

**Plant model I / F**  
**guideline-compliant model**  
**manual for**  
**automobile development**  
**(Fuel efficiency model for series parallel**  
**hybrid1 vehicles)**  
(ver.1.0)

## Revision history

Rev.	date	Contents	Company name	Authorizer
--	2021/03	New issued	AZAPA	Ichihara

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# 1. Overview

## 1.1. Purpose of the guideline-compliant model

This model complies with the "Plant Model I / F Guidelines for Automotive Development" for promoting the distribution of models between companies, and aims to improve understanding of the guidelines through the actual execution of the model. In addition, by replacing the subsystem model with your own model and executing it, it can be expected to be used as a guideline pre-checker when exchanging models and as a hint to detect future issues.

## 1.2. Prerequisites / restrictions of the guideline-compliant model

The functions and structures of automobiles are abstracted so that even those who do not have basic knowledge of automobiles can easily understand them. The physical domain covers the motion system (rotation / translation) and the electrical system. \* Other physical areas will be considered in future developments.

The engine displacement of the car is 1.8 [L], which is a model assuming a series parallel hybrid car. This time, we will create the base on Matlab® Simulink® which is a tool often used in automobile development.

## 1.3. Functional overview of guideline-compliant model

- Control function
  - Engine output control
  - Generator control
  - Motor control
  - Deceleration regeneration control
  - Voltage step-up control
  - Voltage step-down control
- Plant
  - Engine
  - Transmission
  - Differential gear
  - Brake
  - Tire
  - Vehicle
  - Motor drive system
  - High voltage battery
  - High voltage electrical load
  - DCDC boost converter
  - DCDC buck converter
  - Low voltage battery
  - Low voltage electrical load



## 2. Operation / usage environment

The operating environment and usage environment of the guideline-compliant model are shown below.

### 2.1. Operating environment

The guideline-compliant model is guaranteed to work in the following environment and conditions.

#### <OS environment>

OS	Windows 10 64bit
PC specifications	64bit      Memory: 8GB or more

#### <Model usage environment>

Tool name	MATLAB/Simulink
Tool version	2015a (64bit)
Format	.slx
Required library (Non-Simulink standard)	METI_Lib_vehicle_model.slx

#### <Model calculation conditions>

Solver type	Fixed step ode3 (Dormand-Prince)
Sampling time	0.0025[s]
Maximum step size	-
Minimum step size	-
Allowable error	-

## 2.2. Usage environment

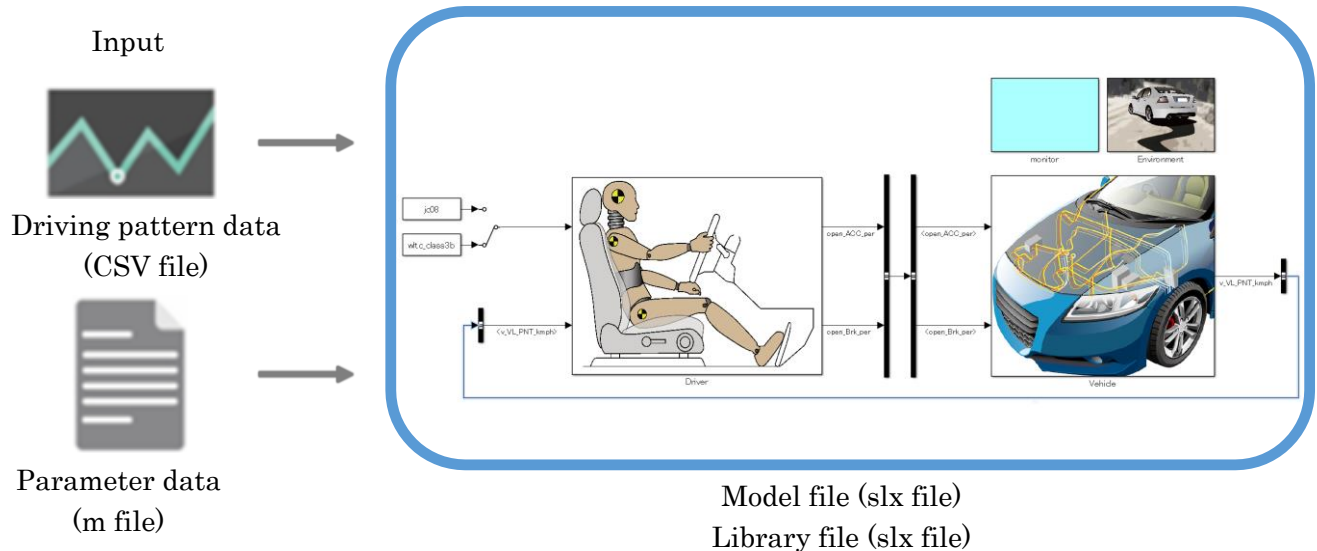
The environment and file and folder structure when simulating the guideline-compliant model are shown below.

<Guideline-compliant model simulation environment>

The environment for simulation using the guideline-compliant model is shown below.

The the fuel consumption simulator consists of a model file and a library file.

Mode driving data, parameter data, etc. are read as input setting information and calculations are performed.



**Fig. 2.2.1 Simulation Environment**

<Guideline-compliant model file structure>

No.	File name	Explanation
1	SPHV_fuel_efficiency_2015a_20210331.slx	Simulator
2	METI_Lib_vehicle_model.slx	METI library
3	init_setting.m	Initial setting script parameter data setting and path setting
4	(subfolder) params	Parameter data storage folder
5	(subfolder) pictures	Block image data storage folder

### 3. How to use

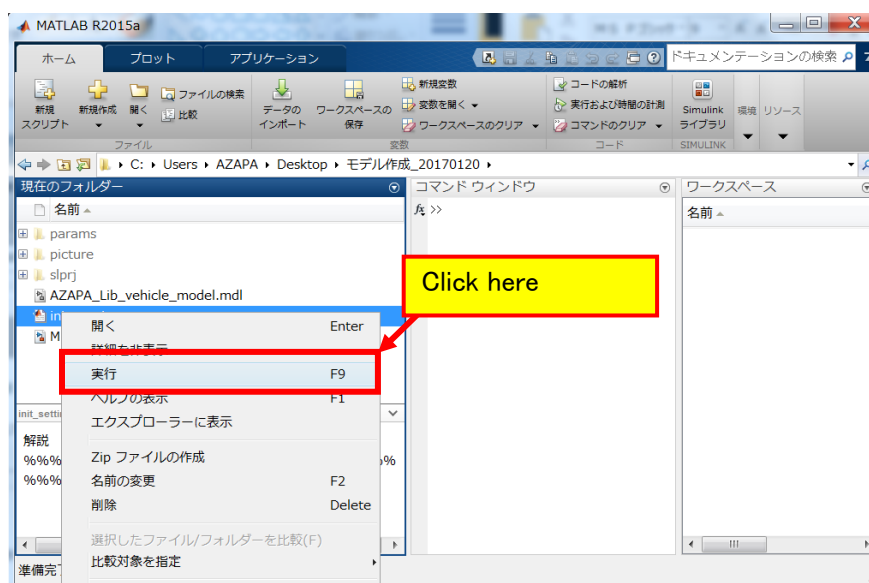
#### 3.1. Simulation execution

##### 3.1.1. Start MATLAB

Launch MATLAB 2015a.

##### 3.1.2. Initial settings

Run “init\_setting.m” to set the paths, set the parameters, and launch the simulation model.

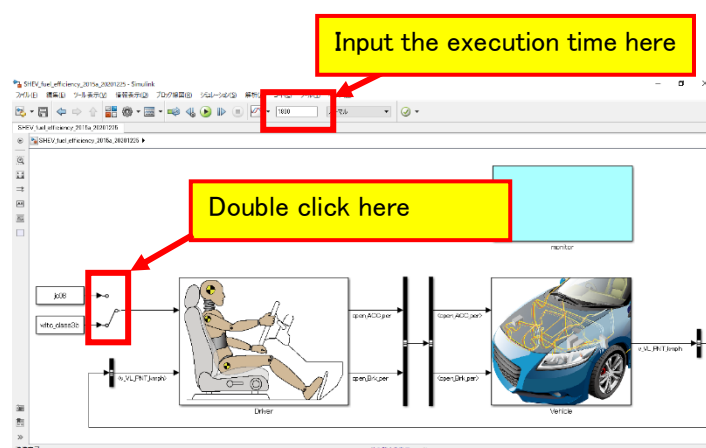


##### 3.1.3. Select the driving pattern to be used

By double-clicking the ManualSwitch block on Simulink, the driving pattern can be selected.

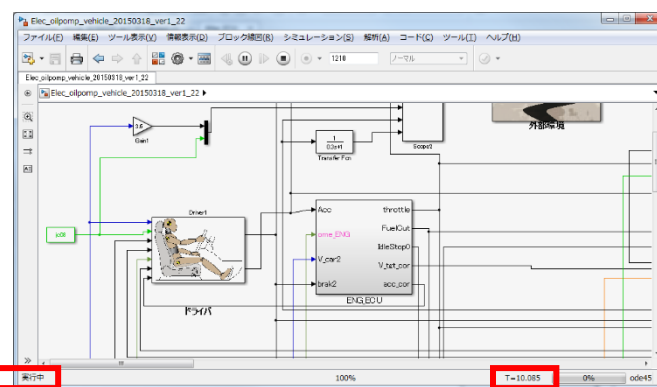
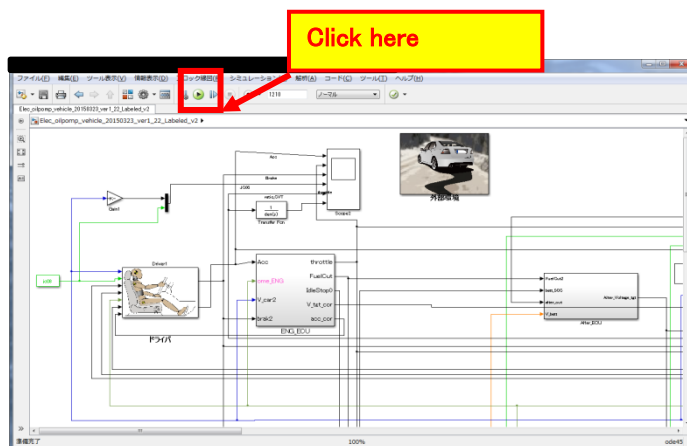
When the driving pattern is changed, the simulation execution time is changed according to the selected driving pattern.

- ① 1204-second JC08 speed pattern  
`jc08 = csvread('JC08_spline_100ms.csv')`  
simulation time=1204s
- ② 1800-second WLTC Class3b speed pattern  
`wltc_class3b= csvread('WLTC_class3b_spline_100ms.csv')`  
simulation time=1800s



### 3.1.4. Start the simulation

Press the run simulation button on Simulink to start the simulation.



"running" is displayed

executed time progress is displayed

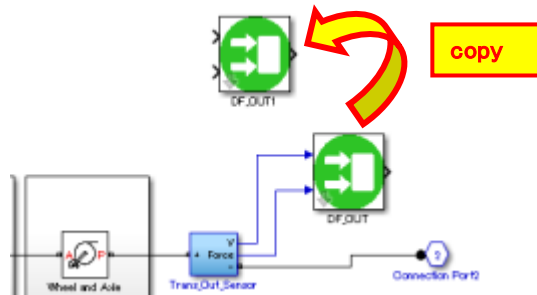
When "running" is no longer displayed, the execution will be complete.

## 3.2. Placement of new energy block

Here we describe the procedure for modifying the model and adding energy blocks. Also refer to the library for energy blocks.

### 3.2.1. Copy the energy block

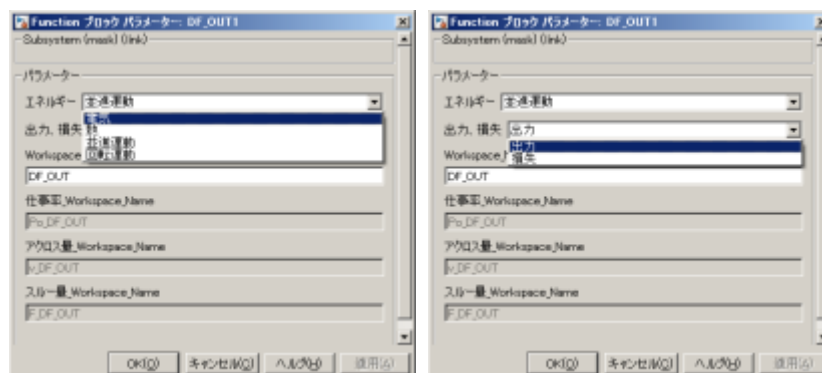
Copy an existing energy block. Any energy block can be copied.



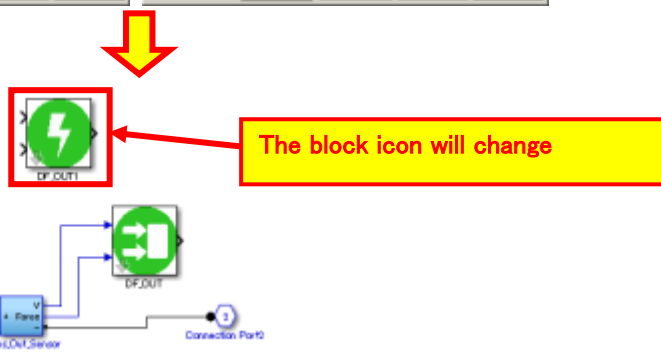
### 3.2.2. Set the corresponding physical quantity.

Select the energy type, output, and loss from the pull-down menu.

In the example, select "Output" of "Electricity".

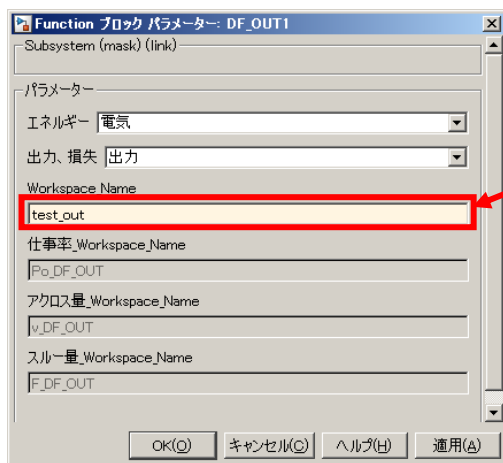


After selecting  
Click "OK" or "Apply"

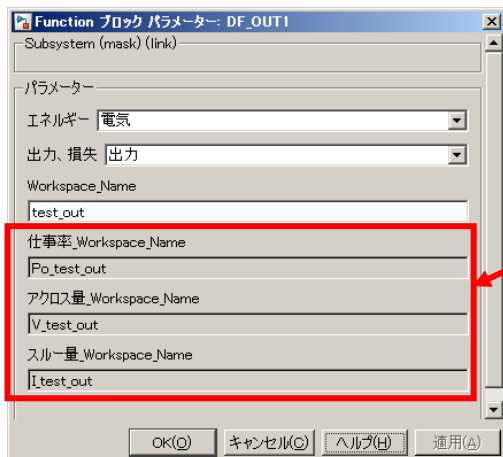


### 3.2.3. Set the energy name

If you set Workspace\_Name and click "OK" or "Apply", the variable names of power, across quantity, and through quantity will be set as default, and the measurement results will be stored in the workspace.



To set new variable click  
"OK" or "Apply"



The variable name is changed  
according to the selected energy  
quantity.

Across quantity:  $v \Rightarrow V$

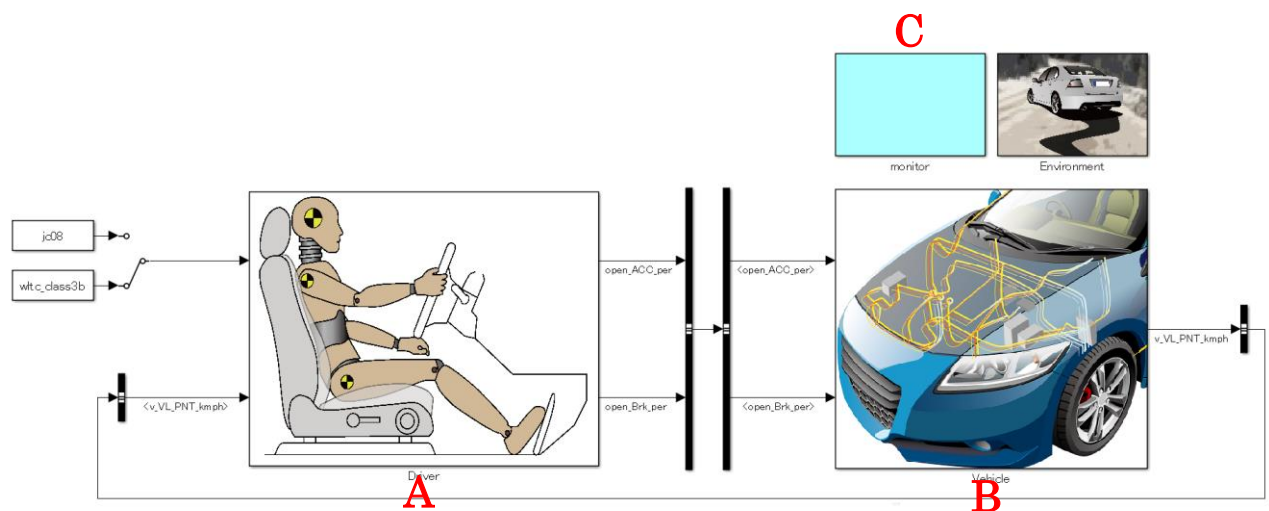
Through quantity:  $F \Rightarrow I$

## 4. Basic structure of guideline-compliant model

The structure of the first layer (top layer) and the second layer of the guideline-compliant model and the systems in each layer (Simulink subsystems classified as functional units) will be described below.

### 4.1. First layer structure

The structure of the first layer (entire model) of the guideline-compliant model is shown below.



**Fig. 4.1.1 Structure of first layer of the guideline-compliant model**

The system and function outline of the first layer of the guideline-compliant model are shown below. The labels (A, B, C) in the table refer to the subsystems in Fig. 4.1.1.

**Table 4.1 Funtional overview of the first layer (entire model) of the guideline-compliant model**

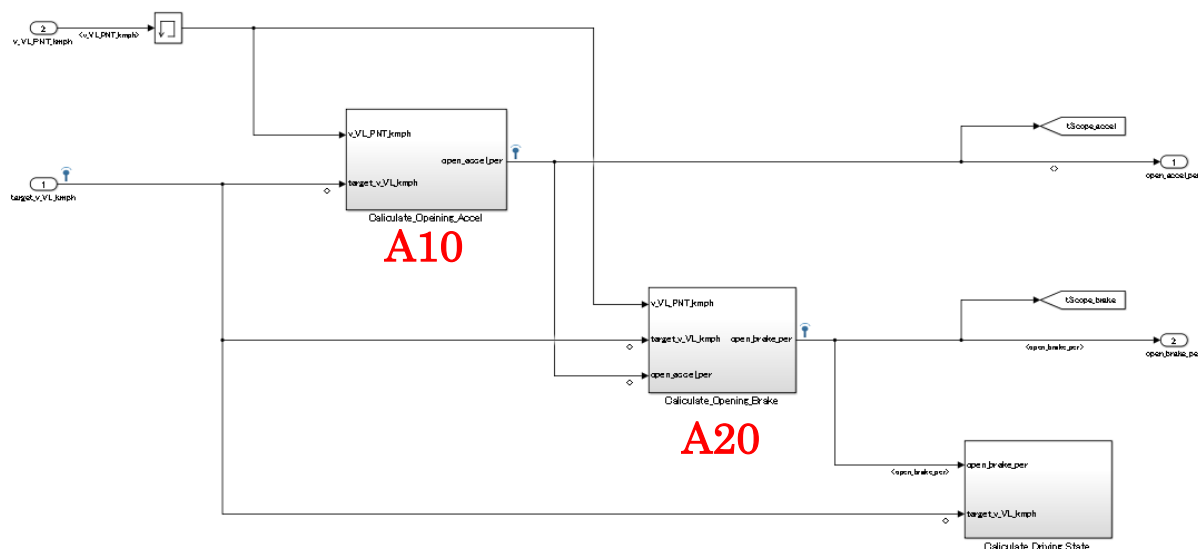
No.	System name	Functional overview
A	Driver	Reads the driving pattern (JC08 / WLTC) and operates the accelerator and brake.
B	Vehicle	Reads the accelerator and brake operations and controls the engine output and motor output to calculate the vehicle speed.
C	Monitor	Monitors various internal vehicle system variables.

## 4.2. Second layer structure

The structure of each system in the second layer of the guideline-compliant model is shown below.

### 4.2.1. [A: Driver] system structure

The structure of the Driver system in the second layer of the guideline-compliant model is shown below.



**Fig. 4.2.1 Structure of the Driver system in the second layer**

The system and the function outline of the Driver system in the second layer of the guideline-compliant model are shown below.

The labels (A10, A20) in the table refer to the system in Fig. 4.2.1.

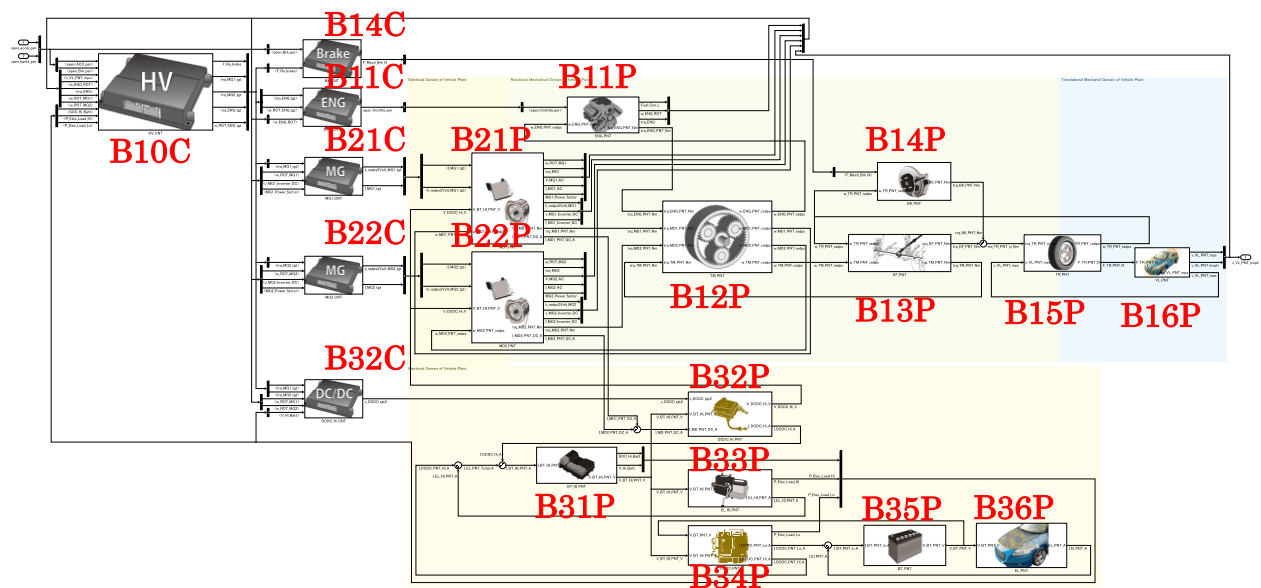
**Table 4.2 Functional overview of the Driver system in second layer of the guideline-compliant model**

No.	System name	Functional overview
A10	Accelerator aperture	<p>The accelerator aperture is calculated based on the sum of the FF control and the FB control. In FF control, the required driving force is calculated based on the target vehicle speed, and the accelerator aperture is calculated from that.</p> <p>In FB control, the accelerator aperture is calculated based on the difference between the target vehicle speed and the actual vehicle speed.</p>
A20	Brake (opening)	<p>The brake pedal stroke is derived from the difference between the target vehicle velocity and the actual vehicle velocity.</p> <p>Pedal misapplication prevention control that prevents the brake from being applied while accelerating.</p>



## 4.2.2. [B: Vehicle] system structure

The structure of the Vehicle system in the second layer of the guideline-compliant model is shown below.



**Fig. 4.2.2 Structure of the Vehicle system in the second layer**

The system and the function outline of the Vehicle system in the second layer of the guideline-compliant model are shown below. The labels in the table refer to the system in Fig. 4.2.2.

Additionally, the final letter C in the B10C label means that it is a Controller, and the final letter in the P of B11P label means that it is Plant.

**Table 4.3 Functional overview of the Vehicle system in second layer of the guideline-compliant model**

No.	System name	Fuctional overview
B10C	HV_CNT	Carries out the hybrid control.
B14C	BK_CNT	Carries out the brake control.
B11C	ENG_CNT	Carries out the engine control.
B21C	MG1_CNT	Carries out the control of the motor drive system 1 (generator).
B22C	MG2_CNT	Carries out the control of the motor drive system 2 (main traction motor).
B32C	DCDC_HI_CNT	Carries out the control of the boost DCDC converter.
B11P	ENG_PNT	Carries out the generation of engine shaft torque and calculates fuel consumption.
B21P	MD1_PNT	Carries out the conversion of electrical energy into rotational mechanical energy.
B22P	MD2_PNT	Carries out the conversion of electrical energy into rotational mechanical energy.
B12P	TM_PNT	Carries out the deceleration of the engine and motor drive system speed against torque.
B13P	DF_PNT	Carries out the deceleration from the transmission output to the driveshaft.
B14P	BK_PNT	Generates brake torque on the driveshaft.
B15P	TR_PNT	Converts the rotational motion of the driveshaft into translational motion.
B16P	VL_PNT	Calculates the running resistance and the vehicle speed.
B31P	BT_HI_PNT	Calculates the terminal voltage from the OCV voltage that is determined from the SOC and the voltage drop by the internal resistance.
B32P	DCDC_HI_PNT	Step-up the voltage from the high-voltage side to motor drive system section.
B33P	EL_HI_PNT	Calculates the high-voltage section current consumption.
B34P	DCDC_PNT	Steps down the voltage from the high-voltage side to the low-voltage section.
B35P	BT_PNT	Calculates the terminal voltage from the OCV voltage that is determined from the SOC and the voltage drop by the internal resistance.
B36P	EL_PNT	Calculates the current consumption on the low-voltage section.

## 4.2.3. [C: Monitor] system structure

The structure of the Monitor system in the second layer of the guideline-compliant model is shown below.

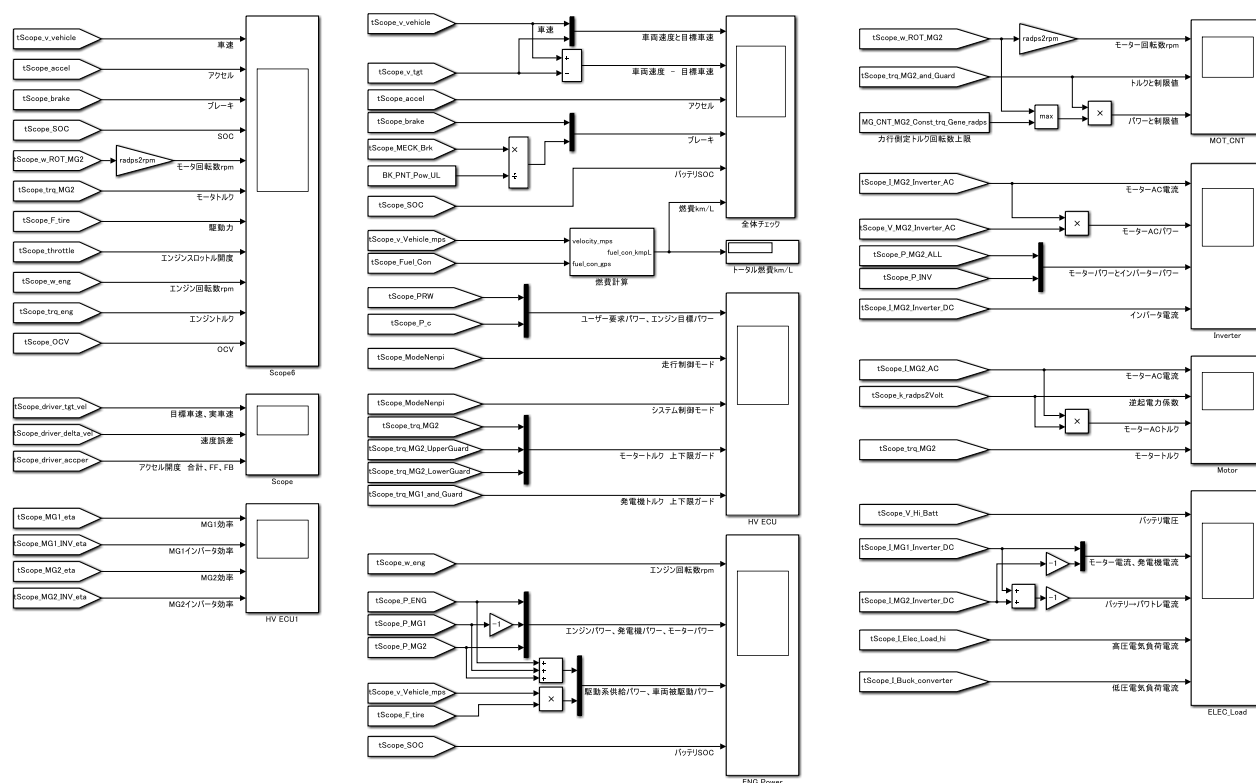


Fig. 4.2.3 Structure of the Monitor system in the second layer

This system monitors the signals calculated by the Driver and Vehicle systems. This system does not possess any further deeper layers.

## 5. Functional specifications of the guideline-compliant model

### 5.1. Functional specifications of the first layer

Description of the functional specifications of the first layer (entire model) of the guideline-compliant model.

#### 5.1.1. Overview

The driver model calculates the amount of operation of the accelerator and brake according to the driving pattern (JC08 / WLTC), and the vehicle model calculates the behavior including acceleration and deceleration in response to the operation.

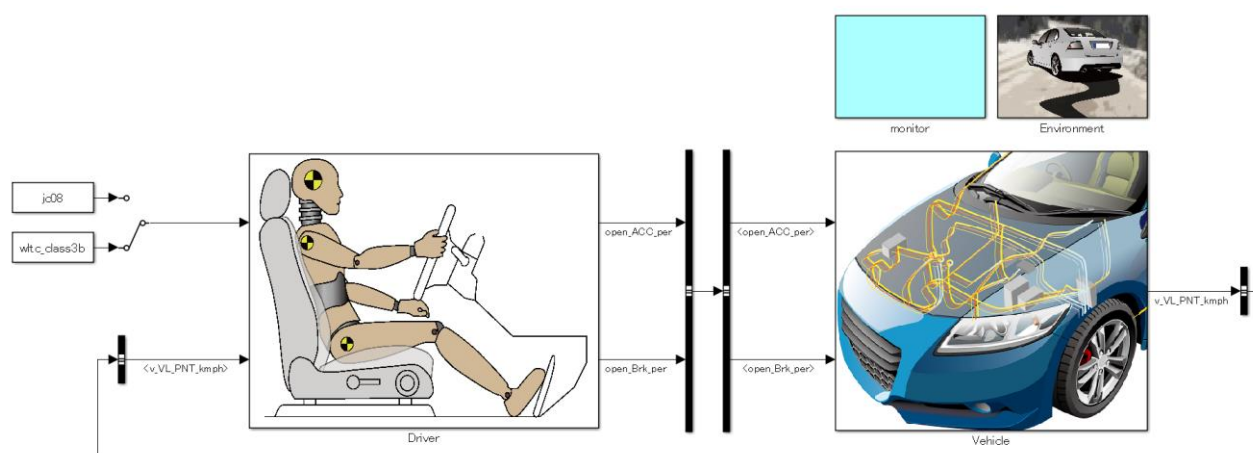
Information such as vehicle speed is passed to the driver model and this information is used to calculate the amount of accelerator and brake operation.

In the external environment block, the driving environment of the vehicle is set.

In the Monitor block, various internal variables from the driver model and the vehicle model can be observed.

#### 5.1.2. Data flow diagram

The data flow diagram of the guideline-compliant model is shown below.



**Fig. 5.1.1 Data flow diagram: First layer (entire guideline-compliant model)**

### 5.1.3. Input / output specifications

The input / output specifications of the entire guideline-compliant model are shown below.

Inputs			
Name	Unit	Scope	Explanation
jc08	km/h	TBD	Target vehicle speed
wltc_class3b	km/h	TBD	Target vehicle speed
v_VL_PNT_kmph	km/h	TBD	Vehicle speed
Outputs			
Name	Unit	Scope	Explanation
v_VL_PNT_kmph	km/h	TBD	Vehicle speed

### 5.1.4. Parameter specifications

The parameter specifications of the entire guideline-compliant model are shown below.

Variable name	Set value	Unit	Explanation
ACC_P_Gain	20	-	Feedback control P gain value
ACC_I_Gain	0	-	Feedback control I gain value
ACC_D_Gain	0	-	Feedback control D gain value
Brk_PGain	-3000	-	Braking force P gain value
Brk_UL	5000	N	Braking force upper limit
Brk_LL	0	N	Braking force lower limit
VEHICLE_CNT_ACCper_UL	100	%	Accelerator aperture upper limit
VEHICLE_CNT_ACCper_LL	0	%	Accelerator aperture lower limit
Driver_Brake_Const1	-0.1	-	Brake depression amount when vehicle is stopped (when target vehicle speed is 0km / h)
Driver_Brake_Const3	0	-	Brake depression amount when vehicle is accelerating (when target vehicle speed is a positive value)
Driver_Brake_Switch_Const2	0.1	km/h	Driver brake model stop decision
Driver_Brk_sh	0.01	km/h/sec	Driver brake model acceleration decision
Driver_Brk_offset	0.5	km/h	Speed error offset when not braking
Thresh_Stop_vCar	0.1	km/h	Vehicle speed stop condition
drivemode_STOP	1	-	Driver state 1: Stop
drivemode_ACC	2	-	Driver state 2: Acceleration
drivemode_Deceleration_Acc	3	-	Driver state 3: Deceleration (powered)
drivemode_Deceleration_Brk	4	-	Driver status 4: Deceleration (regenerative)
drivemode_CONST	5	-	Driver state 5: Steady running
HV_CNT_trq_require_accper	<1x12>	%	Required driving force estimation map Accelerator opening
HV_CNT_trq_require_v_kmph	<13x1>	km/h	Required driving force estimation map Vehicle speed
HV_CNT_trq_require_Nm	<13x12>	Nm	Required driving force estimation map
HV_CNT_trq_req_Gain_OFF	0	-	Required drive torque gain when determining stopped state
HV_CNT_trq_req_Gain_ON	1	-	Required drive torque gain when determining running state
HV_CNT_trq_req_v_vehicle_th	1	km/h	Stop decision vehicle speed threshold
HV_CNT_trq_req_brak_th	0.01	N	Stop decision brake threshold
HV_CNT_trq_req_delaytime	0.2	sec	Gain first-order lag time constant
HV_CNT_Batt_discharge_limit	22000	W	Discharging power limit
HV_CNT_Batt_charge_limit	-30000	W	Charging power limit

Variable name	Set value	Unit	Explanation
HV_CNT_Batt_charge_vel	<7x1>	km/h	Required power map of battery discharge input1 vehicle speed
HV_CNT_Batt_charge_SOC	<1x16>	%	Required power map of battery discharge input2 battery SOC
HV_CNT_Batt_charge_req	<7x16>	W	Required power map of battery discharge
HV_CNT_P_Force_discharge_W	6000	W	Forced discharge power setting when battery SOC is high
HV_CNT_Force_dis_ON_th	65	%	SOC threshold to turn on forced discharge power setting when battery SOC is high
HV_CNT_Force_dis_OFF_th	52	%	SOC threshold to turn off forced discharge power setting when battery SOC is high
HV_CNT_P_Force_charge_W	-6750	W	Forced charge power setting when battery SOC is low
HV_CNT_Force_chr_ON_th	35	%	SOC threshold to turn on forced charge power setting when battery SOC is low
HV_CNT_Force_chr_OFF_th	42	%	SOC threshold to turn off forced charge power setting when battery SOC is low
HV_CNT_P_Gain_trq_MG1_tgt	3	-	P Gain of MG1 torque control in engine starting and stopping
HV_CNT_Power_ref_ENG_ON_vel	<2x1>	km/h	Power threshold map to start engine input1 vehicle speed
HV_CNT_Power_ref_ENG_ON_SOC	<1x4>	%	Power threshold map to start engine input2 SOC
HV_CNT_Power_ref_ENG_ON_Power	<2x4>	W	Power threshold map to start engine
HV_CNT_Power_ref_ENG_OFF_vel	<4x1>	km/h	Power threshold map to stop engine input1 vehicle speed
HV_CNT_Power_ref_ENG_OFF_SOC	<1x6>	%	Power threshold map to stop engine input2 SOC
HV_CNT_Power_ref_ENG_OFF_Power	<4x6>	W	Power threshold map to stop engine
HV_CNT_Power_ref_ENG_under_vel	<4x1>	km/h	Lower limit of engine power target input1 vehicle speed
HV_CNT_Power_ref_ENG_under_SOC	<1x5>	%	Lower limit of engine power target input2 SOC
HV_CNT_Power_ref_ENG_under_Power	<4x5>	W	Lower limit of engine power target
HV_CNT_Power_ref_Motor_Limit_vel	<1x6>	km/h	Upper limit of required power map for EV driving input vehicle speed
HV_CNT_Power_ref_Motor_Limit_power	<1x6>	W	Upper limit of required power map for EV driving
HV_CNT_Power_trq_ENG_Curve_Power_req	<1x10>	W	Target engine power
HV_CNT_Power_trq_ENG_Curve_w_ROT_ENG_tgt	<1x10>	rpm	Target engine speed
HV_CNT_Power_trq_ENG_Curve_trq_ENG_tgt	<1x10>	Nm	Target engine trq
HV_CNT_w_ROT_ENG_low_threshold_ON_rpm	1000	rpm	Engine speed threshold to turn on target engine torque at low engine speed
HV_CNT_w_ROT_ENG_low_threshold_OFF_rpm	400	rpm	Engine speed threshold to turn off target engine torque at low engine speed
HV_CNT_Power_ENG_upper_rate_Power	<1x6>	W	Upper limit of engine required power fluctuation rate map Input engine required power
HV_CNT_Power_ENG_upper_rate_Guard	<1x6>	W	Upper limit of engine required power fluctuation rate map
HV_CNT_Power_ENG_lower_rate_Power	<1x6>	W	Lower limit of engine required power fluctuation rate map Input engine required power
HV_CNT_Power_ENG_lower_rate_Guard	<1x6>	W	Lower limit of engine required power fluctuation rate map
HV_CNT_F_threshold_brake_override_N	10	N	Judgment threshold of brake override
HV_CNT_v_vehicle_threshold_anti_0div_kmph	5	km/h	Vehicle speed of 0 division prevention
HV_CNT_w_ROT_MOT_threshold_anti_0div	50	rad/s	Motor rotation speed of 0 division prevention
HV_CNT_ReGeneBrk_Cut_Gain	<1x4>	-	Regenerative braking force limitation map at low vehicle speed
HV_CNT_ReGeneBrk_Cut_v_kmph	<1x4>	km/h	Vehicle speed input of regenerative braking force limitation map at low vehicle speed
HV_CNT_Power_ENG_req_mode2_W	<1x5>	W	Engine required power map output
HV_CNT_Power_ENG_req_mode2_in_W	<1x5>	W	Engine required power map input

Variable name	Set value	Unit	Explanation
ENG_CNT_Throttle_MAX	100	%	Maximum throttle aperture
ENG_CNT_Throttle_MIN	0	%	Minimum throttle aperture
MG_CNT_Gain_Pmax	2.0	-	Short-time overload tolerance during engine start / stop
MG_CNT_Pmax_MG1_Gene_W	50000[*1]	W	Powering side rated output
MG_CNT_MG1_max_trq_Gene_Nm	40	Nm	Maximum torque on the powering running side
MG_CNT_Pmin_MG1_ReGene_W	-50000[*2]	W	Rated output on the regenerative side
MG_CNT_MG1_max_trq_ReGene_Nm	-40	Nm	Maximum torque on the regenerative side
MG_CNT_MG1_Const_trq_ReGene_radps	1150[*3]	rad/s	Rated rotation speed on the regenerative side
MG_CNT_Pmax_MG2_Gene_W	55000	W	Powering side rated output
MG_CNT_MG2_max_trq_Gene_Nm	170	Nm	Maximum torque on the powering side
MG_CNT_MG2_Const_trq_Gene_radps	325.153[*6]	rad/s	Powering side rated speed
MG_CNT_Pmin_MG2_ReGene_W	-55000	W	Rated output on the regenertative side
MG_CNT_MG2_max_trq_ReGene_Nm	-170	Nm	Maximum torque on the regenerative side
DCDC_Hi_CNT_DCDC_upper_Guard	600	V	Max voltage of boost DCDC converter
DCDC_Hi_CNT_Vtgt_discre1st	275	V	Voltage discretization 1st stage voltage
DCDC_Hi_CNT_Vtgt_discre2nd	350	V	Voltage discretization 2nd stage voltage
DCDC_Hi_CNT_Vtgt_discre3rd	450	V	Voltage discretization 3rd stage voltage
DCDC_Hi_CNT_Vtgt_discre4th	600	V	Voltage discretization 4th stage voltage
DCDC_Hi_CNT_Vtgt_discre_th_1st	230	V	Voltage threshold of voltage discretization 1st stage
DCDC_Hi_CNT_Vtgt_discre_th_2nd	280	V	Voltage threshold of voltage discretization 2nd stage
DCDC_Hi_CNT_Vtgt_discre_th_3rd	355	V	Voltage threshold of voltage discretization 3rd stage
DCDC_Hi_CNT_Vtgt_discre_th_4th	455	V	Voltage threshold of voltage discretization 4th stage
DCDC_Hi_CNT_Vtgt_conv_hi_trq_Nm	<17x1>	Nm	Target voltage map of boost DCDC converter input1 target motor torque
DCDC_Hi_CNT_Vtgt_conv_hi_w_rpm	<1x18>	rpm	Target voltage map of boost DCDC converter input2 target motor speed
DCDC_Hi_CNT_Vtgt_conv_hi_V	<17x18>	V	Target voltage map of boost DCDC converter
ENG_PNT_FuelCon_gps_map_x_pri_rpm	<1x14>	rpm	Fuel consumption rate map x-axis: engine speed
ENG_PNT_FuelCon_gps_map_y_trq_Nm	<1x14>	Nm	Fuel consumption rate map y-axis: engine shaft torque
ENG_PNT_FuelCon_gps_map	<14x14>	g/sec	Fuel consumption rate map
ENG_PNT_trq_Nm_map_x_rpm	<1x11>	rpm	Engine shaft torque map x-axis: engine speed
ENG_PNT_trq_Nm_map_y_throttle	<1x2>	%	Engine shaft torque map y-axis: accelerator throttle opening
ENG_PNT_trq_Nm_map	<11x2>	Nm	Engine shaft torque map z-axis: torque
TM_PNT_Flywheel_Inertia	0.24	kgm <sup>2</sup>	Flywheel inertia
TM_PNT_TM_Inertia	0.3	kgm <sup>2</sup>	Transmission inertia
TM_PNT_number_sungear	30	-	Sun gear number of teeth
TM_PNT_number_ringgear	78	-	Ring gear number of teeth
TM_PNT_number_outergear	65	-	Outer gear number of teeth
TM_PNT_number_MG2gear	17	-	MG2 gear number of teeth
TM_PNT_number_counterdrivengear	53	-	Counter gear number of teeth
TM_PNT_eta_outergear2countergear	0.97	-	Transmission efficiency between outer gear and counter gear
TM_PNT_eta_MG2gear2countergear	0.97	-	Transmission efficiency between MG2 gear and counter gear
TM_PNT_eta_planetarygear	0.95	-	Transmission efficiency of planetary gear
DF_PNT_DF_gear	2.8	-	Differential gear reduction ratio
DF_PNT_eta_DF	0.96	-	Differential gear efficiency

Variable name	Set value	Unit	Explanation
DF_PNT_Driveshaft_Inertia	0.1	kgm <sup>2</sup>	Driveshaft inertia
DF_PNT_Driveshaft_spring	10000	-	Driveshaft spring constant
DF_PNT_Driveshaft_zeta	10	-	Second-order lag damping coefficient
DF_PNT_Driveshaft_damper	632.456[*5]	-	Driveshaft damping coefficient
BK_PNT_Tau_brake	0.15	-	Brake plant model braking force time constant
BK_PNT_Pow_UL	5000	N	Braking force upper limit
BK_PNT_Pow_LL	0	N	Braking force lower limit
VL_PNT_V_wind	0	m/s	Wind speed
VL_PNT_Vehicle_theta_degree	0	deg	Climbing angle
MG_PNT_MG1_Inv_eta	<13x13>	-	Inverter efficiency
MG_PNT_MG1_Inv_eta_x_rpm	<1x13>	rpm	Efficiency map x-axis: rotation speed
MG_PNT_MG1_Inv_eta_y_trq	<1x13>	Nm	Efficiency map y-axis: torque
MG_PNT_MG1_mod_factor	0.78	-	Inverter modulation factor
MG_PNT_MG1_WeakField_UL	1.0	-	Weak field permeability upper limit
MG_PNT_MG1_WeakField_LL	0.05	-	Weak field permeability lower limit
MG_PNT_MG1_eta	<13x13>	-	Motor efficiency
MG_PNT_MG1_eta_x_rpm	<1x13>	rpm	Efficiency map x-axis: rotation speed
MG_PNT_MG1_eta_y_trq	<1x13>	Nm	Efficiency map y-axis: torque
MG_PNT_MG1_Power_factor	0.85	-	Motor power factor
MG_PNT_V_MG1_Rated	600	V	Motor inverter DC side rated voltage
MG_PNT_w_ROT_MG1_Rated	1150[*6]	rad/s	Motor rated rotation speed
MG_PNT_MG2_Inv_eta	<13x13>	-	Inverter efficiency
MG_PNT_MG2_Inv_eta_x_rpm	<1x13>	rpm	Efficiency map x-axis: rotation speed
MG_PNT_MG2_Inv_eta_y_trq	<1x13>	Nm	Efficiency map y-axis: torque
MG_PNT_MG2_mod_factor	0.78	-	Inverter modulation factor
MG_PNT_MG2_WeakField_UL	1.0	-	Weak field permeability upper limit
MG_PNT_MG2_WeakField_LL	0.05	-	Weak field permeability lower limit
MG_PNT_MG2_eta	<13x13>	-	Motor efficiency
MG_PNT_MG2_eta_x_rpm	<1x13>	rpm	Efficiency map x-axis: rotation speed
MG_PNT_MG2_eta_y_trq	<1x13>	Nm	Efficiency map y-axis: torque
MG_PNT_MG2_Power_factor	0.85	-	Motor efficiency
MG_PNT_V_MG2_Rated	600	V	Motor inverter DC side rated voltage
MG_PNT_w_ROT_MG2_Rated	325.153[*7]	rad/s	Motor inverter DC side rated rotation speed
BT_PNT_Hi_Capa_hi_batt	3.6	Ah	High-voltage battery capacity
BT_PNT_Hi_SOC_START_hi_batt	60	%	High-voltage battery SOC_initial value
BT_PNT_Hi_SOC_MAX_hi_batt	100	%	High-voltage battery SOC_maximum
BT_PNT_Hi_SOC_MIN_hi_batt	0	%	High-voltage battery SOC_minimum value
BT_PNT_Hi_ocv_SOC_hi_batt_OCV_V_table_x_SOC	<1x10>	%	High-voltage battery OCV calculation MAP x-axis: SOC term
BT_PNT_Hi_ocv_SOC_hi_batt_OCV_V_table	<1x10>	V	High-voltage battery OCV calculation MAP y-axis: OCV term
BT_PNT_Hi_R_hi_batt_cell	0.005	Ω	High-voltage battery internal cell resistance
BT_PNT_Hi_R_hi_batt_others	0	Ω	Other internal high-voltage battery resistances
BT_PNT_Lo_Capa_lo_batt	45	Ah	Low-voltage battery capacity
BT_PNT_Lo_SOC_START_lo_batt	95	%	Low-voltage battery initial SOC value
BT_PNT_Lo_SOC_MAX_lo_batt	120	%	Low-voltage battery SOC_maximum value
BT_PNT_Lo_SOC_MIN_lo_batt	0	%	Low-voltage battery SOC_minimum value
BT_PNT_Lo_ocv_SOC_lo_batt_OCV_V_table_x_SOC	[0,100]	%	Battery OCV calculation table x-axis: SOC term
BT_PNT_Lo_ocv_SOC_lo_batt_OCV_V_table	[10.5,14]	V	Battery OCV calculation table
BT_PNT_Lo_R_lo_batt_ohm	0.01	Ω	Battery internal resistance
DCDC_Hi_PNT_eta_conv_hi_I	0.97	-	Boost converter efficiency
DCDC_PNT_eta_conv_lo	0.95	-	Buck converter efficiency



Variable name	Set value	Unit	Explanation
DCDC_PNT_R_conv_lo	0.02	$\Omega$	Buck converter resistance [*8]
DCDC_PNT_Vtgt_conv_lo	14.0	V	Target buck converter voltage value
EL_PNT_R_bodyelec_hi	4000	$\Omega$	High-voltage section electrical load resistance
EL_PNT_R_bodyelec_lo	1.037	$\Omega$	Low-voltage section electrical load resistance
sampling_time	0.0025	s	Sampling period
num_tws_mabiki	10	-	Effect to Workspace decimation amount
jc08	<12041x2>	km/h	Target vehicle speed information: 1204 seconds jc08 speed pattern
wltc_class3b	<18001x2>	km/h	Target vehicle speed information: 1800 seconds wltc_class3b speed pattern
rou	1.166	kg/m <sup>3</sup>	Air density (20°C, 1013hPa)
Fuel_density	733	g/L	Regular gasoline density [*9]
percent2mujigen	0.01	-	Percent to dimensionless
mujigen2percent	100	-	Dimensionless to percent
radpsec2rpm	$60/(2*\pi)$	-	rad/sec to rpm
radps2rpm	$60/(2*\pi)$	-	rad/sec to rpm
rpm2radps	$2*\pi/60$	-	rpm to rad/s
kmph2mps	1000/3600	-	km/h to m/sec
mps2kmph	3.6	-	m/sec to km/h
h2sec	3600	-	Hour to sec
sec2h	1/3600	-	sec to Hour
mps2kmph	1/1000	-	m/s to km/s
deg2rad	$\pi/180$	-	degree to rad
rad2deg	$180/\pi$	-	rad to degree
g2L	1/Fuel_density	-	g to L gasoline
g	9.8	m/s <sup>2</sup>	Acceleration due to gravity
M_body	1400	kg	Vehicle mass
M_driver	110	kg	Vehicle passenger mass (55kg×2persons)
M	M_body+M_driver	kg	Vehicle total mass (vehicle mass+passenger mass)
tire_r	0.32	m	Tire radius
vel_max	200	km/h	Maximum vehicle speed (for divergence prevention)
myu	0.0072	-	Rolling resistance coefficient from ISO
Cd	0.24	-	Air resistance coefficient
A	2.2	m <sup>2</sup>	Front projected area

※Uncolored parameters are common to all systems

[\*1] 25000 \* MG\_CNT\_Gain\_Pmax

[\*2] -25000 \* MG\_CNT\_Gain\_Pmax

[\*3] MG\_CNT\_Pmin\_MG1\_ReGene\_W / MG\_CNT\_MG1\_max\_trq\_ReGene\_Nm

[\*4] MG\_CNT\_Pmax\_MG2\_Gene\_W / MG\_CNT\_MG2\_max\_trq\_Gene\_Nm

[\*5] 2 \* DF\_PNT\_Driveshaft\_zeta\*sqrt(DF\_PNT\_Driveshaft\_spring \* DF\_PNT\_Driveshaft\_Inertia)

[\*6] MG\_CNT\_MG1\_Const\_trq\_ReGene\_radps

[\*7] MG\_CNT\_MG2\_Const\_trq\_Gene\_radps

[\*8] If it is smaller than the lead battery's internal resistance, the low voltage system will oscillate.

[\*9] [http://www.jari.or.jp/portals/0/jhfc/data/report/2005/pdf/result\\_ref\\_1.pdf](http://www.jari.or.jp/portals/0/jhfc/data/report/2005/pdf/result_ref_1.pdf)

### 5.1.5. Other information

None

## 5.2. Functional specifications of the second layer

### 5.2.1. [A: Driver] system functional specifications

Description of the functional specifications of the second layer Driver system of the guideline-compliant model.

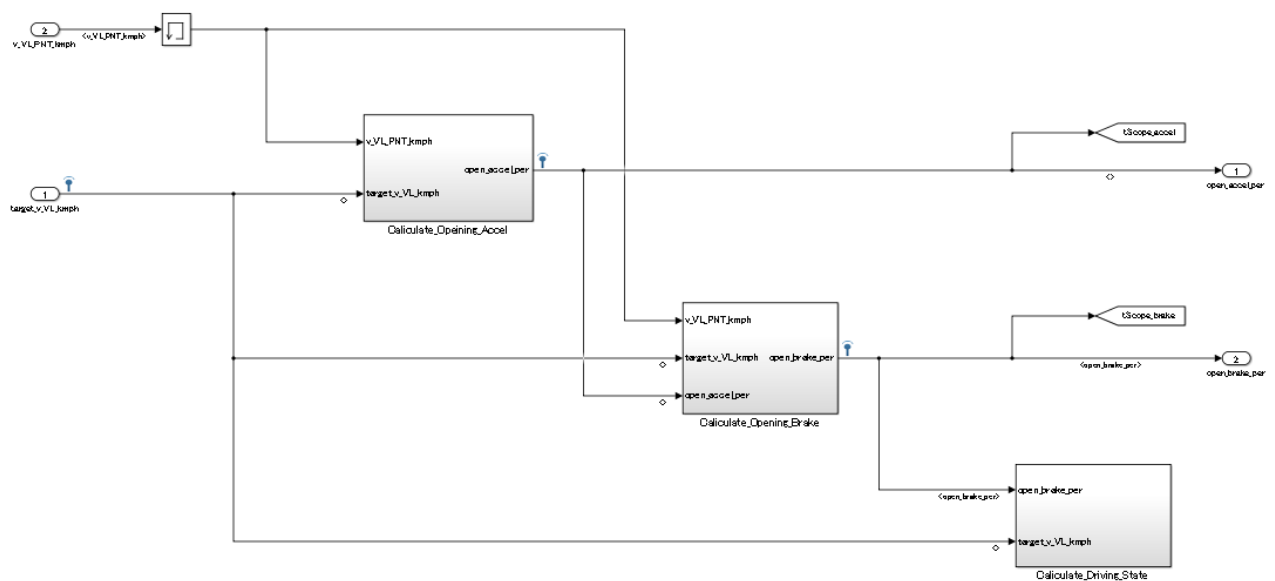
### 5.2.1.1 Overview

The outline of this system is shown below.

- ① Modeling target  
Driver model for fuel efficiency performance evaluation
- ② Scope of modeling / degree of abstraction  
Model of the operation of the accelerator and brake required for the (JC08 / WLTC) driving patterns
- ③ Modeled functions  
Accelerator and brake operation amount calculation functions

#### 5.2.1.2 Data flow diagram

The data flow diagram of this system is shown below.



**Fig. 5.2.1 Data flow diagram: 2nd layer Driver system**

## 5.2.1.3 Input/Output specifications

The input / output specifications of this system are shown below.

Inputs			
Name	Unit	Scope	Explanation
target_v_VL_kmph	km/h	TBD	Target vehicle speed (JC08/WLTC )
v_VL_PNT_kmph	km/h	TBD	Vehicle speed
Outputs			
Name	Unit	Scope	Explanation
open_accel_per	%	[0 100]	Accelerator aperture
open_brake_per	%	[0 100]	Brake aperture

## 5.2.1.4 Parameter specifications

The parameter specifications of this system are shown below.

Variable name	Set value	Unit	Explanation
ACC_P_Gain	20	-	Feedback control P gain value
ACC_I_Gain	0	-	Feedback control I gain value
ACC_D_Gain	0	-	Feedback control D gain value
Brk_PGain	-3000	-	Braking force P gain value
Brk_UL	5000	N	Braking force upper limit
Brk_LL	0	N	Braking force lower limit
VEHICLE_CNT_ACCper_UL	100	%	Accelerator aperture upper limit
VEHICLE_CNT_ACCper_LL	0	%	Accelerator aperture lower limit
Driver_Brake_Const1	-0.1	-	Brake depression amount when stopped (target vehicle speed 0km / h)
Driver_Brake_Const3	0	-	Brake depression amount when accelerating (target vehicle speed is positive)
Driver_Brake_Switch_Const2	0.1	km/h	Driver brake model stop decision
Driver_Brk_sh	0.01	km/h/sec	Acceleration decision
Driver_Brk_offset	0.5	km/h	Speed error offset when not braking
Thresh_Stop_vCar	0.1	km/h	Vehicle speed stop condition
drivemode_STOP	1	-	Driver condition 1: Stop
drivemode_ACC	2	-	Driver condition 2: Acceleration
drivemode_Deceleration_Acc	3	-	Driver condition 3: Deceleration (powered)
drivemode_Deceleration_Brk	4	-	Driver condition 4: Deceleration (regenerative)
drivemode_CONST	5	-	Driver condition 5: Steady running

## 5.2.1.5 Other information

None

### 5.2.2. [B: Vehicle] system functional specifications

Description of the functional specifications of the second layer Vehicle system of the guideline-compliant model.

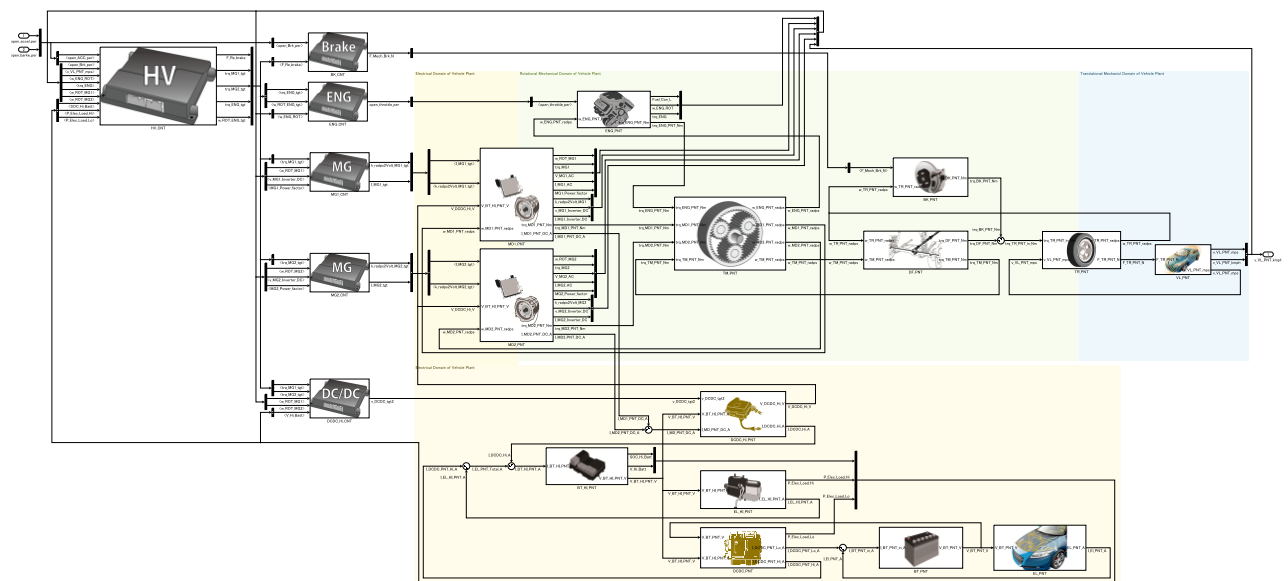
#### 5.2.2.1 Overview

The outline of this system is shown below.

- ① Modeling target  
Series parallel hybrid vehicle model for fuel efficiency performance evaluation
- ② Scope of modeling / degree of abstraction  
A model that calculates fuel consumption during mode driving after warming up the engine
- ③ Modeled functions  
A function that accelerates and decelerates by operating the driver's accelerator and brake to follow the driving pattern.  
A function that calculates the fuel consumption during mode driving.

#### 5.2.2.2 Data flow diagram

The data flow diagram of this system is shown below.



**Fig. 5.2.2 Data flow diagram: 2nd layer Vehicle system**

## 5.2.2.3 Input/Output specifications

The input / output specifications of this system are shown below.

Inputs			
Name	Unit	Scope	Explanation
open_accel_per	%	[0 100]	Accelerator throttle aperture
open_brake_per	%	[0 100]	Brake aperture
Outputs			
Name	Unit	Scope	Explanation
v_VL_PNT_kmph	km/h	TBD	Vehicle speed

## 5.2.2.4 Parameter specifications

The parameter specifications of this system are shown below.

Variable name	Set value	Unit	Explanation
HV_CNT_trq_require_accper	<1x12>	%	Required driving force estimation map Accelerator opening
HV_CNT_trq_require_v_kmph	<13x1>	km/h	Required driving force estimation map Vehicle speed
HV_CNT_trq_require_Nm	<13x12>	Nm	Required driving force estimation map
HV_CNT_trq_req_Gain_OFF	0	-	Required drive torque gain when determining stopped state
HV_CNT_trq_req_Gain_ON	1	-	Required drive torque gain when determining running state
HV_CNT_trq_req_v_vehicle_th	1	km/h	Stop decision vehicle speed threshold
HV_CNT_trq_req_brak_th	0.01	N	Stop decision brake threshold
HV_CNT_trq_req_delaytime	0.2	sec	Gain first-order lag time constant
HV_CNT_Batt_discharge_limit	22000	W	Discharging power limit
HV_CNT_Batt_charge_limit	-30000	W	Charging power limit
HV_CNT_Batt_charge_vel	<7x1>	km/h	Required power map of battery discharge input1 vehicle speed
HV_CNT_Batt_charge_SOC	<1x16>	%	Required power map of battery discharge input2 battery SOC
HV_CNT_Batt_charge_req	<7x16>	W	Required power map of battery discharge
HV_CNT_P_Force_discharge_W	6000	W	Forced discharge power setting when battery SOC is high
HV_CNT_Force_dis_ON_th	65	%	SOC threshold to turn on forced discharge power setting when battery SOC is high
HV_CNT_Force_dis_OFF_th	52	%	SOC threshold to turn off forced discharge power setting when battery SOC is high
HV_CNT_P_Force_charge_W	-6750	W	Forced charge power setting when battery SOC is low
HV_CNT_Force_chr_ON_th	35	%	SOC threshold to turn on forced charge power setting when battery SOC is low
HV_CNT_Force_chr_OFF_th	42	%	SOC threshold to turn off forced charge power setting when battery SOC is low
HV_CNT_P_Gain_trq_MG1_tgt	3	-	P Gain of MG1 torque control in engine starting and stopping
HV_CNT_Power_ref_ENG_ON_vel	<2x1>	km/h	Power threshold map to start engine input1 vehicle speed
HV_CNT_Power_ref_ENG_ON_SOC	<1x4>	%	Power threshold map to start engine

Variable name	Set value	Unit	Explanation
			input2 SOC
HV_CNT_Power_ref_ENG_ON_Power	<2x4>	W	Power threshold map to start engine
HV_CNT_Power_ref_ENG_OFF_vel	<4x1>	km/h	Power threshold map to stop engine input1 vehicle speed
HV_CNT_Power_ref_ENG_OFF_SOC	<1x6>	%	Power threshold map to stop engine input2 SOC
HV_CNT_Power_ref_ENG_OFF_Power	<4x6>	W	Power threshold map to stop engine
HV_CNT_Power_ref_ENG_under_vel	<4x1>	km/h	Lower limit of engine power target input1 vehicle speed
HV_CNT_Power_ref_ENG_under_SOC	<1x5>	%	Lower limit of engine power target input2 SOC
HV_CNT_Power_ref_ENG_under_Power	<4x5>	W	Lower limit of engine power target
HV_CNT_Power_ref_Motor_Limit_vel	<1x6>	km/h	Upper limit of required power map for EV driving input vehicle speed
HV_CNT_Power_ref_Motor_Limit_power	<1x6>	W	Upper limit of required power map for EV driving
HV_CNT_Power_trq_ENG_Curve_Power_req	<1x10>	W	Target engine power
HV_CNT_Power_trq_ENG_Curve_w_ROT_ENG_tgt	<1x10>	rpm	Target engine speed
HV_CNT_Power_trq_ENG_Curve_trq_ENG_tgt	<1x10>	Nm	Target engine trq
HV_CNT_w_ROT_ENG_low_threshold_ON_rpm	1000	rpm	Engine speed threshold to turn on target engine torque at low engine speed
HV_CNT_w_ROT_ENG_low_threshold_OFF_rpm	400	rpm	Engine speed threshold to turn off target engine torque at low engine speed
HV_CNT_Power_ENG_upper_rate_Power	<1x6>	W	Upper limit of engine required power fluctuation rate map Input engine required power
HV_CNT_Power_ENG_upper_rate_Guard	<1x6>	W	Upper limit of engine required power fluctuation rate map
HV_CNT_Power_ENG_lower_rate_Power	<1x6>	W	Lower limit of engine required power fluctuation rate map Input engine required power
HV_CNT_Power_ENG_lower_rate_Guard	<1x6>	W	Lower limit of engine required power fluctuation rate map
HV_CNT_F_threshold_brake_override_N	10	N	Judgment threshold of brake override
HV_CNT_v_vehicle_threshold_anti_0div_kmph	5	km/h	Vehicle speed of 0 division prevention
HV_CNT_w_ROT_MOT_threshold_anti_0div	50	rad/s	Motor rotation speed of 0 division prevention
HV_CNT_ReGeneBrk_Cut_Gain	<1x4>	-	Regenerative braking force limitation map at low vehicle speed
HV_CNT_ReGeneBrk_Cut_v_kmph	<1x4>	km/h	Vehicle speed input of regenerative braking force limitation map at low vehicle speed
HV_CNT_Power_ENG_req_mode2_W	<1x5>	W	Engine required power map output
HV_CNT_Power_ENG_req_mode2_in_W	<1x5>	W	Engine required power map input
ENG_CNT_Throttle_MAX	100	%	Maximum throttle aperture
ENG_CNT_Throttle_MIN	0	%	Minimum throttle aperture
MG_CNT_Gain_Pmax	2.0	-	Short-time overload tolerance during engine start / stop
MG_CNT_Pmax_MG1_Gene_W	50000[*1]	W	Powering side rated output
MG_CNT_MG1_max_trq_Gene_Nm	40	Nm	Maximum torque on the powering running side
MG_CNT_Pmin_MG1_ReGene_W	-50000[*2]	W	Rated output on the regenerative side
MG_CNT_MG1_max_trq_ReGene_Nm	-40	Nm	Maximum torque on the regenerative side
MG_CNT_MG1_Const_trq_ReGene_radps	1150[*3]	rad/s	Rated rotation speed on the regenerative side
MG_CNT_Pmax_MG2_Gene_W	55000	W	Powering side rated output
MG_CNT_MG2_max_trq_Gene_Nm	170	Nm	Maximum torque on the powering side
MG_CNT_MG2_Const_trq_Gene_radps	325.153[*6]	rad/s	Powering side rated speed

Variable name	Set value	Unit	Explanation
MG_CNT_Pmin_MG2_ReGene_W	-55000	W	Rated output on the regenerative side
MG_CNT_MG2_max_trq_ReGene_Nm	-170	Nm	Maximum torque on the regenerative side
DCDC_Hi_CNT_DCDC_upper_Guard	600	V	Max voltage of boost DCDC converter
DCDC_Hi_CNT_Vtgt_discre1st	275	V	Voltage discretization 1st stage voltage
DCDC_Hi_CNT_Vtgt_discre2nd	350	V	Voltage discretization 2nd stage voltage
DCDC_Hi_CNT_Vtgt_discre3rd	450	V	Voltage discretization 3rd stage voltage
DCDC_Hi_CNT_Vtgt_discre4th	600	V	Voltage discretization 4th stage voltage
DCDC_Hi_CNT_Vtgt_discre_th_1st	230	V	Voltage threshold of voltage discretization 1st stage
DCDC_Hi_CNT_Vtgt_discre_th_2nd	280	V	Voltage threshold of voltage discretization 2nd stage
DCDC_Hi_CNT_Vtgt_discre_th_3rd	355	V	Voltage threshold of voltage discretization 3rd stage
DCDC_Hi_CNT_Vtgt_discre_th_4th	455	V	Voltage threshold of voltage discretization 4th stage
DCDC_Hi_CNT_Vtgt_conv_hi_trq_Nm	<17x1>	Nm	Target voltage map of boost DCDC converter input1 target motor torque
DCDC_Hi_CNT_Vtgt_conv_hi_w_rpm	<1x18>	rpm	Target voltage map of boost DCDC converter input2 target motor speed
DCDC_Hi_CNT_Vtgt_conv_hi_V	<17x18>	V	Target voltage map of boost DCDC converter
ENG_PNT_FuelCon_gps_map_x_pri_rpm	<1x14>	rpm	Fuel consumption rate map x-axis: engine speed
ENG_PNT_FuelCon_gps_map_y_trq_Nm	<1x14>	Nm	Fuel consumption rate map y-axis: engine shaft torque
ENG_PNT_FuelCon_gps_map	<14x14>	g/sec	Fuel consumption rate map
ENG_PNT_trq_Nm_map_x_rpm	<1x11>	rpm	Engine shaft torque map x-axis: engine speed
ENG_PNT_trq_Nm_map_y_throttle	<1x2>	%	Engine shaft torque map y-axis: accelerator throttle opening
ENG_PNT_trq_Nm_map	<11x2>	Nm	Engine shaft torque map z-axis: torque
TM_PNT_Flywheel_Inertia	0.24	kgm <sup>2</sup>	Flywheel inertia
TM_PNT_TM_Inertia	0.3	kgm <sup>2</sup>	Transmission inertia
TM_PNT_number_sungear	30	-	Sun gear number of teeth
TM_PNT_number_ringgear	78	-	Ring gear number of teeth
TM_PNT_number_outergear	65	-	Outer gear number of teeth
TM_PNT_number_MG2gear	17	-	MG2 gear number of teeth
TM_PNT_number_counterdrivengear	53	-	Counter gear number of teeth
TM_PNT_eta_outergear2countergear	0.97	-	Transmission efficiency between outer gear and counter gear
TM_PNT_eta_MG2gear2countergear	0.97	-	Transmission efficiency between MG2 gear and counter gear
TM_PNT_eta_planetarygear	0.95	-	Transmission efficiency of planetary gear
DF_PNT_DF_gear	2.8	-	Differential gear reduction ratio
DF_PNT_eta_DF	0.96	-	Differential gear efficiency
DF_PNT_Driveshaft_Inertia	0.1	kgm <sup>2</sup>	Driveshaft inertia
DF_PNT_Driveshaft_spring	10000	-	Driveshaft spring constant
DF_PNT_Driveshaft_zeta	10	-	Second-order lag damping coefficient
DF_PNT_Driveshaft_damper	632.456[*5]	-	Driveshaft damping coefficient
BK_PNT_Tau_brake	0.15	-	Brake plant model braking force time constant
BK_PNT_Pow_UL	5000	N	Braking force upper limit
BK_PNT_Pow_LL	0	N	Braking force lower limit

Variable name	Set value	Unit	Explanation
VL_PNT_V_wind	0	m/s	Wind speed
VL_PNT_Vehicle_theta_degree	0	deg	Climbing angle
MG_PNT_MG1_Inv_eta	<13x13>	-	Inverter efficiency
MG_PNT_MG1_Inv_eta_x_rpm	<1x13>	rpm	Efficiency map x-axis: rotation speed
MG_PNT_MG1_Inv_eta_y_trq	<1x13>	Nm	Efficiency map y-axis: torque
MG_PNT_MG1_mod_factor	0.78	-	Inverter modulation factor
MG_PNT_MG1_WeakField_UL	1.0	-	Weak field permeability upper limit
MG_PNT_MG1_WeakField_LL	0.05	-	Weak field permeability lower limit
MG_PNT_MG1_eta	<13x13>	-	Motor efficiency
MG_PNT_MG1_eta_x_rpm	<1x13>	rpm	Efficiency map x-axis: rotation speed
MG_PNT_MG1_eta_y_trq	<1x13>	Nm	Efficiency map y-axis: torque
MG_PNT_MG1_Power_factor	0.85	-	Motor power factor
MG_PNT_V_MG1_Rated	600	V	Motor inverter DC side rated voltage
MG_PNT_w_ROT_MG1_Rated	1150[*6]	rad/s	Motor rated rotation speed
MG_PNT_MG2_Inv_eta	<13x13>	-	Inverter efficiency
MG_PNT_MG2_Inv_eta_x_rpm	<1x13>	rpm	Efficiency map x-axis: rotation speed
MG_PNT_MG2_Inv_eta_y_trq	<1x13>	Nm	Efficiency map y-axis: torque
MG_PNT_MG2_mod_factor	0.78	-	Inverter modulation factor
MG_PNT_MG2_WeakField_UL	1.0	-	Weak field permeability upper limit
MG_PNT_MG2_WeakField_LL	0.05	-	Weak field permeability lower limit
MG_PNT_MG2_eta	<13x13>	-	Motor efficiency
MG_PNT_MG2_eta_x_rpm	<1x13>	rpm	Efficiency map x-axis: rotation speed
MG_PNT_MG2_eta_y_trq	<1x13>	Nm	Efficiency map y-axis: torque
MG_PNT_MG2_Power_factor	0.85	-	Motor efficiency
MG_PNT_V_MG2_Rated	600	V	Motor inverter DC side rated voltage
MG_PNT_w_ROT_MG2_Rated	325.153[*7]	rad/s	Motor inverter DC side rated rotation speed
BT_PNT_Hi_Capa_hi_batt	3.6	Ah	High-voltage battery capacity
BT_PNT_Hi_SOC_START_hi_batt	60	%	High-voltage battery SOC_initial value
BT_PNT_Hi_SOC_MAX_hi_batt	100	%	High-voltage battery SOC_maximum
BT_PNT_Hi_SOC_MIN_hi_batt	0	%	High-voltage battery SOC_minimum value
BT_PNT_Hi_ocv_SOC_hi_batt_OCV_V_table_x_SOC	<1x10>	%	High-voltage battery OCV calculation MAP x-axis: SOC term
BT_PNT_Hi_ocv_SOC_hi_batt_OCV_V_table	<1x10>	V	High-voltage battery OCV calculation MAP y-axis: OCV term
BT_PNT_Hi_R_hi_batt_cell	0.005	Ω	High-voltage battery internal cell resistance
BT_PNT_Hi_R_hi_batt_others	0	Ω	Other internal high-voltage battery resistances
BT_PNT_Lo_Capa_lo_batt	45	Ah	Low-voltage battery capacity
BT_PNT_Lo_SOC_START_lo_batt	95	%	Low-voltage battery initial SOC value
BT_PNT_Lo_SOC_MAX_lo_batt	120	%	Low-voltage battery SOC_maximum value
BT_PNT_Lo_SOC_MIN_lo_batt	0	%	Low-voltage battery SOC_minimum value
BT_PNT_Lo_ocv_SOC_lo_batt_OCV_V_table_x_SOC	[0,100]	%	Battery OCV calculation table x-axis: SOC term
BT_PNT_Lo_ocv_SOC_lo_batt_OCV_V_table	[10.5,14]	V	Battery OCV calculation table
BT_PNT_Lo_R_lo_batt_ohm	0.01	Ω	Battery internal resistance
DCDC_Hi_PNT_eta_conv_hi_I	0.97	-	Boost converter efficiency
DCDC_PNT_eta_conv_lo	0.95	-	Buck converter efficiency



Variable name	Set value	Unit	Explanation
DCDC_PNT_R_conv_lo	0.02	$\Omega$	Buck converter resistance [*8]
DCDC_PNT_Vtgt_conv_lo	14.0	V	Target buck converter voltage value
EL_PNT_R_bodyelec_hi	4000	$\Omega$	High-voltage section electrical load resistance
EL_PNT_R_bodyelec_lo	1.037	$\Omega$	Low-voltage section electrical load resistance

※Uncolored parameters are common to all systems

- [\*1]       $25000 * MG\_CNT\_Gain\_Pmax$
- [\*2]       $-25000 * MG\_CNT\_Gain\_Pmax$
- [\*3]       $MG\_CNT\_Pmin\_MG1\_ReGene\_W / MG\_CNT\_MG1\_max\_trq\_ReGene\_Nm$
- [\*4]       $MG\_CNT\_Pmax\_MG2\_Gene\_W / MG\_CNT\_MG2\_max\_trq\_Gene\_Nm$
- [\*5]       $2 * DF\_PNT\_Driveshaft\_zeta * \sqrt{DF\_PNT\_Driveshaft\_spring * DF\_PNT\_Driveshaft\_Inertia}$
- [\*6]       $MG\_CNT\_MG1\_Const\_trq\_ReGene\_radps$
- [\*7]       $MG\_CNT\_MG2\_Const\_trq\_Gene\_radps$
- [\*8]      If it is smaller than the lead battery's internal resistance, the low voltage system will oscillate.

#### 5.2.2.5 Other information

None.

### 5.2.3. [C: Monitor] system functional specifications

Description of the functional specifications of the second layer Monitor system of the guideline-compliant model.

#### 5.2.3.1 Overview

The outline of this system is shown below.

- ① Modeling target  
none
- ② Scope of modeling / degree of abstraction  
none
- ③ Modeled functions  
none

#### 5.2.3.2 Data flow diagram

The data flow diagram of this system is shown below.

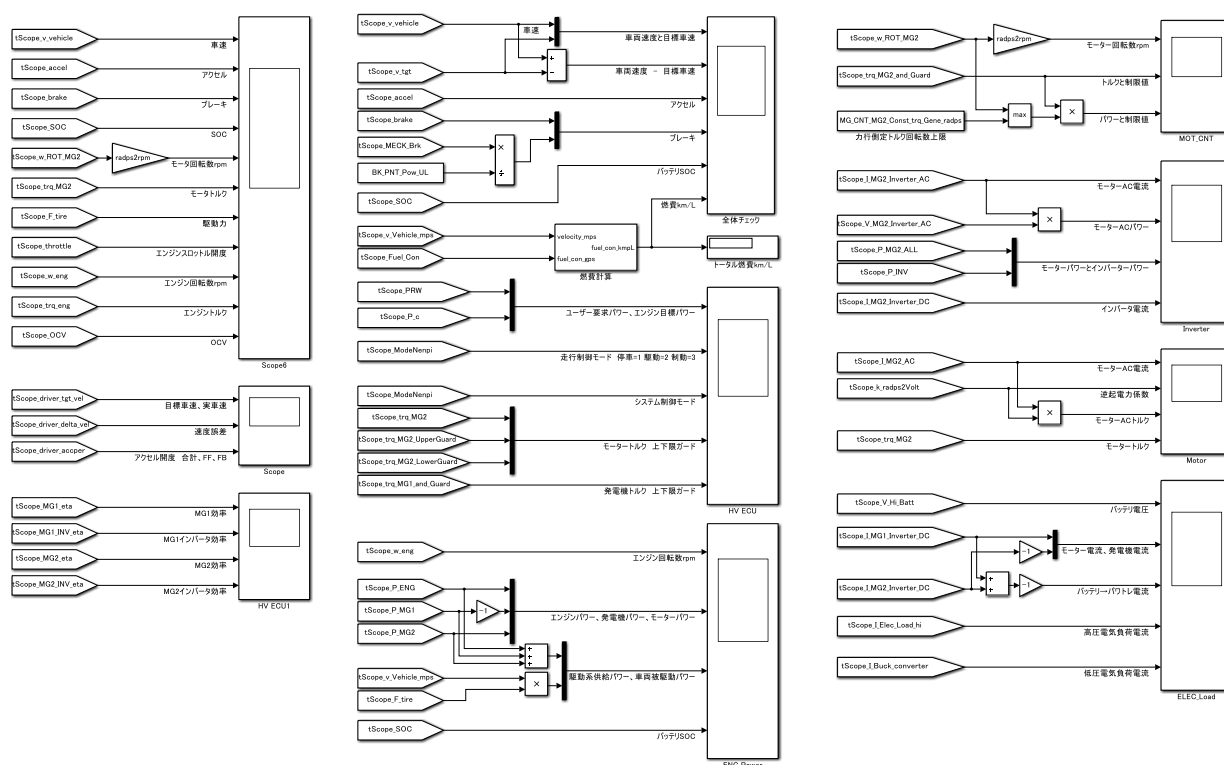


Fig. 5.2.3 Data flow diagram: 2nd layer Monitor system

## 5.2.3.3 Input/Output specifications

The input / output specifications of this system are shown below.

Inputs			
Variable name	Unit	Scope	Explanation
tScope v vehicle	km/h	TBD	Vehicle speed
tScope accel	%	[0 100]	Accelerator aperture
tScope brake	%	[0 100]	Brake aperture
tScope SOC	%	[0 100]	Battery SOC
tScope w ROT MG2	rad/s	TBD	Motor rotation speed
tScope trq MG2	Nm	TBD	Motor torque
tScope F tire	N	TBD	Driving force
tScope throttle	%	[0 100]	Engine throttle aperture
tScope w eng	rpm	TBD	Engine rotation speed
tScope trq eng	Nm	TBD	Engine torque
tScope OCV	V	TBD	OCV
tScope driver tgt vel	km/h	TBD	Target vehicle speed / actual vehicle speed
tScope driver delta vel	km/h	TBD	Speed error
tScope driver accper	%	[0 100]	Accelerator aperture total, FF, FB
tScope MG1 eta	-	TBD	MG1 efficiency
tScope MG1 INV eta	-	TBD	MG1 inverter efficiency
tScope MG2 eta	-	TBD	MG2 efficiency
tScope MG2 INV eta	-	TBD	MG2 inverter efficiency
tScope v Vehicle1	km/h	TBD	Vehicle speed
tScope v tgt	km/h	TBD	Target vehicle speed
tScope MECK Brk	N	TBD	Mechanical brake braking force
tScope Fuel Con	g	TBD	Fuel consumption
tScope PRW	W	TBD	User required power
tScope P c	W	TBD	Engine target power
tScope ModeNenpi	-	[1 5]	Driving control mode, system control mode
tScope trq MG2	Nm	TBD	Motor torque
tScope trq MG2 UpperGuard	Nm	TBD	Motor torque upper guard
tScope trq MG2 LowerGuard	Nm	TBD	Motor torque lower guard
tScope trq MG1 and Guard	Nm	TBD	Generator torque and upper and lower limit guards
tScope w eng	rpm	TBD	Engine rotation speed
tScope P ENG	W	TBD	Engine power
tScope P MG1	W	TBD	Generator power
tScope P MG2	W	TBD	Motor power
tScope F tire	N	TBD	Tire propulsion force
tScope w ROT MG2	rpm	TBD	Motor rotation speed
tScope trq MG2 and Guard	Nm	TBD	Motor torque and upper and lower limit guards
tScope I MG2 Inverter AC	A	TBD	Motor AC current
tScope V MG2 Inverter AC	V	TBD	Motor AC voltage
tScope MG2 ALL	W	TBD	Motor power
tScope P INV	W	TBD	Inverter power
tScope I MG2 Inverter DC	A	TBD	Inverter current
tScope I MG2 AC	A	TBD	Motor AC current
tScope k radps2Volt	-	TBD	Back electromotive force coefficient
tScope trq MG2	Nm	TBD	Motor torque
tScope V Hi Batt	V	TBD	Battery voltage
tScope I MG1 Inverter DC	A	TBD	Generator current
tScope I Elec Load hi	A	TBD	High-voltage electrical load current
tScope I Buck converter	A	TBD	Low-voltage electrical load current
Outputs			
Variable name	Unit	Scope	Explanation
none	none	none	none

## 5.2.3.4 Parameter specifications

The parameter specifications of this system are shown below.

Variable name	Set value	Unit	Explanation
BK_PNT_Pow_UL	5000	N	Braking force upper limit
MG_CNT_MG2_Const_trq_Gene_radps	325.153[*1]	rad/s	Powering side constant torque rotation speed upper limit

[\*1]  $MG\_CNT\_Pmax\_MG2\_Gene\_W / MG\_CNT\_MG2\_max\_trq\_Gene\_Nm$

## 5.2.3.5 Other information

None

## 5.3. Functional specifications of the third layer

### 5.3.1. [A10: Accelerator aperture] system functional specifications

Description of the functional specifications of the third layer accelerator aperture system of the guideline-compliant model.

#### 5.3.1.1 Overview

The outline of this system is shown below.

- ① Modeling target  
Calculation of the amount of operation of the accelerator by the driver
- ② Scope of modeling / degree of abstraction  
A model that calculates the accelerator aperture required to follow the target vehicle speed of the mode driving pattern (JC08 / WLTC)
- ③ Modeled functions  
FF control (Feedforward control) that calculates the accelerator aperture required to output the vehicle driving force that matches the vehicle inertia and running resistance  
FB control (Feedback control) that corrects the accelerator aperture based on the difference between the target vehicle speed and the vehicle speed

#### 5.3.1.2 Data flow diagram

The data flow diagram of this system is shown below.

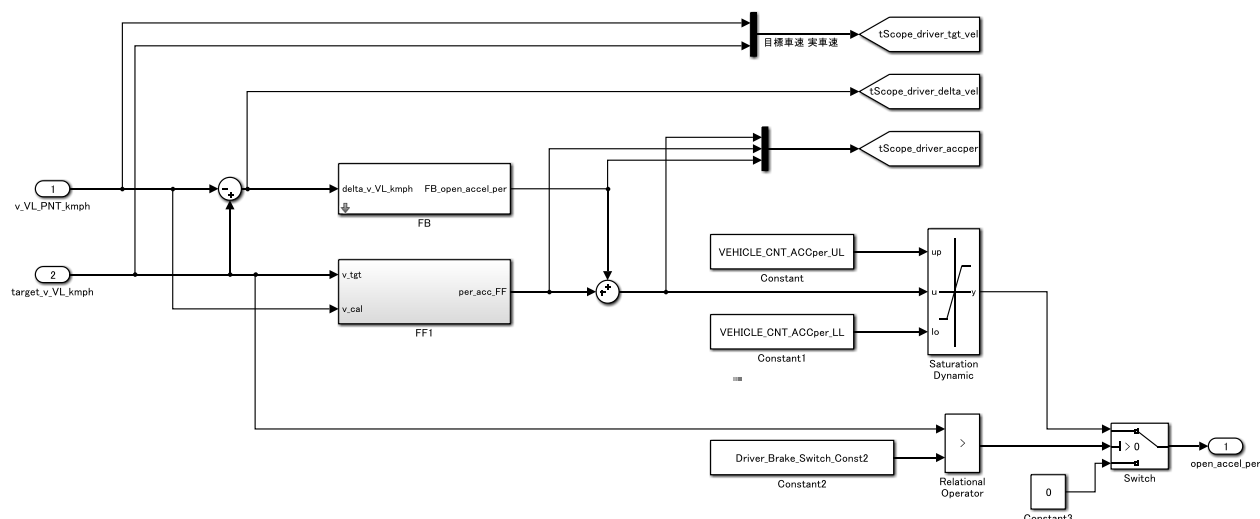


Fig. 5.3.1 Data flow diagram: 3rd layer Accelerator aperture system

## 5.3.1.3 Input/Output specifications

The input / output specifications of this system are shown below.

Inputs			
Name	Unit	Scope	Explanation
target_v_VL_kmph	km/h	TBD	Vehicle target speed (JC08/WLTC)
v_VL_PNT_kmph	km/h	TBD	Vehicle speed
Outputs			
Name	Unit	Scope	Explanation
open_accel_per	%	[0 100]	Accelerator aperture

## 5.3.1.4 Parameter specifications

The parameter specifications of this system are shown below.

Variable name	Set value	Unit	Explanation
ACC_P_Gain	20	-	Feedback control P gain value
ACC_I_Gain	0	-	Feedback control I gain value
ACC_D_Gain	0	-	Feedback control D gain value
VEHICLE_CNT_ACCper_UL	100	%	Upper limit of accelerator aperture
VEHICLE_CNT_ACCper_LL	0	%	Lower limit of accelerator aperture
Brk_PGain	-3000	-	Braking force P gain value
Brk_UL	5000	N	Braking force upper limit
Brk_LL	0	N	Braking force lower limit
VEHICLE_CNT_ACCper_UL	100	%	Accelerator aperture upper limit
VEHICLE_CNT_ACCper_LL	0	%	Accelerator aperture lower limit
Driver_Brake_Const1	-0.1	-	Brake depression amount when stopped (target vehicle speed is 0km/h)
Driver_Brake_Const3	0	-	Brake depression amount when accelerating (when the target vehicle speed is positive)
Driver_Brake_Switch_Const2	0.1	km/h	Driver brake model stopping decision
Driver_Brk_sh	0.01	km/h/sec	Acceleration decision
Driver_Brk_offset	0.5	km/h	Offset of speed error when not braking
Thresh_Stop_vCar	0.1	km/h	Vehicle speed stopping condition
drivemode_STOP	1	-	Driver state 1: Stopped
drivemode_ACC	2	-	Driver state 2: Accelerating
drivemode_Deceleration_Acc	3	-	Driver state 3: Decelerating (powered)
drivemode_Deceleration_Brk	4	-	Driver state 4: Decelerating (regenerative)
drivemode_CONST	5	-	Driver state 5: Steady driving

## 5.3.1.5 Other information

none

### 5.3.2. [A20: Brake aperture] system functional specifications

Description of the functional specifications of the third layer brake aperture system of the guideline-compliant model.

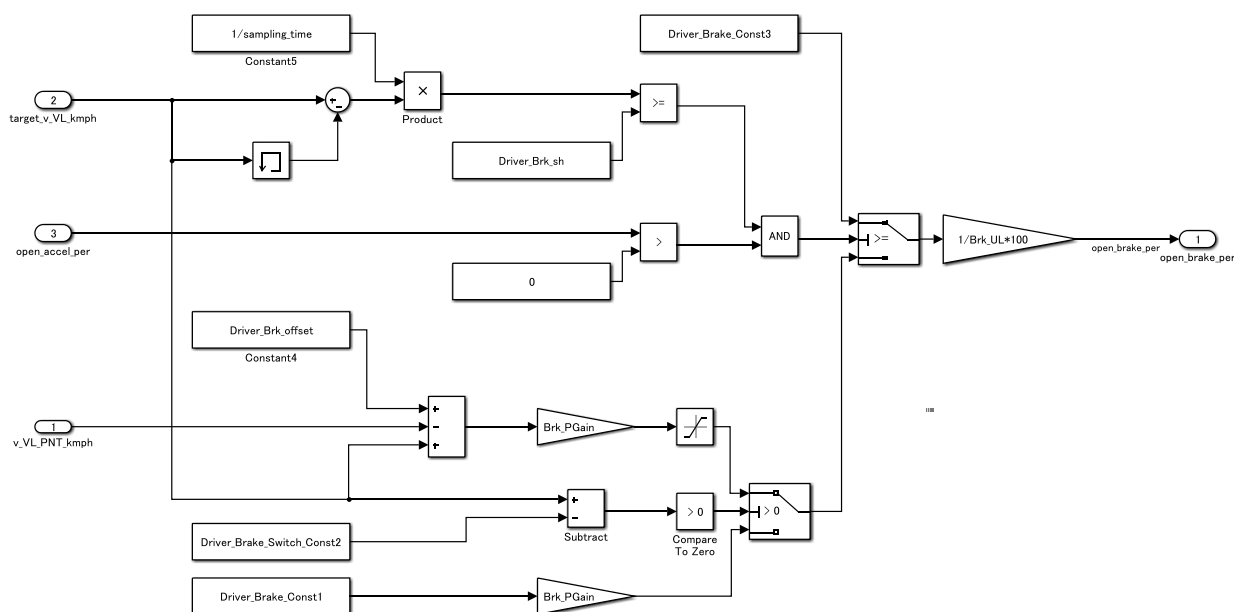
#### 5.3.2.1 Overview

The outline of this system is shown below.

- ① Modeling target  
Calculation of the amount of operation of the brakes by the driver
- ② Scope of modeling / degree of abstraction  
A model that calculates the brake depression amount required to follow the target vehicle speed of the mode driving pattern (JC08 / WLTC)
- ③ Modeled functions  
Proportional control that calculates the amount of brake pedal depression based on the difference between the target vehicle speed and the vehicle speed  
A control to prevent the brakes from being depressed during acceleration  
A control to keep the amount of brake depression constant when the vehicle is stopped

#### 5.3.2.2 Data flow diagram

The data flow diagram of this system is shown below.



**Fig. 5.3.2 Data flow diagram: 3rd layer Brake aperture system**

## 5.3.2.3 Input/Output specifications

The input / output specifications of this system are shown below.

Inputs			
Name	Unit	Scope	Explanation
target_v_VL_kmph	km/h	TBD	Target vehicle speed (JC08/WLTC)
v_VL_PNT_kmph	km/h	TBD	Vehicle speed
open_accel_per	%	[0 100]	Accelerator aperture
Outputs			
Name	Unit	Scope	Explanation
open_brake_per	%	[0 100]	Brake aperture

## 5.3.2.4 Parameter specifications

The parameter specifications of this system are shown below.

Variable name	Set value	Unit	Explanation
ACC_P_Gain	20	-	Feedback control P gain value
ACC_I_Gain	0	-	Feedback control I gain value
ACC_D_Gain	0	-	Feedback control D gain value
VEHICLE_CNT_ACCper_UL	100	%	Upper limit of accelerator aperture
VEHICLE_CNT_ACCper_LL	0	%	Lower limit of accelerator aperture
Brk_PGain	-3000	-	Braking force P gain value
Brk_UL	5000	N	Braking force upper limit
Brk_LL	0	N	Braking force lower limit
VEHICLE_CNT_ACCper_UL	100	%	Accelerator aperture upper limit
VEHICLE_CNT_ACCper_LL	0	%	Accelerator aperture lower limit
Driver_Brake_Const1	-0.1	-	Brake depression amount when stopped (target vehicle speed is 0km/h)
Driver_Brake_Const3	0	-	Brake depression amount when accelerating (when the target vehicle speed is positive)
Driver_Brake_Switch_Const2	0.1	km/h	Driver brake model stopping decision
Driver_Brk_sh	0.01	km/h/sec	Acceleration decision
Driver_Brk_offset	0.5	km/h	Offset of speed error when not braking
Thresh_Stop_vCar	0.1	km/h	Vehicle speed stopping condition
drivemode_STOP	1	-	Driver state 1: Stopped
drivemode_ACC	2	-	Driver state 2: Accelerating
drivemode_Deceleration_Acc	3	-	Driver state 3: Decelerating (powered)
drivemode_Deceleration_Brk	4	-	Driver state 4: Decelerating (regenerative)
drivemode_CONST	5	-	Driver state 5: Steady driving

## 5.3.2.5 Other information

None



### 5.3.3. [B10C: HV CNT] system functional specifications

Description of the functional specifications of the third layer HV\_CNT system of the guideline-compliant model.

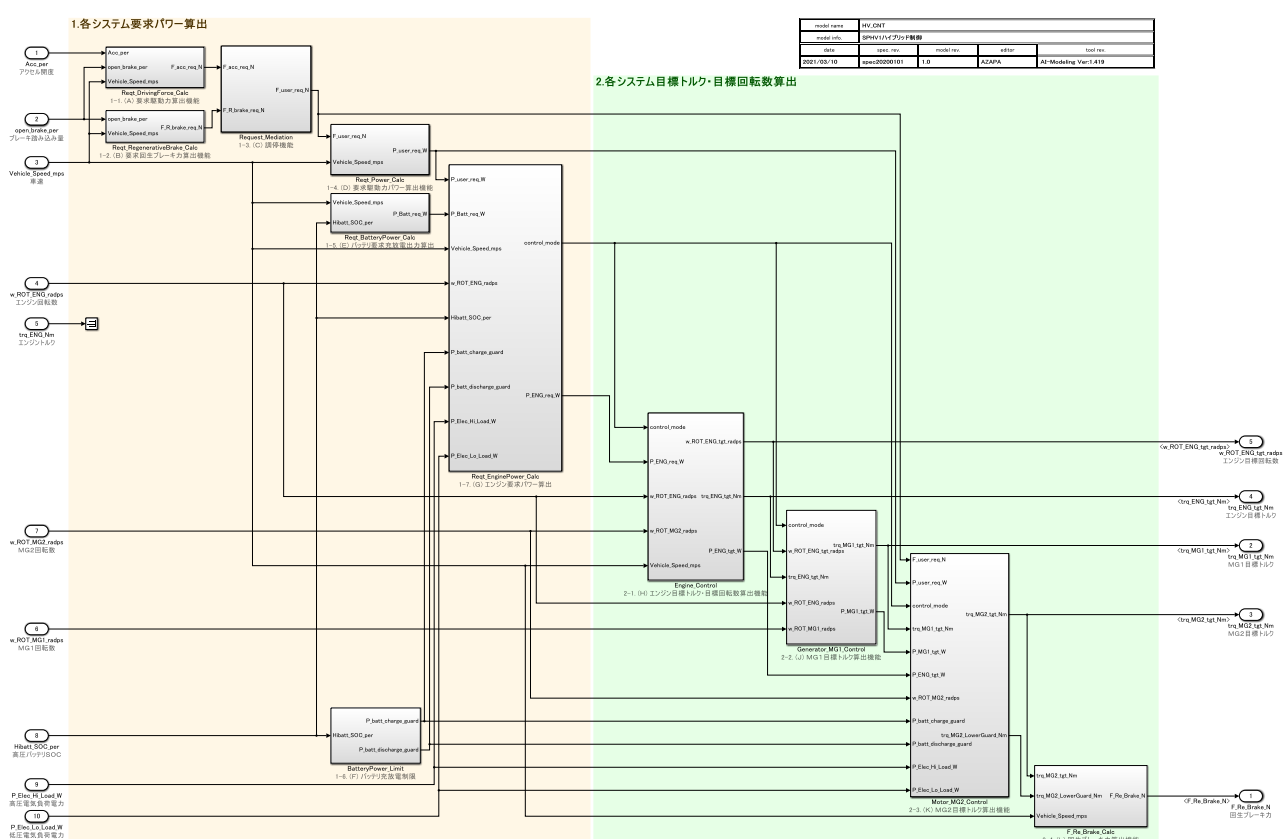
#### 5.3.3.1 Overview

The outline of this system is shown below.

- ① Modeling target  
Hybrid control ECU model for fuel efficiency evaluation
- ② Scope of modeling / degree of abstraction  
Control model that calculates the target value required when driving in mode
- ③ Modeled functions  
Function to calculate battery limits from SOC  
Function to control engine  
Function to control motor drive system  
Function to calculate regenerative braking force

#### 5.3.3.2 Data flow diagram

The data flow diagram of this system is shown below.



**Fig. 5.3.3 Data flow diagram: 3rd layer HV\_CNT system**

## 5.3.3.3 Input/Output specifications

The input / output specifications of this system are shown below.

Inputs			
Name	Unit	Scope	Explanation
ACC_per	%	[0 100]	Accelerator aperture
open_brake_per	%	[0 100]	Brake aperture
Vehicle_Speed_mps	m/s	TBD	Vehicle speed (unit: m/s)
w_ROT_ENG_radps	rad/s	TBD	Engine rotation speed
trq_ENG_Nm	Nm	0 以上	Engine torque
w_ROT_MG1_radps	rad/s	TBD	Motor drive system speed(generator)
w_ROT_MG2_radps	rad/s	TBD	Motor drive system speed(main traction motor)
Hibatt_SOC_per	%	[0 100]	High-voltage battery SOC
P_Elec_Hi_load_W	W	TBD	High-voltage power consumption
P_Elec_Lo_load_W	W	TBD	Low-voltage power consumption
Outputs			
Name	Unit	Scope	Explanation
F_Re_brake_N	N	TBD	Regenerative braking force
trq_MG1_tgt_Nm	Nm	TBD	Target torque value (generator)
trq_MG2_tgt_Nm	Nm	TBD	Target torque value (main traction motor)
trq_ENG_tgt_Nm	Nm	TBD	Engine torque target value
w_ROT_ENG_tgt_radps	rad/s	TBD	Engine rotation speed target value

## 5.3.3.4 Parameter specifications

The parameter specifications of this system are shown below.

Variable name	Set value	Unit	Explanation
HV_CNT_trq_require_accper	<1x12>	%	Required driving force estimation map Accelerator opening
HV_CNT_trq_require_v_kmph	<13x1>	km/h	Required driving force estimation map Vehicle speed
HV_CNT_trq_require_Nm	<13x12>	Nm	Required driving force estimation map
HV_CNT_trq_req_Gain_OFF	0	-	Required drive torque gain when determining stopped state
HV_CNT_trq_req_Gain_ON	1	-	Required drive torque gain when determining running state
HV_CNT_trq_req_v_vehicle_th	1	km/h	Stop decision vehicle speed threshold
HV_CNT_trq_req_brak_th	0.01	N	Stop decision brake threshold
HV_CNT_trq_req_delaytime	0.2	sec	Gain first-order lag time constant
HV_CNT_Batt_discharge_limit	22000	W	Discharging power limit
HV_CNT_Batt_charge_limit	-30000	W	Charging power limit
HV_CNT_Batt_charge_vel	<7x1>	km/h	Required power map of battery discharge input1 vehicle speed
HV_CNT_Batt_charge_SOC	<1x16>	%	Required power map of battery discharge input2 battery SOC
HV_CNT_Batt_charge_req	<7x16>	W	Required power map of battery discharge
HV_CNT_P_Force_discharge_W	6000	W	Forced discharge power setting when battery SOC is high
HV_CNT_Force_dis_ON_th	65	%	SOC threshold to turn on forced discharge power setting when battery SOC is high
HV_CNT_Force_dis_OFF_th	52	%	SOC threshold to turn off forced discharge power setting when battery SOC is high
HV_CNT_P_Force_charge_W	-6750	W	Forced charge power setting when battery SOC is low

HV_CNT_Force_chr_ON_th	35	%	SOC threshold to turn on forced charge power setting when battery SOC is low
HV_CNT_Force_chr_OFF_th	42	%	SOC threshold to turn off forced charge power setting when battery SOC is low
HV_CNT_P_Gain_trq_MG1_tgt	3	-	P Gain of MG1 torque control in engine starting and stopping
HV_CNT_Power_ref_ENG_ON_vel	<2x1>	km/h	Power threshold map to start engine input1 vehicle speed
HV_CNT_Power_ref_ENG_ON_SOC	<1x4>	%	Power threshold map to start engine input2 SOC
HV_CNT_Power_ref_ENG_ON_Power	<2x4>	W	Power threshold map to start engine
HV_CNT_Power_ref_ENG_OFF_vel	<4x1>	km/h	Power threshold map to stop engine input1 vehicle speed
HV_CNT_Power_ref_ENG_OFF_SOC	<1x6>	%	Power threshold map to stop engine input2 SOC
HV_CNT_Power_ref_ENG_OFF_Power	<4x6>	W	Power threshold map to stop engine
HV_CNT_Power_ref_ENG_under_vel	<4x1>	km/h	Lower limit of engine power target input1 vehicle speed
HV_CNT_Power_ref_ENG_under_SOC	<1x5>	%	Lower limit of engine power target input2 SOC
HV_CNT_Power_ref_ENG_under_Power	<4x5>	W	Lower limit of engine power target
HV_CNT_Power_ref_Motor_Limit_vel	<1x6>	km/h	Upper limit of required power map for EV driving input vehicle speed
HV_CNT_Power_ref_Motor_Limit_power	<1x6>	W	Upper limit of required power map for EV driving
HV_CNT_Power_trq_ENG_Curve_Power_req	<1x10>	W	Target engine power
HV_CNT_Power_trq_ENG_Curve_w_ROT_ENG_tgt	<1x10>	rpm	Target engine speed
HV_CNT_Power_trq_ENG_Curve_trq_ENG_tgt	<1x10>	Nm	Target engine trq
HV_CNT_w_ROT_ENG_low_threshold_ON_rpm	1000	rpm	Engine speed threshold to turn on target engine torque at low engine speed
HV_CNT_w_ROT_ENG_low_threshold_OFF_rpm	400	rpm	Engine speed threshold to turn off target engine torque at low engine speed
HV_CNT_Power_ENG_upper_rate_Power	<1x6>	W	Upper limit of engine required power fluctuation rate map Input engine required power
HV_CNT_Power_ENG_upper_rate_Guard	<1x6>	W	Upper limit of engine required power fluctuation rate map
HV_CNT_Power_ENG_lower_rate_Power	<1x6>	W	Lower limit of engine required power fluctuation rate map Input engine required power
HV_CNT_Power_ENG_lower_rate_Guard	<1x6>	W	Lower limit of engine required power fluctuation rate map
HV_CNT_F_threshold_brake_override_N	10	N	Judgment threshold of brake override
HV_CNT_v_vehicle_threshold_anti_0div_kmph	5	km/h	Vehicle speed of 0 division prevention
HV_CNT_w_ROT_MOT_threshold_anti_0div	50	rad/s	Motor rotation speed of 0 division prevention
HV_CNT_ReGeneBrk_Cut_Gain	<1x4>	-	Regenerative braking force limitation map at low vehicle speed
HV_CNT_ReGeneBrk_Cut_v_kmph	<1x4>	km/h	Vehicle speed input of regenerative braking force limitation map at low vehicle speed
HV_CNT_Power_ENG_req_mode2_W	<1x5>	W	Engine required power map output
HV_CNT_Power_ENG_req_mode2_in_W	<1x5>	W	Engine required power map input

### 5.3.3.5 Other information

None

### 5.3.4. [B11C: ENG\_CNT] system functional specifications

Description of the functional specifications of the third layer ENG\_CNT system of the guideline-compliant model.

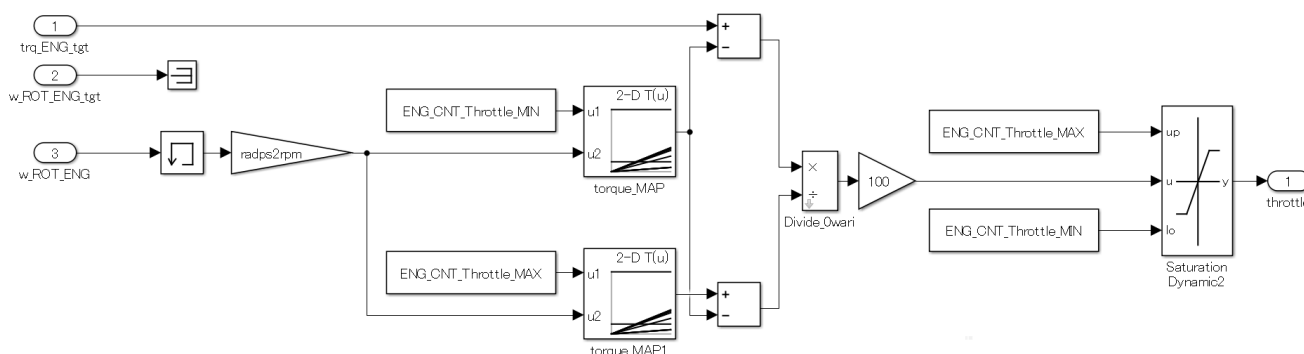
#### 5.3.4.1 Overview

The outline of this system is shown below.

- ① Modeling target  
Engine control ECU model for fuel efficiency performance evaluation
- ② Scope of modeling / degree of abstraction  
Calculation of the throttle aperture necessary for the control of the engine
- ③ Modeled functions  
A function to calculate the throttle aperture from the target engine torque and engine speed

#### 5.3.4.2 Data flow diagram

The data flow diagram of this system is shown below.



**Fig. 5.3.4 Data flow diagram: 3rd layer ENG\_CNT system**

#### 5.3.4.3 Input/Output specifications

The input / output specifications of this system are shown below.

Inputs			
Name	Unit	Scope	Explanation
trq_ENG_tgt	Nm	TBD	Engine torque target value
w_ROT_ENG_tgt	rad/s	TBD	Engine rotation speed target value
w_ROT_ENG	rad/s	greater than 0	Engine rotation speed
Outputs			
Name	Unit	Scope	Explanation
open_throttle_per	%	[0 100]	Throttle aperture

#### 5.3.4.4 Parameter specifications

The parameter specifications of this system are shown below.

Variable name	Set value	Unit	Explanation
ENG_CNT_Throttle_MAX	100	%	Maximum throttle aperture
ENG_CNT_Throttle_MIN	0	%	Minimum throttle aperture

#### 5.3.4.5 Other information

None

### 5.3.5. [B14C: BK\_CNT] system functional specifications

Description of the functional specifications of the third layer BK\_CNT system of the guideline-compliant model.

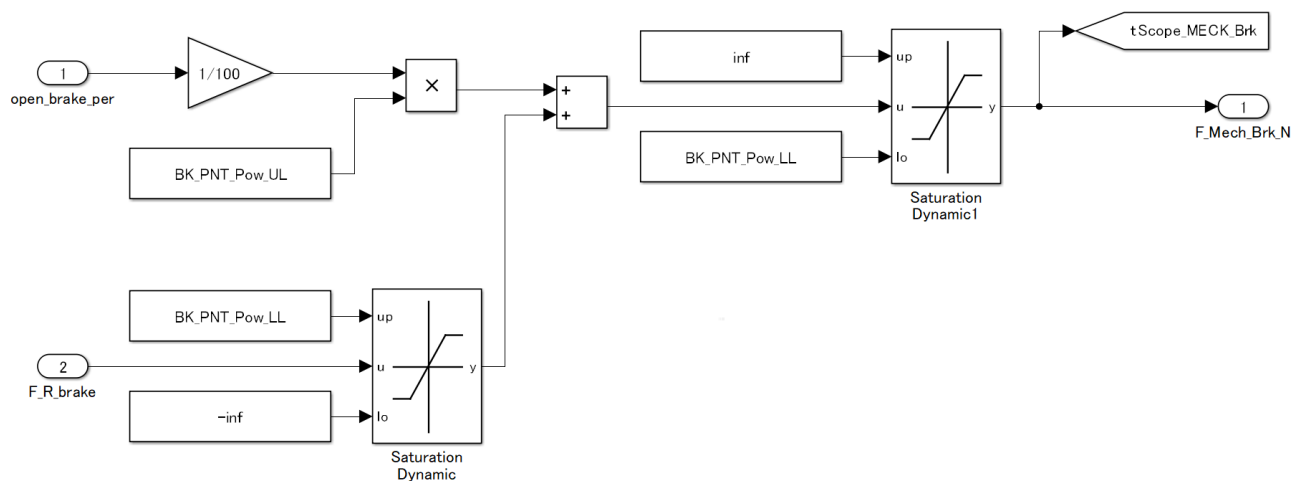
#### 5.3.5.1 Overview

The outline of this system is shown below.

- ① Modeling target  
Brake control ECU model
- ② Scope of modeling / degree of abstraction  
Calculation of braking force of mechanical brake
- ③ Modeled functions  
A function that calculates the braking force according to the amount of brake pedal depression and the regenerative braking force.

#### 5.3.5.2 Data flow diagram

The data flow diagram of this system is shown below.



**Fig. 5.3.5 Data flow diagram: 3rd layer BK\_CNT system**

## 5.3.5.3 Input/Output specifications

The input / output specifications of this system are shown below.

Inputs			
Name	Unit	Scope	Explanation
open_brake_per	%	[0 100]	Brake aperture
F_R_brake	N	TBD	Regenerative braking force
Outputs			
Name	Unit	Scope	Explanation
F_Mech_Brk_N	N	TBD	Braking force

## 5.3.5.4 Parameter specifications

The parameter specifications of this system are shown below.

Variable name	Set value	Unit	Explanation
BK_PNT_Pow_UL	5000	N	Braking force upper limit
BK_PNT_Pow_LL	0	N	Braking force lower limit

## 5.3.5.5 Other information

None

### 5.3.6. [B21C: MG1\_CNT] system functional specifications

Description of the functional specifications of the third layer MG1\_CNT system of the guideline-compliant model.

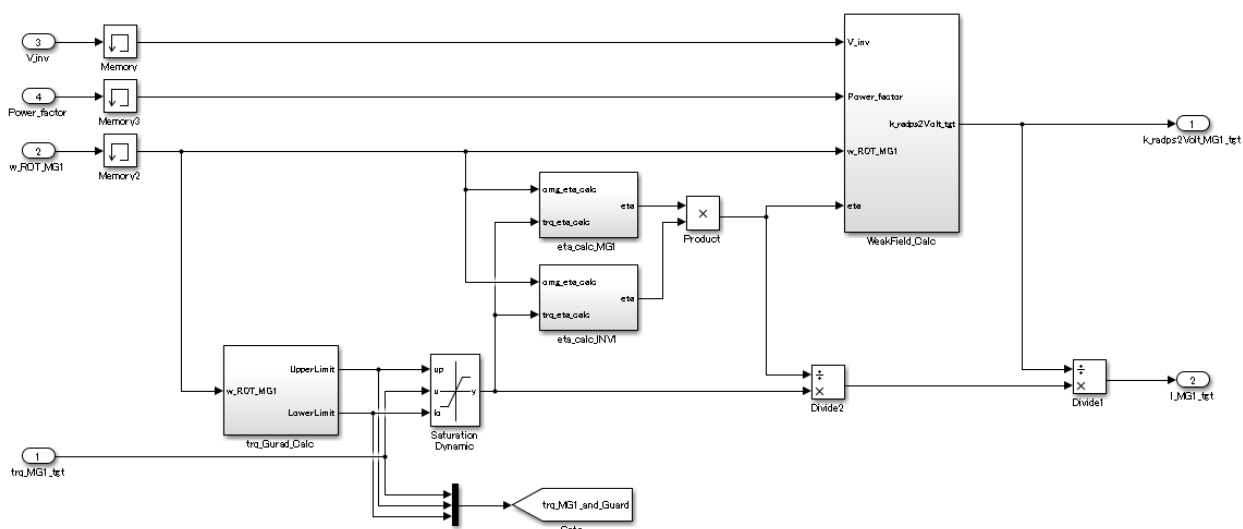
#### 5.3.6.1 Overview

The outline of this system is shown below.

- ① Modeling target  
Motor control ECU model
- ② Scope of modeling / degree of abstraction  
Calculate the target back electromotive force coefficient and target current value for controlling the three-phase AC motor
- ③ Modeled functions  
Function to calculate the target back electromotive force coefficient and target current value

#### 5.3.6.2 Data flow diagram

The data flow diagram of this system is shown below.



**Fig. 5.3.6 Data flow diagram: 3rd layer MG1\_CNT system**



## 5.3.6.3 Input/Output specifications

The input / output specifications of this system are shown below.

Inputs			
Name	Unit	Scope	Explanation
trq_MG1_tgt	Nm	TBD	Target torque value
w_ROT_MG1	rad/s	TBD	Motor drive system rotation speed
v_MG1_Inverter_DC	V	TBD	Inverter DC voltage value
MG1_Power_factor	-	[0 1]	Power factor
Outputs			
Name	Unit	Scope	Explanation
k_radps2Volt_MG1_tgt	-	TBD	Back electromotive force coefficient target value
I_MG1_tgt	A	TBD	Target current value

## 5.3.6.4 Parameter specifications

The parameter specifications of this system are shown below.

Variable name	Set value	Unit	Explanation
MG_CNT_Gain_Pmax	2	-	Short-time overload tolerance when starting / stopping the engine
MG_CNT_Pmax_MG1_Gene_W	50000 [*1]	W	Powering side rated output
MG_CNT_MG1_max_trq_Gene_Nm	40	Nm	Powering side maximum torque
MG_CNT_Pmin_MG1_ReGene_W	-50000 [*2]	W	Regenerative side side rated output
MG_CNT_MG1_max_trq_ReGene_Nm	-40	Nm	Regenerative side maximum torque
MG_CNT_MG1_Const_trq_ReGene_radps	1150 [*3]	rad/s	Regenerative side rated rotation speed

[\*1] 25000 \* MG\_CNT\_Gain\_Pmax

[\*2] -25000 \* MG\_CNT\_Gain\_Pmax

[\*3] MG\_CNT\_Pmin\_MG1\_ReGene\_W / MG\_CNT\_MG1\_max\_trq\_ReGene\_Nm

## 5.3.6.5 Other information

None

### 5.3.7. [B22C: MG2 CNT] system functional specifications

Description of the functional specifications of the third layer MG2\_CNT system of the guideline-compliant model.

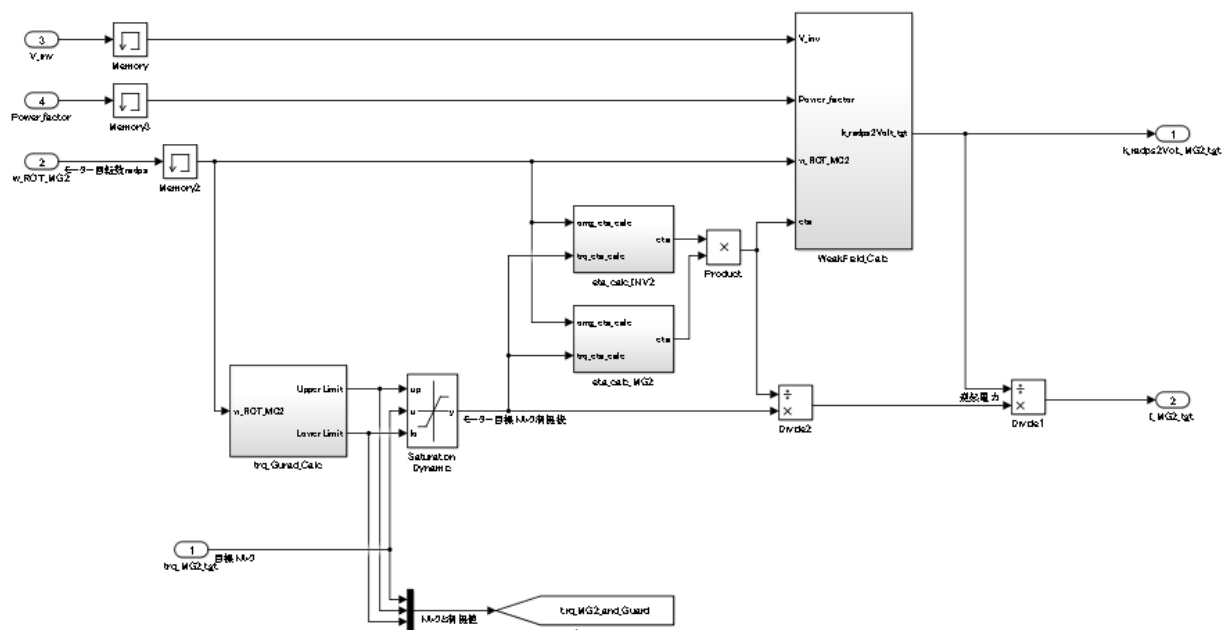
### 5.3.7.1 Overview

The outline of this system is shown below.

- ① Modeling target  
Motor control ECU model
- ② Scope of modeling / degree of abstraction  
Calculate the target back electromotive force coefficient and target current value for controlling the three-phase AC motor
- ③ Modeled functions  
Function to calculate the target back electromotive force coefficient and target current value

#### 5.3.7.2 Data flow diagram

The data flow diagram of this system is shown below.



**Fig. 5.3.7 Data flow diagram: 3rd layer MG2\_CNT system**

## 5.3.7.3 Input/Output specifications

The input / output specifications of this system are shown below.

Inputs			
Name	Unit	Scope	Explanation
trq_MG2_tgt	Nm	TBD	Target torque value
w_ROT_MG2	rad/s	TBD	Motor drive system rotation speed
v_MG2_Inverter_DC	V	TBD	Inverter DC voltage value
MG2_Power_factor	-	[0 1]	Power factor
Outputs			
Name	Unit	Scope	Explanation
k_radps2Volt_MG2_tgt	-	TBD	Back electromotive force coefficient target value
I_MG2_tgt	A	TBD	Target current value

## 5.3.7.4 Parameter specifications

The parameter specifications of this system are shown below.

Variable name	Set value	Unit	Explanation
MG_CNT_Pmax_MG2_Gene_W	55000	W	Powering side rated output
MG_CNT_MG2_max_trq_Gene_Nm	170	Nm	Powering side maximum torque
MG_CNT_MG2_Const_trq_Gene_radps	325.153 [*1]	rad/s	Powering side rated rotation speed
MG_CNT_Pmin_MG2_ReGene_W	-55000	W	Regenerative side side rated output
MG_CNT_MG2_max_trq_ReGene_Nm	-170	Nm	Regenerative side maximum torque

[\*1]  $\text{MG\_CNT\_Pmax\_MG2\_Gene\_W} / \text{MG\_CNT\_MG2\_max\_trq\_Gene\_Nm}$

## 5.3.7.5 Other information

None

### 5.3.8. [B32C: DCDC\_HI\_CNT] system functional specifications

Description of the functional specifications of the third layer DCDC\_HI\_CNT system of the guideline-compliant model.

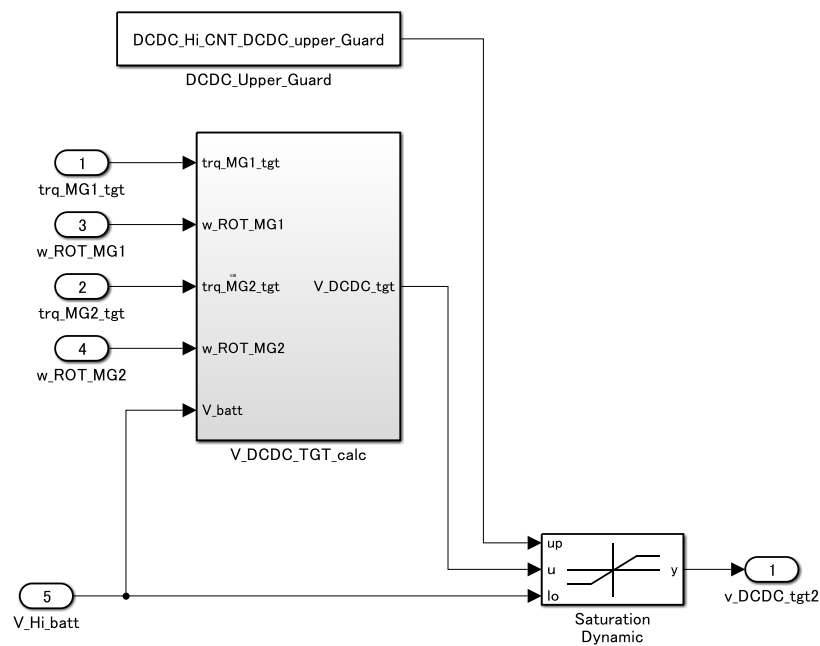
#### 5.3.8.1 Overview

The outline of this system is shown below.

- ① Modeling target  
Boost DCDC converter control ECU model
- ② Scope of modeling / degree of abstraction  
Calculation of the voltage for the motor drive system
- ③ Modeled functions  
A function to calculate the voltage from the target motor torque and motor speed

#### 5.3.8.2 Data flow diagram

The data flow diagram of this system is shown below.



**Fig. 5.3.8 Data flow diagram: 3rd layer DCDC\_HI\_CNT system**

## 5.3.8.3 Input/Output specifications

The input / output specifications of this system are shown below.

Inputs			
Name	Name	Name	Name
trq_MG1_tgt	Nm	TBD	MG1 target torque value
trq_MG2_tgt	Nm	TBD	MG2 target torque value
w_ROT_MG1	rad/s	TBD	MG1 motor drive system rotation speed
w_ROT_MG2	rad/s	TBD	MG2 motor drive system rotation speed
V_Hi_Batt	V	TBD	Voltage signal of High voltage battery output
Outputs			
Name	Name	Name	Name
v_DCDC_tgt2	V	TBD	Target voltage of the boost DCDC converter

## 5.3.8.4 Parameter specifications

The parameter specifications of this system are shown below.

Variable name	Set value	Unit	Explanation
DCDC_Hi_CNT_DCDC_upper_Guard	600	V	Max voltage of boost DCDC converter
DCDC_Hi_CNT_Vtgt_discre1st	275	V	Voltage discretization 1st stage voltage
DCDC_Hi_CNT_Vtgt_discre2nd	350	V	Voltage discretization 2nd stage voltage
DCDC_Hi_CNT_Vtgt_discre3rd	450	V	Voltage discretization 3rd stage voltage
DCDC_Hi_CNT_Vtgt_discre4th	600	V	Voltage discretization 4th stage voltage
DCDC_Hi_CNT_Vtgt_discre_th_1st	230	V	Voltage threshold of voltage discretization 1st stage
DCDC_Hi_CNT_Vtgt_discre_th_2nd	280	V	Voltage threshold of voltage discretization 2nd stage
DCDC_Hi_CNT_Vtgt_discre_th_3rd	355	V	Voltage threshold of voltage discretization 3rd stage
DCDC_Hi_CNT_Vtgt_discre_th_4th	455	V	Voltage threshold of voltage discretization 4th stage
DCDC_Hi_CNT_Vtgt_conv_hi_trq_Nm	<17x1>	Nm	Target voltage map of boost DCDC converter input1 target motor torque
DCDC_Hi_CNT_Vtgt_conv_hi_w_rpm	<1x18>	rpm	Target voltage map of boost DCDC converter input2 target motor speed
DCDC_Hi_CNT_Vtgt_conv_hi_V	<17x18>	V	Target voltage map of boost DCDC converter

## 5.3.8.5 Other information

None

### 5.3.9. [B11P: ENG\_PNT] system functional specifications

Description of the functional specifications of the third layer ENG\_PNT system of the guideline-compliant model.

#### 5.3.9.1 Overview

The outline of this system is shown below.

- ① Modeling target  
Engine model for fuel efficiency performance evaluation
- ② Scope of modeling / degree of abstraction  
A model that calculates the torque output after warming up the engine and the fuel consumption at that time.
- ③ Modeled functions  
Engine shaft torque output  
Fuel consumption calculation

#### 5.3.9.2 Data flow diagram

The data flow diagram of this system is shown below.

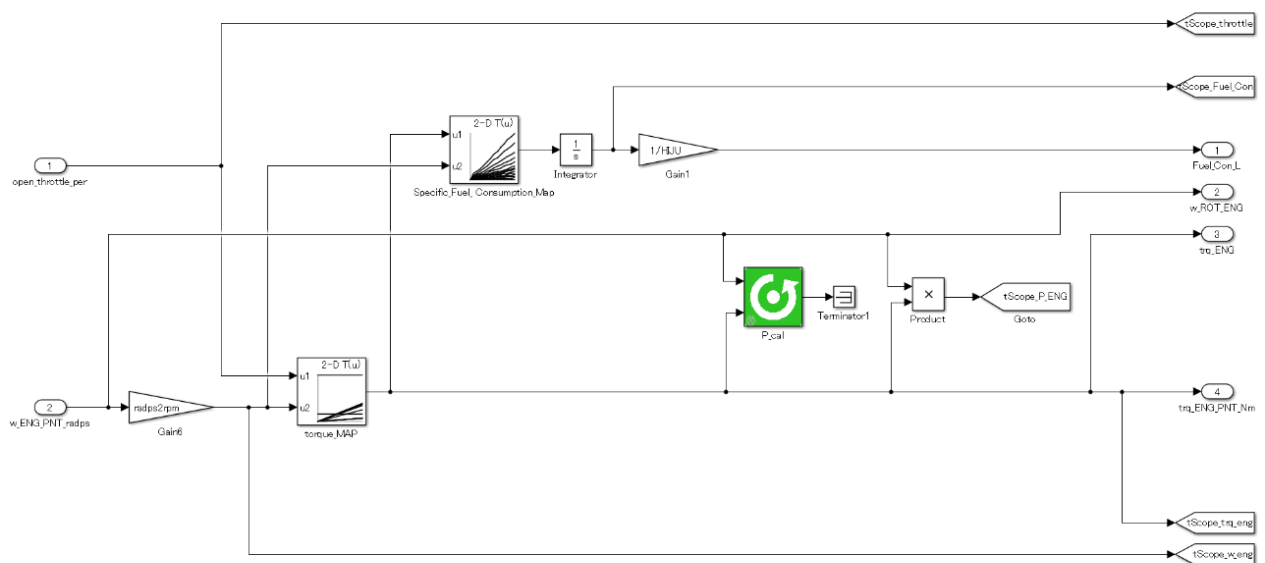


Fig. 5.3.9 Data flow diagram: 3rd layer ENG\_PNT system

## 5.3.9.3 Input/Output specifications

The input / output specifications of this system are shown below.

Inputs			
Name	Unit	Scope	Explanation
open_throttle_per	%	[0 100]	Throttle aperture
w_ENG_PNT_radps	rad/s	TBD	Engine rotation speed (radian base)
Outputs			
Name	Unit	Scope	Explanation
Fuel_Con_L	L	Greater than 0	Fuel consumption
w_ROT_ENG	rad/s	TBD	Engine rotation speed (radian base)
trq_ENG	Nm	TBD	Engine shaft torque
trq_ENG_PNT_Nm	Nm	TBD	Engine shaft torque

## 5.3.9.4 Parameter specifications

The parameter specifications of this system are shown below.

Variable name	Set value	Unit	Explanation
ENG_PNT_FuelCon_gps_map_x_pri_rpm	<1x14>	rpm	Fuel consumption rate map x-axis: engine speed
ENG_PNT_FuelCon_gps_map_y_trq_Nm	<1x14>	Nm	Fuel consumption rate map y-axis: engine shaft torque
ENG_PNT_FuelCon_gps_map	<14x14>	g/sec	Fuel consumption rate map
ENG_PNT_trq_Nm_map_x_rpm	<1x16>	rpm	Engine shaft torque map x-axis: engine speed
ENG_PNT_trq_Nm_map_y_throttle	<1x2>	%	Engine shaft torque map y-axis: accelerator throttle opening
ENG_PNT_trq_Nm_map	<2x16>	Nm	Engine shaft torque map z-axis: torque

## 5.3.9.5 Other information

None

### 5.3.10. [B12P: TM\_PNT] system functional specifications

Description of the functional specifications of the third layer TM\_PNT system of the guideline-compliant model.

#### 5.3.10.1 Overview

The outline of this system is shown below.

- ① Modeling target  
Transmission model for fuel efficiency performance evaluation
- ② Scope of modeling / degree of abstraction  
Engine inertia and transmission inertia  
Transmission reduction function
- ③ Modeled functions  
Function to reduce the motor speed  
Function to mix engine and generator power with planetary gears  
Function to calculate the rotation speed from the torque of each of the engine, generator, and drive shaft applied to the planetary gear

#### 5.3.10.2 Data flow diagram

The data flow diagram of this system is shown below.

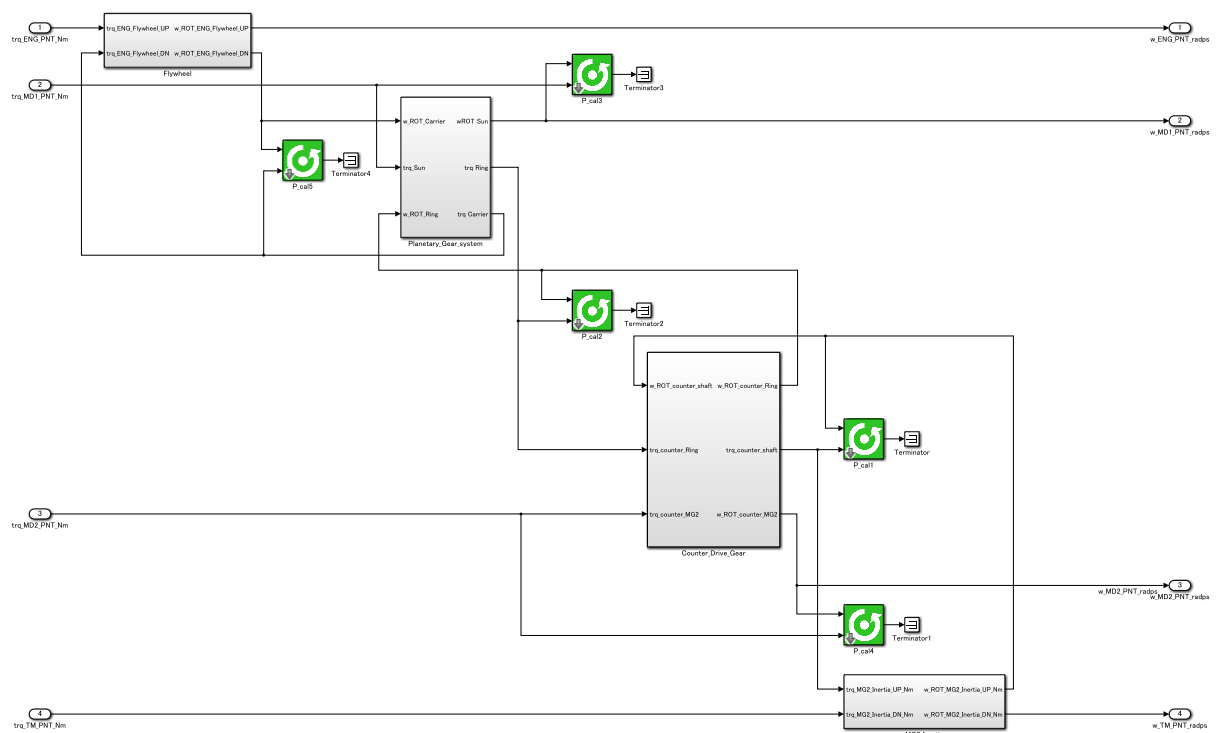


Fig. 5.3.10 Data flow diagram : 3rd layer TM\_PNT system



## 5.3.10.3 Input/Output specifications

The input / output specifications of this system are shown below.

Inputs			
Name	Unit	Scope	Explanation
trq_ENG_PNT_Nm	Nm	TBD	Engine torque
trq_MD1_PNT_Nm	Nm	TBD	Motor drive system torque (generator)
trq_MD2_PNT_Nm	Nm	TBD	Motor drive system torque (main traction motor)
trq_TM_PNT_Nm	Nm	TBD	Driveshaft torque
Outputs			
Name	Unit	Scope	Explanation
w_ENG_PNT_radps	rad/s	TBD	Engine rotation speed
w_MD1_PNT_radps	rad/s	TBD	Motor drive system rotation speed (generator)
w_MD2_PNT_radps	rad/s	TBD	Motor drive system rotation speed (main traction motor)
w_TM_PNT_radps	rad/s	TBD	Differential gear inlet rotation speed

## 5.3.10.4 Parameter specifications

The parameter specifications of this system are shown below.

Variable name	Set value	Unit	Explanation
TM_PNT_Flywheel_Inertia	0.24	kgm <sup>2</sup>	Flywheel inertia
TM_PNT_TM_Inertia	0.3	kgm <sup>2</sup>	Transmission inertia
TM_PNT_number_sungear	30	-	Sun gear number of teeth
TM_PNT_number_ringgear	78	-	Ring gear number of teeth
TM_PNT_number_outergear	65	-	Outer gear number of teeth
TM_PNT_number_MG2gear	17	-	MG2 gear number of teeth
TM_PNT_number_counterdrivengear	53	-	Counter gear number of teeth
TM_PNT_eta_outergear2countergear	0.97	-	Transmission efficiency between outer gear and counter gear
TM_PNT_eta_MG2gear2countergear	0.97	-	Transmission efficiency between MG2 gear and counter gear
TM_PNT_eta_planetarygear	0.95	-	Transmission efficiency of planetary gear

## 5.3.10.5 Other information

None

### 5.3.11. [B13P: DF\_PNT] system functional specifications

Description of the functional specifications of the third layer DF\_PNT system of the guideline-compliant model.

#### 5.3.11.1 Overview

The outline of this system is shown below.

- ① Modeling target  
Differential model for fuel efficiency performance evaluation
- ② Scope of modeling / degree of abstraction  
Transmission mechanism that reflects transmission efficiency during mode driving
- ③ Modeled functions  
Shifting function by differential gear ratio  
Torque loss due to differential gear efficiency

#### 5.3.11.2 Data flow diagram

The data flow diagram of this system is shown below.

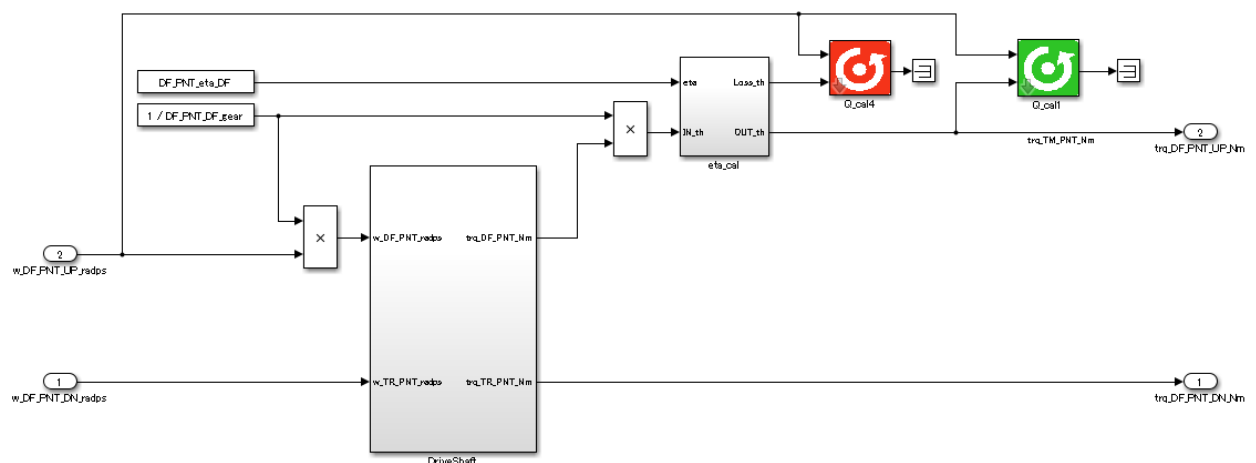


Fig. 5.3.11 Data flow diagram :3rd layerDF\_PNT system

## 5.3.11.3 Input/Output specifications

The input / output specifications of this system are shown below.

Inputs			
Name	Unit	Scope	Explanation
w_TR_PNT_radps	rad/s	TBD	Tire rotation speed
w_TM_PNT_radps	rad/s	TBD	Transmission rotation speed
Outputs			
Name	Unit	Scope	Explanation
trq_DF_PNT_Nm	Nm	TBD	Differential gear outlet torque
trq_TM_PNT_Nm	Nm	TBD	Differential gear inlet torque

## 5.3.11.4 Parameter specifications

The parameter specifications of this system are shown below.

Variable name	Set value	Unit	Explanation
DF_PNT_DF_gear	2.8	-	Differential gear reduction ratio
DF_PNT_eta_DF	0.96	-	Differential gear efficiency
DF_PNT_Driveshaft_Inertia	0.1	kgm <sup>2</sup>	Driveshaft inertia
DF_PNT_Driveshaft_spring	10000	-	Driveshaft spring coefficient
DF_PNT_Driveshaft_zeta	10	-	Second-order lag damping coefficient
DF_PNT_Driveshaft_damper	632.456[*1]	-	Driveshaft damper coefficient

$$[*1] \quad 2 * DF\_PNT\_Driveshaft\_zeta * \sqrt{DF\_PNT\_Driveshaft\_spring * DF\_PNT\_Driveshaft\_Inertia}$$

## 5.3.11.5 Other information

None

### 5.3.12. [B14P: BK\_PNT] system functional specifications

Description of the functional specifications of the third layer BK\_PNT system of the guideline-compliant model.

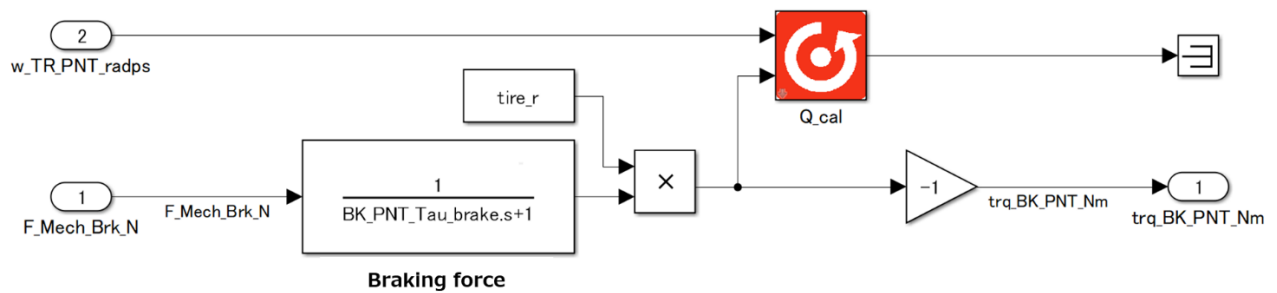
#### 5.3.12.1 Overview

The outline of this system is shown below.

- ① Modeling target  
Brake model for fuel efficiency performance evaluation
- ② Scope of modeling / degree of abstraction  
A model that generates braking force during mode driving
- ③ Modeled functions  
Function that outputs braking force in the form of driveshaft torque

#### 5.3.12.2 Data flow diagram

The data flow diagram of this system is shown below.



**Fig. 5.3.12 Data flow diagram: 3rd layer BK\_PNT system**

## 5.3.12.3 Input/Output specifications

The input / output specifications of this system are shown below.

Inputs			
Name	Unit	Scope	Explanation
F_Mech_Brk_N	N	TBD	Braking force
w_TR_PNT_radps	rad/s	TBD	Tire rotation speed
Outputs			
Name	Unit	Scope	Explanation
trq_BK_PNT_Nm	Nm	TBD	Braking force

## 5.3.12.4 Parameter specifications

The parameter specifications of this system are shown below.

Variable name	Set value	Unit	Explanation
BK_PNT_Tau_brake	0.15	-	Brake plant model braking force time constant
BK_PNT_Pow_UL	5000	N	Braking force upper limit
BK_PNT_Pow_LL	0	N	Braking force lower limit

## 5.3.12.5 Other information

None

### 5.3.13. [B15P: TR\_PNT] system functional specifications

Description of the functional specifications of the third layer TR\_PNT system of the guideline-compliant model.

#### 5.3.13.1 Overview

The outline of this system is shown below.

- ① Modeling target  
Tire model for fuel efficiency performance evaluation
- ② Scope of modeling / degree of abstraction  
A model that converts the rotational movement of the drive shaft into the translational movement of the vehicle and adds rolling resistance when in driving mode
- ③ Modeled functions  
Function that converts rotational motion to and from translational motion  
Function that adds the rolling resistance of the tire to the acceleration force of the translational motion

#### 5.3.13.2 Data flow diagram

The data flow diagram of this system is shown below.

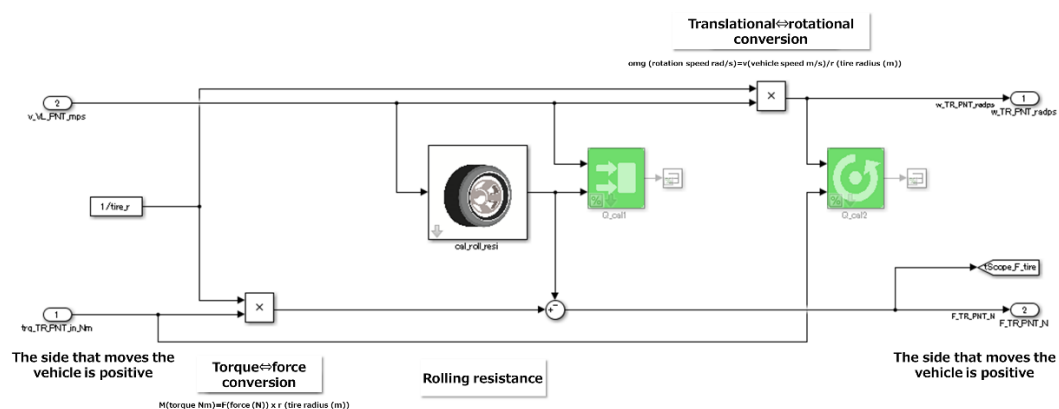


Fig. 5.3.13 Data flow diagram : 3rd layer TR\_PNT system

## 5.3.13.3 Input/Output specifications

The input / output specifications of this system are shown below.

Inputs			
Name	Unit	Scope	Explanation
trq_TR_PNT_in_Nm	Nm	TBD	Differential gear outlet torque braking force
v_VL_PNT_mps	m/s	TBD	Vehicle speed (unit: m/s)
Outputs			
Name	Unit	Scope	Explanation
w_TR_PNT_radps	rad/s	TBD	Tire rotation speed
F_TR_PNT_N	N	TBD	Tire propulsion (the direction in which the vehicle advances is positive)

## 5.3.13.4 Parameter specifications

This system only utilizes parameters common to the rest of the model.

## 5.3.13.5 Other information

None

### 5.3.14. [B16P: VL\_PNT] system functional specifications

Description of the functional specifications of the third layer VL\_PNT system of the guideline-compliant model.

#### 5.3.14.1 Overview

The outline of this system is shown below.

- ① Modeling target  
Vehicle dynamics model for fuel efficiency performance evaluation
- ② Scope of modeling / degree of abstraction  
Calculation of the translational speed of the vehicle and adds air resistance and climbing resistance to the vehicle's translational acceleration force
- ③ Modeled functions  
Function to obtain the vehicle speed from the translational acceleration force of the vehicle  
Function to obtain air resistance from the translation speed of the vehicle and add it to the translation acceleration force  
A function that obtains the climbing resistance on the vehicle and adds it to the translational acceleration force

#### 5.3.14.2 Data flow diagram

The data flow diagram of this system is shown below.

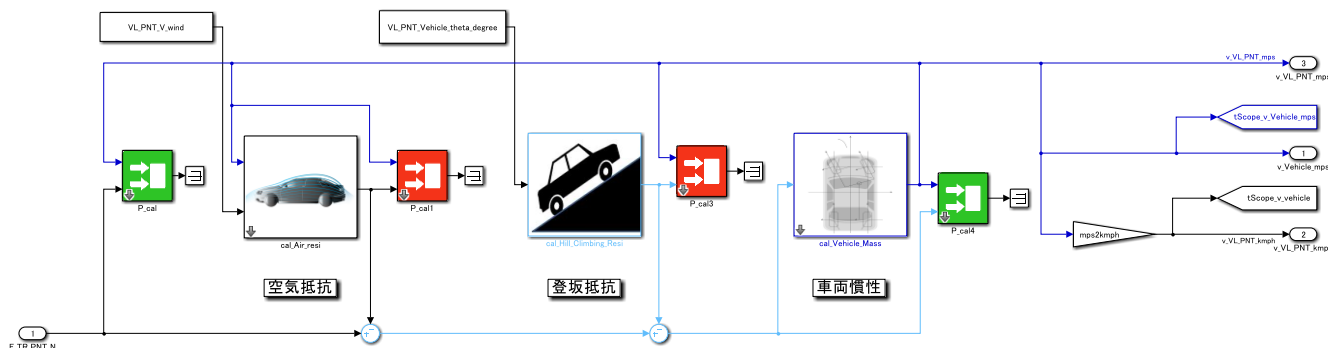


Fig. 5.3.14 Data flow diagram :3rd layer VL\_PNT system



## 5.3.14.3 Input/Output specifications

The input / output specifications of this system are shown below.

Inputs			
Name	Unit	Scope	Explanation
F_TR_PNT_N	N	TBD	Tire propulsion (the direction in which the vehicle advances is positive)
Outputs			
Name	Unit	Scope	Explanation
v_Vehicle_mps	m/s	TBD	Vehicle speed (unit: m/s)
v_VL_PNT_kmph	km/h	TBD	Vehicle speed
v_VL_PNT_mps	m/s	TBD	Vehicle speed (unit: m/s)

## 5.3.14.4 Parameter specifications

The parameter specifications of this system are shown below.

Variable name	Set value	Unit	Explanation
VL_PNT_Vehicle_theta_degree	0	deg	Climbing angle
VL_PNT_V_wind	0	m/s	Wind speed

## 5.3.14.5 Other information

None

### 5.3.15. [B21P:MD1\_PNT] system functional specifications

Description of the functional specifications of the third layer MD1\_PNT system of the guideline-compliant model.

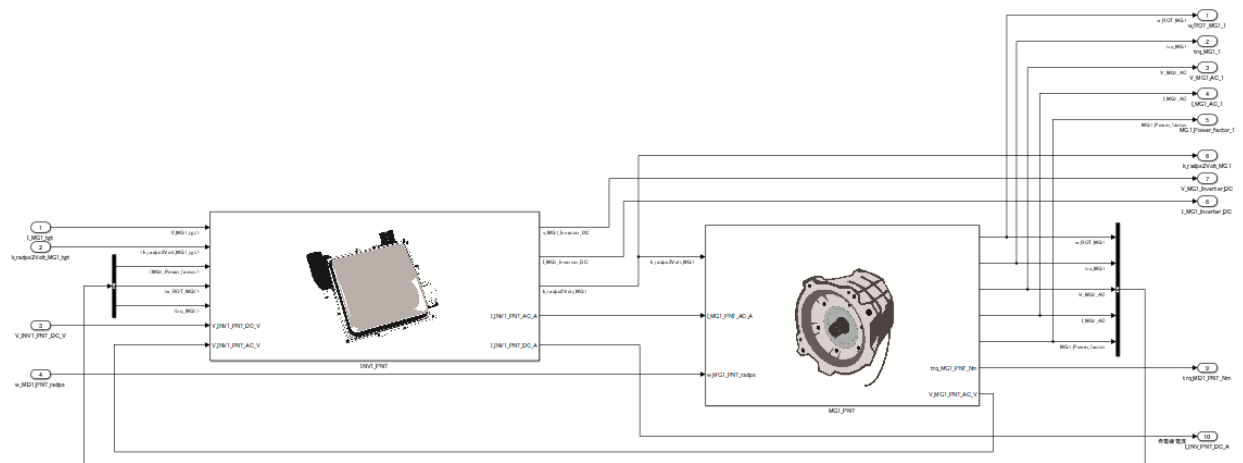
#### 5.3.15.1 Overview

The outline of this system is shown below.

- ① Modeling target  
Motor drive model for fuel efficiency performance evaluation
- ② Scope of modeling / degree of abstraction  
Calculation of electrical power  
Calculation of drive torque
- ③ Modeled functions  
Inverter function to control motor current and voltage  
Function that calculates torque and voltage from the motor

#### 5.3.15.2 Data flow diagram

The data flow diagram of this system is shown below.



**Fig. 5.3.15 Data flow diagram :3rd layer MD1\_PNT system**

## 5.3.15.3 Input/Output specifications

The input / output specifications of this system are shown below.

Inputs			
Name	Unit	Scope	Explanation
I_MG1_tgt	A	TBD	Current target value
k_radps2Volt_MG1_tgt	-	TBD	Back electromotive force coefficient target value
V_BT_HI_PNT_V	V	TBD	High-voltage battery voltage
w_MD1_PNT_radps	rad/s	TBD	Motor drive system rotation speed
Outputs			
Name	Unit	Scope	Explanation
w_ROT_MG1	rad/s	TBD	Motor drive system rotation speed
trq_MG1	Nm	TBD	Motor drive system torque
V_MG1_AC	V	TBD	Motor drive system voltage
I_MG1_AC	A	TBD	Motor drive system current
MG1_Power_factor	-	TBD	Motor drive system power factor
k_radps2Volt_MG1	-	TBD	Back electromotive force coefficient target value
v_MG1_Inverter_DC	V	TBD	Motor drive system voltage
I_MG1_Inverter_DC	A	TBD	Motor drive system current
Trq_MD1_PNT_Nm	Nm	TBD	Motor drive system torque
I_MD1_PNT_DC_A	A	TBD	Motor drive system current

## 5.3.15.4 Parameter specifications

The parameter specifications of this system are shown below.

Variable name	Set value	Unit	Explanation
MG_PNT_MG1_Inv_eta	<13x13>	-	Inverter efficiency
MG_PNT_MG1_Inv_eta_x_rpm	<1x13>	rpm	Efficiency map x-axis: rotation speed
MG_PNT_MG1_Inv_eta_y_trq	<1x13>	Nm	Efficiency map y-axis: torque
MG_PNT_MG1_mod_factor	0.78	-	Inverter modulation rate (sine wave modulation region only)
MG_PNT_MG1_WeakField_UL	1.0	-	Weak field permeability upper limit
MG_PNT_MG1_WeakField_LL	0.05	-	Weak field permeability lower limit
MG_PNT_MG1_eta	<13x13>	-	Motor efficiency
MG_PNT_MG1_eta_x_rpm	<1x13>	rpm	Efficiency map x-axis: rotation speed
MG_PNT_MG1_eta_y_trq	<1x13>	Nm	Efficiency map y-axis: torque
MG_PNT_MG1_Power_factor	0.85	-	Motor power factor
MG_PNT_V_MG1_Rated	600	V	Motor inverter DC rated voltage
MG_PNT_w_ROT_MG1_Rated	[*1]	rpm	Rated motor rotation speed
MG_PNT_loss_mech_MG1_trq	<1x2>	Nm	Torque of friction map
MG_PNT_loss_mech_MG1_rads	<1x2>	rad/s	Torque of friction map input MG1 speed

[\*1] MG\_CNT\_MG1\_Const\_trq\_ReGene\_radps

5.3.15.5 Other information

None

### 5.3.16. [B22P:MD2\_PNT] system functional specifications

Description of the functional specifications of the third layer MD2\_PNT system of the guideline-compliant model.

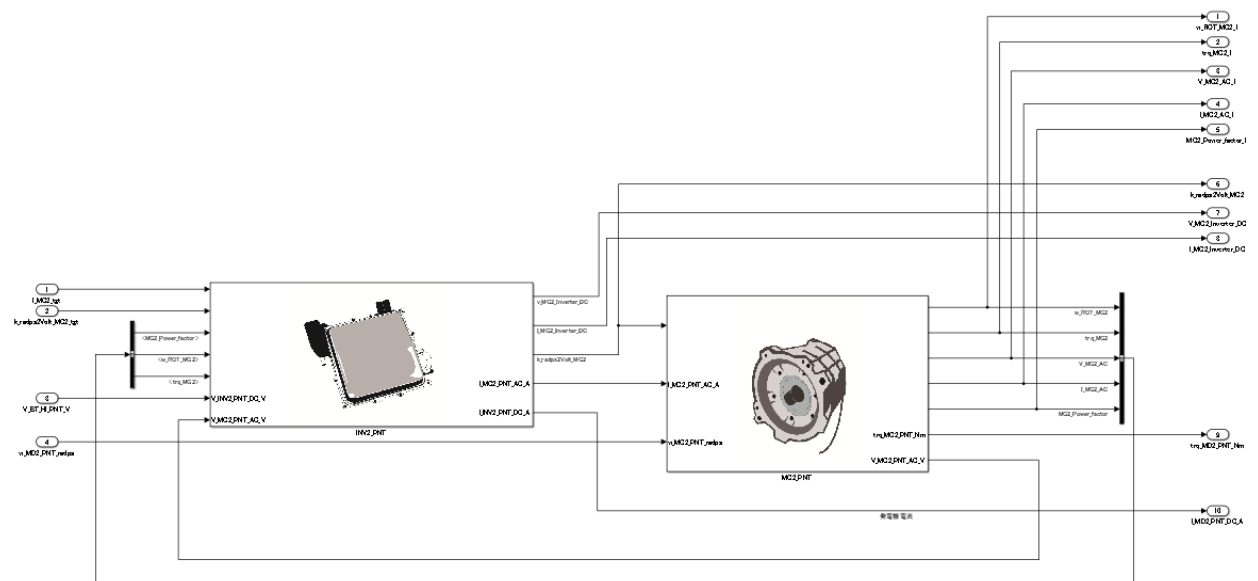
### 5.3.16.1 Overview

The outline of this system is shown below.

- ① Modeling target  
Motor drive system for fuel efficiency performance evaluation
- ② Scope of modeling / degree of abstraction  
Calculation of electrical power  
Calculation of drive torque
- ③ Modeled functions  
Inverter function to control motor current and voltage  
Function that calculates torque and voltage from the motor

#### 5.3.16.2 Data flow diagram

The data flow diagram of this system is shown below.



**Fig. 5.3.16 Data flow diagram :3rd layer MD2 PNT system**

## 5.3.16.3 Input/Output specifications

The input / output specifications of this system are shown below.

Inputs			
Name	Unit	Scope	Explanation
I_MG2_tgt	A	TBD	Current target value
k_radps2Volt_MG2_tgt	-	TBD	Back electromotive force coefficient target value
V_BT_HI_PNT_V	V	TBD	High-voltage battery voltage
w_MD2_PNT_radps	rad/s	TBD	Motor drive system rotation speed
Outputs			
Name	Unit	Scope	Explanation
w_ROT_MG2	rad/s	TBD	Motor drive system rotation speed
trq_MG2	Nm	TBD	Motor drive system torque
V_MG2_AC	V	TBD	Motor drive system voltage
I_MG2_AC	A	TBD	Motor drive system current
MG2_Power_factor	-	TBD	Motor drive system power factor
k_radps2Volt_MG2	-	TBD	Back electromotive force coefficient target value
v_MG2_Inverter_DC	V	TBD	Motor drive system voltage
I_MG2_Inverter_DC	A	TBD	Motor drive system current
Trq_MD2_PNT_Nm	Nm	TBD	Motor drive system torque
I_MD2_PNT_DC_A	A	TBD	Motor drive system current

## 5.3.16.4 Parameter specifications

The parameter specifications of this system are shown below.

Variable name	Set value	Unit	Explanation
MG_PNT_MG2_Inv_eta	<1x13>	-	Inverter efficiency
MG_PNT_MG2_Inv_eta_x_rpm	<13x1>	rpm	Efficiency map x-axis: rotation speed
MG_PNT_MG2_Inv_eta_y_trq	<13x13>	Nm	Efficiency map y-axis: torque
MG_PNT_MG2_mod_factor	0.78	-	Inverter modulation rate (sine wave modulation region only)
MG_PNT_MG2_WeakField_UL	1	-	Weak field permeability upper limit
MG_PNT_MG2_WeakField_LL	0.05	-	Weak field permeability lower limit
MG_PNT_MG2_eta	<1x13>	-	Motor efficiency
MG_PNT_MG2_eta_x_rpm	<13x1>	rpm	Efficiency map x-axis: rotation speed
MG_PNT_MG2_eta_y_trq	<13x13>	Nm	Efficiency map y-axis: torque
MG_PNT_MG2_Power_factor	0.85	-	Motor power factor
MG_PNT_V_MG2_Rated	600	V	Motor inverter DC rated voltage
MG_PNT_w_ROT_MG2_Rated	325.153 [*7]	rpm	Rated motor rotation speed

[\*1] MG\_CNT\_MG2\_Const\_trq\_ReGene\_radps

## 5.3.16.5 Other information

None

### 5.3.17. [B31P: BT\_HI\_PNT] system functional specifications

Description of the functional specifications of the third layer BT\_HI\_PNT system of the guideline-compliant model.

#### 5.3.17.1 Overview

The outline of this system is shown below.

- ① Modeling target  
High-voltage battery model for fuel efficiency performance evaluation
- ② Scope of modeling / degree of abstraction  
Determination of OCV voltage according to the SOC  
Determination of the terminal voltage by subtracting the charge / discharge current and the voltage drop due to internal resistance.
- ③ Modeled functions  
Function to calculate SOC through charge / discharge current  
Function that determines of OCV voltage according to the SOC  
Function that calculates the voltage drop based on the charge / discharge current and internal resistance

#### 5.3.17.2 Data flow diagram

The data flow diagram of this system is shown below.

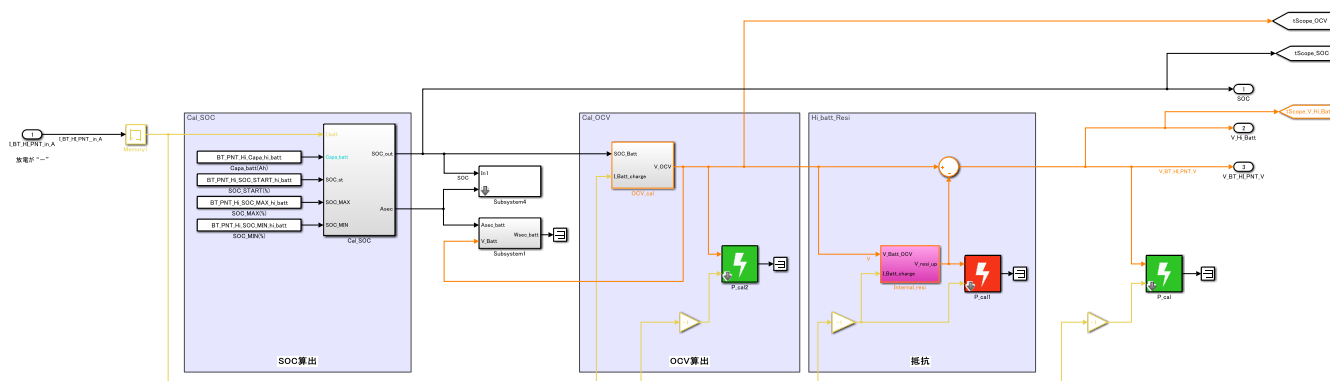


Fig. 5.3.17 Data flow diagram :3rd layer BT\_HI\_PNT system

## 5.3.17.3 Input/Output specifications

The input / output specifications of this system are shown below.

Inputs			
Name	Unit	Scope	Explanation
I_BT_HI_PNT_A	A	TBD	High-voltage battery input current
Outputs			
Name	Unit	Scope	Explanation
SOC	-	TBD	SOC
V_Hi_Batt	V	TBD	High-voltage battery voltage signal
V_BT_HI_PNT_V	V	TBD	High-voltage battery voltage

## 5.3.17.4 Parameter specifications

The parameter specifications of this system are shown below.

Variable name	Set value	Unit	Explanation
BT_PNT_Hi_Capa_hi_batt	3.6	Ah	High-voltage battery capacity
BT_PNT_Hi_SOC_START_hi_batt	72	%	High-voltage battery SOC initial value
BT_PNT_Hi_SOC_MAX_hi_batt	100	%	High-voltage battery SOC maximum value
BT_PNT_Hi_SOC_MIN_hi_batt	0	%	High-voltage battery SOC minimum value
BT_PNT_Hi_ocv_SOC_hi_batt_OCV_V_table_x_SOC	<1x10>	%	High-voltage battery OCV calculation MAP x-axis: SOC
BT_PNT_Hi_ocv_SOC_hi_batt_OCV_V_table	<1x10>	V	High-voltage battery OCV calculation MAP y-axis: OCV
BT_PNT_Hi_R_hi_batt_cell	0.005	Ω	High-voltage battery internal cell resistance
BT_PNT_Hi_R_hi_batt_others	0	Ω	High-voltage battery internal cell resistance

## 5.3.17.5 Other information

None





## 5.3.18.3 Input/Output specifications

The input / output specifications of this system are shown below.

Input			
Name	Unit	Scope	Explanation
v_DCDC_tgt2	V	TBD	Target voltage of boost DCDC converter
V_BT_HI_PNT_V	V	TBD	High-voltage side voltage value
I_MD_PNT_DC_A	A	TBD	Motor drive system side current
Output			
Name	Unit	Scope	Explanation
V_DCDC_Hi_V	V	TBD	Boost DCDC converter voltage
I_DCDC_Hi_A	A	TBD	Boost DCDC converter current

## 5.3.18.4 Parameter specifications

The parameter specifications of this system are shown below.

Variable name	Set value	Unit	Explanation
DCDC_Hi_PNT_eta_conv_hi_I	0.97	-	Boost converter efficiency

## 5.3.18.5 Other information

None

### 5.3.19. [B33P: EL\_HI\_PNT] system functional specifications

Description of the functional specifications of the third layer EL\_HI\_PNT system of the guideline-compliant model.

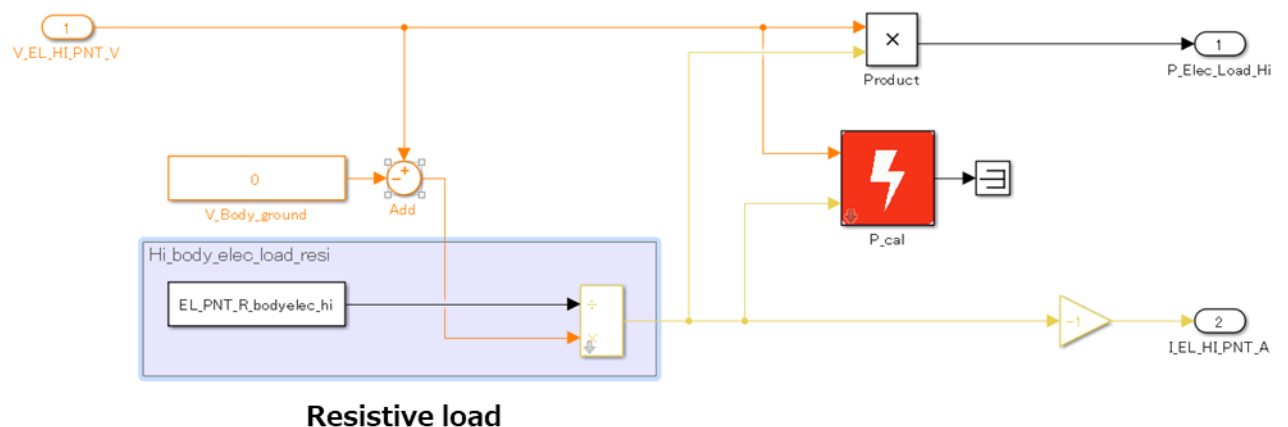
#### 5.3.19.1 Overview

The outline of this system is shown below.

- ① Modeling target  
High-voltage electrical load model for fuel efficiency performance evaluation
- ② Scope of modeling / degree of abstraction  
Calculate the current consumption on the high-voltage side during mode driving
- ③ Modeled functions  
Function to calculate current consumption according to the terminal voltage of high-voltage load

#### 5.3.19.2 Data flow diagram

The data flow diagram of this system is shown below.



**Fig. 5.3.19 Data flow diagram: 3rd layer EL\_HI\_PNT system**

## 5.3.19.3 Input/Output specifications

The input / output specifications of this system are shown below.

Inputs			
Name	Unit	Scope	Explanation
V_EL_HI_PNT_V	V	TBD	High-voltage side voltage value
Outputs			
Name	Unit	Scope	Explanation
P_Elec_Load_Hi	W	TBD	High-voltage side electrical load power consumption
I_EL_HI_PNT_A	A	TBD	High-voltage side current value

## 5.3.19.4 Parameter specifications

The parameter specifications of this system are shown below.

Variable name	Set value	Unit	Explanation
EL_PNT_R_bodyelec_hi	4000 [*1]	$\Omega$	High-voltage side electrical load resistance

[\*1]  $4000(\Omega) = 200(V) / 0.05(A)$  Resistance value at which a current of 0.05A is flows when a 200V voltage is applied

## 5.3.19.5 Other information

None

### 5.3.20. [B34P: DCDC\_PNT] system functional specifications

Description of the functional specifications of the third layer DCDC\_PNT system of the guideline-compliant model.

#### 5.3.20.1 Overview

The outline of this system is shown below.

- ④ Modeling target  
Buck converter model
- ⑤ Scope of modeling / degree of abstraction  
Voltage drops from high-voltage side to low-voltage side
- ⑥ Modeled functions  
Function to drop the voltage from the high voltage side to the low voltage side considering conversion efficiency

#### 5.3.20.2 Data flow diagram

The data flow diagram of this system is shown below.

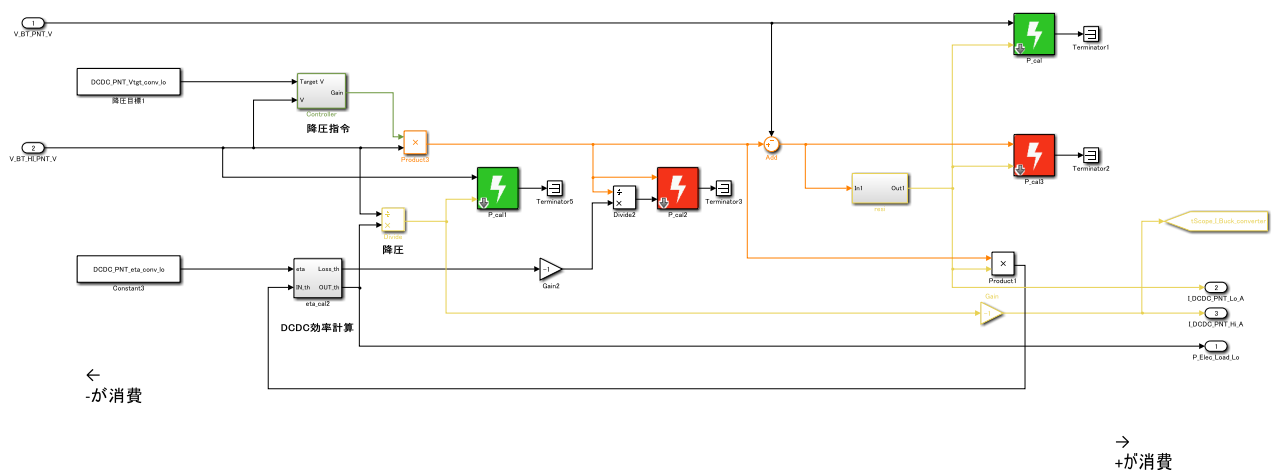


Fig. 5.3.20 Data flow diagram :3rd layer DCDC\_PNT system

## 5.3.20.3 Input/Output specifications

The input / output specifications of this system are shown below.

Inputs			
Name	Unit	Scope	Explanation
V_BT_PNT_V	V	TBD	Low-voltage side voltage value
V_BT_HI_PNT_V	V	TBD	High-voltage side voltage value
Outputs			
Name	Unit	Scope	Explanation
P_Elec_Load_Lo	W	TBD	Buck converter power consumption
I_DCDC_PNT_Lo_A	A	TBD	Low-voltage side current
I_DCDC_PNT_Hi_A	A	TBD	High-voltage side current

## 5.3.20.4 Parameter specifications

The parameter specifications of this system are shown below.

Variable name	Set value	Unit	Explanation
DCDC_PNT_eta_conv_lo	0.95	-	Buck converter efficiency
DCDC_PNT_R_conv_lo	0.02	$\Omega$	Buck converter resistance value
DCDC_PNT_Vtgt_conv_lo	14.0	V	Target buck converter voltage value

## 5.3.20.5 Other information

None

### 5.3.21. [B35P:BT\_PNT] system functional specifications

Description of the functional specifications of the third layer BT\_PNT system of the guideline-compliant model.

#### 5.3.21.1 Overview

The outline of this system is shown below.

- ① Modeling target  
Low-voltage battery model for fuel efficiency performance evaluation
- ② Scope of modeling / degree of abstraction  
Determination of OCV voltage according to the SOC  
Determination of the terminal voltage by subtracting the charge / discharge current and the voltage drop due to internal resistance
- ③ Modeled functions  
Function to calculate SOC through charge / discharge current  
Function that determines of OCV voltage according to the SOC  
Function that calculates the voltage drop based on the charge / discharge current and internal resistance

#### 5.3.21.2 Data flow diagram

The data flow diagram of this system is shown below.

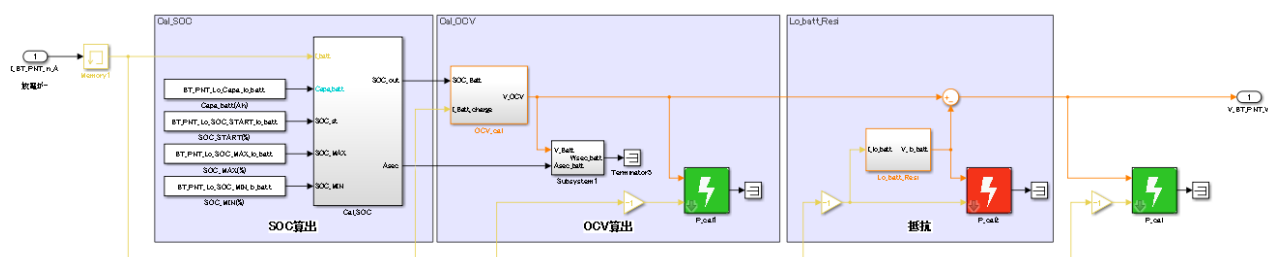


Fig. 5.3.21 Data flow diagram : 3rd layer BT\_PNT system

## 5.3.21.3 Input/Output specifications

The input / output specifications of this system are shown below.

Inputs			
Name	Unit	Scope	Explanation
I_BT_PNT_in_A	A	TBD	Low-voltage battery current value
Outputs			
Name	Unit	Scope	Explanation
V_BT_PNT_V	V	TBD	Low-voltage battery voltage value

## 5.3.21.4 Parameter specifications

The parameter specifications of this system are shown below.

Variable name	Set value	Unit	Explanation
BT_PNT_Lo_Capa_lo_batt	45	Ah	Low-voltage battery capacity
BT_PNT_Lo_SOC_START_lo_batt	95	%	Low-voltage battery SOC initial value
BT_PNT_Lo_SOC_MAX_lo_batt	120	%	Low-voltage battery SOC maximum value
BT_PNT_Lo_SOC_MIN_lo_batt	0	%	Low-voltage battery SOC minimum value
BT_PNT_Lo_ocv_SOC_lo_batt_OCV_V_table_x_SOC	[0,100]	%	Battery OCV calculation TABLE x-axis: SOC
BT_PNT_Lo_ocv_SOC_lo_batt_OCV_V_table	[10.5,14]	V	Battery OCV calculation TABLE
BT_PNT_Lo_R_lo_batt_ohm	0.01	$\Omega$	Battery internal resistance value

## 5.3.21.5 Other information

None



### 5.3.22. [B36P: EL\_PNT] system functional specifications

Description of the functional specifications of the third layer EL\_PNT system of the guideline-compliant model.

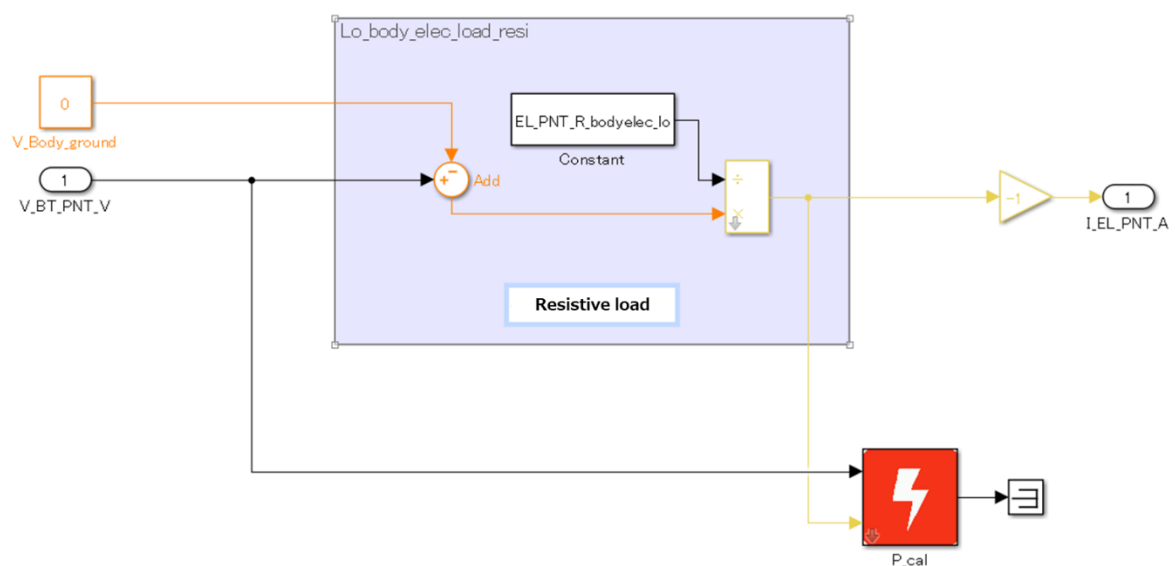
#### 5.3.22.1 Overview

The outline of this system is shown below.

- ① Modeling target  
Low-voltage electrical load model for fuel efficiency performance evaluation
- ② Scope of modeling / degree of abstraction  
Calculate the current consumption on the low-voltage side during mode driving
- ③ Modeled functions  
Function to calculate current consumption according to the terminal voltage of high-voltage load

#### 5.3.22.2 Data flow diagram

The data flow diagram of this system is shown below.



**Fig. 5.3.22 Data flow diagram :3rd layer EL\_PNT system**

## 5.3.22.3 Input/Output specifications

The input / output specifications of this system are shown below.

Inputs			
Name	Unit	Scope	Explanation
V_BT_PNT_V	V	TBD	Low-voltage side voltage value
Outputs			
Name	Unit	Scope	Explanation
I_EL_PNT_A	A	TBD	Low-voltage side current value

## 5.3.22.4 Parameter specifications

The parameter specifications of this system are shown below.

Variable name	Set value	Unit	Explanation
EL_PNT_R_bodyelec_lo_ohm	1.037 [*1]	$\Omega$	Low-voltage side electrical load resistance

[\*1]  $1.037(\Omega) = 14(V) / 13.5(A)$  Resistance value at which a current of 13.5A is flows when a 14V voltage is applied

## 5.3.22.5 Other information

None

## 6. About the description in this model

### 6.1. Purpose

The method of describing the model to in order to understand it is shown below.

It does not specify how to make the descriptions in Matlab® Simulink®.

### 6.2. Prerequisites

JMAAB's "PLANT MODELING GUIDELINES USING MATLAB ® and Simulink ® Version 2.1 Japan MATLAB Automotive Board (JMAAB) December 2, 2008" [2] was used as a reference when creating this model. Hereinafter, this is referred to as the "Plant Modeling Guideline".

However, the notation method of this model does not necessarily follow all the plant modeling guidelines, and is defined as a way to understand this model.

### 6.3. Diagnostic parameter settings

#### 6.3.1. Solver settings

No specifics defined.

#### 6.3.2. Diagnostic parameter settings

Compliant with JP2103 "Diagnostic Parameter Setting" of the Plant Modeling Guideline.

### 6.4. Naming

#### 6.4.1. Allowed characters

The characters used in the label names of subsystems and signal lines are based on the characters that can be used in the names specified in JP2503 "Subsystem".

### 6.4.2. Subsystem naming

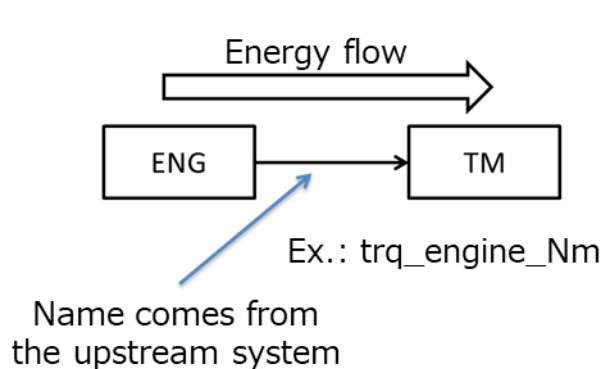
Subsystem names are shown in the table below.

**Table 6.1 Subsystem name table**

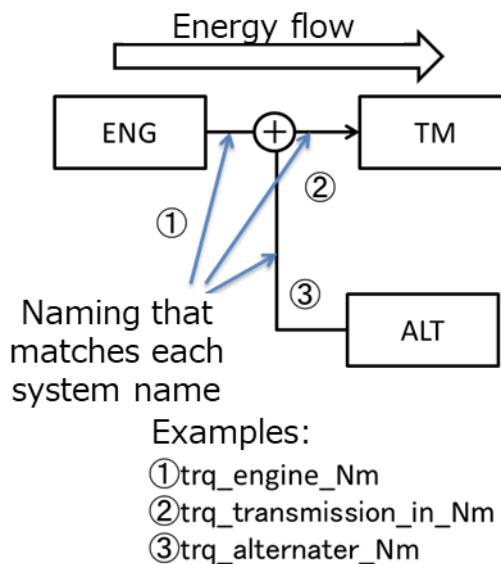
First layer			Second layer			Third layer			Fourth layer		
Part	Notation	Abbreviation	Part	Notation	Abbreviation	Part	Notation	Abbreviation	Part	Notation	Abbreviation
Driver	Driver										
Vehicle	Vehicle		Vehicle Control	VehicleController	VC	Hybrid Control	HybridControl	HV_CNT			
						Brake Control	BrakeControl	BK_CNT			
						Engine Control	EngineControl	ENG_CNT			
						Motor drive system 1 (generator)	MotorGeneratorControl1	MG1_CNT			
						Motor drive system 2 (main traction motor)	MotorGeneratorControl2	MG2_CNT			
						Boost DCDC converter Control	DCDCHiConverterControl	DCDC_HI_CNT			
			Vehicle Plant	VehicleBody	VB	Engine	Engine	ENG_PNT			
						Transmission	Transmission	TM_PNT	Flywheel	Flywheel	FW_PNT
									Planetary Gear	PlanetaryGear	PG_PNT
									Counter Drive Gear	CounterDriveGear	CG_PNT
						Differential gear	DifferentialGear	DF_PNT	Driveshaft	DriveShaft	DS_PNT
						Brake	Brake	BK_PNT			
						Tire	Tire	TR_PNT			
						Vehicle load	VehicleLoad	VL_PNT			
						Motor drive system 1	MotorDrive1	MD1_PNT	Inverter 1	Inverter1	INV1_PNT
									Motor generator 1	MotorGenerator1	MG1_PNT
						Motor drive system 2	MotorDrive2	MD2_PNT	Inverter 2	Inverter2	INV2_PNT
									Motor generator 2	MotorGenerator2	MG2_PNT
						High-voltage battery	BatteryHighVoltage	BT_HI_PNT			
						Boost DCDC converter	DCDCHiConverter	DCDC_HI_PNT			
						High-voltage electrical load	ElectricalLoadHigh	EL_HI_PNT			
						DCDC converter	DCDCConverter	DCDC_PNT			
						Battery	BatteryVoltage	BT_PNT			
						Electrical load	ElectricalLoad	EL_PNT			
Monitor	Monitor										

### 6.4.3. Signal naming

The naming is based on the flow of energy as follows.



In the case they are not separated



In the case they are separated

**Fig. 6.4.1 Signal naming methods**

#### 6.4.4. Inputs/outputs port naming

Name the plant and control separately as follows.

Plant I/F: Quantity table symbol\_ systemname( \_meaning\_ unit)

Control I/F : Meaning\_ systemname \_[unit]

Example: Plant

Physical signal:    omega : rotation speed

system name:       proposal 1: who is giving the output?

proposal 2: Energy flow upstream system name is given: engine is seen as engine

omg\_engine(\_radps)

Example: Control

Engine rotation speed(rpm)

n\_engine\_rpm

#### 6.4.5. Parameter naming

At the beginning of the parameter name, the subsystem name is given.

systemname\_ meaning\_ [unit]

Example: engine\_nEngine\_rpm

## 6.5. System model structure

Regarding the configuration of the plant model, the following proposals have been made, and this model is based on proposal 3.

<Proposal 1>

Refer to the Plant Modeling Guideline JP3001 “Plant model structure (Model Architecture)”.

The control model in the current Simulink model is made independent of the plant model. The reason is that the control and the plant are originally integrated, but depending on the supplier, only the control and only the plant exist, therefore it is made to address this. This is done from a maintenance point of view.

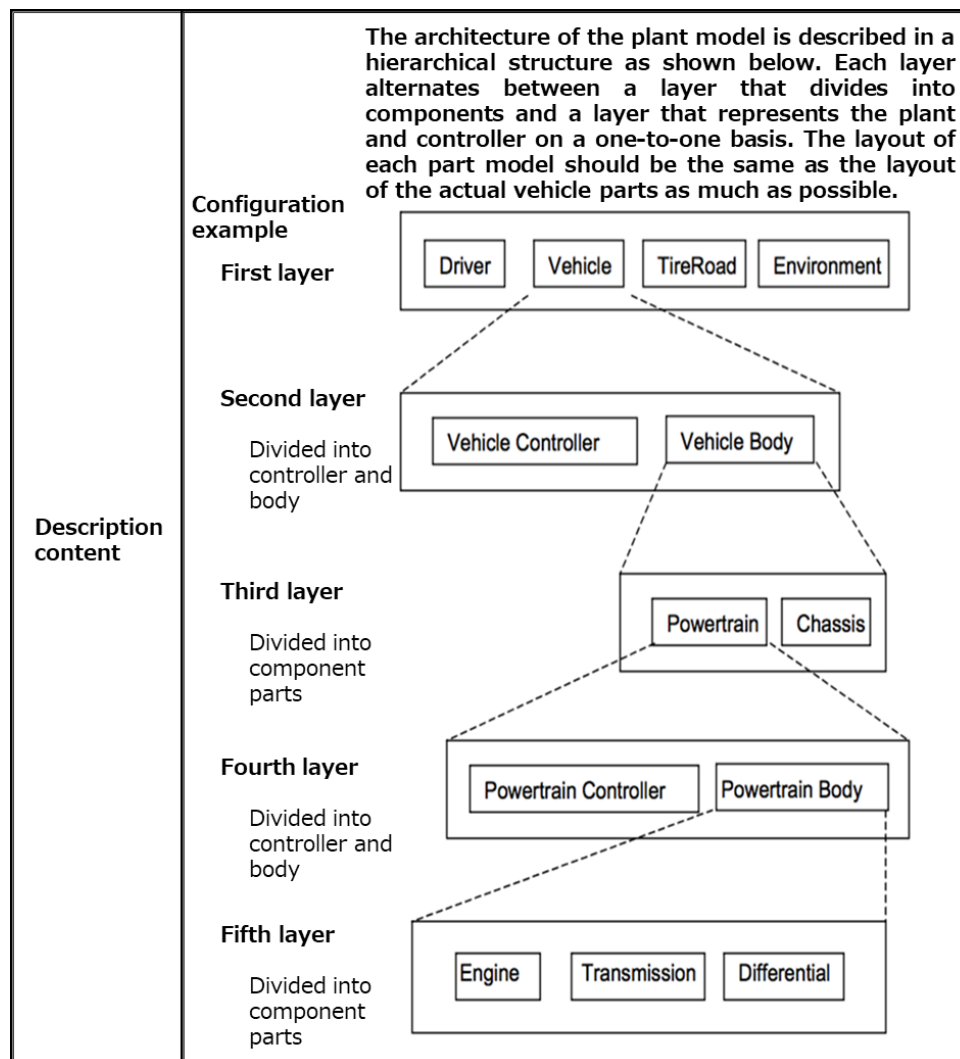


Fig. 6.5.1 JP3001 “plant structure”

<Proposal 2>

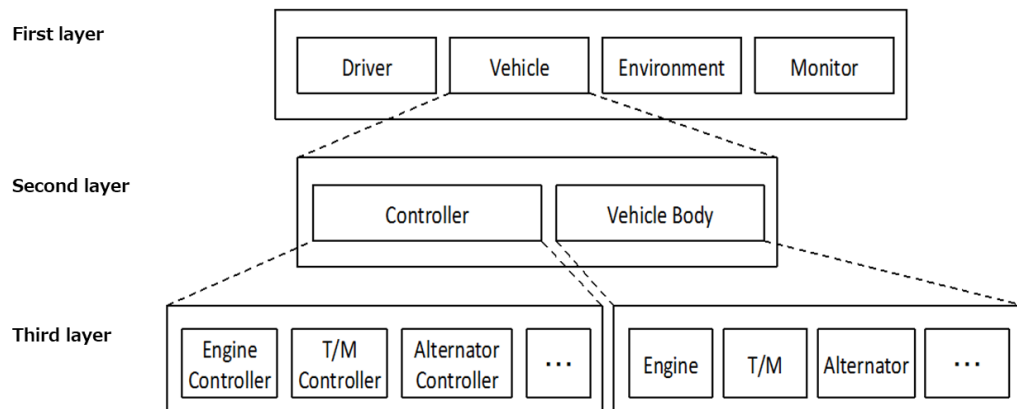
The plant and control model are in the same hierarchy.

In order to carry out the distribution using this model as a base, it is better to make the ECU and mechanism of the system one single sub-system (from the supplier's point of view, there is the concern of the possibility that the know-how can be leaked through the monitoring of the command values from the ECU).

<Proposal 3>

We separate the plant and the control into two broad categories.

In order to clarify it as a model compliant with the I / F guidelines between plant models, we set an architecture between models that makes it easy to understand.

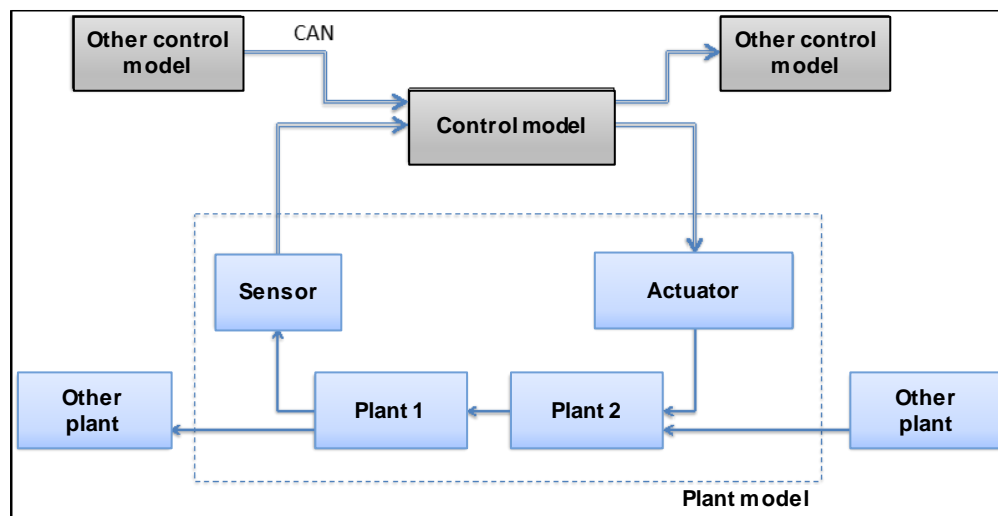


**Fig. 6.5.2 Structure in which control and plant are largely separated in the same layer**

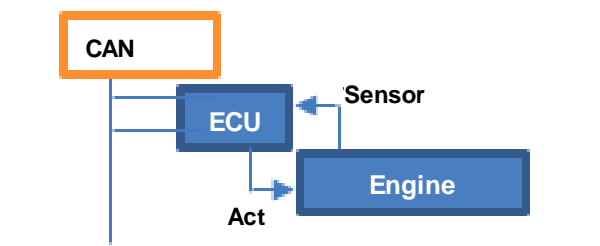
## 6.6. Intefase

### 6.6.1. Types

(1) Physical I / F (2) Sensor (3) Actuator (4) Define I / F separately from CAN. The details are described as follows.



Low readability (hard to understand what signals are sent/received)



**Fig. 6.6.1 I/F Types and description methods**

### 6.6.2. Bus

Buses are basically used for control / sensor / actuator signals. The reason is that the inputs and outputs become too many, and the structure becomes spaghettiified. However, there is a disadvantage and that is that it is difficult to see what kind of inputs and outputs are made from the upper level.

## 6.7. Units

Variables values and quantities handled in the model in should in principle follow the rules shown below.

### ① Plant model

Follow the unit system of the plant model I / F guideline.

However, for monitoring, rotation speed in rpm and speed in km/h are output to the monitors.

### ② Control model

Comply with each I / F specification.

A list of units is shown below.

**Table 6.2 List of units used in the model**

SI base units

Basic quantity	Name	Symbol	Alphabet notation in the model
length	meter	m	m
mass	kilogram	kg	kg
time	second	s	s
current	ampere	A	A
thermodynamic temperature	kelvin	K	K
amount of substance	mol	mol	mol
luminous intensity	candela	cd	cd

SI derived units with special names

Quantity	Name	Symbol	Alphabet notation in the model
plane angle	radian	rad	rad
frequency	hertz	Hz	Hz
force	newton	N	N
pressure, stress	pascal	Pa	Pa
energy	joule	J	J
Work load, heat load			
work rate, electric power	watt	W	W
electric charge	coulomb	C	C
voltage, electric potential	volt	V	V
electrostatic capacitance	farad	F	F
electric resistance	ohm	$\Omega$	ohm
celsius temperature	celsius degree	$^{\circ}\text{C}$	dC(=degree Celsius)
inductance	henry	H	H



## 6.8. Parameter handling

There are m files for each system parameter and each m file is read as an executable file. The following points are covered.

- Overall parameter management
- General physical value
- All common parameters (Unit conversion, etc.)
- Each system parameter

It is basically forbidden to write parameters directly to the model.

In addition, parameters are managed in each system.

## 6.9. Types

Compliant with the Plant Modeling Guideline JP5001 "Data Type".

Basically, use the default values. Logical values are not used in the calculations.

If there are exceptions, describe them in the model specifications.

In addition, although not compliant items, the following points must be noted.

- 64bit / 32bit in double precision floating point
- Necessity to use counters in non-linear models
- Floating point error when writing in double type
- For example, something as a gear stage signal should be handled as an integer, so if the premise of "the physical quantity exchanged between model components" is made, it is agreeable

## 6.10. Other considerations

Regarding the rules for model creation, it is necessary to consider the following viewpoints and issues in the future.

- Use of Simulink standard libraries only
- Use of Stateflow is not allowed in principle  
(because some users may not have a Stateflow libraries available in their environments)

## 7. References

- [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”
- [2] “PLANT MODELING GUIDELINES USING MATLAB® and Simulink® Version 2.1 Japan  
MATLAB Automotive Board (JMAAB) December 2, 2008”  
Source: [http://jmaab.mathworks.jp/doc/plantmodeling\\_sg/PMSG\\_english\\_v2.1.pdf](http://jmaab.mathworks.jp/doc/plantmodeling_sg/PMSG_english_v2.1.pdf)