main Menu> Time History Post Processor > Math Operations

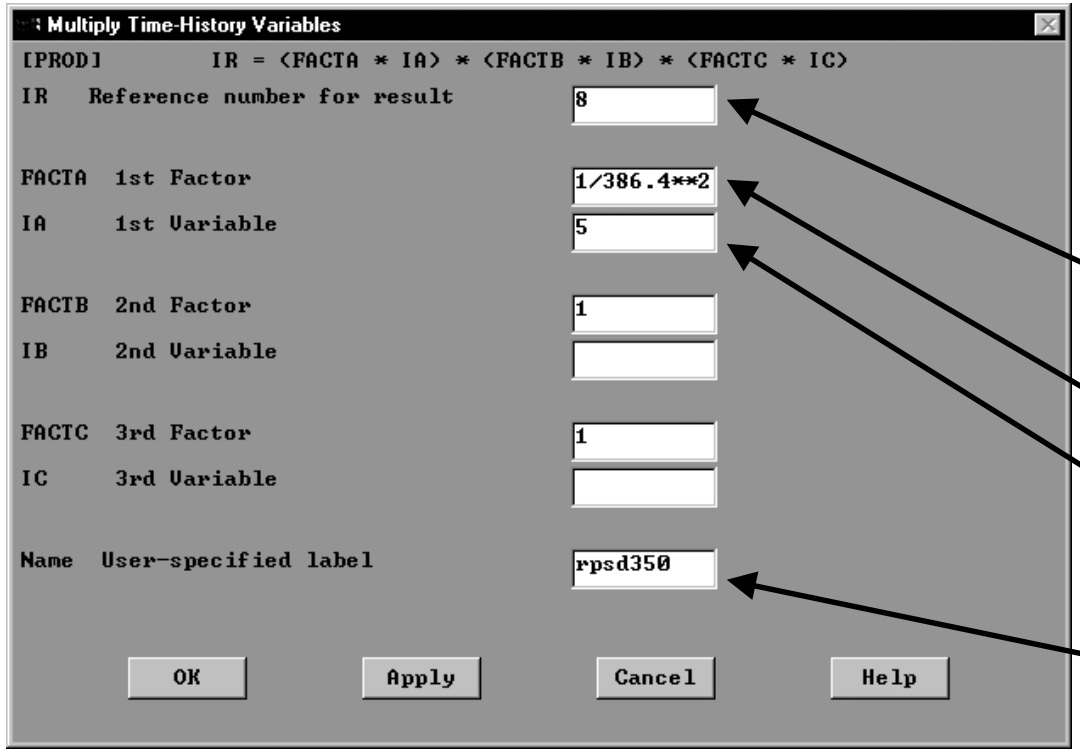


- Convert results from in^2/sec^4/Hz into g^2/Hz by dividing results by 1/g^2 = 1/386.4**2
- Specify variable 7 gets the results of this operation
- Specify 1/g^2 factor
- Specify variable 4 to operate on. This has the input PSD in in^2/sec^4/Hz
- Give new variable a label

CSI ANSYS Tip of the Week

Plotting Response PSD in Post 26

ANSYS Main Menu> Time History Post Processor > Math Operations



- Convert results from in^2/sec^4/Hz into g^2/Hz by dividing results by 1/g^2 = 1/386.4**2
- Specify variable 8 gets the results of this operation
- Specify 1/g^2 factor
- Specify variable 5 to operate on. This has the **component node PSD** in in^2/sec^4/Hz
- Give new variable a label

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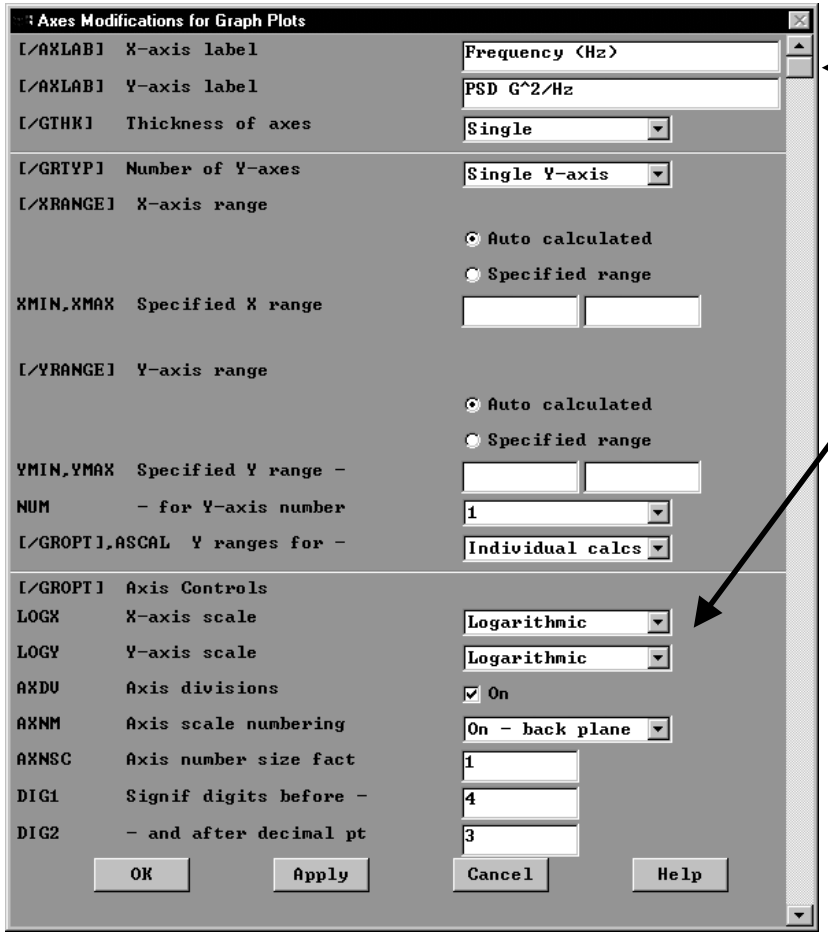
Plotting Response PSD in Post 26

Plot Controls > Style > Graphs > Modify Axes

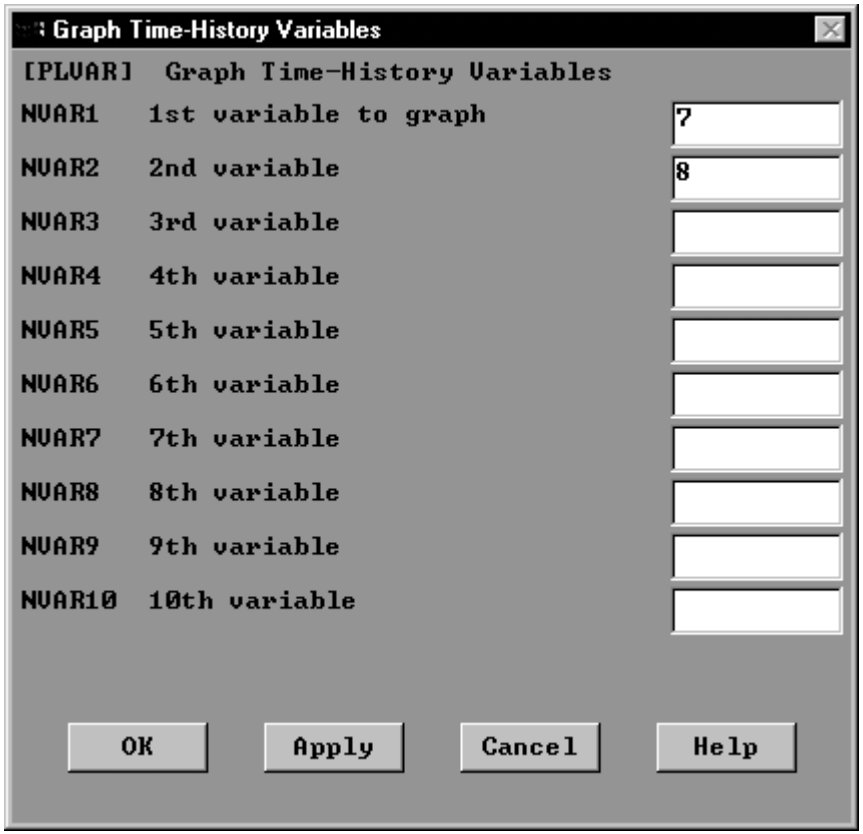


- Define labels for graph
- Set axes to Logarithmic

CSI ANSYS Tip of the Week

Plotting Response PSD in Post 26

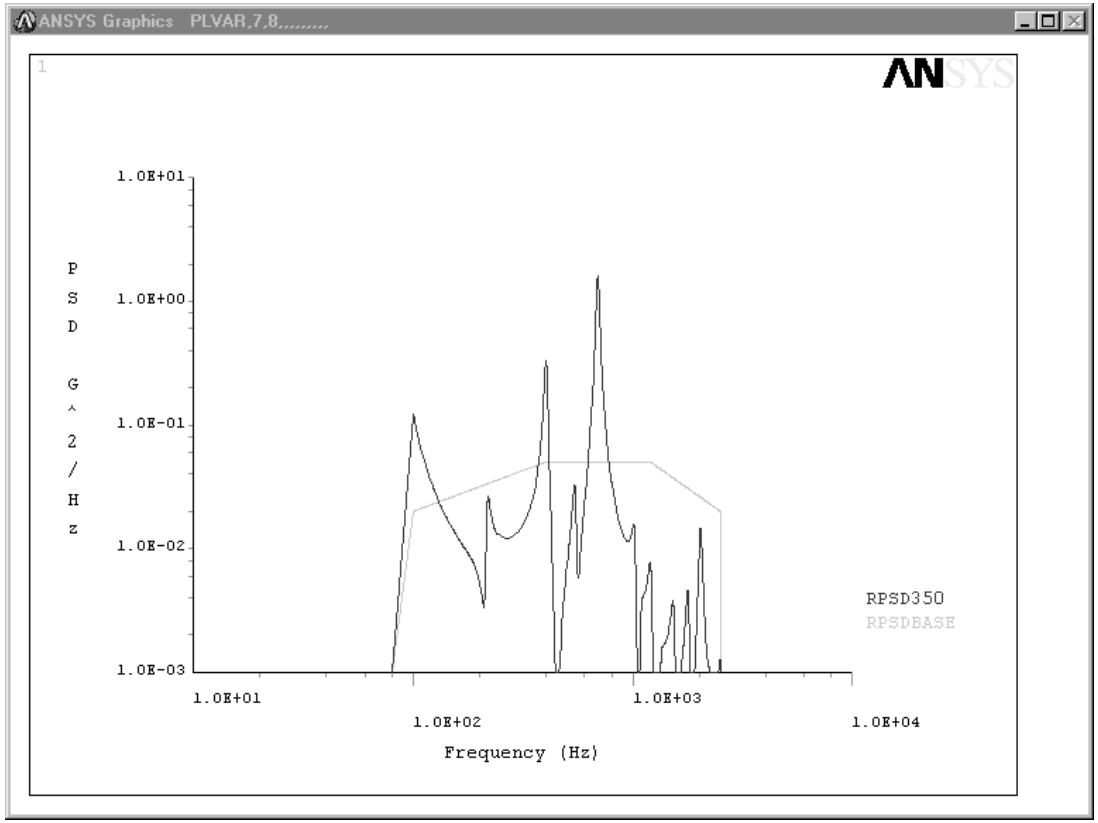
ANSYS Main Menu> Time History Post Processor > Graph Variables



- Plot input PSD (g^2/Hz) variable 7
- Plot response PSD (g^2/Hz) variable 8

Plotting Response PSD in Post 26

ANSYS Main Menu> Time History Post Processor > Graph Variables



- Plot shows the response PSD of the component on the board versus the input PSD at one of the corner nodes.
- From this plot we see the dynamic amplification the circuit board provides from the input PSD.

CSI ANSYS Tip of the Week