User Manual for PC2Tuner

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1. Introduction.

Thank you for your purchase of PC2Tuner. This tool was created by myself (Zach Etier) professional engineer in the real world. I made this tool because to many times on the forums and in videos I see guides for tuning these systems. Most guides focus on solely suspension tuning, however you cannot tune your suspension without also tuning your dampers. This tool helps you do so by looking at Dampening Ratio, Natural Frequencies, and the Time Domain System Response. I hope you enjoy this software, if you have any questions or comments please free to contact me at Zdetier@gmail.com as with your purchase of this software you receive lifetime support, and updates.

2. License Agreement.

With your purchase of PC2Tuner, you agree to not redistribute this software to any other people. This license is a multi-computer, one user license. In no way may you reverse engineer the code. This software is the sole copyright of Zach Etier 2018.

3. How to Install.

1) Download the PC2TunerVX_X_X zip file.
2) Extract the contents of the Folder to a destination on your computer.
3) Navigate to the location you extracted the zip file contents to.
4) Run the “Setup.exe” file. Follow all of the prompts either clicking yes or next.
5) After the program installs, on your Windows Start Bar, you should see a PC2Tuner software, if not navigate to the folder you extracted from the ZIP, click the application file, and create a shortcut on your desktop.
6) To launch the program either click the PC2Tuner application on your windows task bar, or by clicking on the shortcut you created.

4. Inputs and Outputs.

There are several inputs to the program, including suspension geometries, damper geometries, unsprung wrights, sprung weights, spring rates, damper rates, knee spread, and longitudinal weight bias. However, all of these are not required by the user (some are retrieved from the game itself). The inputs the user needs to input themselves which can be found in the Tune UI inside project cars 2 is found below.

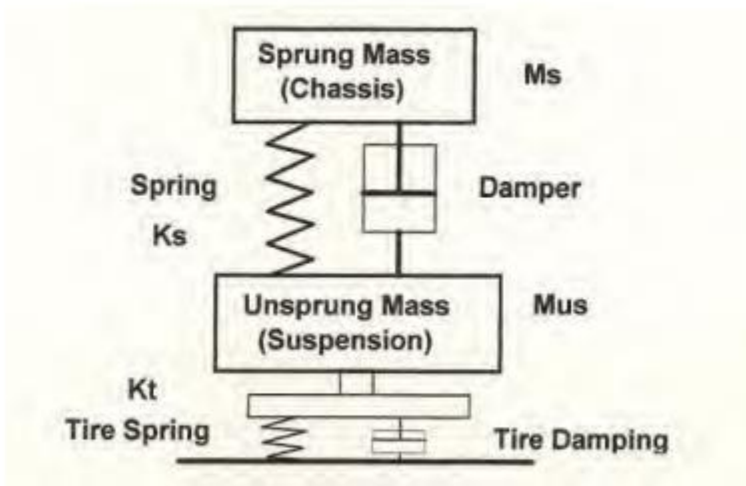
1. Front & Rear Spring Rates (N/mm)
2. Front & Rear Low Speed Bump (N-s/m)
3. Front & Rear Low Speed Rebound (N-s/m)
4. Front & Rear High Speed Bump (N-s/m)
5. Front & Rear High Speed Rebound (N-s/m)
6. Weight (lbs.)
7. Weight Bias (% of Weight on Rear Axle)

After all inputs are given click the “Calculate” button, the program will then give you the following outputs.

1. Front Damper Force vs Damper Velocity Graph
2. Rear Damper Force vs Damper Velocity Graph
3. Low Speed System Response Graph
4. High Speed System Response Graph
5. Front and Rear Dampening Ratios for (Low Speed Bump/Rebound, High Speed Bump/Rebound)
6. Front & Rear Critical Dampening values
7. Front & Rear Natural Frequency
8. Spring Natural Frequency Bias

5. Suspension / Damper Theory.

A suspension system diagram is given below;



The system consists of two springs (Suspension Spring, Tire Spring) in series, and two dampers Suspension Damper, and Tire Damper) in series.

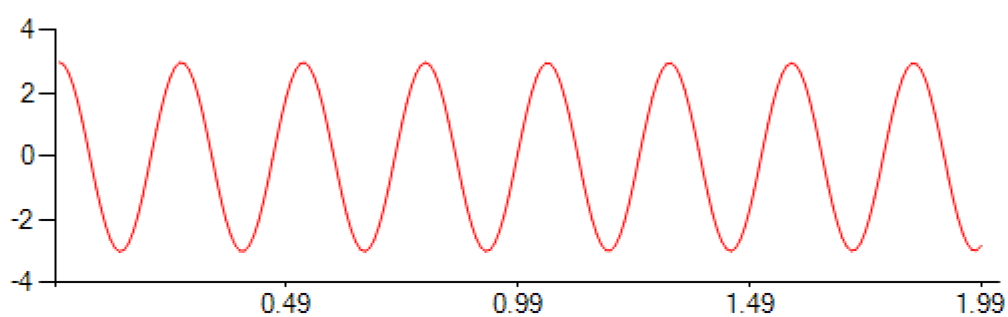
A spring stores potential energy by compressing / decompressing the spring. The equation for a spring is given below;

$$K = M*\Delta X$$

Where K is the spring rate, M is the mass, and X is the position.

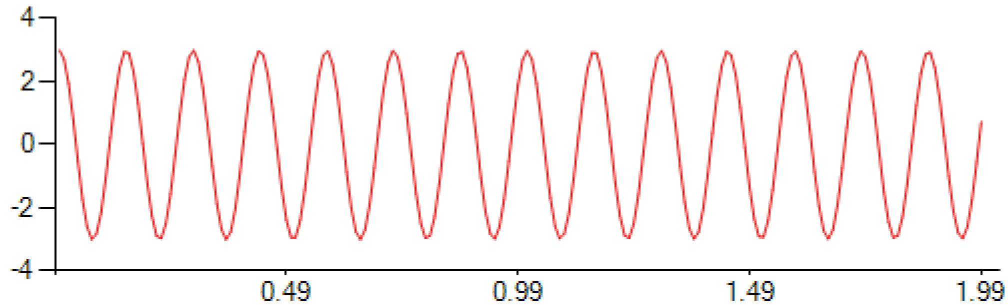
A Damper is similar to a spring, however it dissipates kinetic energy, by resisting velocity. (The higher the velocity, the higher the force). We can think of the damper as a Dynamic Spring of sorts. This type of system is what is known in the engineering world as a damped Oscillator.

When an Oscillator has no damping we get the system response below;

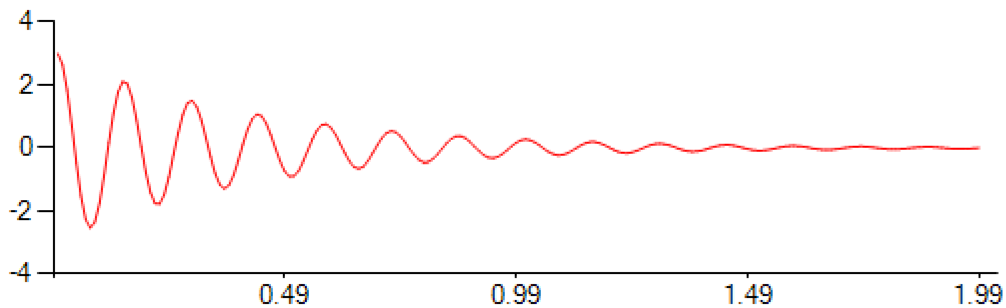


As you can see the signal is a sinusoidal wave where the (amplitude) is constant (no damping).

If we increase the Spring Rate of the system we get the same graph as above but a higher frequency, this graph is given below;

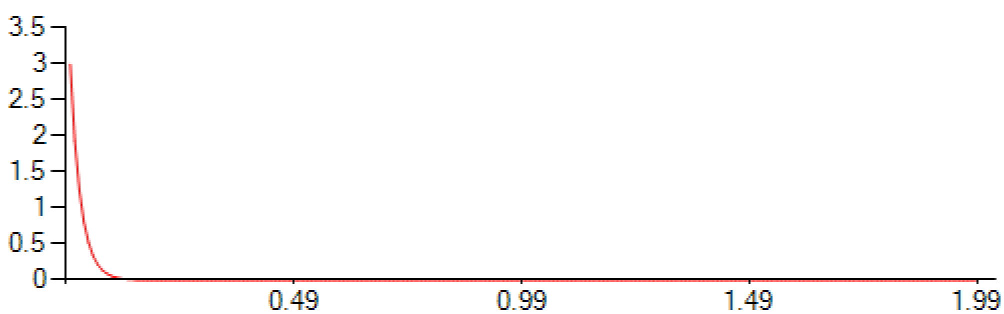


If we add damping into the system we get a system response below;



The amplitude of the system decays, this is why each peak is slightly less than the previous one.

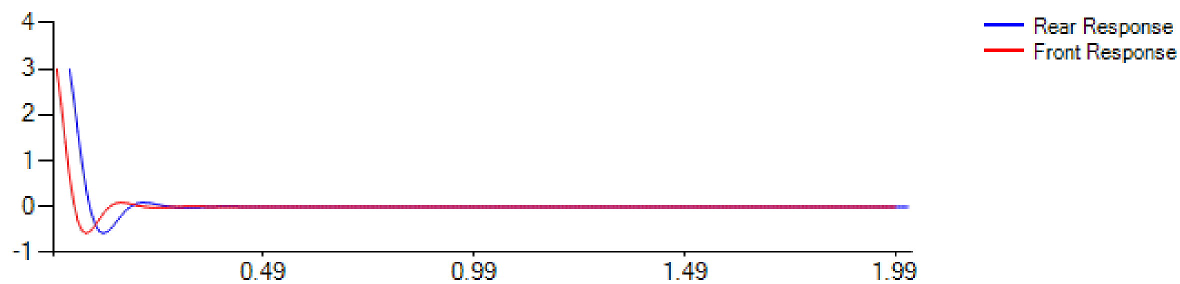
This raises the question how much damping can we add to the system? The factual answer is there is no limit, however there is a "threshold" that we typically do not want to pass, which is called Critical Damping. A system that is critical damped looks like the graph below;



As you can see there is there no overshoot of the response.

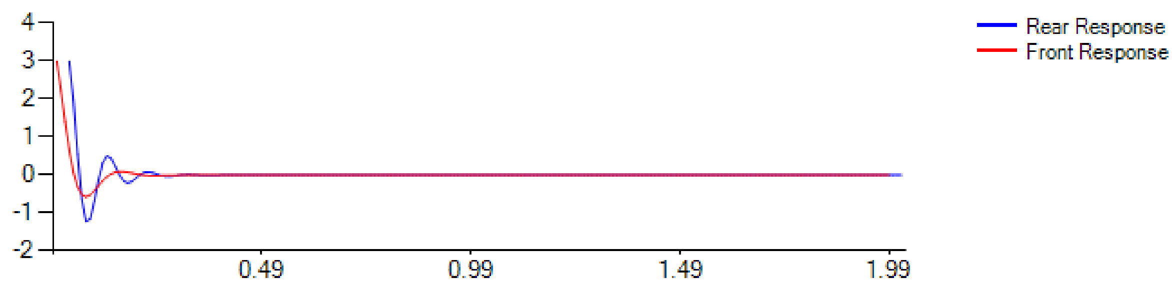
An important concept that we must understand is that as we increase the spring rate we decrease the time constant, that is to say the spring returns to its neutral position faster, however we get overshoot, as we add damping we get less overshoot, but the time constant grows. When tuning our suspension we need to take this into account because of different track conditions (bumpy/smooth). The goal of the suspension is to maintain contact with the road as much as possible. Which requires us to find the balance between acceptable overshoot and the time constant.

In a car we have 4 oscillators, however to simply the analysis we will only look at 2 (front and rear). The graph for the two oscillators with a damping ratio of 50% of critical damping is given below.

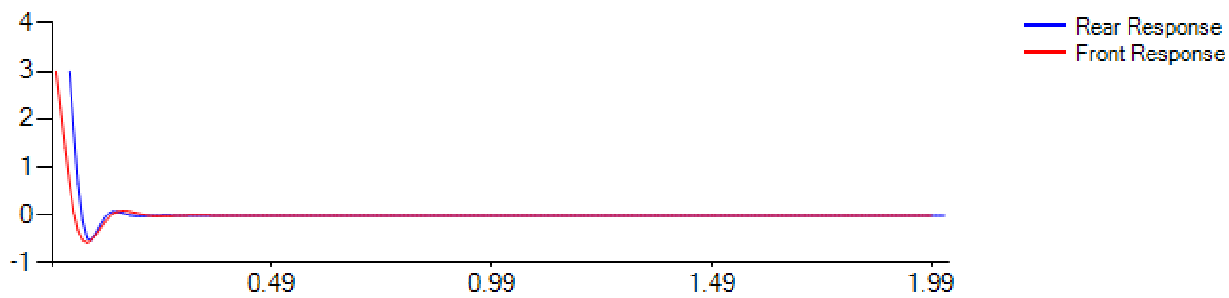


The front axle is in red, and the blue axle is in blue, as we hit a bump the front axle displaced first followed by the rear, because of this we get a small offset between the two signals. This means the front of the car will pitch up, when the front axle is displaced, and the rear axle will pitch down when the rear is displaced, the system will continue to pitch for 1 oscillation at this damping ratio. In car suspension this is undesirable, we want the car to heave rather than pitch. Heave motion is motion in the vertical direction only, it's a translation motion rather than a rotational motion.

If we increase the rear spring rate so that the rear "catches up" with the front, and the two signals overlap (heave motion) we get the following graph.



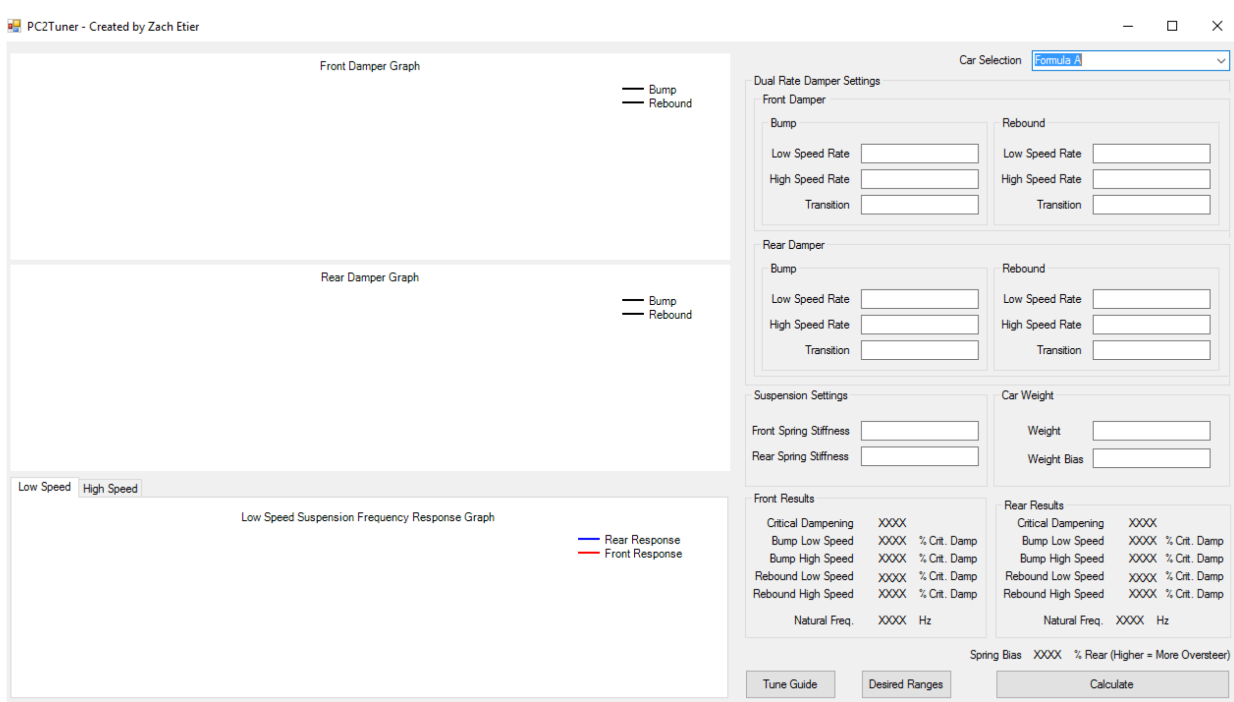
In this graph we can see that the rear catches up the front axle much faster, this is because the time constant of the rear response oscillator has decreased. However the rear axle now needs more damping because we increased the spring rate. If we increase the spring rate so that the front and rear axles have the same damping ratio, we get the following graph,



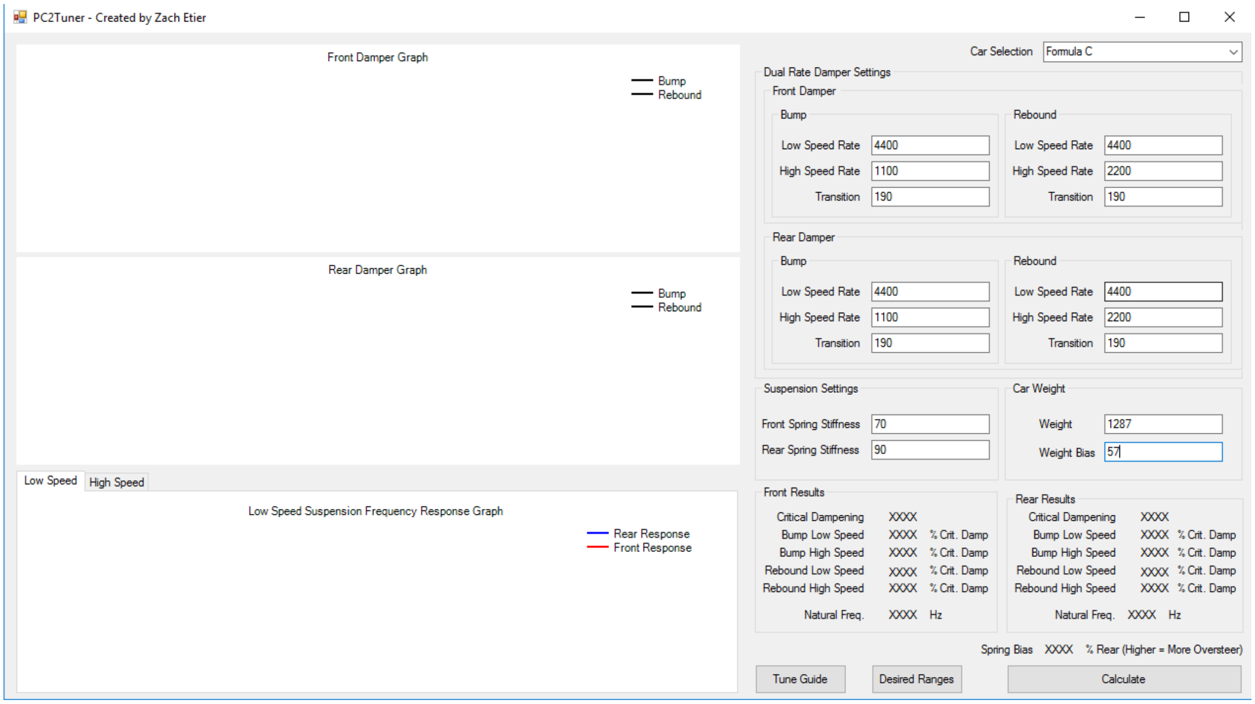
This is considered to be a good tune, the rear axle catches up the front, and the rear and front axles have the same damping ratio. This suspension setup would result in a car chassis that doesn't pitch, but heaves which is desirable.

6. How to Use the Software.

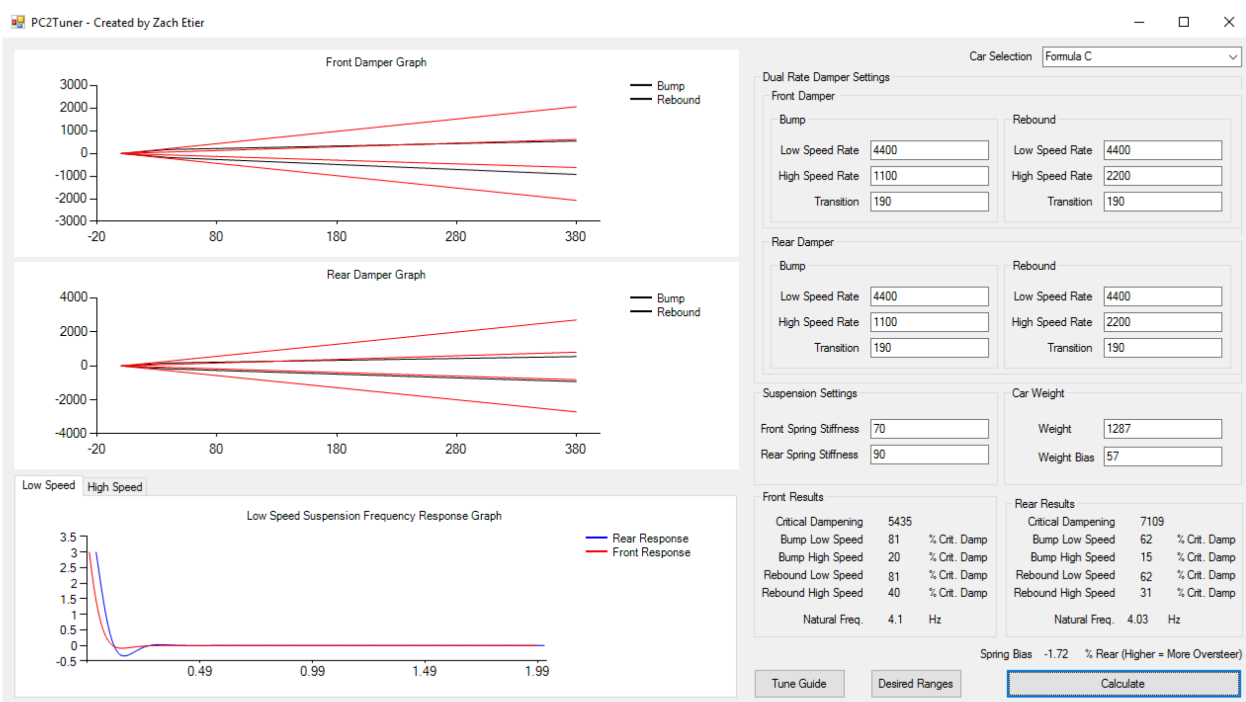
Select your Car by clicking on the dropdown menu at the top right.



Navigate to the car tune page in Project Cars 2, and enter all your rates, remember all rates are given in metric except for weight which is given in pounds. Also the Weight Bias is the Weight Bias on the Rear Axle, so if you have a longitudinal weight bias of 43/57, put 57 in this blank, if you are not sure what the weight bias is, a good estimate would be 58/42 for front engine mounted cars, and 42/58 for rear engine mounted cars.



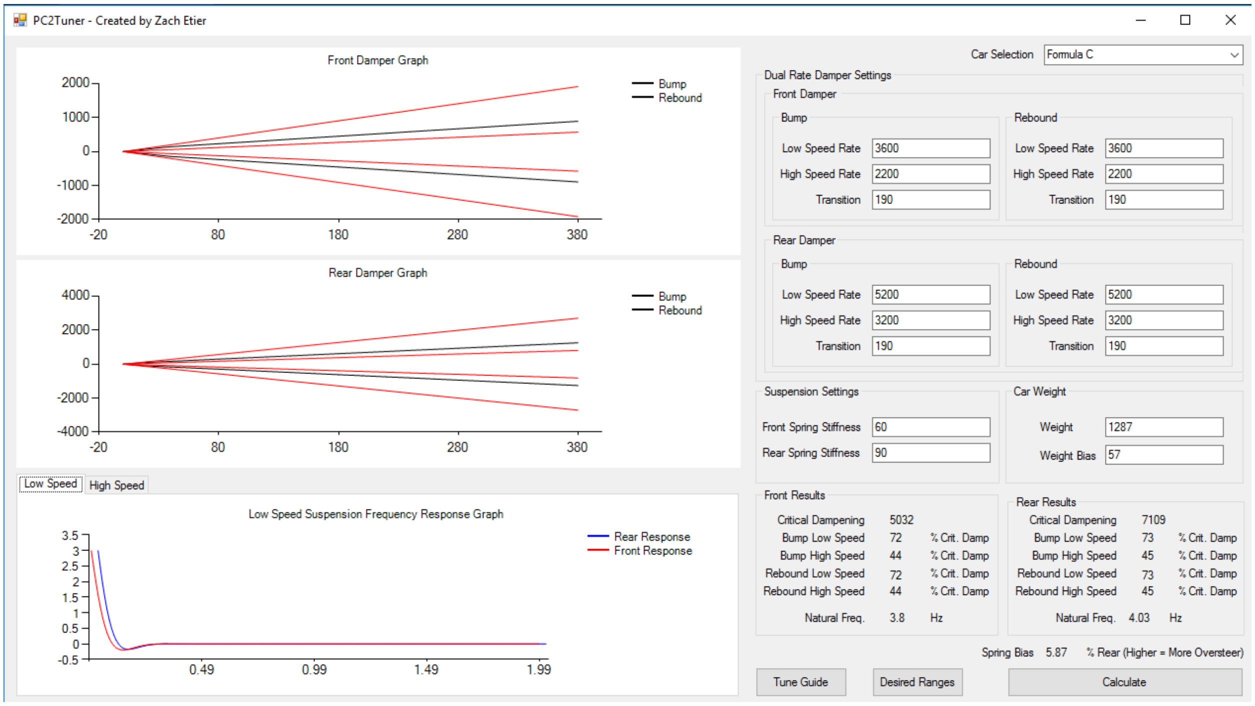
Next click the calculate button,



The outputs are the 3 graphs on the left hand side, and your damping ratios are given in the bottom right. If you are unsure what damping ratios to use refer to section 3.0 of this manual, or click on the "Desired Ranges" Button. The two graphs above given the ranges for 30% (lower bound) and 100% (upper bound) you want your two black lines to be somewhere between these two red lines for both the bump (above the x, axis), and rebound (below the x axis). Additionally spring Bias gives you the overall stiffness of the car as a ratio between front and rear, if the number is negative, the car will be prone to understeer, if its 0 it will be neutral steer, and if it's positive it will be prone to oversteer.

An Ideal tune for a moderate downforce vehicle (formula c) will look like something below;

Low Speed:



High Speed: