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The Choice of the Road Input Signal is very important for the validity of the results. Please do keep this in mind.

The Frequency Transfer Function can be calculated for both the vertical **BOUNCE** or the **PITCH** mode allowing the User to optimize either Heave or Pitch behaviour of the vehicle or finding the best compromise for both.

Both Two Signals can be used simultaneously at both Front and Rear Axle - the so called **SUM** mode - or with Opposite/180 Degree Out-of-Phase Amplitude Input (Front moving up, Rear moving down) - the so called **PITCH** mode.

This Signal does create a constant Peak to Peak Velocity Input Road Signal which allows rather conveniently to excite the vehicle in the range of interest, especially for specific Damper Piston Speeds.

In order to address the increasing Peak to Peak Input Speed of the Linear Signal an alternative signal has been developed with an Exponential Decay of the Input Amplitude over Frequency.

The choice of the road input signal is very important for the validity of the results. Please do keep this in mind.

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The FFT algorithm is by itself rather a complex algorithm and without going into all details a few key factors one should know/consider:

1. The FFT algorithm is a rather cpu intensive procedure. The "delay" in creating the results is almost solely caused by the "Live Execution" of the FFT code. This less performant your computer is, the more time it will take.

2. The FFT algorithm does require a specific formula number of 2^n data points. For this reason the "simulation time" exist out 4,096 seconds that represent 4096 data points (=2^12) and remains always constant.

3. The FFT algorithm should be used only to check the results of the classical method. It does usually create a few problems for the Human FFT procedure.

4. The "standard" FFT algorithm does work in theory only correct on a full linear system. Highly Non-Linear Systems do require Non-Linear FFT Algorithms which are very complex. Since the shock absorber can be both high non-linear (e.g. a symmetric (un)linear/inertia) this does usually create a few problems for the Human FFT procedure.

5. The following chart illustrates some FFT data for a wheel hop at 0 Hz. This is a commonly used approach which assumes that the damping of the vehicle remains constant for the excitation and is calculated as the average of the damping and Rebound Damping for the particular operating point. This advantage is that the Transfer Function is more "linear" understandable, and starts always at 0 Hz with a value of 1. Although this approach should be used only to check the results of the classical method and data do show that there is a very good correlation.

6. If the "standard" FFT algorithm has been added allowing to simulate Kerbing Events.

7. In the Hz - Rm Input Test, the movement of wheel and body can be analyzed over time after applying a stress (e.g. shock testing, normal body). This is done by applying the Displacement of the system Transfer Function at 0 Hz and adjusting the Body Speed, the time for passing the obstacle and as such the Frequency Content of the events being changed. This allows for comparing and analyzing the results of the used procedure.

8. The test procedure is also particularly useful (actually it is a MUST) for finding the best compromise in between jounce & rebound damping, keeping the overall damping constant while looking at different vehicle speeds, and in particular the resonating effect in both vehicles at resonance frequencies and the "roughness" of the road for any tuning made with the 4 Poster Sweep Sine Test Procedure.

9. It is important to know that the Time Domain Ride Model in RELEASE 8.0 is more sophisticated than the Frequency Response Model. In particular the Car Body moves in vertical direction from Front to Rear Axle in a very similar way. This is good for comfort and also for in depth analysis.

10. The amplitude of the Half Sine or the height of the Ramp can be modified (either up or down). Length is also adjustable.

11. The "standard" FFT algorithm does work in theory only correct on a full linear system. Highly Non-Linear Systems do require Non-Linear FFT Algorithms which are very complex.

12. The FFT algorithm is a rather cpu intensive procedure. The "delay" in creating the results is almost solely caused by the "Live Execution" of the FFT code. This less performant your computer is, the more time it will take.

13. The "standard" FFT algorithm does work in theory only correct on a full linear system. Highly Non-Linear Systems do require Non-Linear FFT Algorithms which are very complex.
The Graph is a "Contour" Plot of all the Maximum and Minimum Dynamic Contact Patch Loads during the test. It is a very effective way of looking at how the Setup and thus the Tire does behave over the whole Frequency Range.

% Critical Damping @ Peak Res. Freq (-3dB)

Front Body Results

Time to 95% damped oscillation
Dynamic Peak Overshoot
Maximum Vertical Acceleration

DAMPER GUIDANCE: THE LOWER THE NUMBER THE BETTER FOR MECHANICAL GRIP

Wheel Lift Time

The second graph of interest displays the Dynamic Loads, Contact Patch Load, Spring and Damper Forces are shown over Time. allowing proper understanding of what component takes what load at what time.

Several Upgraded Metrics like maximum Dynamic Contact Patch Load Integrator and new Metrics like Wheel Lift Time do help the user by providing objective measure for grip judgement. This Contact Patch Load integrator does consider Wheel Lift Time.

Especially for Rallye / Off-Road Applications the Time Domain Model has been significantly enhanced. In addition to the visual representation various metrics like "Peak Overshoot" & "Time to 95% Damped Oscillation" allow accurate performance evaluation of the resulting vehicle movements. On top of that a "Conflict Metric" indicates the maximum acceleration induced to the vehicle body.

RELEASE 8.0 Upgrade

Critical New Graphics and Metrics have been added

Now in RELEASE 8.0 a "Second" Important Graph is giving the user a good indication on the Maximum and Minimum Dynamic Contact Patch Loads encountered during the test in the range from 0 - 25 Hz. The Graph is a "Contour" Plot of all the Minimum and Maximum Dynamic Contact Patch Loads during the test. It is a very effective way of looking at how the Setup and thus the Tire does behave over the whole Frequency Range.
Can be used as normal Excel Sheet.

**DO NOT DELETE "EXPORT" BUTTON**
### Percentage Critical Damping Charts

<table>
<thead>
<tr>
<th>Wheel Vertical Speed [mm/s]</th>
<th>Average % Damping Body in Jounce</th>
<th>% Damping Body in Jounce</th>
<th>Average % Damping Wheel in Jounce</th>
<th>% Damping Wheel in Jounce</th>
<th>Wheel Rate [N/mm]</th>
<th>Body CoG Pitch Frequency (frequency one)</th>
<th>Body Rebound Frequency (frequency two)</th>
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</thead>
<tbody>
<tr>
<td>29.9</td>
<td>30.0</td>
<td>32.0%</td>
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<td>24.0%</td>
<td>10.6</td>
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<td>29.0%</td>
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<td>10.6</td>
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<td>-0.15</td>
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<td>-0.15</td>
<td>-0.17</td>
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<td>-0.17</td>
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<td>80.0%</td>
<td>10.6</td>
<td>-0.15</td>
<td>-0.17</td>
</tr>
</tbody>
</table>

### Bounce & Pitch Centers

**Note:** Depending on the weight distribution and spring setup, the two motion centers can exchange positions.

- Bounce Center: the actual motion center is usually higher than the actual bounce frequency.
- Pitch Center: the actual motion center is usually lower than the actual pitch frequency.

**Percentage Critical Damping:**

- FRONT: Note that the calculated percentage critical damping at the bounce center is usually higher than the calculated percentage critical damping at the pitch center.

**Rear Suspension Damper Rate:**

- The rear suspension damper rate is usually lower than the front suspension damper rate.

**Front Body Percent Critical Damping:**

- The front body percent critical damping is usually lower than the rear body percent critical damping.

**Rear Body Percent Critical Damping:**

- The rear body percent critical damping is usually higher than the front body percent critical damping.

**Bounce & Pitch Centers Carpet Plots:**

- The carpet plots provide a visual representation of the motion characteristics of the vehicle.
- The front body percent critical damping is plotted against the wheel rate for both bounce and pitch centers.

**Motion Center "One" Relative to Front Axle:**

- Motion Center "One" is located within the wheelbase.

**Motion Center "Two" Relative to Front Axle:**

- Motion Center "Two" is located outside of the wheelbase.

**Note:** Usually the actual bounce frequency is higher than the actual bounce frequency.
<table>
<thead>
<tr>
<th>Body CoG Pitch Frequency</th>
<th>Frequency “One” (usually Bounce)</th>
<th>Frequency “Two” (usually Pitch)</th>
<th>Motion Center “One” relative to Front Axle (usually Pitch)</th>
<th>Motion Center “Two” relative to Front Axle (usually Bounce)</th>
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</tr>
</tbody>
</table>

** Positive Number = In front of Front Axle  
** Negative Number = Behind Front Axle

** Testable Recommendation:** Pitch Center should be as close as possible to Pitch Center.  
** Testable Recommendation:** Bounce Center should be as far as possible from Bounce Center.  

** Warning:** When Body CoG Pitch Frequency is higher than the Body CoG Frequency the Pitch Center location can vary from what is relative to CoG “Position.”  
** Testable recommendation:** When Body CoG Frequency is higher than the Body CoG Pitch Frequency, Body CoG Position should be used instead of Body CoG “Position.”

** Warning:** When Body CoG Pitch Frequency is higher than the Body CoG Frequency the Pitch Center location can vary from what is relative to CoG “Position.”  
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