Handbook of Plant Modeling I/F Guidelines-Compatible Model (NVH Model) for Vehicle Development (Ver. 1.1)

Revision History

Rev.	Date	Revised contents	Company	Approver
1.0	Mar, 2019	New issued	AZAPA	Ichihara
1.1	Mar, 2020	Revised error	AZAPA	Ichihara

Contents

1. Preface

1.1. Purpose of guidelines-compatible model

The guidelines-compatible model is based on the Plant Modeling I/F Guidelines for Vehicle Development 2.0, which promote the distribution of models between businesses. Actual use of this model will lead to a deeper understanding of these Guidelines. In addition, by replacing and running the subsystem models with your own models, the guidelines-compatible model is expected to be used as a preemptive Guidelines checker and problem identifier when changing models.

1.2. Requirements of guidelines-compatible model

For beginners, in this handbook function and structure of vehicle are given an abstract and scope of this handbook are motion system such as rotation or translation, electric system and thermal system.
*Other physical domains are the challenges in the future.
All of the models in this handbook is based on Matlab® Simulink®.

The guidelines-compatible model is generally based on “Handbook of Plant Modeling I/F Guidelines-Compatible Model for Vehicle Development (Ver. 1.0)”. In consideration of this, references will be provided for items that have not been modified from “Handbook of Plant Modeling I/F Guidelines-Compatible Model for Vehicle Development (Ver. 1.0)”. Items that have been modified or added to will be noted in this text.

1.3. Functions of guidelines-compatible model

●Controller
- None

●Plant
- Occupant
- Seat
- Engine
- Engine mount
- Vehicle body
- Suspension
- Unsprung mass
- Tire
- Road surface environment

2. Operation/Usage Environment

The operating requirement and usage environment of the guidelines-compatible model is shown below.

2.1. Operation requirement

Basically refer to chapter 2.1 of "Handbook of Plant Modeling I/F Guidelines-Compatible Model for Vehicle Development (Ver. 1.0)". On the other hand, the model usage environment is changed as follows;

＜Model usage environment ＞

Tool	MATLAB/Simulink
Tool ver.	R2015a (64bit)
Types	.slx
Library (Except for Simulink standard library)	METI_Lib_vehicle_model

＜Caluculating condition of model＞

Solver type	Fixed step ode3 (Bogacki-Shampine)
Operation of acceleration mode	Default: acceleration mode (For reducing simulation time. Normal mode can be simulated)
Sampling time	0.0001[s]
Max. step size	-
Min. step size	-
Acceptable error	-

2.2. Usage environment

Simulation environment and file/folder composition of the guidelines-compatible model are shown below;

＜Simulation environment of the guidelines-compatible model＞

The simulation environment of the guidelines-compatible model is as shown below.
The NVH simulator is made up of a model file and a library file.
After input data like driving data and parameter data are loaded, the simulation is run.

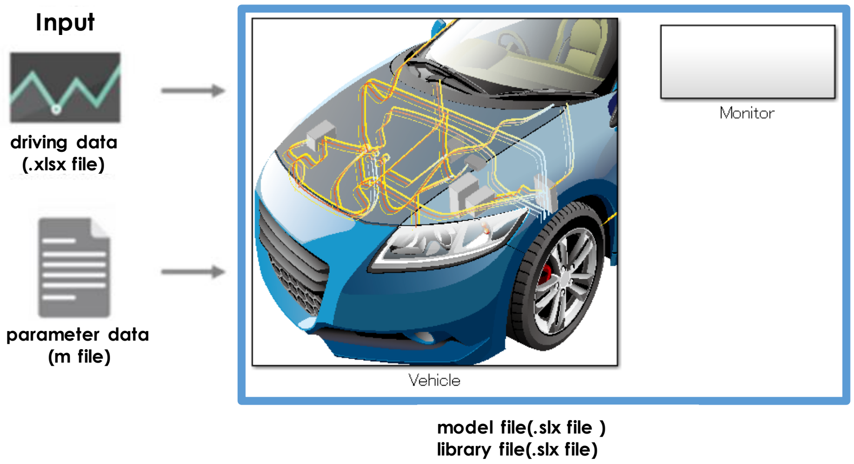

Fig.2.2.1. Simulation environment

＜File composition of the guidelines-compatible model＞

No	File Name	Description
1	METI_Vertical_Vibration_ver.01_2015a.slx	Simulator of NVH
2	METI_Lib_vehicle_model.slx	METI Library
3	init_setting.m	Script for initial setting / setting parameter data / setting pass
4	(subfolder) param	Parameter data folder
5	(subfolder) pictures	Block image data folder

3. Usage

Refer to chapter 3 of “Handbook of Plant Modeling I/F Guidelines-Compatible Model for Vehicle Development (Ver. 1.0)”.

4. Basic structure of guidelines-compatible model

The structures and system of the guidelines-compatible model's first-layer (top) are described below (those separated by Simulink's subsystem into each function).

4.1. Model structure of first-layer

The structure of the first-layer (entire model) in the guidelines-compatible model is shown below.

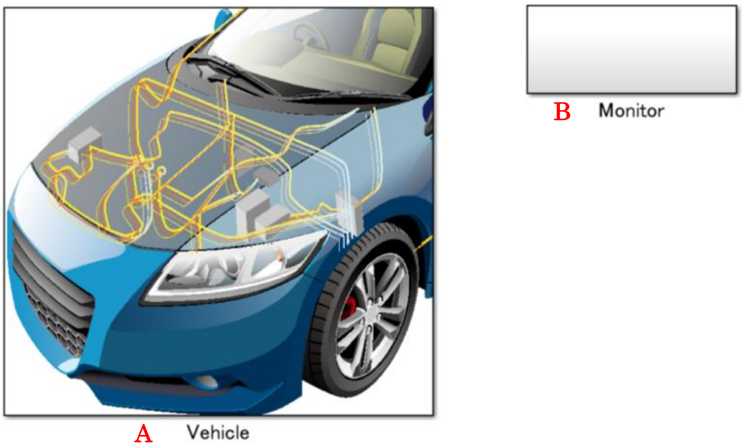

Fig.4.1. Structure of first-layer system

The function overview of first-layer system in the guidelines-compatible model is described.
A and B of the No. column on the table refer to the systems in Fig. 4.1.

Table 4.1. Each system names of first-layer system and function overview

No.	System Name	Function Overview
A	Vehicle	Calculating NVH of occupant and vehicle body based on input of road surface.
B	Monitor	Monitor each variables in the system

4.2. Model structure of second-layer

4.2.1. Structure of [A: Vehicle] system

The structure of the second-layer vehicle system in the guidelines-compatible model is shown below.

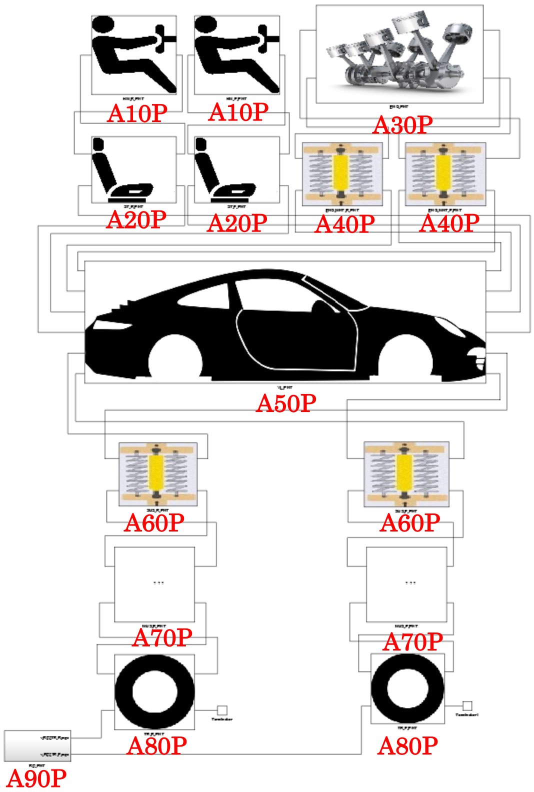

Figure 4.2. Structure of second-layer vehicle system

The function overview of second-layer vehicle system in the guidelines-compatible model is described. The numbered elements in the table represent the system shown in Fig.4.2.

Table 4.2. Each system names of second-layer vehicle system and function overview

No.	System Name	Function Overview
A10P	HM_F_PNT	Calculating each part motion from input of front seats.
	HM_R_PNT	Calculating each part motion from input of rear seats.
A20P	ST_F_PNT	Calculating front seat vertical vibration.
	ST_R_PNT	Calculating rear seat vertical vibration.
A30P	ENG_PNT	Calculating vibration from input of engine mount.
A40P	ENG_MNT_F_PNT	Calculating front engine mount vertical vibration.
	ENG_MNT_R_PNT	Calculating rear engine mount vertical vibration.
A50P	VL_PNT	Calculating vehicle body vibration.
A60P	SUS_F_PNT	Calculating front suspensions motion.
	SUS_R_PNT	Calculating rear suspensions motion.
A70P	MUS_F_PNT	Calculating front unsprung mass motion.
	MUS_R_PNT	Calculating rear unsprung mass motion.
A80P	TR_F_PNT	Calculating front tires motion.
	TR_R_PNT	Calculating rear tires motion.
A90P	RD_PNT	Output unevenness of the ground contact surface of tires.

4.2.2. Structure of [B: Monitor] system

The structure of the second-layer monitor system in the guidelines-compatible model is shown below.

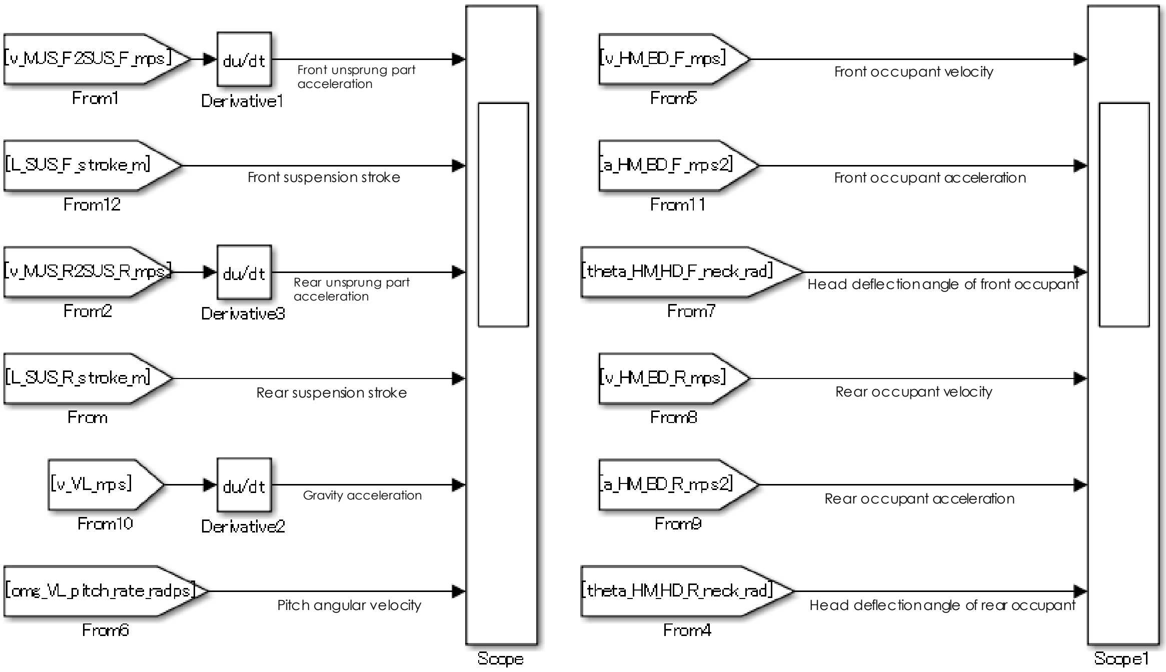

Fig.4.2.2 Structure of second-layer monitor system

This system monitors the signals calculated from the vehicle systems.
It does not have any deeper system layers.

5. Functional specifications of guidelines-compatible model

5.1. Functional specification of first-layer model

The functional specifications of the first-layer (entire model) in the guidelines-compatible model are described.

5.1.1. Abstract

Calculating the motion of tires, unsprung mass suspensions, vehicle body, engine, engine mount, seats and occupant from input of unevenness of road surface.
"Monitor" block monitors the various variables.

5.1.2. Data flow diagram

The data flow diagram of the entire the guidelines-compatible model is shown below.

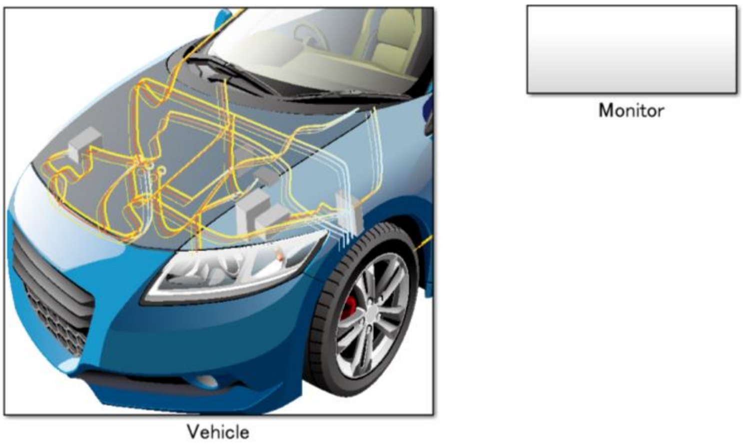

Fig.5.1.2. Data flow diagram: first-layer (entire model)

5.1.3. Input/output specification

No input/output in this system.

5.1.4. Parameter specification

The parameter specification of the entire the guidelines-compatible model is shown below.

Variable Name	Setting value	Unit	Description
jouge_timeseries	<72000x4>	m	Shape of ground contact surface of tires
distance_road_surface	<72000x1>	m	Table of calculating height of ground contact surface of tires x - distance in straight direction
z_hight_road_surface	<72000x1>	m	Table of calculating height of ground contact surface of tires
jouge_datapoint	72000	m	Get the length of data from number of elements in array of distance road surface.
end_of_road_surface	3600	m	End point of road surface data
vel_car_kmph	60	km/h	Vehicle velocity
M	1390	kg	Vehicle mass
M_Fr	790	kg	Front tires distributed mass (two wheels)
M_Rr	600	kg	Rear tires distributed mass (two wheels)
l_wheelbase	2.635	m	Wheelbase
l_center2Fr_sus	1.0213	m	Distance from suspension to center of vehicle body gravity
l_center2Rr_sus	1.6137		
l_center2Fr_Chair	0.3412	m	Distance from seat to center of vehicle body gravity
l_center2Rr_Chair	-1.0237		
l_center2Fr_ENG_mount	1.1374	m	Distance from engine mount to center of vehicle body gravity
l_center2Rr_ENG_mount	0.9099		
i_center_gravity	400	kgm	Vehicle pitch-oriented inertia
M_Fr_head	27.6	kg	Occupant head mass
M_Rr_head	27.6		
I_Fr_head	1.8	kgm	Occupant head inertia
I_Rr_head	1.8		
k_Fr_head	1210	Nm	Occupant head spring rate
k_Rr_head	1210		
d_Fr_head	8.17	Nms	Occupant head attenuation rate
d_Rr_head	8.17		
x_Fr_head	0.05317	m	Occupant head x-axis
x_Rr_head	0.05317		
y_Fr_head	0.212	m	Occupant head y-axis
y_Rr_head	0.212		
r_Fr_head	0.2186	m	Radius from occupant head pole to center of gravity
r_Rr_head	0.2186		
theta_Fr_head	1.3251	rad	Angle from occupant head pole to center of gravity
theta_Rr_head	1.3251		
x_k_Fr_head_ini	-0.0119	rad	Occupant head spring initial rotational angle
x_k_Rr_head_ini	-0.0119		
M_Fr_body_organs	12.8	kg	Occupant internal organs mass
M_Rr_body_organs	12.8		
kz_Fr_body_organs	82200	N/m	Occupant internal organs vertical spring rate
kz_Rr_body_organs	82200		
dz_Fr_body_organs	195	N/(m/s)	Occupant internal organs vertical attenuation rate
dz_Rr_body_organs	195		
z_kz_Fr_body_organs_ini	0.0015	m	Occupant internal organs spring z-stroke initial value
z_kz_Rr_body_organs_ini	0.0015		

Variable Name	Setting value	Unit	Description
M_Fr_body	44.01	kg	Occupant body mass
M_Rr_body	44.01		
M_Fr_human	84.41	kg	Occupant mass
M_Rr_human	84.41		
k_Fr_chair	1000000	N/m	Seat spring rate
k_Rr_chair	2000000		
d_Fr_chair	6634	N/(m/s)	Seat attenuation rate
d_Rr_chair	9381.9		
z_k_Fr_chair_ini	8.2722E-04	m	Seat initial displacement
z_k_Rr_chair_ini	4.1361E-04		
M_ENG	50	kg	Engine mass
l_ENG2Fr_ENG_mount	0	m	Distance from engine mount to center of engine gravity
l_ENG2Rr_ENG_mount	-0.4		
i_center_ENG	100	kgm	Engine pitch-oriented inertia
M_Fr_ENG_mount	50	kg	Engine mount mass
M_Rr_ENG_mount	0		
f_Fr_ENG	8.3	Hz	Engine vertical resonant frequency
f_Rr_ENG	8.3	Hz	Engine rotational resonant frequency
k_Fr_ENG_mount	135980	N/m	Engine mount spring rate
k_Rr_ENG_mount	679920		
d_Fr_ENG_mount	1825.3	N/(m/s)	Engine mount damper rate
d_Rr_ENG_mount	5215		
z_k_Fr_ENG_mount_ini	3.6769 E-04	m	Engine mount initial displacement
z_k_Rr_ENG_mount_ini	0		
M_car_body	1171.2	kg	Vehicle body mass
damper_all	<29x5>	-	Damper rate and friction force of front and rear
L_ratio_Fr_sus	1/0.83	-	Front lever ratio
L_ratio_Rr_sus	1/0.83	-	Rear lever ratio
M_Fr_sus	405.7914	kg	Suspension mass
M_Rr_sus	289.2086		
k_Fr_sus	30690	N/m	Suspension spring rate
k_Rr_sus	30690		
z_k_Fr_sus_ini	0.1075	m	Suspension initial displacement
z_k_Rr_sus_ini	0.0767		
d_Fr_sus_speed	<29x1>	m/s	Table of suspension damper rate calculation x - suspension damper speed
d_Rr_sus_speed	<29x1>		
d_Fr_sus_rate	<29x1>	N/(m/s)	Table of suspension damper rate calculation
d_Rr_sus_rate	<29x1>		
d_Fr_sus_fric	40	N	Suspension friction force
d_Rr_sus_fric	30		
d_Fr_sus_fric_gain	10000	-	Suspension friction coefficient
d_Rr_sus_fric_gain	10000		
M_Fr_wheel	50	kg	Unsprung mass (both wheels＋Lower parts of suspension)
M_Rr_wheel	50		
k_Fr_wheel	200000	N/m	Tires spring rate
k_Rr_wheel	200000		

Variable Name	Setting value	Unit	Description
d_Fr_wheel	3162.3	N/(m/s)	Tires attenuation rate
d_Rr_wheel	3162.3		
z_k_Fr_wheel_ini	0.0223	m	Tires initial displacement
z_k_Rr_wheel_ini	0.0166		
end_time	15	s	Simulation time
sampling_time	1.0E-4	s	Sampling period
percent2mujigen	0.01	-	% → non-dimension
mujigen2percent	100	-	Non-dimension → %
radpsec2rpm	60/(2*pi)	-	rad/sec → rpm
rpm2radpsec	(2*pi)/60	-	rpm → rad/sec
kmph2mps	1000/3600	-	km/h → m/sec
mps2kmph	3.6	-	m/sec → km/h
h2sec	3600	-	Hour → sec
sec2h	1/3600	-	sec → Hour
mps2kmps	1/1000	-	m/s → km/s
deg2rad	pi/180	-	degree → rad
rad2deg	180/pi	-	rad → degree
g	9.8	m/s2	Gravity acceleration

*Parameters in the white boxes are common to all systems.

5.1.5. Other information

None.

5.2. Functional specification of second-layer model

5.2.1. Functional specification of [A: Vehicle] system

The functional specifications of the second-layer vehicle system in the guidelines-compatible model are described.

5.2.1.1 Abstract

The abstract of this system is shown below.

① Modelized object
The vehicle model for NVH evaluation

② Modelized level
The model to calculate vibration of each vehicle components and occupant during driving

③ Modelized function
The function to calculate the motion of tires, unsprung mass, suspensions, vehicle body, engine, engine mount, seats and occupant by input of unevenness of road surface during driving

5.2.1.2 Data flow diagram

The data flow diagram of this system is shown below.

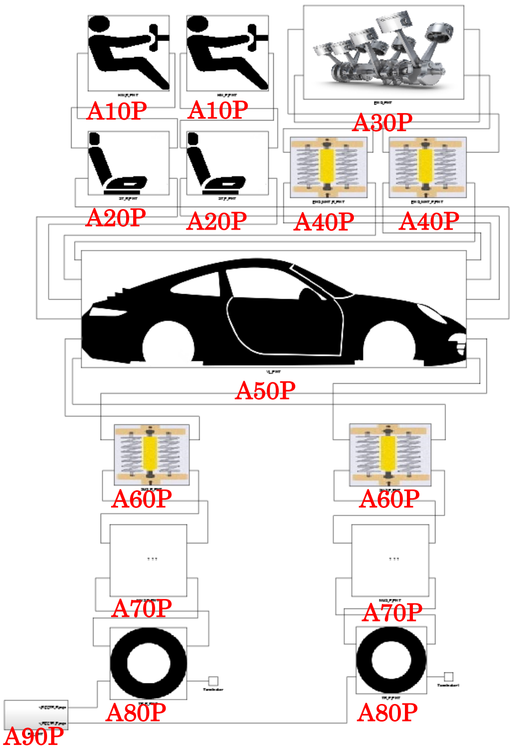

Fig.5.2.1.2. Data flow diagram: second-layer vehicle system

5.2.1.3 Input/output specification

No input/output in this system.

5.2.1.4 Parameter specification

Refer to 5.1.4 Parameter specification.

5.2.1.5 Other information

None.

5.2.2. Functional specification of [B: Monitor] system

The functional specifications of the second-layer monitor system in the guidelines-compatible model are described.

5.2.2.1 Abstract

The abstract of this system is shown below.

① Modelized object
None.

② Modelized level
None.

③ Modelized function
None.

5.2.2.2 Data flow diagram

The data flow diagram of this system is shown below.

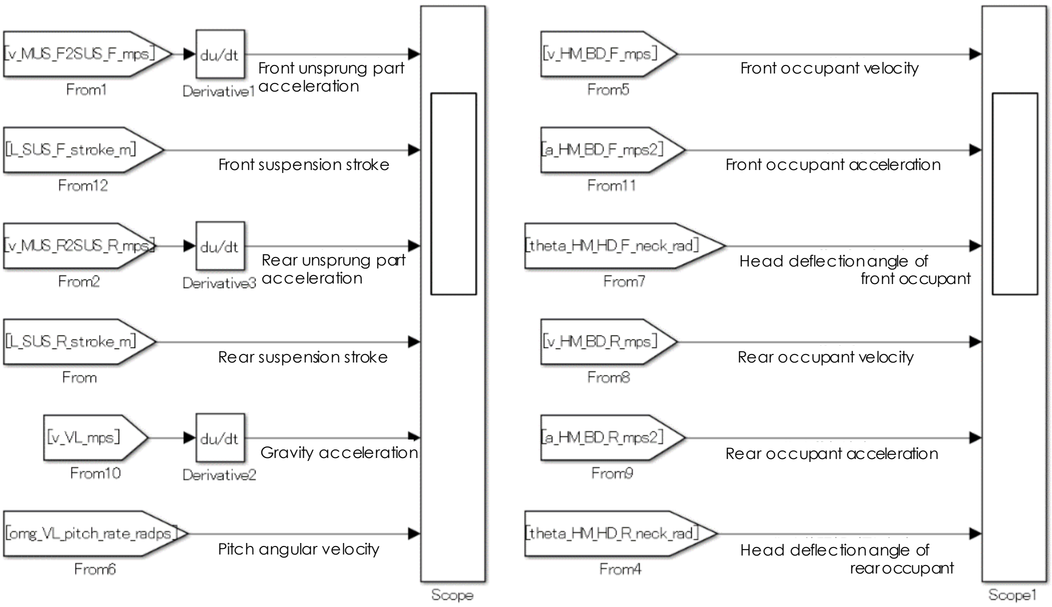

Fig.5.2.2.2. Data flow diagram: second-layer monitor system

5.2.2.3 Input/output specification

The input/output specification of this system is shown below.

Input			
Name	Unit	Area	Description
v_MUS_F2SUS_F_mps	m/s	-	Vertical velocity of front unsprung mass
L_SUS_F_stroke_m	m	-	Front suspension stroke
v_MUS_R2SUS_R_mps	m/s	-	Vertical velocity of rear unsprung mass
L_SUS_R_stroke_m	m	-	Rear suspension stroke
v_VL_mps	m/s	-	Center of gravity velocity
omg_VL_pitch_rate_radps	rad/s	-	Pitch angular velocity
v_HM_BD_F_mps	m/s	-	Front occupant velocity
a_HM_BD_F_mps2	m/s^2	-	Front occupant acceleration
theta_HM_HD_F_neck_rad	rad/s	-	Head deflection angle of front occupant
v_HM_BD_R_mps	m/s	-	Rear occupant velocity
a_HM_BD_R_mps2	m/s^2	-	Rear occupant acceleration
theta_HM_HD_R_neck_rad	rad/s	-	Head deflection angle of rear occupant
Output			
Name	Unit	Area	Description
None	-	–	-

5.2.2.4 Parameter specification

No parameter in this system.

5.2.2.5 Other information

None.

5.3. Functional specification of third-layer model

5.3.1. Functional specification of [A10P: HM_F_PNT/HM_R_PNT] system

The functional specifications of the third-layer HM_F_PNT/HM_R_PNT system in the guidelines-compatible model are described.

5.3.1.1 Abstract

The abstract of this system is shown below.

① Modelized object
The front and rear seat occupant model for vehicle comfort evaluation of NVH

② Modelized level
The model for head, body and internal organs of occupant

③ Modelized function
The function to calculate the motion of head, body and internal organs of occupant

5.3.1.2 Data flow diagram

The data flow diagram of this system is shown below.
HM_R_PNT is same as the below HM_F_PNT except for input/output specification name and variable name.

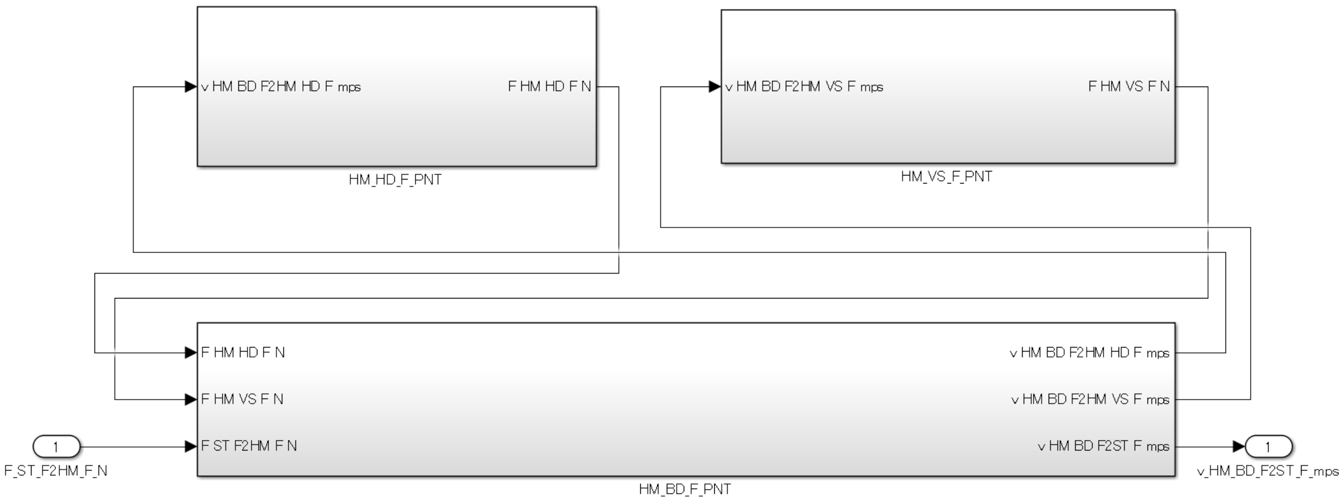

Fig.5.3.1.2. Data flow diagram: third-layer HM_F_PNT system

5.3.1.3 Input/output specification

The input/output specification of this system is shown below.

Input			
Name	Unit	Area	Description
F_ST_F2HM_F_N F_ST_R2HM_R_N	N	-	Force from seats
Output			
Name	Unit	Area	Description
v_HM_BD_F2ST_F_mps v_HM_BD_R2ST_R_mps	m/s	-	Vertical velocity of occupant

5.3.1.4 Parameter specification

The parameter specification of this system is shown below.

Variable Name	Setting value	Unit	Description
M_Fr_head	27.6	kg	Occupant head mass
M_Rr_head	27.6		
I_Fr_head	1.8	kgm	Occupant head inertia
I_Rr_head	1.8		
k_Fr_head	1210	Nm	Occupant head spring rate
k_Rr_head	1210		
d_Fr_head	8.17	Nms	Occupant head attenuation rate
d_Rr_head	8.17		
x_Fr_head	0.05317	m	Occupant head x-axis
x_Rr_head	0.05317		
y_Fr_head	0.212	m	Occupant head y-axis
y_Rr_head	0.212		
r_Fr_head	0.2186	m	Radius from occupant head pole to center of gravity
r_Rr_head	0.2186		
theta_Fr_head	1.3251	rad	Angle from occupant head pole to center of gravity
theta_Rr_head	1.3251		
x_k_Fr_head_ini	-0.0119	rad	Occupant head spring initial rotational angle
x_k_Rr_head_ini	-0.0119		
M_Fr_body_organs	12.8	kg	Occupant internal organs mass
M_Rr_body_organs	12.8		
kz_Fr_body_organs	82200	N/m	Vertical spring rate of occupant internal organs
kz_Rr_body_organs	82200		
dz_Fr_body_organs	195	N/(m/s)	Vertical attenuation rate of occupant 3ttinternal organs
dz_Rr_body_organs	195		
z_kz_Fr_body_organs_ini	0.0015	m	Z-stroke initial value of occupant internal organs
z_kz_Rr_body_organs_ini	0.0015		
M_Fr_body	44.01	kg	Occupant body mass
M_Rr_body	44.01		
M_Fr_human	84.41	kg	Occupant mass
M_Rr_human	84.41		

5.3.1.5 Other information

None.

5.3.2. Functional specification of [A20P: ST_F_PNT/ST_R_PNT] system

The functional specifications of the third-layer ST_F_PNT/ST_R_PNT system in the guidelines-compatible model are described.

5.3.2.1 Abstract

The abstract of this system is shown below.

① Modelized object
The front and rear seat model for vehicle comfort evaluation of NVH

② Modelized level
The model for vertical spring of the seat

③ Modelized function
The function to calculate vertical motion of the seat

5.3.2.2 Data flow diagram

The data flow diagram of this system is shown below.
ST_R_PNT is same as the below ST_F_PNT except for input/output specification name and variable name.

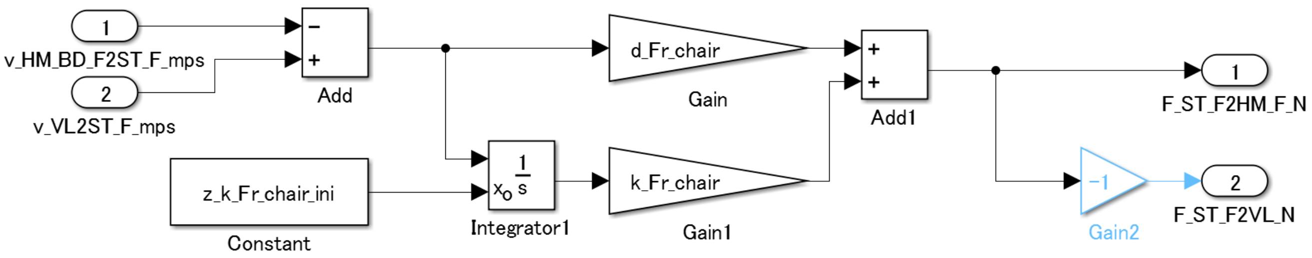

Fig.5.3.2.2. Data flow diagram: third-layer ST_F_PNT system

5.3.2.3 Input/output specification

The input/output specification of this system is shown below.

Input			
Name	Unit	Area	Description
v_HM_BD_F2ST_F_mps	m/s	-	Vertical velocity from occupant
v_HM_BD_F2ST_R_mps			
v_VL2ST_F_mps	m/s	-	Vertical velocity from vehicle body
v_VL2ST_R_mps			
Output			
Name	Unit	Area	Description
F_ST_F2HM_F_N	N	-	Force to occupant
F_ST_R2HM_R_N			
F_ST_F2VL_N	N	-	Force to vehicle body
F_ST_R2VL_N			

5.3.2.4 Parameter specification

The parameter specification of this system is shown below.

Variable Name	Setting value	Unit	Description
k_Fr_chair	1000000	N/m	Seat spring rate
k_Rr_chair	2000000		
d_Fr_chair	6634	N/(m/s)	Seat attenuation rate
d_Rr_chair	9381.9		
z_k_Fr_chair_ini	8.2722E-04	m	Seat initial displacement
z_k_Rr_chair_ini	4.1361E-04		

5.3.2.5 Other information

None.

5.3.3. Functional specification of [A30P: ENG_PNT] system

The functional specifications of the third-layer ENG_PNT system in the guidelines-compatible model are described.

5.3.3.1 Abstract

The abstract of this system is shown below.

① Modelized object
The Engine model for vehicle comfort evaluation of NVH

② Modelized level
The model for mass and mounting position of engine

③ Modelized function
The function to calculate pitching and vertical NVH of engine

5.3.3.2 Data flow diagram

The data flow diagram of this system is shown below.

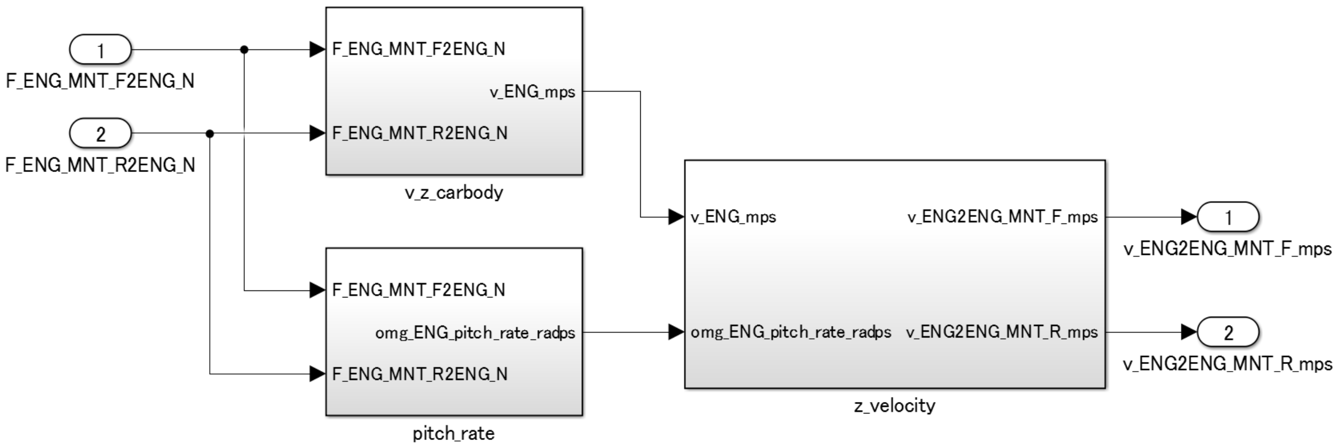

Fig.5.3.3.2. Data flow diagram : third-layer ENG_PNT system

5.3.3.3 Input/output specification

The input/output specification of this system is shown below.

Input			
Name	Unit	Area	Description
F_ENG_MNT_F2ENG_N	N	-	Force from front engine mount
F_ENG_MNT_R2ENG_N	N	-	Force from rear engine mount
Output			
Name	Unit	Area	Description
v_ENG2ENG_MNT_F_mps	m/s	-	Vertical velocity of front engine mount
v_ENG2ENG_MNT_R_mps	m/s	-	Vertical velocity of rear engine mount

5.3.3.4 Parameter specification

The parameter specification of this system is shown below.

Variable Name	Setting value	Unit	Description
M_ENG	100	kg	Engine mass
l_ENG2Fr_ENG_mount	0	m	Distance from front engine mount to center of engine gravity
l_ENG2Rr_ENG_mount	-0.4	m	Distance from rear engine mount to center of engine gravity
i_center_ENG	100	kgm	Engine pitch-oriented inertia

5.3.3.5 Other information

None.

5.3.4. Functional specification of [A40P: ENG_MNT_F_PNT/ ENG_MNT_R_PNT] system

The functional specifications of the third-layer ENG_MNT_F_PNT/ ENG_MNT_R_PNT system in the guidelines-compatible model are described.

5.3.4.1 Abstract

The abstruct of this system is shown below.

① Modelized object
The front and rear engine mount model for vehicle comfort evaluation of NVH

② Modelized level
The model for spring and attenuation of engine mount

③ Modelized function
The function to calculate attenuation of engine mount

5.3.4.2 Data flow diagram

The data flow diagram of this system is shown below.

ENG_MNT_R_PNT is same as the below ENG_MNT_F_PNT except for input/output specification name and variable name.

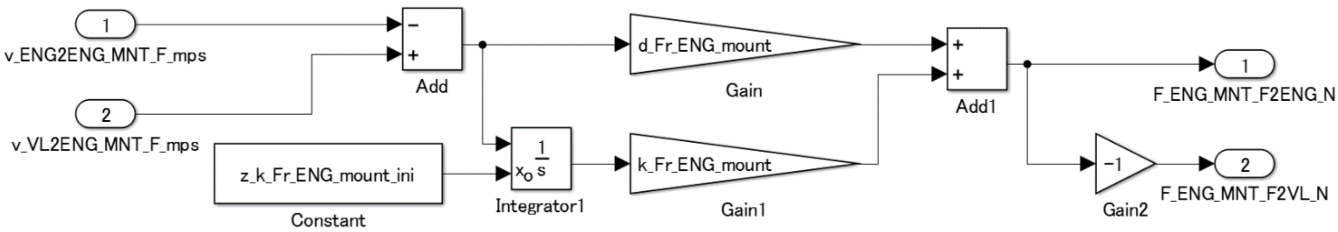

Fig.5.3.4.2. Data flow diagram：third-layer ENG_MNT_F_PNT

5.3.4.3 Input/output specification

The input/output specification of this system is shown below.

Input			
Name	Unit	Area	Description
v_ENG2ENG_MNT_F_mps v_ENG2ENG_MNT_R_mps	m/s	-	Vertical velocity from engine
v_VL2ENG_MNT_F_mps v_VL2ENG_MNT_R_mps	m/s	-	Vertical velocity from vehicle body
Output			
Name	Unit	Area	Description
F_ENG_MNT_F2ENG_N F_ENG_MNT_R2ENG_N	N	-	Force to engine
F_ENG_MNT_F2VL_N F_ENG_MNT_R2VL_N	N	-	Force to vehicle body

5.3.4.4 Parameter specification

The parameter specification of this system is shown below.

Variable Name	Setting value	Unit	Description
k_Fr_ENG_mount	135980	N/m	Engine mount spring rate
k_Rr_ENG_mount	679920		
d_Fr_ENG_mount	1825.3	N/(m/s)	Engine mount damper rate
d_Rr_ENG_mount	5215		
z_k_Fr_ENG_mount_ini	3.6769 E-04	m	Engine mount initial displacement
z_k_Rr_ENG_mount_ini	0		

5.3.4.5 Other information

None.

5.3.5. Functional specification of [A50P: VL_PNT] system

The functional specifications of the third-layer VL_PNT system in the guidelines-compatible model are described.

5.3.5.1 Abstract

The abstruct of this system is shown below.

① Modelized object
The vehicle model for vehicle body comfort evaluation of NVH

② Modelized level
The model for vehicle body mass and each mounting position

③ Modelized function
The function to calculate vertical vibration of vehicle body

5.3.5.2 Data flow diagram

The data flow diagram of this system is shown below.

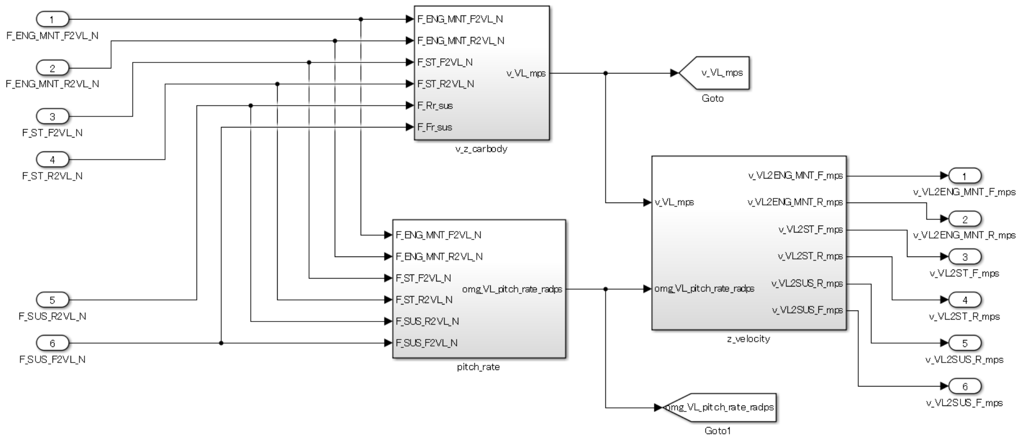

Fig.5.3.5.2. Data flow diagram : third-layer VL_PNT system

5.3.5.3 Input/output specification

The input/output specification of this system is shown below.

Input			
Name	Unit	Area	Description
F_ENG_MNT_F2VL_N	N	-	Force from front engine mount
F_ENG_MNT_R2VL_N	N	-	Force from rear engine mount
F_ST_F2VL_N	N	-	Force from front seat
F_ST_R2VL_N	N	-	Force from rear seat
F_SUS_F2VL_N	N	-	Force from front suspension
F_SUS_R2VL_N	N	-	Force from rear suspension
Output			
Name	Unit	Area	Description
v_VL2ENG_MNT_F_mps	m/s	-	Vertical velocity to front engine mount
v_VL2ENG_MNT_R_mps	m/s	-	Vertical velocity to rear engine mount
v_VL2ST_F_mps	m/s	-	Vertical velocity to front seat
v_VL2ST_R_mps	m/s	-	Vertical velocity to rear seat
v_VL2SUS_F_mps	m/s	-	Vertical velocity to front suspension
v_VL2SUS_R_mps	m/s	-	Vertical velocity to rear suspension

5.3.5.4 Parameter specification

The parameter specification of this system is shown below.

Variable Name	Setting value	Unit	Description
l_center2Fr_sus	1.0213	m	Distance from suspension to center of vehicle body gravity
l_center2Rr_sus	1.6137		
l_center2Fr_Chair	0.3412	m	Distance from seat to center of vehicle body gravity
l_center2Rr_Chair	-1.0237		
l_center2Fr_ENG_mount	1.1374	m	Distance from engine mount to center of vehicle body gravity
l_center2Rr_ENG_mount	0.9099		
i_center_gravity	400	kgm	Vehicle pitch-oriented inertia
M_car_body	1171.2	kg	Vehicle body mass

5.3.5.5 Other information

None.

5.3.6. Functional specification of [A60P: SUS_F_PNT/SUS_R_PNT] system

The functional specifications of the third-layer SUS_F_PNT/ SUS_R_PNT system in the guidelines-compatible model are described.

5.3.6.1 Abstract

The abstruct of this system is shown below.

① Modelized object
The rear suspension model for vehicle comfort evaluation of NVH

② Modelized level
The model for spring and attenuation of suspension

③ Modelized function
The function to calculate vertical vibration of suspension

5.3.6.2 Data flow diagram

The data flow diagram of this system is shown below.
SUS_R_PNT is same as the below SUS_F_PNT except for input/output specification name and variable name.

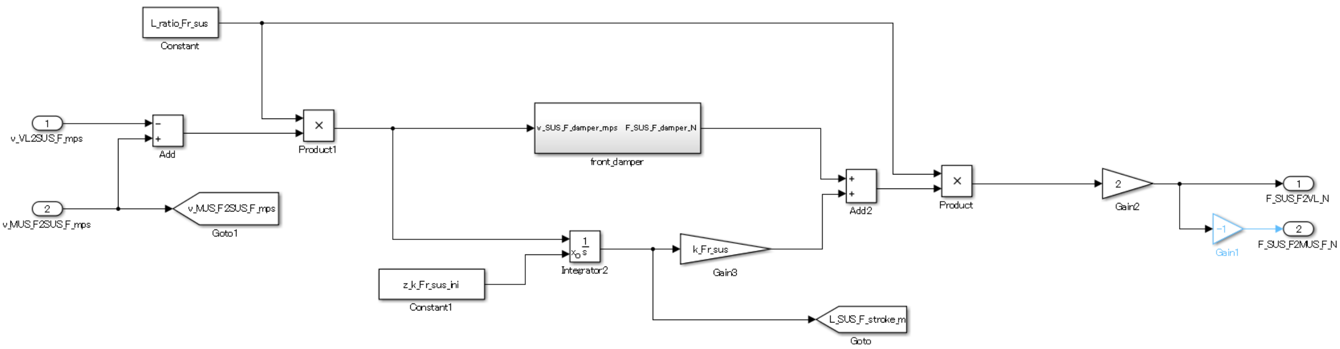

Fig.5.3.6.2. Data flow diagram: third-layer SUS_F_PNT system

5.3.6.3 Input/output specification

The input/output specification of this system is shown below.

Input			
Name	Unit	Area	Description
v_VL2SUS_F_mps	m/s	-	Vertical velocity from vehicle body
v_VL2SUS_R_mps			
v_MUS_F2SUS_F_mps	m/s	-	Vertical velocity of unsprung mass
v_MUS_R2SUS_R_mps			
Output			
Name	Unit	Area	Description
F_SUS_F2VL_N	N	-	Force to vehicle
F_SUS_R2VL_N			
F_SUS_F2MUS_F_N	N	-	Force to unsprung mass
F_SUS_R2MUS_R_N			

5.3.6.4 Parameter specification

The parameter specification of this system is shown below.

Variable Name	Setting value	Unit	Description
L_ratio_Fr_sus	1/0.83	-	Front lever ratio
L_ratio_Rr_sus	1/0.83	-	Rear lever ratio
k_Fr_sus	30690	N/m	Suspension spring rate
k_Rr_sus	30690		
z_k_Fr_sus_ini	0.1075	m	Suspension initial displacement
z_k_Rr_sus_ini	0.0767		
d_Fr_sus_speed	<29x1>	m/s	Table of suspension damper rate calculation x - suspension damper speed
d_Rr_sus_speed	<29x1>		
d_Fr_sus_rate	<29x1>	N/(m/s)	Table of suspension damper rate calculation
d_Rr_sus_rate	<29x1>		
d_Fr_sus_fric	40	N	Suspension friction force
d_Rr_sus_fric	30		
d_Fr_sus_fric_gain	10000	-	Suspension friction coefficient
d_Rr_sus_fric_gain	10000		

5.3.6.5 Other information

None.

5.3.7. Functional specification of [A70P: MUS_F_PNT/ MUS_R_PNT] system

The functional specifications of the third-layer MUS_F_PNT/ MUS_R_PNT system in the guidelines-compatible model are described.

5.3.7.1 Abstract

The abstruct of this system is shown below.

① Modelized object
The front and rear unsprung mass model for vehicle comfort evaluation of NVH

② Modelized level
The model of unsprung mass

③ Modelized function
The function to calculate vertical vibration of unsprung mass

5.3.7.2 Data flow diagram

The data flow diagram of this system is shown below.

MUS_R_PNT is the same as the below MUS_F_PNT in the figure below except for input/output names and variable names.

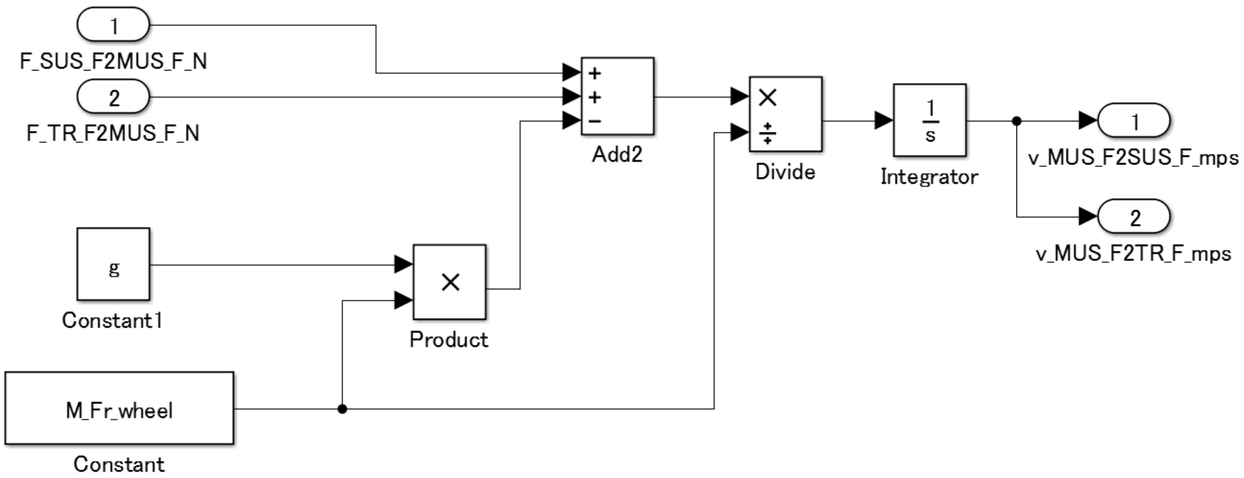

Fig.5.3.7.2. Data flow diagram: third-layer MUS_F_PNT system

5.3.7.3 Input/output specification

The input/output specification of this system is shown below.

Input			
Name	Unit	Area	Description
F_SUS_F2MUS_F_N	m/s	-	Force from suspension
F_SUS_R2MUS_R_N			
F_TR_F2MUS_F_N	m/s	-	Force from tires
F_TR_R2MUS_R_N			
Output			
Name	Unit	Area	Description
v_MUS_F2SUS_F_mps	N	-	Vertical velocity to suspension
v_MUS_R2SUS_R_mps			
v_MUS_F2TR_F_mps	N	-	Vertical velocity to tires
v_MUS_R2TR_R_mps			

5.3.7.4 Parameter specification

The parameter specification of this system is shown below.

Variable Name	Setting value	Unit	Description
M_Fr_wheel	50	kg	Unsprung mass (both wheels＋Lower part of suspension)
M_Rr_wheel	50		

5.3.7.5 Other information

None.

5.3.8. Functional specification of [A80P: TR_F_PNT/TR_R_PNT] system

The functional specifications of the third-layer TR_F_PNT/TR_R_PNT system in the guidelines-compatible model are described.

5.3.8.1 Abstract

The abstruct of this system is shown below.

① Modelized object
The front and rear tire model for vehicle comfort evaluation of NVH

② Modelized level
The model for spring and damper of tires

③ Modelized function
The function to calculate vertical vibration of tires

5.3.8.2 Data flow diagram

The data flow diagram of this system is shown below.

TR_R_PNT is the same as the below TR_F_PNT in the figure below except for input/output names and variable names.

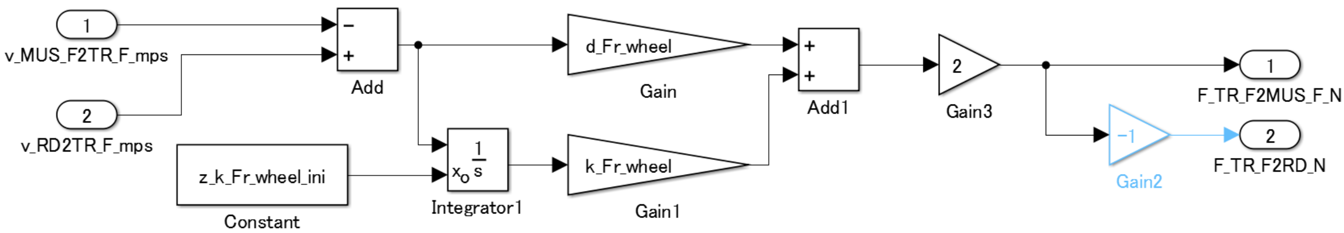

Fig.5.3.8.2. Data flow diagram: third-layer TR_F_PNT system

5.3.8.3 Input/output specification

The input/output specification of this system is shown below.

Input			
Name	Unit	Area	Description
v_MUS_F2TR_F_mps v_MUS_R2TR_R_mps	m/s	-	Vertical velocity of unsprung mass
v_RD2TR_F_mps v_RD2TR_R_mps	m/s	-	Vertical velocity of ground contact surface of tires
Output			
Name	Unit	Area	Description
F_TR_F2MUS_F_N F_TR_R2MUS_R_N	N	-	Force to tires
F_TR_F2RD_N F_TR_R2RD_N	N	-	Force to ground contact surface of tires

5.3.8.4 Parameter specification

The parameter specification of this system is shown below.

Variable Name	Setting value	Unit	Description
k_Fr_wheel	200000	N/m	Tires spring rate
k_Rr_wheel	200000		
d_Fr_wheel	3162.3	N/(m/s)	Tires attenuation rate
d_Rr_wheel	3162.3		
z_k_Fr_wheel_ini	0.0223	m	Tires initial displacement
z_k_Rr_wheel_ini	0.0166		

5.3.8.5 Other information

None.

5.3.9. Functional specification of [A90P: RD_PNT] system

The functional specifications of the third-layer RD_PNT system in the guidelines-compatible model are described.

5.3.9.1 Abstract

The abstruct of this system is shown below.

① Modelized object
The road surface unevenness model for vehicle comfort evaluation of NVH

② Modelized level
The model for unevenness of ground contact surface of front and rear tires

③ Modelized function
The function to output unevenness of the ground contact surface of the front and rear tires during driving

5.3.9.2 Data flow diagram

The data flow diagram of this system is shown below.

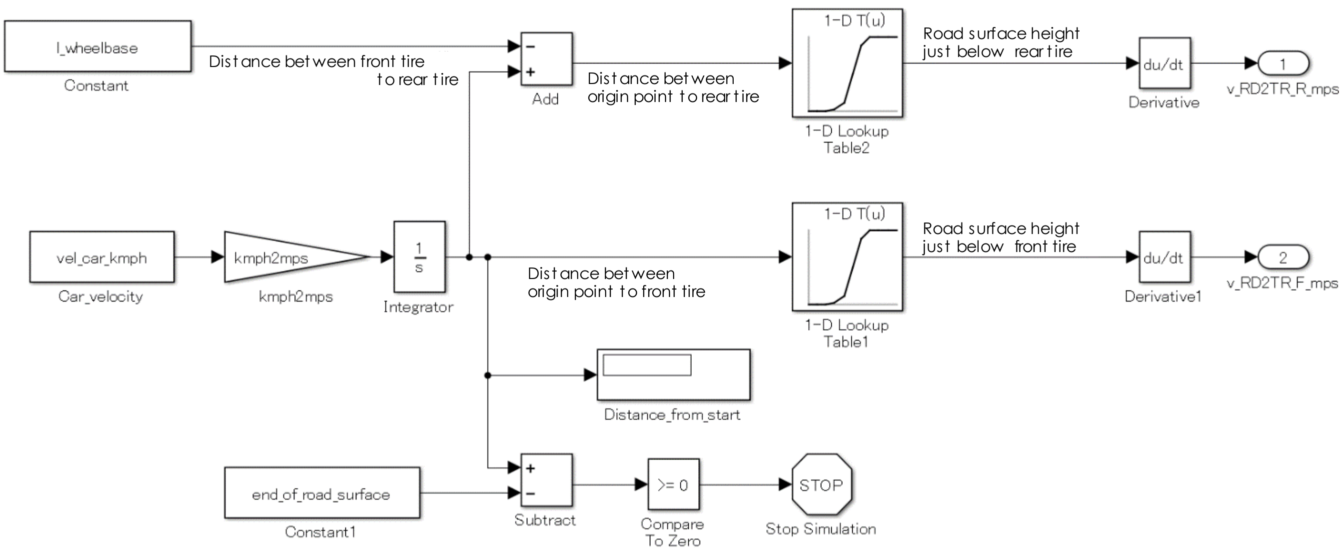

Fig.5.3.9.2. Data flow diagram: third-layer RD_PNT system

5.3.9.3 Input/output specification

The input/output specification of this system is shown below.

Input			
Name	Unit	Area	Description
None	-	-	
Output			
Name	Unit	Area	Description
v_RD2TR_F_mps	m/s	-	Vertical velocity of ground contact surface of front tires
v_RD2TR_R_mps	m/s	-	Vertical velocity of ground contact surface rear tires

5.3.9.4 Parameter specification

The parameter specification of this system is shown below.

Variable Name	Setting value	Unit	Description
distance_road_surface	<72000x1>	m	Table of calculating height of ground contact surface of tires x - distance in straight direction
z_hight_road_surface	<72000x1>	m	Table of calculating height of ground contact surface of tires
vel_car_kmph	60	km/h	Vehicle velocity
l_wheelbase	2.635	m	Wheelbase
end_of_road_surface	3600	m	End point of road surface data

5.3.9.5 Other information

None.

6. Description in this model

Refer to Chapter 6 of “Handbook of Plant Modeling I/F Guidelines-Compatible Model for Vehicle Development (Ver. 1.0)” except for 6.1.4.Input/output terminal names and 6.4 naming 6.4.2 subsystem name.

6.1. Input/output terminal names

Input/ output terminal names are named by the following rules;

-When the physical quantity output from system is the only one, “physical quantity notation_system name_(meaning)_units”

-When the physical quantity output from system are multiple, “physical quantity notation_upstream system name 2 downstream system name_(meaning)_units”

-Please note that “_PNT” is omitted when system is a plant model.

6.2. Subsystem name

The list of the subsystem names is shown below.

Table 6. Subsystem name

First-layer			Second-layer			Third-layer			Forth-layer		
Part	Notation	abbreviation	Part	Notation	abbreviation	Part	Notation	abbreviation	Part	Notation	abbreviation
Vehicle	Vehicle		Vehicle plant	VehicleBody	VB	Engine	Engine	ENG_PNT			
						Engine mount	EngineMount	ENG_MNT_PNT			
						Front occupant	HumanFront	FM_F_PNT	Front occupant head	HumanHeadFront	HM_HD_F_PNT
									Front occupant body	HumanBodyFront	HM_BD_F_PNT
									Front occupant internal organs	HumanVisceraFront	HM_VS_F_PNT
						Front seat	SeatFront	ST_F_PNT			
						Rear occupant	HumanRear	HM_R_PNT	Rear occupant head	HumanHeadRear	HM_HD_R_PNT
									Rear occupant body	HumanBodyRear	HM_BD_R_PNT
									Rear occupant internal organs	HumanVisceraRear	HM_VS_R_PNT
						Rear seat	SeatRear	ST_R_PNT			
						Front tire	TireFront	TR_F_PNT			
						Rear tire	TireRear	TR_R_PNT			
						Front susupension	SusupentionFront	SUS_F_PNT			
						Rear susupension	SusupentionRear	SUS_R_PNT			
						Front unsprng mass	UnsprngMassFront	MUS_F_PNT			
						Rear unsprng mass	UnsprngMassRear	MUS_R_PNT			
						vehicle	VehicleLoad	VL_PNT			
						Road surface environment	RoadEnviroment	RD_PNT			
Monitor	Monitor										

7. Reference document

[1] “非因果モデリングツールを用いた FMI モデル接続ガイドライン Ver.1.0”(Society of Automotive Engineers of Japan) *Japanese only

https://www.jsae.or.jp/tops/topics/1241/1241-1A.pdf

[2] “PLANT MODELING GUIDELINES USING MATLAB® and Simulink® Version 2.1” (Japan MATLAB Automotive Board, JMAAB 2nd Dec. 2008)

http://jmaab.mathworks.jp/doc/plantmodeling_sg/PMSG_english_v2.1.pdf

[3] ”Handbook of Plant Modeling I/F Guidelines-Compatible Model for Vehicle Development（Ver. 1.0）”

https://epc.or.jp/wp-content/uploads/2019/09/Compatible-Modelver1.0EN.pdf