

Lab # 6

Modeling of A Mechanical System In SIMULINK

Objective:

Mathematical Modeling of Physical Systems

The task of mathematical modeling is an important step in the analysis and design of physical systems. The mathematical models of systems are obtained by applying the fundamental physical laws governing the nature of the components making these systems. For example, Newton's laws are used in the mathematical modeling of mechanical systems. Similarly, Kirchhoff's laws are used in the modeling and analysis of electrical systems.

The Laplace transformation is applied to the mathematical model and then the model is converted into an algebraic equation. The properties and behavior of the system can then be represented as a block diagram, with the transfer function of each component describing the relationship between its input and output behavior. We can use state-space model for all types of systems that consist of state variables.

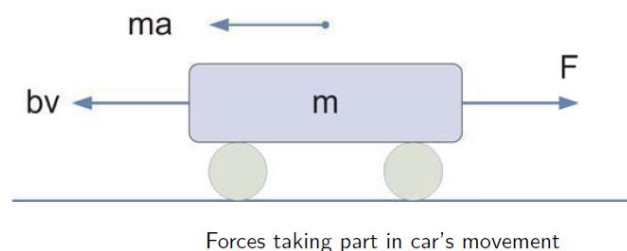
State

State refers to the past, present, and future condition of the system from a mathematical cell. State could be defined as a set of state variables and state equations to model the dynamic system. All the state equations are first-order differential equations.

State variables

State variables is defined as the minimal set of variables $[x_1(t), x_2(t), \dots, x_n(t)]$ such that the knowledge of these variables at any time $t = 0$ and information on the input excitation subsequently applied are sufficient to determine the state of the system at time $t > t_0$.

Modeling Newton's Law



Building the Model

Using Newton's law we derive

$$F = m\dot{v} + bv$$

Physical Description

Summing up all the forces acting on the mass,

Forces acting on the mass:

$$F = m\frac{dv}{dt} + bv$$

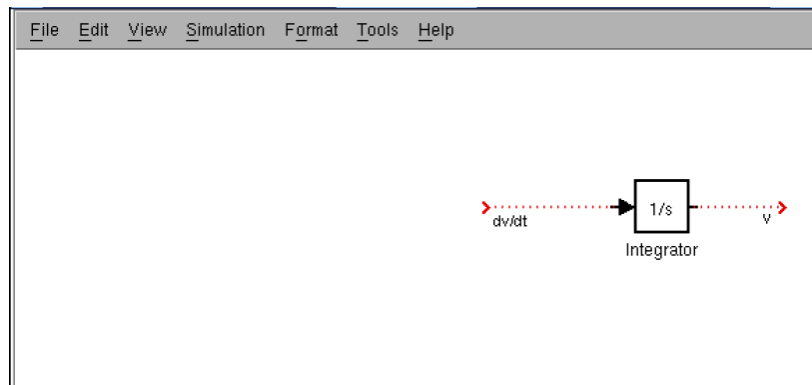
Where: $m=1200[\text{kg}]$, $b=50[\text{Nsec/m}]$, $F=500[\text{N}]$

Integrating the acceleration to obtain the velocity

Integral of acceleration

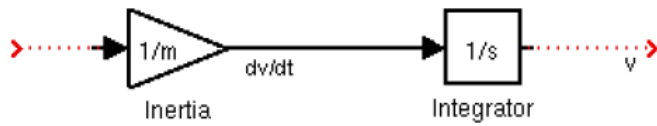
$$a = \frac{dv}{dt} \equiv \int \frac{dv}{dt} = v$$

Building the Model in SIMULINK



Obtaining Acceleration,

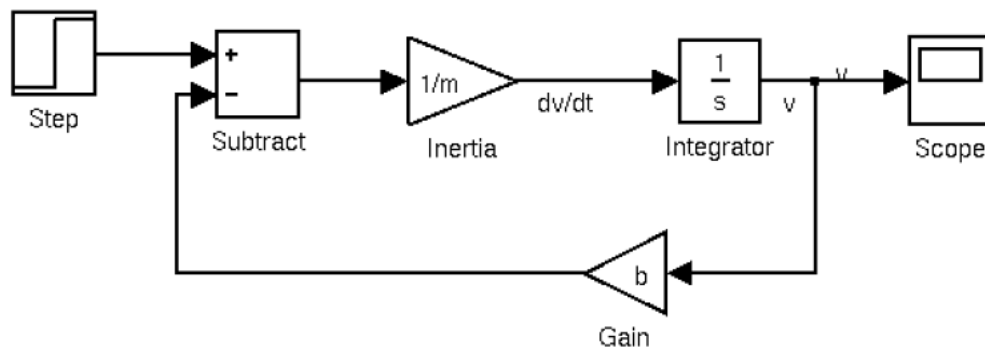
$$a = \frac{dv}{dt} = \frac{F - bv}{m}$$



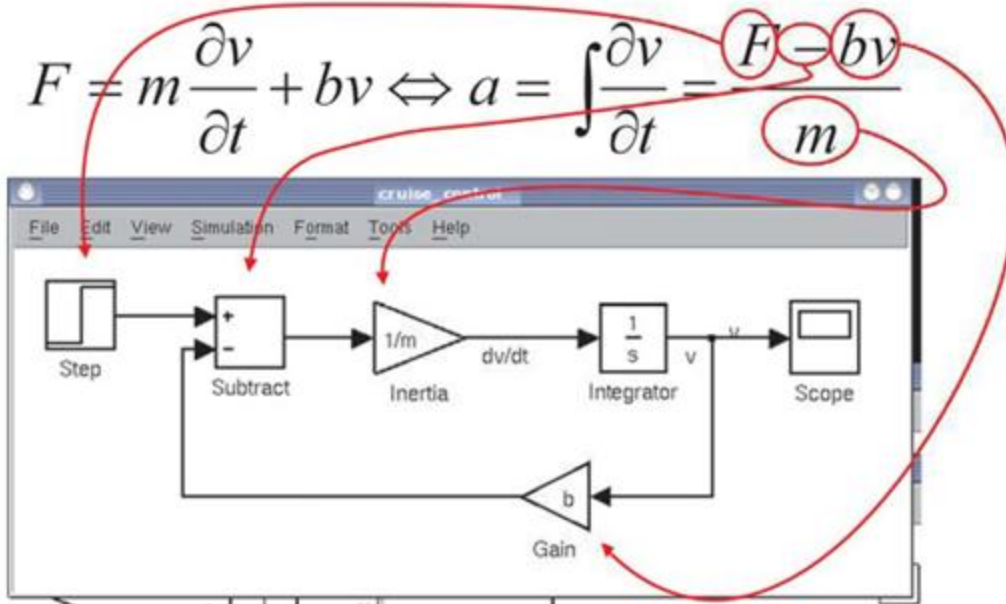
Elements used in Simulink Model

- Friction (Gain block)
- Subtract (from Math Operators)
- Input (Step block from Sources)
- Output (Scope from Sinks)

Complete Model



Mapping of Physical Equations to SIMULINK



Setting up the Variables

- Now it is time to use our input values in Simulink...
- $F=500[\text{N}]$
- In Step block set: Step time = 0 and Final value = 500

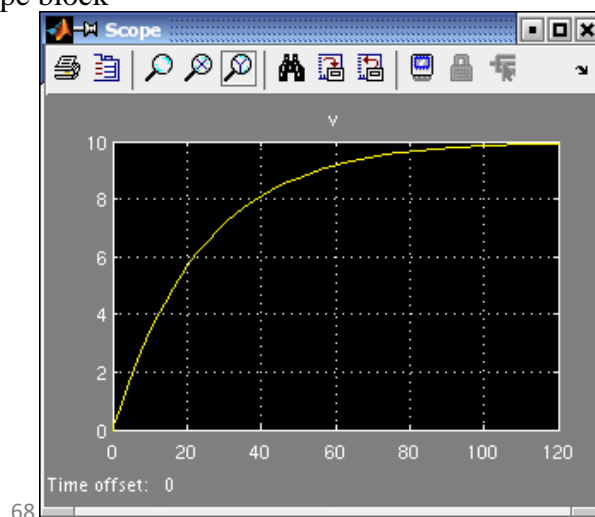
Adjust simulation parameters for the model

- Simulation → Configuration Parameters
- Stop time = 120

Set up variables in Matlab

- $m=1200;$
- $b=50;$

Check output on the Scope block



Post Lab Questions

a) What are state variables?

b) What is the first step before modeling a system?

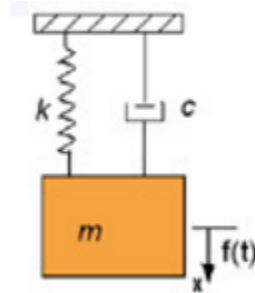
c) What are blocks and lines?

d) What is step signal used for in a mathematical model?

Lab Tasks

Task 1

Create a SIMULINK model for a mass attached to a spring with a linear damping force.



Hint:

Background:

A mass on a spring with a velocity-dependant damping force and a time-dependant force acting upon it will behave according to the following equation:

$$m \ddot{x} + c \dot{x} + kx = f(t)$$

After rearranging we get:

$$\ddot{x} = \frac{1}{m} (f(t) - c \dot{x} - kx)$$

Let $m=5$, $c = 0.35$ and let $k = 0.5$