Transducer Mounting and Test Setup Configurations

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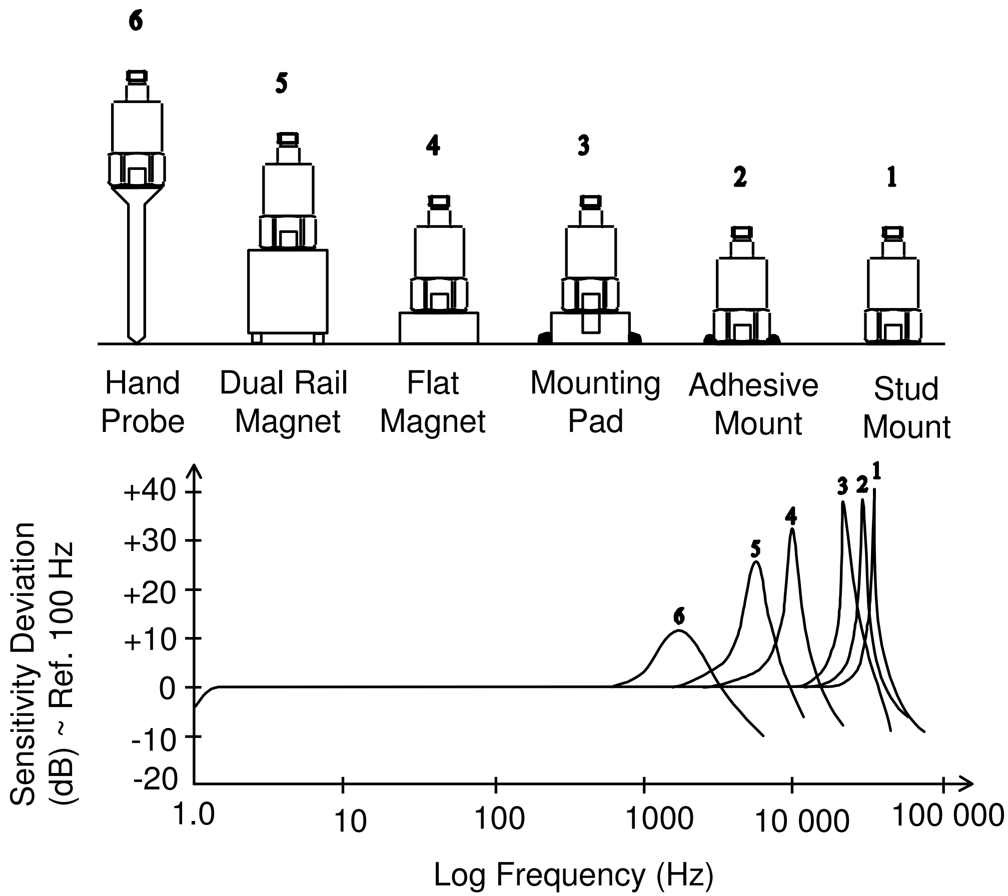
The Modal Shop

Transducer Mounting

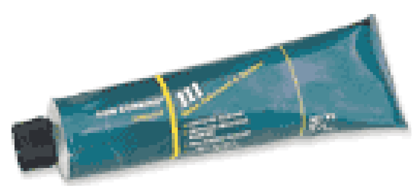
- Mechanical connection method
  - Stud mount
  - Adhesive mount
  - Magnetic mount
  - Press-fit friction mount
- Test parameter considerations
  - Frequency range
  - Mass loading

Mechanical Mounting: Impact on Frequency Range



Stud Mount Transducers

- Best frequency response characteristics – just like the manufacturer’s cal labs
- Apply silicon grease at mating surface
- Requires surface preparation
- Proper torque recommended



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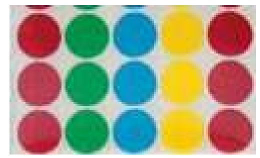
Adhesive Mounting Supplies



Adhesive Mount Transducers

- Cyanoacrylate (superglue)
  - "Instant" adhesive; strong, but still removable
  - Gel vs liquid – depends upon surface flatness
  - Excellent frequency response characteristics

Adhesive Mount Transducers

- Petro wax (bees wax)
  - Ultra convenient and simple
  - Good for short term testing only
  - Frequency response characteristics highly dependent upon surface prep and amount

Adhesive Mount Transducers

- Hot glue
  - Allows attachment to poorly-mated surfaces
  - Good for short term to mid term testing
  - Frequency response characteristics poor, but generally good enough for modal apps

Adhesive Mount Transducers

- Dental cement / fast-cure epoxy
  - Allows attachment to poorly-mated surfaces
  - Pseudo-permanent attachment for reference transducer at shaker input location
  - Use “disposable” mounting pad with stud

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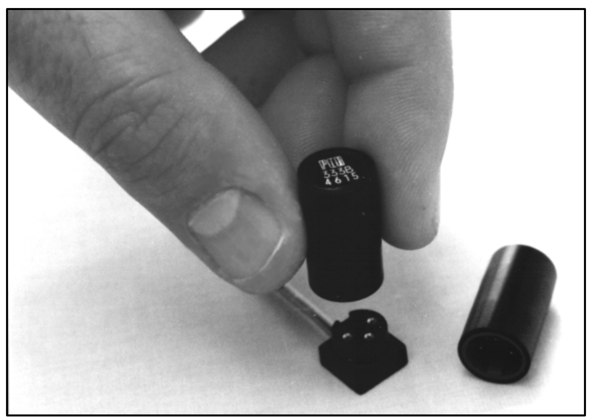
Magnetic Mount Transducers

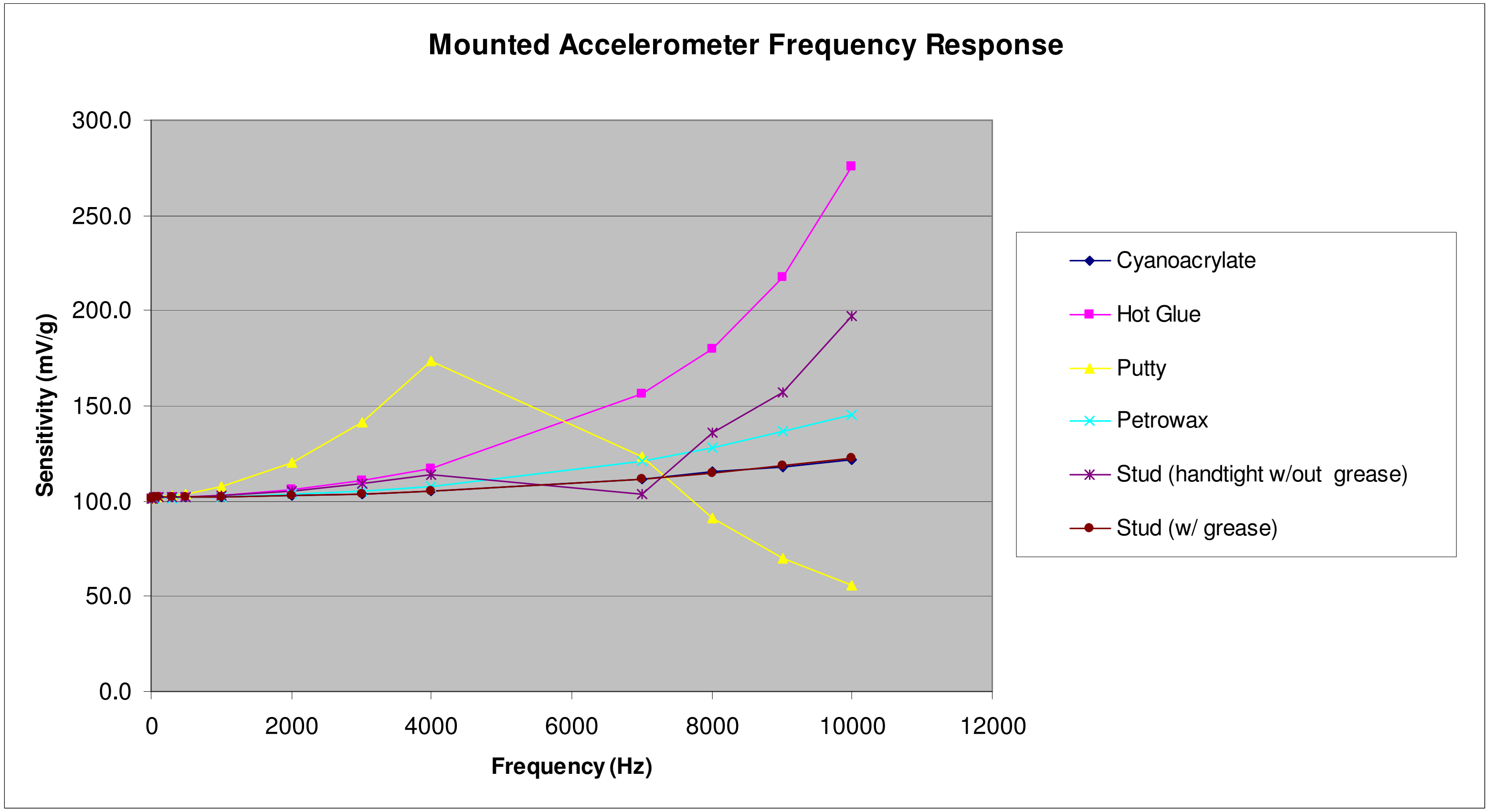
- Extremely convenient
- High attraction forces allow for reasonable high frequency characteristics
- Available in dual-rail style for attachment to curved surfaces

Press-fit Mount Transducers

- Extremely convenient and efficient
- Designed specifically for low frequency (<1000 Hz) laboratory modal applications
- Cable base mounts adhesively, modal sensor mechanically attaches using electrical pins

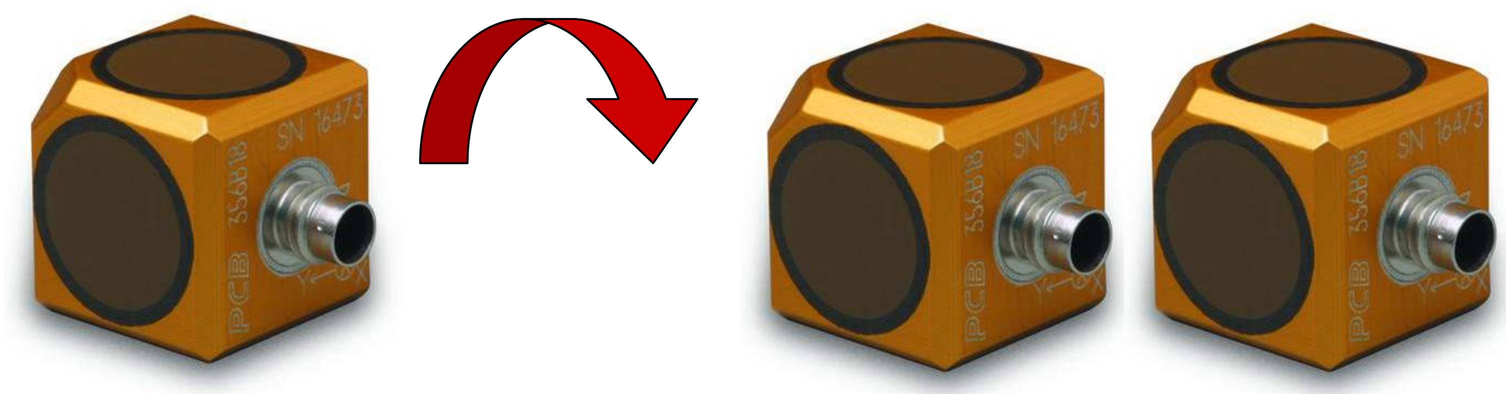


Mounted Accelerometer Frequency Response Calibration



Mass Loading Considerations

- Acquire FRF with a single accelerometer
- Mount a second accelerometer next to the first and re-acquire FRF
- Compare for measurable differences



Test Setup Considerations

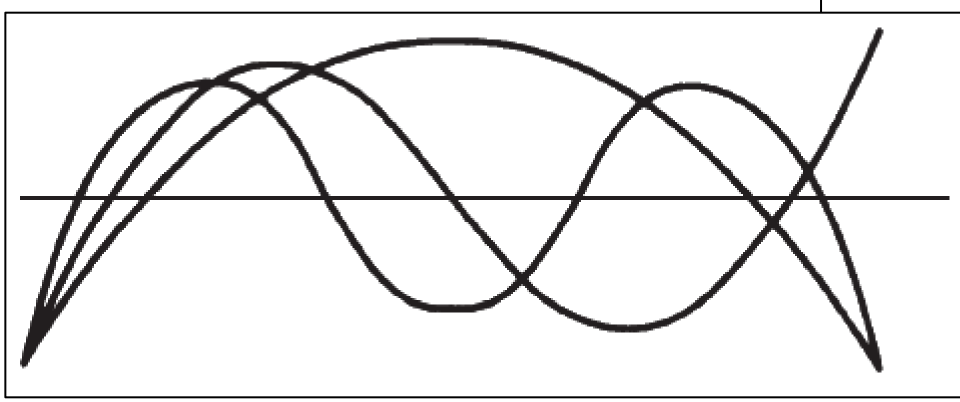
- Understand goals/reasons for performing experimental modal analysis
  - Troubleshooting or failure analysis
  - Finite element model verification
  - Finite element model correction
  - Component substructure / system modeling

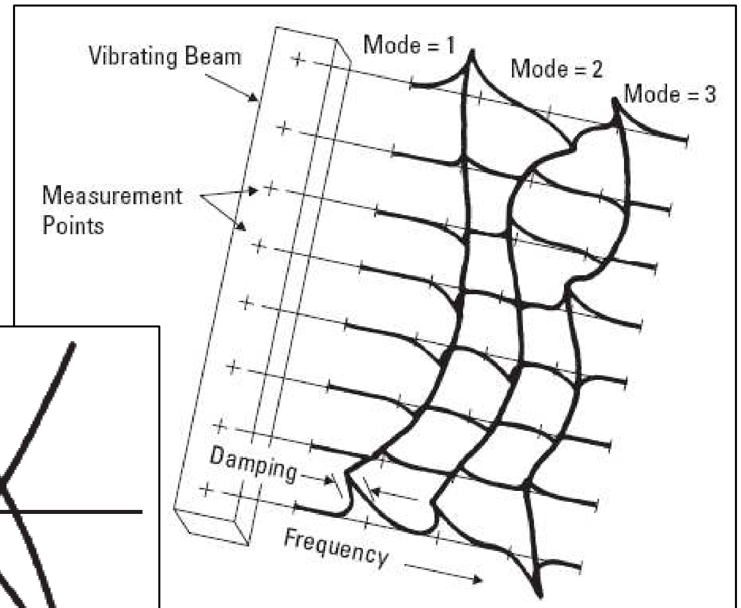
Test Setup Considerations

- Recognize the 4 primary assumptions of experimental modal analysis
  - Observability
  - Time Invariance (Stationarity)
  - Linearity
  - Maxwell's Reciprocity

Observability Assumption

- Response DOF must have adequate spatial resolution to represent the modes of interest

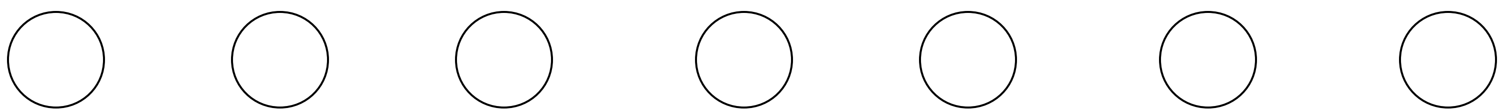




Graphics from Agilent Application Note 243-3

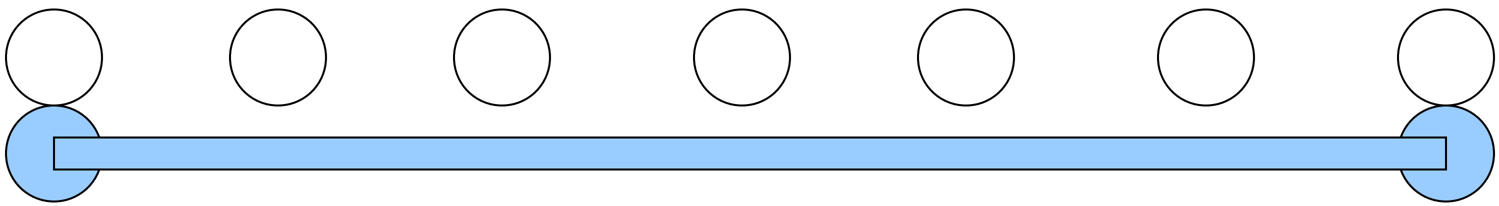
Observability Assumption

First bending – beam with seven accelerometer measurement points

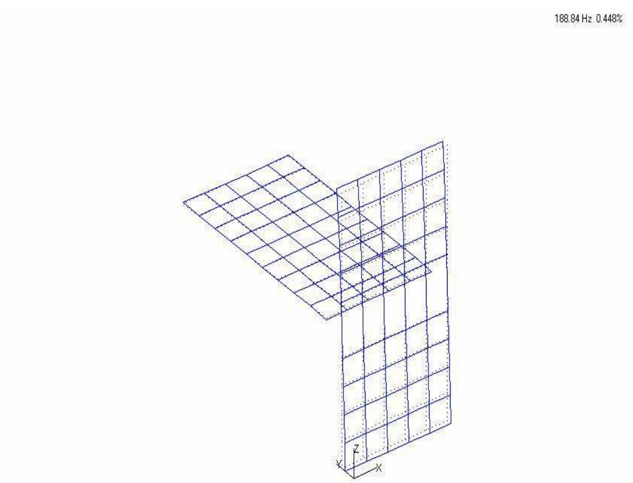


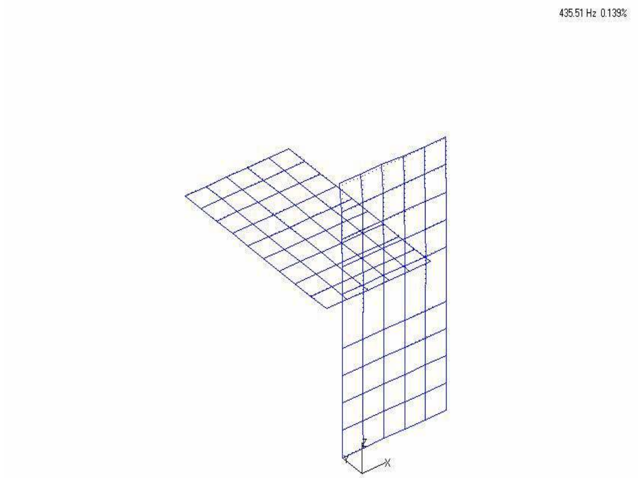
Observability Assumption

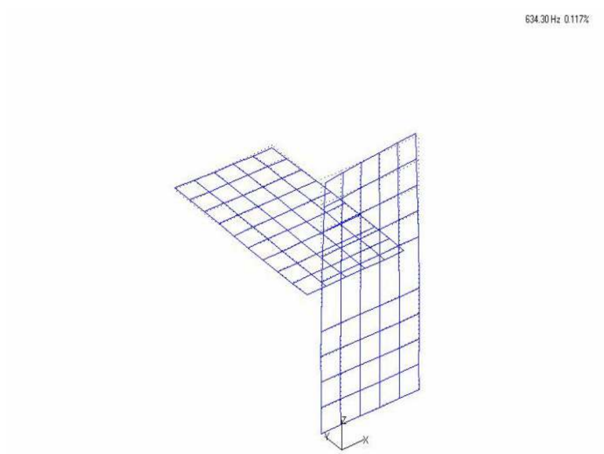
If data acquired only at endpoints… bending is not observable

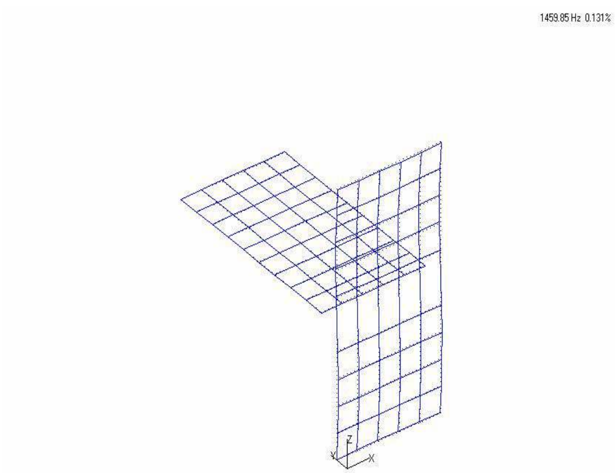


Observability Assumption





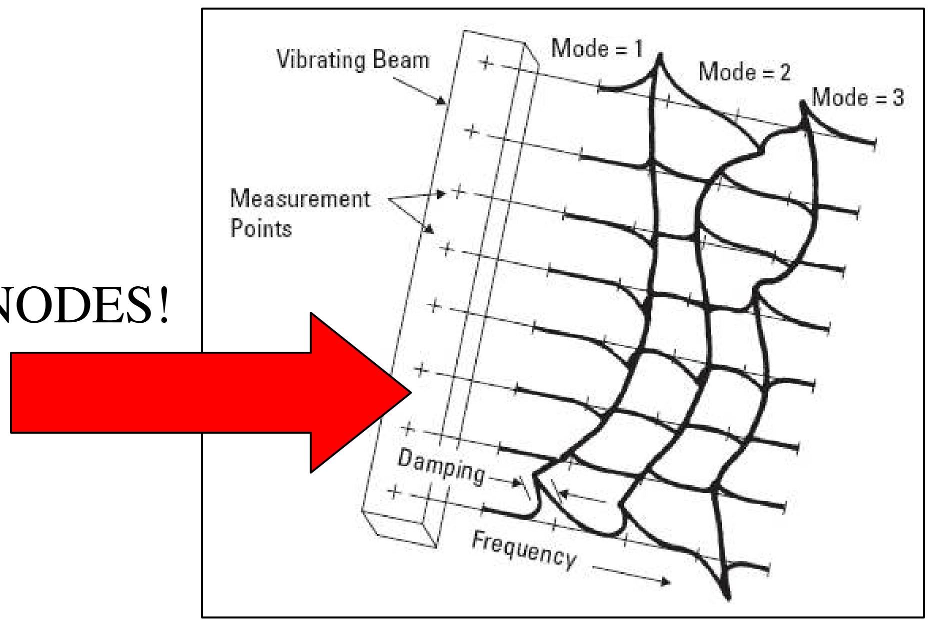




Observability Assumption

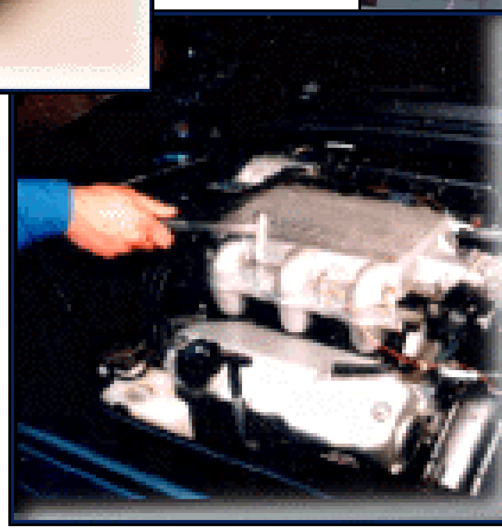
- Forcing function(s) applied at input location(s) must adequately excite the modes of interest

AVOID NODES!

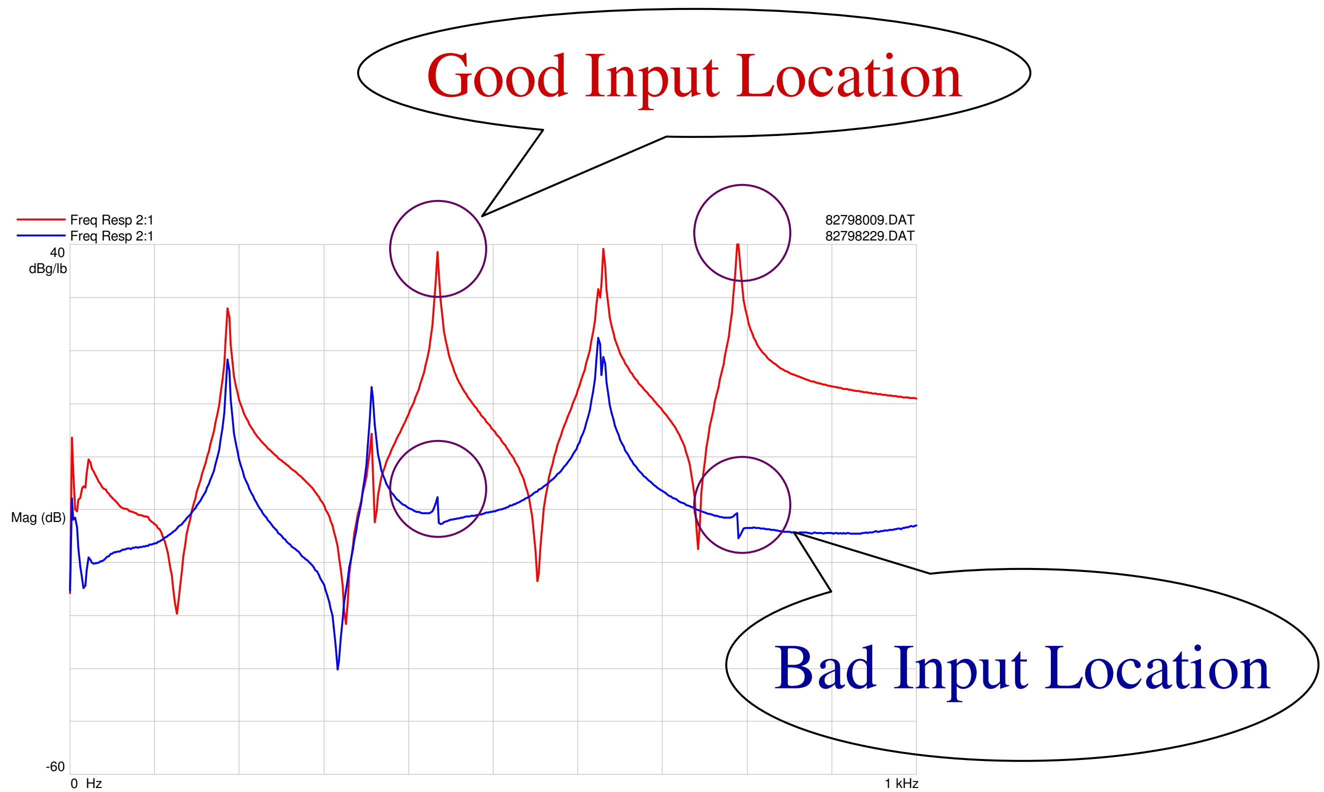


Graphic from Agilent Application Note 243-3

Modally-Tuned Impact Hammers as Pre-Test Tool for Evaluating Structures...

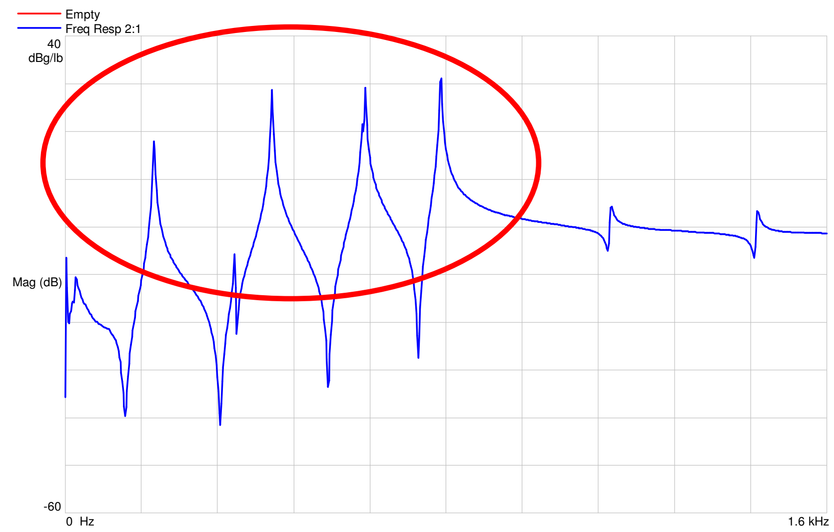


… for Optimizing Reference Locations and Ensuring Observability



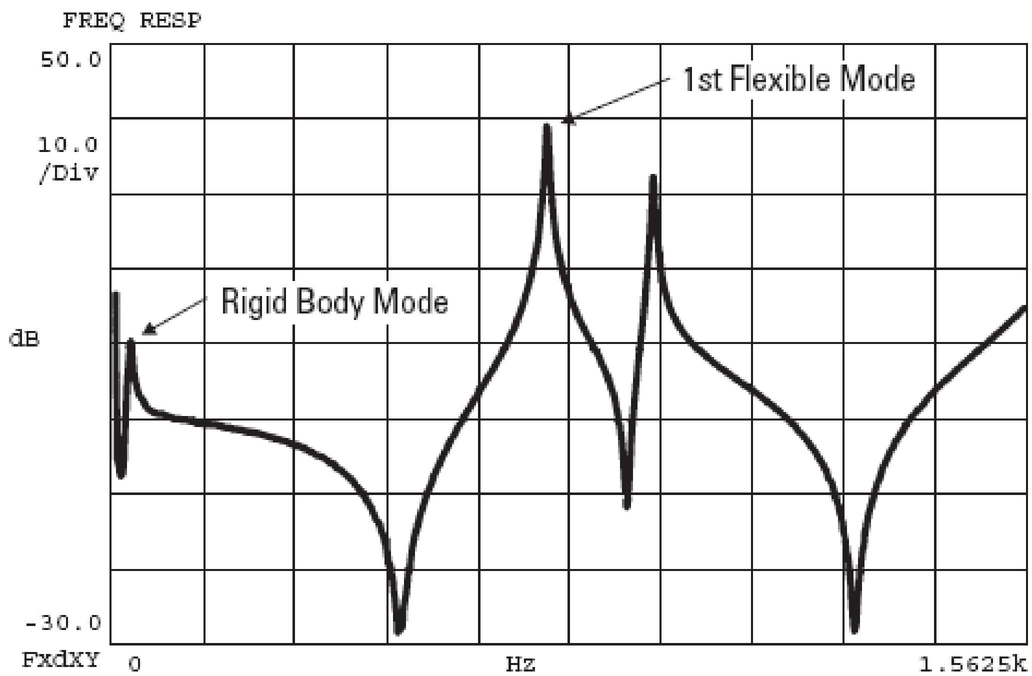
… for Determining Optimal Frequency Range

- Assure adequate spatial resolution to observe:
  - Important, dominant modes
  - Necessary modal density



… for Testing Boundary Conditions

Rule of Thumb: 5-10x separation between rigid body and flexible modes



Graphic from Agilent Application Note 243-3

Time Invariance Assumption

- Test article (and its boundary conditions) must exhibit stationarity
  - Parameter estimation algorithms assume consistent global modal properties throughout data set
  - Environmental changes during data acquisition cause shifts in stiffness/damping properties resulting in measurable shifts in resonant frequencies
  - Roving accelerometers to acquire data set results in variable mass loading on test article

Time Invariance Assumption

- DATA CONSISTENCY
- DATA CONSISTENCY
- DATA CONSISTENCY

- i.e. acquire entire data set simultaneously (single “snapshot”) or at least as fast as possible

Time Invariance Assumption

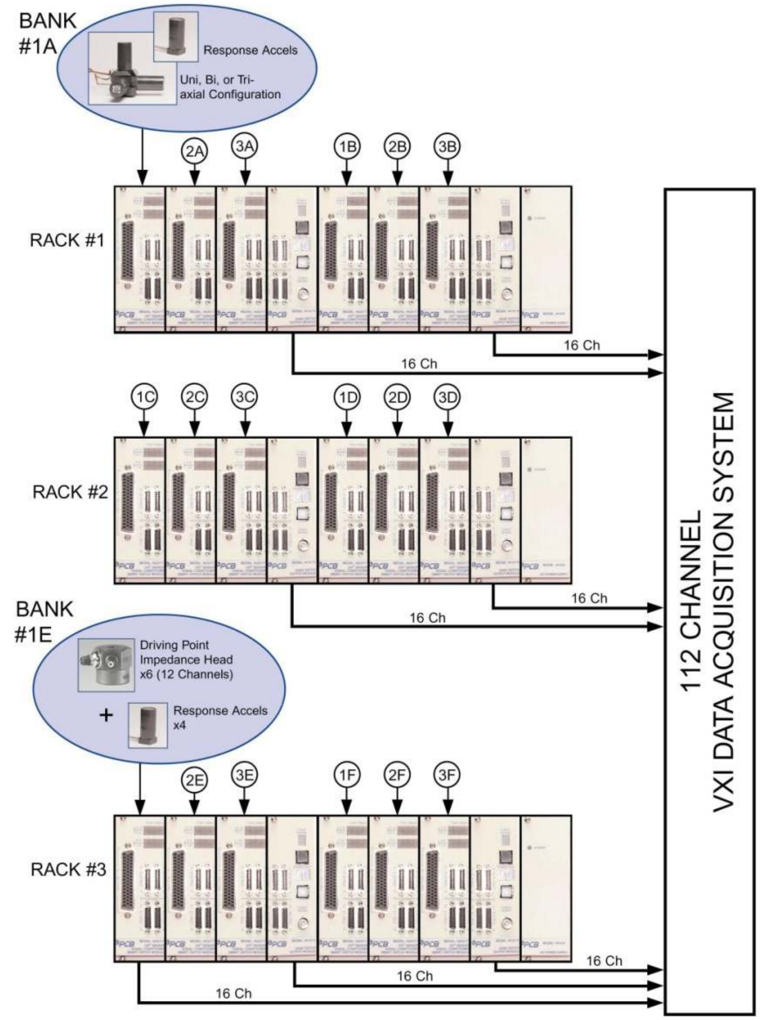
- Test methodology to achieve best data consistency
  - Simultaneous MIMO/SIMO testing
  - Automated bankswitching
  - Manual bankswitching
  - Roving accelerometers
  - Impact testing

Benefits of Bank-Switching

Simultaneous, 288 ch			
No. of Test Configurations	*PreSetup Time*	*Acquisition Time*	*Cost Estimate*
1	9 hrs	5 min	100%
2		5 min	
3		5 min	
4		5 min	
Total Time Allotted			9 hrs 20 min

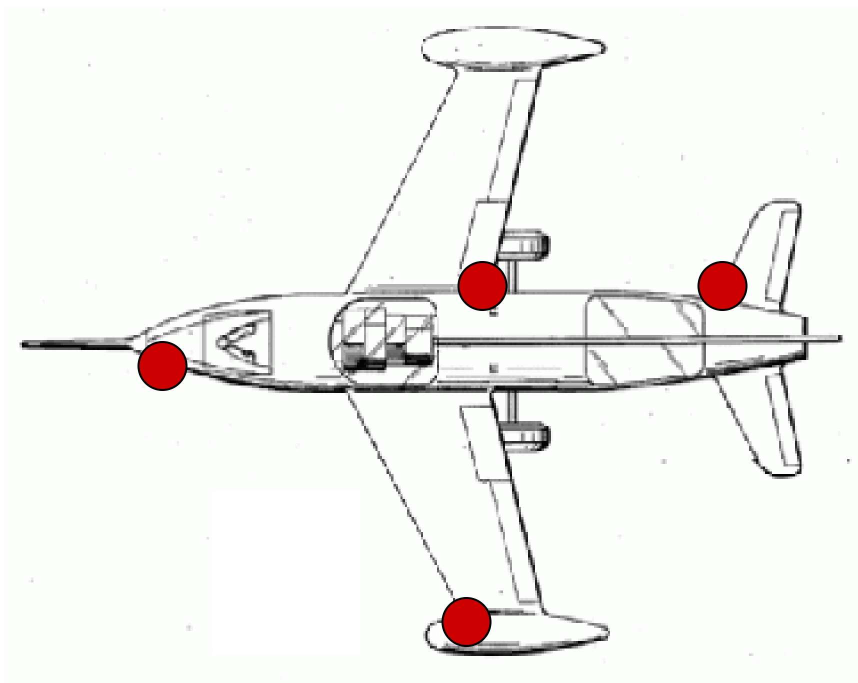
Roving, 112 ch			
No. of Test Configurations	*PreSetup Time*	*Acquisition Time*	*Cost Estimate*
1	3 hrs	6 hrs 17 min	40%
2		6 hrs 17 min	
3		6 hrs 17 min	
4		6 hrs 17 min	
Total Time Allotted			28 hrs 8 min

Bank-switch, 288 to 112 ch			
No. of Test Configurations	*PreSetup Time*	*Acquisition Time*	*Cost Estimate*
1	9 hrs	17 min	60%
2		17 min	
3		17 min	
4		17 min	
Total Time Allotted			10 hrs 8 min



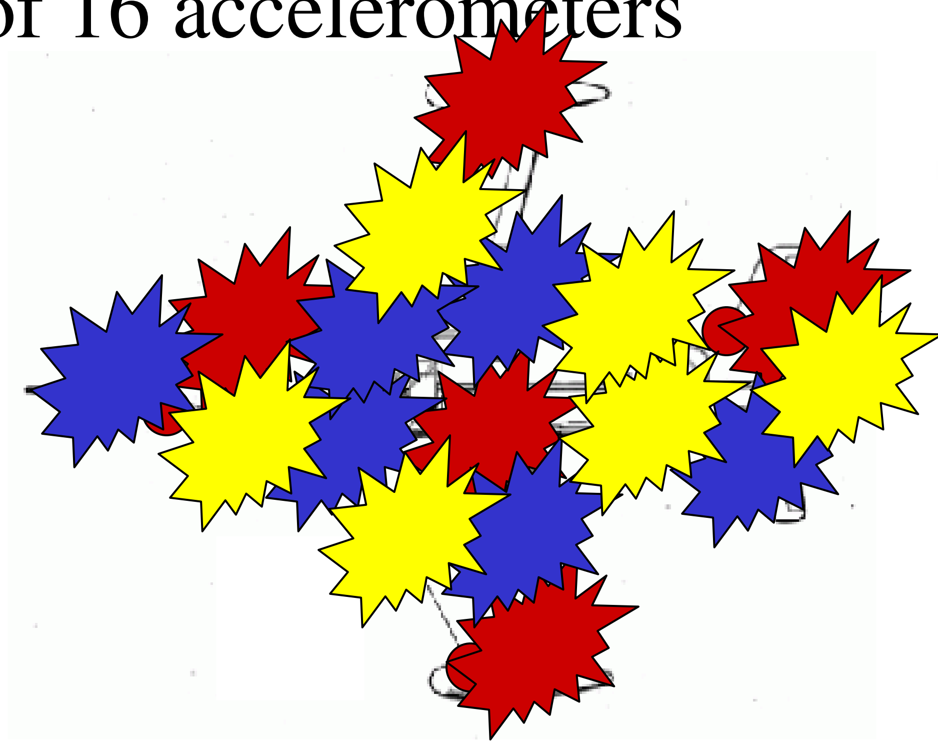
Bank-Switching Example

- Inputs: 2 vertical, 1 lateral, 1 skewed



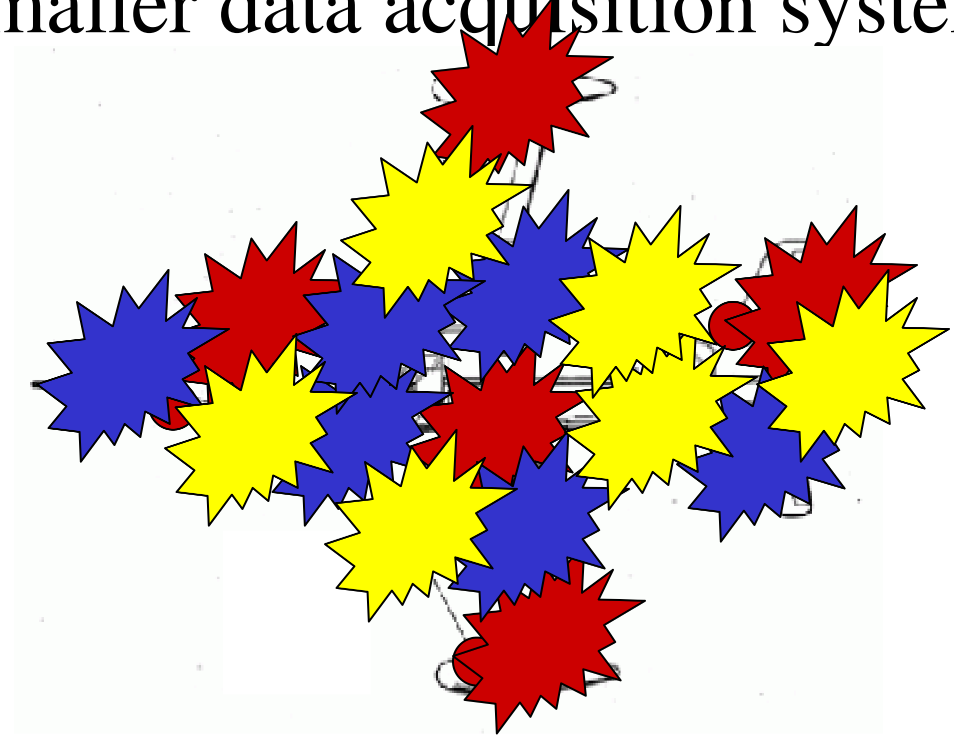
Bank-Switching Example

- Response points: 17 patch panels, each bank of 16 accelerometers



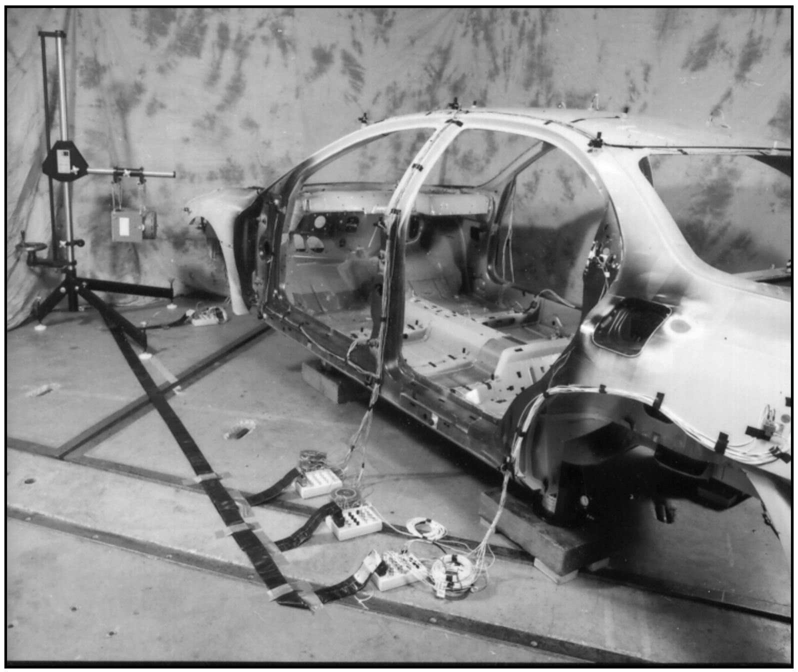
Bank-Switching Example

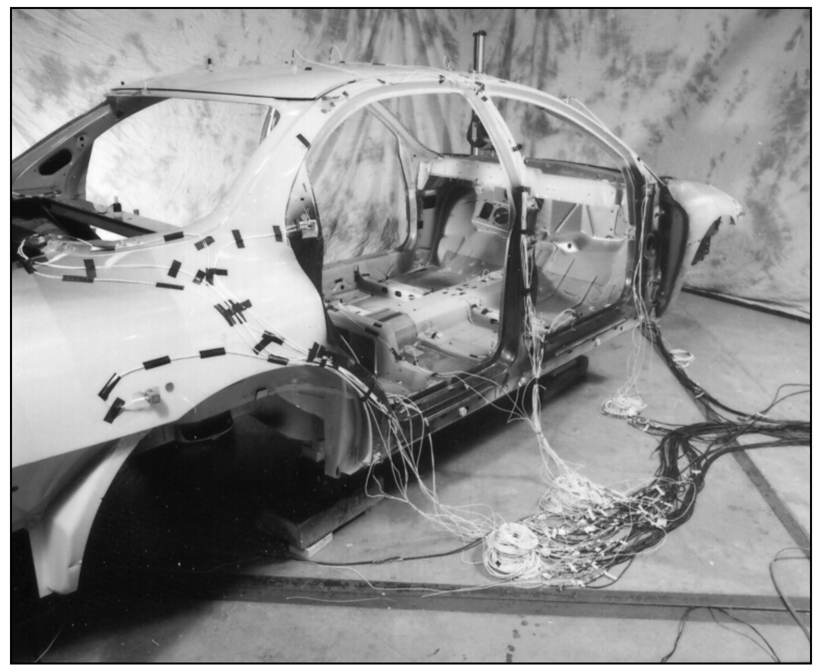
- Bank-switch patches of data (3 x 96 ch) into smaller data acquisition system



Modular Cabling / Patch Panel System for Clean Setup

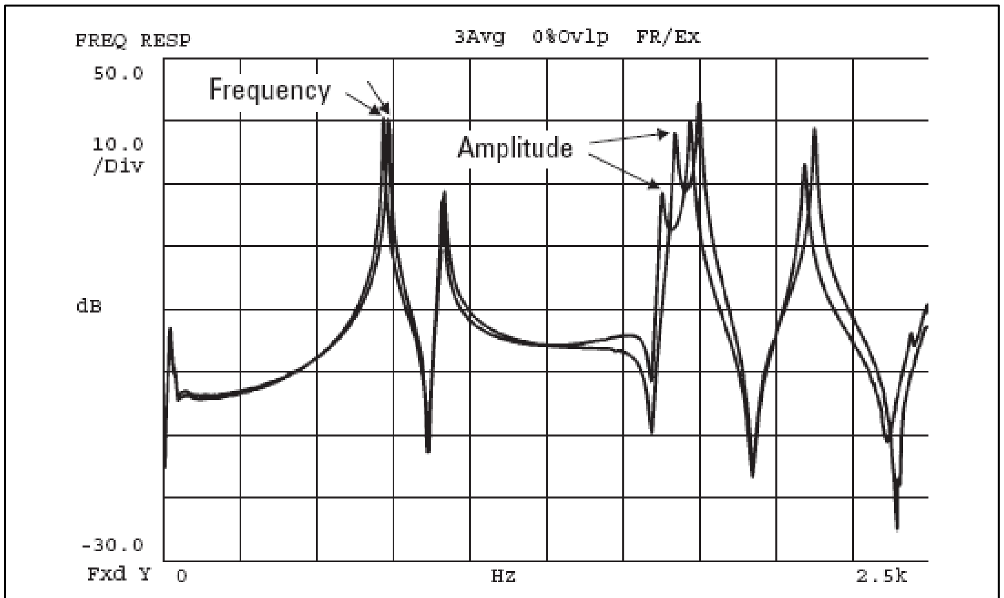
- Eases setup troubleshooting
- Eliminates messy “rat’s nest” of cables
- Economical multi-conductor cabling





Time Invariance Assumption

- Roving accelerometers results in inconsistent global resonant frequencies due to variable mass loading on test structure



Graphic from Agilent Application Note 243-3

Linearity Assumption

- Input and output characteristics remain proportional within measurement range
- Confirm using precisely controlled inputs from shaker(s) across a range force levels
- Impact testing technique poorly suited when dealing with nonlinear test structures

Electrodynamic Modal Shakers as Excitation Source for MIMO

- Allows best control of input forcing function to optimize frequency content and signal-to-noise ratio
- Through-hole armature greatly simplifies setup attachment to test structure

Through-Hole Armature Eases Setup

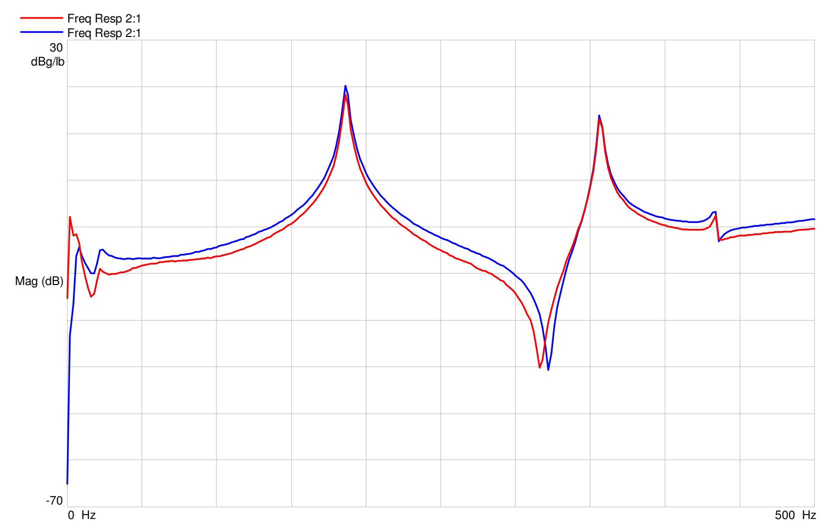
- Traditional shakers with tapped armature connection leave little tolerance since setup has tapped connection at both ends

Reciprocity Assumption

- Maxwell's Theory of Reciprocity states that FRF matrix is symmetric
- FRF between input A and output B is the same as output A and input B
- Confirm using multiple shaker locations and impedance heads for driving point measurement

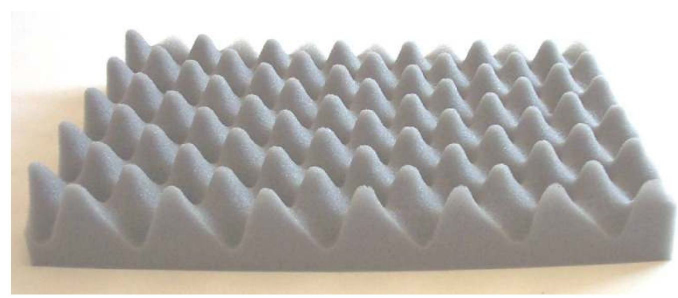
Impedance Heads for Verifying Reciprocity Assumption

Accelerometer built into preload stud of force transducer



Other Pre-Test Considerations

- Free Boundary Conditions
  - Shock Cord
  - Foam Rubber
  - Air Suspension



Other Pre-Test Considerations

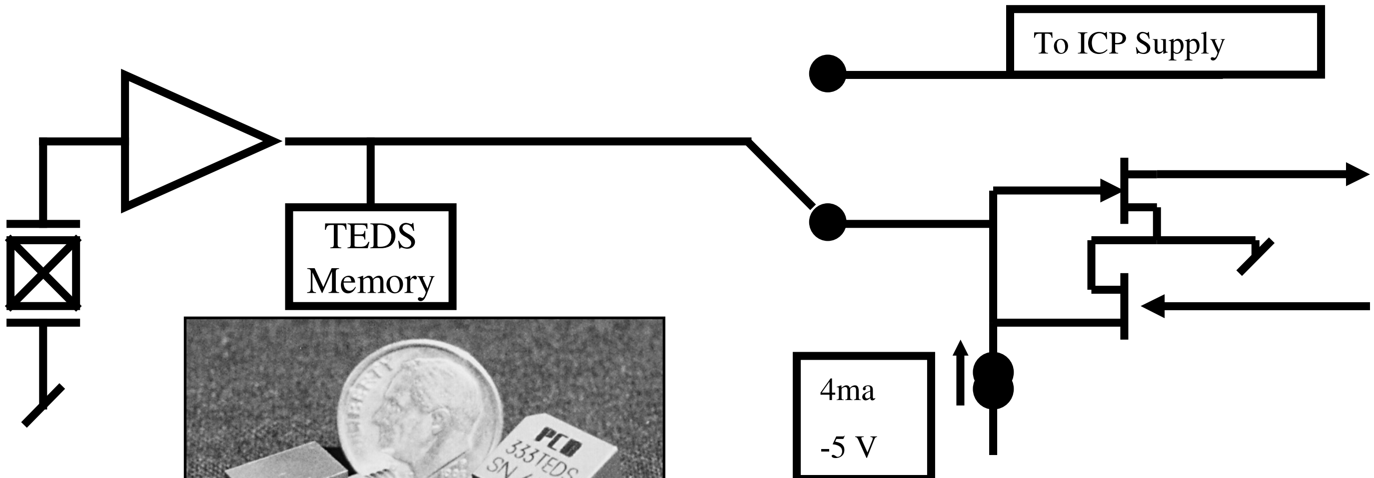
- Fixed Boundary Conditions
- Realistic Boundary Conditions
- Match Impedance(s) at Boundaries
- Mass Loaded Boundary Conditions

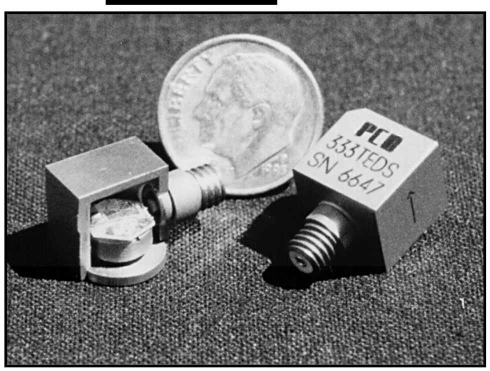
Other Pre-Test Considerations

- Transducer selection
  - Single axis vs triaxial package
  - Sensitivity, measurement range & resolution
  - Frequency range & mass

Transducer Electronic Data Sheet (TEDS, IEEE 1451.4)

- Identifies transducer (type, serial number, location)
- Stores calibration data
- Automates book keeping, reducing errors





Uses reverse bias scheme to access digital memory

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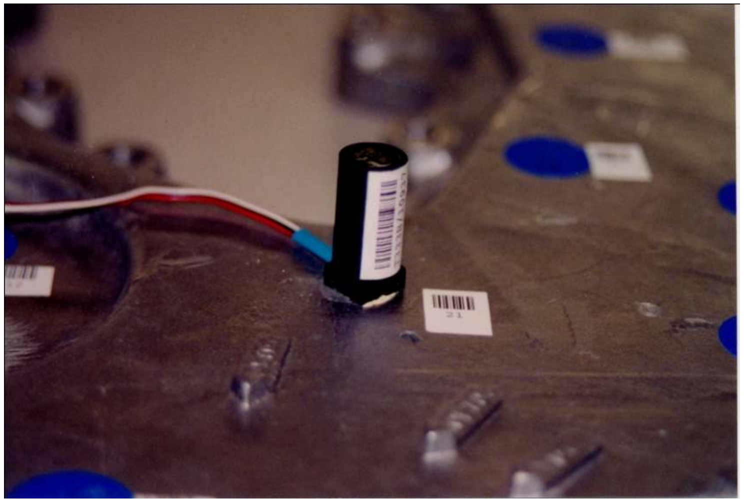
Other Transducer Setup Considerations

- Use PDA scanner with bar-coded TEDS transducers to ease bookkeeping



Final Channel Setup Definition

- Combine Data From Geometry, PDA, and TEDS
- Complete Test Set-up Information Defined in Universal Files
  - Virtual Channel Table (1807)
  - Channel Table (1808)
  - Geometry (15)

Parameter	*Stored In TEDS*	*Stored In PDA*	*Stored On Host (PC)*
Calibration	***X***		
Model / Serial No.	***X***	***X***	
Direction		***X***	
Node No.		***X***	***X***
Meas. Ch.			***X***
Geometry			***X***

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Thank you for your time.