

# EXCITATION DEVICES FOR MODAL ANALYSIS WHY ARE THEY SO IMPORTANT?

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**Open Technology Forum**  
Thursday, April 7<sup>th</sup> 2005  
14 H 00 – 14 H 20



# MODAL ANALYSIS

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

The following equation is used

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

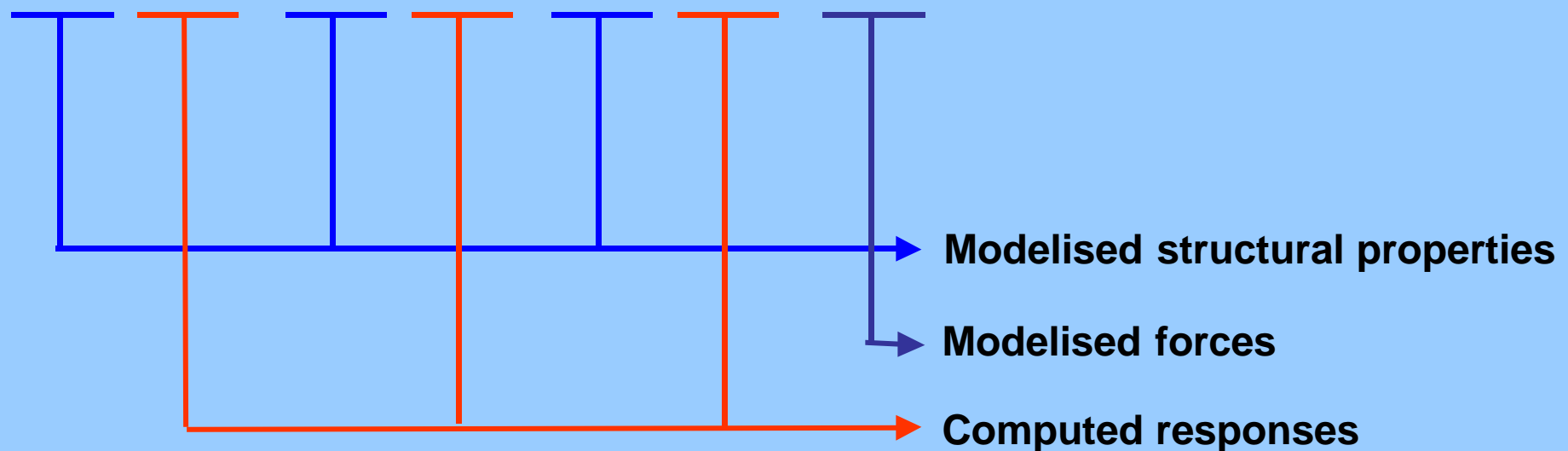
Computation of the modal parameters:

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



# Finite Element Analysis

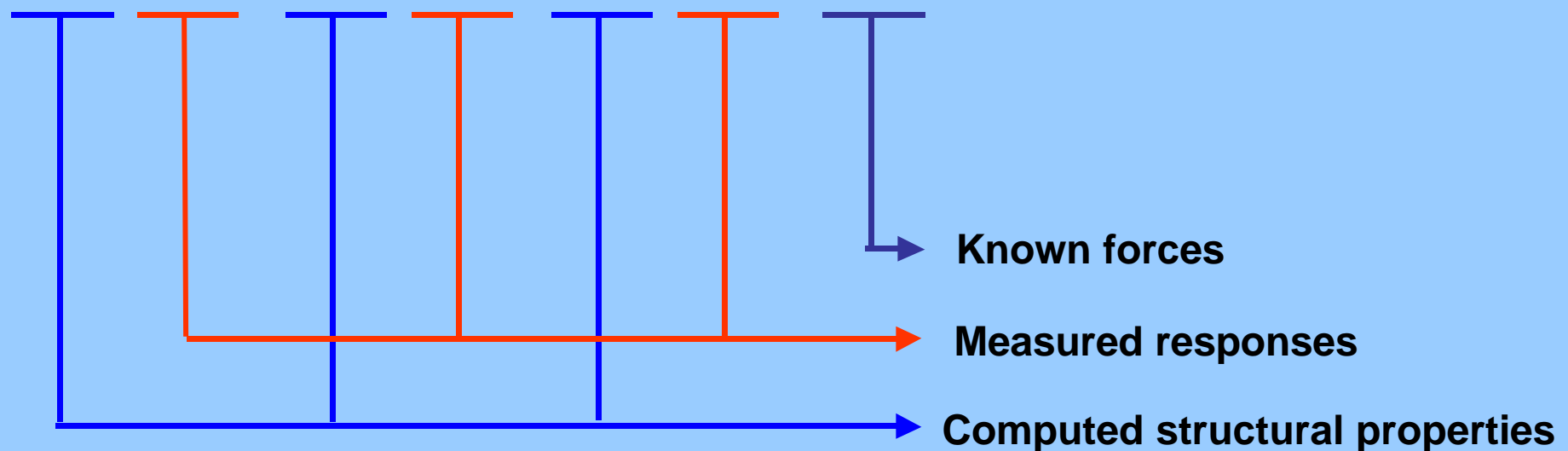
$$[M] \cdot \{\ddot{x}\} + [C] \cdot \{\dot{x}\} + [K] \cdot \{x\} = \{F\}$$





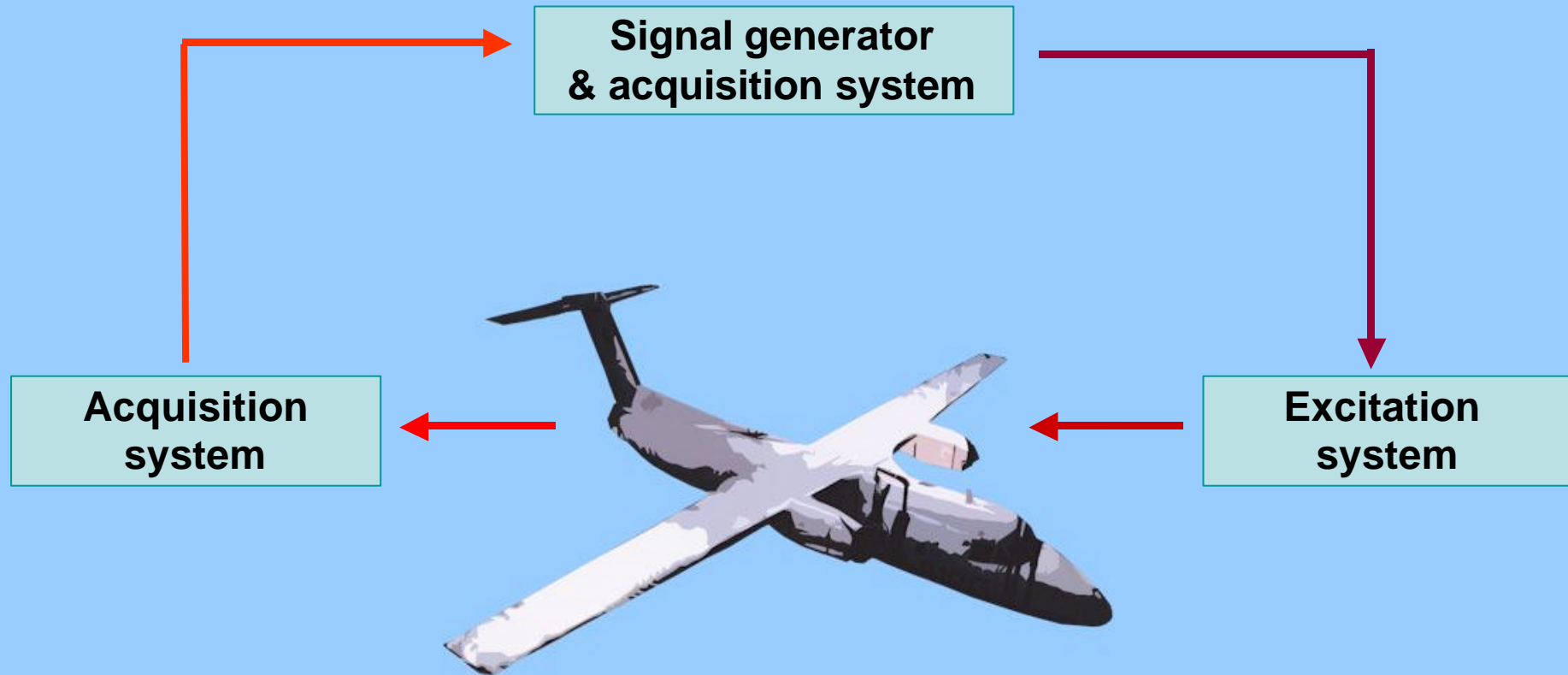
# Experimental Modal Analysis

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





# 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

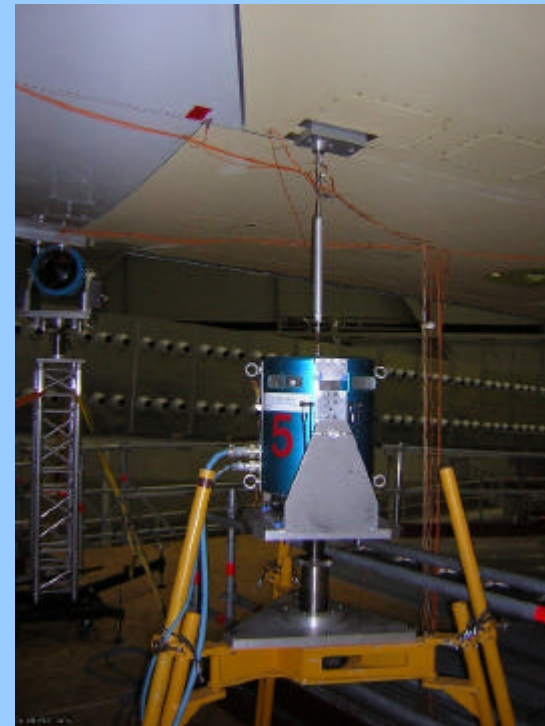
Different types of excitations are available.

Commonly used :

- Use of impact hammers
  - Single point excitation
  - No force control
- Use of electrodynamic 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)  
Pictures copyright AIRBUS S.A.S.**

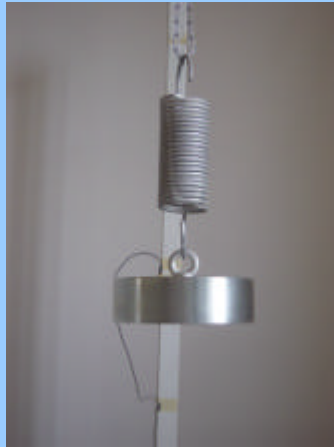


# Question?

**How to be sure that my excitation is correct?**

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

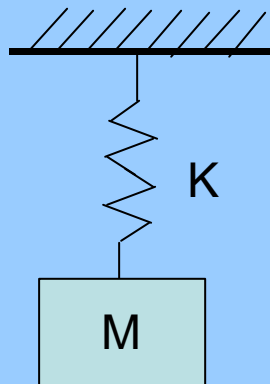
# Test Setup



Very simple test setup that can be implemented in any laboratory

Moving mass  $M$  suspended with a spring of stiffness  $K$

$$\left. \begin{array}{l} K = 2350 \text{ N/m} \\ M = 12.5 \text{ Kg} \end{array} \right| F = \sqrt{\frac{K}{M}} = 2.18 \text{ Hz}$$



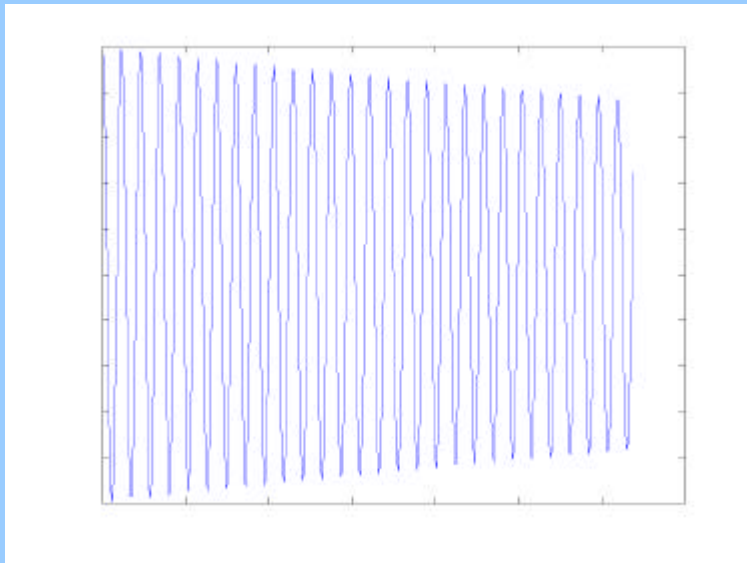
One accelerometer measures the structure response



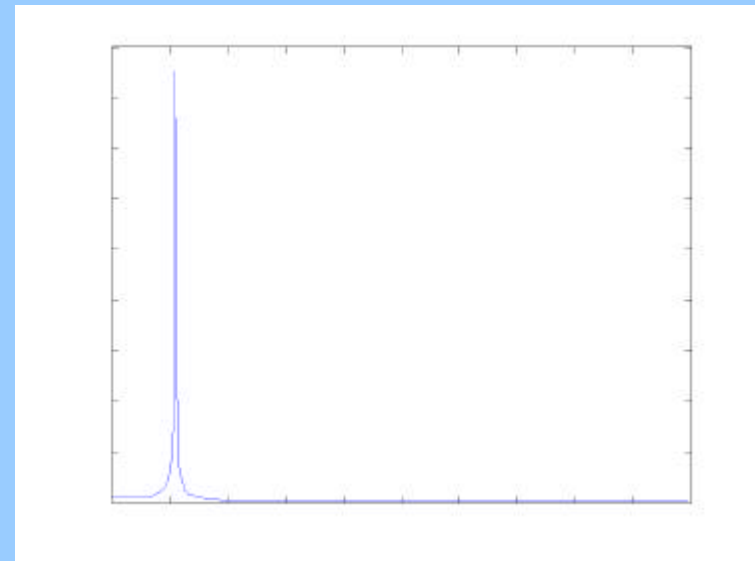
# 1<sup>st</sup> Test: Free Oscillation

The movement of the structure is measured under free oscillation condition

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



Temporal response

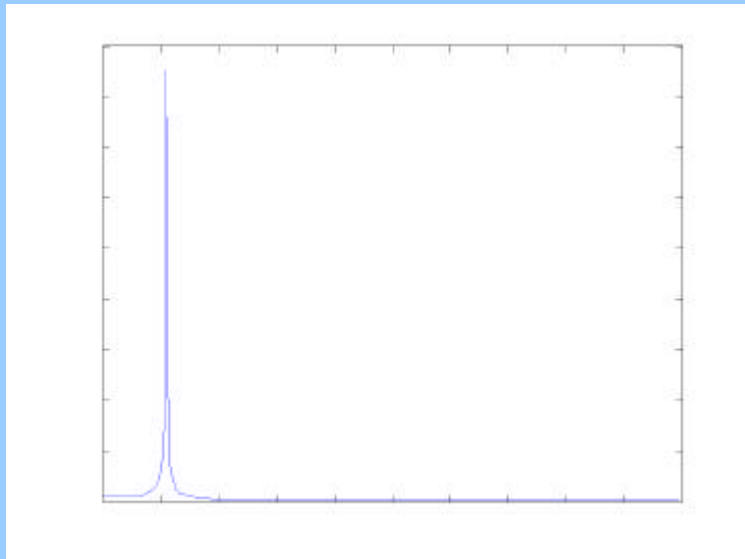


Power spectrum



# 1<sup>st</sup> Test: Free Oscillation

The movement of the structure is measured under free oscillation condition



Measured resonance frequency:

$$F = 2.18 \text{ Hz}$$

Measured damping factor:

$$a = 0.0015$$



# 2<sup>nd</sup> Test: Free Oscillations With Shaker

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

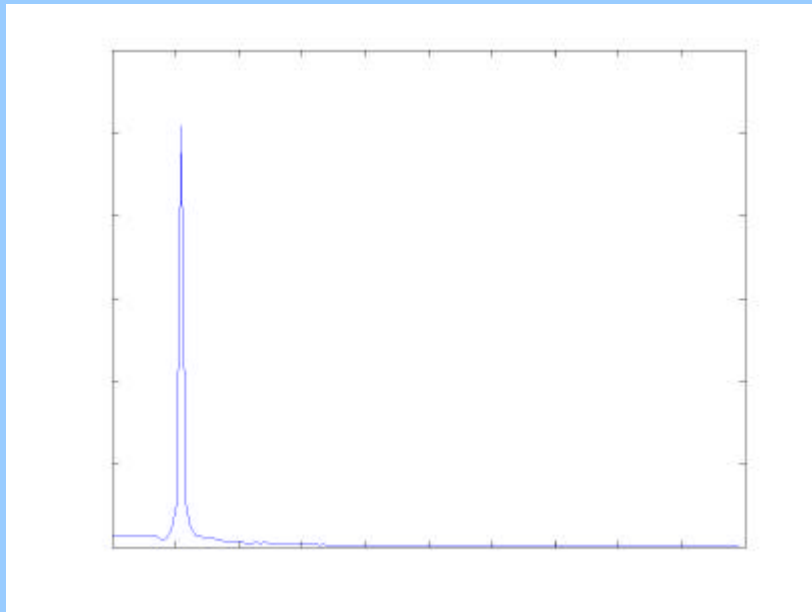
The Resonance frequency will be now:

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



# 2<sup>nd</sup> Test: Free Oscillations With Shaker

The movement of the structure is measured under free oscillation condition



Measured resonance frequency:

$$F = 2.16 \text{ Hz}$$

Measured damping factor:

$$a = 0.015$$

**NO SHAKER INFLUENCE**



# 3<sup>rd</sup> Test: Free Oscillation With Shaker Powered On

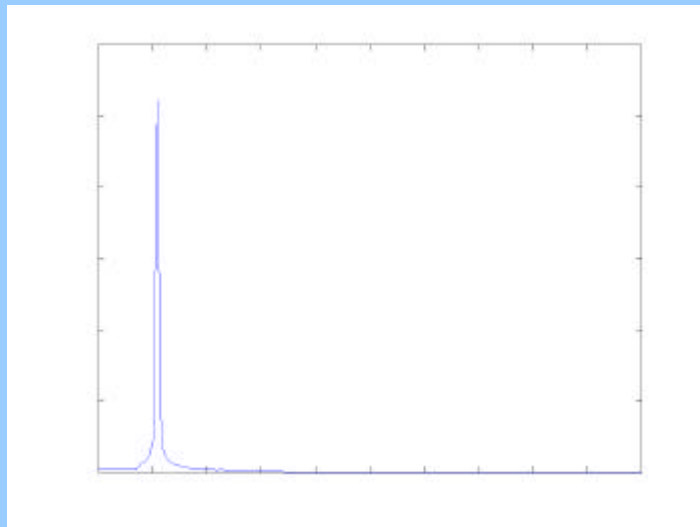
The power amplifier is connected to the shaker, and powered on.  
**No excitation signal**





# 3<sup>rd</sup> Test: Free Oscillation With Shaker Powered On

The movement of the structure is measured under free oscillation condition



Measured resonance frequency:

$$F = 2.16 \text{ Hz}$$

Measured damping factor:

$$a = 0.0015$$

**NO AMPLIFIER INFLUENCE**



# 4<sup>th</sup> Test: Sine Sweep

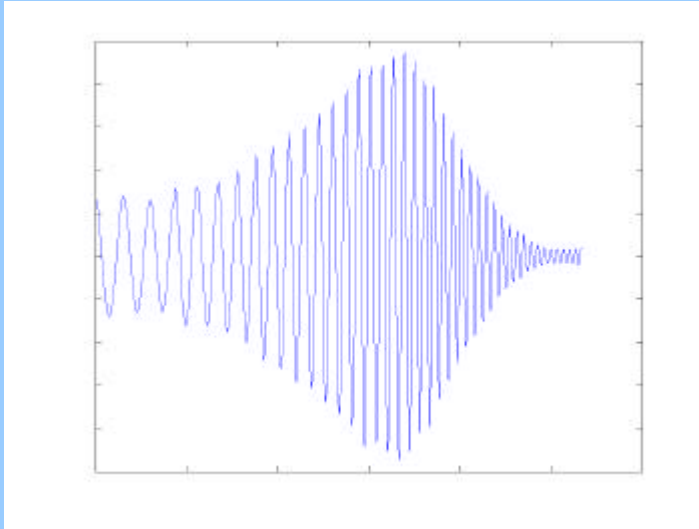
**Sine sweep around the resonance frequency**

**Measured values:**

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



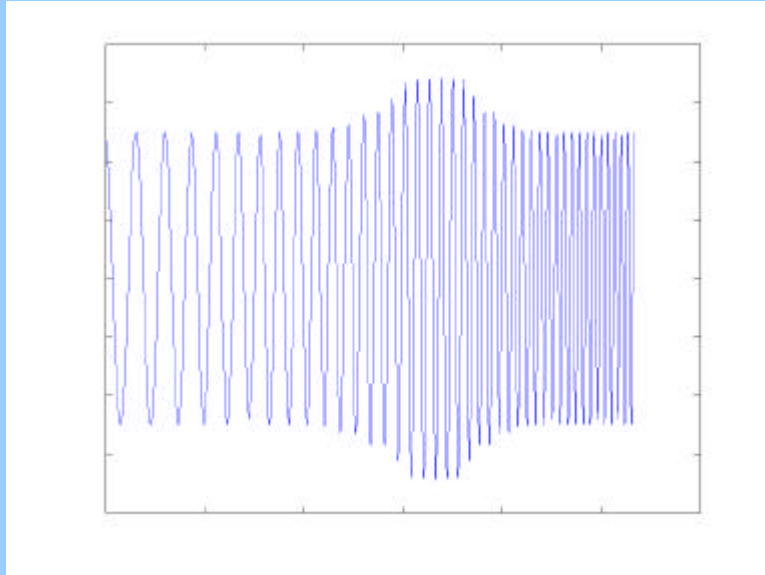
# 4<sup>th</sup> Test: Sine Sweep



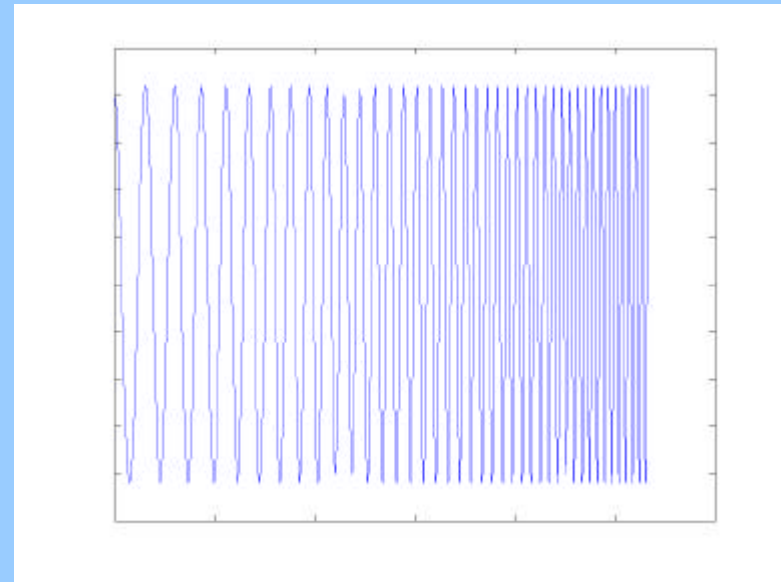
**Temporal response**



## 4<sup>th</sup> Test: Sine Sweep



Voltage on the coil



Current through the coil

With a current controlled power amplifier:

Constant current  $\Rightarrow$  Constant force



# Current Controlled Power Amplifiers

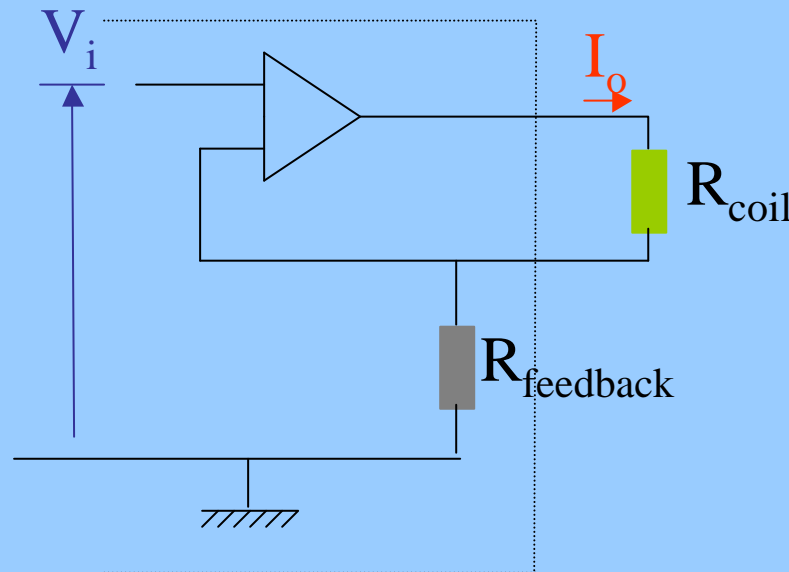
**Defining:**

**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** ➤ **No control feedback required**
- **New shaker design:**
  - **Magnesium moving assembly** ➤ **Low added mass**
  - **No spiders** ➤ **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 <b>NO SPIDERS</b>	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 <b>NO SPIDERS</b>	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 <b>NO SPIDERS</b>	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 <b>NO SPIDERS</b>	300 / 67.44	15 / 3.37	± 25 / ± 0.98	N/A
EX 520 C 50 <b>NO SPIDERS</b>	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

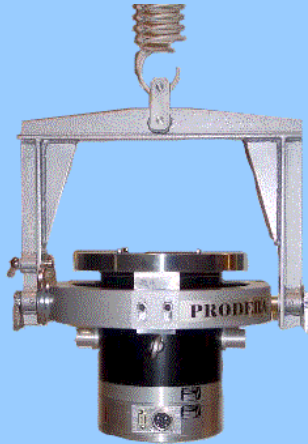


# PRODERA Power Amplifiers

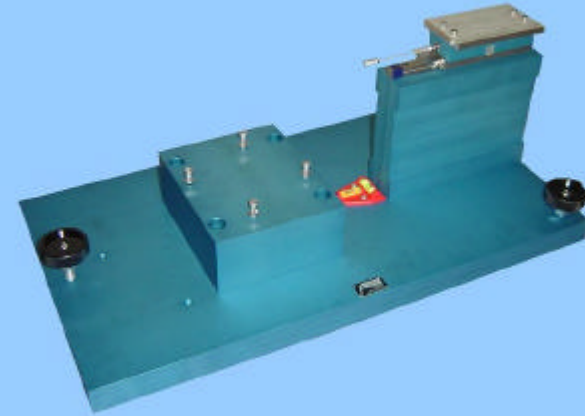
AMPLIFIER	CONTINUOUS RMS OUTPUT (W)	MAX OUTPUT CURRENT (A)	MAX OUTPUT VOLTAGE (V)	INPUT VOLTAGE (V)
A 732	30	± 2	± 30	± 5
	60	± 4	± 30	± 5
A 735	60	± 4	± 30	± 5
	120	± 8	± 30	± 5
A 648 / A 648 S	400	± 20	± 40	± 5
A 649	800	± 40	± 40	± 5
A 649 HV	800	± 20	± 80	± 5
A 651 S1	1,200	± 60	± 40	± 5
A 651 S2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



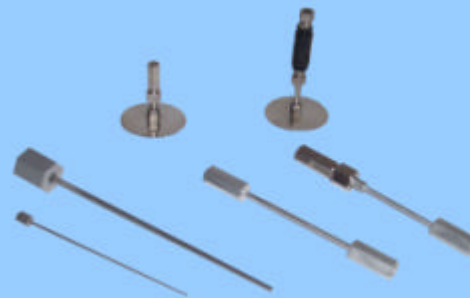
# PRODERA Accessories



**Suspension systems**



**Calibration  
equipment**



**Mechanical links**



**Questions please ....**

**You are welcome to visit our booth:**

**PRODERA Hall 2 Upper  
Booth No 2U/C60**