EXCITATION DEVICES FOR MODAL ANALYSIS
WHY ARE THEY SO IMPORTANT?

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MODAL ANALYSIS

The purpose of Modal Analysis is to characterize the vibration behaviour of a structure

The following equation is used

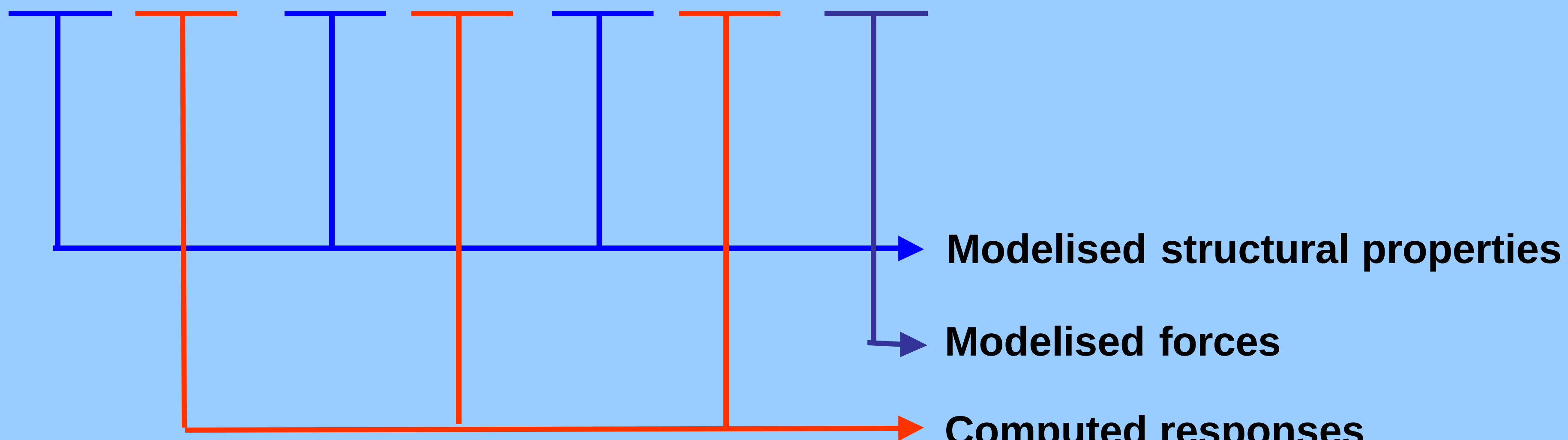
$$[M]\cdot\{\ddot{x}\}+[C]\cdot\{\dot{x}\}+[K]\cdot\{x\}=\{F\}$$

Computation of the modal parameters:

- **Resonance frequency**
- **Damping factor**
- **Mode shape**
- **Generalized mass**
- **Generalized stiffness**

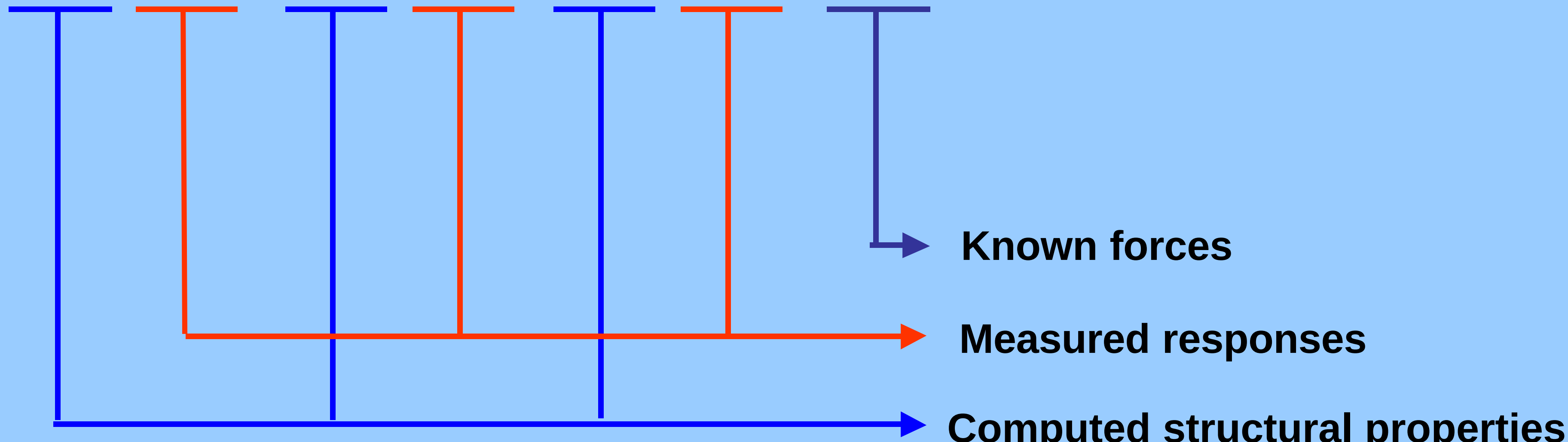
Finite Element Analysis

$$[M]\cdot\{\ddot{x}\}+[C]\cdot\{\dot{x}\}+[K]\cdot\{x\}=\{F\}$$

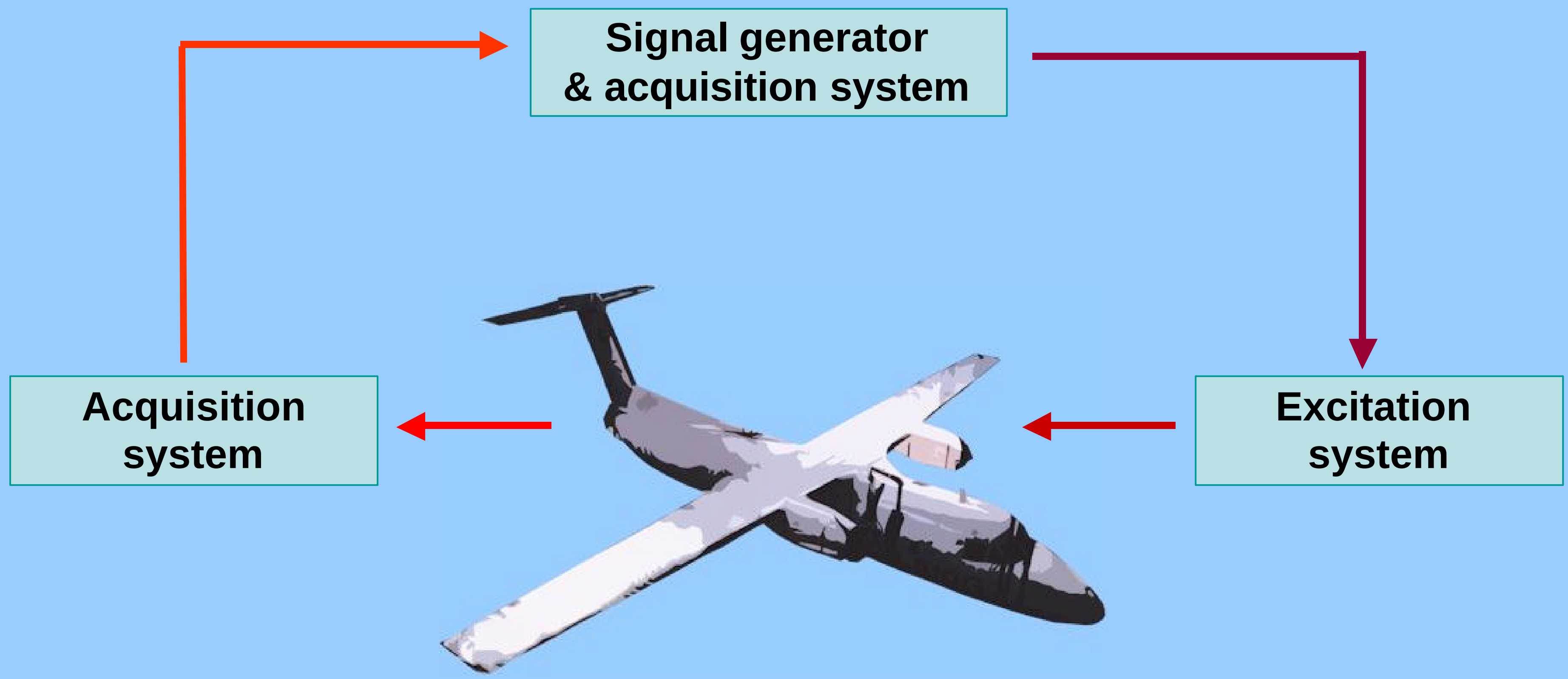


Experimental Modal Analysis

$$[M]\cdot\{\ddot{x}\}+[C]\cdot\{\dot{x}\}+[K]\cdot\{x\}=\{F\}$$



Experimental Modal Analysis



Responses Measurements

Responses are normally measured using accelerometers

- **Low weight**
- **High sensitivity**

Excitation forces

The excitation forces must:

- **Provide sufficient energy to properly excite the structure**
- **The characteristics of the forces must be available without errors**
- **Not disturb the structure**

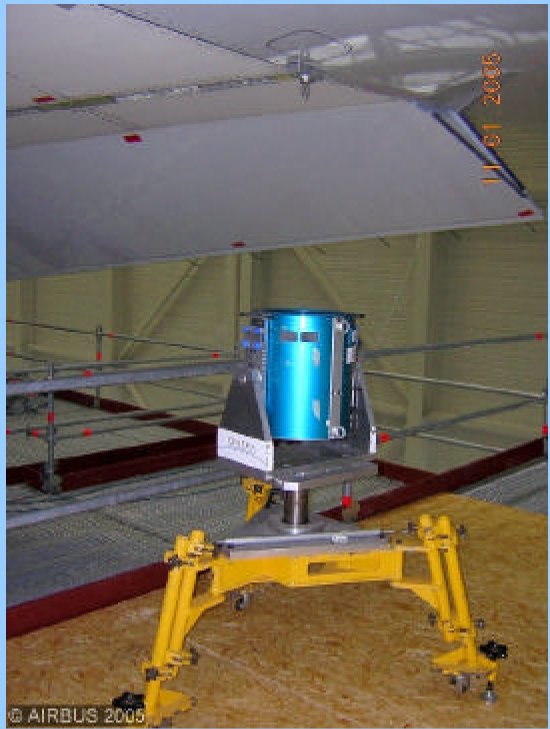
Excitation forces

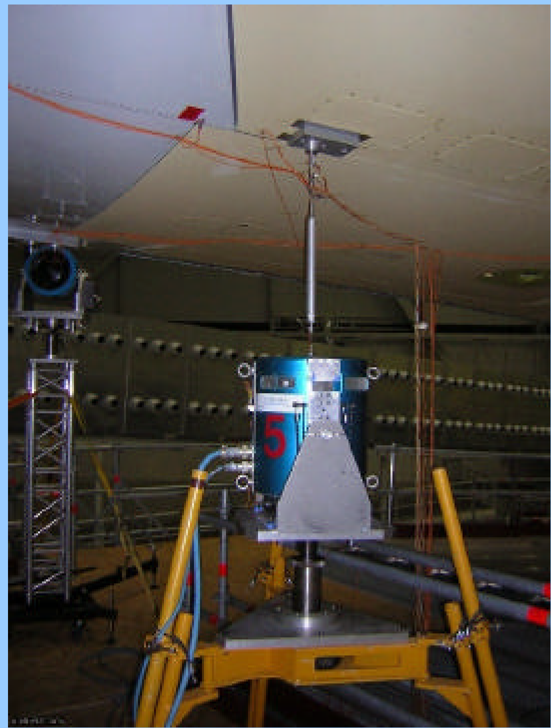
Different types of excitations are available.

Commonly used :

- **Use of impact hammers**
  - **Single point excitation**
  - **No force control**
- **Use of electrodynamics shakers with:**
  - **Current controlled power amplifiers**
  - **Voltage controlled power amplifiers**

Electrodynamics Shakers





EX 520 C50 modal shakers used during the A380 GVT performed by the ONERA-DLR joint team (project leader ONERA)

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Question?

How to be sure that my excitation is correct?

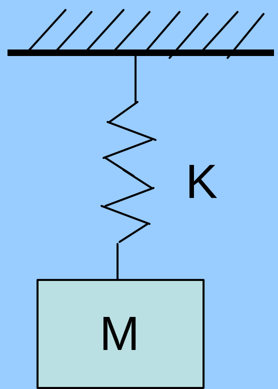
Four simple tests are proposed in order to verify the quality of an excitation

Test Setup

Very simple test setup that can be implemented in any laboratory

Moving mass M suspended with a spring of stiffness K

$$K = 2350 \quad N/m \qquad M = 12.5 \quad Kg \qquad F = \sqrt{\frac{K}{M}} = 2.18 \quad Hz$$

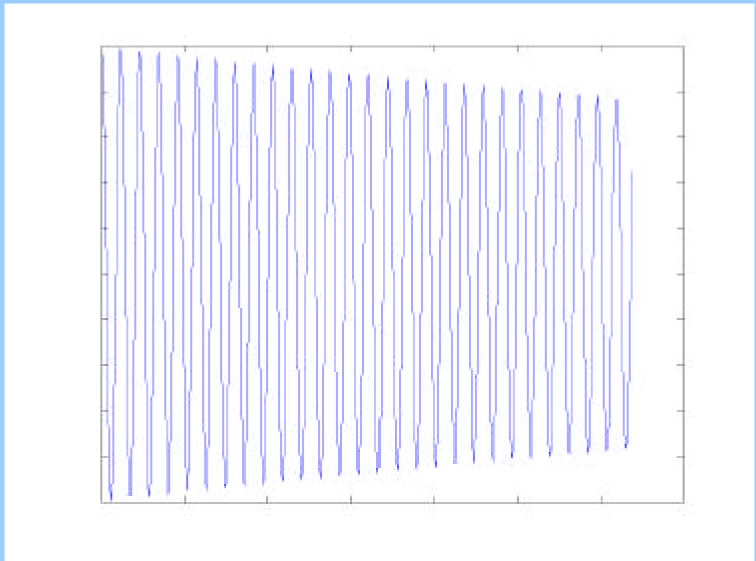


One accelerometer measures the structure response

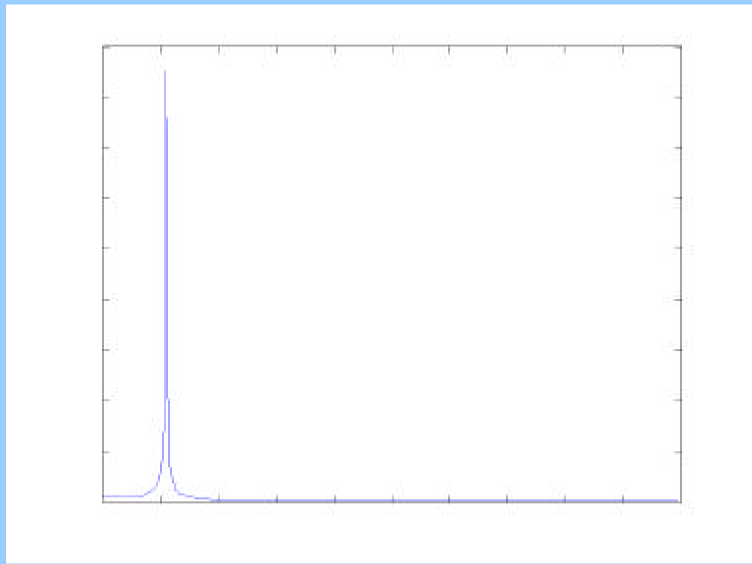
1st Test: Free Oscillation

The movement of the structure is measured under free oscillation condition

$$x(t) = x_0 \cdot e^{-\alpha \cdot \omega_0 \cdot t} \cdot \cos\left(\omega_0 \cdot \sqrt{1-\alpha^2} \cdot t\right)$$



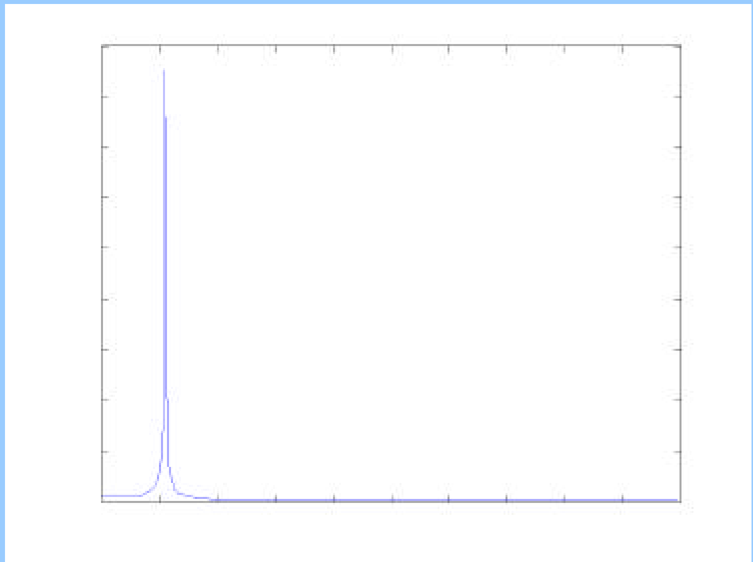
Temporal response



Power spectrum

1st Test: Free Oscillation

The movement of the structure is measured under free oscillation condition



Measured resonance frequency:

F = 2.18 Hz

Measured damping factor:

a = 0.0015

2^{nd} Test: Free Oscillations With Shaker

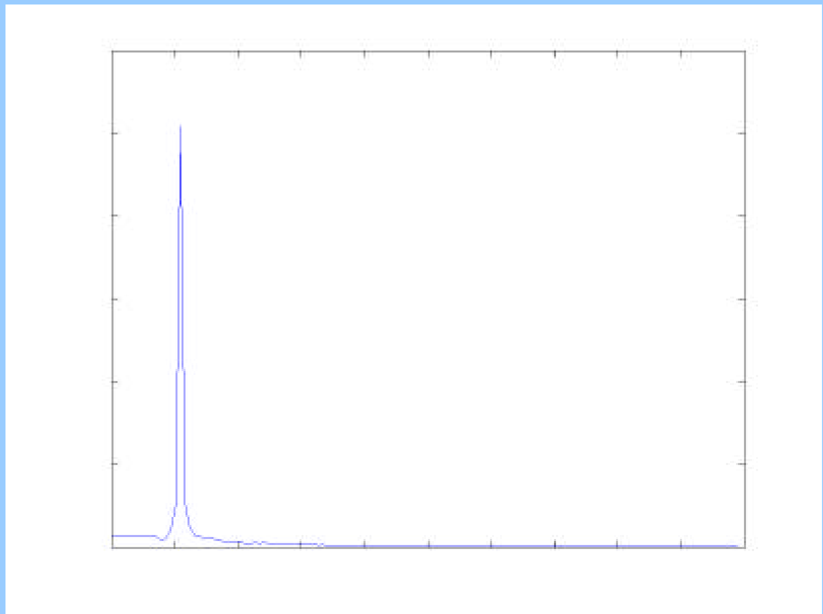
A shaker is connected to the moving mass. The power cable is not connected

The Resonance frequency will be now:

$$F = \sqrt{\frac{K}{M+m}} \approx 2.16 \quad Hz$$

2nd Test: Free Oscillations With Shaker

The movement of the structure is measured under free oscillation condition



Measured resonance frequency:

F = 2.16 Hz

Measured damping factor:

a = 0.015

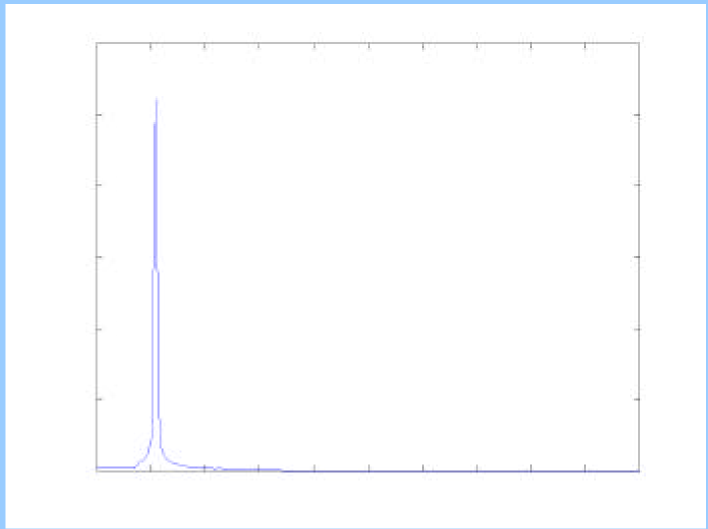
NO SHAKER INFLUENCE

3rd Test: Free Oscillation With Shaker Powered On

The power amplifier is connected to the shaker, and powered on.
No excitation signal

3rd Test: Free Oscillation With Shaker Powered On

The movement of the structure is measured under free oscillation condition



Measured resonance frequency:

F = 2.16 Hz

Measured damping factor:

a = 0.0015

NO AMPLIFIER INFLUENCE

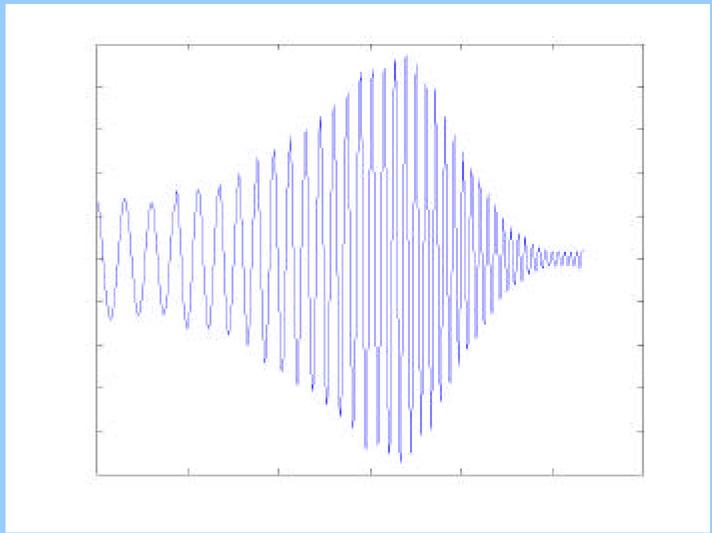
4^{th} Test: Sine Sweep

Sine sweep around the resonance frequency

Measured values:

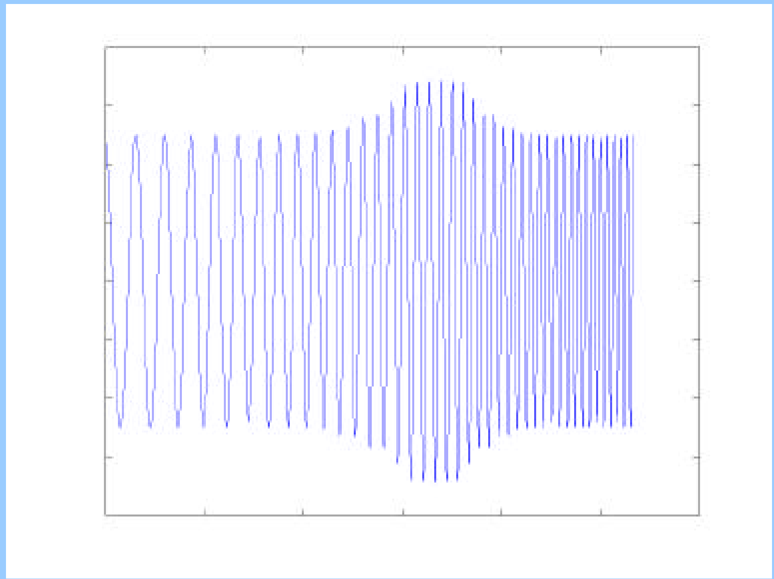
- **Acceleration**
- **Current through the coil**
- **Voltage across the coil**

4th Test: Sine Sweep

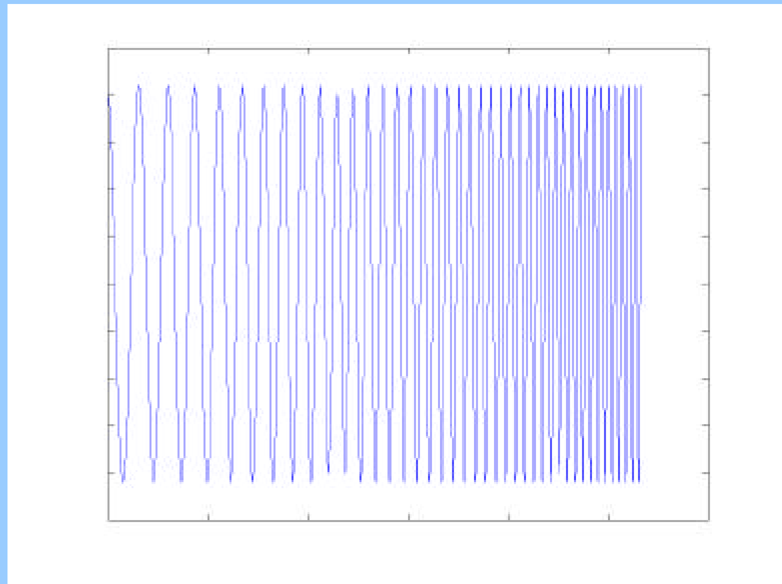


Temporal response

4th Test: Sine Sweep



Voltage on the coil

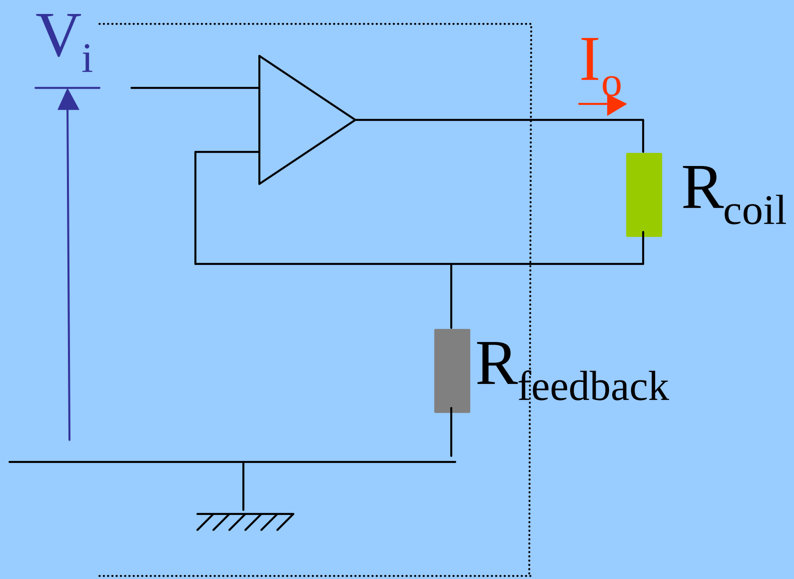


Current through the coil

With a current controlled power amplifier:

Constant current Þ Constant force

Current Controlled Power Amplifiers



Defining:

Z: The output impedance of the amplifier

Due to the amplifier's design:

The ratio between the output impedance and the coil impedance is high

- ✓ **The output current is directly proportional to the input voltage, independent of the movement of the coil, even at resonance**
- ✓ **No need for force transducer**

CONCLUSION

- **Excitation is critical during Modal Analysis**

- **Current controlled power amplifiers do not disturb the excitation signals Þ No control feedback required**

- **New shaker design:**
  - **Magnesium moving assembly Þ Low added mass**
  - **No spiders Þ No added stiffness**

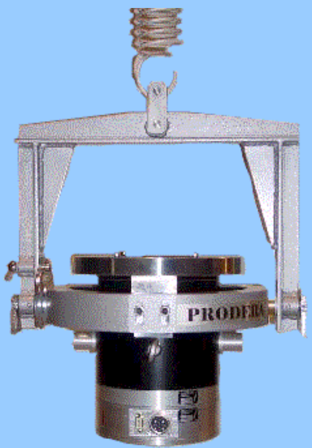
PRODERA Modal Shakers

SHAKER		NOMINAL FORCE (N/lbf)	FORCE FACTOR (N/A / lff/A)	STROKE (mm / inch)	MOVING MASS (gr / lbs)
EX 6/3.2	NO SPIDERS	3-6 / 0.67-1.34	1.5-2 / 0.33-0.44	± 1.5-± 3 / ± 0.05 ± 0.11	8.5-13.5 / 0.01-0.03
EX 8/4.2	NO SPIDERS	4-8 / 0.89-1.79	2-2.5 / 0.44-0.56	± 1.5-± 3 / ± 0.05 ± 0.11	8.5-13.5 / 0.01-0.03
EX 12		10 / 2.24	5 / 1.12	± 5 / ± 0.19	30 / 0.06
EX 24		20 / 4.49	5 / 1.12	± 5 / ± 0.19	61 / 0.13
EX 20	NO SPIDERS	20 / 4.29	5 / 1.12	± 5 / ± 0.19	35 / 0.07
EX 58		50 / 11.24	6.25 / 1.46	± 6 / ± 0.23	110 / 0.24
EX 220 / EX 220 SC		200 / 44.96	10 / 2.24	± 10 / ± 0.39	195 / 0.42
EX 320 C 50	NO SPIDERS	300 / 67.44	15 / 3.37	± 25 / ± 0.98	N/A
EX 520 C 50	NO SPIDERS	550 / 123.64	27.5 / 6.18	± 25 / ± 0.98	680 / 1.49
EX 540 A		500 / 112.4	13 / 2.92	± 12.5 / ± 0.49	950 / 2.09
EX 1060 A		1,200 / 224.8	20 / 4.49	± 12.5 / ± 0.49	1,000 / 2.20
EX 2060A		2,040 / 449.6	34 / 7.64	± 12.5 / ± 0.49	1,000 / 2.20
EX 5080 A		5,000 / 1124	63 / 14.16	± 20 / ± 0.78	5,300 / 11.68

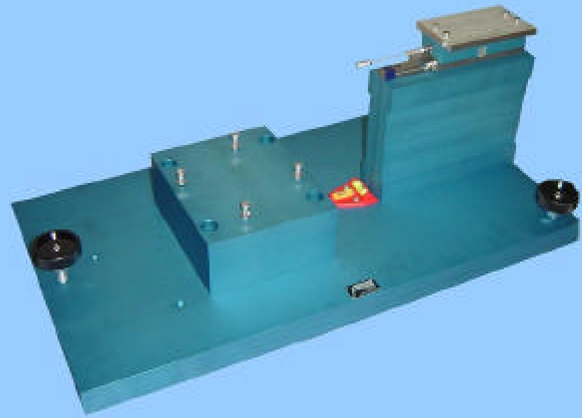
PRODERA Power Amplifiers

AMPLIFIER	CONTINUOUS RMS OUTPUT (W)	MAX OUTPUT CURRENT (A)	MAX OUTPUT VOLTAGE (V)	INPUT VOLTAGE (V)
A 732	30	± 2	± 30	± 5
	60	± 4	± 30	± 5
A 735	60	± 4	± 30	± 5
	120	± 8	± 30	± 5
A 648 / A 648 S	400	± 20	± 40	± 5
A 649	800	± 40	± 40	± 5
A 649 HV	800	± 20	± 80	± 5
A 651 S1	1,200	± 60	± 40	± 5
A 651 S2	2,400	± 60	± 80	± 5
A 709	4,000	± 80	± 100	± 5

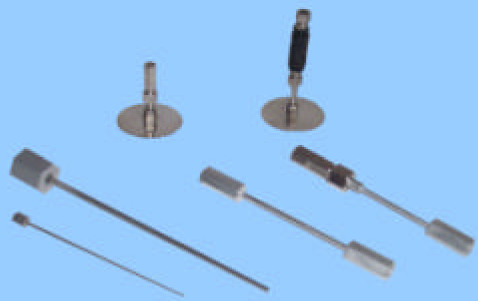
PRODERA Accessories



Suspension systems



Calibration equipment



Mechanical links

Questions please ….

You are welcome to visit our booth:

PRODERA Hall 2 Upper
Booth No 2U/C60