What’s up with Bump Testing?

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What is a bump test?

- A bump test is the measured response of an impact to an object.
- The force of the impact is not controlled or measured.
- The response of the object is not controlled, BUT IS MEASURED.
- A single channel response measurement.
Why do a bump test?

- To excite and measure the natural frequency(s) of an object.
  - To identify a resonance
  - To understand a change in mass
  - To understand a change in stiffness
  - To understand a change in damping
How does it work?

- Fundamental 1
- 2nd Harmonic 1
- 3rd Harmonic 1
- 4th Harmonic 1
- 5th Harmonic 1
- 10th Harmonic 1
- 20th Harmonic 1
- 50th Harmonic 1
- 100th Harmonic 1
- Bump 1
Sine Waves?

-0.1 V

0 s 1.999023 s

Real

Fundamental 1

0.1 V

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Bumps from Sine Waves?

Time Record 1

0 s 1.999023 s

8 V

-8 V

Real

0.1 V

-0.1 V

Real

0 s 1.999023 s
Bump Testing

100\textsuperscript{th} Harmonic

- Fundamental 1
- 2nd Harmonic 1
- 3rd Harmonic 1
- 4th Harmonic 1
- 5th Harmonic 1
- 10th Harmonic 1
- 20th Harmonic 1
- 50th Harmonic 1
- 100th Harmonic 1

Bump 1

8 V

Real

-8 V

0 s 1.999023 s
Bump Testing

50th Harmonic

- Fundamental 1
- 2nd Harmonic 1
- 3rd Harmonic 1
- 4th Harmonic 1
- 5th Harmonic 1
- 10th Harmonic 1
- 20th Harmonic 1
- 50th Harmonic 1
- Bump 1

Real

4 V

0 s 1.999023 s
20th Harmonic
Bump Testing

10th Harmonic

- Fundamental 1
- 2nd Harmonic 1
- 3rd Harmonic 1
- 4th Harmonic 1
- 5th Harmonic 1
- 10th Harmonic 1
- Bump 1
- Empty
- Empty
- Empty

Real

V

0 s 1.999023 s
Bump Testing

5th Harmonic

- Fundamental 1
- 2nd Harmonic 1
- 3rd Harmonic 1
- 4th Harmonic 1
- 5th Harmonic 1
- Bump 1
- Empty
- Empty
- Empty

0.5 V

Real

0 s 1.999023 s
Bump Testing

4th Harmonic

- Fundamental 1
- 2nd Harmonic 1
- 3rd Harmonic 1
- 4th Harmonic 1
- Bump 1
- Empty
- Empty
- Empty
- Empty
- Empty

0.4 V

Real

-0.4

0 s

1.999023 s
Bump Testing

3rd Harmonic

- Fundamental 1
- 2nd Harmonic 1
- 3rd Harmonic 1
- Bump 1
- Empty
- Empty
- Empty
- Empty
- Empty
- Empty

Real

0.3 V

-0.3 Real

0 s 1.999023 s
2nd Harmonic

Fundamental 1
2nd Harmonic 1
Bump 1
Empty
Empty
Empty
Empty
Empty
Empty
Empty

0.2 V

Real

-0.2

0 s 1.999023 s
Fundamental

0.1 V

Real

-0.1

0 s 1.999023 s
Bump Testing

2\textsuperscript{nd} Harmonic

![Graph showing 2\textsuperscript{nd} Harmonic with labels for Fundamental 1, 2\textsuperscript{nd} Harmonic 1, Bump 1, Empty, Empty, Empty, Empty, Empty, Empty, Empty, Empty. The graph plots voltage (V) against time (s).]
3rd Harmonic

- Fundamental 1
- 2nd Harmonic 1
- 3rd Harmonic 1
- Bump 1
- Empty
- Empty
- Empty
- Empty
- Empty
- Empty

0.3 V

Real

-0.3

0 s to 1.999023 s
4\textsuperscript{th} Harmonic

- Fundamental 1
- 2nd Harmonic 1
- 3rd Harmonic 1
- 4th Harmonic 1
- Bump 1
- Empty

0.4 V

Real

-0.4

0 s 1.999023 s
Bump Testing

5\textsuperscript{th} Harmonic

<table>
<thead>
<tr>
<th>Harmonic 1</th>
<th>2nd Harmonic 1</th>
<th>3rd Harmonic 1</th>
<th>4th Harmonic 1</th>
<th>5th Harmonic 1</th>
<th>Bump 1</th>
<th>Empty</th>
<th>Empty</th>
<th>Empty</th>
<th>Empty</th>
</tr>
</thead>
</table>

0.5 V

Real

-0.5

0 s to 1.999023 s
10th Harmonic

Diagram showing various harmonic components.
20\textsuperscript{th} Harmonic
Bump Testing

50\textsuperscript{th} Harmonic

- Fundamental 1
- 2nd Harmonic 1
- 3rd Harmonic 1
- 4th Harmonic 1
- 5th Harmonic 1
- 10th Harmonic 1
- 20th Harmonic 1
- 50th Harmonic 1
- Bump 1

Fundamental 1

4 V

Real

0 s 1.999023 s
100th Harmonic
Bump Testing

How does it work?

- Bump testing or impact testing works because the bump or impact contains all of the individual frequencies or sign waves.
- When you bump or impact the object under test, you will excite all of the natural frequencies of that object.
What do you impact with?

- **Pin Drops!**
  - High frequency content
  - Low energy value

- **Cow Plops!**
  - Low frequency content
  - High energy value
Energy Value vs. Frequency

- The item used to deliver the impact to the object under test will determine the energy that is delivered to the object.
  - Large objects with considerable mass should be impacted with rubber or wood. This will generate high energy low frequency responses. (cow plops)
  - Small objects with considerable stiffness should be impacted with metal or hard plastics. This will generate low energy high frequency responses. (pin drops)
Set-up

UNIFORM WINDOW

- Take your time – Bump around
- Do not over range or clip the input signal
- 800 – 1600 lines of resolution
- Try some different frequency spans
- Only 1 bump for each time record
- About 4 averages (depends on noise)
Why the Uniform Window?
What to Bump?

- 1” diameter steel round stock
- 36” length
- Clamped in “V” blocks at each end
- CTC AC140 accelerometer stud mounted on center (100 mV/g)
Bump Testing

Bump It! Two Responses!

Time Waveform

- X: 23.4375 ms, Y: 1.63297 G
- dX: 76.17188 ms, dY: -1.36474 G

Time Record 1

Frequency Spectrum

- X: 58.75 Hz, Y: 8.550765 mG
- X: 65.5 Hz, Y: 12.23725 mG
- X: 70.75 Hz, Y: 8.475402 mG

Auto Pwr Spec 1

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Mental Health Check!

Time Waveform

\[ \text{76.17 msec/5 = 15.23 msec} \]

\[ F = \frac{1}{0.01523 \text{ sec}} = 65.64 \text{ Hz} \]

Frequency Spectrum

\[ \text{65.5 Hz} \]
CASE HISTORY

Bumps in the Road!
So Easy !!!!!!
Case History

Zoom

**Time Waveform**

- X:164.0625 ms
- Y:1.379613 G
- dX:554.6875 ms
dY:-729.2974 mG

**Frequency Spectrum**

- X:109.125 Hz
- Y:214.7374 mG

109.125 Hz
554 msec/5 = 110.8 msec

F = 1/0.1108 sec = 9.02 Hz

109.125 Hz
So Easy ???????

**Time Waveform**

- Time Record 1
- X: 109 Hz, Y: 539.6552 mG
- Time: 0 to 3.998047 s

**Frequency Spectrum**

- Auto Pwr Spec 1
- Frequency: 0 to 200 Hz
- Peak at 109 Hz
What’s This?

Time Waveform

Frequency Spectrum

X: 109 Hz
Y: 539.6552 mG

109 Hz
Log – Can’t Live With It, Can’t Live Without It!
Case History

0 – 50 Hz Span

Time Waveform

Frequency Spectrum

10.81 Hz
0 - 50 Hz (expanded “x” scale)

Time Waveform

460.9 msec/5 = 92.18 msec

F = 1/0.09218 sec = 10.84 Hz

Frequency Spectrum

10.81 Hz
Back to Bump Testing

**Time Waveform**

76.17 msec/5 = 15.23 msec

**Frequency Spectrum**

65.5 Hz

F = 1/0.01523 sec = 65.64 Hz
Using the Time Waveform

Log decrement = \[\frac{1}{n \ln \left( \frac{A_0}{A_n} \right)}\] = \[\frac{1}{5 \ln \left( \frac{1.633}{0.268} \right)}\] = 0.36

Damping ratio = Log dec/2Pi = 0.36/2Pi = 0.36/6.28 = 0.057

Amplification factor = \(\frac{1}{2 \times \text{Damping}}\) = \(\frac{1}{2 \times 0.057}\) = 8.68
Using the Spectrum

Find the –3dB points = $A_F \times 0.707 = 12.24 \text{ mG} \times 0.707 = 8.65 \text{ mG}$

Find the frequencies at the –3dB points ($f_1$ and $f_2$)

Amplification factor = $F / (f_2 - f_1) = 65.5 / (70.75 - 58.75) = 5.46$
\[ F_n = \frac{1}{2\pi} \sqrt{\frac{k}{m}} \]

- INCREASE the stiffness (\( k \))
- INCREASE the mass (\( m \))
- DECREASE the frequency (\( F \))
Control the Response

Un-Damped

Damped

Gain at 85 Hz = 85
Gain at 82.5 Hz = 8
Summary

- Take your time
- Choose your weapon
- Bump around
- Uniform Window
- Look at the time waveform
- Look at the frequency spectrum
- Do a mental health check
- Calculate the amplification factor
- Change the mass
- Change the stiffness
- Add damping
- Bump around
Thank You!

You can find technical papers on this and other subjects at www.ctconline.com in the “Technical Resources” section.