Robotics Report

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Introduction

The **mass-spring-damper system** is a fundamental mechanical model that represents a variety of real-world physical systems. It consists of three main components:

1. **Mass (m)**: A rigid body that can move in response to forces.
2. **Spring (k)**: An elastic element that resists displacement from its equilibrium position, applying a restoring force proportional to the displacement (Hooke's Law: F=−kxF = -kxF=−kx).
3. **Damper (c)**: A damping element that resists velocity, simulating friction or air resistance, applying a force proportional to the velocity (Damping force: F=−cvF = -cvF=−cv).

Importance in Mechanical Systems

The mass-spring-damper system is important because it provides a simple yet powerful model for understanding dynamic behavior in mechanical systems. It's commonly used to study:

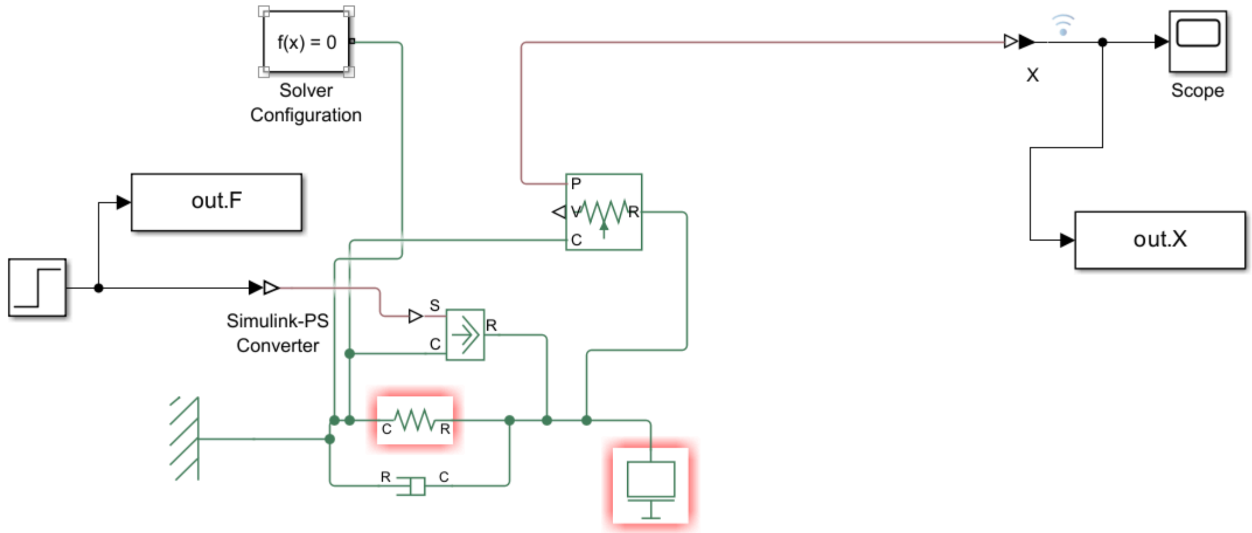
- **Vibration analysis**: This system can model how objects respond to external forces, especially in automotive suspension systems, building structures during earthquakes, or machinery subject to oscillations.
- **Control systems**: It is used to design and optimize systems that require precise motion control, like robotics or aerospace engineering.
- **Energy dissipation**: The damper helps to simulate real-world effects like friction, which is crucial in studying how energy is absorbed or dissipated in systems.

By analyzing the response of this system, engineers can predict system behavior, optimize design, and ensure stability and performance.

Method 1: Simscape

a. Simscape allows you to quickly create models of physical systems within the Simulink environment by assembling components based on physical connections. It is used for modeling systems such as electric motors, hydraulic actuators, and refrigeration systems. Simscape integrates with block diagrams, making it easy to simulate and analyze physical components alongside other modeling paradigms.

b. Model is shown below



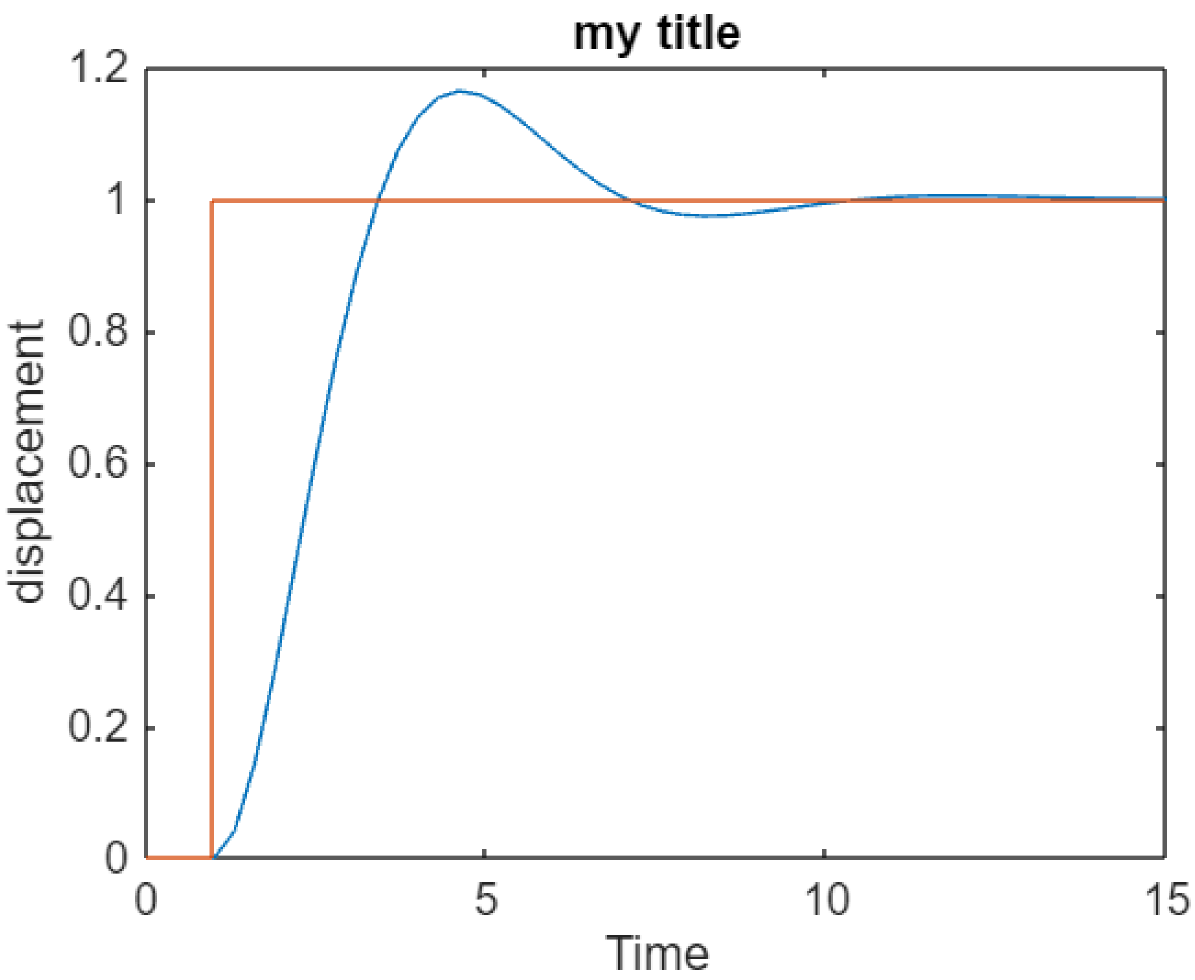
This model is created using simulink and its easy as it looks:

We are using a spring, mass and a damper with reading the output at the end(displacement) and surly we can change the damping coefficient along with any other variable to check the differences.

And this is by manipulating the code below:

```
sim_time = 15;
F = 1;
b = 1;
m = 1;
K = 1;
sim("Mass.slx");
```

But now lets plot the figures and see the results and these inputs:

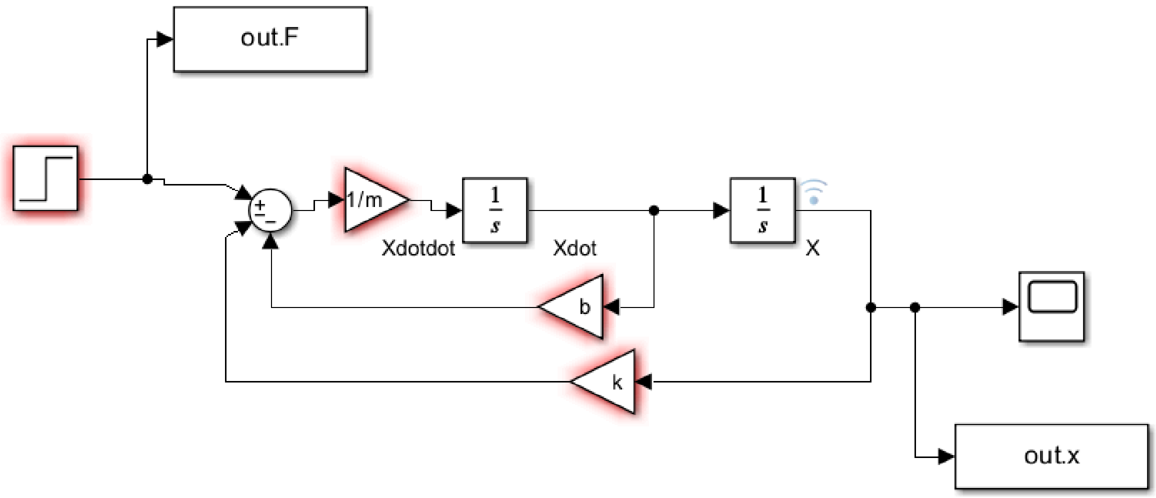


c. As shown these are the inputs (displacement and Force) using the simscape model.

Methos 2: Simulink with time domain

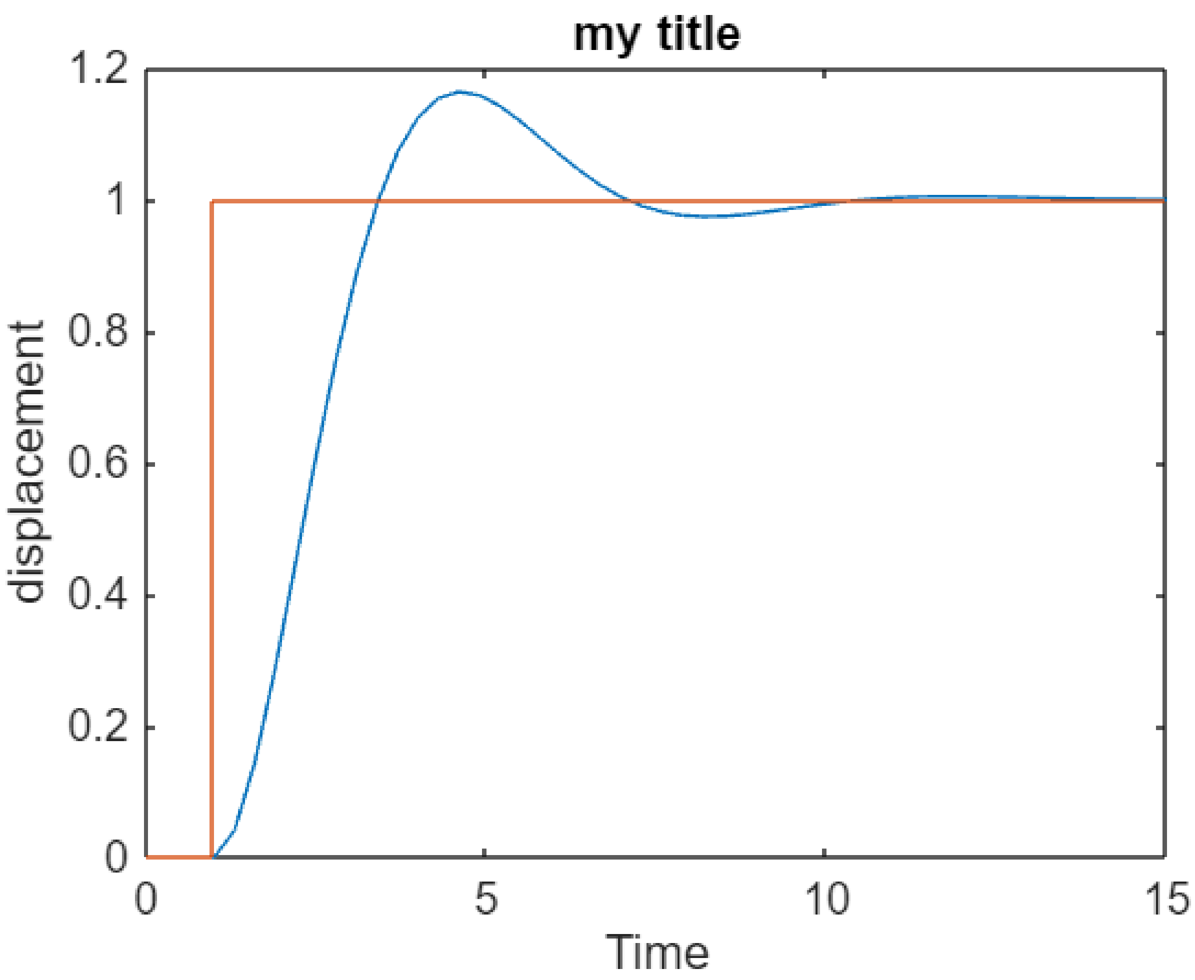
a. Newton's second law states that the sum of forces acting on an object is equal to the mass of the object multiplied by its acceleration, F=maF = maF=ma. This can be applied in Simulink to model dynamic systems, such as the mass-spring-damper system, using basic blocks like **integrators**, **sum**, and **gain** blocks.

b. This is the model used in this case by simulink:



Step input for the force, 1/m to multiply the equation by 1/m , 1/s is for integrating then we use b and k as factors of the spring and the damper and we scan the output to see the results.

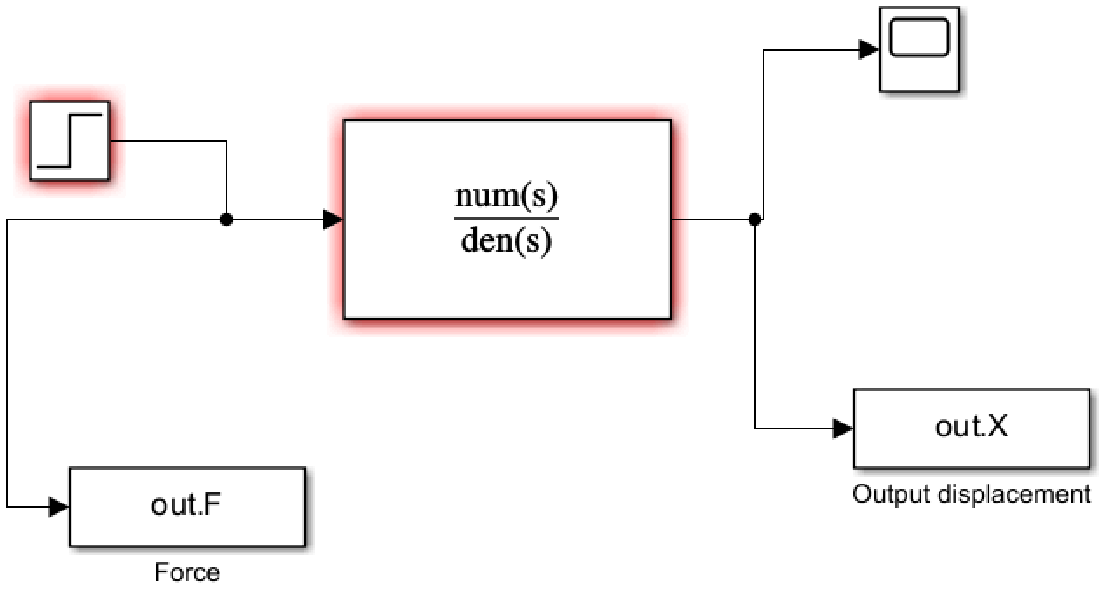
c. Result are shown below:



Method 3: Simulink using transfer function in laplace domain

a. In the **Laplace domain**, the mass-spring-damper system can be represented by a **transfer function**, which relates the system's input (force) to its output (displacement or velocity) using algebraic equations rather than differential equations.

b. This is the model used for this study:



this is how the equation is calculated:

Simulink with transfer function:

$$M\ddot{x} = F - kx - b\dot{x} \quad \text{Laplace}$$

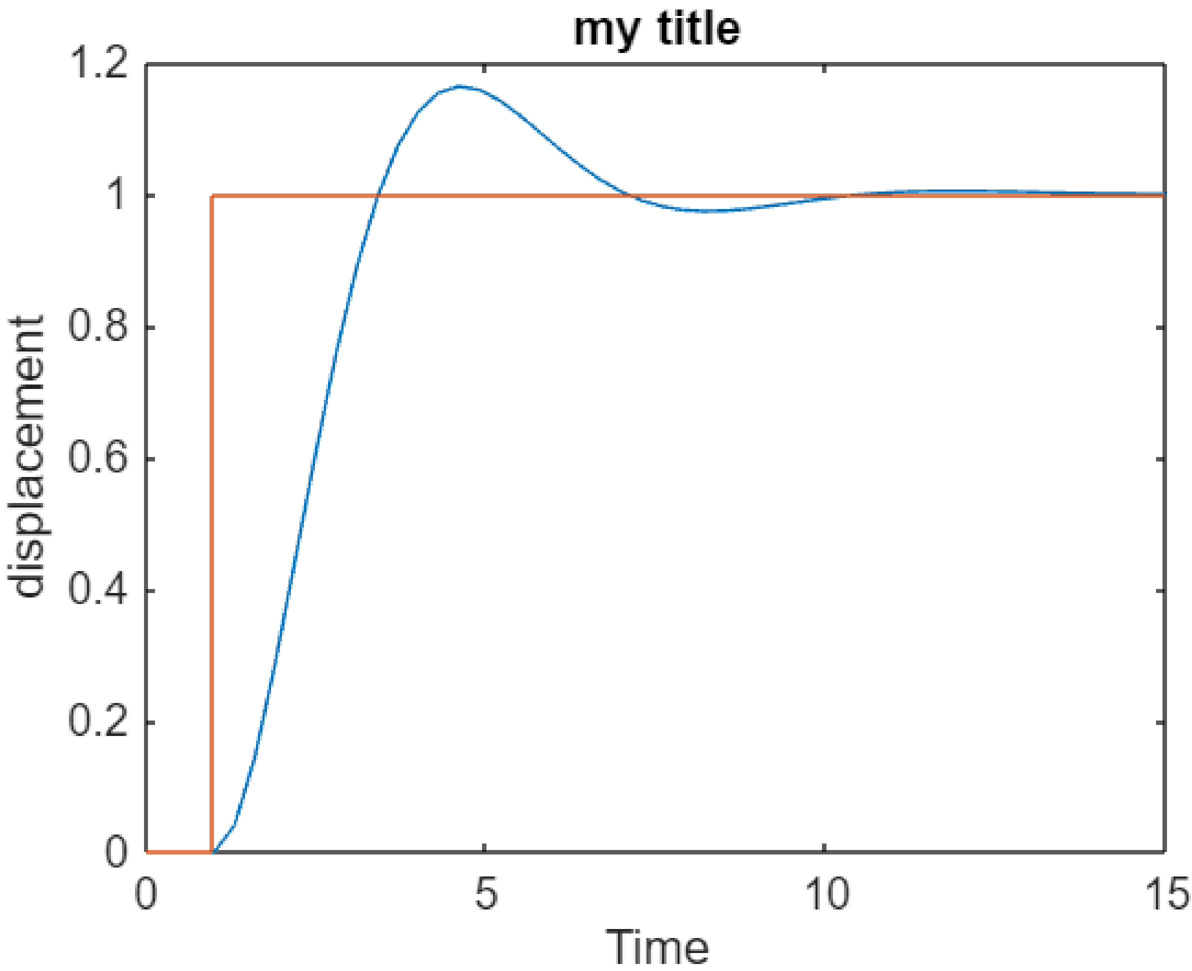
$$Ms^2X(s) = F(s) - kX(s) - bsX(s)$$

$X(s)$ = output , $F(s)$ = input

$$\Rightarrow (Ms^2 + bs + k)X(s) = F(s)$$

$$\frac{X(s)}{F(s)} = \frac{1}{Ms^2 + bs + k}$$

c. And as For the results:



Conclusion

As we can see the results are the same for every method so what is the difference of using each one?