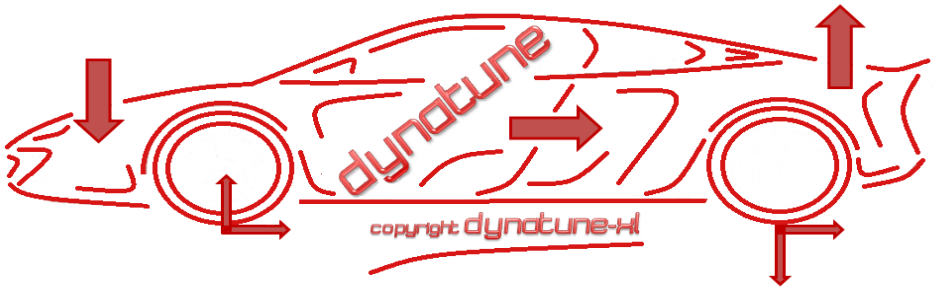

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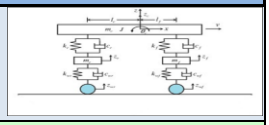
DYNATUNE SUSPENSION TUNING MODULE - RELEASE 8.0

On each worksheet one can click on the pictures in the header which will redirect to the corresponding web page (left) or the related FAQ support page (right).

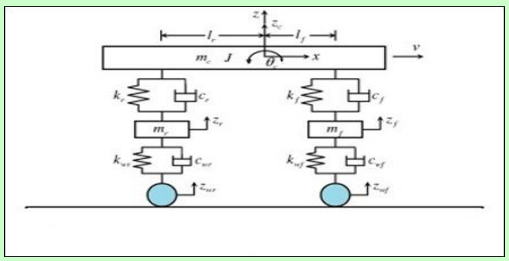


Analytical Model:

This workbook does allow the calculation of Spring & Damper Setup of a Vehicle. .
The Simulation Model behind it is a classical 5 DOF / 3 PART Spring & Damper Bicycle model with Interactions of the Unsprung Mass of Front and Rear Axles on the Sprung Mass & Pitch Inertia Vehicle Body.
The model itself is based on Fully Linear Differential Equations with a partially Non-Linear Representation of the Damper data. The tire and the road are always connected for Frequency Domain Simulations
and can be disconnected in the Time Domain from Release 8.0 onwards. Non-Linear Bump Stops are NOT considered.
The differential equations of the vehicle system are being solved by numerical integration/differentiation over time with a step size of 0.001 sec.

Input Data:

Vehicle Data - Masses, Weight Distribution & Inertia
Spring, Tire Stiffness and Percentage Tire Damping
Suspension Motion Ratio
Measured Damper Data for Jounce & Rebound (@ standard damper speeds)
Scaling Factors for Spring Rates and Jounce & Rebound Damping allowing Quick Tuning Sessions
Road Profile Data



Output / Results:

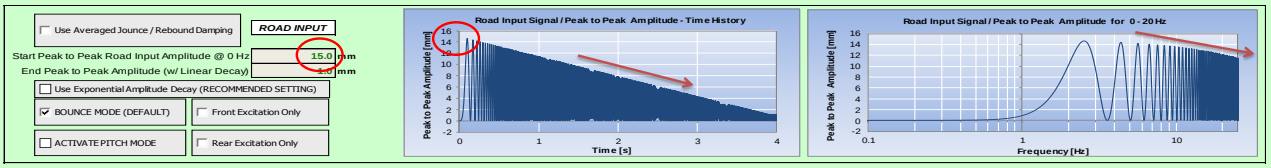
Front & Rear Body & Wheel Ride Frequencies
Bounce & Pitch Center Location
Percentage Critical Damping Graphs
Frequency Transfer Function Graphs for Body & Wheel Movements with respect to a Sinusoidal Road Input Signal
Dynamic Wheel Loads and dissipated Damper & Tire Energies
Half Sine / Ramp Time History Response Function Graphs for Body, Wheel, Damper Speeds and Dynamic Wheel Loads
KPI / Metrics for Contact Patch Load Fluctuations, Grip, Body Movements & Accelerations

4 POSTER SWEEP SINE TEST (FREQUENCY DOMAIN - TRANSFER FUNCTION):

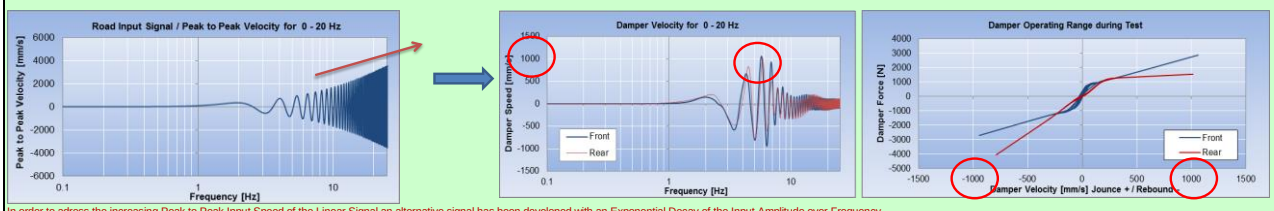
The 4 Poster Sweep Sine Test replicates virtually some of the tests that ary physically executed on hydraulic 4 (or 7) poster rigs. The car is usually excited with some kind of sinusoidal road input in a range of 0 to 25 Hz.
In order to see how the vehicle reacts at various inputs speeds and frequencies, so called Frequency Transfer Function of the vehicle are being created. These FFT functions basically "tell" how much an Excitation does make an object react.
If the object is light it moves more than if it is heavy. If the "Punch" is fast it has a different effect than when it is slow.
A Frequency Transfer Function describes thus the Relationship between an Output Value and an Input Value - in this case typically an amplitude ratio - and is valid for a certain frequency range (Frequency Domain).
Frequency Transfer Functions are usually plotted in logarithmic scales.
In the Automotive World of Vehicle Dynamics this Frequency Range is defined from 0 Hz to 25 Hz as most Suspension and Car-Body related Natural Frequencies typically can be found there.
In order to create a Frequency Transfer Function an artificial sinusoidal signal (in the time domain) is being used that starts at 0 Hz and goes up to around 100 Hz over time (in about 4 "seconds").
The high frequency of 100 Hz is necessary because the algorithm that is being used to create this function - a so called Fast Fourier Transformation (FFT) - does need to have approximately 4 times more frequency for correct results
and create a smooth curve for a range of 0 to 25 Hz. Besides that the algorithm does also need to have sufficient "energy" input in the lower frequency range to create reliable results.

Considering the Signal Requirements, the virtual 4 Poster can in **RELEASE 8.0** be driven with 2 types of road input signals, each with their unique advantages:

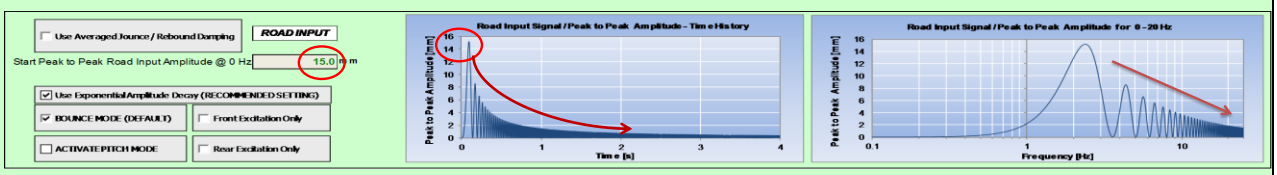
1 Linear Decaying Amplitude Signal



This signal is "Focused" on Peak to Peak Input Displacements and will generate an Input Signal with Non-Constant Peak to Peak Input Speeds as shown below. Damper Speeds are shown too.
Due to the increasing of Peak to Peak Input Speed with increasing Frequency the induced Energy is not constant, which makes this signal less preferable as several parameters (Amplitude, Speed and Frequency) change simultaneously.
However the Signal Initial and Final Amplitude can be adjusted which in certain applications might be an advantage.



In order to adress 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



Resulting in a constant Peak to Peak Input Speed as shown in the graph below. For Reference also Damper Speeds

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.
The initial Start Amplitude of the signal defines the Maximum Value of the Input Velocity AND defines the Amplitude Decay for the complete Frequency Spectrum. The final Amplitude cannot be manually set as in the Linear Decay Signal.

Both Two Signals can be used simultaneously at both Front and Rear Axle - the so called BOUNCE mode - or with Opposite/180 Degree Out-of-Phase Amplitude Input (Front moving up, Rear moving down) - the so called PITCH mode.
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.
The Choice of the Road Input Signal is very important for the validity of the results. Please do keep this in mind.

Some Info on FFT

The FFT algortihm 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. The 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.
This number of data points allows a resolution of around 0.25 Hz in the results.

3) 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 highly non-linear (knee-point) as a-symmetric (jounce/rebound ratio) this does usually creates a few problems for the linear FFT procedure.
Dynatune does allow the user to choose out of two "Damping" Options:

a) BASELINE SETTING
Averaging both Jounce & Rebound Damping over a (Half) Sine Oscillation - This is a commonly used approach which "assumes" that the damping of the vehicle remains "constant" for the oscillation and is calculated as the average of the Jounce and Rebound Damping for that particular operating point. The advantage is that the Transfer Function is more "smooth" and stable, and starts always at 0 Hz with a value of 1. Although this approach should be in theory less accurate than option b) the experience and comparison with real world measurements and data do show that there is a very good correlation.

b) OPTIONAL SETTING **- RELEASE 8.0 NEW FEATURE**
Use the full NON-Linear & A-Symmetric Damper Data as in "real life". This will however lead to a less "smooth" Transfer Function which will potentially also be more difficult to understand. A very high rebound damping will for instance "pull" the car down during the frequency sweep. Changes in Jounce/Rebound Damping can influence the Transfer Function significantly. It is highly recommended to use the Exponential Decay Road Input.
In real life the effects will be less dramatic since in particular suspension compliances and for instance rubber topmounts will "smoothen out" these non-linearities.
This option is recommended to be used only by experts for in depth analysis.

4) Similar to point 3) the Tire must always be in contact with the road as a "Lifting-Off" would introduce a rather severe non-linearity in the system. In fact in the 4 Poster Ride Model the Tire is always connected to the road and "pull the car back" in situations where it would normally lift off. This is purely done to allow robust FFT post-processing

HALF SINE / RAMP INPUT TEST (TIME DOMAIN):

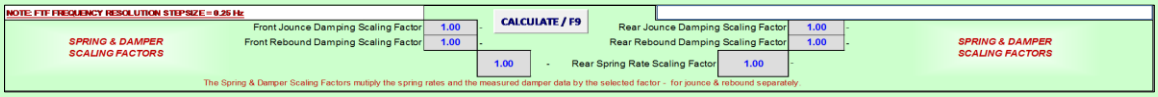
RELEASE 8.0 NEW FEATURE:
A Half Sine Event has been added allowing to simulate Kerbing Events.

In the Half Sine / Ramp Input Test, the movements of wheel and body can be analyzed over time after passing a ramp (smooth 1/2 sinusoidal resp. smooth 1/4 sinusoidal).
The amplitude of the Half Sine or the height of the Ramp can be modified (either up or down). Length is also adjustable.
By the Defined Length of the Half Sine / Ramp and by adjusting the Vehicle Speed, the time for passing the obstacle and as such the Frequency Content of the events are being changed.
The calculated "Frequency Content" is usefull for relating the results of this test to the 4 Poster Sweep Sine test procedure results.
The test procedure is also particularily usefull (actually it is a MUST) for finding the best compromise/ratio between jounce & rebound damping, keeping the overall damping constant whilst looking at different vehicle speeds (= excitation frequency) and represents the "real world" test for any tuning made with the 4-Poster Sweep Sine Test Procedure.

RELEASE 8.0 NEW FEATURE:
It is important to know that the Time Domain Ride Model in RELEADE 8.0 is more sophisticated than the Frequency Response Model. In particular the tire can loose contact with the road.

TUNING CONTROL CENTRE

In between the Frequency Domain and Time Domain Calculation Sections one can conveniently find the "Tuning Control Centre". Here the User can scale Front & Rear Spring Rates and Jounce & Rebound Damper Rates.
The effect of changing one single parameter or several ones at once can instantly can be reviewed. Typically we would recommend to use one Vehicle Worksheet as "Scaling Sheet" and use the other Vehicle Worksheet as a Reference Setting Sheet. In the Comparison Sheet the main differences between both Setups can be evaluated and used for further tuning steps.



General Notes on the Workbook:

The default calculation setting of the workbook is set to automatic recalculation. Since hower both the real time resolution of the differential equations for the Sweep Sine & Ramp Sine Test as the FFT post processing procedure are quite cpu intensive the sheets can be slow in updating (depending on the hardware of the computer). One can set the default calculation mode to manual calculation on the sheets, but in order to update the results one must either press key F9 (default Excel) or use the Calculation Button on the sheets.

RESULTS

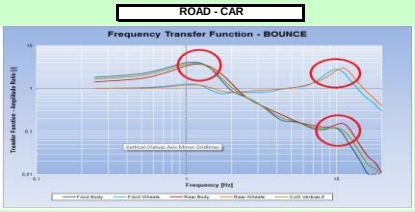
The "Lower Part" of the Vehicle 1 & Vehicle 2 Worksheets provide all the classical metrics and characteristics that are being used by the automotive engineers. Natural frequencies, Pecentage Critical Damping and other interesting metrics like Bounce and Pitch Centers. These are commonly used terms which can be found in literature and are therefor not further explained. There is a presentation on the FAQ page about them.

The Focus of the Tool is on the "Upper Part" of the Worksheets which are providing the results for FREQUENCY DOMAIN with the 4 Poster Frequency Sweep and below the scaling dashboard all results for the TIME DOMAIN with Ramp and Half Sine functions.

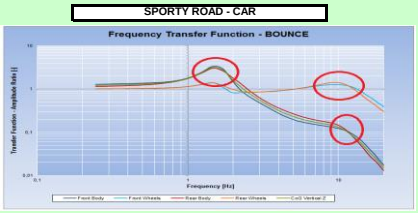
The dominant graph for the 4 Poster Test is the Frequency Transfer Function. The graph does basically show "how much" the Body or the Wheel of the vehicle reacts to a defined road input at a Range of Frequencies.
At 0 Hz this function starts at 1 and typically shows "peaks" near the Natural (Heave and Pitch) Frequencies of Sprung and Unsprung masses. Below some are examples for "good" Transfer Functions

EXAMPLES FOR "GOOD" TARGET TRANSFER FUNCTIONS:

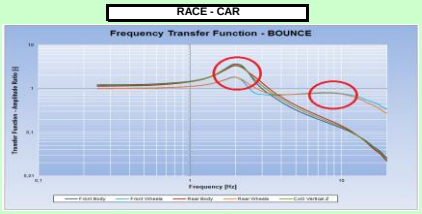
ROAD - CAR



SPORTY ROAD - CAR



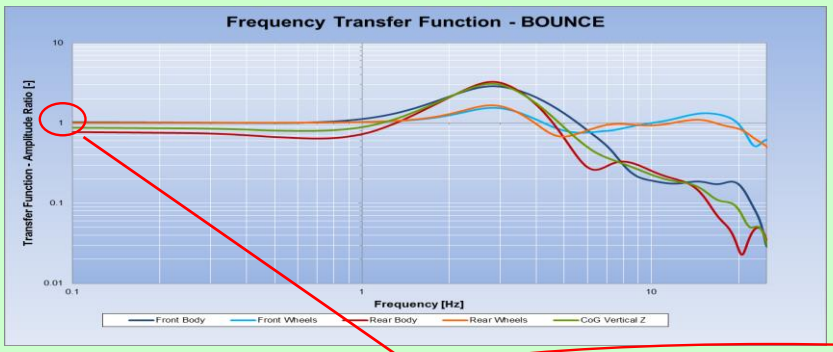
RACE - CAR



If Front Body FFT, Rear body FFT and Centre of Gravity FFT transfer function are very similar it does mean that the Car Body moves in vertical direction from Front to Rear Axle in a verey similar way. This is good for comfort and if both axles have also similar FFT plots they move similarily which should be good for grip. The "sportier" a car becomes - in effect the higher the Spring and Damping Rates become - the lower become the Peak Wheel FFT Values (right red cricles) at Wheel Hop Natural Frequency. They do become however more pronounced at Body Natural Frequency due to the fact that the system becomes more "coupled". The more the FFT Funtion of the Wheels does follow the Body the more the system is "coupled".
Next to the visual appearance of the curves there are several metrics in the tool that allow judging the quality of the setup based on specific characteristics of the Frequency Transfer Function.

Example Results Explanation

The First important Graph of the 4 Poster Test is the Frequency Transfer Function



FRONT	Body	Wheel	
Peak Resonance Frequency in FTF	2.75	2.75	Hz
Dynamic Overshoot @ Peak Resonance Freq.	2.88	1.55	mm/mm
% Crtical Damping @ Peak Res. Freq (-3dB)	37.52	46.92	%
Dynamic Wheel Load Indicator 0 - 25 Hz *		5.706	-

Note: If the Frequency Transfer Function at 0.1 Hz is not Starting at 1, it does usually mean that the amount of Damping is in general too high for the amount of Spring Rate. Looking for instance at the Rear Body Value of 0.8 - which is lower than 1 - one can generally say that the amount of Rebound Damping is significantly higher than the amount of Jounce Damping. If vice versa the Start Value is significantly above 1, the amount of Jounce Damping would be higher than the amount of Rebound damping (forcing the Rear Body to move more Up than Down resulting in an overall Higher Dynamic Ride Height over one Frequency Cycle.) **This Phenomenon is the Key for understanding FFT Graphs.**

a) **Peak Resonance Frequency:** The Frequency in the Frequency Response Function with the highest Amplitude. Depending on the amount of Damping these frequencies can be different or fall together. In this particular case the dynamic overshoot of the front wheel is higher at the natural body frequency than at the to be expected wheel natural frequency. This happens usually with racing cars

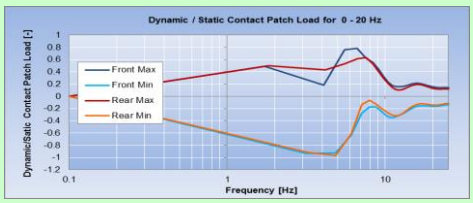
b) **Dynamic Overshoot @ Peak Resonance Frequency**: This metric does indicate how well damped the body or wheelis when excited with the natural frequency of the system. In general once can say, the more damped the system is the lower & wider are the peak curves. If one would be a passenger in the car sitting near the front axle it would mean that for any vertical movement of the road by 1mm the passenger would move 2.88 mm.

c) **% Critical Damping @ Peak Frequency:** Out of the FTF one can extract by using the -3dB rule the percentage critcal damping of the system at that frequency. This method depends however on the shape of the FTF and the resolution of frequencies steps in the Fast Fourier Transformation. The values can differ sometimes slightly from the damping percentages calculated with the classical method.

d) **Dynamic Wheel Load Indicator 0 - 25 Hz**: This metric does indicate how close the Wheel Transfer Function remains close to the Value "1" in the Frequency Range from 0 - 25 Hz. This metric can be used as a first indication for the general amount of grip of the tires in the range from 0 - 25 Hz. In the RELEASE 8.0 various additional metrics have been developed to explore in greater detail Grip Performance.

RELEASE 8.0 Upgrade
Several New Graphs and Metrics have been added

Now in RELEASE 8.0 a "Second" Important Graph is giving the user an 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 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.

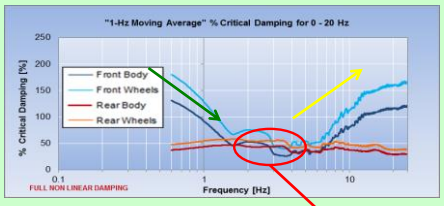


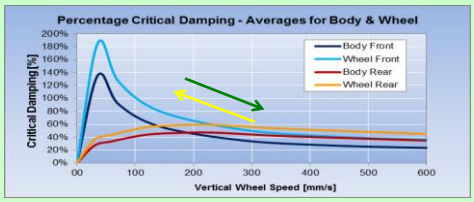
	FRONT AXLE	
Max. Dyn./Stat. CPL	0.783	-
Min. Dyn./Stat. CPL	-0.932	-
Diss. Energy in Dampers	135.19	Ws
Diss. Energy in Tires	67.38	WS

	REAR AXLE	
Max. Dyn./Stat. CPL	0.633	-
Min. Dyn./Stat. CPL	-0.967	-
Diss. Ener. Dampers	154.16	Ws
Diss. Energy Tires	88.93	Ws

Whenever the minimum Dynamic Contact Patch Load is below "-1", the wheel would start to lift in real life. This condition should be avoided. This New Graph and these New Metrics do allow a back to back comparison of various setups and will give a good indication of the amount of "work" the Tire has to endure. The amount of Dissipated Energy for Tires and Dampers is calculated over the duration of the test from 0 - 25 Hz.
The less energy is consumed in the tire, the better the vehicle will handle road undulations or - alternatively - if desired, specific setups can be created to generate more energy consumption in the tire in order to heat it more/quicker up.
There can (and will) be differences between the Min Dyn./Stat. CPL metric and the Dynamic Wheel Load Indicator from the FFT Function. As the latter is an approximation based on the assumption that the contact patch load will be better the closer the Transfer Function is to 1 for the wheel, it is recommended to always preveal the New Dynamic Contact Patch Load Metric which is more accurate.

Another New "Third" Interesting Graph is the "Percentage Critical Damping" Moving Average during the 4 Poster Test.





When Full Non-Linear Damping is activated Jounce and Rebound damping can alternate during a frequency cycle quite severly. This graph represents a "1 Hz Moving Average" and thus filters out all the singular peaks and allows to display the amount of "averaged" Percentage Critical Damping during the 4 Poster Test. In fact, the graph does offer an interesting "Visualization" of the % Critical Damping over the Frequency Range giving the user good information of Levels of Damping at the various interesting key frequencies. Most of all this Graph does show how the % Critical Damping Value does change from "Static" to "Dynamic" and how it does change through the Frequency Spectrum.
Quite Interesting to see is that for instance Front Body & Wheel start at low Frequence around 150% Critical Damping which with increasing Frequency deminuishes to around 50% Crtical Damping. Around 7 Hz it does start to rise up ending at 25 Hz around the same values as at the start. Basically the Damper Speed Force Graph is in the first part crossed from left to right and in the second part vice versa.

If we do take the results from the FFT graph above it, is interesting to see that indeed the FFT calculated % Critical Damping at 2.75Hz comes very close to the "Moving Average" Procedure Value around 3 Hz - as indicated in the Red Circle

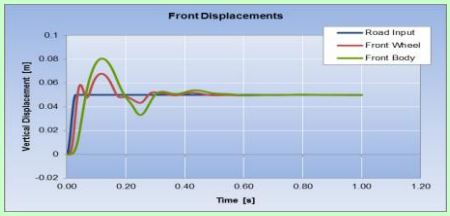
FRONT	Body	Wheel	
Peak Resonance Frequency in FTF	2.75	2.75	Hz
% Crtical Damping @ Peak Res. Freq (-3dB)	37.52	46.92	%

Note: Between 35% and 45% Critical Damping at the Peak Resonance Frequency has emperically proved to be a good compromise between Body Control and Tire Grip.

TIME DOMAIN - Ramp & Half Sine

Although the Frequency Domain results are a good indication, the only correct way to verify a setup is a simulation in the Time Domain. One can select from a "RAMP" event, representing road obstacles like access ramps or one can select "HALF SINE" events representing obstacles like "Curb Strikes" in racing or "Sleeping Policemen" on ordinary roads.

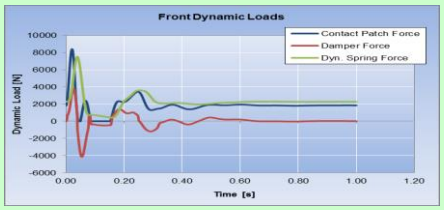
The first important graph is showing the various displacements of Road, Wheel and Body. In addition to this visual representation various metrics - like "Peak Overshoot" & "Time to 95% Damped Oscillation" allow accurate performance evaluation of the resulting vehicle movements. On top of that a "comfort metric" indicates the maximum acceleration induced to the vehicle body



	Front Body Results	
Time to 95% dampened oscillation	0.472	s
Dynamic Peak Overshoot	1.610	m/m
Time to reach Peak Value	0.120	s
Maximum Vertical Acceleration	62.95	m/s²

TUNING GUIDANCE: THE LOWER THE NUMBERS THE BETTER FOR MECHANICAL GRIP

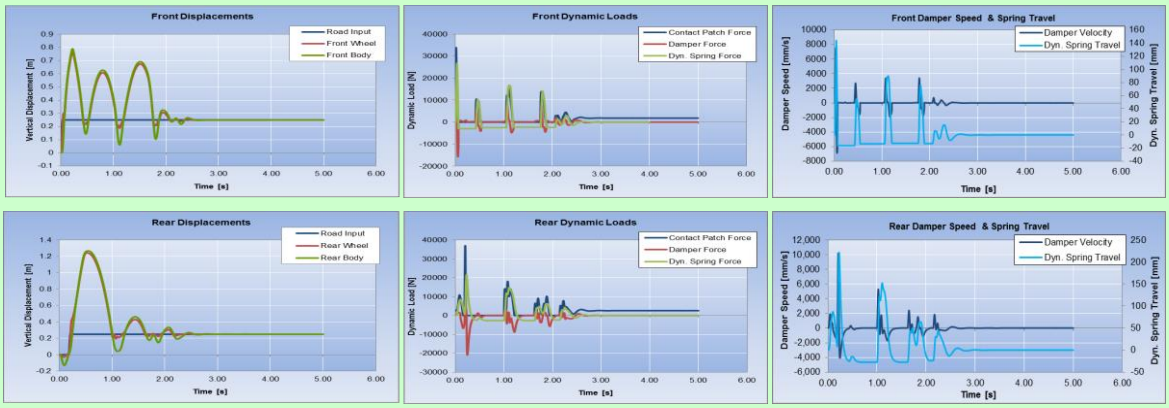
The second graph of interest displays the Dynamic Loads. Contact Patch Load, Spring and Damper Forces are shown over Time, allowing proper understanding of what component takes what load at what time.



	Front Wheel Results	
Max. Dynamic Contact Patch Load	8386.4	N
Wheel Lift Time	0.078	s
Dynamic Contact Patch Load Integrator *	234.50	Ns

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

Especially for Rallye / Off-Road Applications the Time Domain Ride Model has been significantly enhanced with respect to the Frequency Domain Model. Next to the Capability of dealing with Zero Contact Patch Load, the model does now also permit to "Jump" with Suspension and Wheel Position correctly positioned at the "Zero Spring Load" Rebound Position. An Example of such an event is shown below for Front and Rear Axle.



Furthermore are graphs available showing Translational and Rotational Displacement, Velocity & Acceleration for the Center of Gravity.

COMPARISON SHEET

The Workbook does also provide a COMPARISON Sheet on which the most important GRAPHS & METRICS of the VEHICLE 1 and VEHICLE 2 Sheets are being confronted.
For the Convenience of the User, the Metrics which are better in one Vehicle Setup than in the other Vehicle Setup are highlighted in Green Cells with White Font. This does give an instant overview of the Quality of one setup versus another.

UNPROTECTED SHEET FREE FOR USAGE - CANNOT BE RENAMED

Can be used as normal Excel Sheet.

DO NOT DELETE "EXPORT" BUTTON

EXPORT COMPLETE USER SHEET

DYNATUNE SUSPENSION TUNING MODULE - RELEASE 8.0

Vehicle Data

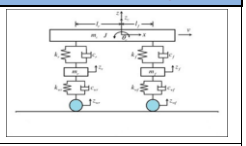
Wheel Base	3000.0	mm
Weight Distribution	41.50	%Front
Total Mass	900.0	kg
Fr. Wheel Load	1832.0	N
Rr. Wheel Load	2582.5	N
Vehicle Pitch Inertia	800.0	kgm²
Pitch Inertia Sprung Mass	542.1	kgm²

BLUE = ENTER DATA (SUSPENSION)
GREEN = ENTER DATA (CAR & CONTROL)
RED = CALCULATED RESULTS - DO NOT TOUCH

☐ Manual Calculation

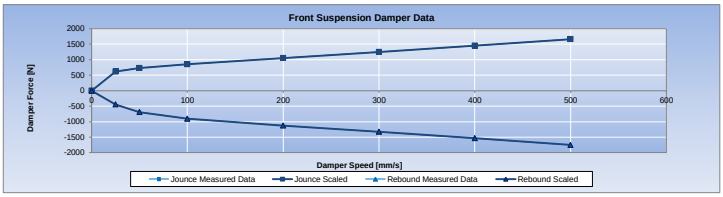
CALCULATE / F9

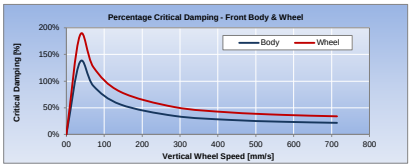
DAMPER SETUP 1



Front Suspension Data

Front Unprung Mass (Corner)	25.0	kg
Fr. Tire Vert. Stiffness	240.00	N/mm
Fr. Tire % Critical Damping	5.00	%
Fr. Tire Damping Rate	287.51	Ns/m
Fr. Spring/Damper to Wheel Motion Ratio *	0.70	-
Fr. SPRING Rate	185.00	N/mm
Front Spring Static Deflection / Pre-Load	12.25	mm
Fr. WHEEL Rate (incl. Scaling)	90.65	N/mm
Fr. RIDE Rate (incl. Tire)	65.80	N/mm
* motion ratio from 0 to 1 (1 = wheel travel)		
Fr. Body Frequency	3.768	Hz
Fr. Body Ride Frequency (incl. Tire)	3.210	Hz
Fr. Wheelhop Frequency	18.304	Hz



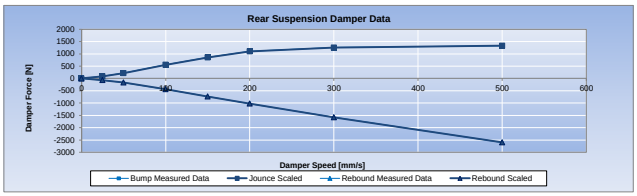


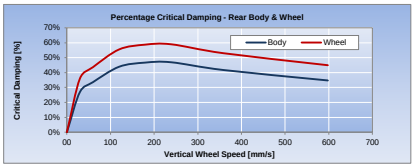
Front Suspension Measured Damper Data

Damper Speed [mm/s]	Jounce Force [N]	Rebound Force [N]	Damping Rate Jounce [Ns/m]	Damping Rate Rebound [Ns/m]	Rebound/Jounce Ratio [-]
0.0	0.0	0.0	0.0	0.0	0.0
25.0	618.7	-441.6	24749.2	-17662.3	0.71
50.0	731.0	-689.6	14619.0	-13791.3	0.94
100.0	854.2	-904.6	8541.6	-9045.6	1.06
200.0	1051.9	-1124.6	5259.7	-5623.2	1.07
300.0	1249.5	-1324.8	4164.9	-4416.2	1.06
400.0	1452.3	-1532.9	3630.8	-3832.3	1.06
500.0	1663.4	-1752.1	3326.7	-3504.3	1.05

Rear Suspension Data

Rear Unsprung Mass (Corner)	33.5	kg
Rr. Tire Vert. Stiffness	285.00	N/mm
Rr. Tire % Critical Damping	5.00	%
Rr. Tire Damping Rate	343.95	Ns/m
Rr. Spring/Damper to Wheel Motion Ratio *	0.84	-
Rr. SPRING Rate	97.50	N/mm
Rear Spring Static Deflection / Pre-Load	27.65	mm
Rr. WHEEL Rate (incl. Scaling)	68.14	N/mm
Rr. RIDE Rate (incl. Tire)	54.99	N/mm
* motion ratio from 0 to 1 (1 = wheel travel)		
Rr. Body Frequency	2.741	Hz
Rr. Body Ride Frequency (incl. Tire)	2.462	Hz
Rr. Wheelhop Frequency	16.341	Hz





Rear Suspension Measured Damper Data

Damper Speed [mm/s]	Jounce Force [N]	Rebound Force [N]	Damping Rate Jounce [Ns/m]	Damping Rate Rebound [Ns/m]	Rebound/Jounce Ratio [-]
0.0	0.0	0.0	0.0	0.0	0.0
25.0	83.5	-69.0	3341.1	-2760.9	0.83
50.0	213.5	-166.6	4269.4	-3331.9	0.78
100.0	555.5	-438.2	5555.1	-4382.3	0.79
150.0	852.9	-732.7	5685.9	-4884.5	0.86
200.0	1100.5	-1023.1	5502.3	-5115.5	0.93
300.0	1255.4	-1577.5	4184.6	-5258.3	1.26
500.0	1329.8	-2599.2	2659.5	-5198.4	1.95

FREQUENCY DOMAIN ANALYSIS - 4 POSTER SWEEP SINE TEST

☐ Use Averaged Jounce / Rebound Damping

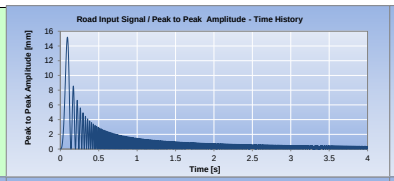
ROAD INPUT

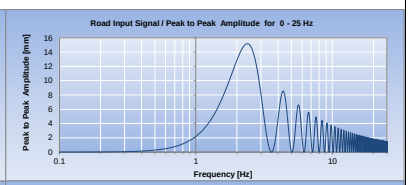
Start Peak to Peak Road Input Amplitude @ 0 Hz: 15.0 mm

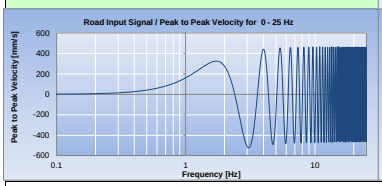
☑ Use Exponential Amplitude Decay (RECOMMENDED SETTING)

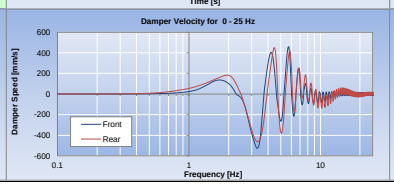
☑ BOUNCE MODE (DEFAULT) | ☐ Front Excitation Only

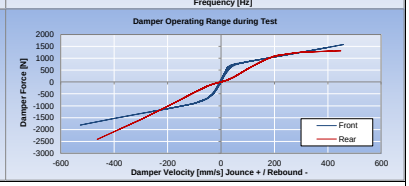
☐ ACTIVATE PITCH MODE | ☐ Rear Excitation Only

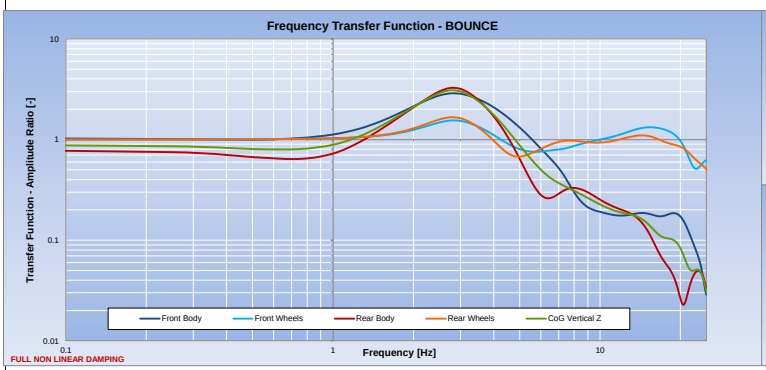


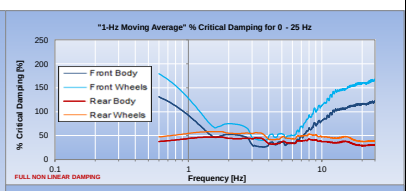


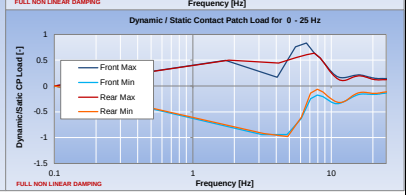












FRONT	Body	Wheel		REAR	Body	Wheel			FRONT AXLE		REAR AXLE	
Peak Resonance Frequency in FTF	2.75	2.75	Hz	CoG 2.75	2.75	2.75	Hz	-	0.832	Max. Dyn./Stat. CPL	0.635	-
Dynamic Overshoot @ Peak Resonance Freq.	2.88	1.55	mm/mm	3.09	3.26	1.67	mm/mm	-	-0.941	Min. Dyn./Stat. CPL	-0.980	-
%Crtical Damping @ Peak Res. Freq (-3dB)	37.52	46.92	%	28.93	26.10	38.55	%	Ws	137.69	Diss. Damper Energy	153.77	Ws
Dynamic Wheel Load Indicator 0 - 25 Hz *	5.706	-				4.320	-	Ws	67.55	Diss. Tire Energy	89.11	Ws

* Area under/above of wheel curves with respect to value 1. The lower this value is, the closer the curve remains to 1.

Note: When Dynamic/Static CPL < -1, Wheel Lift Occurs which should be avoided.

SPRING & DAMPER SCALING FACTORS

Fr. Jounce Damping Scaling Factor	1.00		Rr. Jounce Damping Scaling Factor	1.00
Fr. Rebound Damping Scaling Factor	1.00		Rr. Rebound Damping Scaling Factor	1.00
Fr. Spring Rate Scaling Factor	1.00		Rr. Spring Rate Scaling Factor	1.00

CALCULATE / F9

SPRING & DAMPER SCALING FACTORS

The Spring & Damper Scaling Factors multiply the spring rates and the measured damper data by the selected factor - for jounce & rebound separately.

TIME DOMAIN ANALYSIS - VERTICAL RAMP & HALF SINE INPUT TEST

All geometric input units in [m]

z- Height Amplitude of Half Sine (Up +, Down -)	0.0500	m
x-Length of Half Sine	1.000	m
Velocity over Half Sine	60.0	kph

Set ramp height / amplitude to 0 for test deactivation

Simulation Time (0 - 5s)	1.00 s
☐ Use Smoothed Step/Ramp	☑ Use Smoothed Half Sine
☐ Front Excitation Only	☐ Rear Excitation Only

Signal Data

Time for Half Sine	0.060	s
Delay Rear to Front Axle	0.180	s
Excitation Frequency	8.33	Hz

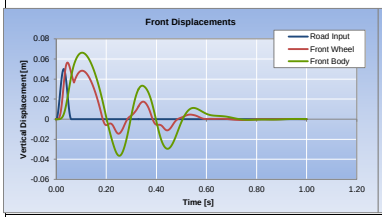
HALF SINE

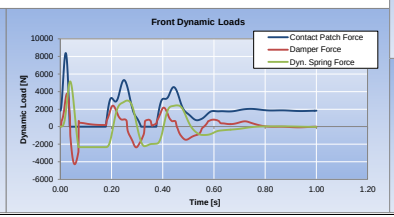
TUNING GUIDANCE: THE LOWER THE NUMBERS THE BETTER FOR MECHANICAL GRIP

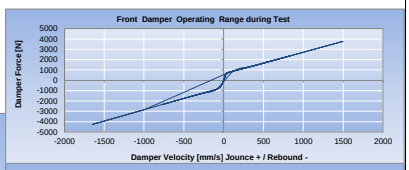
Front Body Results		
Time to 95% dampened oscillation	0.680	s
Dynamic Peak Overshoot	1.325	m/m
Time to Reach Peak Value	0.103	s
Maximum Vertical Acceleration	62.95	m/s²

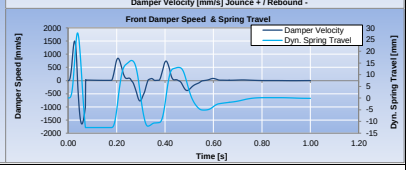
Front Wheel Results		
Max. Contact Patch Load	8386.4	N
Wheel Lift Time	0.201	s
Dyn. CP Load Integrator *	481.07	Ns

* Integral of the area of the Dynamic Wheel Load Curver over time







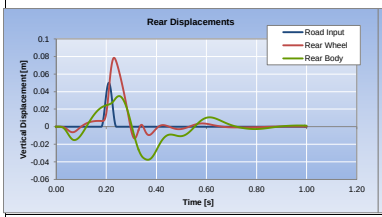


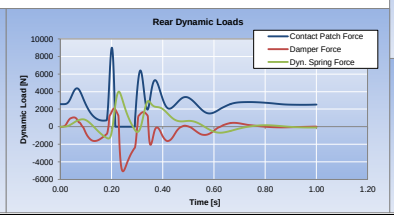
TUNING GUIDANCE: THE LOWER THE NUMBERS THE BETTER FOR MECHANICAL GRIP

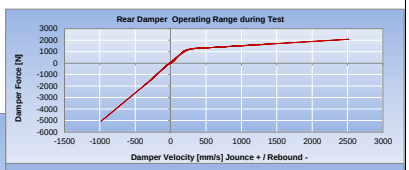
Rear Body Results		
Time to 95% dampened oscillation **	0.630	s
Dynamic Peak Overshoot	0.753	m/m
Time to Reach Peak Value **	0.186	s
Maximum Vertical Acceleration	32.24	m/s²

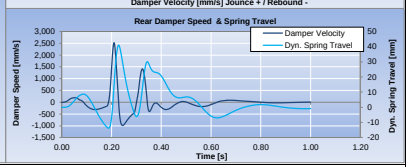
Rear Wheel Results		
Max. Contact Patch Load	8997.8	N
Wheel Lift Time	0.077	s
Dyn. CP Load Integrator *	435.09	Ns

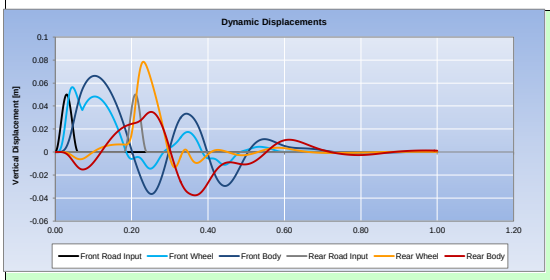
** Without considering delay time due to wheelbase

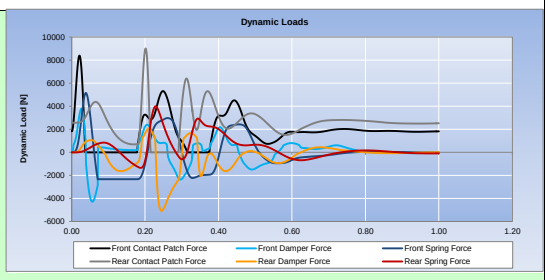


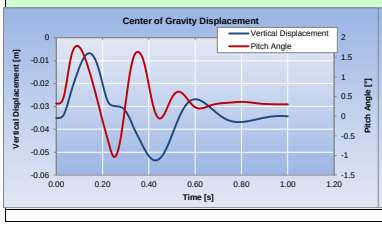


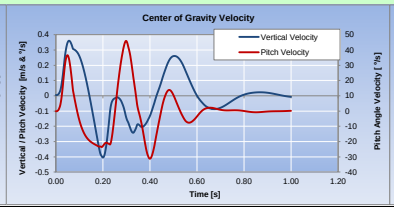


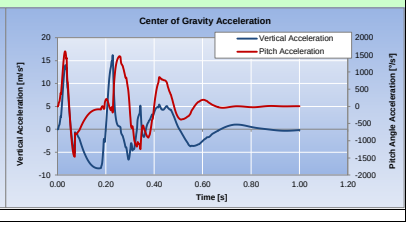






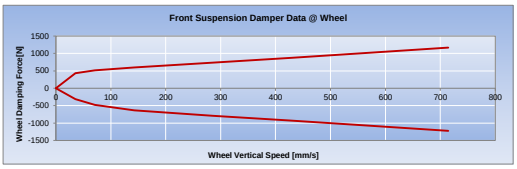




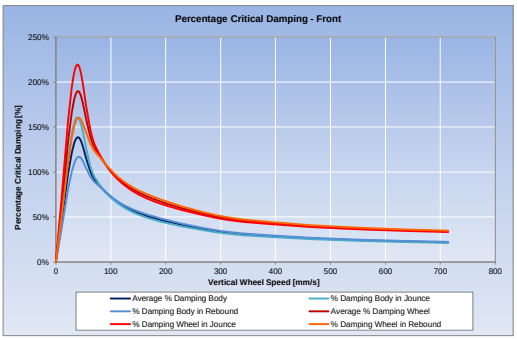


PRECENTAGE CRITICAL DAMPING CHARTS

Calculated FRONT Damper Force @ WHEEL (considering Motion Ratio & Scaling Factor)			
Wheel Vertical Speed [mm/s]	Jounce Force [N]	Rebound Speed [mm/s]	Rebound Force [N]
0.0	0.0	0.0	0.0
35.7	433.1	-35.7	-309.1
71.4	511.7	-71.4	-482.7
142.9	597.9	-142.9	-633.2
285.7	736.4	-285.7	-787.3
428.6	874.6	-428.6	-927.4
571.4	1016.6	-571.4	-1073.0
714.3	1164.4	-714.3	-1226.5

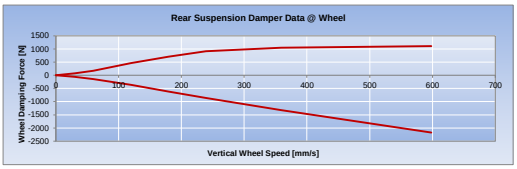


Front Body % Critical Damping (considering Motion Ratio & Scaling Factor)			
Wheel Vertical Speed [mm/s]	Average % Damping Body	% Damping Body in Jounce	% Damping Body in Rebound
0.0	0.0%	0.0%	0.0%
35.7	135.7%	158.4%	113.0%
71.4	90.9%	93.5%	88.2%
142.9	56.3%	54.7%	57.9%
285.7	34.8%	33.7%	36.0%
428.6	27.5%	26.6%	28.3%
571.4	23.9%	23.2%	24.5%
714.3	21.9%	21.3%	22.4%



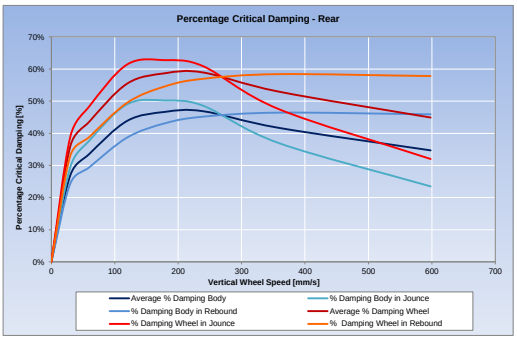
Front Wheel % Critical Damping (considering Motion Ratio & Scaling Factor)			
Wheel Vertical Speed [mm/s]	Average % Damping Wheel	% Damping Wheel in Jounce	% Damping Wheel in Rebound
0.0	0.0%	0.0%	0.0%
35.7	185.7%	215.9%	155.5%
71.4	126.0%	129.6%	122.5%
142.9	79.9%	77.8%	82.1%
285.7	51.4%	49.8%	52.9%
428.6	41.6%	40.5%	42.6%
571.4	36.8%	35.9%	37.7%
714.3	34.1%	33.3%	34.9%

Calculated REAR Damper Force @ WHEEL (considering Motion Ratio & Scaling Factor)			
Wheel Vertical Speed [mm/s]	Jounce Force [N]	Rebound Speed [mm/s]	Rebound Force [N]
0.0	0.0	0.0	0.0
29.9	69.8	-29.9	-57.7
59.8	178.5	-59.8	-139.3
119.6	464.4	-119.6	-366.4
179.4	713.0	-179.4	-612.5
239.2	920.0	-239.2	-855.3
358.9	1049.5	-358.9	-1318.8
598.1	1111.7	-598.1	-2172.9



Rear Body % Critical Damping (considering Motion Ratio & Scaling Factor)			
Wheel Vertical Speed [mm/s]	Average % Damping Body	% Damping Body in Jounce	% Damping Body in Rebound
0.0	0.0%	0.0%	0.0%
29.9	26.9%	29.5%	24.4%
59.8	33.6%	37.7%	29.4%
119.6	43.9%	49.1%	38.7%
179.4	46.7%	50.2%	43.1%
239.2	46.9%	48.6%	45.2%
358.9	41.7%	37.0%	46.4%
598.1	34.7%	23.5%	45.9%

Rear Wheel % Critical Damping (considering Motion Ratio & Scaling Factor)			
Wheel Vertical Speed [mm/s]	Average % Damping Wheel	% Damping Wheel in Jounce	% Damping Wheel in Rebound
0.0	0.0%	0.0%	0.0%
29.9	36.0%	38.9%	33.1%
59.8	43.6%	48.4%	38.9%
119.6	55.5%	61.4%	49.5%
179.4	58.7%	62.8%	54.6%
239.2	58.9%	60.9%	57.0%
358.9	53.0%	47.5%	58.4%
598.1	44.9%	32.0%	57.8%



BOUNCE & PITCH CENTERS

Output Parameter	RESULTS	
Fr. Ride Frequency	3.210	Hz
Rr. Ride Frequency	2.462	Hz
Ratio Rr/Fr Ride Frequency	0.767	-
Body CoG Pitch Frequency (frequency one)	5.252	Hz
Body CoG Bounce Frequency (frequency two)	2.672	Hz
Pitch Center (motion center one)	-0.154	m *
Bounce Center (motion center two)	4.499	m *

The differential equations for the analytical model of the body movement provide 2 solutions, so called Motion Centers ("one" and "two"). The Motion Center that is located at the nearest distance from the CoG (usually solution "one") is called PITCH CENTER and is located within the Wheel Base.The Motion Center that is located at the furthest distance from the CoG (usually solution "two") is called BOUNCE CENTER and is located outside of the Wheel Base.

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

Note 1: Usually the natural Pitch Frequency is higher than the natural Bounce Frequency

Note 2: The sign indicates whether the Motion Center is located fore or aft relative to CoG x-Position

* Positive number = distance from CoG in forward direction

* Negative number = distance from CoG in rearward direction

Relative to FRONT AXLE		
Pitch Center (motion center one)	-1.909	m **
Bounce Center (motion center two)	2.744	m **

** Positive Number = In Front of Front Axle

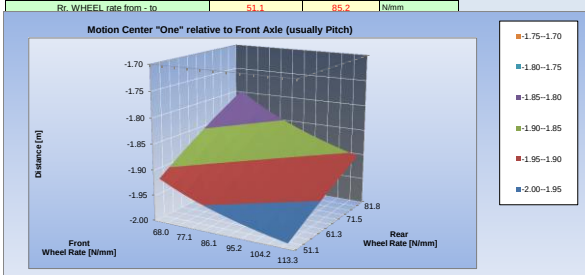
** Negative Number = Behind Front Axle

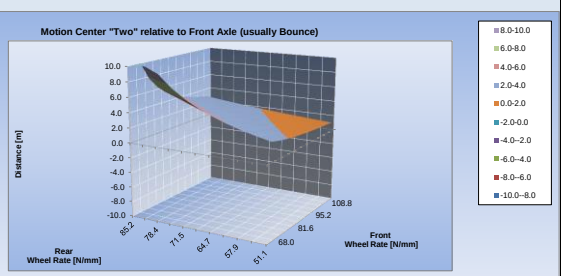
Tuning Recommendation: Pitch Center should be as close as possible to Front Axle

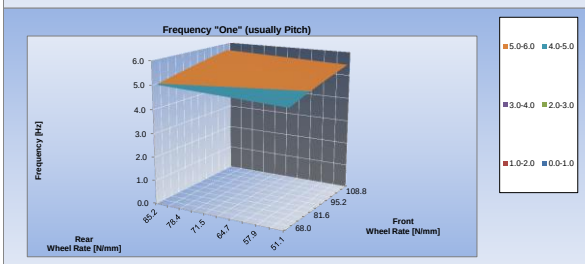
Tuning Recommendation: Bounce Center should be as far as possible from Front Axle - ideally at least as far away as the equivalent to one wheelbase length

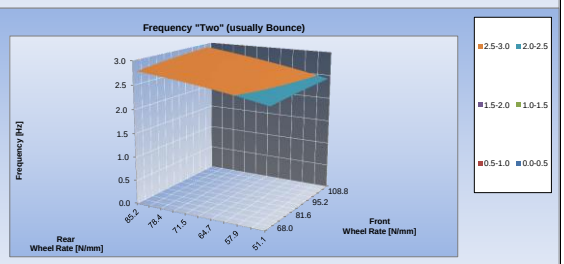
RANGE CARPET PLOTS FROM 75% TO 125% WHEEL RATE			
Fr. WHEEL Rate from - to	68.0	113.3	N/mm
Rr. WHEEL rate from - to	51.1	85.2	N/mm

BOUNCE & PITCH CENTER CARPET PLOTS

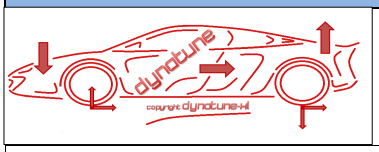








DYNATUNE SUSPENSION TUNING MODULE - RELEASE 8.0



Vehicle Data

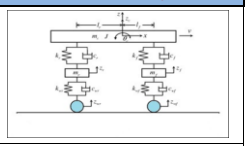
Wheel Base	3000.0	mm
Weight Distribution	41.50	%Front
Total Mass	900.0	kg
Fr. Wheel Load	1832.0	N
Rr. Wheel Load	2582.5	N
Vehicle Pitch Inertia	800.0	kgm²
Pitch Inertia Sprung Mass	542.1	kgm²

BLUE = ENTER DATA (SUSPENSION)
GREEN = ENTER DATA (CAR & CONTROL)
RED = CALCULATED RESULTS - DO NOT TOUCH

☐ Manual Calculation

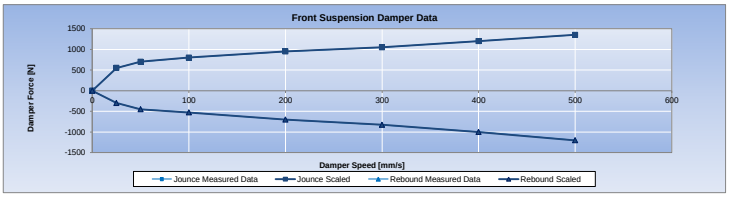
CALCULATE / F9

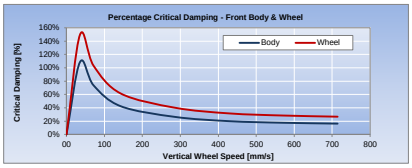
DAMPER SETUP 2



Front Suspension Data

Front Unprung Mass (Corner)	25.0	kg
Fr. Tire Vert. Stiffness	240.00	N/mm
Fr. Tire % Critical Damping	5.00	%
Fr. Tire Damping Rate	287.51	Ns/m
Fr. Spring/Damper to Wheel Motion Ratio *	0.70	-
Fr. SPRING Rate	185.00	N/mm
Front Spring Static Deflection / Pre-Load	12.25	mm
Fr. WHEEL Rate (incl. Scaling)	90.65	N/mm
Fr. RIDE Rate (incl. Tire)	65.80	N/mm
* motion ratio from 0 to 1 (1 = wheel travel)		
Fr. Body Frequency	3.768	Hz
Fr. Body Ride Frequency (incl. Tire)	3.210	Hz
Fr. Wheelhop Frequency	18.304	Hz



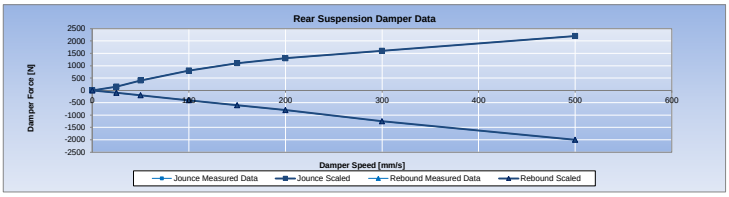


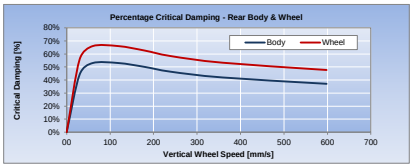
Front Suspension Measured Damper Data

Damper Speed [mm/s]	Jounce Force [N]	Rebound Force [N]	Damping Rate Jounce [Ns/m]	Damping Rate Rebound [Ns/m]	Rebound/Jounce Ratio [-]
0.0	0.0	0.0	0.0	0.0	0.0
25.0	550.0	-300.0	22000.0	-12000.0	0.55
50.0	700.0	-450.0	14000.0	-9000.0	0.64
100.0	800.0	-525.0	8000.0	-5250.0	0.66
200.0	950.0	-700.0	4750.0	-3500.0	0.74
300.0	1050.0	-825.0	3500.0	-2750.0	0.79
400.0	1200.0	-1000.0	3000.0	-2500.0	0.83
500.0	1350.0	-1200.0	2700.0	-2400.0	0.89

Rear Suspension Data

Rear Unsprung Mass (Corner)	33.5	kg
Rr. Tire Vert. Stiffness	285.00	N/mm
Rr. Tire % Critical Damping	5.00	%
Rr. Tire Damping Rate	343.95	Ns/m
Rr. Spring/Damper to Wheel Motion Ratio *	0.84	-
Rr. SPRING Rate	97.50	N/mm
Rear Spring Static Deflection / Pre-Load	27.65	mm
Rr. WHEEL Rate (incl. Scaling)	68.14	N/mm
Rr. RIDE Rate (incl. Tire)	54.99	N/mm
* motion ratio from 0 to 1 (1 = wheel travel)		
Rr. Body Frequency	2.741	Hz
Rr. Body Ride Frequency (incl. Tire)	2.462	Hz
Rr. Wheelhop Frequency	16.341	Hz





Rear Suspension Measured Damper Data

Damper Speed [mm/s]	Jounce Force [N]	Rebound Force [N]	Damping Rate Jounce [Ns/m]	Damping Rate Rebound [Ns/m]	Rebound/Jounce Ratio [-]
0.0	0.0	0.0	0.0	0.0	0.0
25.0	150.0	-100.0	6000.0	-4000.0	0.67
50.0	400.0	-200.0	8000.0	-4000.0	0.50
100.0	800.0	-400.0	8000.0	-4000.0	0.50
150.0	1100.0	-600.0	7333.3	-4000.0	0.55
200.0	1300.0	-800.0	6500.0	-4000.0	0.62
300.0	1600.0	-1250.0	5333.3	-4166.7	0.78
500.0	2200.0	-2000.0	4400.0	-4000.0	0.91

FREQUENCY DOMAIN ANALYSIS - 4 POSTER SWEEP SINE TEST

☐ Use Averaged Jounce / Rebound Damping

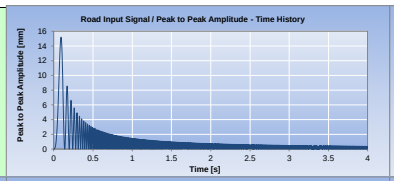
ROAD INPUT

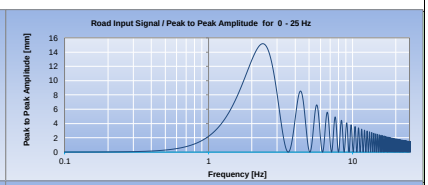
Start Peak to Peak Road Input Amplitude @ 0 Hz: 15.0 mm

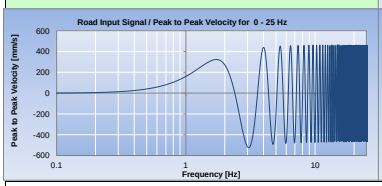
☑ Use Exponential Amplitude Decay (RECOMMENDED SETTING)

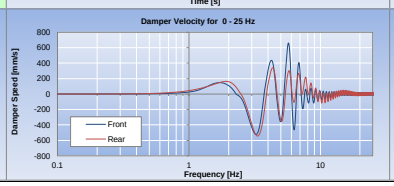
☑ BOUNCE MODE (DEFAULT) | ☐ Front Excitation Only

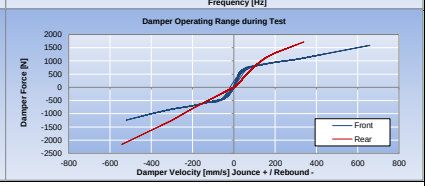
☐ ACTIVATE PITCH MODE | ☐ Rear Excitation Only

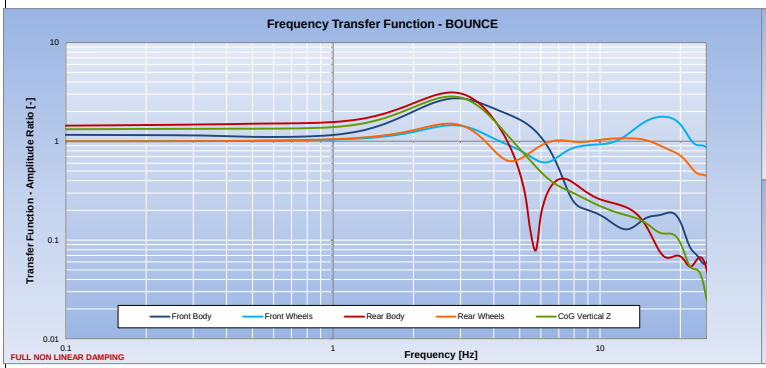


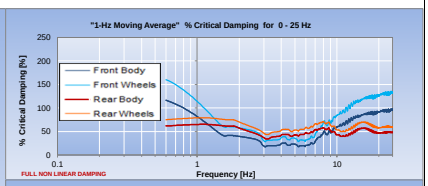


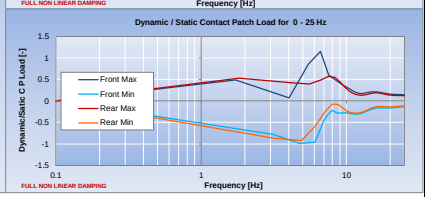












FRONT	Body	Wheel		CoG		REAR	Body	Wheel			FRONT AXLE		REAR AXLE	
Peak Resonance Frequency in FTF	3.00	17.26	Hz	2.75	Hz		2.75	2.75	Hz	-	1.150	Max. Dyn./Stat. CPL	0.571	-
Dyn. Overshoot @ Peak Resonance Freq.	2.72	1.77	mm/mm	2.84	mm/mm		3.12	1.51	mm/mm	-	-0.988	Min. Dyn./Stat. CPL	-0.922	-
%Crtical Damping @ Peak Res. Freq (-3dB)	39.66	22.34	%	33.87	%		33.09	47.80	%	Ws	142.83	Diss. Damper Energy	147.86	Ws
Dynamic Wheel Load Indicator 0 - 25 Hz *		7.297	-					5.021	-	Ws	77.92	Diss. Tire Energy	83.99	Ws

* Area under/above of wheel curves with respect to value 1. The lower this value is, the closer the curve remains to 1.

Note: When Dynamic/Static CPL < -1, Wheel Lift Occurs which should be avoided.

CALCULATE / F9

SPRING & DAMPER SCALING FACTORS

Fr. Jounce Damping Scaling Factor	1.00		Rr. Jounce Damping Scaling Factor	1.00
Fr. Rebound Damping Scaling Factor	1.00		Rr. Rebound Damping Scaling Factor	1.00
Fr. Spring Rate Scaling Factor	1.00		Rr. Spring Rate Scaling Factor	1.00

SPRING & DAMPER SCALING FACTORS

The Spring & Damper Scaling Factors multiply the spring rates and the measured damper data by the selected factor - for jounce & rebound separately.

TIME DOMAIN ANALYSIS - VERTICAL RAMP & HALF SINE INPUT TEST

NOTE: All geometric input units in [m]

z-Height of Ramp (Up +, Down -)	0.0500	m
x-Length of Ramp	1.000	m
Velocity over Ramp	60.0	kph

Set ramp height to 0 for test deactivation

Simulation Time (0 - 5s)	1.00 s

☑ Use Smoothed Step/Ramp ☐ Use Smoothed Half Sine

☐ Front Excitation Only ☐ Rear Excitation Only

Signal Data

Time to pass over Ramp	0.060	s
Delay Rear to Front Axle	0.180	s
Excitation Frequency	4.17	Hz

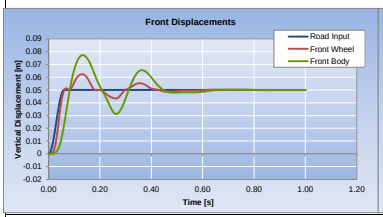
RAMP

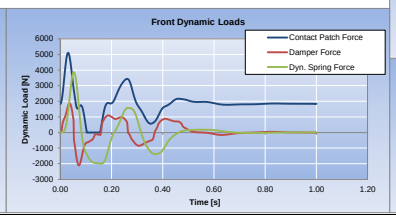
TUNING GUIDANCE: THE LOWER THE NUMBERS THE BETTER FOR MECHANICAL GRIP

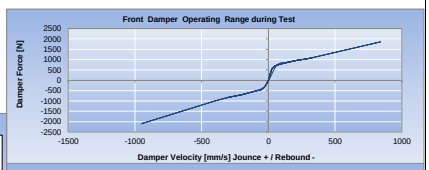
Front Body Results		
Time to 95% dampened oscillation	0.431	s
Dynamic Peak Overshoot	1.545	m/m
Time to Reach Peak Value	0.133	s
Maximum Vertical Acceleration	42.27	m/s²

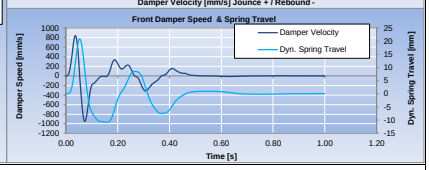
Front Wheel Results		
Max. Contact Patch Load	5106.1	N
Wheel Lift Time	0.053	s
Dyn. CP Load Integrator *	227.19	Ns

* Integral of the area of the Dynamic Wheel Load Curver over time







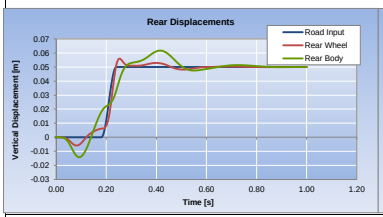


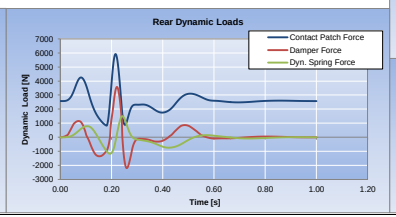
TUNING GUIDANCE: THE LOWER THE NUMBERS THE BETTER FOR MECHANICAL GRIP

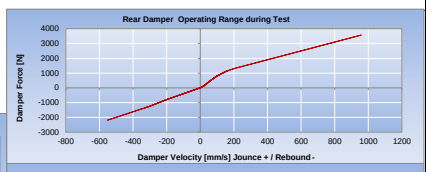
Rear Body Results		
Time to 95% dampened oscillation **	0.307	s
Dynamic Peak Overshoot	1.234	m/m
Time to Reach Peak Value **	0.235	s
Maximum Vertical Acceleration	18.95	m/s²

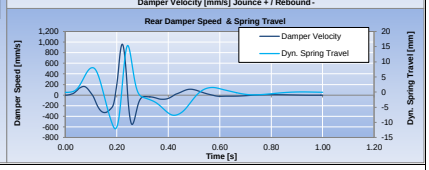
Rear Wheel Results		
Max. Contact Patch Load	5918.8	N
Wheel Lift Time	0.000	s
Dyn. CP Load Integrator *	221.45	Ns

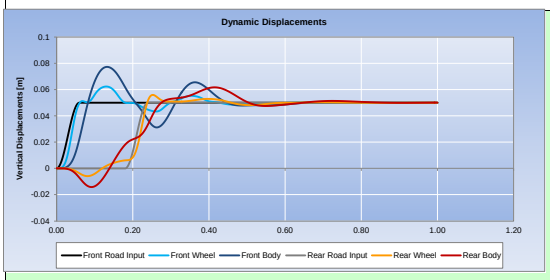
** Without considering delay time due to wheelbase

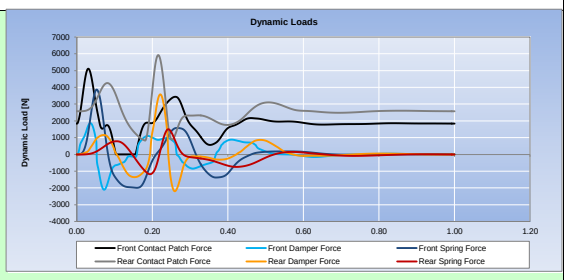


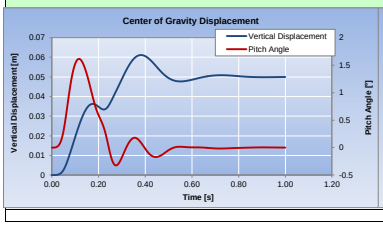


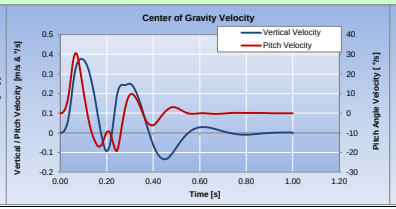


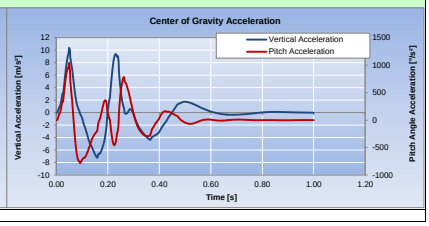






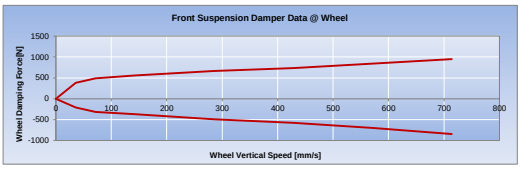




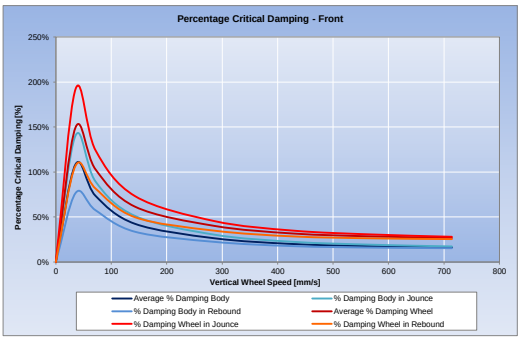


PRECENTAGE CRITICAL DAMPING CHARTS

Calculated FRONT Damper Force @ WHEEL (considering Motion Ratio & Scaling Factor)			
Wheel Vertical Speed [mm/s]	Jounce Force [N]	Rebound Speed [mm/s]	Rebound Force [N]
0.0	0.0	0.0	0.0
35.7	385.0	-35.7	-210.0
71.4	490.0	-71.4	-315.0
142.9	560.0	-142.9	-367.5
285.7	665.0	-285.7	-490.0
428.6	735.0	-428.6	-577.5
571.4	840.0	-571.4	-700.0
714.3	945.0	-714.3	-840.0

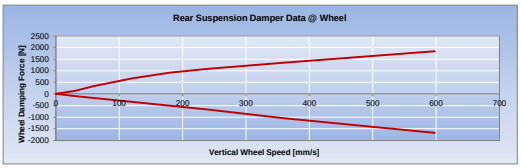


Front Body % Critical Damping (considering Motion Ratio & Scaling Factor)			
Wheel Vertical Speed [mm/s]	Average % Damping Body	% Damping Body in Jounce	% Damping Body in Rebound
0.0	0.0%	0.0%	0.0%
35.7	108.8%	140.8%	76.8%
71.4	73.6%	89.6%	57.6%
142.9	42.4%	51.2%	33.6%
285.7	26.4%	30.4%	22.4%
428.6	20.0%	22.4%	17.6%
571.4	17.6%	19.2%	16.0%
714.3	16.3%	17.3%	15.4%

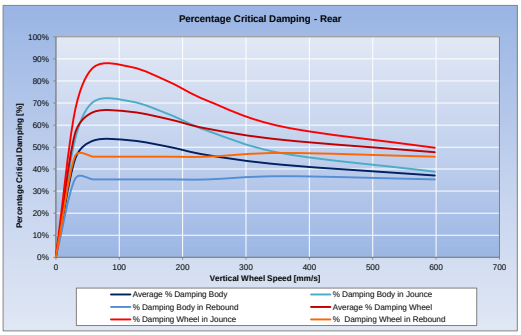


Front Wheel % Critical Damping (considering Motion Ratio & Scaling Factor)			
Wheel Vertical Speed [mm/s]	Average % Damping Wheel	% Damping Wheel in Jounce	% Damping Wheel in Rebound
0.0	0.0%	0.0%	0.0%
35.7	149.9%	192.5%	107.3%
71.4	103.0%	124.3%	81.7%
142.9	61.5%	73.2%	49.7%
285.7	40.2%	45.5%	34.8%
428.6	31.6%	34.8%	28.4%
571.4	28.4%	30.6%	26.3%
714.3	26.7%	28.0%	25.5%

Calculated REAR Damper Force @ WHEEL (considering Motion Ratio & Scaling Factor)			
Wheel Vertical Speed [mm/s]	Jounce Force [N]	Rebound Speed [mm/s]	Rebound Force [N]
0.0	0.0	0.0	0.0
29.9	125.4	-29.9	-83.6
59.8	334.4	-59.8	-167.2
119.6	668.8	-119.6	-334.4
179.4	919.6	-179.4	-501.6
239.2	1086.8	-239.2	-668.8
358.9	1337.6	-358.9	-1045.0
598.1	1839.2	-598.1	-1672.0



Rear Body % Critical Damping (considering Motion Ratio & Scaling Factor)			
Wheel Vertical Speed [mm/s]	Average % Damping Body	% Damping Body in Jounce	% Damping Body in Rebound
0.0	0.0%	0.0%	0.0%
29.9	44.2%	53.0%	35.3%
59.8	53.0%	70.7%	35.3%
119.6	53.0%	70.7%	35.3%
179.4	50.0%	64.8%	35.3%
239.2	46.4%	57.4%	35.3%
358.9	42.0%	47.1%	36.8%
598.1	37.1%	38.9%	35.3%



Rear Wheel % Critical Damping (considering Motion Ratio & Scaling Factor)			
Wheel Vertical Speed [mm/s]	Average % Damping Wheel	% Damping Wheel in Jounce	% Damping Wheel in Rebound
0.0	0.0%	0.0%	0.0%
29.9	55.8%	66.0%	45.6%
59.8	66.0%	86.3%	45.6%
119.6	66.0%	86.3%	45.6%
179.4	62.6%	79.5%	45.6%
239.2	58.3%	71.0%	45.6%
358.9	53.3%	59.2%	47.3%
598.1	47.7%	49.7%	45.6%

BOUNCE & PITCH CENTERS

Output Parameter	RESULTS	
Fr. Ride Frequency	3.210	Hz
Rr. Ride Frequency	2.462	Hz
Ratio Rr/Fr Ride Frequency	0.767	-
Body CoG Pitch Frequency (frequency one)	5.252	Hz
Body CoG Bounce Frequency (frequency two)	2.672	Hz
Pitch Center (motion center one)	-0.154	m *
Bounce Center (motion center two)	4.499	m *

The differential equations for the analytical model of the body movement provide 2 solutions, so called Motion Centers ("one" and "two"). The Motion Center that is located at the nearest distance from the CoG (usually solution "one") is called PITCH CENTER and is located within the Wheel Base.The Motion Center that is located at the furthest distance from the CoG (usually solution "two") is called BOUNCE CENTER and is located outside of the Wheel Base.
Note: Depending on the weight distribution & spring setup, the two motion centers can exchange positions.

Note 1: Usually the natural Pitch Frequency is higher than the natural Bounce Frequency
Note 2: The sign indicates whether the Motion Center is located fore or aft relative to CoG x-Position
* Positive number = distance from CoG in forward direction
* Negative number = distance from CoG in rearward direction

Relative to FRONT AXLE		
Pitch Center (motion center one)	-1.909	m **
Bounce Center (motion center two)	2.744	m **

** Positive Number = In Front of Front Axle

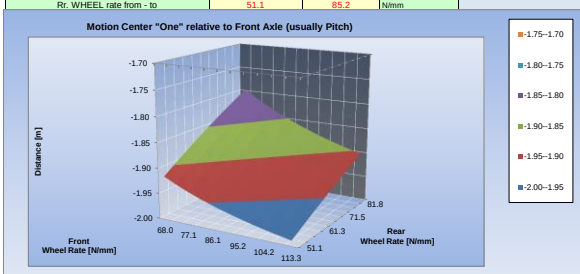
** Negative Number = Behind Front Axle

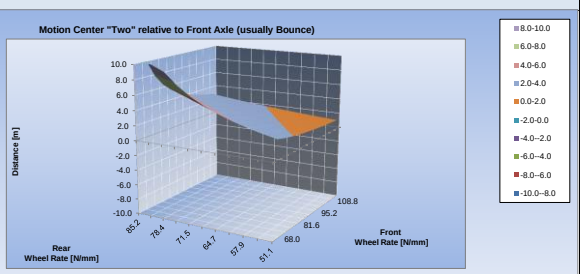
Tuning Recommendation: Pitch Center should be as close as possible to Front Axle

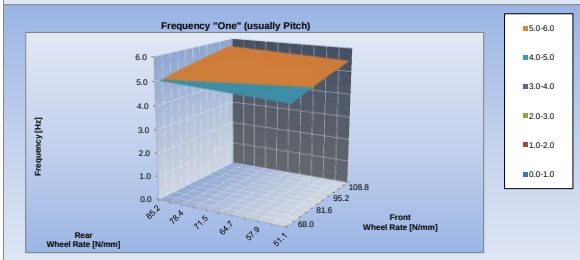
Tuning Recommendation: Bounce Center should be as far as possible from Front Axle - ideally at least as far away as the equivalent to one wheelbase length

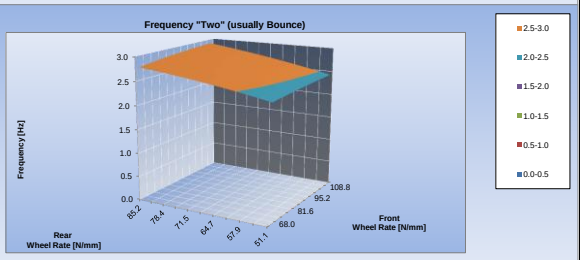
RANGE CARPET PLOTS FROM 75% TO 125% WHEEL RATE			
Fr. WHEEL Rate from - to	68.0	113.3	N/mm
Rr. WHEEL rate from - to	51.1	85.2	N/mm

BOUNCE & PITCH CENTER CARPET PLOTS









DYNATUNE SUSPENSION TUNING MODULE - RELEASE 8.0

VEHICLE 1

DAMPER SETUP 1

Wheel Base	3000.0	mm
Weight Distribution	41.50	%Front
Total Mass	900.0	kg
Vehicle Pitch Inertia	800.0	kgm2

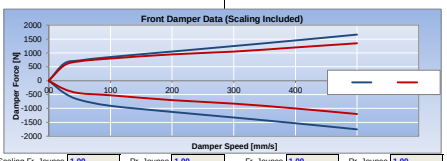
Bounce & Pitch Center rel. To Front Axle		
Pitch Centre	-1.909	m
Bounce Centre	2.744	m

	Front	Rear	
Body Frequency	3.768	2.741	Hz
Body Ride Frequency	3.210	2.462	Hz
Wheelhop Frequency	18.304	16.341	Hz

Front Unprung Mass	25.0	kg
Fr. Tire Vert. Stiffness	240.00	N/mm
Fr. Tire % Critical Damping	5.00	%
Fr. Tire Damping Rate	287.51	Ns/m
Fr. Spring/Damper Motion Ratio	0.70	-
Fr. SPRING Rate (incl. Scaling)	185.00	N/mm
Fr. SPRING Pre-Load (incl. Scaling)	12.25	mm
Fr. WHEEL Rate (incl. Scaling)	90.65	N/mm
Fr. RIDE Rate	65.80	N/mm

SCALED Front Damper Data

Jounce Speed [mm/s]	Jounce Force [N]	Rebound Speed [mm/s]	Rebound Force [N]
0.0	0.0	0.0	0.0
25.0	618.7	-25.0	-441.6
50.0	731.0	-50.0	-689.6
100.0	854.2	-100.0	-904.6
200.0	1051.9	-200.0	-1124.6
300.0	1249.5	-300.0	-1324.8
400.0	1452.3	-400.0	-1532.9
500.0	1663.4	-500.0	-1752.1

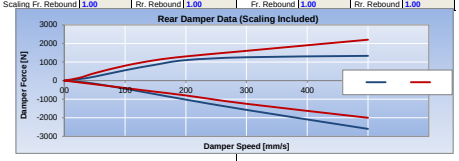


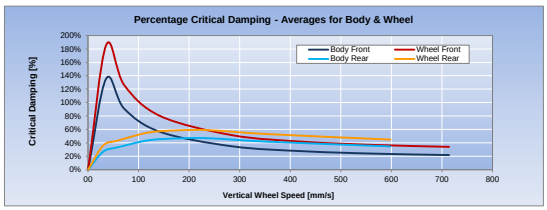
Scaling Fr. Jounce	1.00	Rr. Jounce	1.00	Fr. Jounce	1.00	Rr. Jounce	1.00
Scaling Fr. Spring	1.00	Rr. Spring	1.00	Fr. Spring	1.00	Rr. Spring	1.00
Scaling Fr. Rebound	1.00	Rr. Rebound	1.00	Fr. Rebound	1.00	Rr. Rebound	1.00

Rear Unsprung Mass	33.5	kg
Rr. Tire Vert. Stiffness	285.00	N/mm
Rr. Tire % Critical Damping	5.00	%
Rr. Tire Damping Rate	343.95	Ns/m
Rr. Spring/Damper Motion Ratio	0.84	-
Rr. SPRING Rate (incl. Scaling)	97.50	N/mm
Rr. SPRING Pre-Load (incl. Scaling)	27.65	mm
Rr. WHEEL Rate (incl. Scaling)	68.14	N/mm
Rr. RIDE Rate	54.99	N/mm

SCALED Rear Damper Data

Jounce Speed [mm/s]	Jounce Force [N]	Rebound Speed [mm/s]	Rebound Force [N]
0.0	0.0	0.0	0.0
25.0	83.5	-25.0	-69.0
50.0	213.5	-50.0	-166.6
100.0	555.5	-100.0	-438.2
150.0	852.9	-150.0	-732.7
200.0	1100.5	-200.0	-1023.1
300.0	1255.4	-300.0	-1577.5
500.0	1329.8	-500.0	-2599.2





VEHICLE 2

DAMPER SETUP 2

	Front	Rear	
Body Frequency	3.768	2.741	Hz
Body Ride Frequency	3.210	2.462	Hz
Wheelhop Frequency	18.304	16.341	Hz

Bounce & Pitch Center rel. To Front Axle		
Pitch Centre	-1.909	m
Bounce Centre	2.744	m

Wheel Base	3000.0	mm
Weight Distribution	41.50	%Front
Total Mass	900.0	kg
Vehicle Pitch Inertia	800.0	kgm2

Front Unprung Mass	25.0	kg
Fr. Tire Vert. Stiffness	240.00	N/mm
Fr. Tire % Critical Damping	5.00	%
Fr. Tire Damping Rate	287.51	Ns/m
Fr. Spring/Damper Motion Ratio	0.70	-
Fr. SPRING Rate (incl. Scaling)	185.00	N/mm
Fr. Spring Pre-Load (incl. Scaling)	12.25	mm
Fr. WHEEL Rate (incl. Scaling)	90.65	N/mm
Fr. RIDE Rate	65.80	N/mm

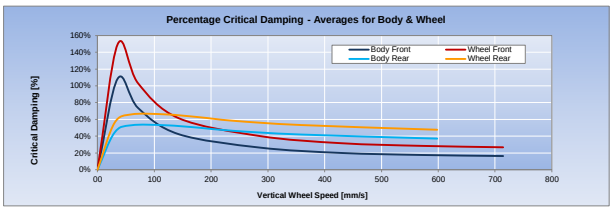
SCALED Front Damper Data

Jounce Speed [mm/s]	Jounce Force [N]	Rebound Speed [mm/s]	Rebound Force [N]
0.0	0.0	0.0	0.0
25.0	550.0	-25.0	-300.0
50.0	700.0	-50.0	-450.0
100.0	800.0	-100.0	-525.0
200.0	950.0	-200.0	-700.0
300.0	1050.0	-300.0	-825.0
400.0	1200.0	-400.0	-1000.0
500.0	1350.0	-500.0	-1200.0

Rear Unsprung Mass	33.5	kg
Rr. Tire Vert. Stiffness	285.00	N/mm
Rr. Tire % Critical Damping	5.00	%
Rr. Tire Damping Rate	343.95	Ns/m
Rr. Spring/Damper Motion Ratio	0.84	-
Rr. SPRING Rate (incl. Scaling)	97.50	N/mm
Rr. Spring Pre-Load (incl. Scaling)	27.65	mm
Rr. WHEEL Rate (incl. Scaling)	68.14	N/mm
Rr. RIDE Rate	54.99	N/mm

SCALED Rear Damper Data

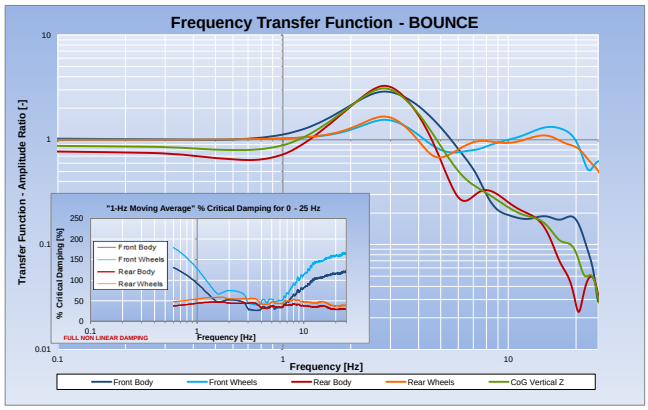
Jounce Speed [mm/s]	Jounce Force [N]	Rebound Speed [mm/s]	Rebound Force [N]
0.0	0.0	0.0	0.0
25.0	150.0	-25.0	-100.0
50.0	400.0	-50.0	-200.0
100.0	800.0	-100.0	-400.0
150.0	1100.0	-150.0	-600.0
200.0	1300.0	-200.0	-800.0
300.0	1600.0	-300.0	-1250.0
500.0	2200.0	-500.0	-2000.0



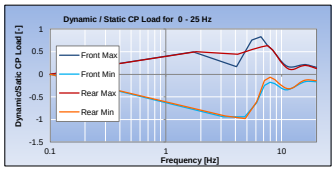
FREQUENCY DOMAIN RESULTS - 4 POSTER SWEEP SINE TEST

FULL NON LINEAR DAMPING

	FRONT Body	FRONT Wheel		CoG		REAR Body	REAR Wheel	
Peak Resonance Frequency in FTF	2.75	2.75	Hz	2.75	Hz	2.75	2.75	Hz
Dynamic Overshoot @ Peak Res. Freq.	2.88	1.55	mm/mm	3.09	mm/mm	3.26	1.67	mm/mm
% Crtical Damping @ Peak Res. Freq (-3dB)	37.52	46.92	%	28.93	%	26.10	38.55	%
Dynamic Wheel Load Indicator 0 - 25 Hz *		5.706	-				4.320	-



	FRONT		REAR
Max. Dynamic /Static Contact Patch Load	0.832	-	0.635
Min. Dynamic /Static Contact Patch Load	-0.941	-	-0.980
Diss. Damper Energy	137.692	Ws	153.772
Diss. Tire Energy	67.549	Ws	89.108

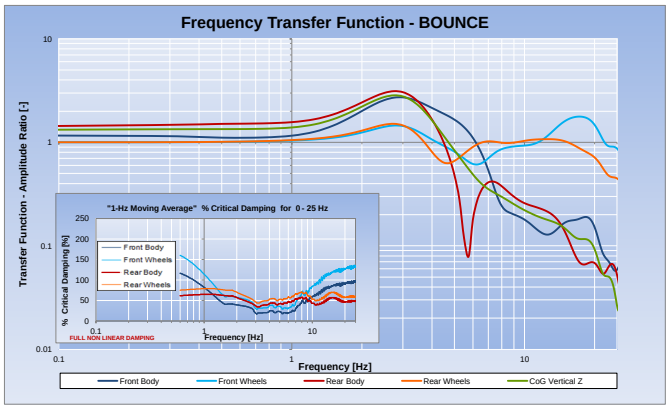


Exponentially Decaying Amplitude

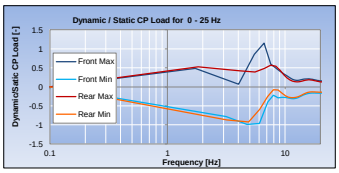
Start Peak to Peak Road Input Amplitude @ 0 Hz 15.0 mm

FULL NON LINEAR DAMPING

	FRONT Body	FRONT Wheel		CoG		REAR Body	REAR Wheel	
Peak Resonance Frequency in FTF	3.00	17.26	Hz	2.75	Hz	2.75	2.75	Hz
Dynamic Overshoot @ Peak Res. Freq.	2.72	1.77	mm/mm	2.84	mm/mm	3.12	1.51	mm/mm
% Crtical Damping @ Peak Res. Freq (-3dB)	39.66	22.34	%	33.87	%	33.09	47.80	%
Dynamic Wheel Load Indicator 0 - 25 Hz *		7.297	-				5.021	-



	FRONT		REAR
Max. Dynamic /Static Contact Patch Load	1.150	-	0.571
Min. Dynamic /Static Contact Patch Load	-0.988	-	-0.922
Diss. Damper Energy	142.828	Ws	147.860
Diss. Tire Energy	77.920	Ws	83.992

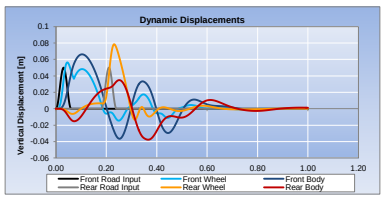


Exponentially Decaying Amplitude

Start Peak to Peak Road Input Amplitude @ 0 Hz 15.0 mm

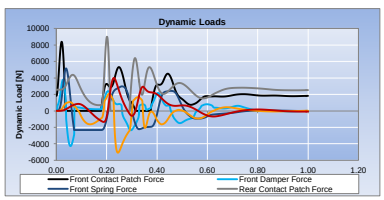
TIME DOMAIN RESULTS - HALF SINE / RAMP TEST

z- Height Amplitude of Half Sine (Up +, Down -)	0.050	m
x-Length of Half Sine	1.000	m
Velocity over Half Sine	60.000	kph
Time for Half Sine	0.060	s
Delay Rear to Front Axle	0.180	s
Excitation Frequency	8.333	Hz



Front Body Results		
Time to 95% dampened oscillation	0.680	s
Dynamic Peak Overshoot	1.325	m/m
Time to Reach Peak Value	0.103	s
Maximum Vertical Acceleration	62.95	m/s²

Rear Body Results		
Time to 95% dampened oscillation	0.630	s
Dynamic Peak Overshoot	0.753	m/m
Time to Reach Peak Value	0.186	s
Maximum Vertical Acceleration	32.24	m/s²



Front Wheel Results		
Max. Contact Patch Load	8386.0	N
Wheel Lift Time	0.201	s
Dynamic CP Load Integrator	481.07	Ns

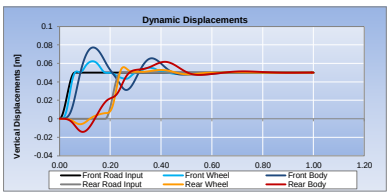
Rear Wheel Results		
Max. Contact Patch Load	8997.8	N
Wheel Lift Time	0.08	s
Dynamic CP Load Integrator	435.09	Ns

MORE FAVOURABLE VALUES HIGHLIGHTED IN GREEN

Time to pass over Ramp	0.060	s
Delay Rear to Front Axle	0.180	s
Excitation Frequency	4.167	Hz
z-Height of Ramp (Up +, Down -)	0.050	m
x-Length of Ramp	1.000	m
Velocity over Ramp	60.000	kph

Front Body Results		
Time to 95% dampened oscillation	0.431	s
Dynamic Peak Overshoot	1.545	m/m
Time to Reach Peak Value	0.133	s
Maximum Vertical Acceleration	42.27	m/s²

Rear Body Results		
Time to 95% dampened oscillation	0.307	s
Dynamic Peak Overshoot	1.234	m/m
Time to Reach Peak Value	0.235	s
Maximum Vertical Acceleration	18.95	m/s²



Front Wheel Results		
Max. Contact Patch Load	5106.1	N
Wheel Lift Time	0.053	s
Dynamic CP Load Integrator	227.19	Ns

Rear Wheel Results		
Max. Contact Patch Load	5918.8	N
Wheel Lift Time	0.00	s
Dynamic CP Load Integrator	221.45	Ns