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DYNATURE has been developed in order to provide a convenient MS EXCEL based tool for quick parameter studies based on a elementary car data set. DYNATURE is entirely based on analytical equations which are commonly available in automotive engineering and for decades have proven their validity. DYNATURE has been developed to be used especially in the conceptual phase and/or during the final chassis development where it has proved to be also an excellent support for the engineers providing either a quick setup tool allowing theoretical support to their daily business or a useful tracking tool for their data. Every aspect of setting up a car is analyzed in a specific sheet. Main objective for the development of DYNATURE was providing a robust customer driven development tool in EXCEL with a minimum of data necessary. **In the full version of DYNATURE 7.0 a Lap Simulator & Test -Tracks have been included with resp. control panels.**

All frequently used data are being entered in the "MASTER DASHBOARD" sheet. The sheet permits thus next to simulation control also quick model overview. From there on the data will be distributed to the various detailed calculation sheets and specific calculation options can be set. In the specific sheets ADDITIONAL (less commonly used) data has to be entered.

All relevant vehicle data (Mass, Dimensions, Pay-Load, Aerodynamics etc.) have to be entered in the "VEHICLE DATA" sheet. Once entered they remain fixed for all calculations.

In the "CHASSIS DATA" sheet all additional specific TIRE & SUSPENSION data have to be provided: Basic Kinematic Data, Compliances and Elementary Tire Data. In Version 7.0 and above specific User Guidance Tools are available for Tire Data and Suspension K&C Data. Also an "enhanced" Tire model is available for more in depth tire data presentation and calculation.

In the "RESULTS" Sheet one can find for comparison all input and results data for the actual vehicle and a reference vehicle (each in one column) with metrics and plots. Data can be im-/exported.

The "VEHICLE MODEL" sheet represents the core 6 DOF-vehicle model. Based on the requested load condition the 6 DOF-model will calculate all data for the 4 corners and all necessary data will be passed onwards to the other (bicycle-model) sheets. Detailed wheel data of all 4 corners are available. From Version 7.0 onwards Performance Envelope Graphs are available.

The "SPRING TUNING" sheet provides specific information on typical spring setup parameters of a car. Natural Frequencies, Bounce & Pitch Centers etc.

The "DAMPER TUNING" sheet requires all DAMPER data and allows a typical analysis of damper characteristics like percentage of critical damping and various transient ride transfer functions

The "ROLLBAR TUNING" sheet provides info about basic mechanical balance, based on roll couple distribution, roll center heights and lateral load transfer (distribution)

In the "UNDERSTEER" sheet a prediction of the LINEAR range understeer behaviour (UG) is GENERICALLY calculated (based on a bicycle model & the formulas of BUNDORF). Considering spring & rollbar settings (=load transfer) and elementary tire behaviour, understeer gradients are predicted for various g-Levels. Furthermore, if selected in the MASTER DASHBOARD sheet - for a given SPECIFIC lateral acceleration - the UG for one single operating point (considering eventual effects of non-linear bump-stops) will be calculated. From Version 7.0 onwards a Performance Envelope Graph for Understeer Gradient and Vehicle Side Slip Angle Gradient can be plotted as function of Ax, Ay and Velocity.

The "FREQUENCY STEER" sheet calculates the Generic Frequency Steer Response for YAW, SLIP ANGLE and LATERAL ACCELERATION. In addition - if selected in the MASTER DASHBOARD sheet - a specific "Partially Linearized" Frequency Response can be calculated by entering a specific STEERING WHEEL ANGLE (SWA). By doing so, degressive tire vertical & lateral load characteristics will be taken into account for the resulting lateral acceleration. All calculations are based on a bicycle model.

The "STEP STEER" sheet calculates the generic STEP STEER Response for YAW, SLIP ANGLE and LATERAL ACCELERATION. In addition - if selected in the MASTER DASHBOARD sheet - a specific "Partially Linearized" STEP STEER Response can be calculated by entering a specific STEERING WHEEL ANGLE (SWA). By doing so, degressive tire vertical & lateral load characteristics will be taken into account for the resulting lateral acceleration. All calculations are based on a bicycle model.

Version 7.0 onwards:

The "CIRCUIT LAYOUT" Sheet permits creation of a virtual Test/Race Track / Stage Section. The track MUST consist of at least 4 Straight/Corner sections as indicated below. The maximum number of corners is 20. All Track-Data is 2D-Only. Available are a typical real life High-Speed & Low-Speed Handling Track and a Generic Test Track for quick comparison studies. The ACTUAL Track Data can be exported/imported to a specific EXCEL file (*.xlsx) for convenient data transfer.

The "LAPTIME CONTROL" Sheet is the 2nd heart of DYNATURE. In analogy to the "MASTER DASHBOARD" Sheet is here all simulation control concentrated for the Laptime Simulation and related settings.

The "LAP RESULTS" Sheets provides in analogy to the "RESULTS" Sheet a customizable sheet with some example of comparison graphs for a current actual lap and a reference lap. Reference Lap data can be exported for external postprocessing.

This Workbook requires the activation of iterations in EXCEL options (manual, 50 iterations, 0.001 accuracy) and b) the activation of the ANALYSIS TOOLPAK Add-Inn

Description of Worksheets

MASTER DASHBOARD - Master Control Sheet

Input	Most frequently used common parameters, which will be passed onwards through to the actual reference & calculation sheets - for user convenience.
Output	Most Frequently used results, both GENERIC and SPECIFIC (= in case of input of a specific Steering Wheel Angle or Lateral Acceleration)

REMEMBER: Lateral Acceleration and Steering Wheel Angle (SWA) do trigger specific calculations whenever they are not equal to 0. The "START" Button will initialise the model with G-lat=0, G-Long=0, Steering Wheel Angle = 0 & Velocity of 120 kph (it will also set iteration parameters to default). The "GO GENERIC" Button will run a GENERIC Calculation which permits you to change VELOCITY and LONGITUDINAL acceleration. The "GO SPECIFIC" Button runs a calculation addressing ONE SPECIFIC Load case for G-LAT, G-LONG, SWA & VELOCITY. (The SPECIFIC calculation will partially use results of the GENERIC calculation). The "GO FULL NON-LINEAR" Procedure will run a full NON-LINEAR sweep from 0 to G-LAT-MAX in 10 intermediate steps, saving all of them in the "RESULTS" SHEET. In Version 7.0 the "GO LAPTIME" Button will enable laptime simulation.

VEHICLE DATA - Aerodynamics, Dimensions, Masses Input & Other Vehicle Data

Input	Mass Values and Locations, Brakes and Driveline data, Aerodynamic Data. REFERENCE RIDE HEIGHT IS DEFINED FOR CURB WEIGHT . Wheel Locations, Passenger and Pay-Load (H-)Points - Unsprung Masses are located @ X,Y Wheel Locations & and Tire Static Loaded Radius Z - Location, Brake Distribution, Drive Torque Distribution, Vehicle Aerodynamic LIFT & DRAG data & their eventual Ride-Height dependency (Aermaps).
Output	NOTE: If Aerodynamic Data are provided as Aermaps, these maps must be continuous without singularities, discontinuities or severe local non-linearities. All Relevant Mass and Inertia data and Instantaneous Aerodynamic Lift & Drag Values

CHASSIS DATA - Tire and K&C Suspension Data

Input	Suspension Kinematic and Compliance Characteristics, Tire Data. Version 7.0 comes with specific knowledge bases for Tire Data and K&C Data. Basic suspension characteristics (wheel rates, toe & camber) available from K&C Measurements, or CAE Multibody calculations & Tire Data: SLR speed dependency. Cornering Stiffness, Aligning Torque and Camber Stiffness - In Version 7.0 an optional Enhanced Tire Model is implemented which creates from the equations of the Base Tire Model non-linear curvefits for Slip Angle and Lateral Force (similar to a B-Spline/Pacejka Tire Model). The Enhanced Tire Model will give in particular more accurate results in the non-linear range of the tire. The Enhanced Tire Model will only be used in calculations combined with the 6DOF Model. Steer Steep & Frequency Response are unaffected. Side-View Swing Arms with Anti-Lift, Anti-Dive and Anti-Squat Angles. NOTE: SUSPENSION ANTI'S DO CHANGE ACCORDING SPRUNG MASS VERTICAL Cog POSITION. Roll Center Heights and Motion Ratios for Roll Center Height migration vs. wheel travel. Kinematic and Compliant Data are entered as linear rates. Wheel rates are linear. If applicable a NON-LINEAR Bump-Stop can be superimposed. ALL DATA REFER TO WHEEL PLANE. Bump-Stop is defined by Bump-Stop Gap, Bump-Stop Final Rate & Bump-Stop Displacement to Final Bump-Stop Rate. Details on Wheel Load Deflection Curve.
Output	Load Deflection Curve & Suspension Anti's

RESULTS - Sheet for Comparison of 2 or more vehicle (custom)

Input	All model data and results for the actual model and a reference data set - Data for a reference model can be exported or imported to/from an external file
Output	Comparison of most important metrics and graphs. Sheet can be customized

VEHICLE SIMULATION MODEL - 6 DOF-Model

Input	Longitudinal and Lateral Acceleration, Speed & Aerodynamic Loads All 4 wheel displacements & reaction forces (X,Y,Z) and all relevant suspension/vehicle data for further detailed analysis like Vehicle Roll, Vehicle Pitch, Compliant Wheel Deflections and resulting Kinematic Toe & Camber changes. Combined load cases are possible. In Version 7.0 with Enhanced Tire Model the lateral axle forces are distributed also according to tire slip angles and not to vertical load conditions only. This can lead to a more accurate representation and slightly different results from the base tire model In Version 7.0 Performance Envelope Graphs for Ax & Ay as function of Velocity. Both can be created either with LINEAR as NON-LINEAR approach
Output	NOTE: All calculations are partially LINEAR. Effects of Bump-Stops, Payload & Aerodynamics are considered if applicable in the actual load condition

SPRING TUNING - Natural Frequencies and Pitch & Bounce Center Calculation

Input	Wheel rates and Tire Vertical Rates for specified load condition
Output	Front and Rear Rake Frequencies, Bounce and Pitch Frequencies of the sprung mass. Bounce and Pitch Centre & carpet plots for the best combinations of front & rear spring rates NOTE: All calculations are partially LINEAR. Effects of Bump-Stops, Payload & Aerodynamics are considered if applicable in the actual load condition

DAMPER TUNING - Percent Critical Damping

Input	Measured Damper Force/Velocity Data and Damper Motion Ratio's for conversion of Damper Data to numbers @ Wheel plane
Output	Various Curves for Percent Critical Damping for Body and Wheel in compression and rebound damping. Ride Step Input Response with following damped oscillation in the time domain (CAN BE DEACTIVATED).
	Ride Frequency Transfer Function with maximal amplification factor and dynamic wheel load factor (DEACTIVATED BY DEFAULT IN ORDER TO SAVE COMPUTING TIME)

Note: All calculations are based on LINEAR damper characteristics - calculated out the first 3 bump and rebound velocities of NON-LINEAR damper data. Effects of Payload, Aerodynamics & Bump-Stops are considered if applicable in the actual load condition

ROLLBAR TUNING - Mechanical Balance

Input	Front and Rear Suspension roll rates from Chassis Data Input sheet (GENERIC) or actual values provided by 6 DOF VEHICLE MODEL in case of a specific load case
Output	Linear Roll angle Gradient, Roll couple Distribution, Wheel Load Transfer & Lateral Load Transfer Distribution. NOTE: All calculations are partially LINEAR. Effects of Bump-Stops, Payload & Aerodynamics are considered if applicable in the actual load condition

UNDERSTEER - Bicycle Model for Linear Understeer Behaviour

Input

Front and Rear Tire Data corresponding to the vertical load condition of the operating point, Spring & Rollbar Settings (Roll Rates), Suspension Kinematics & Compliance Data.
NOTE 1): THE TIRE MODEL IS PARAMETRIC AND BASED ON CORNERING STIFFNESS APPROACH. DATA WILL BE SCALED FROM REFERENCE LOAD PARTIALLY LINEAR TO IT'S VERTICAL & LATERAL LOAD CONDITION @ OPERATING POINT. THE COMBINED SLIP TIRE MODEL IS BASED ON ELEMENTARY FRICTION CIRCLE BEHAVIOUR, MEANING THAT AT TIRE CORNERING STIFFNESS WILL BE MAXIMAL AND AT FULL LONGITUDINAL MUE SATURATION THE CORNERING STIFFNESS WILL BE MINIMAL.

NOTE 2): STEERING GEOMETRY EFFECTS ARE NOT CONSIDERED.

NOTE 3): IN VERSION 7.0 THE ENHANCED TIRE MODEL ALLOWS MORE DETAILED ANALYSIS DUE TO THE LOOK-UP TABLE APPROACH. COMBINED SLIP REMAINS AS IN NOTE 1)

Output

Linear Range Understeer Gradient (UG), Vehicle Slip Angle Gradient (VG). In Version 7.0 Performance Envelopes for UG and VG as function of Ax, Ay & Velocity

Approximated Understeer Characteristics (UG, VG) for various lateral g-Levels based on Tire Load Characteristics & Roll Rates at those lateral g-Levels.

NOTE: "Partially Linearized" Understeer Predictions at various lateral acceleration levels are based on the "partially" linearization of all tire characteristics at the specific operating conditions defined by the corner loads provided by the 6 DOF-Vehicle Model.

Note: All calculations are partially LINEAR. Payload, Speed, Aerodynamics AND LONGITUDINAL ACCELERATIONS are considered (Aerodynamic & Brake induced U/Oversteer).

FREQUENCY STEER - Bicycle Model for Frequency Steer Response

Input

Speed, Aerodynamics, Longitudinal Acceleration & optionally Steering Wheel Angle (which also acts as a TRIGGER for a specific calculation using vehicle understeer data for the lateral acceleration corresponding to the given SWA).

Output

GENERIC- Linear Frequency Transfer Function Data (FFT) for Yaw, Vehicle Slip Angle and Lateral Acceleration & Corresponding Phase Shift Data

SPECIFIC- Frequency Transfer Function Data (FFT) for Yaw, Vehicle Slip Angle and Lateral Acceleration & Corresponding Phase Shift Data using vehicle understeer data for the lateral acceleration corresponding to the given SWA.

Key Metrics & Undamped Yaw Natural Frequencies for various speeds with corresponding Yaw Damping Values

Note: All calculations are partially LINEAR. Payload, Aerodynamics AND LONGITUDINAL ACCELERATIONS are considered (Aerodynamic & Braking Stability).

STEP STEER - Bicycle Model for Step Steer Response

Input

Speed, Aerodynamics, Longitudinal Acceleration & optionally Steering Wheel Angle (which also acts as a TRIGGER for a specific calculation using vehicle understeer data for the lateral acceleration corresponding to the given SWA).

Output

GENERIC- Linear Step Steer time domain data for Yaw, Vehicle Slip Angle and Lateral Acceleration & Corresponding Key Metrics

SPECIFIC- Step Steer time domain data for Yaw, Vehicle Slip Angle and Lateral Acceleration & Corresponding Key Metrics using vehicle understeer data for the lateral acceleration corresponding to the given SWA.

Note: All calculations are partially LINEAR. Payload, Aerodynamics AND LONGITUDINAL ACCELERATIONS are considered (Aerodynamic & Braking Stability).

VERSION 7.0

CIRCUIT LAYOUT - Create your own Test Track

Input

2D Circuit Data. X & Y coordinates of "Driving Line". 5 Points per Corner and 2 Points for every Straight. Track data can be ex-/imported to/from an external file

Output

Circuit Graph, Distances and Cornering Radii

LAPTIME CONTROL - CONTROL Sheet for Laptime Simulation

Input

Laptime Simulation Control Data, Stepsize, Understeer Gradient and Vehicle Side Slip Angle Gradient Limits. Both LINEAR as NON-LINEAR calculations

Output

Laptime, Section Data, Elementary Laptime Results

LAP RESULTS - Sheet for Comparison of Laptime results of 2 vehicles (custom)

Input

Time History Data Set of a Laptime Simulation for the actual model and a reference data set. Reference Lap data can be exported to an external file.

Output

Comparison of most important metrics and graphs of a Lap. Sheet can be customized

10 EASY STEPS TO HAPPY SIMULATIONS IN DYNATURE

1) REMEMBER THAT THE WORKBOOK IS COPY PROTECTED. IF YOU DO WANT TO SAVE THE WORKBOOK UNDER A DIFFERENT NAME, DO SO AS DESCRIBED IN THE EULA SHEET. THIS IS AN INCONVENIENCE DUE TO THE PROTECTION SOFTWARE. EACH VERSION OF DYNATURE HAS ITS OWN FEATURES ENABLED/DISABLED. **REMEMBER THAT THE PROTECTION SOFTWARE WILL ALWAYS SAVE THE WORKBOOK ON EXIT.**

2) REMEMBER THAT THE WORKBOOK IS BASED ON ANALYTICAL EQUATIONS. THIS IS IT'S STRENGTH FOR VELOCITY- HOWEVER, IF YOU ENTER NUMBERS THAT FOR SOME PHYSICAL REASON DO NOT MAKE SENSE OR CREATE SINGULARITIES THE WORKBOOK CAN SHOW "#NUMBER"- SOMETIMES NOT RECOVERABLE. **WHEN THIS HAPPENS FIRST RUN THE START/INITIALISE PROCEDURE WHICH SHOULD RESOLVE THE PROBLEM. IF THIS DOES NOT FIX THE PROBLEM AND IF YOU DID NOT MAKE A BACKUP COPY BUT DO NOT WANT TO LOSE YOUR INPUT DATA DO NOT EXIT THE SHEET (WHICH SAVES ALL THE ERRORS). BUT KILL MANUALLY THE EXCEL PROCESS IN WINDOWS TASK MANAGER AND THEN RE-OPEN THE FILE.** IN CASE THAT A BACKUP FILE EXISTS, ONE CAN EXIT AND START WITH THE BACKUP SHEET.

3) ALL RELEVANT INPUT FIELDS HAVE BEEN PROVIDED WITH SENSIBLE PHYSICAL LIMITS IN ORDER TO AVOID SINGULARITIES IN THE CALCULATION. SINCE A NOVICE COULD PRODUCE CASE 2) IT IS HOWEVER STRONGLY RECOMMENDED TO MAKE A COPY OF THE ORIGINAL SHEET IN WINDOWS EXPLORER FOR REFERENCE. SEE 1)

4) DO READ THE "README PAGE" AND MAKE SURE THAT YOU HAVE FOLLOWED ALL MENTIONED RECOMMENDATIONS. MOST OF ALL MAKE SURE THAT YOUR TIRE DATA ARE CORRECT FOR THE OPERATING POINT VERTICAL LOAD CONDITION THAT YOU DO WANT TO INVESTIGATE.

5) THE TIRE MODEL IS BASED ON ALGORITHMS OF CORNERING STIFFNESS IN FUNCTION OF VERTICAL, LATERAL & LONGITUDINAL LOAD AND HAS BEEN KEPT AS LEAN AS NECESSARY IN ORDER TO AVOID TO GO TO COMPLEX PACEJKA INTERPOLATIONS OR OTHER TIRE-MODELS. VERIFY WHETHER YOUR TIRES ARE OPERATING IN THE CORRECT LOAD RANGE.

6) DYNATURE HAS BEEN SPECIFICALLY DEVELOPED AND ADAPTED TO MS EXCEL, ESPECIALLY FOR USING THE STANDARD ITERATION PROCEDURE OF EXCEL. BEAR IN MIND, THAT THE EXCEL-ITERATION ALGORITHM IS NOT AS PERFECT AS SOME SOPHISTICATED COMMERCIALLY AVAILABLE SOLVERS, SO PAY IN PARTICULAR ATTENTION WHEN EXECUTING CALCULATIONS WHILST USING BUMP STOPS. MAKE SURE THAT ALL RATE CHANGES ARE SMOOTH. ALL CALCULATIONS ARE PROGRAMMED IN SUCH A WAY THAT THE CALCULATIONS WILL ALWAYS FINISH. SEE ALSO 7)

7) AS LONG AS YOU DO NOT USE BUMP-STOPS OR RIDEHEIGHT DEPENDENT AERODYNAMICS, YOUR CALCULATIONS WILL BE STRAIGHT FORWARD. ONCE ENTERING INTO NON-LINEARITY OF THOSE FEATURES AND THUS BY PHYSICS ENFORCED NECESSARY "CIRCULAR" ITERATIONS YOUR SOLVER TIME WILL INCREASE. DO USE THESE ONLY IF YOU WANT OR NEED TO DO SO.

8) IF ACTIVATED, THE RIDE FREQUENCY TRANSFER FUNCTION WILL SLOW ALL CALCULATIONS DOWN, SINCE IN THE BACKGROUND VERY COMPLEX (I) FFT CALCULATIONS HAVE TO BE EXECUTED AT EACH ITERATION. DO ONLY USE THIS SWITCH IF YOU WANT TO INVESTIGATE THIS PARTICULAR MATTER AND TURN IT OFF AGAIN WHEN NOT NEEDED.

9) UNDERSTANDING THE WORD "LINEAR" & "GENERIC" IN CHASSIS DYNAMICS

A) LINEAR BEHAVIOR OF A SYSTEM: THIS SIGNIFIES THAT THE RESPONSE OF THE SYSTEM IS ALWAYS DIRECTLY PROPORTIONAL TO THE INPUT (EITHER "1" OR "10") WITHOUT ANY CHANGE OF STATE OF YOUR SYSTEM (ALL PARAMETERS REMAIN LINEAR & UNCHANGED). DUE TO THE LINEARITY THESE SYSTEMS CAN BE ANALYZED "GENERICALLY" AND PERMIT LINEAR EXTRAPOLATION TOWARDS A PARTICULAR CONDITION (PREDICTION).

NON-LINEAR BEHAVIOR OF A SYSTEM: THIS SIGNIFIES THAT THERE IS NO DIRECT PROPORTIONAL RESPONSE CAUSING USUALLY A CHANGE OF STATE WHICH MAKES A "SPECIFIC" INVESTIGATION AROUND THIS POINT NECESSARY. A NUMERICAL ITERATION IS NECESSARY TO APPROACH THIS POINT OF NON-LINEARITY, IT CANNOT BE PREDICTED BY LINEAR EXTRAPOLATION.

B) LINEAR TIRE BEHAVIOR: MEANS THAT THE TIRE CHANGES LINEARLY ITS MAJOR CHARACTERISTICS LIKE F.I. CORNERING STIFFNESS WITH LOAD & SLIP ANGLE.

NON-LINEAR TIRE BEHAVIOR: STARTS BECOMING NOTICEABLE USUALLY ABOVE 0.5 - 0.7 G LATERAL ACCELERATION CAUSING A NON-LINEAR CHANGE OF TIRE CORNERING STIFFNESS. THIS BEHAVIOR CAN BE SIMULATED BY CHANGING LINEAR CHARACTERISTICS STEPWISE OVER OPERATING RANGE (=PARTIALLY LINEARIZED).

C) LINEAR SUSPENSION CHARACTERISTICS: BOTH (ELASTO-)KINEMATICS & VERTICAL WHEEL RATE ARE LINEAR.

NON-LINEAR WHEEL RATES (=BUMP-STOPS) PROVOKE NON-LINEAR VERTICAL FORCE REACTIONS WHICH WILL RESULT IN A DIFFERENT TIRE BEHAVIOR, EFFECTIVELY CAUSING A CHANGE OF STATE WHICH REQUIRES ITERATIONS. NOT USING BUMP-STOPS WHILST CORNERING WILL KEEP YOUR SUSPENSION LINEAR & THEREFORE THE TIRE MORE LINEAR.

D) LINEAR RANGE UNDERSTEER: UNDERSTEER IN THE LINEAR RANGE OF VEHICLE DYNAMICS- THIS RANGE IS PRIMARILY DEFINED BY THE LINEAR RANGE OF THE TIRE AND CAN GO - DEPENDING ON THE TIRE - UP TO 0,7 G. THE LINEAR RANGE DEFINES ALL ON-CENTER HANDLING CHARACTERISTICS & BASIC TRANSIENT STABILITY OF A VEHICLE.

IMPORTANT NOTE 1): LINEAR RANGE UNDERSTEER CANNOT BE SENSED BY DRIVERS. THE TYPICAL DRIVER SENSED UNDERSTEER IS THE NON-LINEAR RANGE UNDERSTEER.

IMPORTANT NOTE 2): A VEHICLE WITHOUT LINEAR RANGE UNDERSTEER IS PHYSICALLY NOT STABLE AND CANNOT BE ANALYZED !

NON-LINEAR RANGE UNDERSTEER: UNDERSTEER IN THE RANGE WHERE EITHER TIRE OR SUSPENSION OR BOTH BECOME SIGNIFICANTLY NON-LINEAR (HIGH G-LOADS). THE NON-LINEAR UNDERSTEER BEHAVIOR AT HIGH G CAN BE SIGNIFICANTLY DIFFERENT FROM THE LINEAR RANGE AND CAN BE "UNDERSTEERING", "OVERSTEERING" OR "NEUTRAL".

10) USE THE SIMULATION BUTTONS ON THE MASTERSHEET CORRECTLY

A) AFTER ENTERING DATA DO **ALWAYS** RUN THE "**START/INITIALISE**" PROCEDURE. THIS WILL CALCULATE ALL INITIAL SETTINGS AND VERIFY WHAT PHYSICAL LIMITS ARE APPLICABLE TO THE VEHICLE. YOU WILL SEE THESE LIMITS AS LIMITS FOR THE SIMULATION. THE PROCEDURE WILL SET G-LAT, G-LONG, SWA TO ZERO & SET THE VELOCITY TO 120KPH. ALSO DEFAULT DYNATURE ITERATION VALUES WILL BE (RE-)SET.

B) THE "**GO GENERIC**" PROCEDURE WILL CREATE GENERIC (**G-LAT=0/SWA=0**) FOR LINEAR RANGE UNDERSTEER BEHAVIOR, FREQUENCY STEER RESPONSE AND STEP TEST. ONE CAN MODIFY ONLY "SPEED" AND "G-LONG" (IN ORDER TO SIMULATE THE EFFECTS OF AERO & LONGITUDINAL WEIGHT TRANSFER ON VERTICAL AXLE LOAD CHANGES AND THUS ON THE LINEAR LATERAL DYNAMIC BEHAVIOR OF THE TIRE). ONE CANNOT MODIFY THE STEERING WHEEL ANGLE. THE GENERIC CALCULATION DOES NOT PERMIT A CHANGE OF STATE OF THE MODEL MEANING THAT IN PARTICULAR WHEEL RATES REMAIN CONSTANT AS BEING CALCULATED AT THE START OF THE CALCULATION. THE LINEARIZED UNDERSTEER BUDGET CALCULATION FROM 0 TO G-LAT-MAX IS BASED ENTIRELY ON THIS PRINCIPLE AND MERELY CONSIDERS THE EFFECT OF LINEAR LATENT LOAD TRANSFER ON TIRE CHARACTERISTICS (=CORNERING STIFFNESS) AND THE CONSEQUENT EFFECT ON UNDERSTEER.

C) THE "GO SPECIFIC" PROCEDURE WILL ALLOW TO ENTER "G-LAT", "G-LONG", "SPEED" & "SWA" IN ORDER TO INVESTIGATE ONE SINGLE SPECIFIC CONDITION ALLOWING ANALYSIS OF THE RESULTS FOR ALL 4 CORNERS OF THE VEHICLE IN THAT CONDITION. IN THE "SPECIFIC" CALCULATION A CHANGE OF STATE OF THE MODEL - REFLECTING FOR INSTANCE WHEEL RATE CHANGES DUE TO A BUMPSTOP- IS POSSIBLE. SINCE A CHANGE OF STATE IS PERMITTED THE RESULTS FROM C) CAN DIFFER SIGNIFICANTLY FROM B). THE RESULTS OF ALL 4 CORNERS WILL BE USED FOR CALCULATING THE EFFECTIVE AXLE CORNERING STIFFNESS'S WHICH WILL BE USED FOR THE BICYCLE MODEL. IF HOWEVER NO CHANGE OF STATE OCCURS (I.E NO BUMPSTOP ACTIVATION) THE RESULTS OF THE SPECIFIC CALCULATION WILL BE EQUAL TO THE GENERIC ONE.
DO NOTE THAT A SPECIFIC STEERING WHEELANGLE (SWA) INPUT WILL ONLY AFFECT THE "STEP STEER" & "FREQUENCY STEER" PROCEDURE CHANGING THEM FROM "GENERIC" RESULTS TO "SPECIFIC" RESULTS FOR ONE PARTICULAR LATERAL ACCELERATION WHICH IS CORRELATED TO THE IMPOSED STEERING WHEELANGLE. PLEASE NOTE THAT DIFFERENT FROM ALL ABOVE A CHANGE OF STATE OF THE MODEL IS FOR THESE TYPE OF CALCULATIONS NOT POSSIBLE (LINEAR BICYCLE MODEL). ENTERING A SPECIFIC SWA WILL ALLOW A FAST COMPARISON WITH MEASURED TEST DATA - WHICH ARE USUALLY RECORDED FOR A DEFINED SWA OR A DEFINED LATERAL ACCELERATION. SPEED AND G-LONG ARE AGAIN FREE TO BE CHANGED IN ORDER TO SIMULATE THEIR EFFECT ON VERTICAL AXLE LOAD & CORNERING STIFFNESS.

D) THE "GO FULL NON-LINEAR" PROCEDURE REPEATS BASICALLY THE "GO-SPECIFIC" PROCEDURE FROM "0" TO "G-LAT-MAX" IN 10 STEPS. ALL RESULTS WILL BE SAVED FOR EACH INTERMEDIATE STEP IN THE "RESULTS" SHEET. THE "GO FULL NON-LINEAR" PROCEDURE WILL PERMIT DETAILED ANALYSIS OF THE WHOLE RANGE OF LATERAL ACCELERATION.

E) THE "CLEAR FULL NON-LINEAR" PROCEDURE WILL ERASE ALL THE RESULTS FROM THE "GO FULL NON-LINEAR" PROCEDURE LEAVING ONLY THE LAST DATA POINT.

F) THE "SET DATA REFERENCE" PROCEDURE WILL COPY ALL OF YOUR EXISTING "ACTUAL" MODEL DATA IN THE "RESULTS" SHEETS TO THE "REFERENCE" COLUMN AS VALUES. THIS PERMITS AN EASY COMPARISON BETWEEN TWO VEHICLES. REVERTING THE PROCEDURE CAN BE DONE WITH THE "LOAD DATA REFERENCE" PROCEDURE WHICH WILL COPY ALL INPUT DATA FROM THE REFERENCE DATA SET TO THE ACTUAL DATA BEING USED.

G) THE "EXPORT REFERENCE DATA" PROCEDURE WILL EXPORT ALL OF YOUR "REFERENCE" MODEL DATA IN THE "RESULTS" SHEETS TO AN EXTERNAL EXCEL SHEET IN .XLSM FORMAT. VICE VERSA THE "IMPORT REFERENCE DATA" PROCEDURE WILL IMPORT A PREVIOUSLY CREATED "EXPORT" DATASET ON TO THE REFERENCE DATA.

F9 however still works and can be used when working in detailed tuning sheets

VERSION 7.0

AND ANOTHER 10 STEPS FOR HAPPY LAPTIME SIMULATION

1) APPLY ALL 10 PREVIOUS STEPS FROM HAPPY SIMULATIONS. STRICTLY

2) THE EASIEST TRACKS ARE LIKE THE INCLUDED "GENERIC" TRACK- BRAKE ON THE STRAIGHT AND THEN CORNER TO THE MAX. ALL OTHER COMBINATIONS ARE MORE DEMANDING BOTH FOR THE DRIVER AS FOR THE CALCULATION. REMEMBER THAT.

3) KEEP TRACKS AS SHORT AS POSSIBLE. DO NOT USE 20 CORNERS JUST BECAUSE YOU CAN. A QUICK SCAN ON 4 CORNERS WILL OFTEN GIVE ALSO GOOD INDICATIONS.

4) WHEN RUNNING A NEW TRACK FOR THE FIRST TIME, THE STANDARD 250 ITERATIONS WILL NOT BE SUFFICIENT TO CONVERGE TO A ROBUST SOLUTION. THE MORE COMPLEX THE TRACK, THE MORE NON-LINEAR THE CAR, THE MORE TIME IS NEEDED. DEPENDING ON YOUR HARDWARE INCREASE ITERATIONS TO 10.000 AND LET IT RUN FOR A WHILE. REPEAT IF NECESSARY.

5) ALWAYS VERIFY THE LAPTIME RESULT BY RUNNING AN ADDITIONAL STANDARD RUN (250 ITERATIONS) IN ORDER TO VERIFY THAT THE LAPTIME DOES NOT CHANGE ANYMORE INDICATING THAT THE OPTIMIZATION PROCEDURE HAS FINISHED CORRECTLY.

6) TRY TO AVOID A "NON-LINEAR" CAR WITH BUMPSTOPS ACTING IN CORNERING. A LINEAR CALCULATION IS A LOT FASTER THAN A NON-LINEAR.

7) THE BASE TIRE MODEL IS A LOT FASTER THAN THE ENHANCED TIRE MODEL. WITH RESPECT TO LAPTIMES THE DIFFERENCES BETWEEN THE TWO TIRE MODELS ARE MARGINAL. AND DIFFERENCES ARE SOLELY DUE TO LIMIT UNDERSTEER GRADIENT BEHAVIOUR. IF YOU ARE NOT INTERESTED IN DETAILED UNDERSTEER ANALYSIS USE BASE TIRE MODEL.

8) UNLESS YOU ARE INTERESTED IN CORRELATING THE UNDERSTEER LIMITS OF THE MODEL TO DRIVER PERCEPTION LET THE LIMITS FOR UNDERSTEER GRADIENT AND VEHICLE SIDE SLIP ANGLE GRADIENT AS HIGH AS POSSIBLE. THIS WILL AVOID MANY ITERATIVE CALCULATIONS TOWARDS THE IMPOSED LIMITS FOR THEM.

9) DO NOT RUN TIME HISTORY CALCULATIONS UNLESS YOU ARE SURE YOU WANT TO. THE TIME HISTORY CALCULATION WILL TAKE EVERY DATAPoint OF THE LAPTIME SIMULATION AND RUN IT AS A "SPECIFIC" CALCULATION CREATING ALL DATA FOR THAT SPECIFIC POINT. DO ONLY DO THIS IF YOU ARE SURE THAT YOU NEED THIS INFORMATION.

10) REMEMBER THAT THE MORE COMPLEX YOUR MODEL IS (BUMPSTOPS), THE MORE COMPLEX YOUR TIRE MODEL IS (ENHANCED vs. BASE), THE MORE COMPLEX YOUR TRACK IS AND THE TIGHTER YOUR UNDERSTEER GRADIENT / SIDE SLIP ANGLE GRADIENT LIMITS ARE THE MORE TIME YOUR SIMULATION WILL TAKE. CREATING A NON-LINEAR PERFORMANCE ENVELOPE WILL TAKE BY ITSELF APPROXIMATELY 10 TIMES MORE CPU TIME THAN CREATING A LINEAR MAP. THE ENHANCED TIRE MODEL USES APPROXIMATELY 2,5 TIMES MORE CPU TIME THAN THE BASE TIRE MODEL. TIGHTNING UP THE LIMITS FOR UNDERSTEER GRADIENT / SIDE SLIP ANGLE GRADIENTS WILL INCREASE SIGNIFICANTLY THE NUMBER OF ITERATIONS IN ORDER TO FIND THE ACCORDING AX,AY POINTS ON THE PERFORMANCE ENVELOPE.

TUNING PARAMETERS & KEY TABULAR RESULTS

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DYNATURE-XL

This worksheet contains the most frequently used parameters for tuning and trade-off studies. All Parameters will be passed on to the calculation sheets. For definitions and more info see detailed sheets.

Output: Summary of most frequent results from calculation sheets. BEWARE that G-LAT and SWA do trigger specific calculations if they are different from 0.

After Changing Setup Data of the Car Hit "START" for the Initialisation. "GO GENERIC" executes the standard Calc. and "GO SPECIFIC" the Specific Calcs. This will first run the "Go Generic" Procedure and then execute the requested SPECIFIC Calculation. The "Go Full Non-Linear" Procedure does iterate the calculation for lateral acceleration from 0 to maximum lateral acceleration in 10 steps saving the results in the RESULTS Sheet.

In version 7.0 a Laptime Simulator has been incorporated. See detailed information in the Read Me Section & the Laptime Control sheet.

YOU CAN ONLY ENTER DATA IN THE BLUE/GREY CELLS. RESULTS ARE SHOWN IN THE YELLOW/RED CELLS

Aerodynamics
Fr. Lift Coeff. **0,100**

Drag Coeff. **0,350**
Frontal Area **2,500 m²**

Aerodynamics
Rr. Lift Coeff. **0,050**

Front Suspension Rates (w/o Tires)

Fr. Wheel Rate **20,0** N/mm
Bump-Stop Gap @ Wheel **25,0** mm
Displ. to Final Bump-Stop Rate **75,0** mm
Bump-Stop Final Rate @ Wheel **200,0** N/mm
Fr. Rollbar Roll Rate **38,20** N/m°
(Front Roll rate w/Tires) **750,0** N/m°
(Front Roll rate w/Tires) **791,2** N/m°

Physical Limits [g]	Lat. Acc.	Long. Acc. (Dec. Neg. / Acc. Pos.)
Aerodynamics & μ	0,88 g	-0,93 g
Aero Balance & Drag	0,86 g	-0,77 g
2 Wheel Lift	1,32 g	-1,93 g
Est. Limit due US/OS	0,85 g	0,23 g
		Traction, Power & Aero

Rear Suspension Rates (w/o Tires)

Rr. Wheel Rate **18,0** N/mm
Bump-Stop Gap @ Wheel **25,0** mm
Displ. to Final Bump-Stop Rate **75,0** mm
Bump-Stop Final Rate @ Wheel **200,0** N/mm
Rr. Rollbar Roll Rate **17,83** N/m°
(Pear Roll Rate w/Tires) **350,0** N/m°
(Pear Roll Rate w/Tires) **552,4** N/m°

- [GO TO VEHICLE DATA](#)
- [GO TO CHASSIS DATA](#)
- [GO TO RESULTS](#)
- [GO TO VEHICLE MODEL](#)
- [GO TO SPRUNG TUNING](#)
- [GO TO DAMPER TUNING](#)
- [GO TO ROLLBAR TUNING](#)
- [GO TO UNDERSTEER](#)
- [GO TO FREQUENCY](#)
- [GO TO STEP STEER](#)
- [GO TO LAPTIME](#)

start initial

go generic

go specific

go full non-linear

clear full non-linear

set data reference

load data reference

HIDE TRANSFER FUNCTION IS ACTIVE / CALCULATION WILL BE SLOW!

Front Tire Data

Fr. Tire Vertical Stiffness **131,0** N/mm
Fr. Tire Cornering Stiffness **899,0** N° @ Ref. Load
(@ operating point @ 0 g-lat) **911,2** N°

Tire Grip Level
Maximum Tire Friction Coefficient (μ) **0,90**
Tire Rolling Resistance Coefficient **0,013**

Front Suspension Geometry

Fr. Total Static Toe **-0,10** °
Fr. Static Camber **-0,50** °
Fr. Bump Steer **-3,0** %/m
Fr. Roll Center Height **50,0** mm
(Fr. Inst. Roll Center Height) **72,0** mm

Fr. Track Width **1500,0** mm

Fr. Ride Frequency **1,185** Hz

Fr. Anti-Dive **10,5** %

Fr. Anti-Lift **0,0** %

LF Wheel Load **3517,5** N
LF Wheel Travel **-8,1** mm
LF Toe **-0,017** °
LF Camber **-0,419** °
LR Toe **0,050** °
LR Camber **-0,750** °
LR Wheel Travel **1,0** mm
LR Wheel Load **2586,4** N

CURB WEIGHT CONDITION

Vehicle Data

Wheel Base **2600,0** mm
Total Mass **1275,0** kg
Overall CoG Height **556,6** mm
Weight Distribution **58,9** % Front
Total Yaw Inertia **2104,2** kgm²
Total Pitch Inertia **1891,6** kgm²

Pitch Center rel. to Fr. Axle **-0,45** m
Bounce Center rel. to Fr. Axle **-3,37** m

CALCULATION RESULTS FROM 6-DOF VEHICLE MODEL

Delta Fr. Ride Height **Susp. rebound** **9,4** mm
Delta Rr. Ride Height **susp. jounce** **-1,1** mm

Vehicle Roll Angle **0,0** °
Lat. Load Transf. Distr. (% Fr.) **58,2** %
LLT Bias rel. to CoG (+Fwd) **-0,7** %

Vehicle Pitch Angle **Squat** **0,23** °
Delta H-Point (Pitch & Roll) **Up** **4,32** mm

Rr. Anti Squat **0,0** %

Rr. Anti Lift **11,3** %

RF Wheel Load **3517,5** N

RF Wheel Travel **-8,1** mm

RF Toe **-0,017** °

RF Camber **-0,419** °

RR Toe **0,050** °

RR Camber **-0,750** °

RR Wheel Travel **1,0** mm

RR Wheel Load **2586,4** N

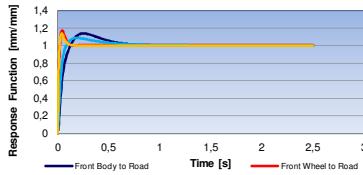
Tire Data ?
Click Here

Suspension Data ?
Click Here

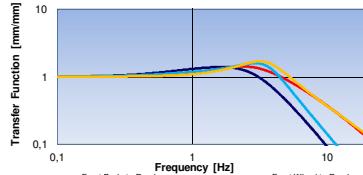
RIDE CHARACTERISTICS

calc. ride step calc. ride frequency calc. step & freq.
disable ride step disable ride frequency disable step & freq.

Ride Step Input Response Function



Ride Frequency Transfer Function



UNDERSTEER BUDGET 120,0 kph

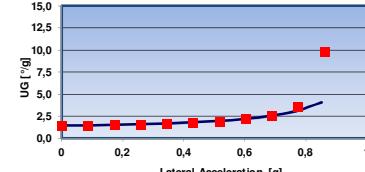
Characteristic Speed **114,65** kph
Linear Roll Angle Gradient **4,2** %/g

Fr. AXLE Cornering Stiffness @ 0 g **74573** N/rad
Rr. AXLE Cornering Stiffness @ 0 g **69797** N/rad
Understeer Gradient @ Wheel @ 0 g **1,44** %g
Side Slip Angle Gradient @ 0 g **4,22** %g

Understeer (US) Gradient @ g **0,85** **4,06** %g
Sideslip Angle (SSA) Gradient @ g **0,85** **14,83** %g

(SPECIFIC Calculation considering non-linear Bump-Stop effects)

Understeer Gradient



Imposed US Gradient Limit [%g]
(Cornering) in Laptime Simulation
15,0

Imposed Fr. & Rr. SSA Limit [%g]
(Cornering) in Laptime Simulation
15,0

GENERIC STEP STEER 120,0 kph

90% Response Time **0,210** s **0,570** s **0,470** s
Peak Value **0,447** 1/s **0,082** - **0,024** g/s
Time to Peak Value **0,480** s **0,930** s **0,830** s
Overshoot @ Peak **1,168** - **1,048** - **1,048** -

Yaw Gain [1/s] **0,210** s **0,570** s **0,470** s
Slip Angle Gain [-] **0,078** - **0,082** - **0,024** g/s
G-Lat Gain [g/s] **0,023** g/s **3,446** %g **0,830** s

Yaw Gain [1/s] **0,210** s **0,570** s **0,470** s
Slip Angle Gain [-] **0,078** - **0,082** - **0,024** g/s
G-Lat Gain [g/s] **0,023** g/s **3,446** %g **0,830** s

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Slip Angle Gain [-] **0,078** - **0,082** - **0,024** g/s
G-Lat Gain [g/s] **0,023** g/s **3,446** %g **0,830** s

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Slip Angle Gain [-] **0,078** - **0,082** - **0,024** g/s
G-Lat Gain [g/s] **0,023** g/s **3,446** %g **0,830** s

Yaw Gain [1/s] **0,210** s **0,570** s **0,470** s
Slip Angle Gain [-] **0,078** - **0,082** - **0,024** g/s
G-Lat Gain [g/s] **0,023** g/s **3,446** %g **0,830** s

Yaw Gain [1/s] **0,210** s **0,570** s **0,470** s
Slip Angle Gain [-] **0,078** - **0,082** - **0,024** g/s
G-Lat Gain [g/s] **0,023** g/s **3,446** %g **0,830** s

Yaw Gain [1/s] **0,210** s **0,570** s **0,470** s
Slip Angle Gain [-] **0,078** - **0,082** - **0,024** g/s
G-Lat Gain [g/s] **0,023** g/s **3,446** %g **0,830** s

Yaw Gain [1/s] **0,210** s **0,570** s **0,470** s
Slip Angle Gain [-] **0,078** - **0,082** - **0,024** g/s
G-Lat Gain [g/s] **0,023** g/s **3,446** %g **0,830** s

Yaw Gain [1/s] **0,210** s **0,570** s **0,470** s
Slip Angle Gain [-] **0,078** - **0,082** - **0,024** g/s
G-Lat Gain [g/s] **0,023** g/s **3,446** %g **0,830** s

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Yaw Gain [1/s] **0,210** s **0,570** s **0,470** s
Slip Angle Gain [-] **0,078** - **0,082** - **0,024** g/s

VEHICLE MASS & GEOMETRY DATA

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DYNATUNE-XL

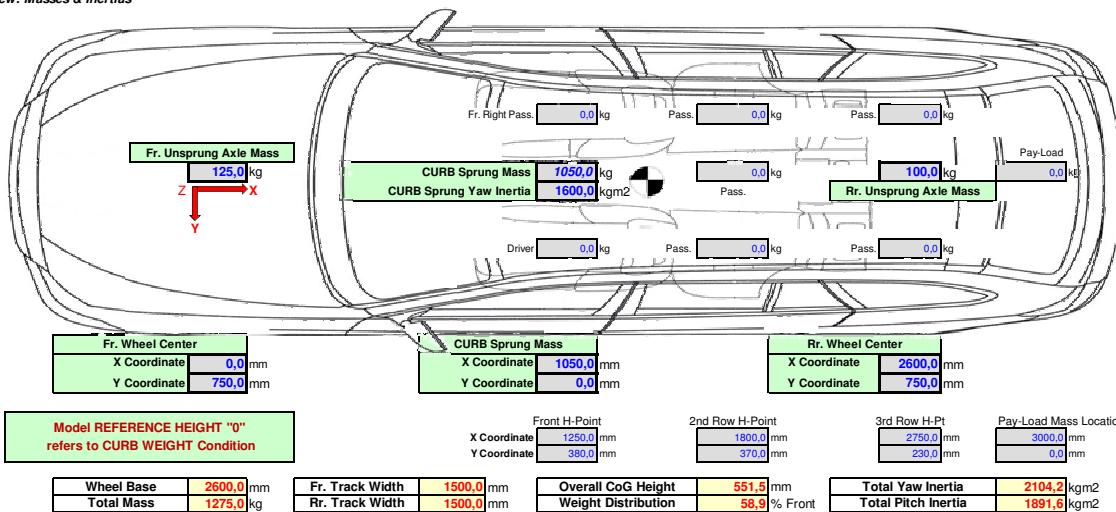
This sheet contains mass and geometric data which will be used in all calculation sheet. CURB WEIGHT = SPRUNG MASS & UNSPRUNG MASS, NO PASSENGERS, NO PAYLOAD
COORDINATE SYSTEM ORIGIN AT THE MIDDLE OF THE FRONT AXLE @ GROUND HEIGHT, MODEL REFERENCE HEIGHT "0" REFERS TO CURB WEIGHT CONDITION

[GO TO MASTER](#)

YOU CAN ONLY ENTER DATA IN THE BLUE/GREY CELLS. RESULTS ARE SHOWN IN THE YELLOW/RED CELLS
BLUE W/ YELLOW CELLS ARE PASSED THROUGH NUMBERS FROM THE MASTER CONTROL SHEET

Plan View

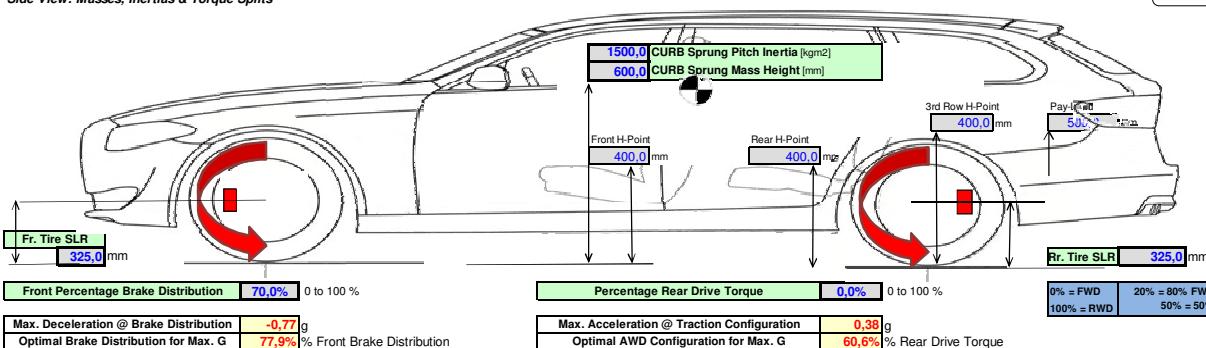
Plan View: Masses & Inertias



Side View

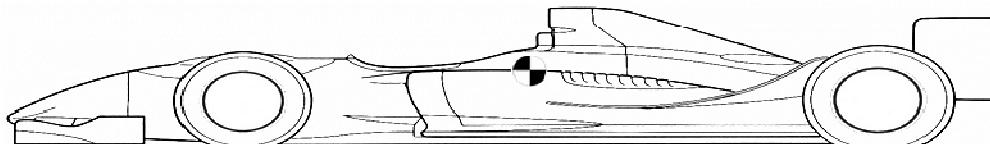
Side View: Masses, Inertias & Torque Splits

[GO TO MASTER](#)



Aerodynamic Data

Fr. Tire Lift Coef: 0.000 Fr. Tire Drag Coef: 0.000 Fr. Tire Frontal Area: 0.000 m² Speed: 120 kph
Fr. Tire Frontal Area: 0.000 m² Frontal Area: 2.50 m² Rr. Tire Lift Coef: 0.000 Rr. Tire Drag Coef: 0.000
Static Fr. Body Lift Coef. @ Ref RH: 0.10 Fr. Inst. Body Lift Force: 166.7 N Static Rr. Body Lift Coef. @ Ref RH: 0.05
Static Body Drag Coefficient @ Ref. RH: 0.35



[GO TO MASTER](#)

Delta Fr. Ride Height: 9.4 mm
Instant. Fr. Body Lift Coef: 0.100
Fr. Inst. Body Lift Force: 166.7 N

Tire Lift & Drag Force
Lift: 0.0 N
Drag: 0.0 N
Deceleration due to Drag Forces: -0.047 g
Inst. Body Drag Coef: 0.350
Inst. Body Drag Force: -583.3 N

Delta Rr. Ride Height: -1.1 mm
Inst. Rr. Body Lift Coef: 0.050
Rr. Inst. Lift Force: 83.3 N

Tire Lift & Drag Force
Lift: 0.0 N
Drag: 0.0 N

Theoretical G-Max: 0.882 g
(total aero load & tire grip)

ENABLE AEROMAPS: 0 Y/N 1/0
(static lift & drag values - used for linear prediction - will be set to average map value !)
WARNING: AEROMAP CALCULATION WILL INCREASE CALCULATION TIME !

G-Lat Max due to Aerodynamic Balance: 0.859 g
(aerodynamic load distribution, drag & tire grip)

FRONT LIFT COEFFICIENT AEROMAP [-]					
FRH	RRH [mm]				
-50.0	-25.0	0.0	25.0	50.0	
-25.0	-100.0	0.000	0.100	0.200	0.300
0.0	0.000	0.100	0.200	0.300	0.400
25.0	0.100	0.200	0.300	0.400	0.500
50.0	0.200	0.300	0.400	0.500	0.600

DRAG COEFFICIENT AEROMAP [-]					
FRH	RRH [mm]				
-50.0	0.050	0.100	0.150	0.200	0.250
-25.0	0.150	0.200	0.250	0.300	0.350
0.0	0.200	0.250	0.300	0.350	0.400
25.0	0.250	0.300	0.350	0.400	0.450
50.0	0.300	0.350	0.400	0.450	0.500

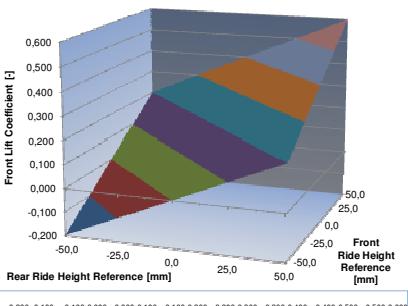
REAR LIFT COEFFICIENT AEROMAP [-]					
FRH	RRH [mm]				
-50.0	-200.0	-100.0	0.000	0.100	0.200
-25.0	-100.0	0.050	0.100	0.150	0.200
0.0	0.000	0.150	0.200	0.150	0.000
25.0	0.100	0.250	0.300	0.250	0.100
50.0	0.200	0.350	0.400	0.350	0.200

FRONT LIFT SCALING FACTOR: 1.00 -
(scaling of aeromaps, original data will be multiplied with value)

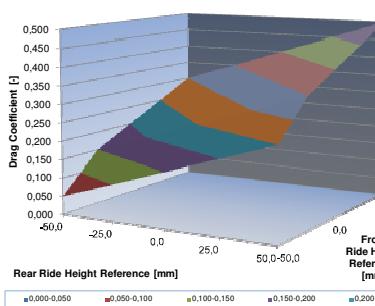
DRAG SCALING FACTOR: 1.00 -
(scaling of aeromaps, original data will be multiplied with value)

REAR LIFT SCALING FACTOR: 1.00 -
(scaling of aeromaps, original data will be multiplied with value)

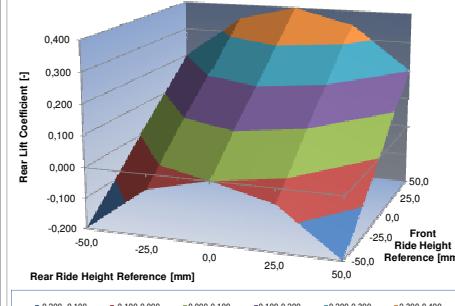
Front Lift Coefficient Aeromap



Drag Coefficient Aeromap



Rear Lift Coefficient Aeromap



ALL AEROMAP DATA MUST BE CONSISTENT WITHOUT SINGULARITIES OR SEVERE LOCAL NON-LINEARITIES

CHASSIS DATA FOR TIRE, SUSPENSION KINEMATICS & COMPLIANCE DATA

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This worksheet contains all relevant Chassis, Tire and K&C data that will be used in various calculation sheets. Specific damper data are to be entered in the Damper Tuning sheet.
Various helpful User Tools are available. From Version 7.0 onwards especially a generic Tire Data and Suspension K&C Data knowledge database can be used as a guidance for meaningful input data.

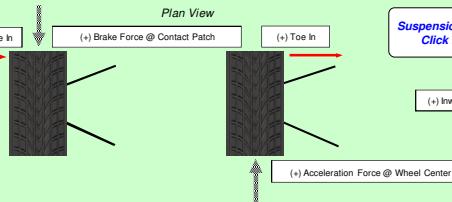
PAY ATTENTION TO THE SIGN CONVENTIONS BELOW

[GO TO MASTER](#)

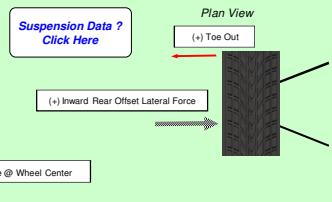
YOU CAN ONLY ENTER DATA IN THE BLUE/GREY CELLS. RESULTS ARE SHOWN IN THE YELLOW/RED CELLS

BLUE W/ YELLOW CELLS ARE PASSED THROUGH NUMBERS FROM THE MASTER CONTROL SHEET

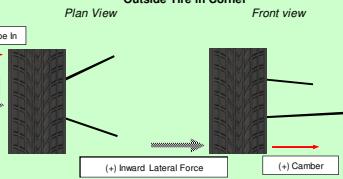
Longitudinal Compliance Sign Conventions



Aligning Torque Compliance Steer Sign Conventions



Lateral Compliance Sign Conventions Outside Tire in Corner



Front Suspension Static Toe and Camber Settings

Fr. Total Static Toe **-0.1** U °
Fr. Static Camber **-0.5** O °

Front Suspension Kinematic Ride Motion

Fr. Bump Steer **-3.0** U °/m
Fr. Camber Gain **-10.0** O °/m

Front Suspension Compliances

Fr. Lat. Force Toe Compliance **-0.250** U °/kN
Fr. Lat. Force Camber Compliance **0.300** U °/kN
Fr. Brake Steer **0.030** O °/kN
Fr. Acceleration Steer **0.030** O °/kN
Fr. Aligning Torque Compliance Steer **3.500** U °/kNm

Front Suspension Anti-Angles (SEE BELOW)

Fr. Anti-Lift Angle **0.0** °
Fr. Anti-Dive Angle **2.0** °

Front Suspension Roll Center

Fr. Roll Center @ Ref. Ride Height **50.0** mm
Roll Center Movement vs. Wheel Travel Ratio **2.65** - (0 fixed)

Front Suspension Wheel & Roll Rates

Fr. Linear Wheel Rate **20.0** N/mm
Bump-Stop Gap @ Wheel **25.0** mm ■
Displ. to Final Bump-Stop Rate **75.0** mm ■
Final Bump-Stop Rate @ Wheel **200.0** N/mm (see user tool)

Fr. Rollbar Rate **750.0** N/m°
Rollbar Wheel Rate **38.2** N/mm
(Total Linear Roll Rate **1142.7** N/m°)

Axle Type

0 = Independent	Front	Rear
1 = Solid Axle	0	2
2 = Twist Beam (rear only)	Independent	Twistbeam

U = Understeer

U = Understeer
O = Oversteer
N = Neutral

Rear Suspension Static Toe and Camber Settings

Rr. Total Static Toe **0.10** U °
Static Camber **-0.8** O °

Rear Suspension Kinematic Ride Motion

Rr. Bump Steer **0.0** N °/m
Rr. Camber Gain **0.1** O °/m

Rear Suspension Compliances

Rr. Lat. Force Toe Compliance **-0.04** O °/kN
Rr. Lat. Force Camber Compliance **0.300** O °/kN
Rr. Brake Steer **-0.030** O °/kN
Rr. Acceleration Steer **0.020** U °/kN
Rr. Aligning Torque Compliance Steer **1.000** N/m

Rear Suspension Anti-Angles (SEE BELOW)

Rr. Anti-Squat Angle **-2.0** °
Rr. Anti-Lift Angle **5.0** °

Rear Suspension Roll Center

Rr. Roll Center @ Ref Ride Height **150.0** mm
Roll Center Mov. vs. Wheel Travel Ratio **0** - SHOULD BE 0

Rear Suspension Wheel & Roll Rates

Rr. Linear Wheel Rate **18.0** N/mm
Bump-Stop Gap @ Wheel **25.0** mm ■
Displ. to Final Bump-Stop Rate **75.0** mm ■
Fin. Bump-Stop Rate @ Wheel **200.0** N/mm

Rr. Rollbar Rate **350.0** N/m°
Rollbar Wheel Rate **17.8** N/mm
(Total Linear Roll Rate **703.4** N/m°)

(RACING) Coupling of Vert. & Roll Rate **1** -Yes, 0 -No

Normally Vertical and Roll Rates are coupled, meaning that both rates act in roll. However some suspension types permit Vertical and Roll Rates to act independently (1=Standard)

(RACING) Coupling of Vert. & Roll Rate **1** -Yes, 0 -No

Front Tire Data @ REF LOAD

Fr. Tire Vertical Stiffness **131.0** N/mm
Fr. Tire Cornering Stiffness **899.0** N°/m

REFERENCE LOAD FOR TIRE DATA **4000.0** N

Tire Lat/AT/Camber Stiffness Load Dependency **72.0** %

Aligning Torque Stiffness **32.0** N/m°

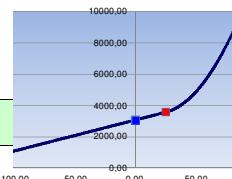
Camber Thrust **18.0** N°/m

(RACING) % Growth of Loaded Radius w/ Speed **0.0** %/100kph

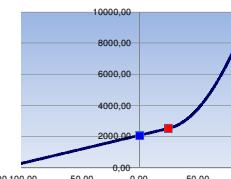
NON-LINEAR SPRING, IF NOT WANTED ENTER LARGE GAP

USING BUMP-STOPS WILL INCREASE ITERATIONS & SOLVER TIME

Front Load Deflection Curve



Rear Load Deflection Curve



Rear Tire Data @ REF LOAD

Rr. Tire Vert. Stiffness **131.0** N/mm
Rr. Tire Cornering Stiffness **899.0** N°/m

REFERENCE LOAD FOR TIRE DATA **4000.0** N

Tire Lat/AT/Camber Stiffness Load Dep. **72.0** %

Aligning Torque Stiffness **32.0** N/m°

Camber Thrust **18.0** N°/m

(RACING) % Growth of Loaded Radius w/ Speed **0.0** %/100kph

ENTER TIRE & RIM SIZE, ASPECT RATIO AND TIRE TYPE FOR ESTIMATED TIRE CHARACTERISTICS *

TIRE DATA TOOL

Select Tire Width [mm]	Size Rim ["]	Select Aspect Ratio [%]	Select Tire Type [-]	Enter Tire Data Reference Load [N]	Cornering Stiffness [N/mm]	Aligning Torque Stiffness [N°/m]	Camber Thrust [N°]	Load Dependency [%]	Tire Grip μ [-]	Vertical Stiffness [N/mm]		
Database Front Tire	185	15	55	Standard Production Tire	4000	4000	899	32	18	72	0.9	131
Database Rear Tire	185	15	55		4000	4000	899	32	18	72	0.9	131

* Nominal Values for One Specific Reference Load (4kN)

Tire Graph Generator: Enter Basic Tire Parameters to see resulting Graphs (Enhanced Tire Model)

Cornering Stiffness [N°/m] μ [-] Cornering Stiffness Load Dependency [%] Reference Load [N]

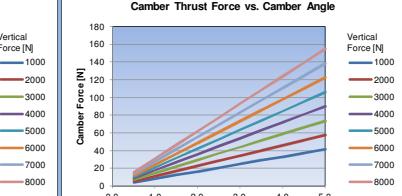
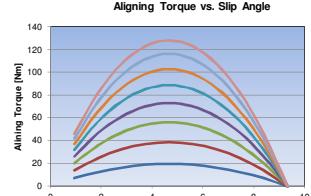
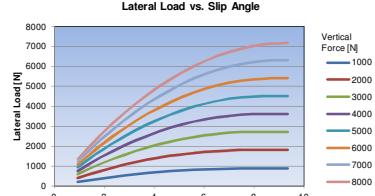
899 0.90 72 4000

Aligning Torque Stiffness [N/m°] μ [-] Align. Torque Stiffness Load Dependency [%] Reference Load [N]

32 0.90 72 4000

Camber Thrust [N°] Camber Thrust Load Dep. [%] Reference Load [N]

18 72 4000



[GO TO MASTER](#)

FRONT SUSPENSION K&C DATA TOOL

Select Suspension - Click on Type

Strut Standard

Typical Suspension Data Numbers

Power Steering

Front Bump Steer **-3.0** °/m

Front Camber Gain **-10.0** °/m

Front Lateral Force Toe Compliance **-0.25** °/kN

Front Lateral Force Camber Compliance **0.30** °/kN

Front Brake Steer **0.03** °/kN

Front Acceleration Steer **0.03** °/kN

Front Aligning Torque Compliance Steer **3.50** °/Nm

Roll Steer (Solid Axle Only) **0.00** °/m

Roll Camber (Solid Axle Only) **0.00** °/m

Front Roll Center Height **50.0** mm

Roll Center Movement vs. Wheel Travel Ratio **2.65**

Front Anti-Lift Angle **0.0** °

Front Anti-Dive Angle **2.0** °

Front Damper to Wheel Motion Ratio **0.95**

VERIFY STEERING RATIO ! if Suspension not available select closest similar

REAR SUSPENSION K&C DATA TOOL

Select Suspension - Click on Type

Twist Beam Standard

Typical Suspension Data Numbers

Rear Bump Steer **0.0** °/m

Rear Camber Gain **0.0** °/m

Rear Lateral Force Toe Compliance **-0.04** °/kN

Rear Lateral Force Camber Compliance **0.30** °/kN

Rear Brake Steer **-0.03** °/kN

Rear Acceleration Steer **0.02** °/kN

Rear Aligning Torque Compliance Steer **1.00** °/Nm

Roll Steer (Solid Axle & Twist Beam Only) **0.05** °/m

Roll Camber (Solid Axle & Twist Beam Only) **-0.20** °/m

Rear Roll Center Height **150.0** mm

Roll Center Movement vs. Wheel Travel Ratio **0.00** °

Rear Anti-Squat Angle **2.0** °

Rear Anti-Lift Angle **5.0** °

Rear Damper to Wheel Motion Ratio **1.00**

if Suspension not available select closest similar

USER TOOL - CONVERSION FROM SPRING TO WHEELRATE						USER TOOL - CONVERSION VERTICAL TO ROLL					
Spring (Component) to Wheel Rate	Rate of Spring	Spring to Wheel Motion Ratio	Suspension Parasitic Wheel Rate (N/mm)	Final Result Total Wheel Rate		Conversion Calculator from N/mm ->Nm/in ²	Spring Rate @ wheel	0,0	N/mm		
Spring Rate (Component) [N/mm]	23,0	0,9	4,0	22,6	N/mm WHEEL rate	Rollbar Rate @ wheel	15,2	N/mm			
Rollbar Rate @ Point 1 [N/mm]	23,7	0,8	0,0	15,2	N/mm WHEEL rate	Track Width	1,926	m			
						Total Roll Rate @ wheel	15,2	N/mm			
						Roll Stiffness in Nm/deg	308,9	Nm/ ^o			

NOTES on Conversion Calculator:

- * Best to use K&C data
- ** Rate conversion is an approximate since the effects of nonlinear motion ratio and spring force on wheel rate are only considered for the parasitic rate.
- *** Motion ratio is assumed to be standard between 0 and 1 (= same displacement as wheel).
- **** ATTENTION in User Tool for Spring & Anti-rollbar calc. consider protection coating thickness on effective diameter of steel coil / rollbar

USER TOOL - CALCULATION COIL SPRING COMPONENT RATE (STEEL MATERIAL ONLY)					
	Coil d: 10,0 mm	Spring D: 120,0 mm	Coil Nr. i_eff: 2,50	typically Nr. of total coils -1	
	Spring Rate: 23,44 N/mm				
i_eff = number of effectively working coils.					

USER TOOL - ROLLBAR ATTACHMENT VERTICAL RATE CALCULATION (ROLL MOTION, STEEL MATERIAL ONLY)					
	Rollbar Vertical Rate @ Pt 1: 23,7 N/mm (in roll motion)				

USER TOOL - BUMP-STOP COMPONENT TO WHEEL RATE CALCULATOR					
Component Displacement [mm]	Component Force [N]	Comp. Inst. Rate [N/mm]	Displacement @ Wheel [mm]	Force @ Wheel [N]	Rate @ Wheel [N/mm]
0,0	0,0	0,0	0,0	0,0	0,0
5,0	500	10,0	5,4	46,0	8,5
10,0	1000	20,0	10,9	138,0	16,9
15,0	1500	40,0	16,3	322,0	33,9
20,0	2000	80,0	21,7	690,0	67,7

Motion Ratio Bump-Stop to Wheel: 0,92

[GO TO MASTER](#)

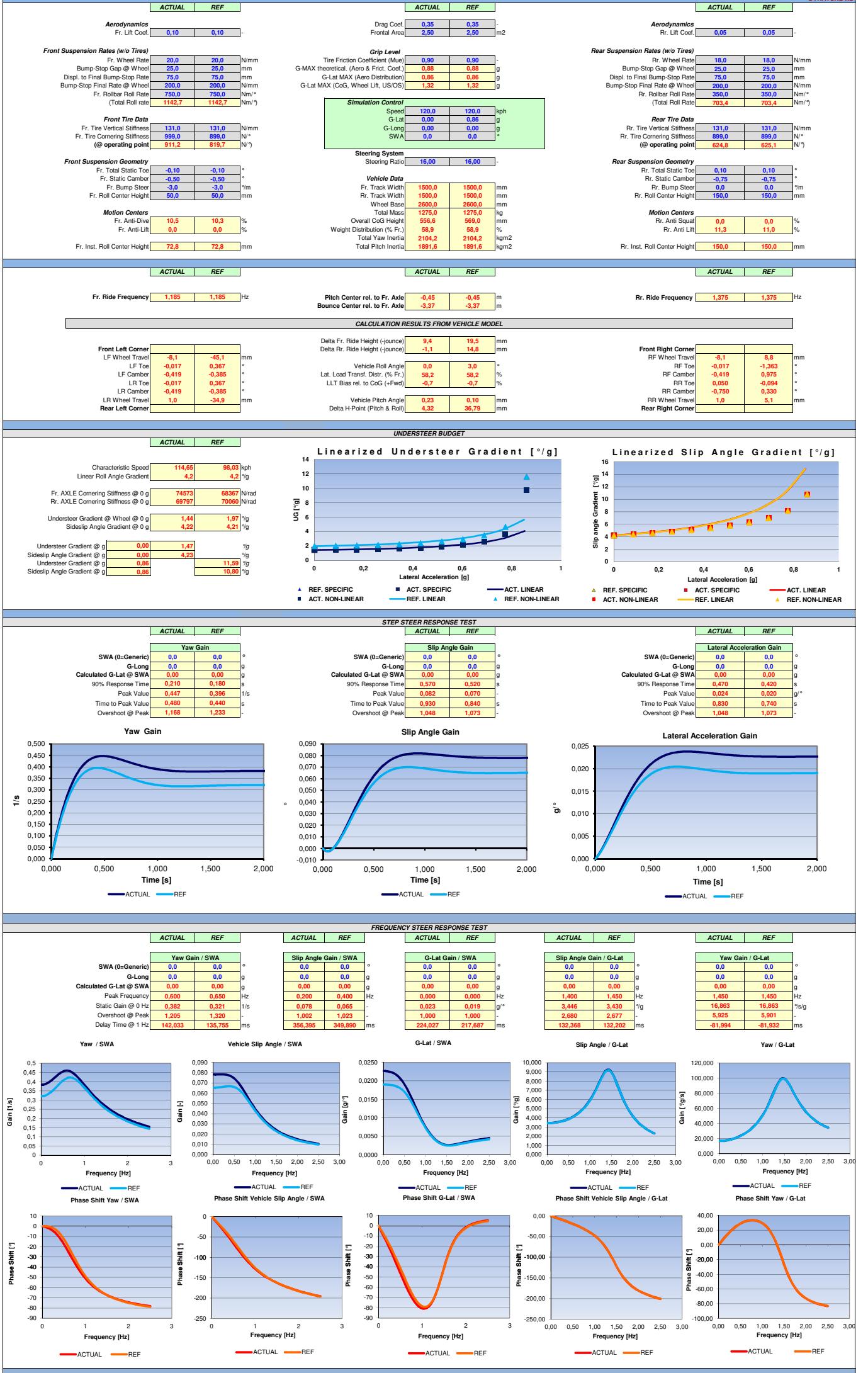
Suspension Instantaneous Rotation Centers

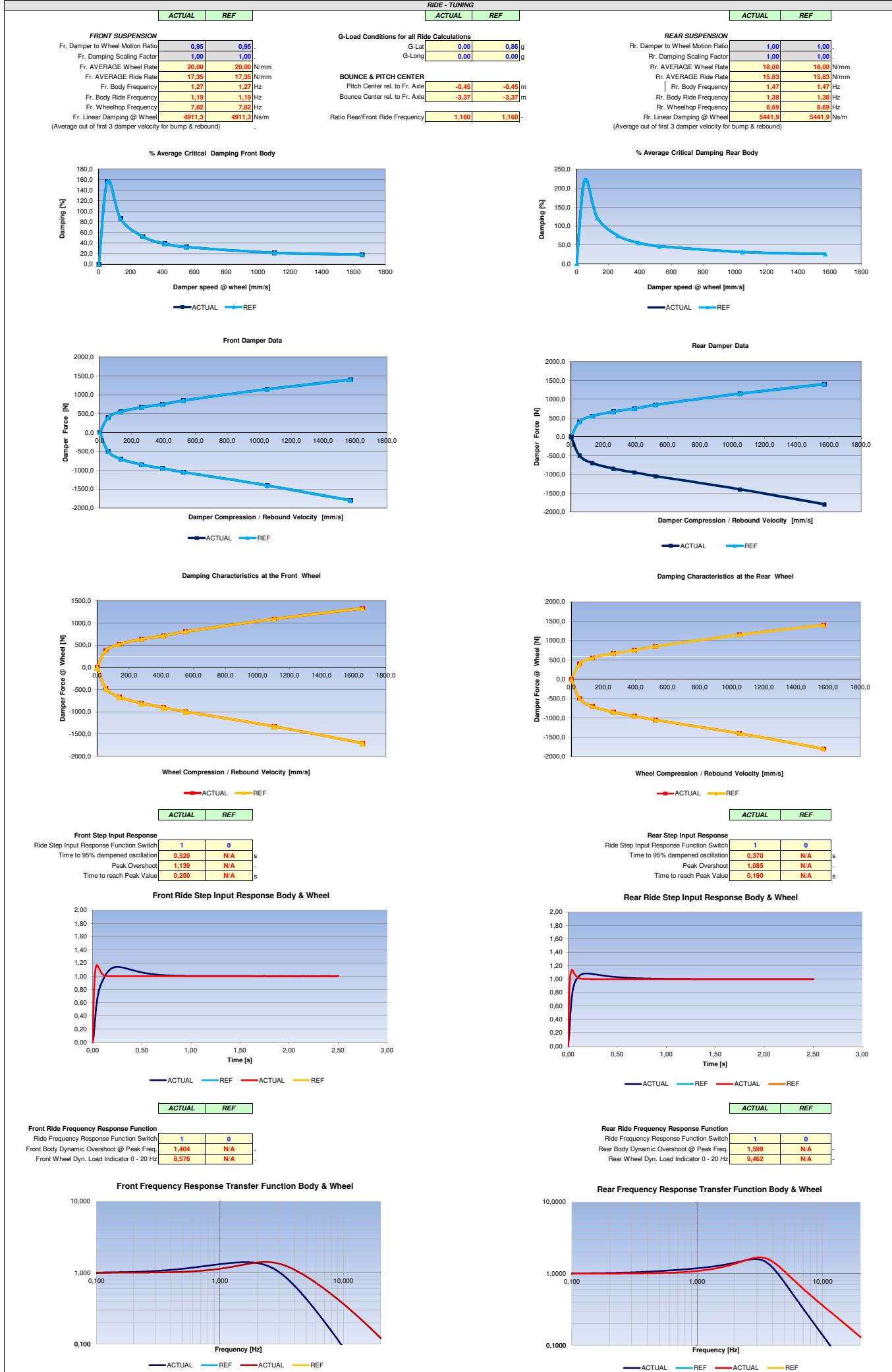
Front Anti Dive %: 10,50% Front Anti Lift %: 0,00%

Rear Anti Squat %: 0,00% Rear Anti Lift %: 11,27%

CUSTOM DASHBOARD - RESULTS

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CIRCUIT & TEST TRACK LAYOUT

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This sheet contains all the geometric information of the Test-Track/Circuit. The track MUST consist of at least 4 Straight/Corner sections as indicated below. The maximum number of corners is 20. All Data is 2D-Only. Available are a typical real life High-Speed & Low-Speed Handling Track and a Generic Test Track for quick comparison studies. The ACTUAL Track Data can be exported/imported to a specific excel file (*.xslm) for convenient data transfer.

THE TEST-TRACK DOES NOT NEED TO BE A CIRCUIT, IT CAN ALSO BE FOR INSTANCE A RALLYE SECTION WITH STANDING START AND FLYING FINISH.

[GO TO MASTER](#)

[GO TO LAPTIME](#)

When creating a custom Test Track follow this procedure:

- 1) Include All Sections (Push Button) - DO NOT Include/Exclude Sections at Random. Strictly Follow Procedure.
- 2) Enter the data for the mandatory Start Section at the Top and Finish Section at the Bottom meaning Start, First & Second Corner and Finish, Ultimate & Penultimate Corner (See GENERIC Test Track for Reference).
- 3) Enter your track data "top down" until arriving at the end of your data or the data already entered at 2). Basically you need to enter only 5 data points for every corner. The straights are in between. The 5 points should be on the driving line and are: corner entry, intermediate point between entry and apex, apex, intermediate point between apex and exit and corner exit point.
- 4) Make sure that every straight has a calculated length of at least 1m (the number in calculated distance in orange/red cell). If not so, laptime simulation results can be inaccurate.
- 5) Make sure that calculated corner radius decreases from corner entry to apex and increases from apex to exit. If not so, laptime simulation results will be inaccurate. This is very important. The calculated corner radius defines via geometrical equations the length of the circle section. If corner geometry does not permit "add" short straight and extra "corner".
- 6) Finally exclude the first following unnecessary section. This will cancel automatically ALL following sections and copy down the last valid geometry point to the mandatory Finish Section and close the track layout.
- 7) Hit F9 (calculate) and verify if all Calculated Corner Radius look plausible and see if graphics look OK. If not fine tune point locations. RADIUS CALCULATION ALGORITHM IS VERY SENSITIVE TO COORDINATE TOLERANCES! Make sure that there are no Error Messages or your Laptime Simulation will be incorrect.

YOU CAN ONLY ENTER DATA IN THE BLUE/GREY CELLS. RESULTS ARE SHOWN IN THE YELLOW/RED CELLS

LOW SPEED TRACK (enter above the name of the track for graphs)		Section	Description	Actual Track Coordinate x [m]	Actual Track Coordinate y [m]	Calculated Distance s [m]	Calculated Corner Radius R [m]	ERROR MESSAGES
		START	START / STRAIGHT 1	-50,0	8,0	0,0	N/A	
		S1/C1	END OF STRAIGHT / CORNER ENTRY	-154,5	11,0	104,5	26,8	
			INTERMEDIATE SECTION	-164,9	9,4	10,6	22,3	
			CORNER APEX POINT	-170,3	6,7	6,1	17,7	
			INTERMEDIATE SECTION	-173,9	3,1	5,1	30,7	
			CORNER EXIT / START OF STRAIGHT	-177,3	-1,2	5,4	43,7	
		S2/C2	END OF STRAIGHT / CORNER ENTRY	-189,0	-14,0	17,4	48,4	
			INTERMEDIATE SECTION	-192,0	-17,7	4,8	34,2	
			CORNER APEX POINT	-197,0	-22,5	7,0	20,0	
			INTERMEDIATE SECTION	-206,6	-25,5	10,2	32,1	
			CORNER EXIT / START OF STRAIGHT	-216,7	-27,0	10,2	44,2	
		S3/C3	END OF STRAIGHT / CORNER ENTRY	-340,0	-20,0	123,5	80,6	
			INTERMEDIATE SECTION	-363,4	-25,0	24,0	74,4	
			CORNER APEX POINT	-380,0	-33,6	18,7	68,1	
			INTERMEDIATE SECTION	-395,0	-48,0	20,9	72,1	
			CORNER EXIT / START OF STRAIGHT	-408,0	-72,9	28,3	76,0	
		S4/C4	END OF STRAIGHT / CORNER ENTRY	-492,3	-299,9	242,1	63,7	
			INTERMEDIATE SECTION	-491,2	-324,1	24,4	48,8	
			CORNER APEX POINT	-478,7	-349,4	28,6	34,0	
			INTERMEDIATE SECTION	-443,5	-354,1	36,6	41,9	
			CORNER EXIT / START OF STRAIGHT	-415,6	-336,3	33,7	49,8	
		S5/C5	END OF STRAIGHT / CORNER ENTRY	-182,8	-101,9	330,5	88,1	
			INTERMEDIATE SECTION	-129,8	-90,7	58,0	86,2	
			CORNER APEX POINT	-63,5	-106,0	73,2	84,4	
			INTERMEDIATE SECTION	-40,0	-174,0	74,3	84,9	
			CORNER EXIT / START OF STRAIGHT	-62,1	-223,0	54,7	85,4	
		S6/C6	END OF STRAIGHT / CORNER ENTRY	-67,2	-246,1	34,1	58,4	
			INTERMEDIATE SECTION	-98,4	-279,9	36,2	57,7	
			CORNER APEX POINT	-83,0	-320,0	44,0	56,9	
			INTERMEDIATE SECTION	-31,7	-337,2	55,4	74,2	
			CORNER EXIT / START OF STRAIGHT	6,2	-329,9	38,8	91,4	
		S7/C7	END OF STRAIGHT / CORNER ENTRY	34,7	-312,3	33,5	76,9	
			INTERMEDIATE SECTION	65,7	-302,1	32,9	68,1	
			CORNER APEX POINT	107,1	-309,3	42,7	59,3	
			INTERMEDIATE SECTION	132,5	-340,0	40,0	128,5	
			CORNER EXIT / START OF STRAIGHT	143,7	-359,0	22,0	197,7	
		S8/C8	END OF STRAIGHT / CORNER ENTRY	153,0	-372,2	16,2	53,8	
			INTERMEDIATE SECTION	164,2	-383,0	15,6	46,1	
			CORNER APEX POINT	174,9	-389,0	12,4	38,5	
			INTERMEDIATE SECTION	183,2	-391,0	8,5	53,6	
			CORNER EXIT / START OF STRAIGHT	197,6	-392,0	14,5	68,7	
		S9/C9	END OF STRAIGHT / CORNER ENTRY	370,1	-373,9	173,4	16,5	
			INTERMEDIATE SECTION	385,4	-378,2	16,6	15,1	
			CORNER APEX POINT	389,8	-385,6	8,7	13,6	
			INTERMEDIATE SECTION	385,1	-399,0	14,7	16,5	
			CORNER EXIT / START OF STRAIGHT	375,4	-405,1	11,6	19,4	
		S10/C10	END OF STRAIGHT / CORNER ENTRY	206,7	-419,0	167,3	17,9	
			INTERMEDIATE SECTION	196,5	-427,1	15,0	17,3	
			CORNER APEX POINT	194,0	-439,3	12,8	16,7	
			INTERMEDIATE SECTION	202,6	-451,2	15,2	16,8	
			CORNER EXIT / START OF STRAIGHT	215,2	-452,5	12,9	16,8	
		S11/C11	END OF STRAIGHT / CORNER ENTRY	423,0	-403,0	213,7	46,3	
			INTERMEDIATE SECTION	457,6	-406,5	35,6	44,4	
			CORNER APEX POINT	476,0	-424,2	25,9	42,5	
			INTERMEDIATE SECTION	479,0	-458,0	34,9	42,9	
			CORNER EXIT / START OF STRAIGHT	457,9	-483,0	33,6	43,3	
		S12/C12	END OF STRAIGHT / CORNER ENTRY	436,9	-489,3	21,9	42,3	
			INTERMEDIATE SECTION	421,5	-505,5	22,7	41,5	
			CORNER APEX POINT	417,0	-531,8	27,1	40,6	
			INTERMEDIATE SECTION	427,6	-553,1	24,1	44,5	
			CORNER EXIT / START OF STRAIGHT	450,7	-568,0	27,9	48,4	
		S13/C13	END OF STRAIGHT / CORNER ENTRY	677,0	-677,4	251,3	67,2	
			INTERMEDIATE SECTION	724,3	-672,4	48,6	60,5	
			CORNER APEX POINT	758,6	-630,9	55,8	53,7	
			INTERMEDIATE SECTION	749,0	-590,2	42,6	63,2	
			CORNER EXIT / START OF STRAIGHT	715,1	-560,0	46,1	72,6	
		S14/C14	END OF STRAIGHT / CORNER ENTRY	675,0	-550,0	41,3	66,1	
			INTERMEDIATE SECTION	655,0	-551,6	20,1	57,4	
			CORNER APEX POINT	640,0	-556,0	15,9	48,7	
			INTERMEDIATE SECTION	630,0	-563,0	12,2	57,5	
			CORNER EXIT / START OF STRAIGHT	618,9	-575,0	16,4	66,4	
		S15/C15	END OF STRAIGHT / CORNER ENTRY	604,4	-592,0	22,4	72,6	
			INTERMEDIATE SECTION	583,4	-597,2	21,7	71,5	
			CORNER APEX POINT	537,7	-586,1	47,9	70,4	
			INTERMEDIATE SECTION	512,0	-556,0	40,1	70,6	
			CORNER EXIT / START OF STRAIGHT	511,0	-500,0	57,6	70,8	
		S16/C16	END OF STRAIGHT / CORNER ENTRY	521,0	-478,5	23,7	113,5	
			INTERMEDIATE SECTION	517,0	-426,0	53,1	112,2	
			CORNER APEX POINT	492,9	-384,2	48,7	110,9	
			INTERMEDIATE SECTION	451,0	-355,7	51,1	111,8	
			CORNER EXIT / START OF STRAIGHT	402,4	-348,3	49,5	112,7	
		S17/C17	END OF STRAIGHT / CORNER ENTRY	248,5	-364,0	154,6	76,4	
			INTERMEDIATE SECTION	206,1	-356,9	43,6	74,9	
			CORNER APEX POINT	171,4	-323,2	49,2	73,5	
			INTERMEDIATE SECTION	163,7	-289,9	34,4	78,7	
			CORNER EXIT / START OF STRAIGHT	169,0	-268,6	22,1	82,8	
		S18/C18	END OF STRAIGHT / CORNER ENTRY	176,0	-232,6	26,8	65,2	
			INTERMEDIATE SECTION	165,6	-210,5	24,8	64,1	
			CORNER APEX POINT	151,0	-196,0	20,6	63,0	
			INTERMEDIATE SECTION	132,7	-187,0	20,5	65,0	
			CORNER EXIT / START OF STRAIGHT	109,8	-184,0	23,1	66,9	
		S19/C19	END OF STRAIGHT / CORNER ENTRY	30,8	-183,5	79,1	63,2	
			INTERMEDIATE SECTION	14,4	-178,1	17,3	51,4	
			CORNER APEX POINT	1,3	-169,5	15,8	39,7	
			INTERMEDIATE SECTION	-8,3	-154,5	17,9	41,2	
			CORNER EXIT / START OF STRAIGHT	-11,0	-140,3	14,6	42,6	
		S20/C20	END OF STRAIGHT / CORNER ENTRY	-2,0	-34,0	108,6	58,7	
			INTERMEDIATE SECTION	-6,0	-16,0	18,5	43,9	
			CORNER APEX POINT	-10,0	-7,7	9,2	29,2	
			INTERMEDIATE SECTION	-24,0	3,0	17,8	36,7	
			CORNER EXIT / START OF STRAIGHT	-37,0	7,0	13,7	44,2	
			FINISH FINISH / STRAIGHT	-50,0	8,0	13,0	N/A	

Include All Sections

(Re-) Load
High Speed Track

(Re-) Load
Low Speed Track

(Re-) Load
Gen. Test Track

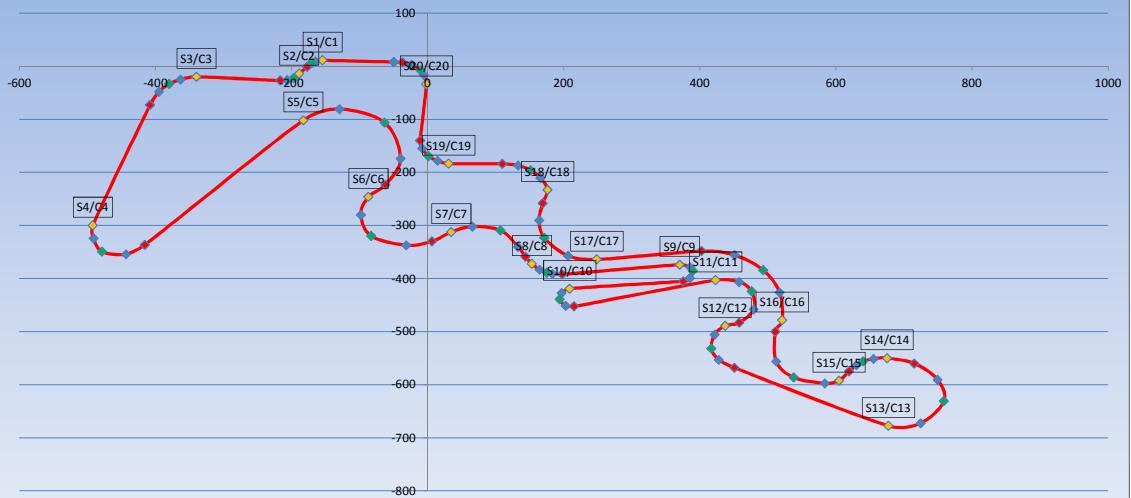
F9
(calc)

Total Length
4434,5 m

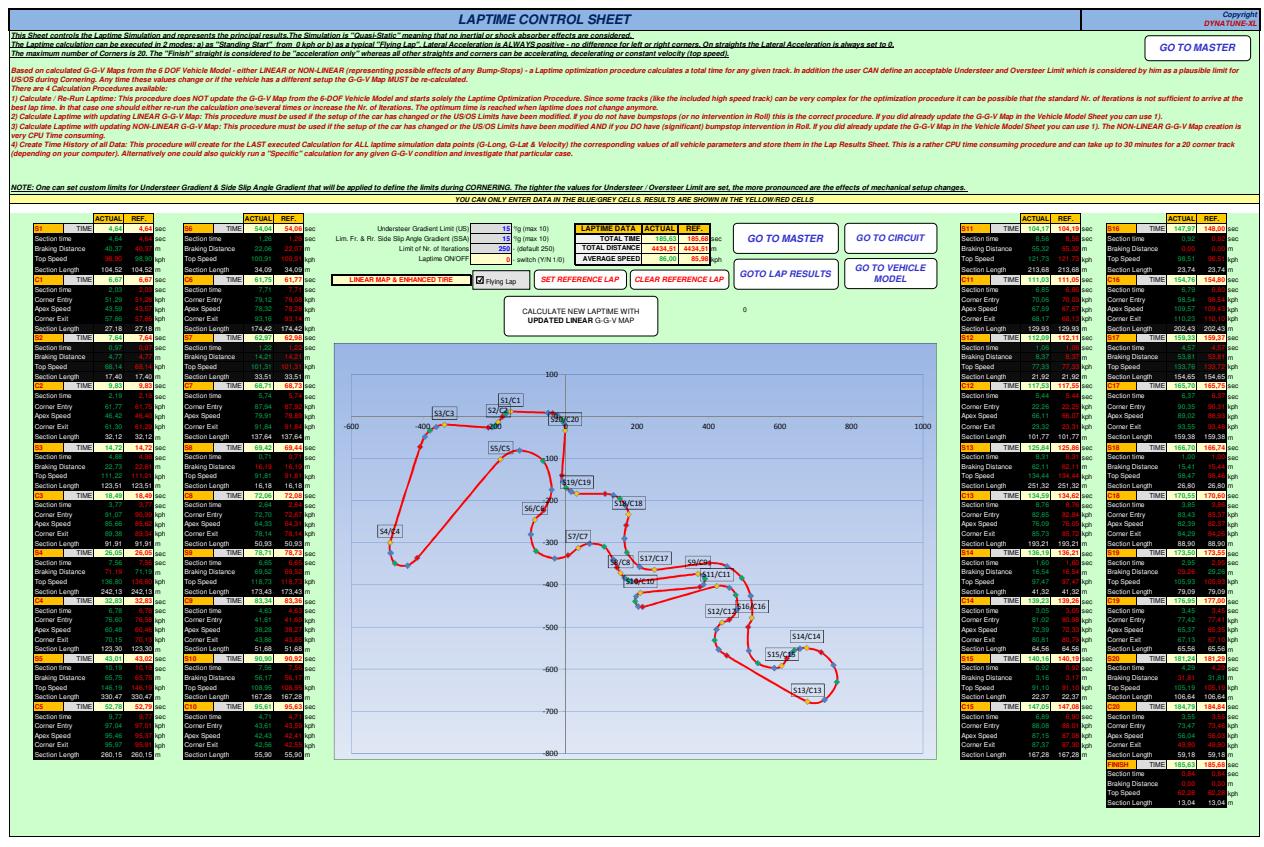
GO TO LAPTIME

Export Track Data
to External

Import Track Data
from External

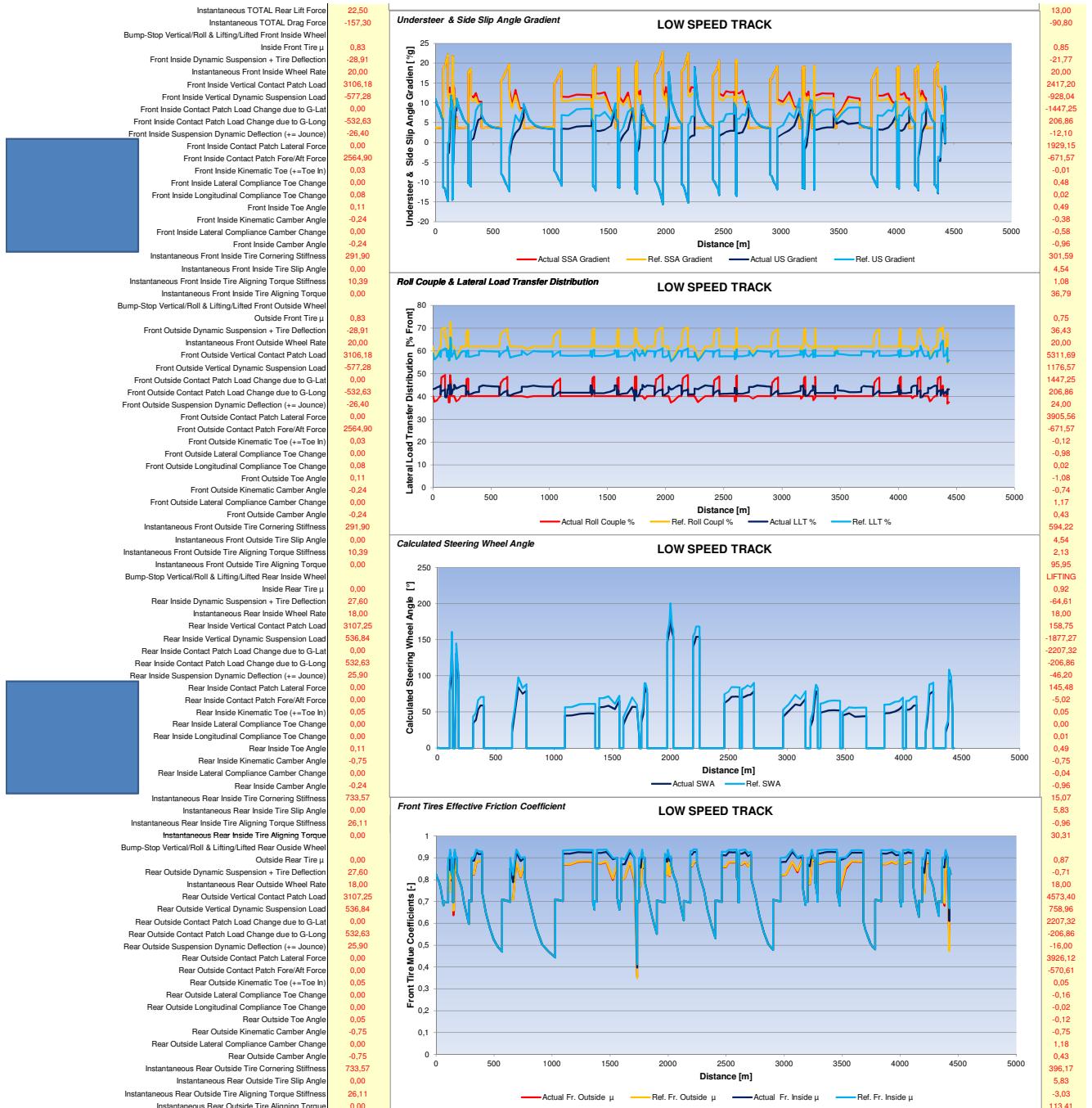


ZOOM *	UNDO ZOOM *	RESET *	
selected chart			
* Track Map can be zoomed into: Select Map Click Zoom Button and draw Rectangle to zoom in Chart			
			
START			
S1/C1	HIGH SPEED TRACK	LOW SPEED TRACK	GENERIC TEST TRACK
	0,0	-50,0	8,0
	-950,0	-154,5	11,0
	-1150,0	-60,0	9,4
	-1255,0	-150,0	6,7
	-1290,0	-250,0	3,1
	-1295,0	-300,0	-1,2
	-1290,0	-340,0	-14,0
	-1280,0	-365,0	-192,0
	-1250,0	-385,0	-197,0
	-1230,0	-385,0	-206,6
	-1200,0	-380,0	-216,7
	-1170,0	-371,0	-340,0
	-1150,0	-369,0	-363,4
	-1125,0	-375,0	-380,0
	-1110,0	-391,0	-395,0
	-1105,0	-417,0	-406,0
	-1100,0	-436,0	-492,3
	-1095,0	-471,0	-491,2
	-1080,0	-500,0	-478,7
	-1055,0	-520,0	-443,5
	-1025,0	-532,0	-415,6
	-925,0	-555,0	-182,8
	-876,0	-581,0	-129,8
	-852,0	-596,0	-63,5
	-825,0	-617,0	-40,0
	-773,0	-664,0	-62,1
	-621,0	-815,0	-87,2
	-587,0	-818,0	-98,4
	-568,0	-801,0	-83,0
	-565,0	-776,0	-31,7
	-582,0	-753,0	6,2
	-621,0	-740,0	34,7
	-650,0	-725,0	65,7
	-680,0	-704,0	107,1
	-720,0	-650,0	132,5
	-746,0	-607,0	143,7
	-802,0	-501,0	153,0
	-825,0	-465,0	164,2
	-847,0	-437,0	174,9
	-880,0	-410,0	183,2
	-914,0	-391,0	197,6
	-1000,0	-346,0	370,1
	-1070,0	-253,0	385,4
	-1060,0	-170,0	389,8
	-990,0	-130,0	385,1
	-900,0	-144,0	375,4
	-750,0	-255,0	208,7
	-709,0	-268,0	196,5
	-671,0	-264,0	194,0
	-633,0	-239,0	202,6
	-606,0	-202,0	215,2
	-579,0	-155,0	423,0
	-507,0	-122,0	457,6
	-425,0	-135,0	476,0
	-373,0	-198,0	479,0
	-370,0	-270,0	457,9
	-425,0	-500,0	436,9
	-432,0	-545,0	421,5
	-434,0	-607,0	417,0
	-430,0	-636,0	427,6
	-415,0	-705,0	450,7
	-369,0	-801,0	677,0
	-375,0	-821,0	724,3
	-355,0	-833,0	756,6
	-330,0	-835,0	749,0
	-303,0	-830,0	715,1
	-199,0	-780,0	675,0
	-180,0	-760,0	655,0
	-168,0	-737,0	640,0
	-164,0	-714,0	630,0
	-165,0	-685,0	618,9
	-192,0	-572,0	604,4
	-199,0	-540,5	583,4
	-202,0	-509,0	537,7
	-199,0	-478,0	512,0
	-195,0	-457,0	511,0
	-188,0	-434,0	521,0
	-186,0	-409,5	517,0
	-181,0	-385,0	492,9
	-185,0	-366,0	451,0
	-188,0	-347,0	402,4
	-206,0	-307,0	249,5
	-217,0	-287,0	206,1
	-225,0	-267,0	171,4
	-229,0	-249,0	163,7
	-231,0	-231,0	169,0
	-230,0	-185,0	176,0
	-225,0	-150,0	165,6
	-215,0	-126,0	151,0
	-183,0	-100,0	132,7
	-123,0	-85,0	109,8
	-44,0	-71,0	30,8
	-22,0	-67,0	14,4
	0,0	-66,0	1,3
	15,0	-66,0	-8,3
	35,0	-72,0	-11,0
	60,0	-83,0	-2,0
	100,0	-75,0	-6,0
	121,0	-45,0	-10,0
	100,0	-10,0	-24,0
	52,0	0,0	-37,0
	FINISH	0,0	-50,0
		8,0	-34,0
		-20,0	468,0
		-16,0	458,9
		-7,7	432,9
		3,0	393,9
		7,0	348,0
		-34,0	0,0



CUSTOM LAP - RESULTS EXAMPLE





VEHICLE SIMULATION MODEL - 6 DOF

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This worksheet contains the 6 DOF-Vehicle Model which calculates all load conditions, accelerating, braking, cornering and aerodynamic loads on the vehicle model. All calculations are partially LINEAR. Powertrain Forces are distributed ideally amongst all 4 wheels (ideal working LSD differentials) according to vertical contactpatch load. From Version 7.0 onwards the enhanced tire model allows lateral wheel load calculation with tire slip angle consideration.

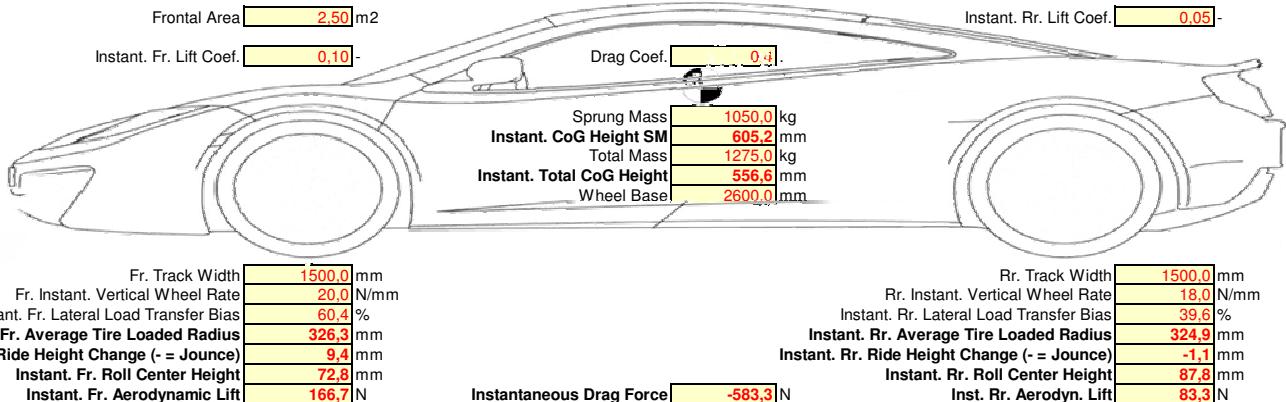
[GO TO MASTER](#)

[GO TO LAPTIME](#)

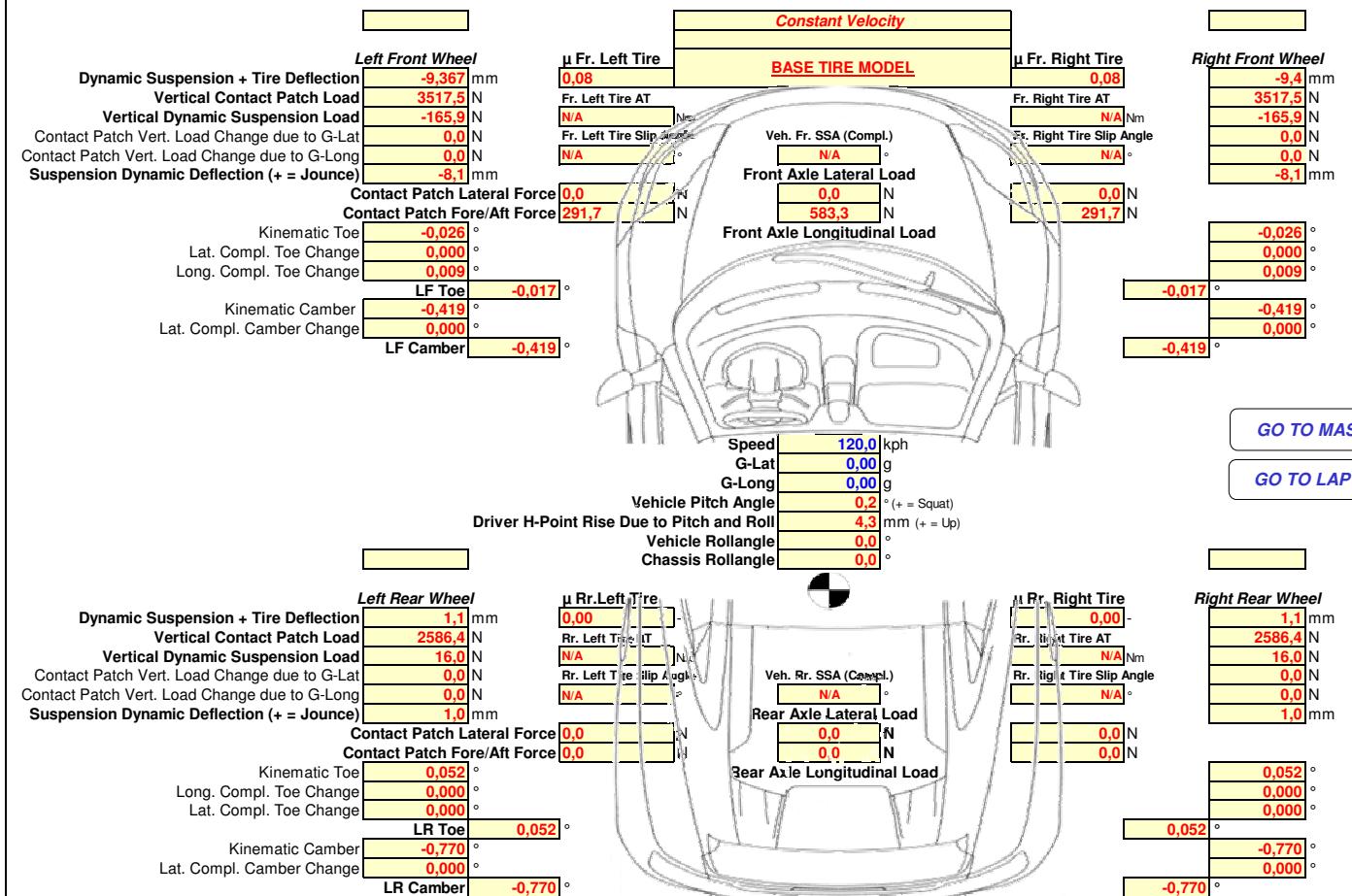
In version 7.0 Performance Envelopes for Ax and Ay can be calculated in function of velocity. The 3-Dimensional G-G-V Performance Envelope Plots are basically "classic" 2-Dimensional Gx-Gy Plots that have been extended with the effect of Speed in order to evaluate the effect of Aerodynamics AND can also be limited by user defined maximum values for Understeer Gradient & Front/Rear Vehicle Side Slip Angle Gradient. The procedure can be executed in LINEAR or NON-LINEAR mode.

Output: X, Y, Z Loads, Kinematic and Compliant Toe and Camber values, all relevant values for other worksheets and 3D Performance Envelope Charts

YOU CAN ONLY ENTER DATA IN THE BLUE/GREY CELLS. RESULTS ARE SHOWN IN THE YELLOW/RED CELLS
BLUE W/ YELLOW CELLS ARE PASSED THROUGH NUMBERS FROM THE MASTER CONTROL SHEET



6 DOF-Model Results



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ALL VALUES REFER TO WHEEL PLANE

Gx-Gy-V Performance Envelope Plots

[GO TO MASTER](#)
[GO TO LAPTIME](#)

Creating a LINEAR G-G-V Map is CPU time consuming. If any Bump-Stops are activated in Roll the results can be incorrect. In that particular case a NON-LINEAR calculation is recommended. The LINEAR G-G-V Map procedure will ALWAYS use the BASE Tire Model !

[CREATE LINEAR G-G-V MAP](#)
[CREATE NON-LINEAR G-G-V MAP](#)

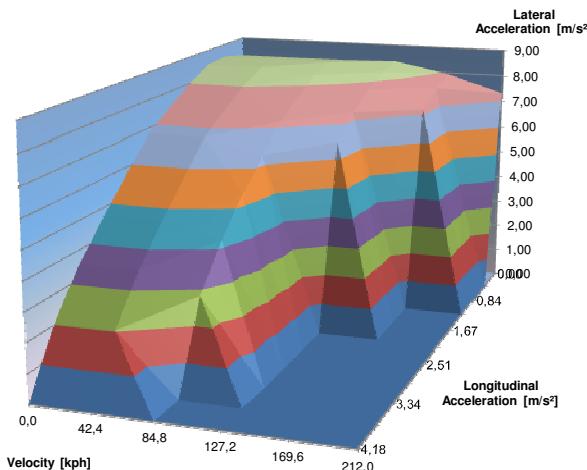
Imposed US Gradient Limit (Cornering) **15** [%g]
Imp. Fr. & Rr. SSA Gradient Limit (Cornering) **15** [%g]

ACTIVE MAP
LINEAR

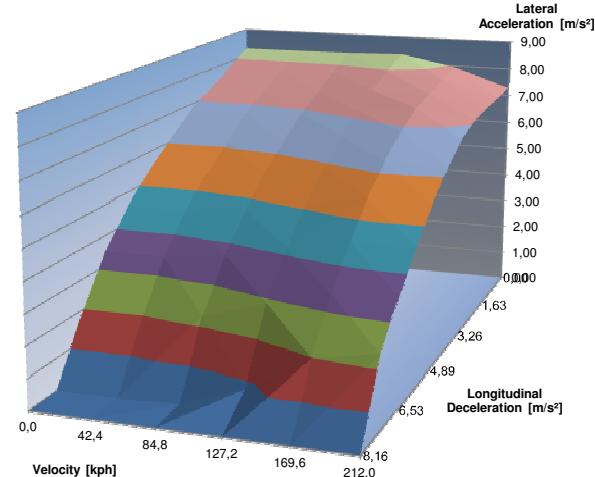
Automatically Calculated Data Points for Velocity [kph]	0,0	42,3	84,7	127,0	169,4	211,7
Custom Data Points for Velocity	0,0	80,0	140,0	200,0	240,0	211,7

 Use Custom Reference Velocity Points

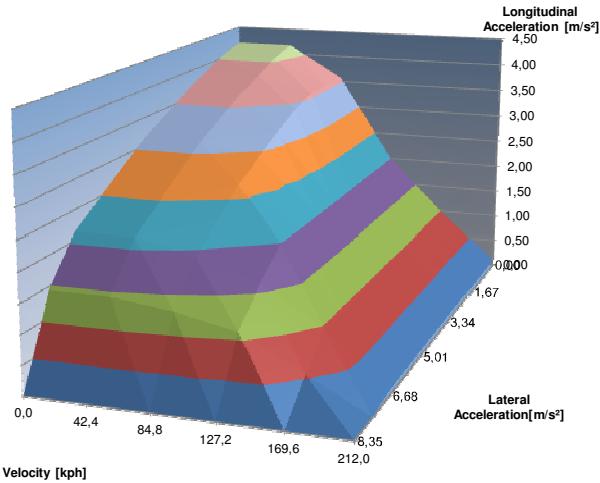
Lateral Acceleration Ay = f (Ax,V) under Traction



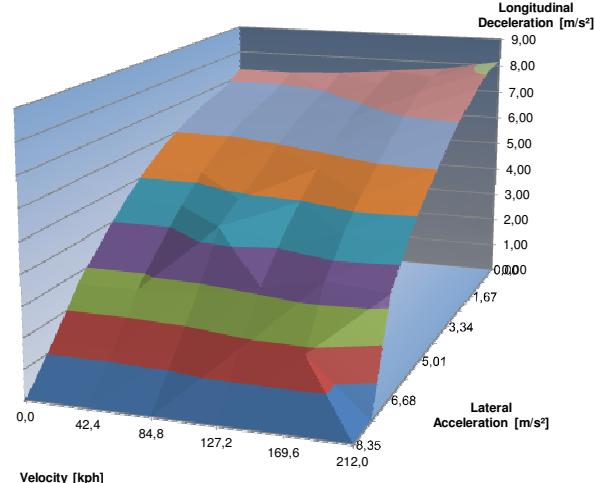
Lateral Acceleration Ay = f (Ax,V) under Braking



Longitudinal Acceleration Ax = f (Ay,V) under Traction



Longitudinal Deceleration Ax = f (Ay,V) under Braking


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[GO TO MASTER](#)

Data Reference Table

Vel [kph]	Max. Ax TRACTION [g]	Max. Ax BRAKING [g]	Max. Ay [g]
42,3	0,426	0,743	0,844
84,7	0,365	0,752	0,845
127,0	0,207	0,772	0,852
169,4	0,102	0,792	0,811
211,7	0,011	0,832	0,743

	GENERAL VEHICLE REFERENCE DATA				
	VELOCITY [kph]				
Front End	42,3	84,7	127,0	169,4	211,7
Fr. Instant. Vertical Wheel Rate [N/mm]	20,0	20,0	20,0	20,0	20,0
Instant. Fr. Lateral Load Transfer Bias [%]	57,4	57,8	58,3	59,0	59,9
Instant. Fr. Average Tire Loaded Radius [mm]	325,2	325,6	326,4	327,5	329,0
Instant. Fr. Ride Height Change (- = Jounce) [mm]	1,3	4,7	10,5	19,4	30,1
Instant. Fr. Roll Center Height [mm]	53,1	61,5	75,5	97,4	123,2
Instant. Fr. Aerodynamic Lift [N]	20,7	83,0	186,7	332,0	518,7
Body					
Instant. Drag Force [N]	-72,6	-290,5	-653,6	-1162,0	-1815,6
Instant. CoG Height SM [mm]	600,8	602,7	605,8	610,6	616,6
Instant. Total CoG Height [mm]	552,2	554,2	557,2	562,0	567,8
Rear End					
Rr. Instant. Vertical Wheel Rate [N/mm]	18,0	18,0	18,0	18,0	18,0
Instant. Rr. Lateral Load Transfer Bias [%]	42,6	42,2	41,7	41,0	40,1
Instant. Rr. Average Tire Loaded Radius [mm]	325,0	324,9	324,9	324,7	324,6
Instant. Rr. Ride Height Change (- = Jounce) [mm]	0,0	-0,2	-1,1	-2,3	-3,4
Instant. Rr. Roll Center Height [mm]	150,0	150,0	150,0	150,0	150,0
Inst. Rr. Aerodyn. Lift [N]	10,4	41,5	93,4	166,0	259,4

LINEAR UNDERSTEER BUDGET CALCULATION

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DYNATUNE-XL

This worksheet calculates linear understeer assuming linear K&C data and a partially linearized tire model considering static toe and camber settings, bump steer and camber gain.

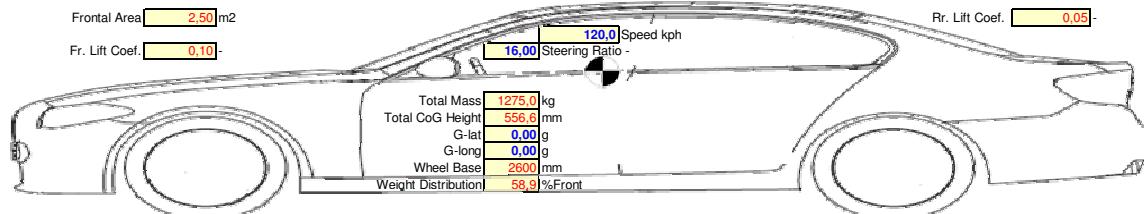
All GENERIC calculations for the Understeer Budget DO NOT consider transient Bump-Stop engagements, however ALL Vertical loads (Rise to CURB due to Payload & Aerodynamic Lift and Braking loads) are considered (and their effect on cornering stiffness) in order to investigate understeer behaviour at any possible vehicle condition. If a SPECIFIC G-Level is entered in the Master Control Sheet an approximate Understeer Gradient will be calculated ONLY for this specific lateral acceleration WITH consideration of NON-LINEAR Bump-Stops.

From Version 7.0 onwards a the performance envelopes can be calculated. Part of this procedure is the calculation of Understeer Gradient and Vehicle Side Slip Angle Gradient as a function of Ax, Ay and V.

[GO TO MASTER](#)

Output Understeer/Oversteer Budget and Front and Rear AXLE cornering stiffness. Generic Calculation of Linear Understeer Behaviour for various G-Levels. From version 7.0 onwards Understeer Gradient and SSA Gradient Performance Envelopes

YOU CAN ONLY ENTER DATA IN THE BLUE/GREY CELLS. RESULTS ARE SHOWN IN THE YELLOW/RED CELLS
BLUE W/ YELLOW CELLS ARE PASSED THROUGH NUMBERS FROM THE MASTER CONTROL SHEET



Fr. Tire Vert. Stiffness: 131.0 N/mm

Fr. Instant. Roll Center Height: 72.8 mm
Fr. Instant. Roll Stiffness w/ Tires: 791.2 Nm/^o
Fr. Instant. Lateral Load Transfer: 58.2 %
Fr. Delta Ride Height (-jounce): 9.4 mm

Generic Understeer		0.0	g Longitudinal Acc.
1.47	U	%g @ Wheel	
23.5	U	%g @ Steering Wheel	

Rr. Tire Vertical Stiffness: 131.0 N/mm

Rr. Instant. Roll Center Height: 150.0 mm
Rr. Instant. Roll Stiffness w/ Tires: 552.4 Nm/^o
Rr. Instant. Lateral Load Transfer: 41.8 %
Rr. Delta Ride Height (-jounce): -1.1 mm

Fr. Instant. Tire Cornering Stiffness: 911.2 N/^o
Fr. Instant. Tire Camber Thrust: 16.4 N/^o
Fr. Instant. Tire AT Stiffness: 29.2 Nm/^o
Fr. Total Ride Toe: -0.03 °
Fr. Ride Camber: -0.42 °

GENERIC UNDERSTEER BUDGET

U = Understeer
O = Oversteer

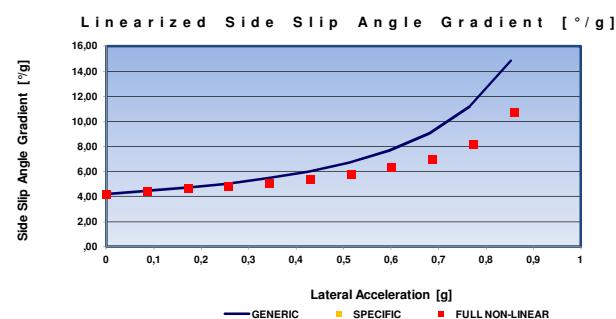
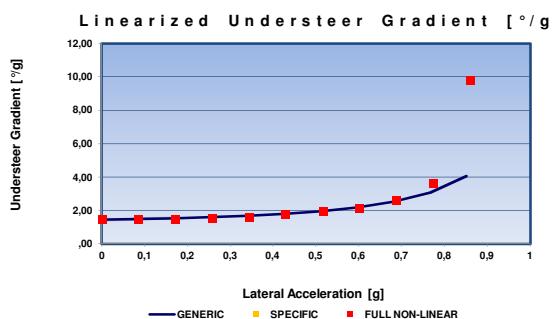
Rr. Instant. Tire Cornering Stiffness: 624.8 N/^o
Rr. Instant. Camber Thrust: 12.5 N/^o
Rr. Instant. AT Stiffness: 22.2 Nm/^o
Rr. Total Ride Toe: 0.10 °
Rr. Ride Camber: -0.75 °

Fr. Instant. AXLE Cornering Stiffness: 74573.4 N/rad
(@ operating point vx & g-long @ 0 g-lat)
Fr. Cornering Compliance: 5.66 U %g

LINEAR UNDERSTEER GRADIENT

1.44 U %g @ WHEEL
23.1 U %g @ STEERING WHEEL

Rr. Instant. AXLE Cornering Stiffness: 69796.9 N/rad
(@ operating point vx & g-long @ 0 g-lat)
Rr. Cornering Compliance: 4.22 O %g



Cornering Compliance & Understeer Calculation (modified BUNDORF)

[GO TO MASTER](#)

Contribution of Weight Distribution and Tire & Suspension Compliance

Weight distribution & Tire Cornering Stiffness
Ride Toe and Ride Camber
Lateral Force Compliance Steer
Aligning Torque Compliance Steer

Effect of aligning torque on whole vehicle

FRONT AXLE			REAR AXLE			DELTA FRONT- REAR		
4.04	U		4.11	O		-0.07	O	
0.00	U		-0.02	U		0.02	O	
0.92	U		0.10	O		0.82	U	
0.41	U		0.09	O		0.32	U	
5.38	U		4.29	O		1.09	U	
1.02	U		x 0.97	O		4.16	O	
5.50	U					1.34	U	
Total								
Grand Total	5.66	U	4.22	O		1.44	U	

Contribution of Vehicle Roll

Roll Steer
Roll Camber / Inclination Angle Gain

Interactions:
Inclination Angle Gain with Aligning Torque Compliance Steer
Inclination Angle Gain with Lateral Force Compliance Steer
Inclination Angle Gain with Aligning Torque on whole vehicle

Total Axle Cornering Compliance

Grand Total

5.66 U

All Units are %g

Understeer Gradient & Side Slip Angle Gradient Performance Envelope Plots

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[GO TO LAPTIME](#)

Creating a LINEAR G-G-V Map is CPU time consuming. If any Bump-Stops are activated in Roll the results can be incorrect. In that particular case a NON-LINEAR calculation is recommended. The LINEAR G-G-V Map procedure will ALWAYS use the BASE Tire Model !

[CREATE LINEAR G-G-V MAP](#)

Understeer & Side Slip Angle Gradient are calculated automatically within the G-G-V Map Procedure.

[CREATE NON-LINEAR G-G-V MAP](#)

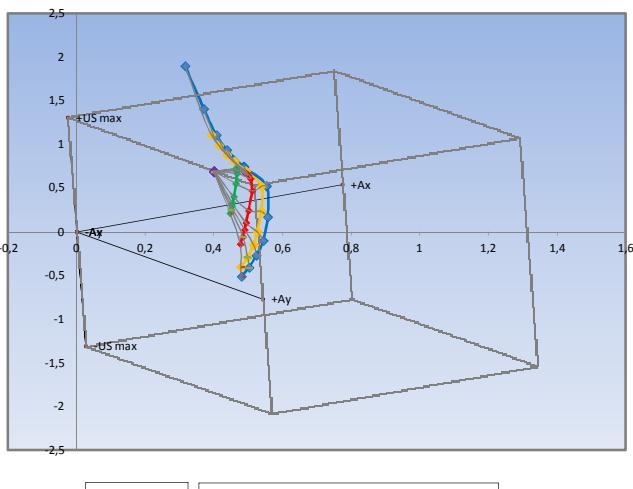
Imposed US Gradient Limit (Cornering) 15 (%g)
Imposed SSA Gradient Limit (Cornering) 15 (%g)

ACTIVE TIRE
ENHANCED TIRE

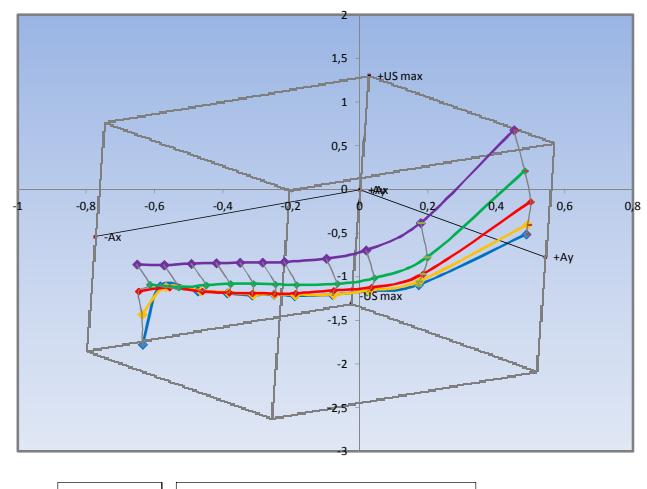
ACTIVE MAP
LINEAR

Creating a NON-LINEAR G-G-V Map causes a major increase of CPU time (about 10x). If no Bump-Stops are activated in Roll and the BASE Tire model is being used a LINEAR Analysis is sufficient. The NON-LINEAR G-G-V Map Calculation in combination with the ENHANCED Tire Model represents the most detailed graphic presentation of a vehicles Performance Envelope.

Understeer Gradient f (Ax, Ay, V) under Traction



Understeer Gradient = f (Ax, Ay, V) under Braking



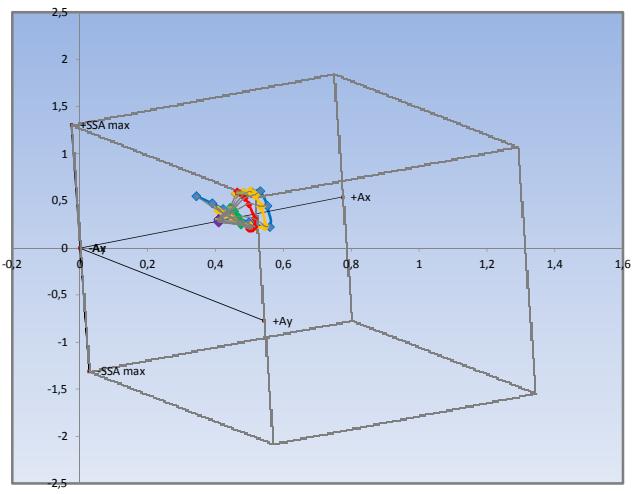
Angles of Rotation for Chart

Top View	Front View	Side View	Activate/Reset Graph
<input checked="" type="checkbox"/> Default Angles			

Graph Reference Data Table

V [kph]	Ax [g]	Ay [g]	US Grad [%g]
42	0,00	0,84	2,0
42	0,43	0,00	19,0
85	0,00	0,85	3,3
85	0,36	0,20	12,2
127	0,00	0,85	6,3
127	0,21	0,59	12,0
169	0,00	0,81	10,0
169	0,10	0,71	14,2
212	0,00	0,74	14,8
212	0,01	0,72	14,6

Rear Side Slip Angle Gradient f (Ax, Ay, V) under Traction



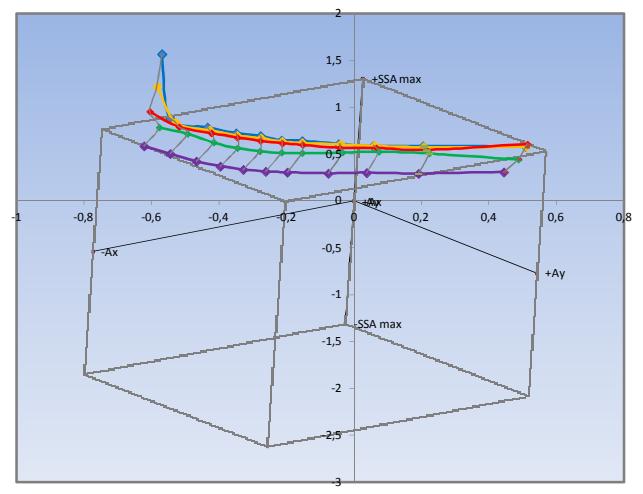
Angles of Rotation for Chart

Top View	Front View	Side View	Activate/Reset Graph
<input checked="" type="checkbox"/> Default Angles			

Graph Reference Data Table

V [kph]	Ax [g]	Ay [g]	US Grad [%g]
42	0,00	0,84	2,0
42	-0,74	0,00	-15,5
85	0,00	0,85	3,3
85	-0,75	0,00	-11,5
127	0,00	0,85	6,3
127	-0,77	0,00	-8,3
169	0,00	0,81	10,0
169	-0,79	0,08	-6,6
212	0,00	0,74	14,8
212	-0,83	0,06	-3,8

Rear Side Slip Angle Gradient f (Ax, Ay, V) under Braking



Angles of Rotation for Chart

Top View	Front View	Side View	Activate/Reset Graph
<input checked="" type="checkbox"/> Default Angles			

Graph Reference Data Table

V [kph]	Ax [g]	Ay [g]	SSA Grad [%g]
42	0,00	0,84	14,5
42	0,43	0,00	3,6
85	0,00	0,85	14,6
85	0,36	0,20	4,1
127	0,00	0,85	14,9
127	0,21	0,59	6,5
169	0,00	0,81	12,7
169	0,10	0,71	8,7
212	0,00	0,74	10,5
212	0,01	0,72	9,9

Angles of Rotation for Chart

Top View	Front View	Side View	Activate/Reset Graph
<input checked="" type="checkbox"/> Default Angles			

Graph Reference Data Table

V [kph]	Ax [g]	Ay [g]	SSA Grad [%g]
42	0,00	0,84	14,51
42	-0,74	0,00	22,83
85	0,00	0,85	14,56
85	-0,75	0,00	18,93
127	0,00	0,85	14,90
127	-0,77	0,00	16,01
169	0,00	0,81	12,67
169	-0,79	0,08	14,96
212	0,00	0,74	10,49
212	-0,83	0,06	12,75

DAMPER TUNING - PERCENTAGE CRITICAL DAMPING

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This worksheet calculates the damper characteristics at the wheel (considering the effect of motion ratio's) and the percentage of critical damping in bump, rebound and overall for several damper speeds both in "impact" (starting from 0) mode as in "continuous" damper actuation (from speed point to speed point). The sheet uses at front & rear average wheelrates (between left & right).

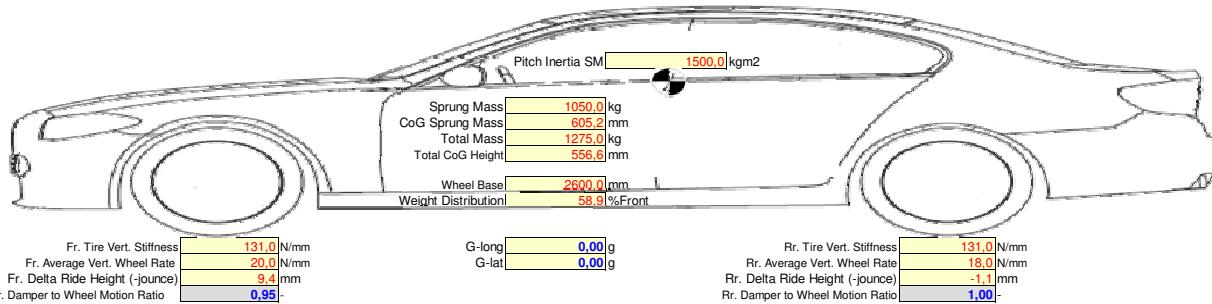
Tire Damping is considered generically with a 5% critical damping. Free oscillations of front and rear body are calculated based on differential equations for a generic step input.

Optionally the ride transfer function can be calculated but since this is numerically highly intensive (both calculation time and saving time of the whole workbook increase significantly) it can be turned off.

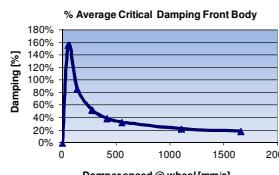
All calculations are based on a LINEAR model assuming LINEAR damper characteristics - calculated as average from the first 3 bump/rebound velocities of NON-LINEAR damper data - Payload, Aerodynamics & Bump-Stops (non-linear wheel rates) are considered in partially linear calculations

[GO TO MASTER](#)

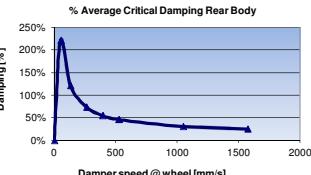
YOU CAN ONLY ENTER DATA IN THE BLUE/GREY CELLS. RESULTS ARE SHOWN IN THE YELLOW/RED CELLS
BLUE W/ YELLOW CELLS ARE PASSED THROUGH NUMBERS FROM THE MASTER CONTROL SHEET



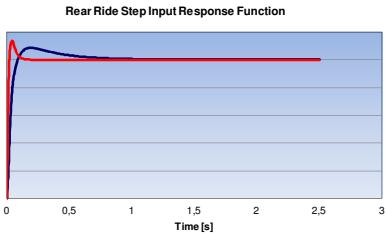
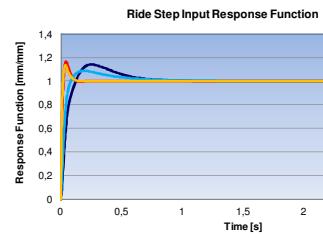
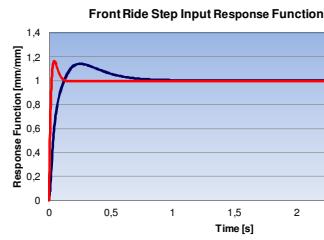
FRONT SUSPENSION
 Fr. Body Frequency **1.27** Hz
 Fr. Body Ride Frequency **1.19** Hz
 Fr. Wheelhop Frequency **7.62** Hz
 Fr. Linear Damping @ Wheel **4911.3** Ns/m
 (Average out of first 3 damper velocity for bump & rebound)
 Fr. Damping Scaling Factor **1.00**.
 (Permits Scaling of Fr. Linear Damping @ Wheel for Analysis)



REAR SUSPENSION
 Rr. Body Frequency **1.47** Hz
 Rr. Body Ride Frequency **1.38** Hz
 Rr. Wheelhop Frequency **8.69** Hz
 Rr. Linear Damping @ Wheel **5441.9** Ns/m
 (Average out of first 3 damper velocity for bump & rebound)
 Rr. Damping Scaling Factor **1.00**.
 (Permits Scaling of Rr. Linear Damping @ Wheel for Analysis)



ENABLE RIDE STEP RESPONSE CALCULATION **1** (Y/N 1/0)

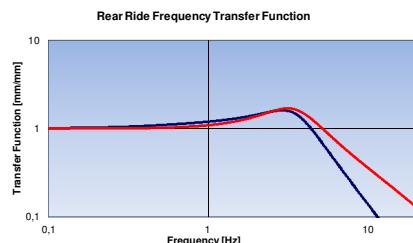
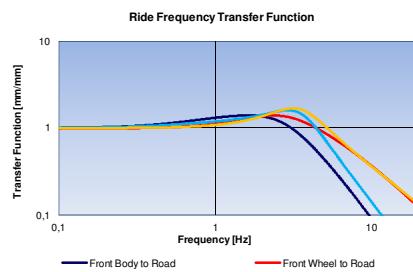
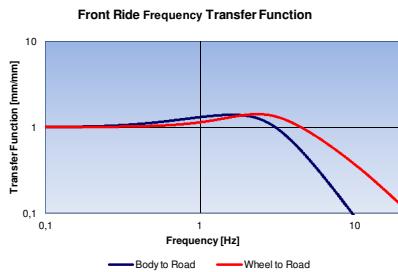


Front Body
 Time to 95% damped oscillation **0,520** s
 Peak Overshoot **1,139**
 Time to reach Peak Value **0,25** s

Rear Body
 Time to 95% damped oscillation **0,370** s
 Peak Overshoot **1,085**
 Time to reach Peak Value **0,19** s

ENABLE FREQUENCY RESPONSE CALCULATION **1** (Y/N 1/0)
 WARNING: FREQUENCY RESPONSE CALCULATION WILL SIGNIFICANTLY INCREASE CALCULATION TIME !!

[GO TO MASTER](#)

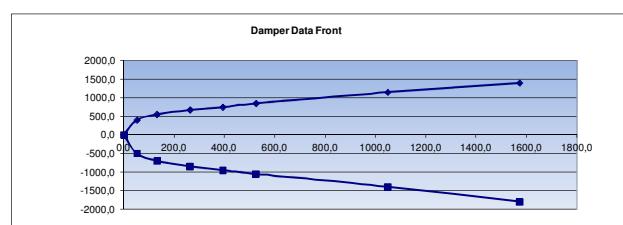


Front Frequency Sweep Results
 Body Dynamic Overshoot @ Peak Freq. **1,40**
 Front Wheel Dyn. Load Indicator 0 - 20 Hz **8,58**

Rear Frequency Sweep Results
 Body Dynamic Overshoot @ Peak Freq. **1,60**
 Rear Wheel Dyn. Load Indicator 0 - 20 Hz **9,46**

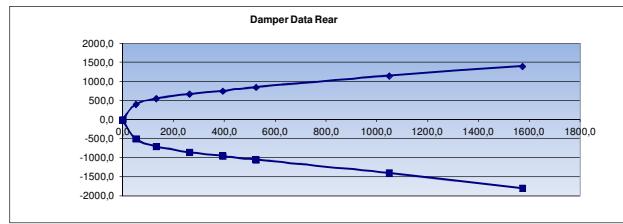
Front suspension Shock (measured shock data)

Measured Damper Data			
Bump Speed (mm/s)	Force (N)	Reb. Speed (mm/s)	Force (N)
0,0	0,0	0,0	0,0
52,0	400,0	-52,0	-500,0
131,0	550,0	-131,0	-700,0
262,0	670,0	-262,0	-850,0
393,0	750,0	-393,0	-950,0
524,0	850,0	-524,0	-1050,0
1048,0	1150,0	-1048,0	-1400,0
1572,0	1400,0	-1572,0	-1800,0



Rear suspension Shock (measured shock data)

Measured Damper Data			
Bump Speed (mm/s)	Force (N)	Reb. Speed (mm/s)	Force (N)
0,0	0,0	0,0	0,0
52,0	400,0	-52,0	-500,0
131,0	550,0	-131,0	-700,0
262,0	670,0	-262,0	-850,0
393,0	750,0	-393,0	-950,0
524,0	850,0	-524,0	-1050,0
1048,0	1150,0	-1048,0	-1400,0
1572,0	1400,0	-1572,0	-1800,0

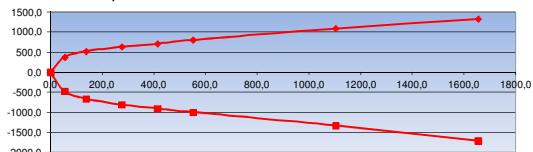


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Output Parameter

Calculated Front Damper @ WHEEL (considering motion ratio)			
Bump Speed (mm/s)	Force (N)	Reb. Speed (mm/s)	Force (N)
0,0	0,0	0,0	0,0
54,7	380,0	-54,7	-475,0
137,9	522,5	-137,9	-665,0
275,8	636,5	-275,8	-807,5
413,7	712,5	-413,7	-902,5
551,6	807,5	-551,6	-997,5
1103,2	1092,5	-1103,2	-1330,0
1654,7	1330,0	-1654,7	-1710,0

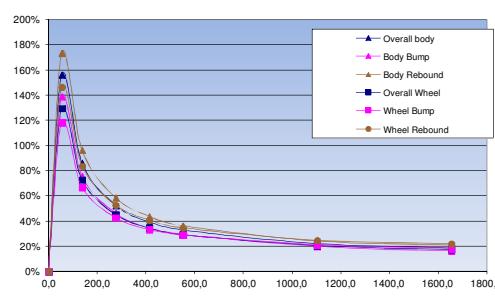
Damper Characteristics at the Front Wheel



Front Body

Percent Critical Damping for "IMPACT" events (damper "rate" from 0 to operating point)			
Bump/Rebound Speed (mm/s)	Overall body	Body Bump	Body Rebound
0,0	0,0	0,0	0,0
54,7	1,56	1,39	1,73
137,9	0,86	0,76	0,96
275,8	0,52	0,46	0,59
413,7	0,39	0,34	0,44
551,6	0,33	0,29	0,36
1103,2	0,22	0,20	0,24
1654,7	0,18	0,16	0,21

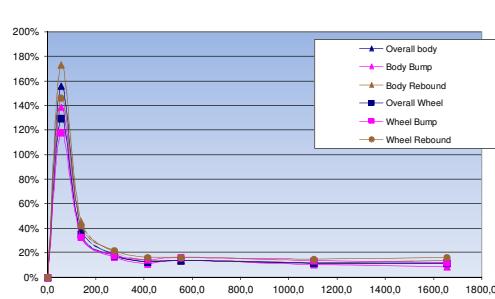
Percentage Critical Damping FRONT IMPACT



Front Wheel

Percent Critical Damping for "IMPACT" events (damper "rate" from 0 to operating point)			
Bump/Rebound Speed (mm/s)	Overall Wheel	Wheel Bump	Wheel Rebound
0,0	0,0	0,0	0,0
54,7	1,30	1,18	1,46
137,9	0,73	0,67	0,83
275,8	0,45	0,43	0,53
413,7	0,34	0,33	0,41
551,6	0,29	0,29	0,34
1103,2	0,20	0,21	0,25
1654,7	0,17	0,18	0,22

Percentage Critical Damping FRONT CONTINUOUS



Front Body

Percent Critical Damping for "CONTINUOUS" EVENTS (instantaneous damper rate)			
Bump/Rebound Speed (mm/s)	Overall body	Body Bump	Body Rebound
0,0	0,0	0,0	0,0
54,7	1,56	1,39	1,73
137,9	0,40	0,34	0,46
275,8	0,19	0,17	0,21
413,7	0,12	0,11	0,14
551,6	0,14	0,14	0,14
1103,2	0,11	0,10	0,12
1654,7	0,11	0,09	0,14

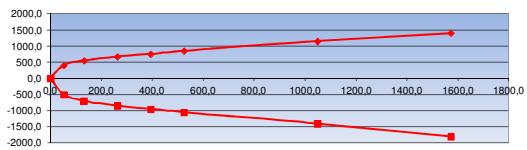
Front Wheel

Percent Critical Damping for "CONTINUOUS" EVENTS (instantaneous damper rate)			
Bump/Rebound Speed (mm/s)	Overall Wheel	Wheel Bump	Wheel Rebound
0,0	0,0	0,0	0,0
54,7	1,30	1,18	1,46
137,9	0,35	0,33	0,42
275,8	0,18	0,18	0,22
413,7	0,13	0,14	0,16
551,6	0,14	0,16	0,16
1103,2	0,12	0,13	0,15
1654,7	0,12	0,12	0,16

Rear Damper @ WHEEL (considering motion ratio)

Bump Speed (mm/s)	Force (N)	Reb. Speed (mm/s)	Force (N)
0,0	0,0	0,0	0,0
52,0	400,0	-52,0	-500,0
131,0	550,0	-131,0	-700,0
262,0	670,0	-262,0	-850,0
393,0	750,0	-393,0	-950,0
524,0	850,0	-524,0	-1050,0
1048,0	1150,0	-1048,0	-1400,0
1572,0	1400,0	-1572,0	-1800,0

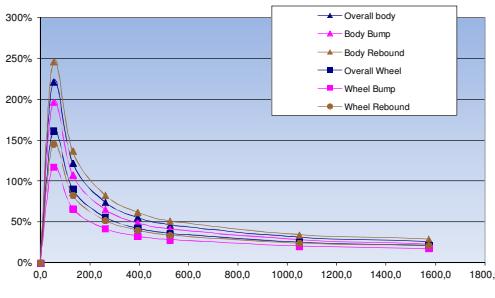
Damper Characteristics at the Rear Wheel



Rear Body

Percent Critical Damping for "IMPACT" events (damper "rate" from 0 to operating point)			
Bump/Rebound Speed (mm/s)	Overall body	Body Bump	Body Rebound
0,0	0,0	0,0	0,0
52,0	2,21	1,97	2,46
131,0	1,22	1,07	1,37
262,0	0,74	0,65	0,83
393,0	0,55	0,49	0,62
524,0	0,46	0,42	0,51
1048,0	0,31	0,28	0,34
1572,0	0,26	0,23	0,29

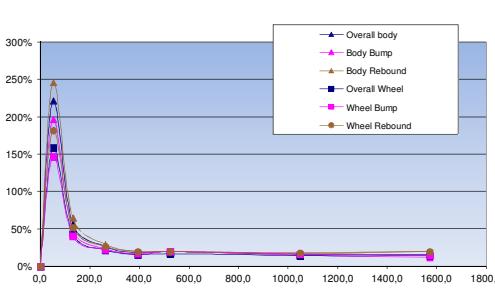
Percentage Critical Damping REAR IMPACT



Rear Wheel

Percent Critical Damping for "IMPACT" events (damper "rate" from 0 to operating point)			
Bump/Rebound Speed (mm/s)	Overall Wheel	Wheel Bump	Wheel Rebound
0,0	0,0	0,0	0,0
52,0	1,61	1,17	1,45
131,0	0,90	0,66	0,83
262,0	0,56	0,42	0,52
393,0	0,42	0,32	0,40
524,0	0,36	0,28	0,34
1048,0	0,25	0,21	0,24
1572,0	0,21	0,18	0,21

Percentage Critical Damping REAR CONTINUOUS



Rear Body

Percent Critical Damping for "CONTINUOUS" EVENTS (instantaneous damper rate)			
Bump/Rebound Speed (mm/s)	Overall body	Body Bump	Body Rebound
0,0	0,0	0,0	0,0
52,0	2,21	1,97	2,46
131,0	0,57	0,49	0,65
262,0	0,26	0,23	0,29
393,0	0,18	0,16	0,20
524,0	0,20	0,20	0,20
1048,0	0,16	0,15	0,17
1572,0	0,16	0,12	0,20

Rear Wheel

Percent Critical Damping for "CONTINUOUS" EVENTS (instantaneous damper rate)			
Bump/Rebound Speed (mm/s)	Overall Wheel	Wheel Bump	Wheel Rebound
0,0	0,0	0,0	0,0
52,0	1,59	1,47	1,82
131,0	0,43	0,40	0,52
262,0	0,22	0,22	0,27
393,0	0,15	0,17	0,20
524,0	0,17	0,20	0,20
1048,0	0,14	0,16	0,18
1572,0	0,14	0,14	0,20

* motion ratio from 0 to 1 (1 = wheel travel)

** Unsprung mass is considered for each corner

*** Damping in tire empirically considered (5% critical)

**** Bump positive, rebound negative

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This worksheet calculates instantaneous wheelrates, natural bounce and pitch frequency as well as the bounce and pitch centers.
All calculations are partially LINEAR, Payload, Aerodynamics & Bump-Stops are considered

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YOU CAN ONLY ENTER DATA IN THE BLUE/GREY CELLS. RESULTS ARE SHOWN IN THE YELLOW/RED CELLS
BLUE W/ YELLOW CELLS ARE PASSED THROUGH NUMBERS FROM THE MASTER CONTROL SHEET

LF Instant. Suspension WHEEL Rate

20,0

RF Instant. Suspension WHEEL Rate

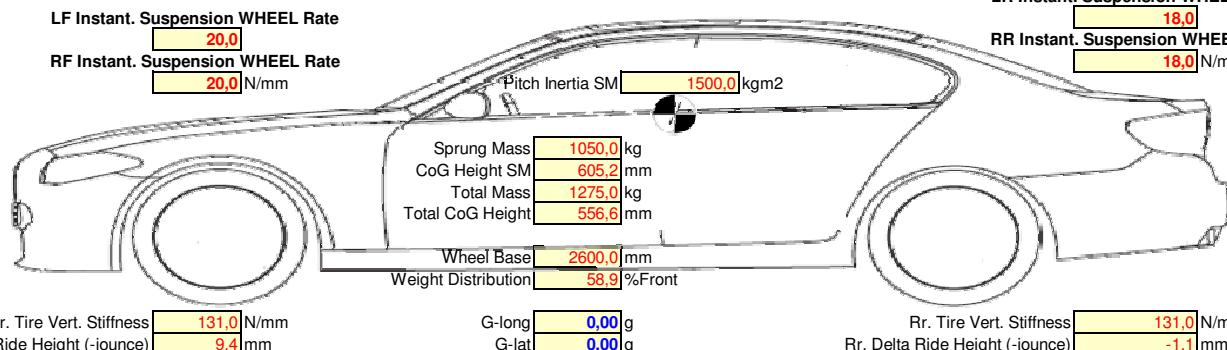
20,0 N/mm

LR Instant. Suspension WHEEL Rate

18,0

RR Instant. Suspension WHEEL Rate

18,0 N/mm



Output Parameter RESULTS

Fr. Ride Frequency **1,185** Hz
Rr. Ride Frequency **1,375** Hz
Ratio Rr/Fr Ride Frequency **1,160** -

Average Wheelrate (In case of a-symmetric left & right Bump-Stop activation the average of left & right will be used)

Average Front Wheel Rate	20,0 N/mm	Average Rear Wheel Rate	18,0 N/mm
--------------------------	------------------	-------------------------	------------------

Ride Rates (including tires)

Average Front Ride Rate	17,4 N/mm	Average Rear Ride Rate	15,8 N/mm
-------------------------	------------------	------------------------	------------------

Pitch Frequency (frequency one) **1,429** Hz
Bounce Frequency (frequency two) **1,217** Hz

Pitch Center (motion center one) **0,622** m
Bounce Center (motion center two) **-2,296** m

The sign indicates whether the Motion Center is located fore or aft relative to CoG position with respect to CoG x-position (positive numbers = distance from CoG in forward direction) with respect to CoG x-position (negative numbers = distance from CoG in rearward direction)

Relative to FRONT AXLE

Pitch Center (motion center one) **-0,447** m
Bounce Center (motion center two) **-3,365** m

negative = behind front axle
negative = behind front axle

The differential equations for the analytical model of the body movement provide 2 solutions, so called motion centres ("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

RANGE CARPET PLOTS FROM 75% to 125% WHEEL RATE

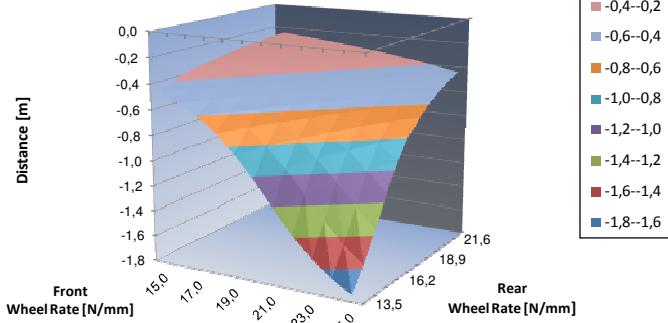
front WHEEL rate from to
rear WHEEL rate from to

15,0 **25,0** N/mm
13,5 **22,5** N/mm

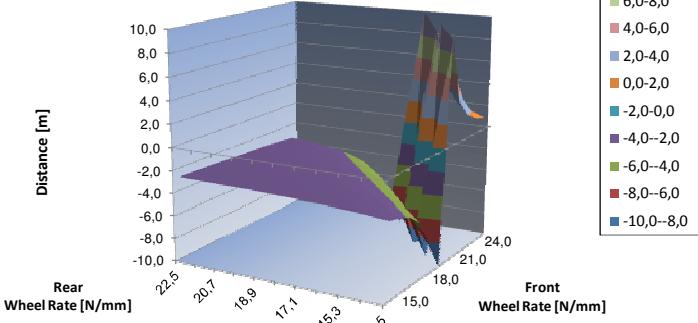
BOUNCE & PITCH CENTER CARPET PLOTS

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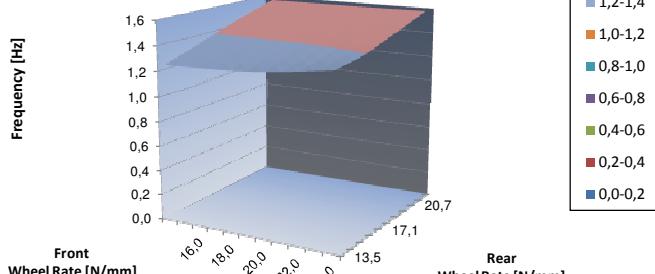
Motion Center "One" Relative to Front Axle (usually Pitch)



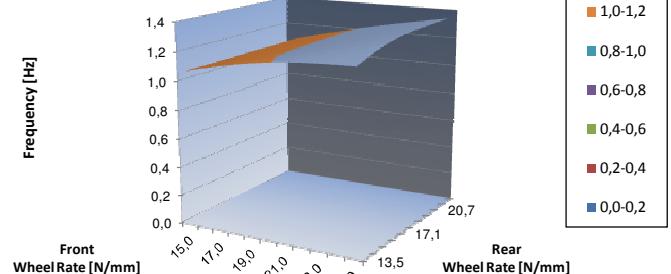
Motion Center "Two" Relative to Front Axle (usually Bounce)



Frequency "One" (usually Pitch)



Frequency "Two" (usually Bounce)



ROLLBAR TUNING - BASIC MECHANICAL BALANCE

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This worksheet calculates body on chassis roll, roll couple distribution and the percentage of front lateral load transfer distribution.

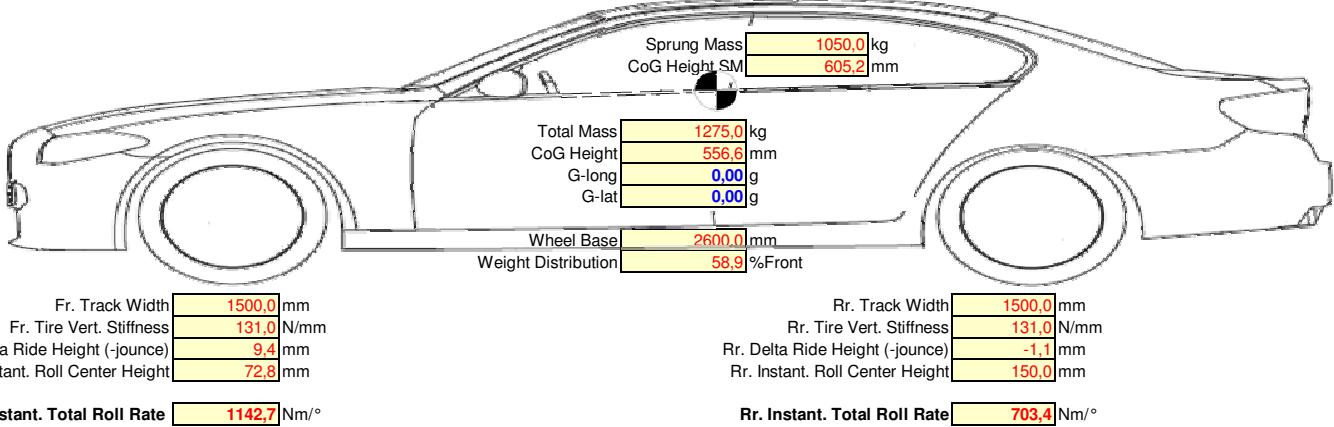
ALL Vertical loads (Rise to CURB due to Payload & Aerodynamic Lift and Braking loads)are considered

All calculations are partially LINEAR

Output: Linear Rollangle Gradient, Roll Couple and Lateral Load Transfer Distribution both linear as non-linear (Bump-Stops) if applicable

YOU CAN ONLY ENTER DATA IN THE BLUE/GREY CELLS. RESULTS ARE SHOWN IN THE YELLOW/RED CELLS

BLUE W/ YELLOW CELLS ARE PASSED THROUGH NUMBERS FROM THE MASTER CONTROL SHEET



SPECIFIC CALCULATION (G-lat >0) INSTANTANEOUS VALUES

[GO TO MASTER](#)

Output Parameter	RESULTS
Inst. Lat. Load Transfer Dist. (Wheel Lift)	58,2 % front
Inst. Lateral Load Transfer Distribution	58,2 % front
Instant. Roll Couple Distribution	61,9 % front
Instant. L.L.T. Bias	-0,7 % rel. to CoG

Rollangle due to Roll Moment	0,00 °
Rollangle @ Bump-Stop Activation	1,83 °
Lateral G @ Bump-Stop	0,66 g

(Pure Roll, no Lifting Effects of Roll Center Height)

TOTAL FR. & RR. SUSPENSION ROLL RATE 1846,1 Nm/° (without tires)

FRONT TOTAL ROLLRATE	1142,7 Nm/°	REAR TOTAL ROLLRATE	703,4 Nm/°
Front Roll Rate due to Springs	392,7 Nm/°	Rear Roll Rate due to springs	353,4 Nm/°
Front Roll Rate due to ARB	750,0 Nm/°	Rear Roll Rate due to ARB	350,0 Nm/°
% Contribution of ARB to total	65,6 %	% contribution of ARB to total	49,8 %

TOTAL FR. & RR. ROLL RATE WITH TIRES 1343,6 Nm/° (with tires)

FRONT	REAR
Front Roll Stiffness w/ Tires	791,2 Nm/°
Rear Roll Stiffness w/ Tires	552,4 Nm/°

Lateral Load Transfer Calculation considering Roll Rates, Roll Center Heights & Unsprung Masses

Suspension Load Transfer	Total	0,0 N	
Fr. Suspension Load Transfer	0,0 N	Rr. Suspension Load Transfer	0,0 N
Lateral Load Transfer	Total	0,0 N	
Fr. Load Transfer	0,0 N	Rr. Lateral Load Transfer	0,0 N

0 0 0 0

[GO TO MASTER](#)

Output Parameter RESULTS

Linear Body on Chassis Rollangle	2,79 %g
Linear Vehicle Rollangle (w/ Tires)	4,19 %g
(pure roll, no jacking effects of Roll Center Height)	
Linear Lateral Load Transfer Distribution	58,2 % front
Linear Roll Couple Distribution	61,9 % front
L.L.T. Bias	-0,7 % rel. to Cog

GENERIC CALCULATION (G-Lat=0) GENERIC VALUES

TOTAL FR. & RR. SUSPENSION ROLL RATE 1846,1 Nm/° (without tires)

FRONT TOTAL ROLLRATE	1142,7 Nm/°	REAR TOTAL ROLLRATE	703,4 Nm/°
Front Roll Rate due to Springs	392,7 Nm/°	Rear Roll Rate due to springs	353,4 Nm/°
Front Roll Rate due to ARB	750,0 Nm/°	Rear Roll Rate due to ARB	350,0 Nm/°
% Contribution of ARB to total	65,6 %	% contribution of ARB to total	49,8 %

TOTAL FR. & RR. ROLL RATE WITH TIRES 1343,6 Nm/° (with tires)

FRONT	REAR
Front Roll Stiffness w/ Tires	791,2 Nm/°
Rear Roll Stiffness w/ Tires	552,4 Nm/°

Total Roll Rate of Tires Only 5144,2 Nm/°

Front Tires Roll Rate	2572,1 Nm/°	Rear Tires Roll Rate	2572,1 Nm/°
-----------------------	-------------	----------------------	-------------

0 0 0 0

Lateral Load Transfer Calculation considering Roll Rates, Roll Center Heights & Unsprung Masses

Lateral Load Transfer	Total	4639,8 N/g	
Fr. Load Transfer	2699,0 N/g	Rr Load Transfer	1940,8 N/g

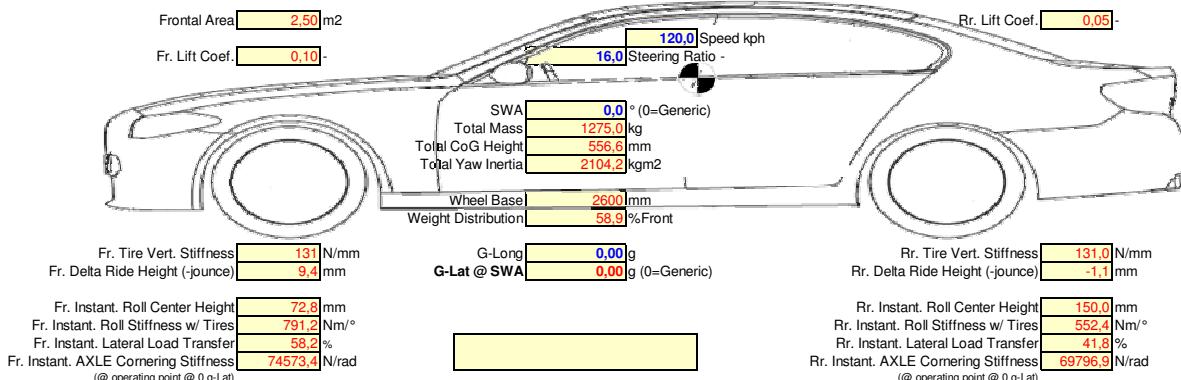
LINEAR BICYCLE MODEL FREQUENCY STEER RESPONSE CALCULATION

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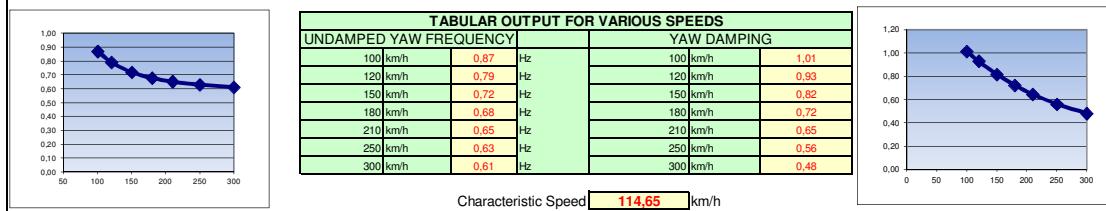
This worksheet calculates linear frequency response based on a bicycle model. ALL Vertical loads (Rise to CURB due to Payload & Aerodynamic Lift and Braking loads) are considered (and their effect on cornering stiffness) in order to investigate stability behaviour at any possible vehicle condition
All calculations are partially LINEAR.
If a specific STEERING WHEEL ANGLE is specified a non-generic calculation will be executed based on the resulting front and rear total cornering stiffness at that SWA & G-level.

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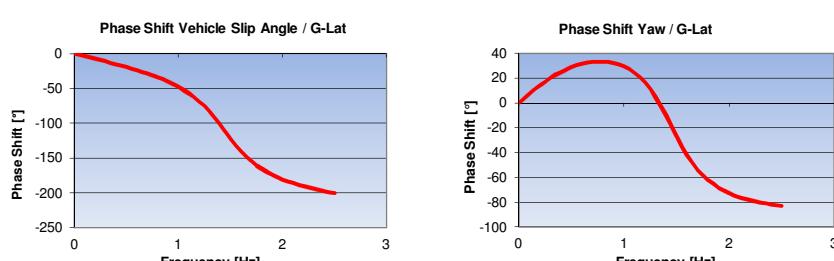
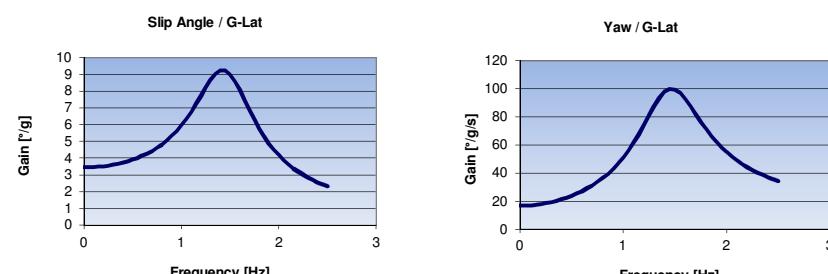
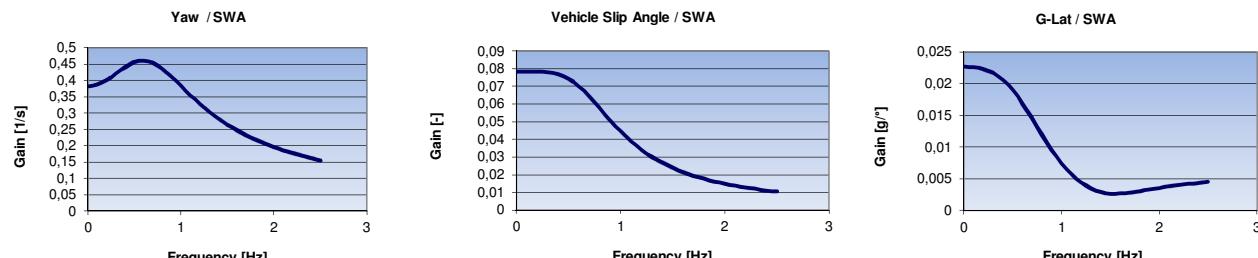
YOU CAN ONLY ENTER DATA IN THE BLUE/GREY CELLS. RESULTS ARE SHOWN IN THE YELLOW/RED CELLS
BLUE W/ YELLOW CELLS ARE PASSED THROUGH NUMBERS FROM THE MASTER CONTROL SHEET



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Frequency Steer Response Data	Yaw / SWA	Slip Angle / SWA	G-Lat / SWA	Slip Angle / G-Lat	Yaw / G-Lat
Peak Frequency	0,600 Hz	0,200 Hz	0,000 Hz	1,400 Hz	1,450 Hz
Static Gain @ 0 Hz	0,382 1/s	0,078	0,023 g/°	3,446 °/g	16,863 °/s/g
Dynamic Overshoot @ Peak	1,205	1,002	1,000	2,680	5,925
Delay Time @ 1 Hz	142,03 ms	356,40 ms	224,03 ms	132,37 ms	-81,99 ms



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LINEAR BICYCLE MODEL STEP STEER RESPONSE CALCULATION

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This worksheet calculates linear step steer response based on a bicycle model. ALL Vertical loads (Rise to CURB due to Payload & Aerodynamic Lift and Braking loads) are considered (and their effect on cornering stiffness) in order to investigate stability behaviour at any possible vehicle condition

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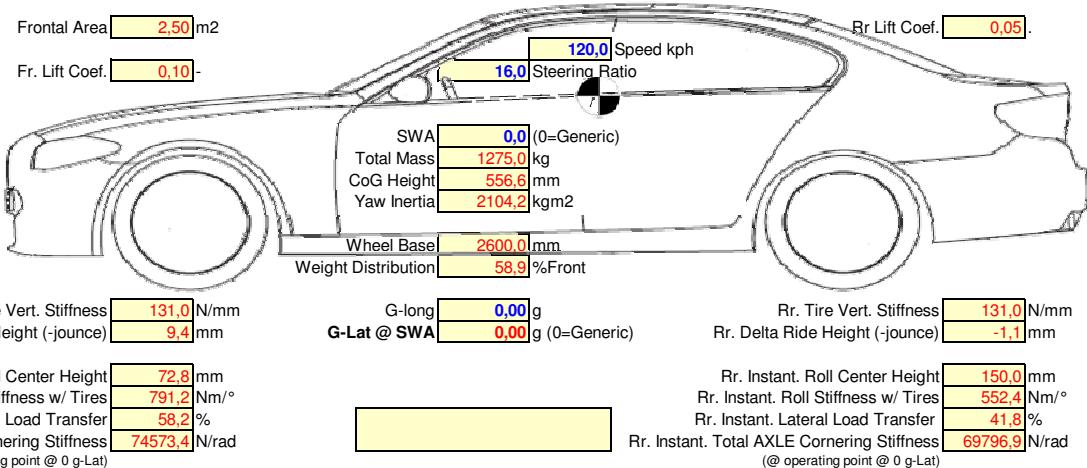
All calculations are partially LINEAR.

Generic Step Steer Responses are calculated as linear gradients. When a specific STEERING WHEEL ANGLE is specified all absolute values will be calculated based on the resulting final lateral acceleration and the according front and rear total cornering stiffness at that SWA / G-level.

Output: Yaw, Slip and lateral acceleration responses with specific response times

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BLUE W/ YELLOW CELLS ARE PASSED THROUGH NUMBERS FROM THE MASTER CONTROL SHEET



Step Steer Response Data	Yaw Gain [1/s]	Slip Angle Gain [-]	G-Lat Gain [g/ ¹]
90% Response Time	0,21 s	0,57 s	0,47 s
Peak Value	0,45 1/s	0,08 -	0,02 g/ ⁰
Time to reach Peak Value	0,48 s	0,93 s	0,83 s
Dynamic Overshoot @ Peak	1,17 -	1,05 -	1,05 -

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