MARMARA UNIVERSITY
FACULTY OF ENGINEERING

DESIGN OF A BUS SUSPENSION

OMAR FREIJE

GRADUATION PROJECT REPORT

Department of Mechanical Engineering

Supervisor
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Design of a Bus Suspension

by

Omar Freije

June 07, 2023, Istanbul

SUBMITTED TO THE DEPARTMENT OF MECHANICAL ENGINEERING IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE

OF

BACHELOR OF SCIENCE

AT

MARMARA UNIVERSITY

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ACKNOWLEDGEMENT

First of all, I would like to thank my supervisor Assoc. Prof. Dr. Mustafa ÖZDEMİR, for the valuable guidance and advice on preparing this thesis and giving me moral and material support.

June, 2023 Omar FREIJE

CONTENTS

ABSTRACT

The bus suspension system is a system made of tires, bus body, and we use springs to join bus body to the tires. The tires allow the bus to moves and the spring decrease the contact between the bus and the tires. We have three suspension systems for a bus like quarter, half, and full bus suspension system and each has its own advantages and disadvantages. When the driver drives the bus, he will face many vibrations and shocks so the driver will lose his comfort ability. To improve the driver's comfort ability we use different bus suspension system. We should use programs like Matlab to get the limits of the velocity and acceleration needed for the driver in order to have low vibration and to be in comfort zone while driving. Unexceeding the limit of the velocity and acceleration will protect the driver and the passengers from making accident and will protect their lives.

SYMBOLS:
$\ddot{x_1}$ is the acceleration of the suspension seat M_1. (m/s^2)
$\dot{x_1}$ is the velocity of the suspension seat M_1. (m/s)
$\ddot{x_2}$ is the acceleration of the bus's body M_2.
$\dot{x_2}$ is the velocity of the bus's body M_2
$\ddot{x_3}$ is the acceleration of the Tires M_3.
$\dot{x_3}$ is the velocity of the Tires M_3..
$\ddot{x_4}$ is the acceleration of the ground.
$\dot{x_4}$ is the velocity of the ground
D_1: is the damper for the suspension seat M_1 (Ns/m)
D_2: is the damper for the driver's body M_2
D_3 : is the damper for the wheel M_3
k_1: is the stiffness for the suspension seat M_1 (N/m)
k_2: is the stiffness for the driver's body M_2
k_3: is the stiffness for the wheel M_3
x_1 :is the position of the suspension seat M_1. (m)
x_2 :is the position of the bus's body M_2.
x_3 is the position of the Tires M_3.
x_4 is the position of the ground .

ABREVIATIONS

RMS : is the root mean square for the needed values

1. INTRODUCTION

1.1. General Information

A system that includes tires, tire air, springs, shock absorbers, and the connections that links the vehicle and its wheels and creates the movement between these components called the suspension system. This system should maintain carrying of the road to the system and the quality of the ride.

There are many suspension systems in the world like bus suspension system and car suspension system. The bus suspension system is a passenger vehicle that contains solid axles as the primary suspension system. The solid axle contains central deferential for single housing which includes the drive shafts that join the differential to the wheel. This axle connected to the leaf springs and shock absorbers. However, the car suspension system made up of protective lattice of shock absorbing components like springs and dampers [11]. The car suspension system makes the driver sure about the safety and the smoothness of the car through the absorption of the energy that comes from different smashes of road [11].

For bus suspension system there are many systems like the quarter bus suspension system, half, and full bus suspension system.

For the quarter bus suspension system the driver oscillatory comfort system should have spring of small stiffness and shock absorber of low damping coefficient. In case for safety, the system should have spring with small stiffness and a shock absorber with high damping coefficient, while the minimum movement of the wheel must include springs that have huge stiffness and also it should have huge damping coefficient shock absorbers. The main aim of this article is to focus on increasing the comfort ability of the vehicle occupants to sustain the contact between the tire and the road, also to minimize the dynamic forces, which are acting on the structure of load bearing and vehicle when the bus is moving. The second aim of this article is to obtain the values of the spring stiffness and shock observer to design good and accepted oscillatory actions.

There are many advantages of this quarter system like, it can maintain the same height the bus floor even if the bus has different static and dynamic loads, and it has same oscillation frequency of spring mass of the bus and high oscillatory comfort. On the other hand, the disadvantages of this quarter system are being complex, and having high prices.

Lastly, this system has many effects on the bus suspension system as if the increment of the suspension spring stiffness of the bus decreased the riding comfort of the driver. The increment of the bus suspension spring stiffness for frequencies less than 1 Hz decreased the suspension deformation, also the deformation amplitudes increase when the stiffness of the spring increases, change in the PSD values of virtual wheel loads were seen at low frequencies [1].

Turkkan and Yagiz used active controller to stop vibration of **full**

suspension bus model, which contain air spring. Turkkan and Yagiz used multi-input-single fuzzy logic controller to reduce the abnormalities of road surfaces. They realize the effects of changing the auxiliary chambers on the vehicle vibrations. The results include that the fuzzy logic controller improves the ride comfort and the road holding [2].

Le Xuang Long, Le Van Quynh, Bui Van Cuong examined the suspension parameters that include the stiffness and damping parameters according to the weighted r.m.s to control the comfort ability of the ride. Le Xuang Long, Le Van Quynh, Bui Van Cuong recognized that the stiffness and damping ratios are so important and have high effect on the ride comfort. Le Xuang Long, Le Van Quynh, Bui Van Cuong established the parameters of passive suspension system in order to enhance the comfort ability of the bus ride and the safety of the vehicle design. The matching of parameters and suspension system's optimization are important to enhance the comfort ability of the vehicle ride. Le Xuang Long, Le Van Quynh, Bui Van Cuong used the method for the optimized design of the vehicle suspension system in order to enhance the comfort ability, road holding, and workspace and stopping rollover. In addition, Le Xuang Long, Le Van Quynh, Bui Van Cuong used the optimal parameters to enhance the safety of ride comfort ability of vehicle design. Le Xuang Long, Le Van Quynh, Bui Van Cuong get the values of spring stiffness and damping coefficient for rear and front passive suspension system by applying different velocities by using genetic algorithm optimization technique and this technique enhance the vehicle ride performance. Le Xuang Long, Le Van Quynh, Bui Van Cuong also used the pareto front optimization method to get the parameters of active and semi-active suspension system, and they applied the active control strategy to the full bus suspension system to enhance ride comfort. To know the effects of vibrations on ride comfort ability Le Xuang Long, Le Van Quynh, Bui Van Cuong used the bus spatial vibration model with 10 DOF and this model shows that when the spring stiffness of the driver's seat suspension system increases the vibration exposure time for the body of the driver decreases. The evaluation can indicate the vibration signals in different bus locations and it shows the vibration comfort in real time. Le Xuang Long, Le Van Quynh, Bui Van Cuong establish the domestic vehicle with two DOF vibration model according to vehicle dynamics theory. Le Xuang Long, Le Van Quynh, Bui Van Cuong calculated the root mean square by using Matlab software when car moves on grade C root surface and this calculations till that they found the influence rule of each parameter of suspension on vehicle ride comfort [3].

Turkken and Yagiz have also **half bus suspension system**, in the system the bus assumed to move speed over the bump road and formed like a five degree of freedom system. Turkken and Yagiz improve the half bus system by using Lagrange equations. In addition, the vibrations can stop and the comfort ability of the ride can enhance by using the controllers. The wheels, brakes, suspension linkages and other components are the components that the vehicle module consist of. In addition, the vehicle model is from spring and unspring masses. The location of suspension system is spring and unspring masses. There are three types of suspension systems like passive, semi active, and active. The ordinary springs and dampers whose coefficients are fixed are the components of the passive suspension system. The semi-active systems are made of passive springs and dampers with variable coefficients. Finally, active suspension systems have actuators that give force to stop the vibrations that happen from irregularities that come from the surface of the road .In the past PID controllers, fuzzy logic controllers and back stepping controller were the plans used to enhance the comfort ability of the ride and the road holding. They used robust control strategies to put in the non-linear systems like sliding mode control because it is impossible to avoid the undesired disruptive effect and uncertainty such as pressure, temperature, and modeling errors in real system. They used sliding mode controller to limit the vibrations and to increase the comfort ability of the bus [4]. Therefore, as a result using the sliding mode control increases the comfort ability of the bus traveler or rider.

I will design a quarter bus suspension system because it has many advantages and these advantages can help to maintain the sustain ability of the rider and the bus driver.

2. SUSPENSION SYSTEM

2.1. From what parts are the quarter bus mechanism made from?

The bus suspension system is a **solid axle** that is made from **central differential** in a single housing which have the **driven shafts** that connects the **differential** to the **wheels**. The **leaf springs and shock absorbers hang the axle**. They should have also high shock absorbers and leaf springs because they hold high amounts of passengers [7].

2.2. What is the function of the parts of bus suspension system?

Leaf springs have two types' multi-leaf springs and parabolic leaf springs. Since parabolic leaf springs are simple in design and have less interleaf friction, they use it as primary suspension system in buses. Parabolic leaf springs contain parabolic profile from center to the end of the leaf with slowly decreasing thickness. There is also the shock absorber that decreases the kinetic energy, and it can absorbs the shock from the road [8].

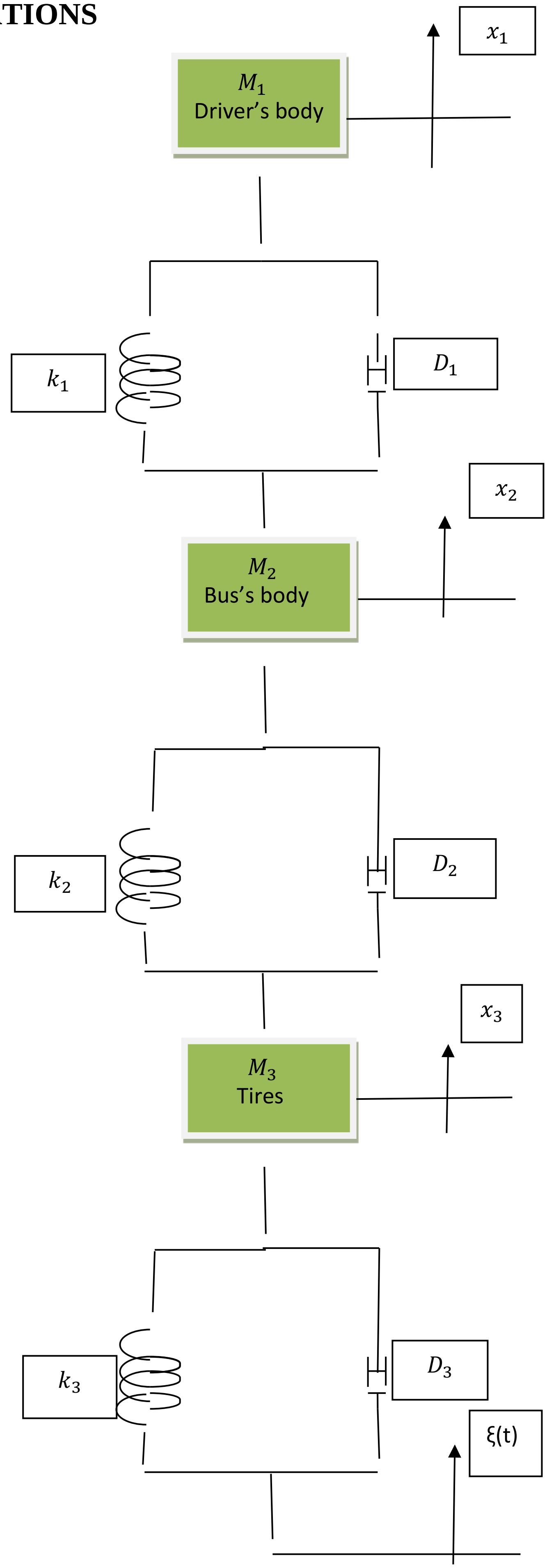
2.3. How does the bus suspension system work?

A suspension system transforms force into heat by using springs, dampers, and struts and this process removes the crash that force can make [9].

2.4. What are the functions of suspension system for the bus?

- supporting of the exact height of the vehicle ride
- decreasing the consequences of the shock forces
- preserving the exact wheel alignment
- helping the vehicle weight
- Maintaining the tires and the wheel in touch.
- Management of the direction of the vehicle during the whole trip [10].

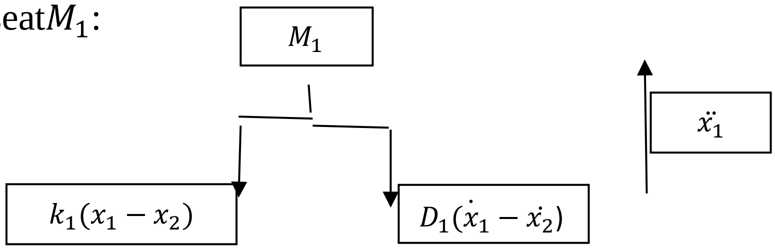
3. CALCULATIONS



Where

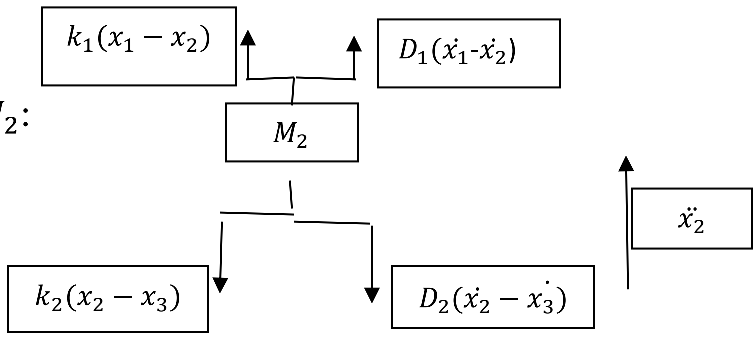
D_1: is the damper for the suspension seat M_1 (Ns/m)
D_2: is the damper for the driver's body M_2
D_3 : is the damper for the wheel M_3
k_1: is the stiffness for the suspension seat M_1 (N/m)
k_2: is the stiffness for the driver's body M_2
k_3: is the stiffness for the wheel M_3

For suspension seat M_1:



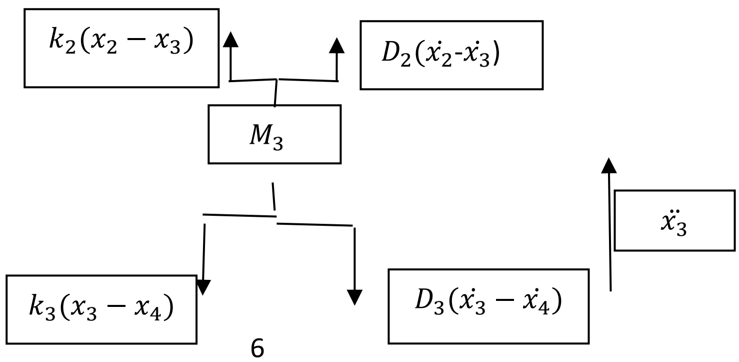
$$\sum F_y = M_1\ddot{x}_1 = -k_1(x_1 - x_2) - D_1(\dot{x}_1 - \dot{x}_2) \ldots\ldots.1$$

For Bus's body M_2:



$$\sum F_y = M_2\ddot{x}_2 = -k_2(x_2 - x_3) - D_2(\dot{x}_2 - \dot{x}_3) + k_1(x_1 - x_2) + D_1(\dot{x}_1\text{-}\dot{x}_2) \ldots\ldots.2$$

For Tire's body M_3:



$$\uparrow \sum F_y = M_3\ddot{x_3} = -k_3(x_3 - x_4) - D_3(\dot{x_3}-\dot{x_4}) + k_2(x_2 - x_3) + D_2(\dot{x_2}-\dot{x_3}) \ldots\ldots 3$$

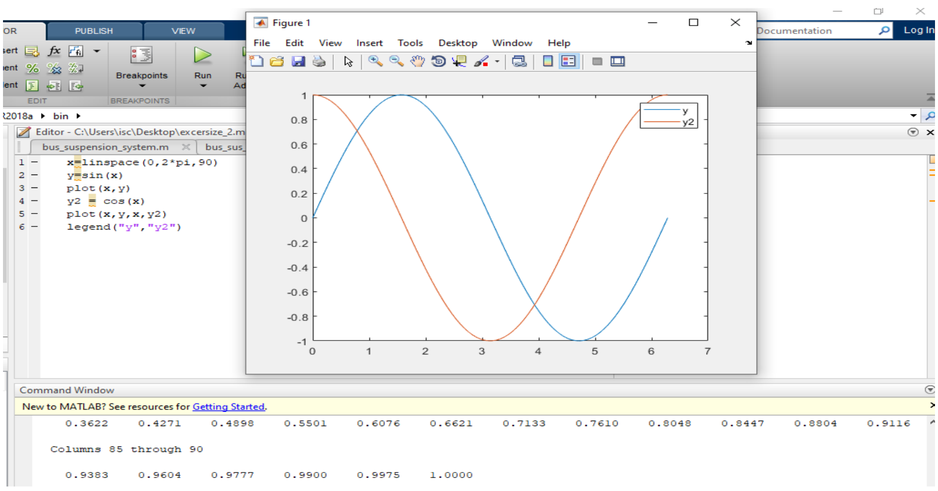
Where, $\ddot{x_1}$, $\ddot{x_2}$, and $\ddot{x_3}$ are the accelerations of suspension seat M_1, bus body M_2, and Tires M_3 respectively. (m/s^2)
$\dot{x_1}$, $\dot{x_2}$, $\dot{x_3}$, $\dot{x_4}$ are the velocities of the suspension seat M_1, bus body M_2, Tires M_3, and the ground respectively. (m/s)
$x_1$is the position of the suspension seat M_1. (m)
x_2 is the position of the bus's body M_2.
x_3 is the position of the Tires M_3.
x_4 is the position of the ground

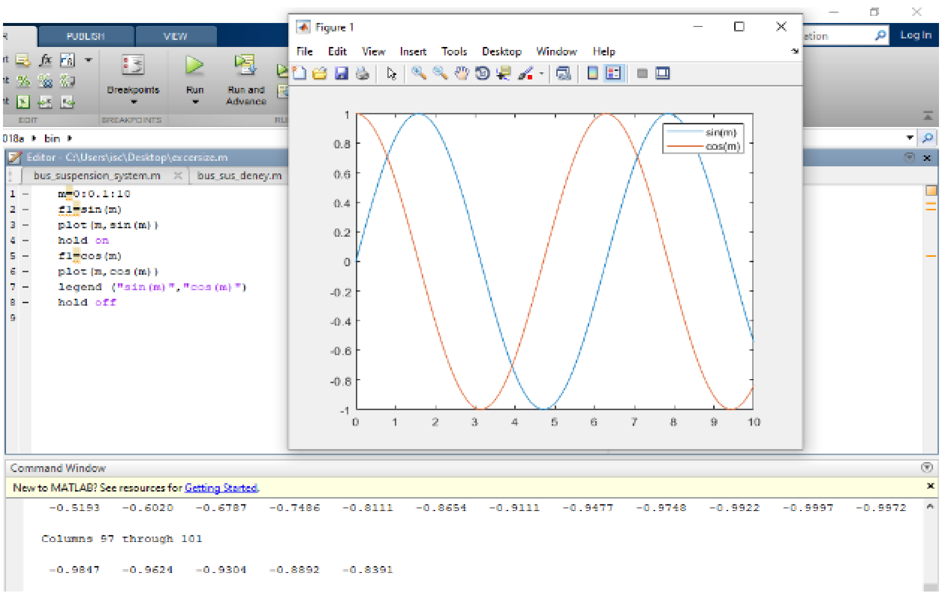
4. WEEKLY PLAN:

For Week 1:

I learned how to plot graphs in Matlab , and how to add , subtract, and divide matrixes by using this youtube link: https://youtu.be/T_ekAD7U-wU

- *I did arbitrary plots to learn about the Matlab software*





What I did in week 2:

1. For suspension seat M_1:

$\uparrow \sum F_y = M_1\ddot{x}_1$ = - $k_1(x_1 - x_2)$ - $D_1(\dot{x}_1 - \dot{x}_2)$ 1

$M_1\ddot{x}_1$+ $k_1(x_1 - x_2)$+ $D_1(\dot{x}_1 - \dot{x}_2)$=0 1

2. For Bus's body M2:

$\uparrow \sum F_y = M_2\ddot{x}_2$ = - $k_2(x_2 - x_3)$ - $D_2(\dot{x}_2 - \dot{x}_3)$ +$k_1(x_1 - x_2)$ + $D_1(\dot{x}_1$-$\dot{x}_2)$ 2

$M_2\ddot{x}_2$+$k_2(x_2 - x_3)$+ $D_2(\dot{x}_2 - \dot{x}_3)$ - $k_1(x_1 - x_2)$ - $D_1(\dot{x}_1$-$\dot{x}_2)$ = 0....2

3. For Tire's body M_3:

$\uparrow \sum F_y = M_3\ddot{x}_3 = -\,k_3(x_3 - x_4)$ - $D_3(\dot{x}_3$-$\dot{x}_4)$ +$k_2(x_2 - x_3)$ + $D_2(\dot{x}_2$-$\dot{x}_3)$ 3

$M_3\ddot{x}_3$ +$k_3(x_3 - x_4)$ + $D_3(\dot{x}_3$-$\dot{x}_4)$- $k_2(x_2 - x_3)$- $D_2(\dot{x}_2$-$\dot{x}_3)$ = 0........3

Where, $\ddot{x}_1$, $\ddot{x}_2$, and $\ddot{x}_3$ are the accelerations of suspension seat M1, bus body M2, and Tires M3 respectively. (m/s^2)

$\dot{x}_1$, $\dot{x}_2$, $\dot{x}_3$, $\dot{x}_4$ are the velocities of the suspension seat M_1, bus body M_2, Tires M_3, and the ground respectively. (m/s)

$x_1$is the position of the suspension seat M_1. (m)

x_2 is the position of the bus's body M_2.

x_3 is the position of the Tires M_3.

x_4 is the position of the ground.

$$\ddot{x}_1 = \frac{-\,k_1(x_1 - x_2)}{M_1} + \frac{-D_1(\dot{x}_1 - \dot{x}_2)}{M_1} \text{ .....1}$$

$$\ddot{x}_2 = \frac{-\,k_2(x_2 - x_3)}{M_2} + \frac{-\,D_2(\dot{x}_2 - \dot{x}_3)}{M_2} + \frac{k_1(x_1 - x_2)}{M_2} + \frac{D_1(\dot{x}_1 - \dot{x}_2)}{M_2} \text{ ....2}$$

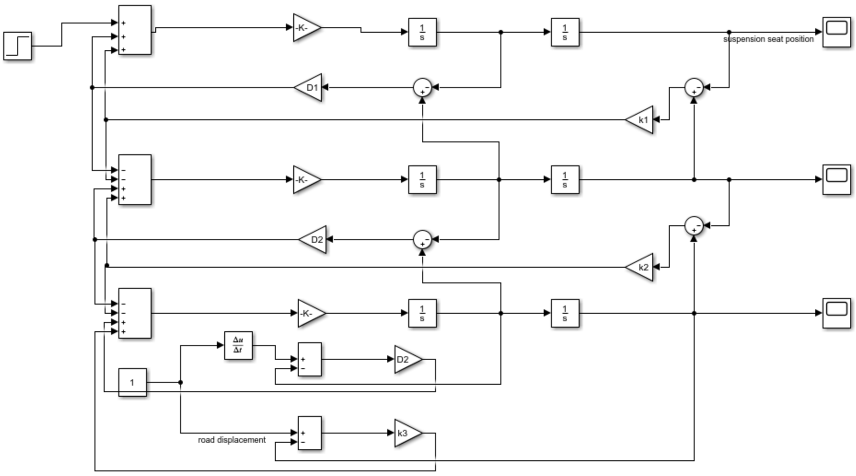
$$\ddot{x}_3 = \frac{-\,k_3(x_3 - x_4)}{M_3} + \frac{-\,D_3(\dot{x}_3 - \dot{x}_4)}{M_3} + \frac{k_2(x_2 - x_3)}{M_3} + \frac{D_2(\dot{x}_2 - \dot{x}_3)}{M_3} \text{ ....3}$$

$$\begin{vmatrix} \ddot{x}_1 \\ \ddot{x}_2 \\ \ddot{x}_3 \end{vmatrix} = \begin{vmatrix} \frac{-\,k_1}{M_1} & \frac{k_1}{M_1} & 0 \\ \frac{-k_1}{M_2} & \frac{-\,k_2 - k_1}{M_2} & \frac{k_2}{M_2} \\ 0 & 0 & \frac{-k_3 - k_2}{M_3} \end{vmatrix} \begin{vmatrix} x_1 \\ x_2 \\ x_3 \end{vmatrix} + \begin{vmatrix} \frac{-D_1}{M_1} & \frac{D_1}{M_1} & 0 \\ \frac{D_1}{M_2} & \frac{-D_1 - D_2}{M_2} & \frac{D_2}{M_2} \\ 0 & \frac{D_2}{M_3} & \frac{-D_2 - D_3}{M_3} \end{vmatrix} \begin{vmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{vmatrix} +$$

$$\begin{bmatrix}0 & 0 & 0\\ 0 & 0 & 0\\ 0 & \frac{k_3}{M_3} & \frac{D_3}{M_3}\end{bmatrix}\begin{bmatrix}0\\ x_4\\ \dot{x}_4\end{bmatrix}.$$

In week 4:

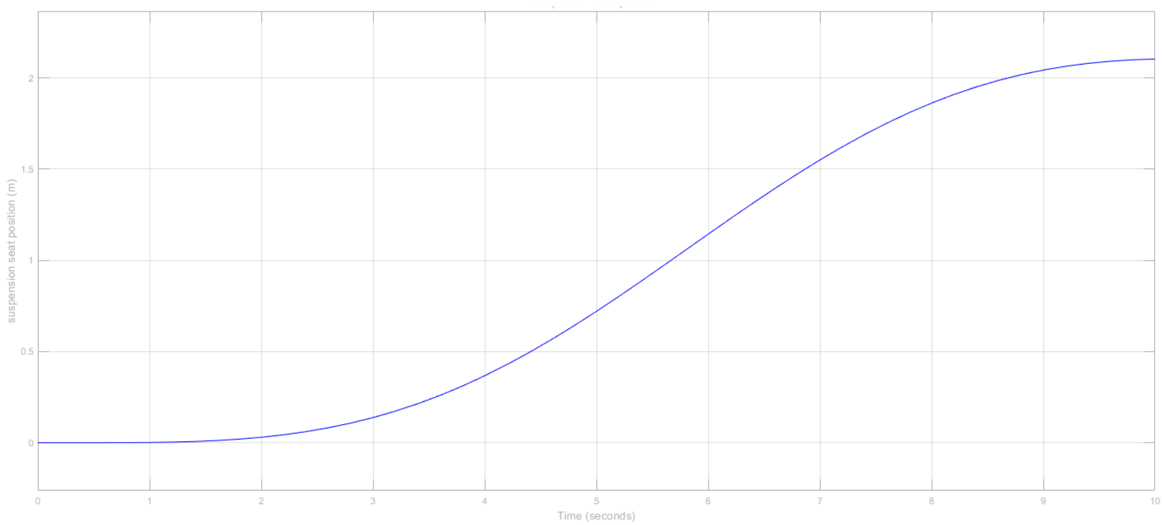
1. I check and rewrite the motion equations.
2. I used the motion equation and I draw the Simulink for the bus suspension model



3. I used these values for the stifnesses, dampers, and masses:

k_1	20 N/m
k_2	15 N/m
k_3	45 N/m
D_1	10 Ns/m
D_2	17 Ns/m
D_3	50 Ns/m
M_1	60 kg
M_2	70 kg
M_3	80 kg

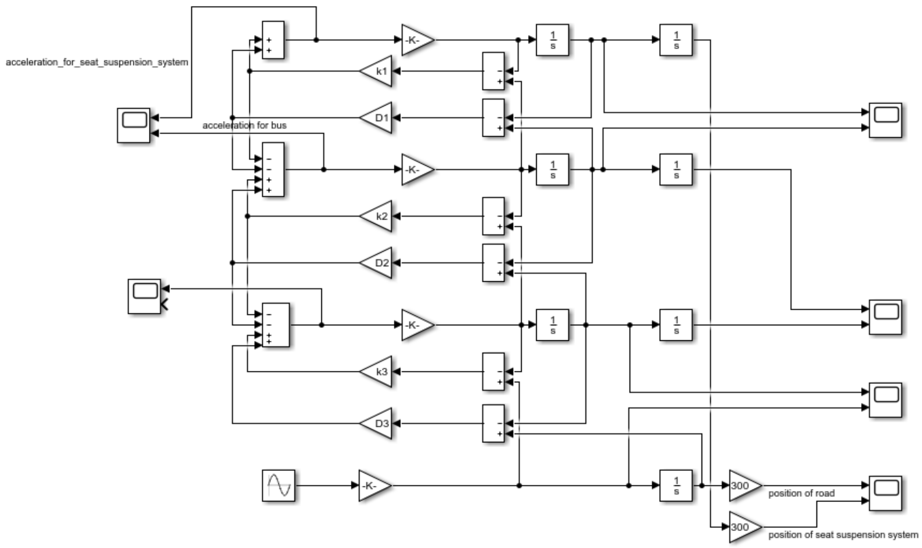
4. I got the seat suspension position graph as this:



5. This graph was wrong because the graph was only increasing.

Week 6:

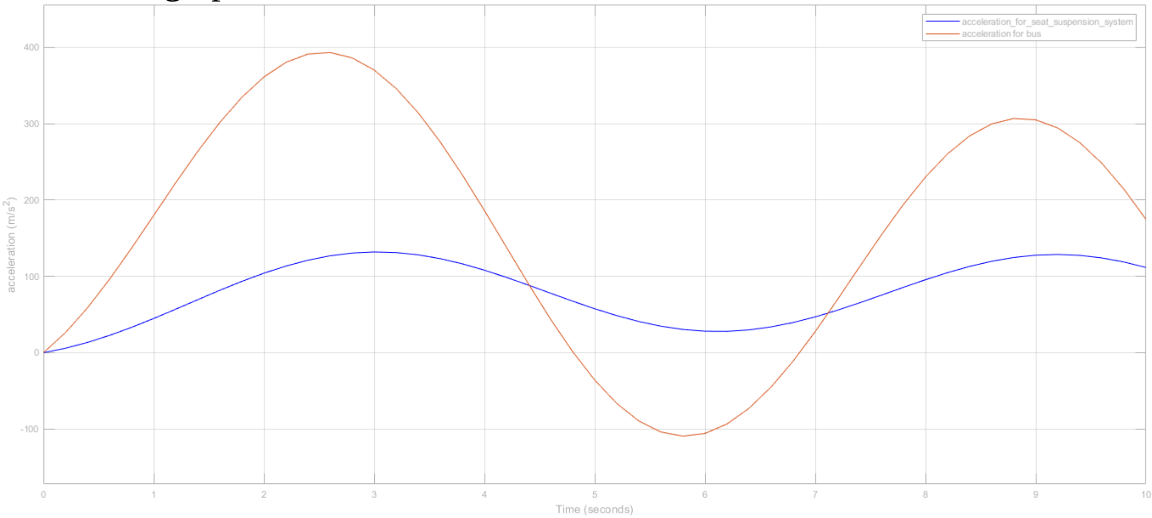
1. I revised my old module and I made a new module because old one is wrong.
2. I got the position, velocity, and acceleration of the bus suspension seat, bus body, tires, and of the road by using the Simulink module.



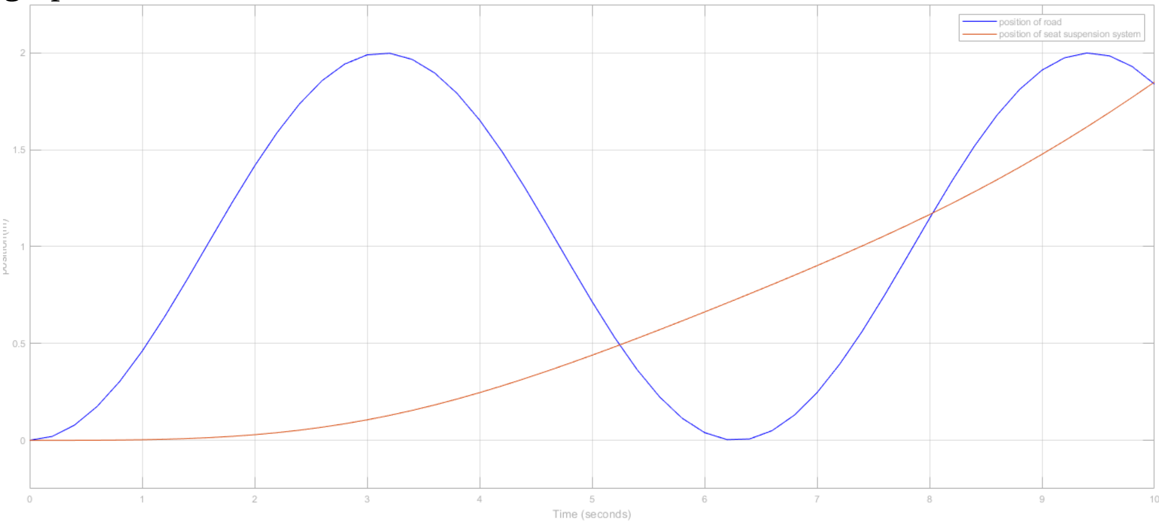
3. I used these values to get the graphs:

k_1	200000 N/m
k_2	150000 N/m
k_3	450000 N/m
D_1	100000 Ns/m
D_2	170000 Ns/m
D_3	500000 Ns/m
M_1	600000 kg
M_2	700000 kg
M_3	800000 kg

4. I got the acceleration of seat suspension system and the acceleration of bus in this graph:



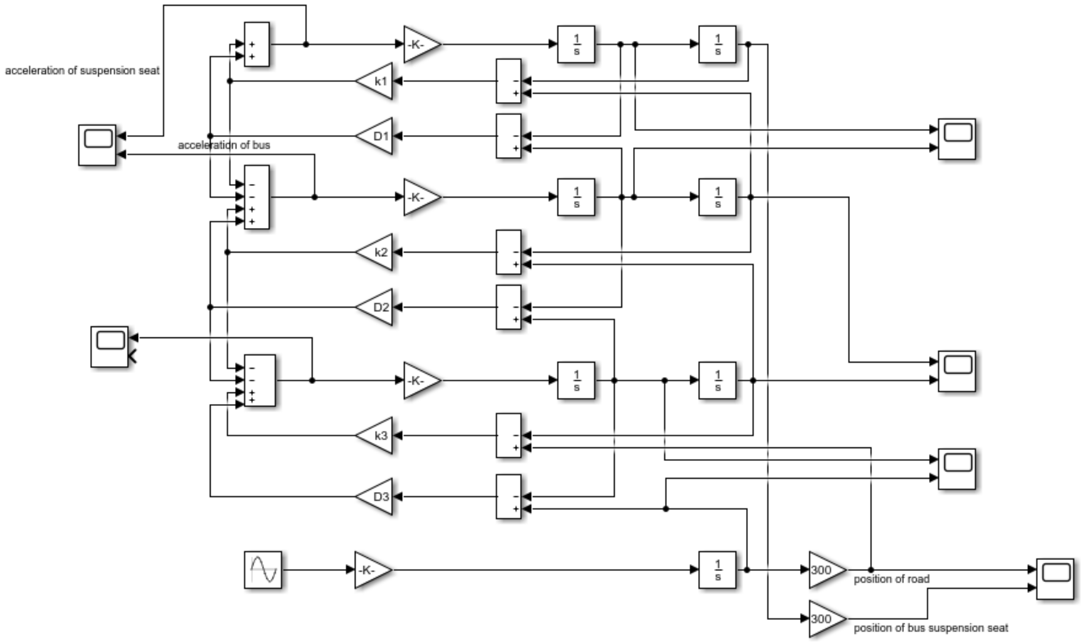
5. Also, I got the position of road, and seat suspension system in this graph:



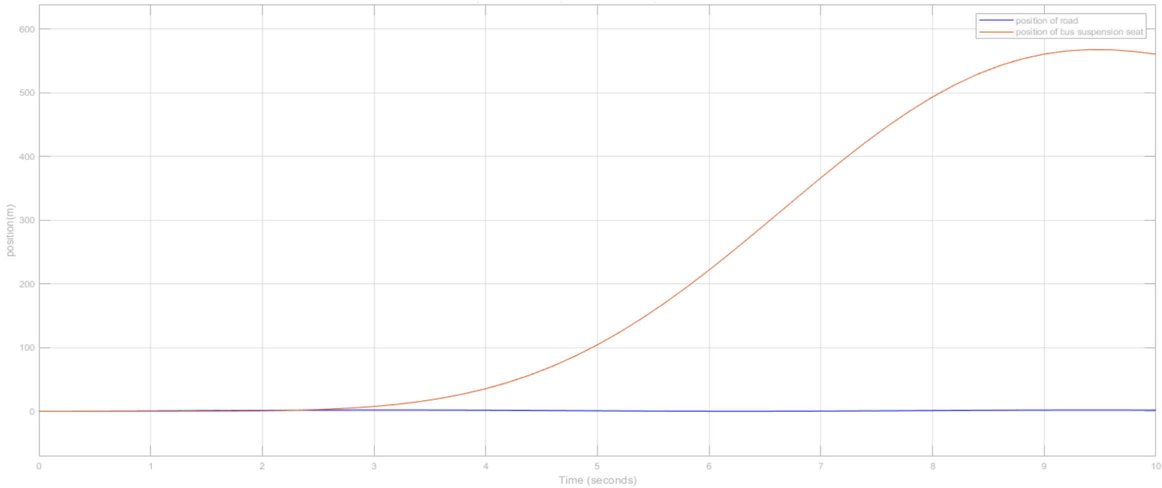
6. Here the graphs are not increasing and decreasing continuously so these graphs are wrong.

Week 7:

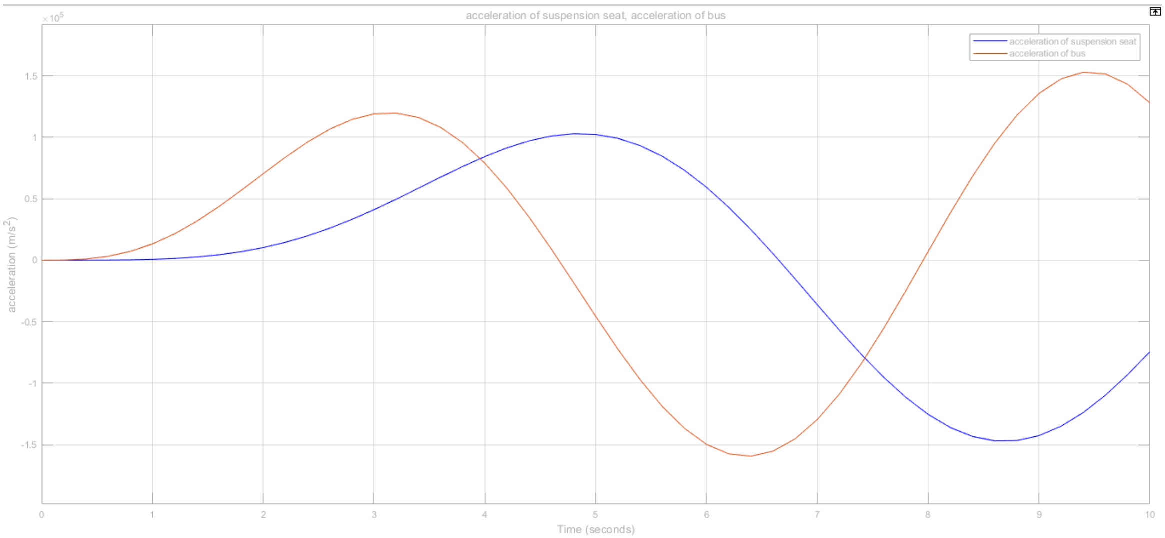
1. I corrected my old module :



2. I get the graph for suspension seat position, and position of the road:



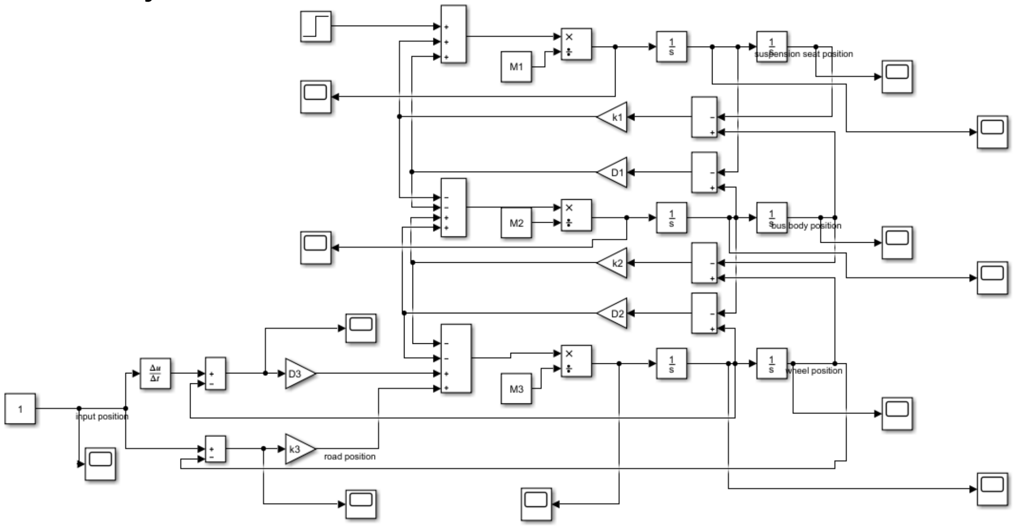
3. I get the graph for the suspension seat acceleration, and the bus acceleration:



4. Since the values for position for suspension seat, position for road, and acceleration for suspension seat, and acceleration for bus are too high; so these values are wrong.

Week 8:

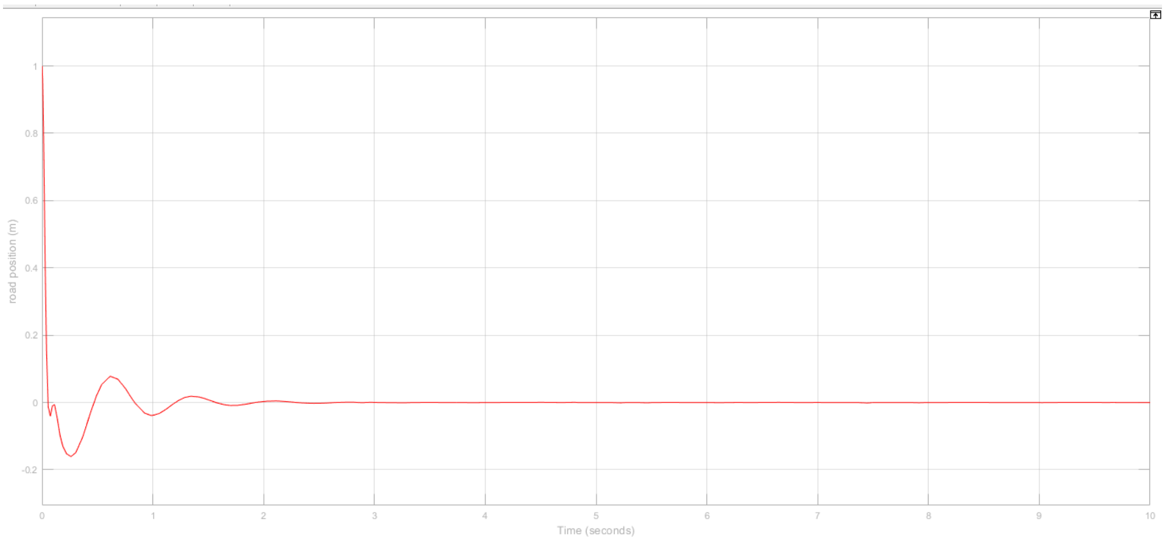
1. I corrected my old module and I used this simulation module



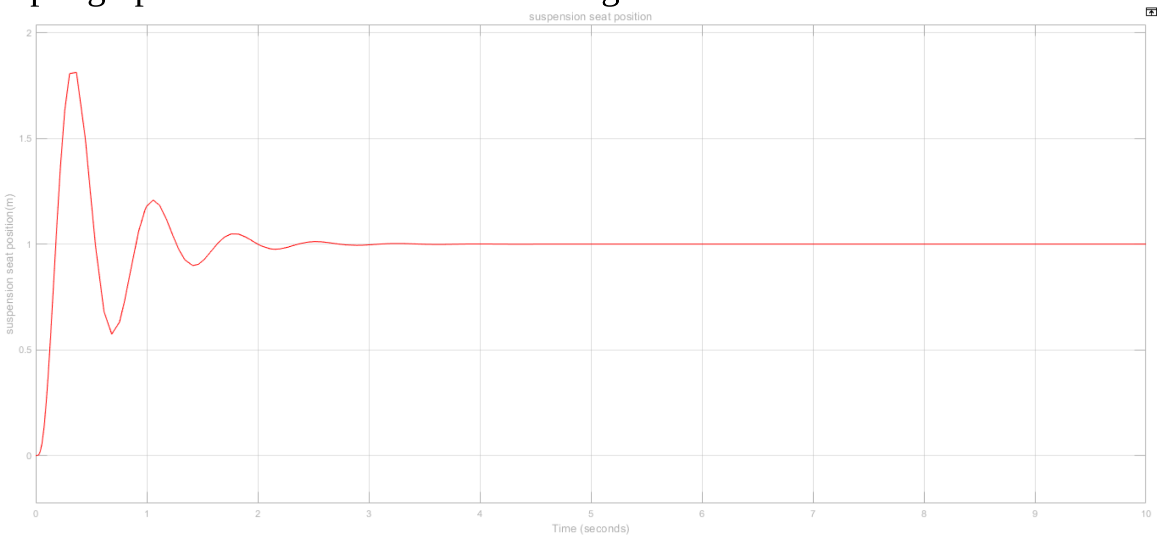
2. I put these values for stiffness, dampers, and masses:

k_1	40000 N/m
k_2	600000 N/m
k_3	2000000 N/m
D_1	3000 Ns/m
D_2	40000 Ns/m
D_3	350 Ns/m
M_1	200 kg
M_2	6000 kg
M_3	700 kg

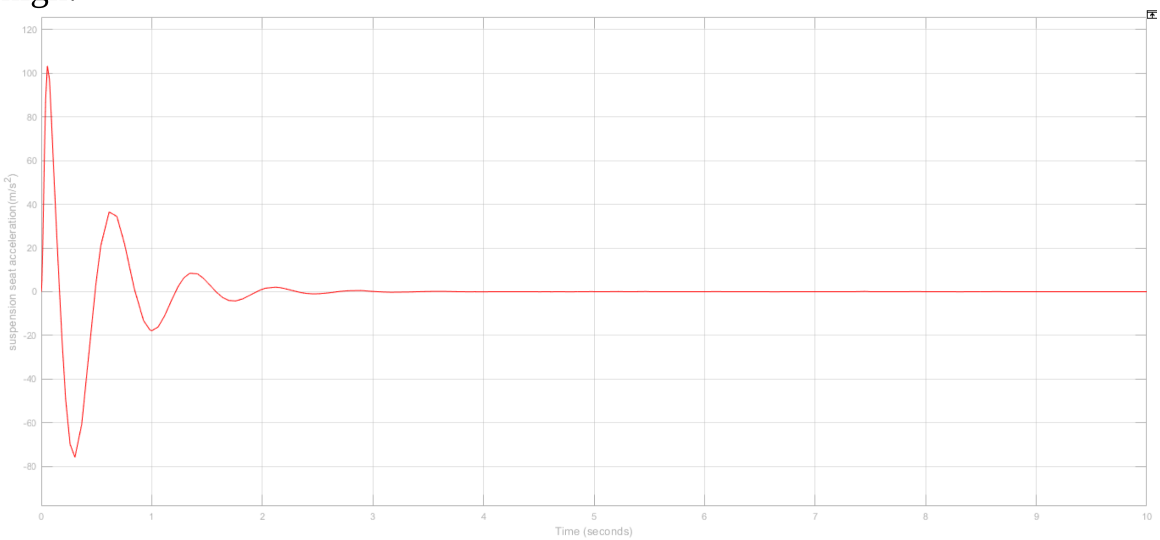
3. I get the road position graph as this, but because the road input graph was constant it will be wrong:



4. I get the suspension seat position graph, but also because the road input graph was constant it will be wrong:



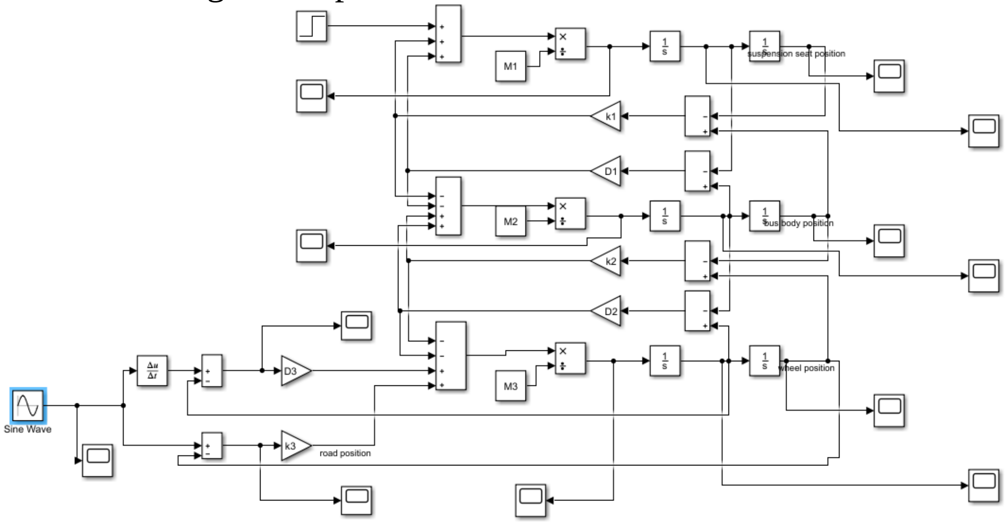
5. I get the suspension seat acceleration graph, but the numbers was so high:



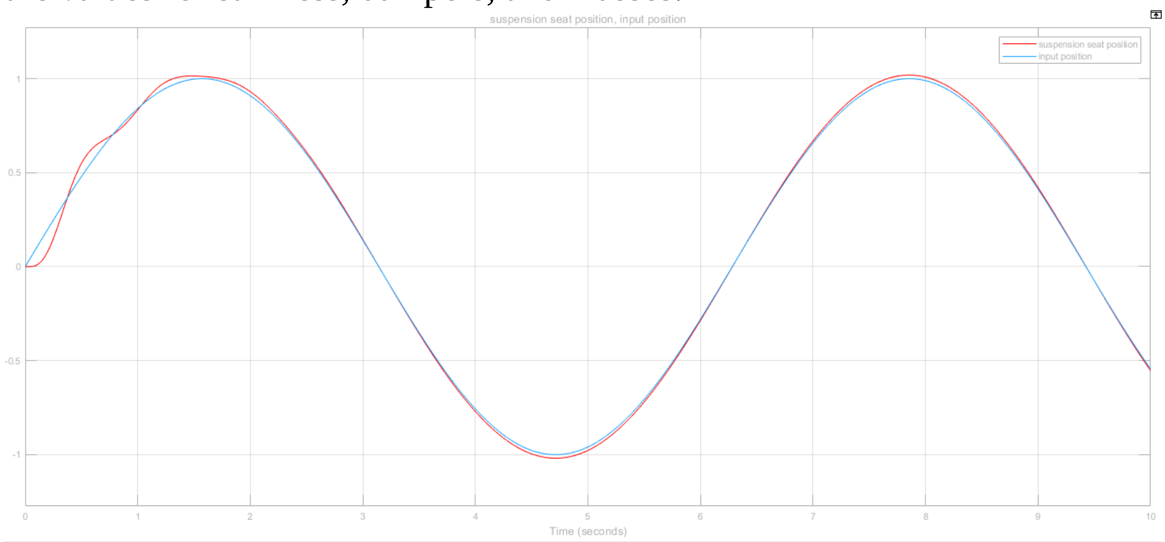
6. Because we have constant road input in the simulation, and since we have high values for suspension seat acceleration these graphs are

wrong. So, we should put sinusoidal road input.

7. When we change the input to sinusoidal we have this simulation:

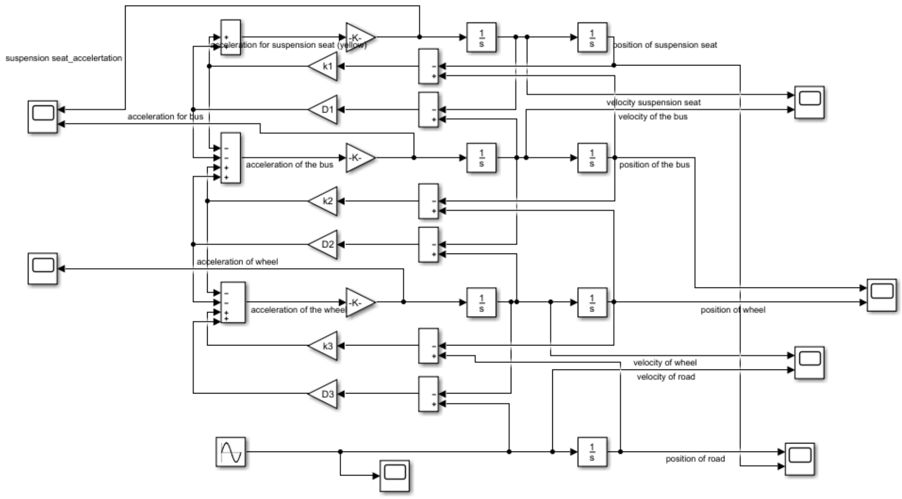


8. Due to the non-difference between the input and the suspension seat position, which means that there no damping effect, we should change the values for stiffness, dampers, and masses.



Week 9:

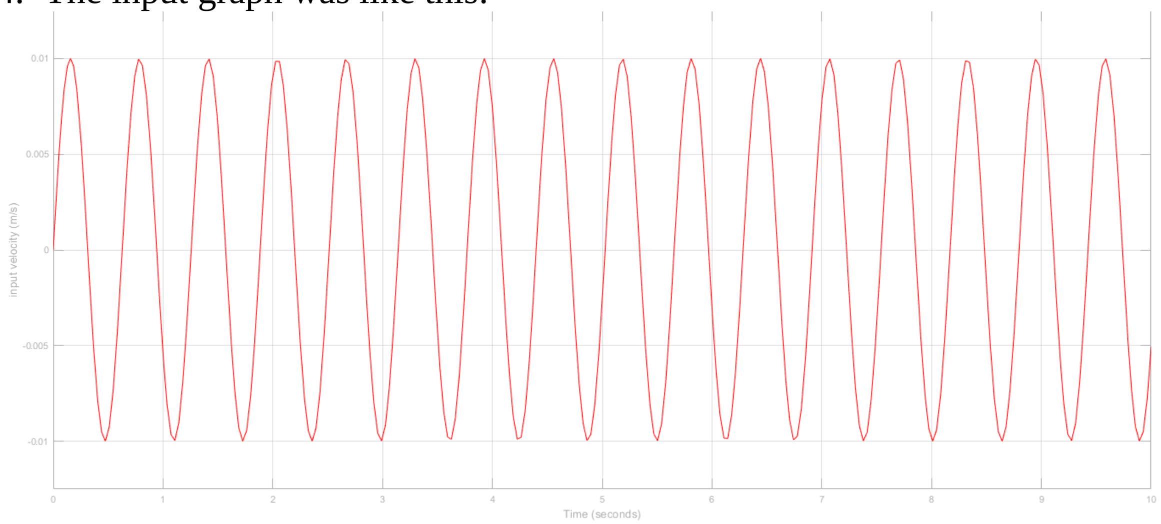
1. I used the down module simulation because it has the most correct position and acceleration graphs:



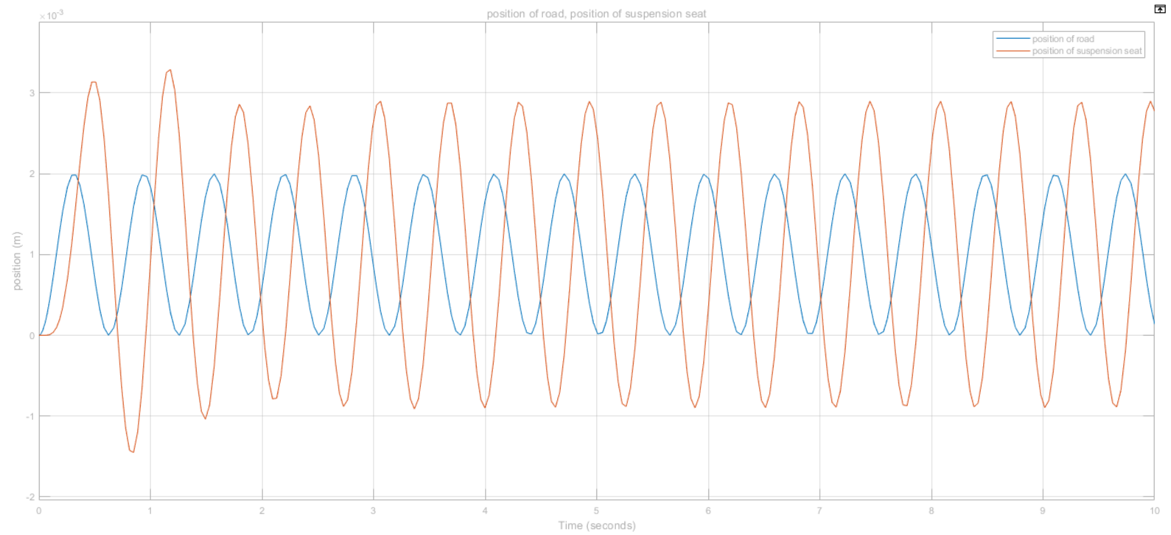
2. I used these values for this simulation:

k_1	25000 N/m
k_2	300000 N/m
k_3	1600000 N/m
D_1	1000 Ns/m
D_2	20000 Ns/m
D_3	150 Ns/m
M_1	100 kg
M_2	4500 kg
M_3	500 kg

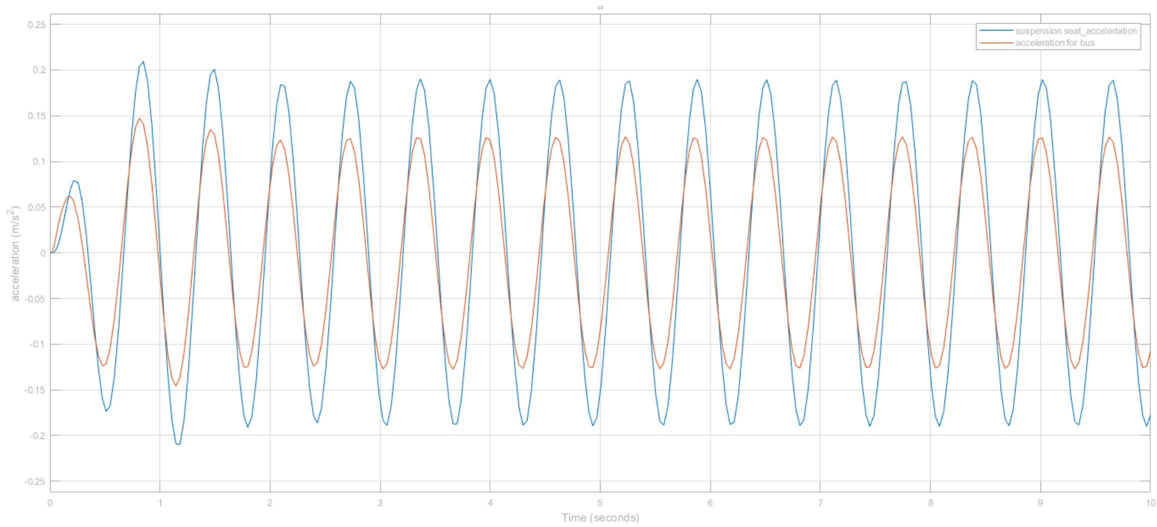
3. I got the upper values from "The Effect of Stiffness and Damping of the Suspension System Elements on the Optimization of the Vibrational Behavior of a Bus" article [1].
4. The input graph was like this:



5. I got the position for the road and the suspension seat like this:



6. I got the acceleration for suspension seat, and for bus as this:



7. In the graphs for the position of road, position of suspension seat, the acceleration of suspension seat, and the acceleration for bus's body there is damping response. These graphs are true but it is used for non-comfort ride.

Week 11:

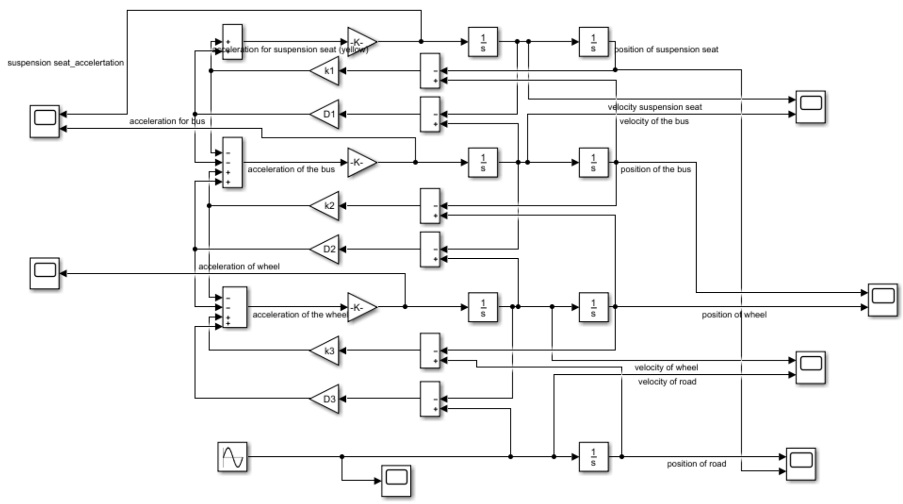
1. For comfort ride I searched for comfort values for RMS acceleration. For a comfort ride RMS acceleration should be less than 0.315 m/s^2.

   RMS acceleration is the root mean square for the acceleration values. For sinusoidal graph response we can get the a_{RMS} by using this equation: a_{RMS}= $\frac{a_{peak}}{\sqrt{2}}$, a_{peak} is the highest value for acceleration in the graph.
2. I put these values of stifnesses, dampers, and masses to get the suspension system for comfort ride.

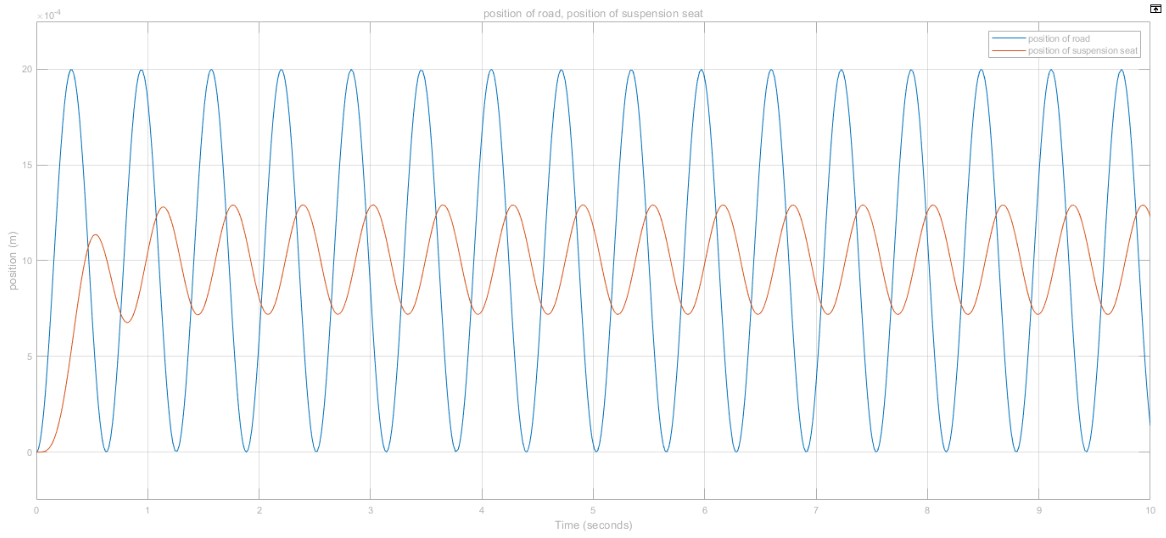
   I used these values for the simulation:

k_1	25 N/m
k_2	300 N/m
k_3	16000000 N/m
D_1	1000 Ns/m
D_2	20000 Ns/m
D_3	150 Ns/m
M_1	100 kg
M_2	4500 kg
M_3	500 kg

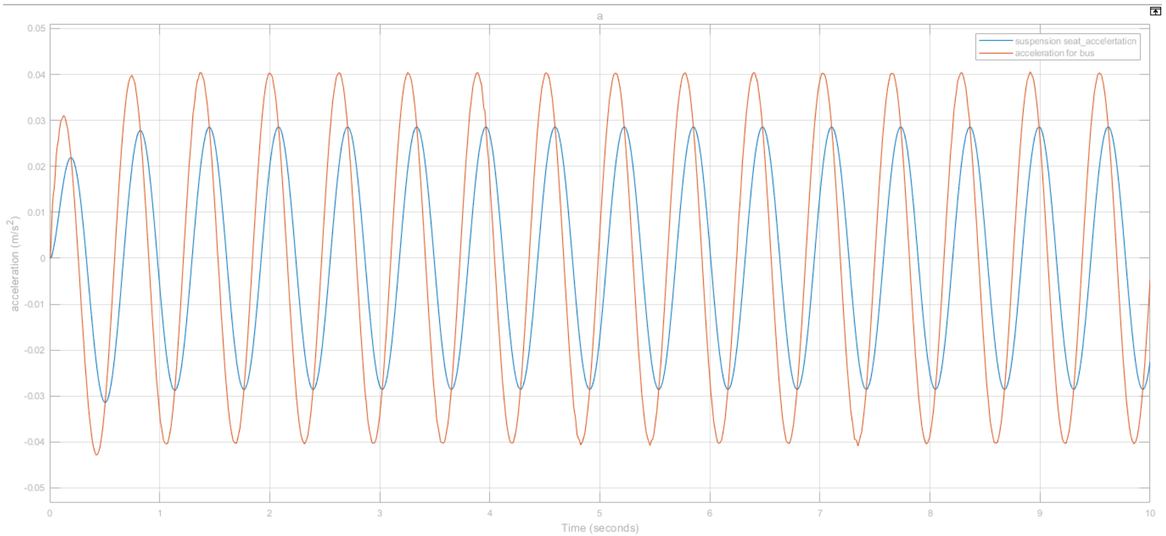
3. I used this simulation connections to get graphs for comfort ride:



4. I get the position of road and seat suspension system as this:



5. Here we have the graph of the acceleration of suspension seat and of bus.

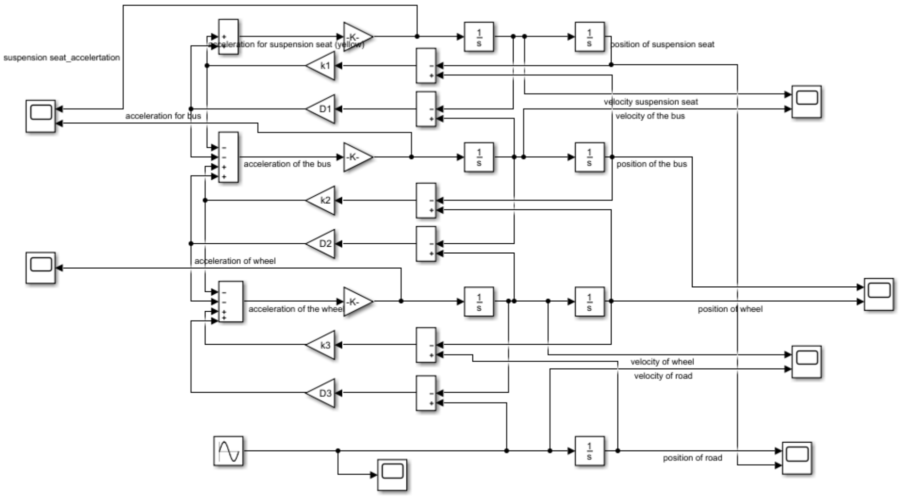


6. The graphs that I get was true for a comfort ride because the graph for position for road is higher than the graph of the suspension seat,

but the values for stiffnesses were not true.

Week 12:

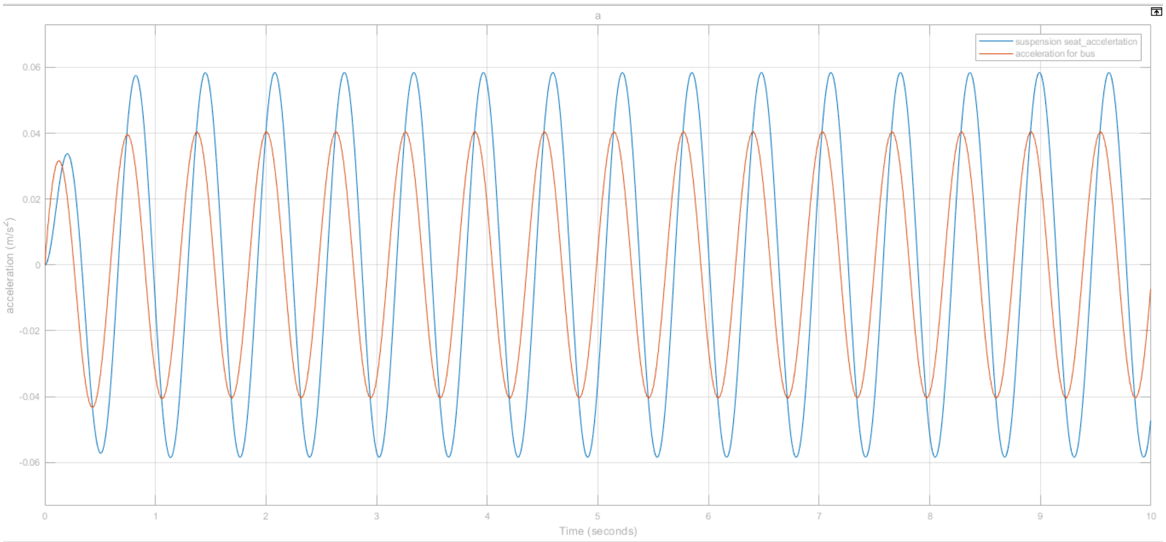
1. RMS acceleration is the root mean square for the acceleration values. For sinusoidal graph response we can get the a_{RMS} by using this equation: $a_{RMS}= \frac{a_{peak}}{\sqrt{2}}$, a_{peak} is the highest value for acceleration in the graph.
2. For comfort ride I get that RMS acceleration should be less than 0.315 m/s^2.
   $a_{RMS}= \frac{0.058\ \mathrm{m}/s^2}{\sqrt{2}}$ = 0.041 m/s^2 which is less than 0.315 m/s^2
3. I used this simulation connections for comfort ride in this week:



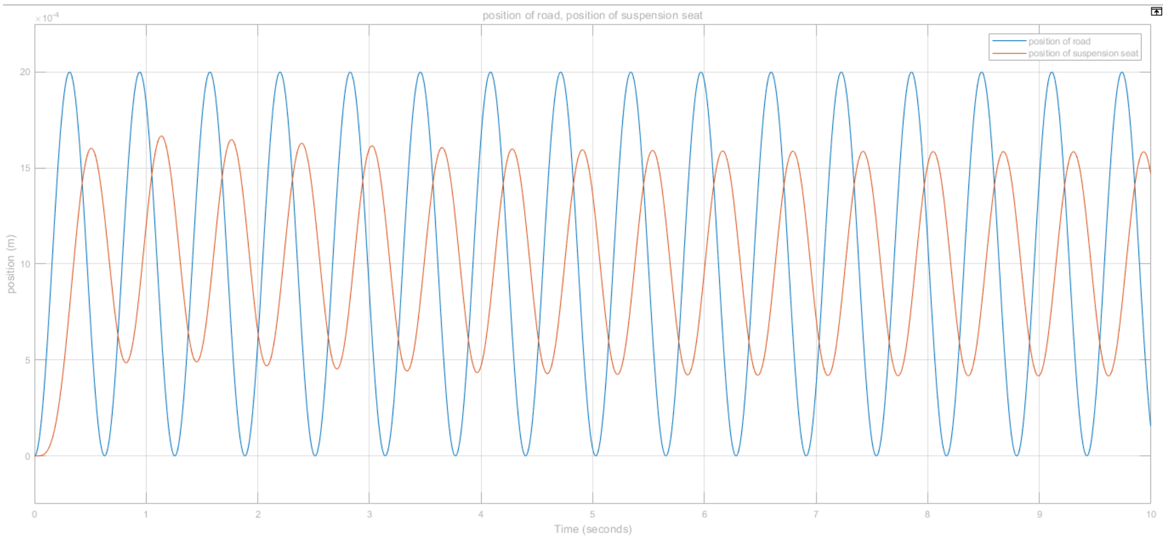
4. I changed the values of stiffnesses, dampers, and masses. I used these values:

k_1	10500 N/m
k_2	10000 N/m
k_3	90000000 N/m
D_1	1000 Ns/m
D_2	20000 Ns/m
D_3	150 Ns/m
M_1	100 kg
M_2	4500 kg
M_3	500 kg

5. Here we can see the graph of the acceleration of suspension seat and bus :

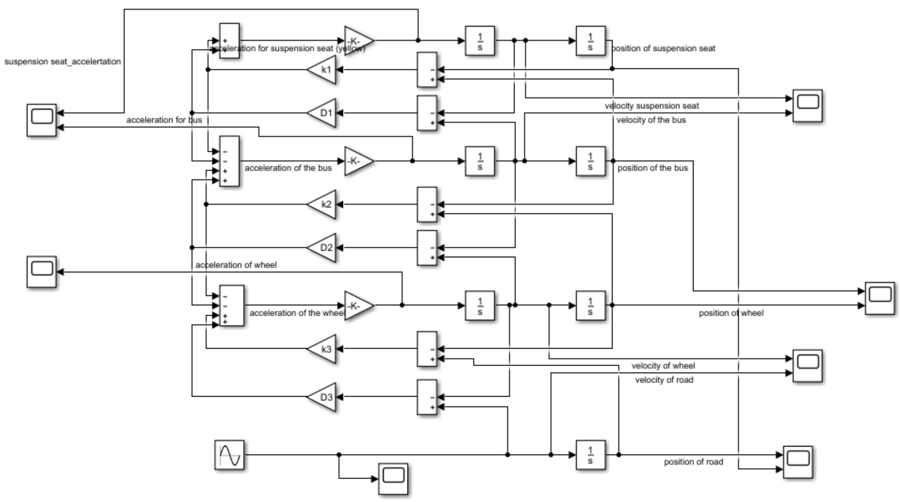


6. Here we have the position of suspension seat, and the position of road.



Week 13:

1. I used this Simulink module:

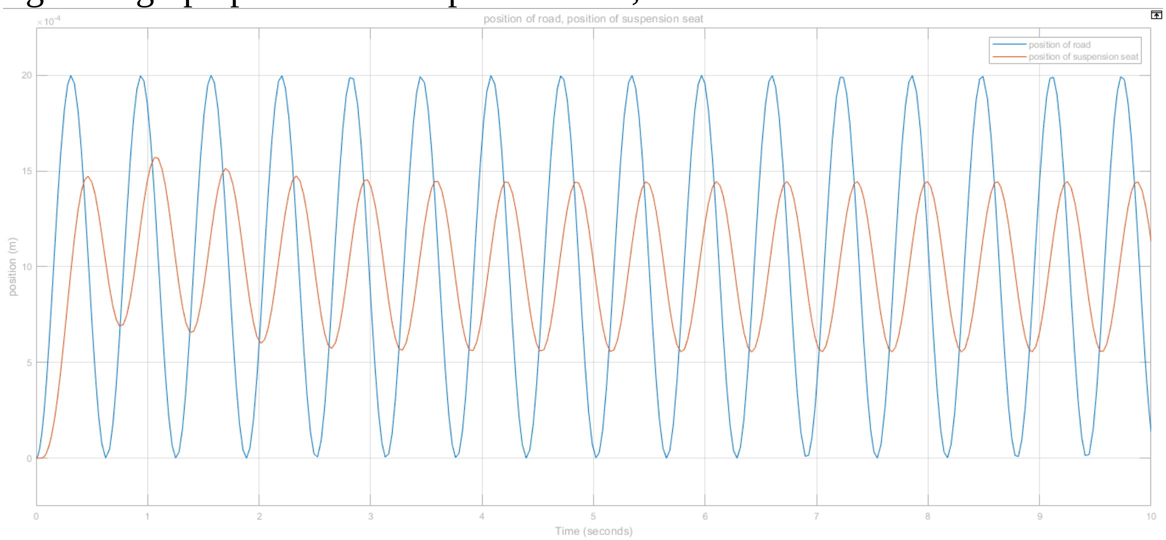


2. I used these values to get the graphs:

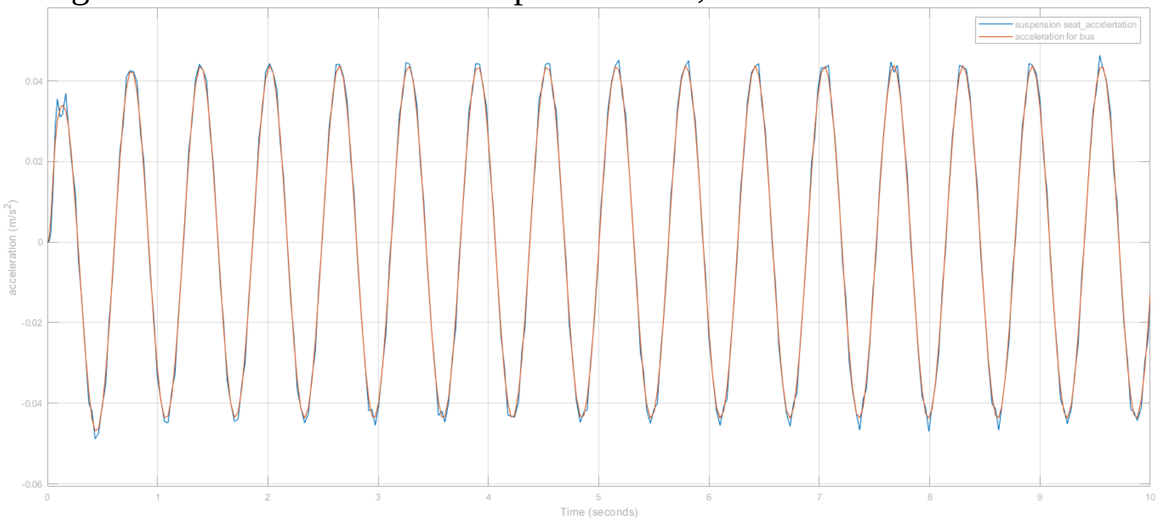
k_1	600000 N/m
k_2	20000 N/m
k_3	2000000 N/m
D_1	1000 Ns/m
D_2	20000 Ns/m
D_3	150 Ns/m
M_1	100 kg
M_2	4500 kg
M_3	500

3. I changed the values for stiffness k_1 , k_2, k_3, and I got the values for k_1 from "Modelling and Wavelet-Based Identification of 3-DOF Vehicle Suspension System" article page:677 [6] , k_2 from "Relay Experiment method for PID tuning of Bus suspension system" [5] article page:146, and k_3 from "The Effect of Stiffness and Damping of the Suspension System Elements on the Optimization of the Vibrational Behavior of a Bus" article [1].
4. RMS acceleration is the root mean square for the acceleration values. For sinusoidal graph response we can get the a_{RMS} by using this equation: $a_{RMS}=\frac{a_{peak}}{\sqrt{2}}$, a_{peak} is the highest value for acceleration in the graph.
5. For comfort ride I get that RMS acceleration should be less than 0.315 m/s^2. $a_{RMS}=\frac{0.042\ \mathrm{m}/s^2}{\sqrt{2}}$ = 0.029 m/s^2 which is less than 0.315 m/s^2. So, by using these numbers we can design a bus suspension system with comfort ride.

6. I get the graph position of suspension seat, and road:



7. I get the acceleration of the suspension seat, and bus :



5. CONCLUSION

The point of this research is to design a bus suspension system that has a comfort ride. I chose quarter bus suspension system and I used Matlab software to design it. My system was three degree of freedom system since it has three masses which were the suspension seat (M_1), the bus's body (M_2), and the tires (M_3). Between $M_1$and M_2 we have the stiffness (k_1) and damper (D_1) for suspension seat, between M_2 and M_3 we have the stiffness (k_2) and damper (D_2) for bus's body, and between $M_3$and ground we have the stiffness (k_3) and damper (D_3) for the tires. I wrote the equations and I used Matlab to put the values of the stiffness, dampers, and masses that I will use for the design, also I used the Matlab Simulink to draw the Simulink module. I created three different Simulink modules using Matlab Simulink, and for each module I put numbers for stiffness, dampers, and masses to know the correct values and the correct Simulink module. First I created Simulink module and I put values for stiffness, dampers, and for masses from my own, but the graphs that I got were only increasing. These graphs are wrong because the response should be increasing and decreasing continuously. I changed and corrected the Simulink module connections, and I corrected my equations and the variable values but I got wrong graphs. I developed the Simulink module until I got the correct and needed graphs for my design, also I used values for the variables from an article. For these values and Simulink module I got the correct graphs for seat suspension system position, road position, and suspension seat acceleration but the system was damping and not comfortable because the position of the suspension seat graph was greater than that of the road position. So, I used the same Simulink module but I changed the values for the stiffness and I got them from three different articles. For these values I got the correct graphs for seat suspension system position, road position, and suspension seat acceleration for the design of quarter bus suspension system that has comfort ride because the seat suspension system position that I get was less than that of the road position. Therefore, for design of bus suspension system having a comfort ride we should use the correct Simulink module and the following values: k_1=600000 N/m, k_2=20000N/m, k_3 =2000000N/m, D_1=1000Ns/m, D_2=20000Ns/m, D_3=150Ns/m, M_1=100kg, M_2=4500kg, M_3=500kg.

Therefore, to design a quarter bus suspension system that has comfort ride we should put values that will give me the graph of position for bus suspension system less than that of the road position, and these values should be realistic because we will use these values to design a real bus suspension system. As a result, using the above values the graph that we get for the road position was between 0 and 2mm, the graph for suspension seat position was between 1.5 mm and 0.6 mm, and the graph for suspension seat acceleration was between -0.042m/s^2 and 0.042 m/s^2.

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	Week1	Week2	week3	week4	week5	week6	week7
Tasks	Selection and training of suitable system for numerical experiments	Selection and training of suitable system for numerical experiments	Selection and training of suitable system for numerical experiments	Selection and training of suitable system for numerical experiments	Construction of mathematical model in selected software environment	Construction of mathematical model in selected software environment	Construction of mathematical model in selected software environment
Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Week 15
No tasks	Construction of mathematical model in selected software environment	Performance of numerical experiments	Performance of numerical experiments	Performance of numerical experiments	Analysis and compare of numerical results	Analysis and compare of numerical results	Prepare of final report