# Plant model I / F guideline-compliant model manual for automobile development (Fuel efficiency model for series hybrid 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 1.2 [L], which is a model assuming a series 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-down control
- Plant
  - Engine
  - Transmission
  - Differential gear
  - Brake
  - Tire
  - Vehicle
  - Motor drive system
  - High voltage battery
  - High voltage electrical load
  - 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.

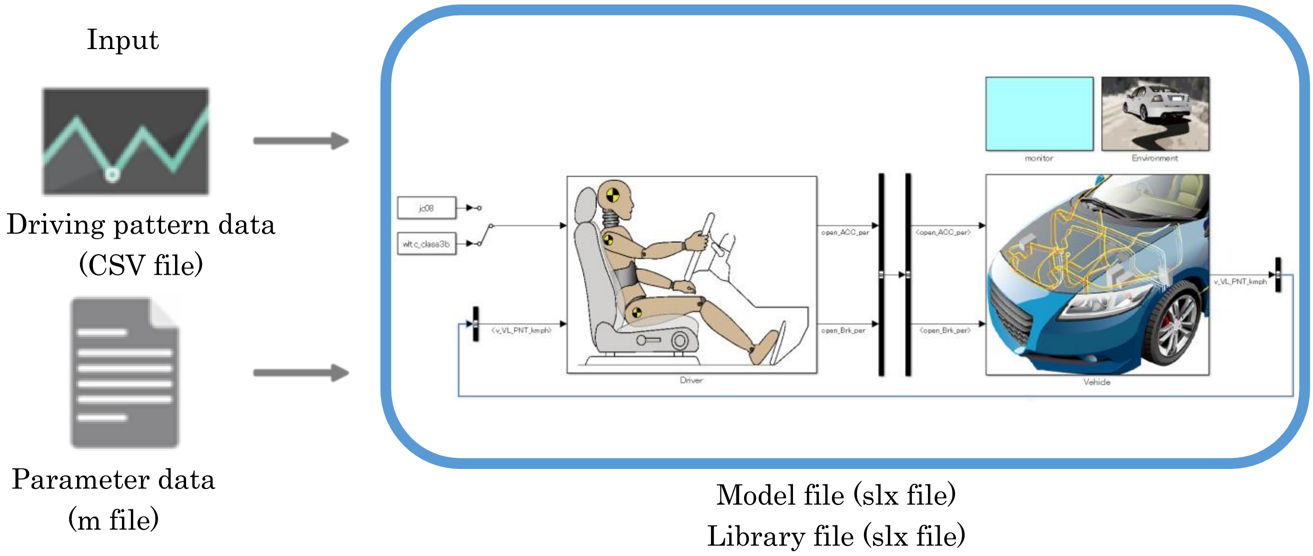



**Fig. 2.2.1 Simulation Environment**

<Guideline-compliant model file structure>

| No. | File name | Explanation |
|---|---|---|
| 1 | SHEV_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

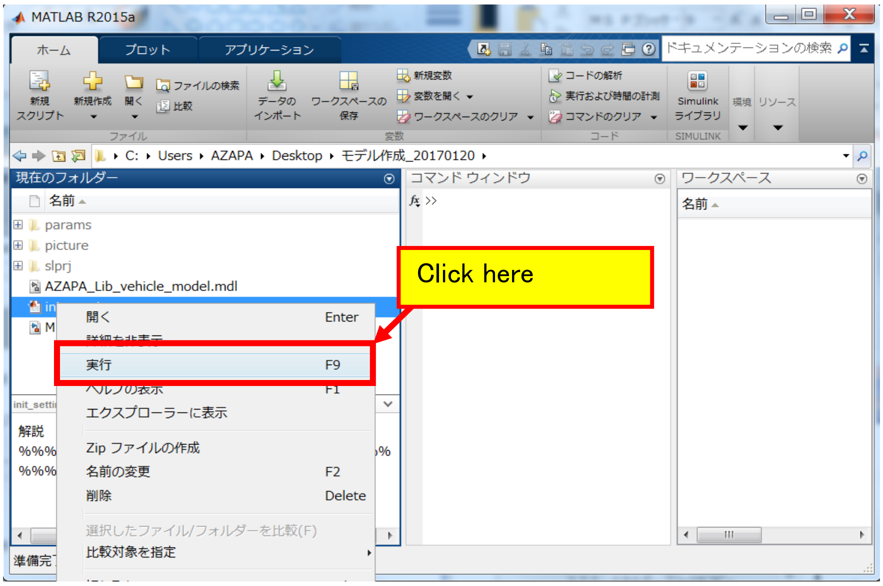
## 3.1. Simulation execution

### 3.1.1. Start MATLAB

Launch MATLAB 2015a.

### 3.1.2. Initial settings

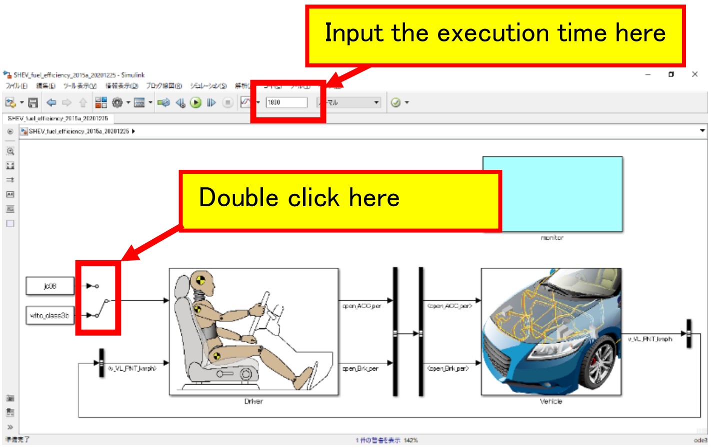
Run “init_setting.m” to set the paths, set the parameters, and launch the simulation model.




### 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.

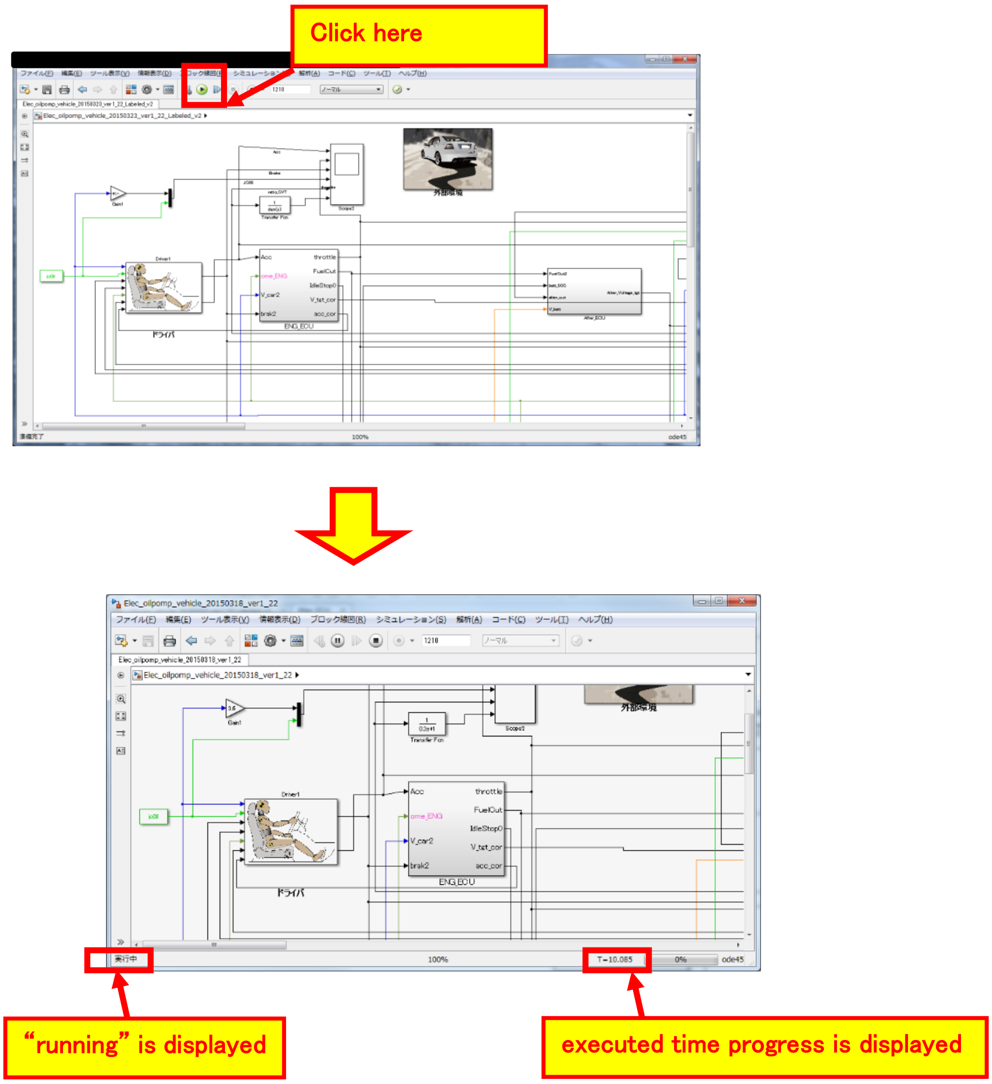



① 1204-second JC08 speed pattern
jc08 = csvread('JC08_spline_100ms.csv')
simulation time=1204s

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.



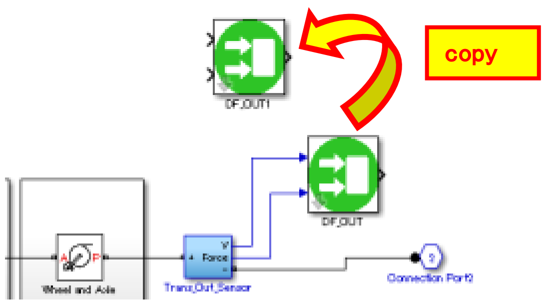

When “running” is no longer displayed, the execution will be complete.

## 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.

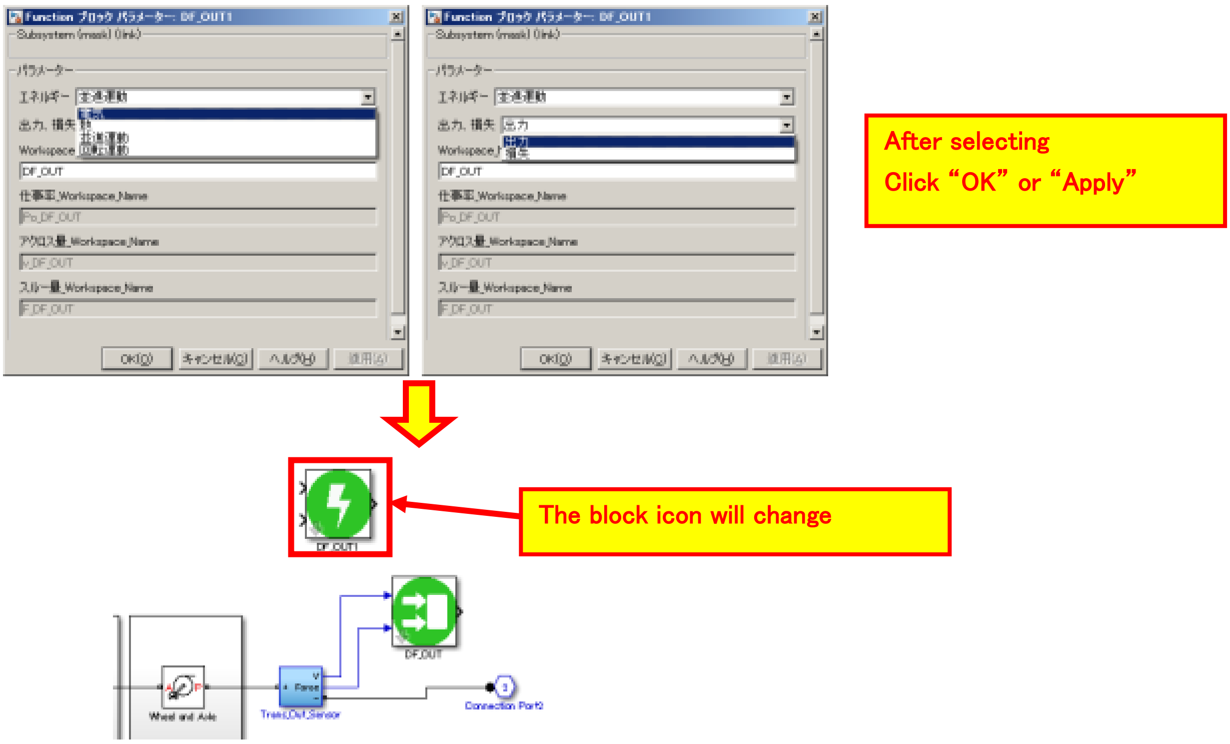
### 3.2.1. Copy the energy block

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



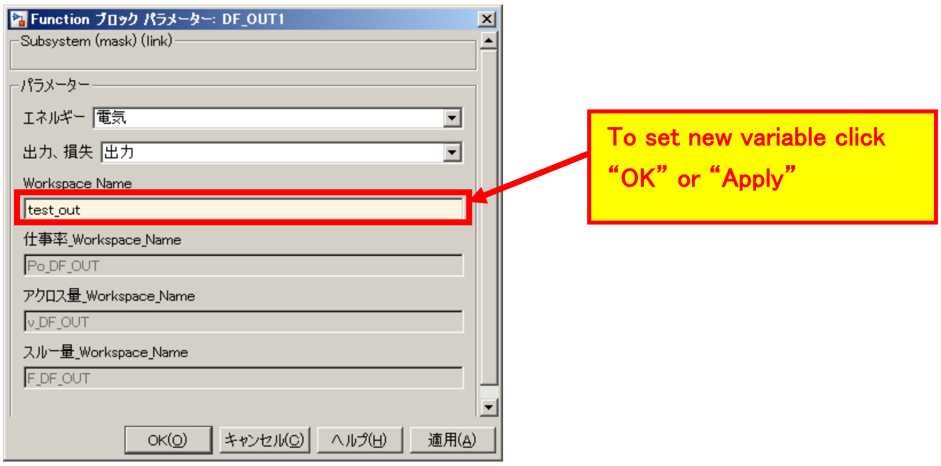

### 3.2.2. Set the corresponding physical quantity.

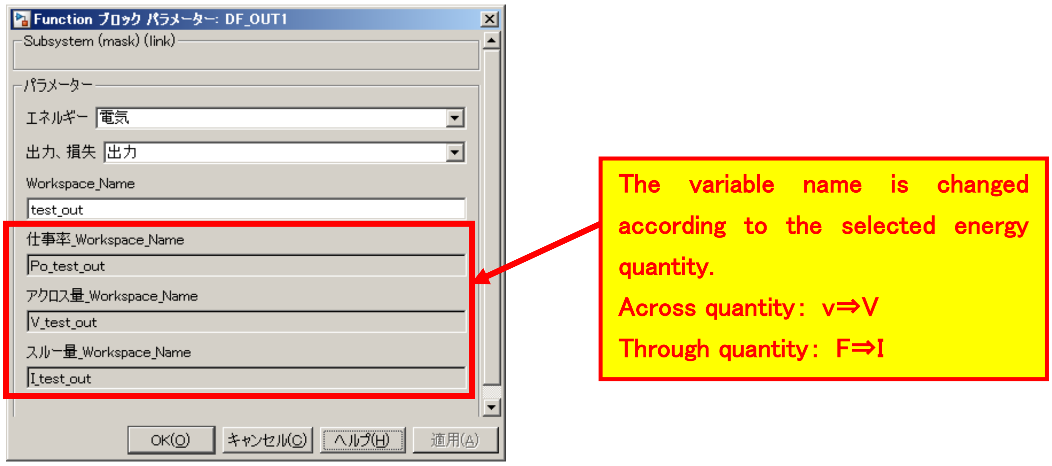
Select the energy type, output, and loss from the pull-down menu.
In the example, select "Output" of "Electricity".



### 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.



# 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.

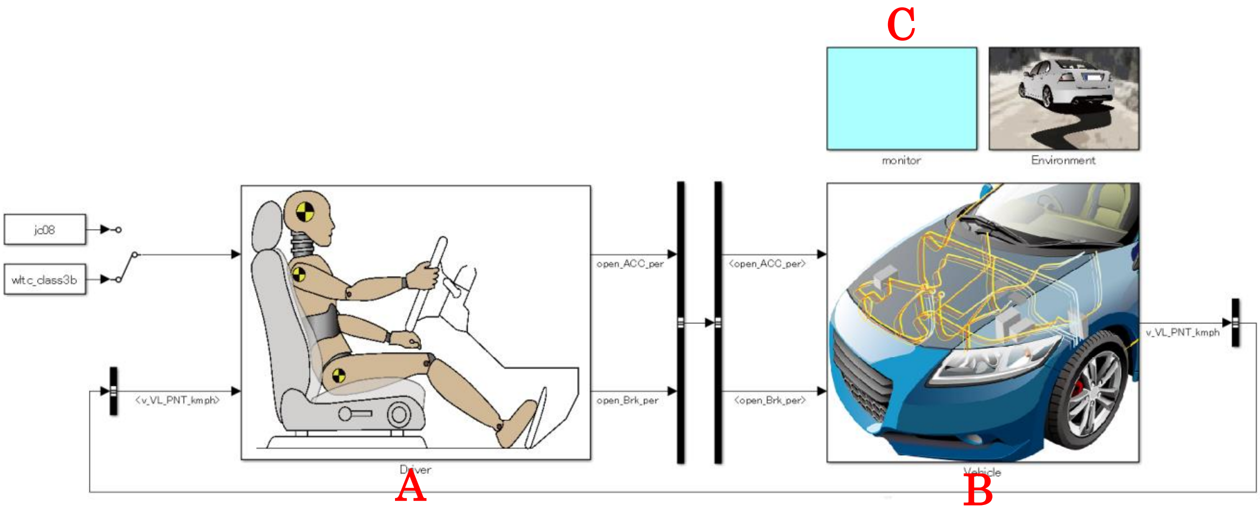



**Fig. 4.1.1 Structure of first layer of the guideline-compliant model**

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.

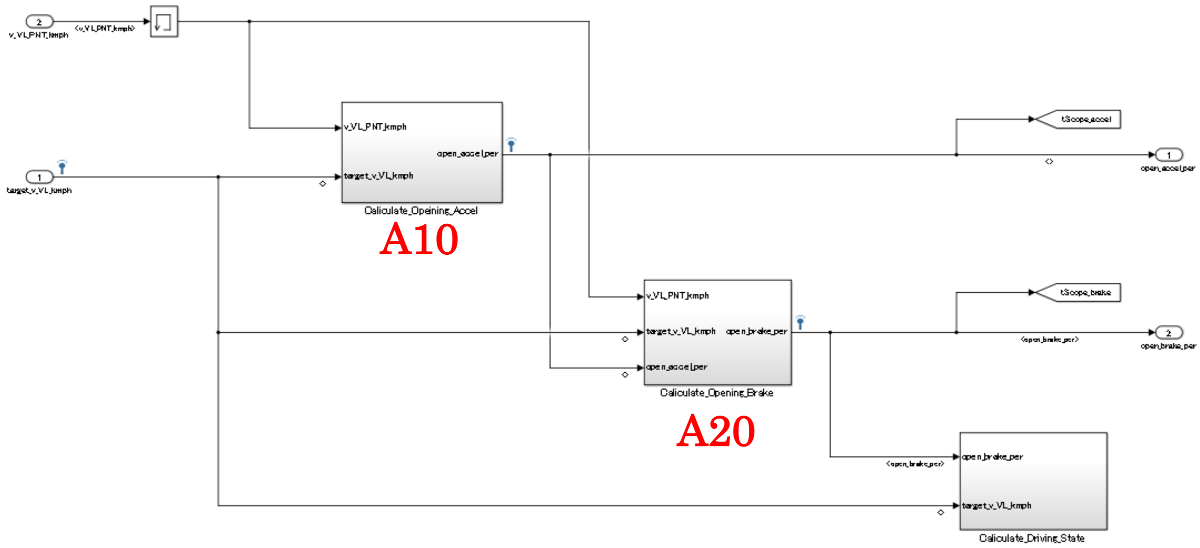



**Fig. 4.2.1 Structure of the Driver system in the second layer**

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 | Fuctional overview |
|---|---|---|
| A10 | Accelerator aperture | 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. In FB control, the accelerator aperture is calculated based on the difference between the target vehicle speed and the actual vehicle speed. |
| A20 | Brake (opening) | The brake pedal stroke is derived from the difference between the target vehicle velocity and the actual vehicle velocity. Pedal misapplication prevention control that prevents the brake from being applied while accelerating. |

### 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.

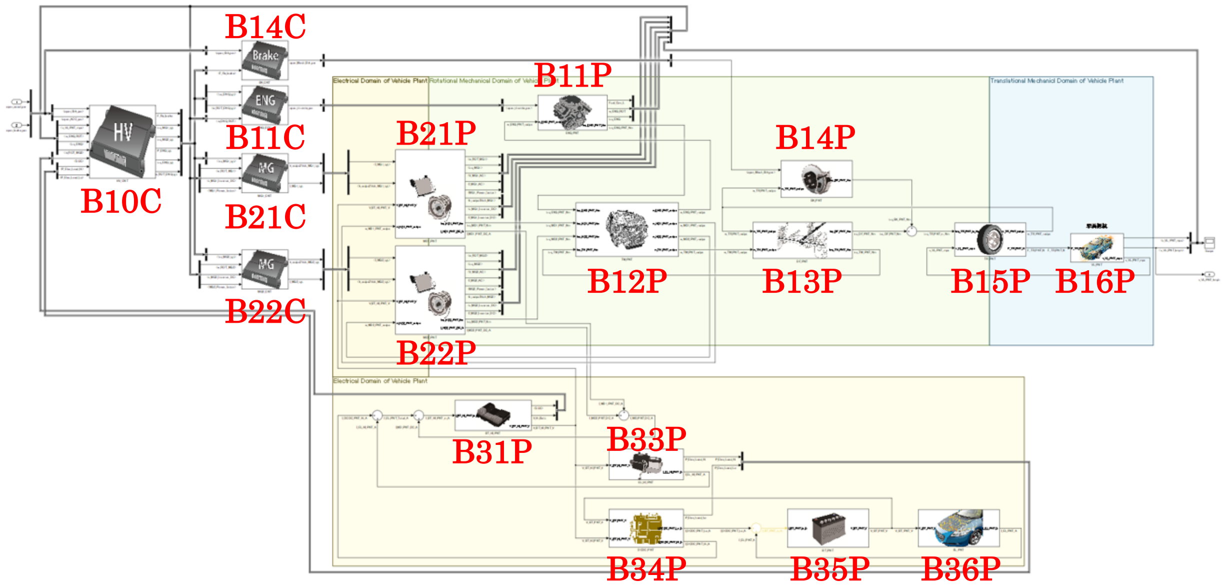



**Fig. 4.2.2 Structure of the Vehicle system in the second layer**

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). |
| 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. |
| 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.

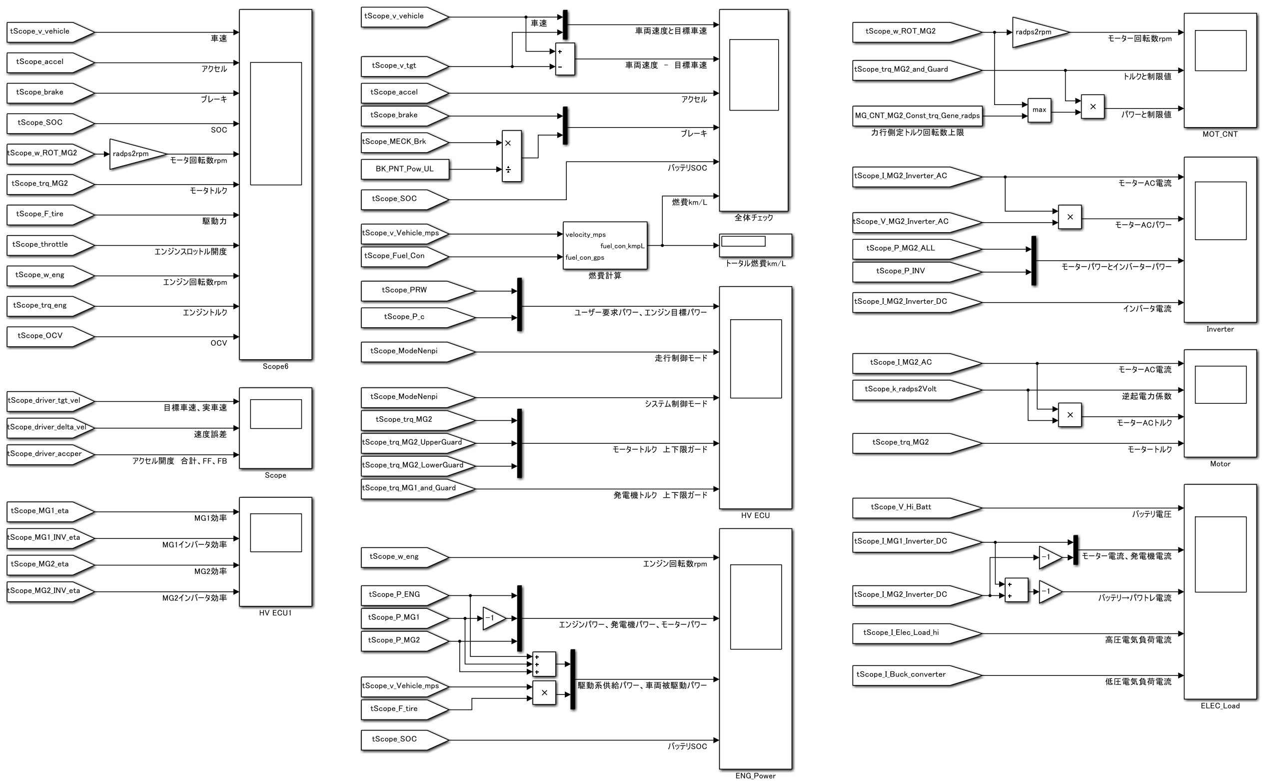



**Fig. 4.2.3 Structure of the Monitor system in the second layer**

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.

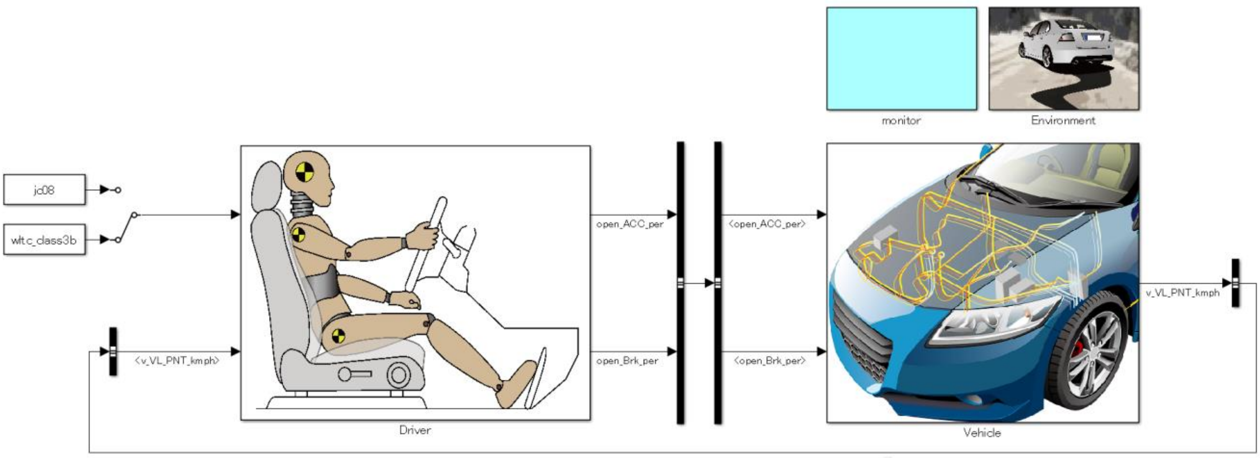



**Fig. 5.1.1 Data flow diagram: First layer (entire guideline-compliant model)**

### 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 | 10 | - | 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 | -5000 | - | 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 | -0.2 | - | 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 |
| drivmode_STOP | 1 | - | Driver state 1: Stop |
| drivmode_ACC | 2 | - | Driver state 2: Acceleration |
| drivemode_Deceleration_Acc | 3 | - | Driver state 3: Deceleration (powered) |
| drivemode_Deceleration_Brk | 4 | - | Driver status 4: Deceleration (regenerative) |
| drivmode_CONST | 5 | - | Driver state 5: Steady running |
| HV_CNT_P_limit_charge | -58000 | W | Charging power limit |
| HV_CNT_P_limit_discharge | 58000 | W | Discharging power limit |
| HV_CNT_PSoFin_soc | <1x4> | % | Charging power map SOC |
| HV_CNT_PSoFin_battpw | <1x4> [*1] | W | Charging power map battery power |
| HV_CNT_PSoFout_soc | <1x4> | % | Discharging power map SOC |
| HV_CNT_PSoFout_battpw | <1x4> [*2] | W | Discharging power map battery power |
| HV_CNT_trq_require_accper | <1x8> | % | Required driving force estimation map Accelerator opening |
| HV_CNT_trq_require_v_kmph | <1x20> | km/h | Required driving force estimation map Vehicle speed |
| HV_CNT_trq_require_Nm | <8x20> | Nm | Required driving force estimation map |

| Variable name | Set value | Unit | Explanation |
|---|---|---|---|
| HV_CNT_trq_req_Gain_OFF | 0.001 | - | 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 | 0.0001 | N | Stop decision brake threshold |
| HV_CNT_trq_req_delaytime | 0.20 | sec | Gain first-order lag time constant |
| HV_CNT_mode2_Ge_power_P_Prw2 | <1x15> | W | Motor output power |
| HV_CNT_mode2_Ge_power_P_SOC2 | <1x3> | % | Hi Voltage battery SOC |
| HV_CNT_mode2_Ge_power_P | <3x15> | W | Engine target power generation |
| HV_CNT_mode12hys_out_SOC | <1x10> | % | mode1 SOC |
| HV_CNT_mode12hys_out_Prw | <1x10> | W | mode1 motor output |
| HV_CNT_mode21hys_out_SOC | <1x10> | % | mode2 SOC |
| HV_CNT_mode21hys_out_Prw | <1x10> | W | mode2 motor output |
| HV_CNT_mode21hys_in_SOC | 45 | % | Engine stop threshold |
| HV_CNT_Ge_stop_hys | 1000 | W | Motor power threshold |
| HV_CNT_w_ROT_ENG_tgt2_Power_req | <1x26> | W | Generator target generated power |
| HV_CNT_w_ROT_ENG_tgt2_v_kmph | <1x6> | W | Generator target generated power |
| HV_CNT_w_ROT_ENG_tgt2_rpm | <26x6> | rpm | Target engine speed when in driving state |
| HV_CNT_trq_ENG_crank_rpm | <1x12> | rpm | Engine speed during cranking |
| HV_CNT_trq_ENG_crank_map | <1x12> | Nm | Engine target torque during cranking |
| HV_CNT_w_ROT_ENG_crank_rpm_on_threshold | 1600 | rpm | Switching ON decision threshold from cranking mode |
| HV_CNT_w_ROT_ENG_crank_rpm_off_threshold | 200 | rpm | Switching OFF decision threshold from cranking mode |
| HV_CNT_P_Gain_GEN_Hi_ENG_rpm | 1.0 | - | Generator torque P control<br>P gain at high engine speed |
| HV_CNT_P_Gain_GEN_Lo_ENG_rpm | 2.0 | - | Generator torque P control<br>P gain at low engine speed |
| HV_CNT_F_threshold_brake_override_N | 10 | N | Judgment threshold of brake override |
| HV_CNT_w_ROT_MOT_threshold_anti_0div | 10 | rpm | Motor rotation speed of 0 division prevention |
| HV_CNT_flag_RegeneBrake_cooperate | 1 | - | Regenerative cooperative brake activation flag<br>When the flag is 1, regenerative braking is enabled. |
| HV_CNT_v_vehicle_threshold_anti_0div_kmph | 5 | km/h | Vehicle speed of 0 division prevention |
| HV_CNT_ReGeneBrk_Cut_v_kmph | [0,0.1,0.2,1] | km/h | Vehicle speed input of regenerative braking force limitation map at low vehicle speed |
| HV_CNT_ReGeneBrk_Cut_Gain | [0,0,1,1] | - | Regenerative braking force limitation map at low vehicle speed |
| 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 | [*3] | W | Powering side rated output |
| MG_CNT_MG1_max_trq_Gene_Nm | 130 | Nm | Maximum torque on the powering running side |
| MG_CNT_Pmin_MG1_ReGene_W | [*4] | W | Rated output on the regenerative side |
| MG_CNT_MG1_max_trq_ReGene_Nm | -130 | Nm | Maximum torque on the regenerative side |
| MG_CNT_MG1_Const_trq_ReGene_radps | [*5] | rad/s | Rated rotation speed on the regenerative side |
| MG_CNT_Pmax_MG2_Gene_W | 80000 | W | Powering side rated output |
| MG_CNT_MG2_max_trq_Gene_Nm | 260 | Nm | Maximum torque on the powering side |
| MG_CNT_MG2_Const_trq_Gene_radps | [*6] | rad/s | Powering side rated speed |
| MG_CNT_Pmin_MG2_ReGene_W | -80000 | W | Rated output on the regenertative side |
| MG_CNT_MG2_max_trq_ReGene_Nm | -260 | Nm | Maximum torque on the regenerative side |
| ENG_PNT_FuelCon_gps_map_x_pri_rpm | <1x14> | rpm | Fuel consumption rate map<br>x-axis: engine speed |
| ENG_PNT_FuelCon_gps_map_y_trq_Nm | <1x14> | Nm | Fuel consumption rate map<br>y-axis: engine shaft torque |

| Variable name | Set value | Unit | Explanation |
|---|---|---|---|
| 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<br>x-axis: engine speed |
| ENG_PNT_trq_Nm_map_y_throttle | <1x2> | % | Engine shaft torque map<br>y-axis: accelerator throttle opening |
| ENG_PNT_trq_Nm_map | <11x2> | Nm | Engine shaft torque map<br>z-axis: torque |
| TM_PNT_Flywheel_Inertia | 0.3 | kgm^2 | Flywheel inertia |
| TM_PNT_TM_Inertia | 0.3 | kgm^2 | Transmission inertia |
| TM_PNT_ratio_MG1_gear | 0.600 | - | Transmission gear ratio |
| TM_PNT_eta_MG1_gear | 0.97 | - | Generator primary deceleration efficiency |
| DF_PNT_DF_gear | 7.4 | - | Differential gear reduction ratio |
| DF_PNT_eta_DF | 0.96 | - | Differential gear efficiency |
| DF_PNT_Driveshaft_Inertia | 0.1 | kgm^2 | Driveshaft inertia |
| DF_PNT_Driveshaft_spring | 10000 | - | Driveshaft spring constant |
| DF_PNT_Driveshaft_zeta | 4 | - | Second-order lag damping coefficient |
| DF_PNT_Driveshaft_damper | [*7] | - | 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 | 0.707 | - | Inverter modulation factor 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 | 300 | V | Motor inverter DC side rated voltage |
| MG_PNT_w_ROT_MG1_Rated | [*8] | 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 | 0.707 | - | Inverter modulation factor sine wave modulation region only |
| 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 | 300 | V | Motor inverter DC side rated voltage |
| MG_PNT_w_ROT_MG2_Rated | [*9] | rad/s | Motor inverter DC side rated rotation speed |
| BT_PNT_Hi_Capa_hi_batt | 5.0 | 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<br>x-axis: SOC term |

| Variable name | Set value | Unit | Explanation |
|---|---|---|---|
| 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_PNT_eta_conv_lo | 0.95 | - | Buck converter efficiency |
| DCDC_PNT_R_conv_lo | 0.02 | Ω | Buck converter resistance [*1] |
| DCDC_PNT_Vtgt_conv_lo | 14.0 | V | Target buck converter voltage value |
| EL_PNT_R_bodyelec_hi | 5800 | Ω | High-voltage section electrical load resistance |
| EL_PNT_R_bodyelec_lo | 1.037 | Ω | 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^3 | Air density (20℃, 1013hPa) |
| Fuel_density | 733 | g/L | Regular gasoline density[*11] |
| 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 |
| mps2kmps | 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^2 | Acceleration due to gravity |
| M_body | 1200 | 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 | 0.300 | m | Tire radius |
| vel_max | 200 | km/h | Maximum vehicle speed (for divergence prevention) |
| myu | 0.0077 | - | Rolling resistance coefficient from ISO |
| Cd | 0.24 | - | Air resistance coefficient |
| A | 2.8 | m^2 | Front projected area |

※Uncolored parameters are common to all systems

| | |
|---|---|
| [*1] | [1,1,0,0]*HV_CNT_P_limit_charge |
| [*2] | [0,0,1,1]*HV_CNT_P_limit_discharge |
| [*3] | 50000 * MG_CNT_Gain_Pmax |
| [*4] | -50000 * MG_CNT_Gain_Pmax |
| [*5] | MG_CNT_Pmin_MG1_ReGene_W / MG_CNT_MG1_max_trq_ReGene_Nm |
| [*6] | MG_CNT_Pmax_MG2_Gene_W / MG_CNT_MG2_max_trq_Gene_Nm |
| [*7] | 2*DF_PNT_Driveshaft_zeta*sqrt(DF_PNT_Driveshaft_spring*DF_PNT_Driveshaft_Inertia) |
| [*8] | MG_CNT_MG1_Const_trq_ReGene_radps |
| [*9] | MG_CNT_MG2_Const_trq_ReGene_radps |
| [*10] | If it is smaller than the lead battery's internal resistance, the low voltage system will oscillate. |
| [*11] | 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.

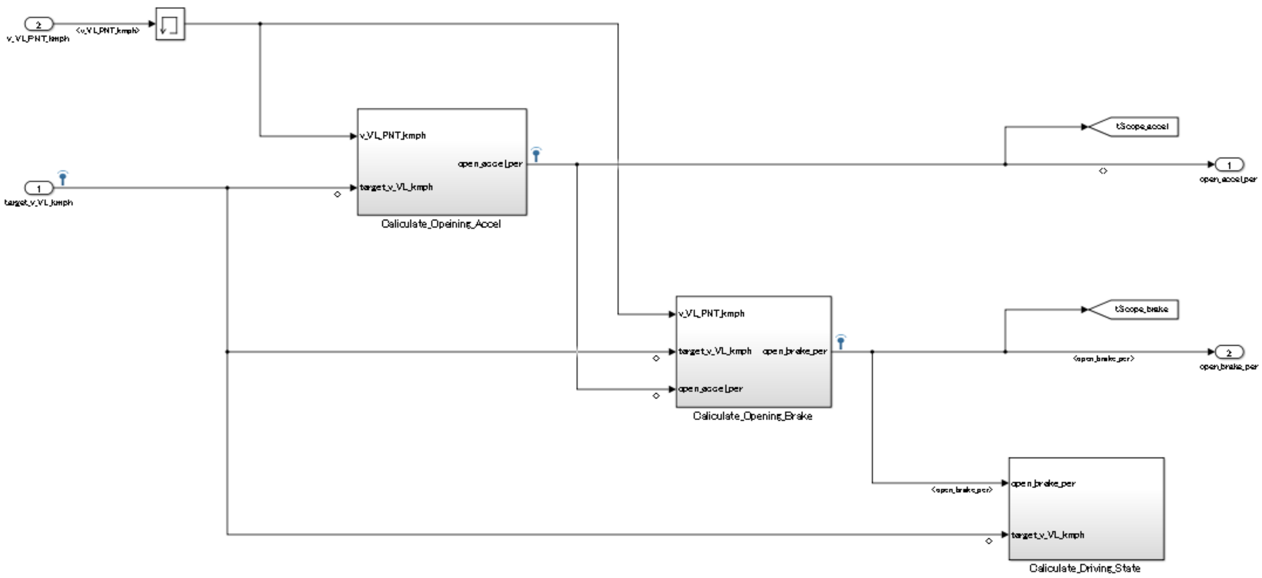



**Fig. 5.2.1 Data flow diagram: 2nd layer Driver system**

#### 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 | 10 | - | 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 | -5000 | - | 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 | -0.2 | - | Brake depression amount when stopped (target vehicle speed is 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 |
| drivmode_STOP | 1 | - | Driver condition 1: Stop |
| drivmode_ACC | 2 | - | Driver condition 2: Acceleration |
| drivemode_Deceleration_Acc | 3 | - | Driver condition 3: Deceleration (powered) |
| drivemode_Deceleration_Brk | 4 | - | Driver condition 4: Deceleration (regenerative) |
| drivmode_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 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.

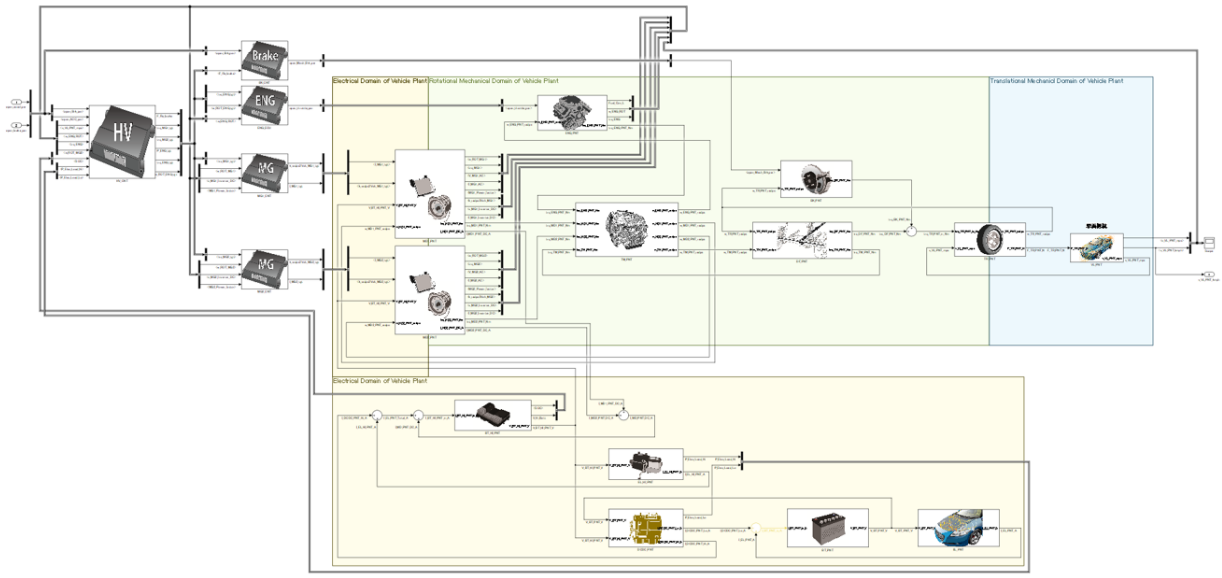



**Fig. 5.2.2 Data flow diagram: 2nd layer Vehicle system**

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_P_limit_charge | -58000 | W | Charging power limit |
| HV_CNT_P_limit_discharge | 58000 | W | Discharging power limit |
| HV_CNT_PSoFin_soc | <1x4> | % | Charging power map SOC |
| HV_CNT_PSoFin_battpw | <1x4> [*1] | W | Charging power map battery power |
| HV_CNT_PSoFout_soc | <1x4> | % | Discharging power map SOC |
| HV_CNT_PSoFout_battpw | <1x4> [*2] | W | Discharging power map battery power |
| HV_CNT_trq_require_accper | <1x8> | % | Required driving force estimation map Accelerator opening |
| HV_CNT_trq_require_v_kmph | <1x20> | km/h | Required driving force estimation map Vehicle speed |
| HV_CNT_trq_require_Nm | <8x20> | Nm | Required driving force estimation map |
| HV_CNT_trq_req_Gain_OFF | 0.001 | - | 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 | 0.0001 | N | Stop decision brake threshold |
| HV_CNT_trq_req_delaytime | 0.20 | sec | Gain first-order lag time constant |
| HV_CNT_mode2_Ge_power_P_Prw2 | <1x15> | W | Motor output power |
| HV_CNT_mode2_Ge_power_P_SOC2 | <1x3> | % | Hi Voltage battery SOC |
| HV_CNT_mode2_Ge_power_P | <3x15> | W | Engine target power generation |
| HV_CNT_mode12hys_out_SOC | <1x10> | % | mode1 SOC |
| HV_CNT_mode12hys_out_Prw | <1x10> | W | mode1 motor output |
| HV_CNT_mode21hys_out_SOC | <1x10> | % | mode2 SOC |
| HV_CNT_mode21hys_out_Prw | <1x10> | W | mode2 motor output |
| HV_CNT_mode21hys_in_SOC | 45 | % | Engine stop threshold |
| HV_CNT_Ge_stop_hys | 1000 | W | Motor power threshold |
| HV_CNT_w_ROT_ENG_tgt2_Power_req | <1x26> | W | Generator target generated power |
| HV_CNT_w_ROT_ENG_tgt2_v_kmph | <1x6> | W | Generator target generated power |
| HV_CNT_w_ROT_ENG_tgt2_rpm | <26x6> | rpm | Target engine speed when in driving state |
| HV_CNT_trq_ENG_crank_rpm | <1x12> | rpm | Engine speed during cranking |
| HV_CNT_trq_ENG_crank_map | <1x12> | Nm | Engine target torque during cranking |
| HV_CNT_w_ROT_ENG_crank_rpm_on_threshold | 1600 | rpm | Switching ON decision threshold from cranking mode |
| HV_CNT_w_ROT_ENG_crank_rpm_off_threshold | 200 | rpm | Switching OFF decision threshold from cranking mode |
| HV_CNT_P_Gain_GEN_Hi_ENG_rpm | 1.0 | - | Generator torque P control P gain at high engine speed |
| HV_CNT_P_Gain_GEN_Lo_ENG_rpm | 2.0 | - | Generator torque P control P gain at low engine speed |

| Variable name | Set value | Unit | Explanation |
|---|---|---|---|
| HV_CNT_F_threshold_brake_override_N | 10 | N | Judgment threshold of brake override |
| HV_CNT_w_ROT_MOT_threshold_anti_0div | 10 | rpm | Motor rotation speed of 0 division prevention |
| HV_CNT_flag_RegeneBrake_cooperate | 1 | - | Regenerative cooperative brake activation flag<br>When the flag is 1, regenerative braking is enabled. |
| HV_CNT_v_vehicle_threshold_anti_0div_kmph | 5 | km/h | Vehicle speed of 0 division prevention |
| HV_CNT_ReGeneBrk_Cut_v_kmph | [0,0.1,0.2,1] | km/h | Vehicle speed input of regenerative braking force limitation map at low vehicle speed |
| HV_CNT_ReGeneBrk_Cut_Gain | [0,0,1,1] | - | Regenerative braking force limitation map at low vehicle speed |
| 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 | [*3] | W | Powering side rated output |
| MG_CNT_MG1_max_trq_Gene_Nm | 130 | Nm | Maximum torque on the powering running side |
| MG_CNT_Pmin_MG1_ReGene_W | [*4] | W | Rated output on the regenerative side |
| MG_CNT_MG1_max_trq_ReGene_Nm | -130 | Nm | Maximum torque on the regenerative side |
| MG_CNT_MG1_Const_trq_ReGene_radps | [*5] | rad/s | Rated rotation speed on the regenerative side |
| MG_CNT_Pmax_MG2_Gene_W | 80000 | W | Powering side rated output |
| MG_CNT_MG2_max_trq_Gene_Nm | 260 | Nm | Maximum torque on the powering side |
| MG_CNT_MG2_Const_trq_Gene_radps | [*6] | rad/s | Powering side rated speed |
| MG_CNT_Pmin_MG2_ReGene_W | -80000 | W | Rated output on the regenertative side |
| MG_CNT_MG2_max_trq_ReGene_Nm | -260 | Nm | Maximum torque on the regenerative side |
| ENG_PNT_FuelCon_gps_map_x_pri_rpm | <1x14> | rpm | Fuel consumption rate map<br>x-axis: engine speed |
| ENG_PNT_FuelCon_gps_map_y_trq_Nm | <1x14> | Nm | Fuel consumption rate map<br>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<br>x-axis: engine speed |
| ENG_PNT_trq_Nm_map_y_throttle | <1x2> | % | Engine shaft torque map<br>y-axis: accelerator throttle opening |
| ENG_PNT_trq_Nm_map | <11x2> | Nm | Engine shaft torque map<br>z-axis: torque |
| TM_PNT_Flywheel_Inertia | 0.3 | kgm^2 | Flywheel inertia |
| TM_PNT_TM_Inertia | 0.3 | kgm^2 | Transmission inertia |
| TM_PNT_ratio_MG1_gear | 0.600 | - | Transmission gear ratio |
| TM_PNT_eta_MG1_gear | 0.97 | - | Generator primary deceleration efficiency |
| DF_PNT_DF_gear | 7.4 | - | Differential gear reduction ratio |
| DF_PNT_eta_DF | 0.96 | - | Differential gear efficiency |
| DF_PNT_Driveshaft_Inertia | 0.1 | kgm^2 | Driveshaft inertia |
| DF_PNT_Driveshaft_spring | 10000 | - | Driveshaft spring constant |
| DF_PNT_Driveshaft_zeta | 4 | - | Second-order lag damping coefficient |
| DF_PNT_Driveshaft_damper | [*7] | - | 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 | 0.707 | - | Inverter modulation factor 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 |

| Variable name | Set value | Unit | Explanation |
|---|---|---|---|
| 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 | 300 | V | Motor inverter DC side rated voltage |
| MG_PNT_w_ROT_MG1_Rated | [*8] | 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 | 0.707 | - | Inverter modulation factor sine wave modulation region only |
| 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 | 300 | V | Motor inverter DC side rated voltage |
| MG_PNT_w_ROT_MG2_Rated | [*9] | rad/s | Motor inverter DC side rated rotation speed |
| BT_PNT_Hi_Capa_hi_batt | 5.0 | 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_PNT_eta_conv_lo | 0.95 | - | Buck converter efficiency |
| DCDC_PNT_R_conv_lo | 0.02 | Ω | Buck converter resistance [*1] |
| DCDC_PNT_Vtgt_conv_lo | 14.0 | V | Target buck converter voltage value |
| EL_PNT_R_bodyelec_hi | 5800 | Ω | High-voltage section electrical load resistance |
| EL_PNT_R_bodyelec_lo | 1.037 | Ω | Low-voltage section electrical load resistance |

※Uncolored parameters are common to all systems

[*1] [1,1,0,0]*HV_CNT_P_limit_charge

[*2] [0,0,1,1]*HV_CNT_P_limit_discharge

[*3] 50000 * MG_CNT_Gain_Pmax

[*4] -50000 * MG_CNT_Gain_Pmax

[*5] MG_CNT_Pmin_MG1_ReGene_W / MG_CNT_MG1_max_trq_ReGene_Nm

[*6] MG_CNT_Pmax_MG2_Gene_W / MG_CNT_MG2_max_trq_Gene_Nm

[*7] 2*DF_PNT_Driveshaft_zeta*sqrt(DF_PNT_Driveshaft_spring*DF_PNT_Driveshaft_Inertia)

[*8] MG_CNT_MG1_Const_trq_ReGene_radps

[*9] MG_CNT_MG2_Const_trq_ReGene_radps

[*10] 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.

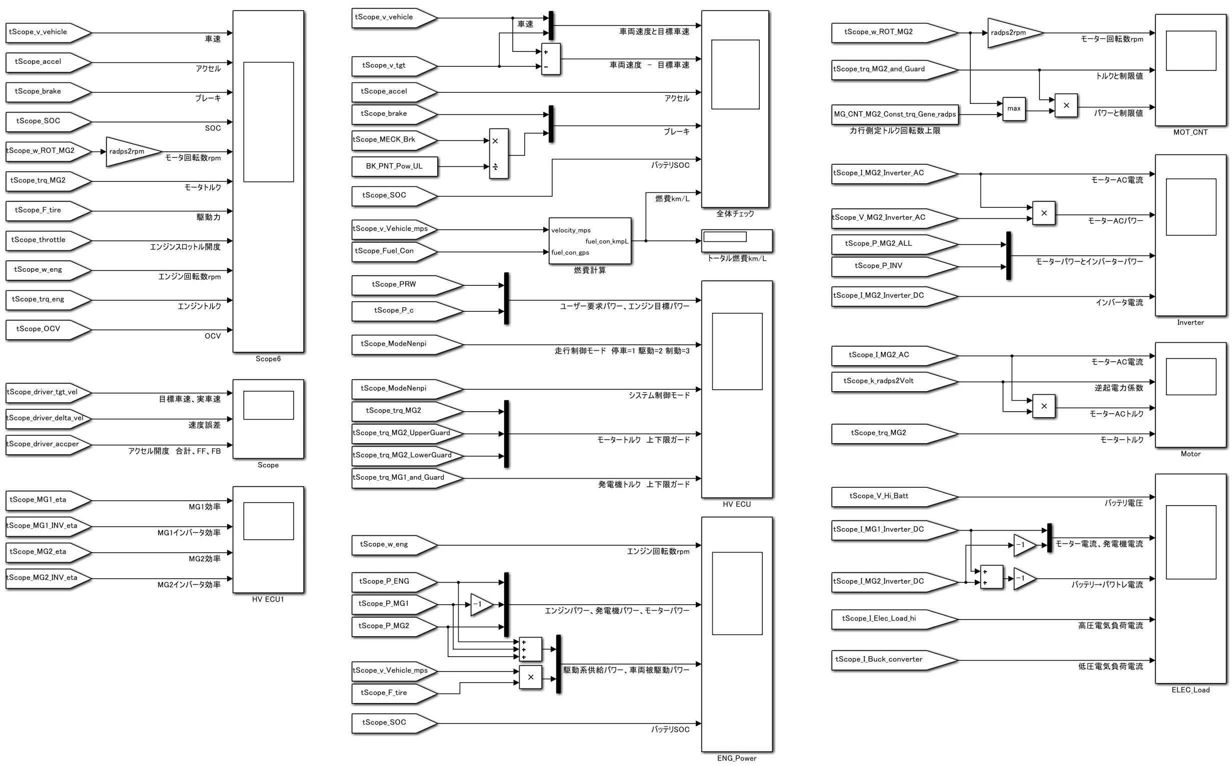



**Fig. 5.2.3 Data flow diagram: 2nd layer Monitor system**

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 | [*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.

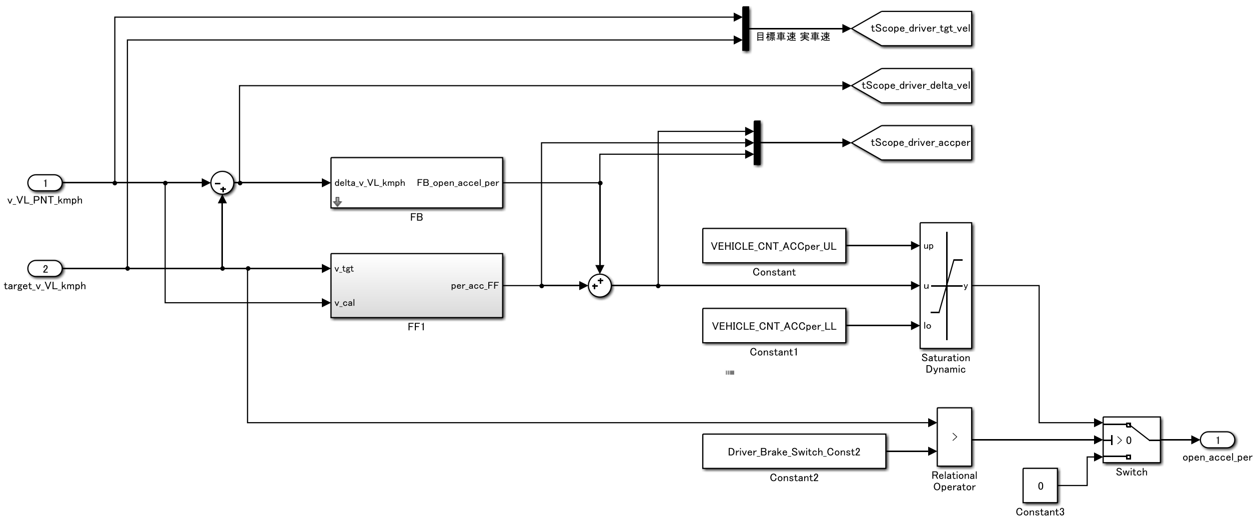



**Fig. 5.3.1 Data flow diagram: 3rd layer Accelerator aperture system**

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 | 10 | - | 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 | -5000 | - | 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 | -0.2 | - | 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 |
| drivmode_STOP | 1 | - | Driver state 1: Stopped |
| drivmode_ACC | 2 | - | Driver state 2: Accelerating |
| drivemode_Deceleration_Acc | 3 | - | Driver state 3: Decelerating (powered) |
| drivemode_Deceleration_Brk | 4 | - | Driver state 4: Decelerating (regenerative) |
| drivmode_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.

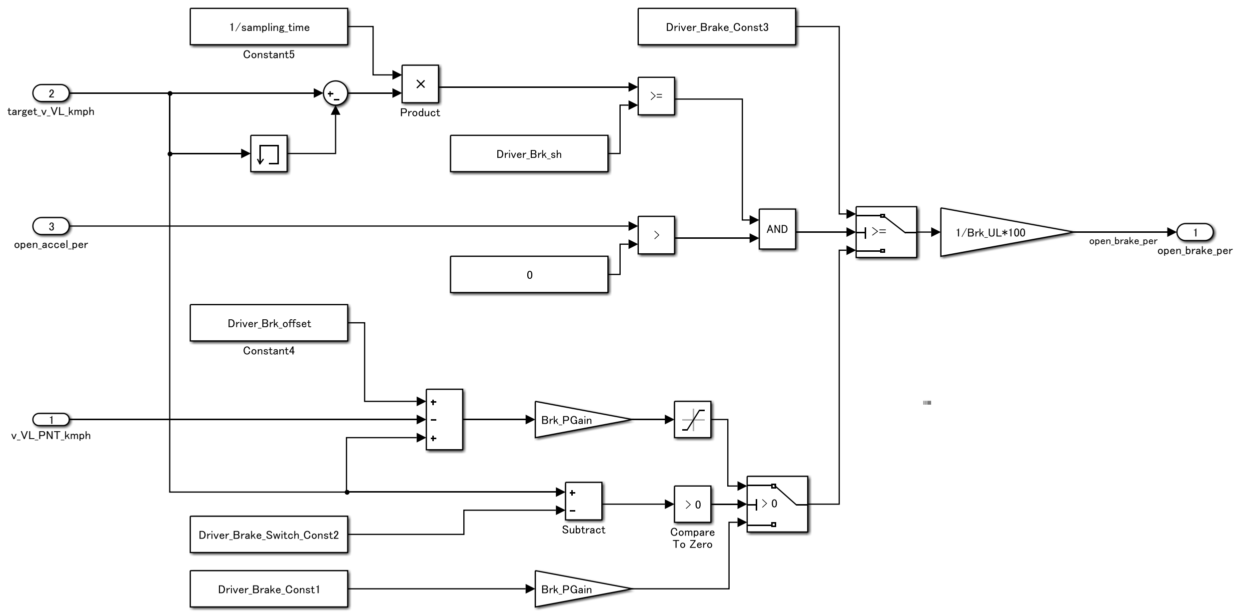



**Fig. 5.3.2 Data flow diagram: 3rd layer Brake aperture system**

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 | 10 | - | 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 | -5000 | - | 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 | -0.2 | - | 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 |
| drivmode_STOP | 1 | - | Driver state 1: Stopped |
| drivmode_ACC | 2 | - | Driver state 2: Accelerating |
| drivemode_Deceleration_Acc | 3 | - | Driver state 3: Decelerating (powered) |
| drivemode_Deceleration_Brk | 4 | - | Driver state 4: Decelerating (regenerative) |
| drivmode_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.

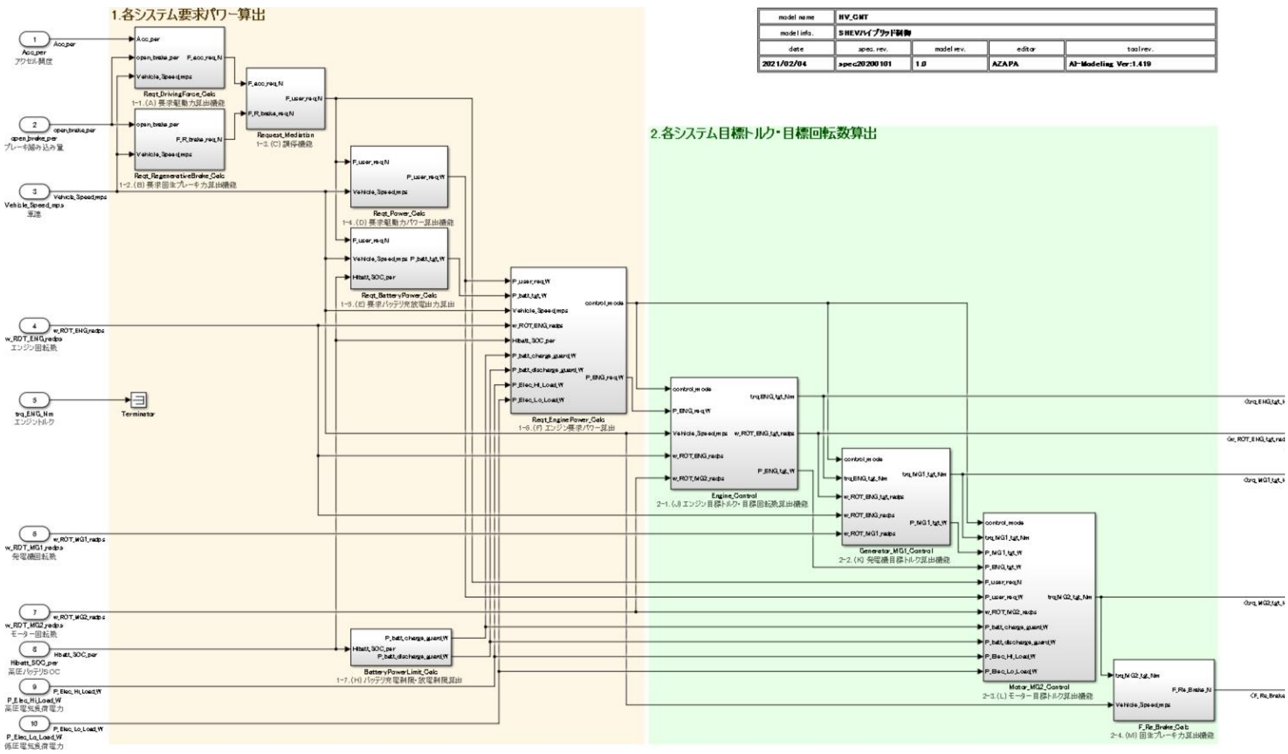



**Fig. 5.3.3 Data flow diagram: 3rd layer HV_CNT system**

5.3.3.3 Input/Output specifications

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

| Name | Unit | Scope | Explanation |
|---|---|---|---|
| **Inputs** | | | |
| 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_P_limit_charge | -58000 | W | Charging power limit |
| HV_CNT_P_limit_discharge | 58000 | W | Discharging power limit |
| HV_CNT_PSoFin_soc | [0,85,90,100] | % | Charging power map: SOC |
| HV_CNT_PSoFin_battpw | [*1] | W | Charging power map: battery power |
| HV_CNT_PSoFout_soc | [0,40,45,100] | % | Discharging power map: SOC |
| HV_CNT_PSoFout_battpw | [*2] | W | Discharging power map: battery power |
| HV_CNT_trq_require_accper | <1x8> | % | Required driving force estimation map: accelerator aperture |
| HV_CNT_trq_require_v_kmph | <1x20> | km/h | Required driving force estimation map: vehicle speed |
| HV_CNT_trq_require_Nm | <8x20> | Nm | Required driving force estimation map |
| HV_CNT_trq_req_Gain_OFF | 0.001 | - | Required drive torque gain at stopping decision |
| HV_CNT_trq_req_Gain_ON | 1 | - | Required drive torque gain at driving decision |
| HV_CNT_trq_req_v_vehicle_th | 1 | km/h | Stopping decision vehicle speed threshold |
| HV_CNT_trq_req_brak_th | 0.0001 | N | Stopping decision brake threshold |
| HV_CNT_trq_req_delaytime | 0.20 | sec | Gain value first-order lag time constant |
| HV_CNT_mode2_Ge_power_P_Prw2 | <1x15> | W | Motor output power |
| HV_CNT_mode2_Ge_power_P_SOC2 | <1x3> | % | Hi Voltage battery SOC |
| HV_CNT_mode2_Ge_power_P | <3x15> | W | Engine target power generation |

| | | | |
|---|---|---|---|
| HV_CNT_mode12hys_out_SOC | <1x10> | % | mode1 SOC |
| HV_CNT_mode12hys_out_Prw | <1x10> | W | mode1 motor output |
| HV_CNT_mode21hys_out_SOC | <1x10> | % | mode2 SOC |
| HV_CNT_mode21hys_out_Prw | <1x10> | W | mode2 motor output |
| HV_CNT_mode21hys_in_SOC | 45 | % | Engine stop threshold |
| HV_CNT_Ge_stop_hys | 1000 | W | Motor power threshold |
| HV_CNT_w_ROT_ENG_tgt2_Power_req | <1x26> | W | Generator target generated power |
| HV_CNT_w_ROT_ENG_tgt2_v_kmph | <1x6> | W | Generator target generated power |
| HV_CNT_w_ROT_ENG_tgt2_rpm | <26x6> | rpm | Target engine speed when in driving state |
| HV_CNT_trq_ENG_crank_rpm | <1x12> | rpm | Engine speed during cranking |
| HV_CNT_trq_ENG_crank_map | <1x12> | Nm | Engine target torque during cranking |
| HV_CNT_w_ROT_ENG_crank_rpm_on_threshold | 1600 | rpm | Switching ON decision threshold from cranking mode |
| HV_CNT_w_ROT_ENG_crank_rpm_off_threshold | 200 | rpm | Switching OFF decision threshold from cranking mode |
| HV_CNT_P_Gain_GEN_Hi_ENG_rpm | 1.0 | - | Generator torque P control<br>P gain at high rpm |
| HV_CNT_P_Gain_GEN_Lo_ENG_rpm | 2.0 | - | Generator torque P control<br>P gain at low rpm |
| HV_CNT_F_threshold_brake_override_N | 10 | N | Judgment threshold of brake override |
| HV_CNT_w_ROT_MOT_threshold_anti_0div | 10 | rpm | Motor rotation speed of 0 division prevention |
| HV_CNT_flag_RegeneBrake_cooperate | 1 | - | Regenerative cooperative brake activation flag<br>When the flag is 1, regenerative braking is enabled. |
| HV_CNT_v_vehicle_threshold_anti_0div_kmph | 5 | km/h | Vehicle speed of 0 division prevention |
| HV_CNT_ReGeneBrk_Cut_v_kmph | [0,0.1,0.2,1] | km/h | Vehicle speed input of regenerative braking force limitation map at low vehicle speed |
| HV_CNT_ReGeneBrk_Cut_Gain | [0,0,1,1] | - | Regenerative braking force limitation map at low vehicle speed |

[*1] [1,1,0,0]*HV_CNT_P_limit_charge
[*2] [0,0,1,1]*HV_CNT_P_limit_discharge

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.

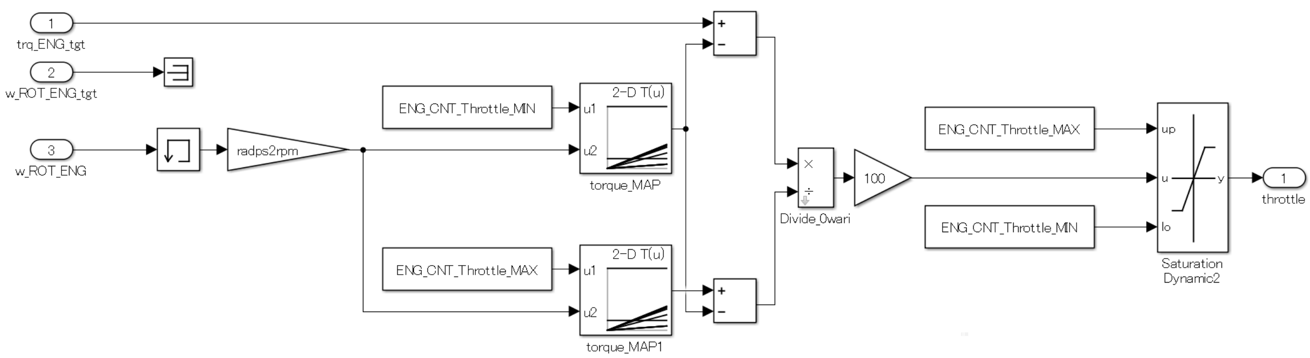



**Fig. 5.3.4 Data flow diagram: 3rd layer ENG_CNT system**

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.

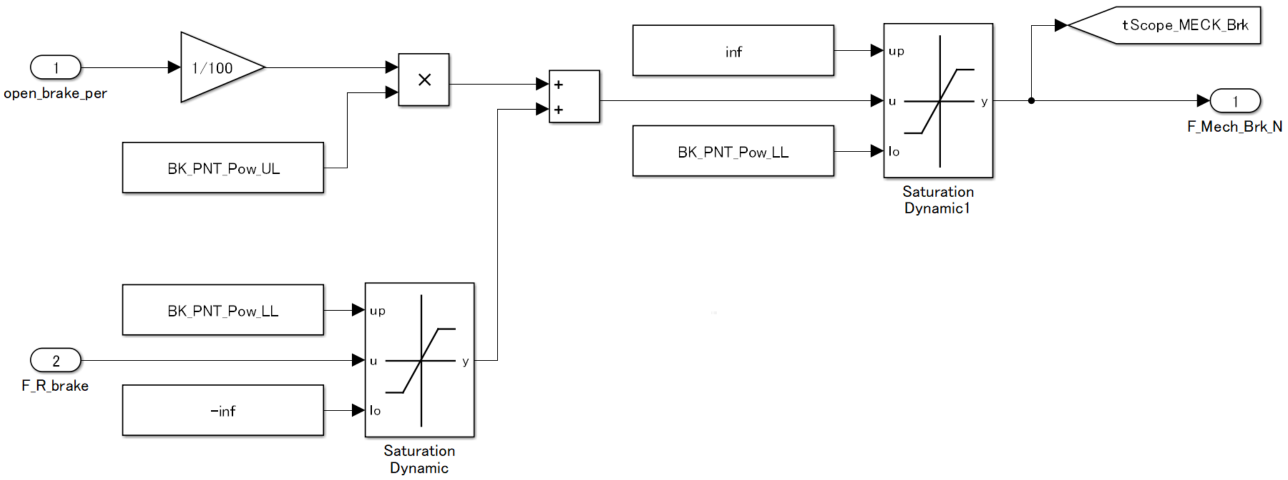



**Fig. 5.3.5 Data flow diagram: 3rd layer BK_CNT system**

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 foce |

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.

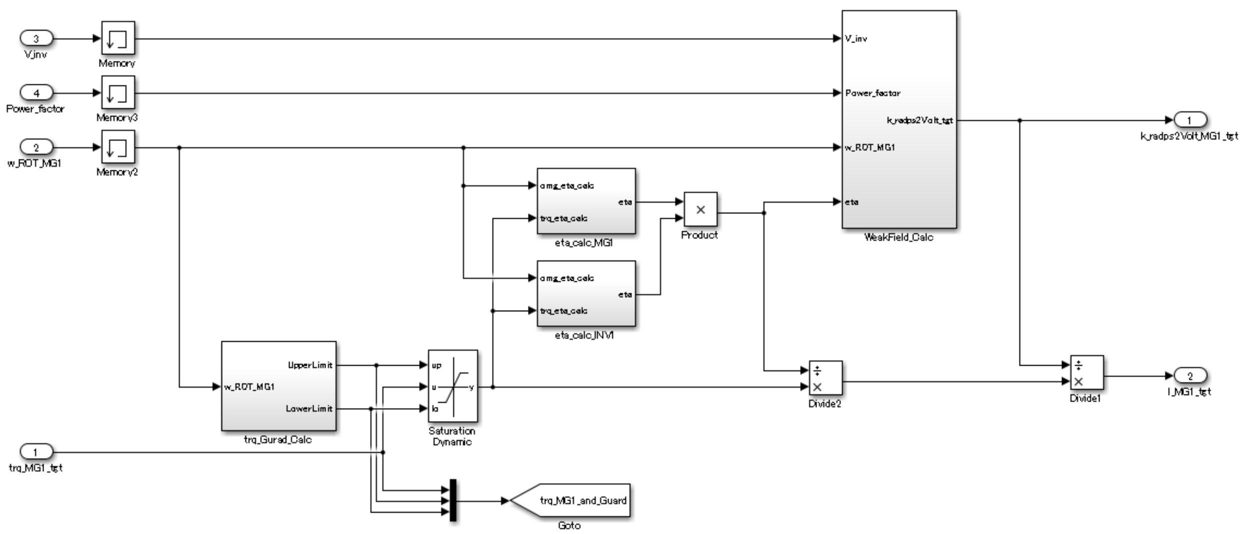



**Fig. 5.3.6 Data flow diagram: 3rd layer MG1_CNT system**

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 | 2.0 | - | Short-time overload tolerance when starting / stopping the engine |
| MG_CNT_Pmax_MG1_Gene_W | [*1] | W | Powering side rated output |
| MG_CNT_MG1_max_trq_Gene_Nm | 130 | Nm | Powering side maximum torque |
| MG_CNT_Pmin_MG1_ReGene_W | [*2] | W | Regenerative side side rated output |
| MG_CNT_MG1_max_trq_ReGene_Nm | 130 | Nm | Regenerative side maximum torque |
| MG_CNT_MG1_Const_trq_ReGene_radps | [*3] | rad/s | Regenerative side rated rotation speed |

[*1] 50000 * MG_CNT_Gain_Pmax

[*2] -50000 * 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.

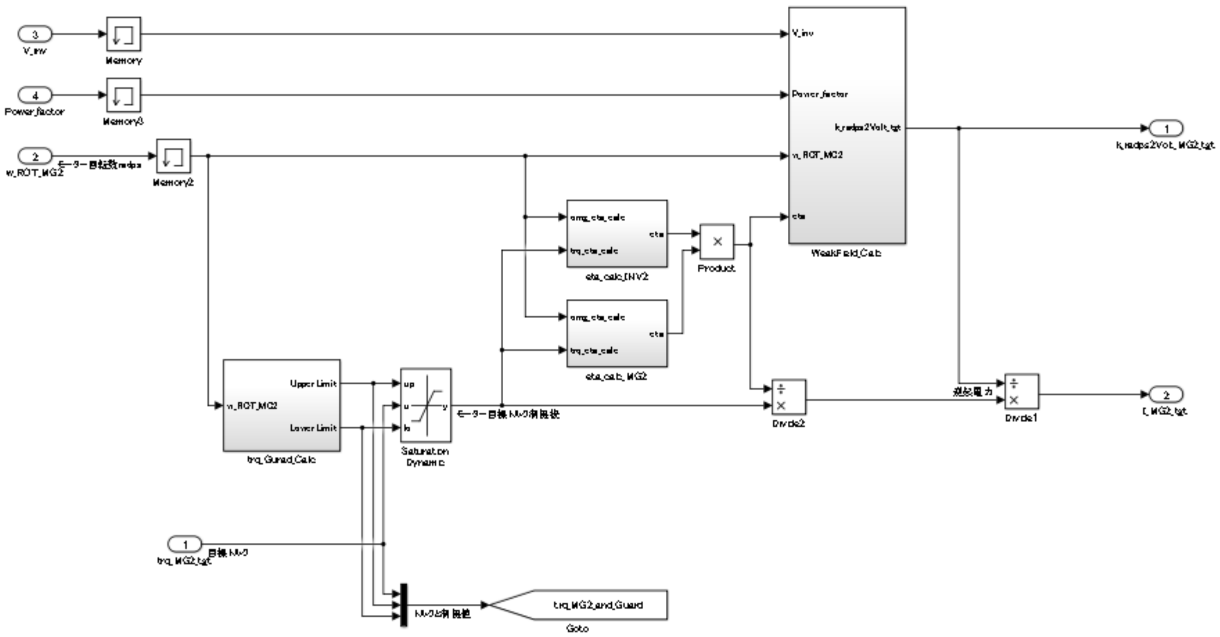



**Fig. 5.3.7 Data flow diagram: 3rd layer MG2_CNT system**

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 | 80000 | W | Powering side rated output |
| MG_CNT_MG2_max_trq_Gene_Nm | 260 | Nm | Powering side maximum torque |
| MG_CNT_MG2_Const_trq_Gene_radps | [*1] | rad/s | Powering side rated rotation speed |
| MG_CNT_Pmin_MG2_ReGene_W | -80000 | W | Regenerative side side rated output |
| MG_CNT_MG2_max_trq_ReGene_Nm | -260 | Nm | Regenerative side maximum torque |

[*1] MG_CNT_Pmax_MG2_Gene_W / MG_CNT_MG2_max_trq_Gene_Nm

5.3.7.5 Other information

None

### 5.3.8. [B11P: ENG_PNT] system functional specifications

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

#### 5.3.8.1 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

#### 5.3.8.2 Data flow diagram

The data flow diagram of this system is shown below.

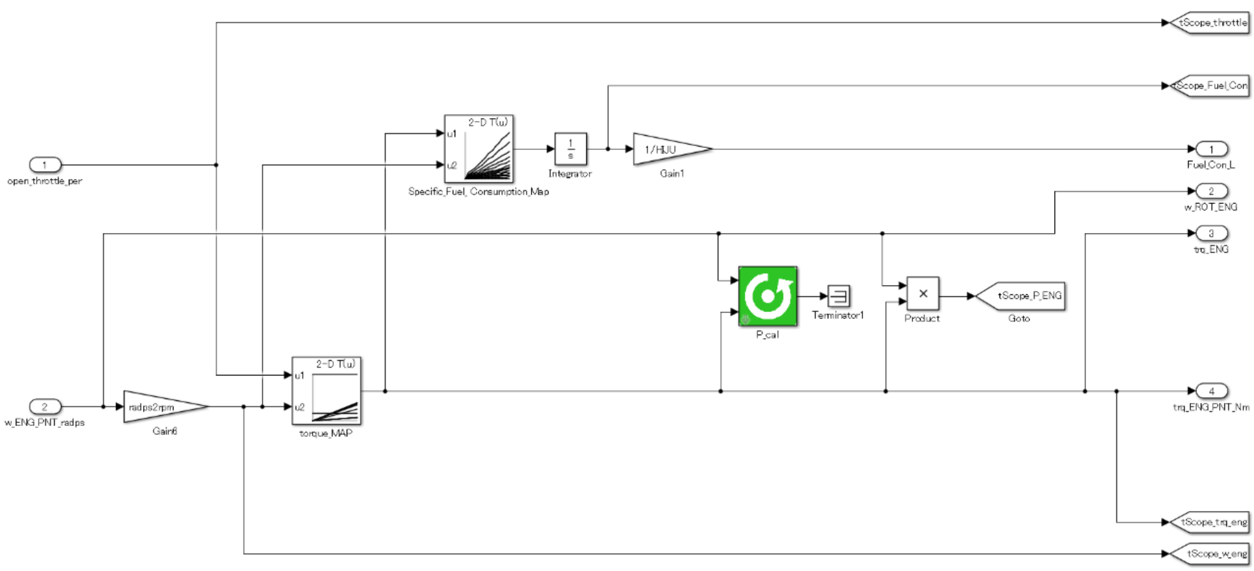



**Fig. 5.3.8 Data flow diagram: 3rd layer ENG_PNT system**

#### 5.3.8.3 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 |

#### 5.3.8.4 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 | <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 |

#### 5.3.8.5 Other information

None

## 5.3.9. [B12P: TM_PNT] system functional specifications

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

### 5.3.9.1 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 change the motor speed

Function to calculate engine rotation speed from engine torque and generator torque

Function to calculate the motor rotation speed from the motor torque and transmission torque

### 5.3.9.2 Data flow diagram

The data flow diagram of this system is shown below.

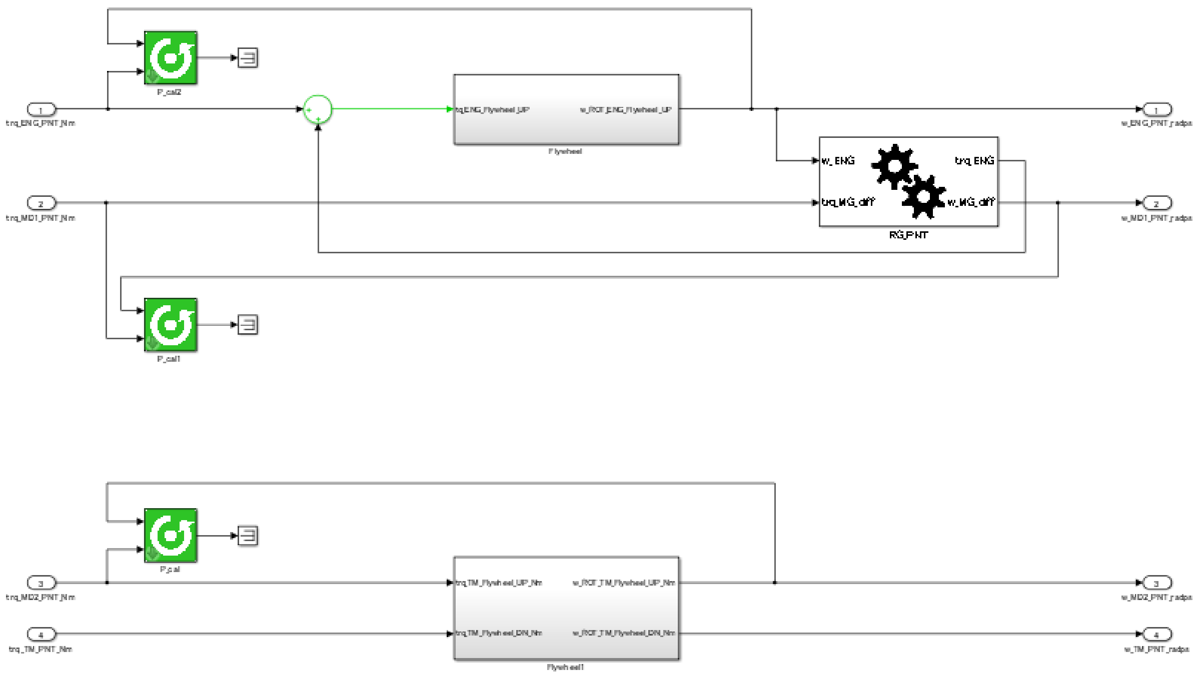



**Fig. 5.3.9 Data flow diagram：3rd layer TM_PNT system**

5.3.9.3 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 |

5.3.9.4 Parameter specifications

The parameter specifications of this system are shown below.

| Variable name | Set value | Unit | Explanation |
|---|---|---|---|
| TM_PNT_Flywheel_Inertia | 0.3 | kgm^2 | Flywheel inertia |
| TM_PNT_TM_Inertia | 0.3 | kgm^2 | Transmission inertia |
| TM_PNT_ratio_MG1_gear | 0.600 | - | Transmission gear ratio |
| TM_PNT_eta_MG1_gear | 0.97 | - | Generator primary deceleration efficiency |

5.3.9.5 Other information

None

### 5.3.10. [B13P: DF_PNT] system functional specifications

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

#### 5.3.10.1 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

#### 5.3.10.2 Data flow diagram

The data flow diagram of this system is shown below.

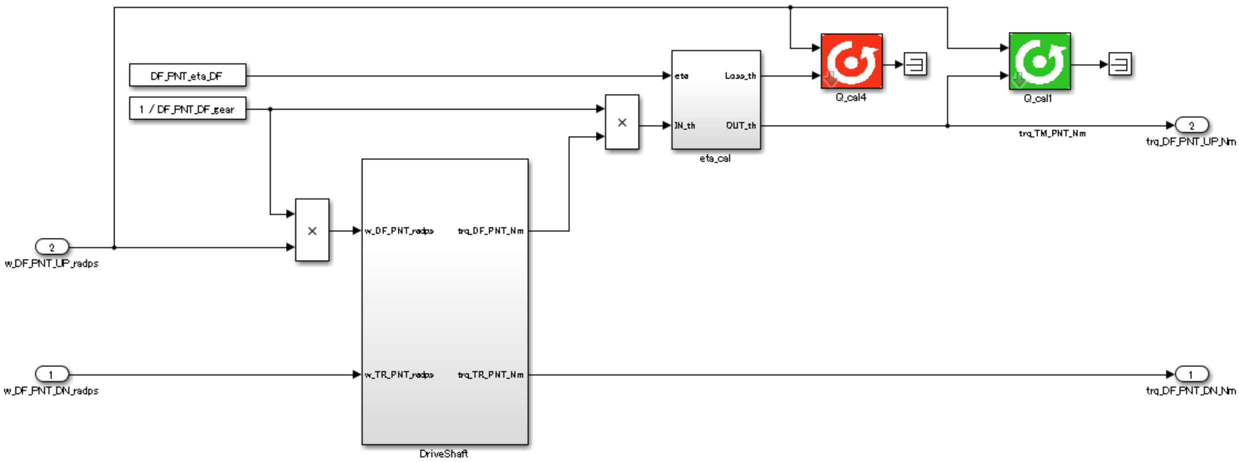



**Fig. 5.3.10 Data flow diagram：3rd layerDF_PNT system**

5.3.10.3 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 |

5.3.10.4 Parameter specifications

The parameter specifications of this system are shown below.

| Variable name | Set value | Unit | Explanation |
|---|---|---|---|
| DF_PNT_DF_gear | 7.4 | - | Differential gear reduction ratio |
| DF_PNT_eta_DF | 0.96 | - | Differential gear efficiency |
| DF_PNT_Driveshaft_Inertia | 0.1 | kgm^2 | Driveshaft inertia |
| DF_PNT_Driveshaft_spring | 10000 | - | Driveshaft spring coefficient |
| DF_PNT_Driveshaft_zeta | 4 | - | Second-order lag damping coefficient |
| DF_PNT_Driveshaft_damper | [*1] | - | Driveshaft damper coefficient |

[*1] 2*DF_PNT_Driveshaft_zeta*sqrt(DF_PNT_Driveshaft_spring*DF_PNT_Driveshaft_Inertia)

5.3.10.5 Other information

None

## 5.3.11. [B14P: BK_PNT] system functional specifications

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

### 5.3.11.1 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

### 5.3.11.2 Data flow diagram

The data flow diagram of this system is shown below.

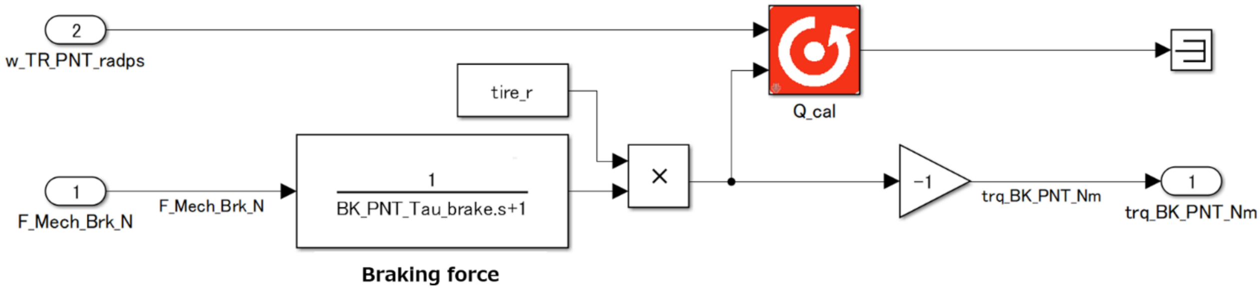



**Fig. 5.3.11 Data flow diagram : 3rd layer BK_PNT system**

5.3.11.3 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 |

5.3.11.4 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 |

5.3.11.5 Other information

None

## 5.3.12. [B15P: TR_PNT] system functional specifications

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

### 5.3.12.1 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

### 5.3.12.2 Data flow diagram

The data flow diagram of this system is shown below.

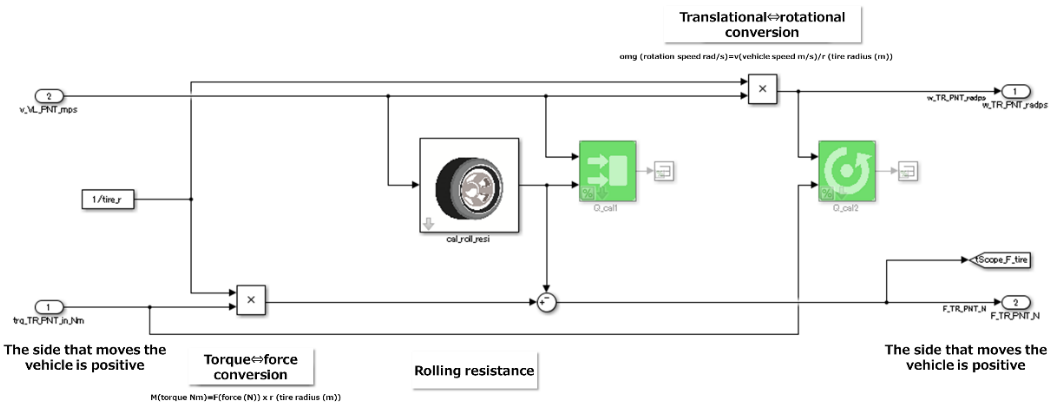



**Fig. 5.3.12 Data flow diagram：3rd layer TR_PNT system**

5.3.12.3 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) |

5.3.12.4 Parameter specifications

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

5.3.12.5 Other information

None

### 5.3.13. [B16P: VL_PNT] system functional specifications

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

#### 5.3.13.1 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

#### 5.3.13.2 Data flow diagram

The data flow diagram of this system is shown below.

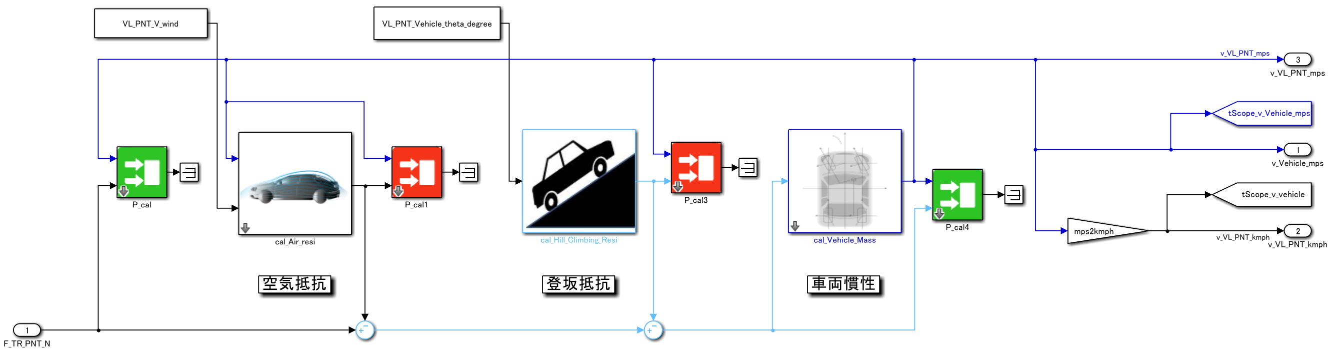



**Fig. 5.3.13 Data flow diagram：3rd layer VL_PNT system**

5.3.13.3 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) |

5.3.13.4 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 |

5.3.13.5 Other information

None

## 5.3.14. [B21P:MD1_PNT] system functional specifications

Description of the functional specifications of the third layer MD1_PNT system of the guideline-compliant model.

### 5.3.14.1 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

### 5.3.14.2 Data flow diagram

The data flow diagram of this system is shown below.

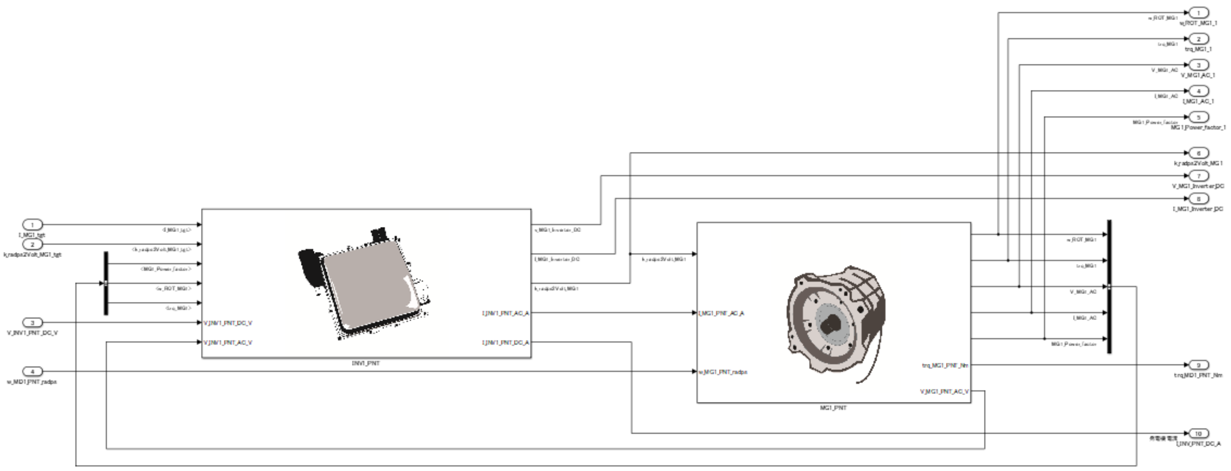



**Fig. 5.3.14 Data flow diagram：3rd layer MD1_PNT system**

5.3.14.3 Input/Output specifications

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

| Name | Unit | Scope | Explanation |
|---|---|---|---|
| **Inputs** | | | |
| 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 |

5.3.14.4 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 | 0.707 | - | nverter 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 | 300 | V | Motor inverter DC rated voltage |
| MG_PNT_w_ROT_MG1_Rated | [*1] | rpm | Rated motor rotation speed |

[*1] MG_CNT_MG1_Const_trq_ReGene_radps

5.3.14.5 Other information

None

### 5.3.15. [B22P:MD2_PNT] system functional specifications

Description of the functional specifications of the third layer MD2_PNT system of the guideline-compliant model.

#### 5.3.15.1 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

#### 5.3.15.2 Data flow diagram

The data flow diagram of this system is shown below.

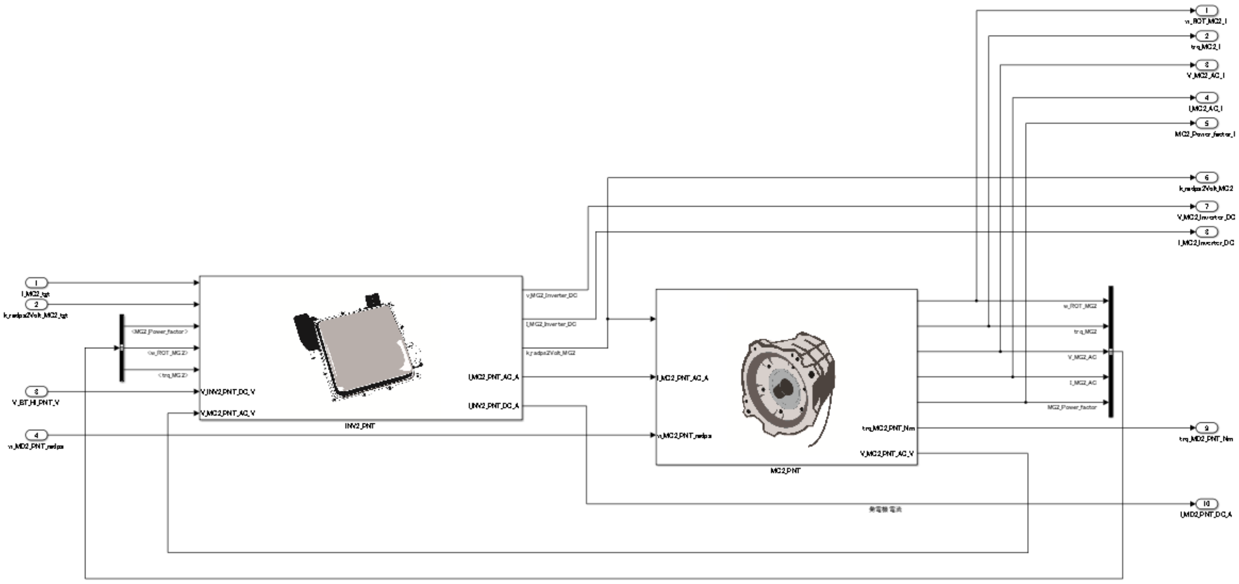



**Fig. 5.3.15 Data flow diagram：3rd layer MD2_PNT system**

5.3.15.3 Input/Output specifications

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

| Inputs | | | |
|---|---|---|---|
| Name | Unit | Scope | Explanation |
| I_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 |

5.3.15.4 Parameter specifications

The parameter specifications of this system are shown below.

| Variable name | Set value | Unit | Explanation |
|---|---|---|---|
| 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 | 0.707 | - | nverter modulation rate (sine wave modulation region only) |
| 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 power factor |
| MG_PNT_V_MG2_Rated | 300 | V | Motor inverter DC rated voltage |
| MG_PNT_w_ROT_MG2_Rated | [*1] | rpm | Rated motor rotation speed |

[*1] MG_CNT_MG2_Const_trq_ReGene_radps

5.3.15.5 Other information

None

## 5.3.16. [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.

### 5.3.16.1 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

### 5.3.16.2 Data flow diagram

The data flow diagram of this system is shown below.

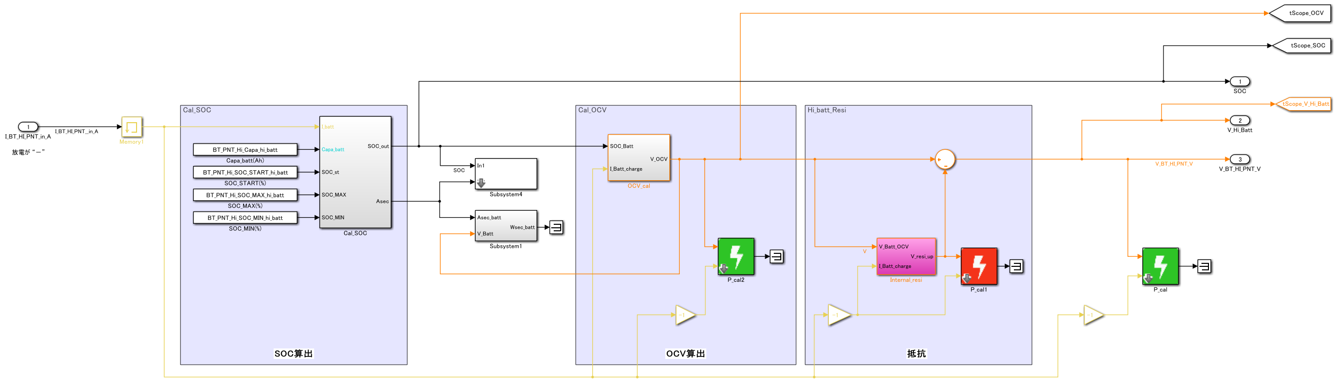



**Fig. 5.3.16 Data flow diagram：3rd layer BT_HI_PNT system**

5.3.16.3 Input/Output specifications

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

| Inputs | | | |
|---|---|---|---|
| Name | Unit | Scope | Explanation |
| I_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 |

5.3.16.4 Parameter specifications

The parameter specifications of this system are shown below.

| Variable name | Set value | Unit | Explanation |
|---|---|---|---|
| BT_PNT_Hi_Capa_hi_batt | 5.0 | 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 value |
| BT_PNT_Hi_SOC_MIN_hi_batt | 0 | % | High-voltage batterySOC minimum value |
| BT_PNT_Hi_ocv_SOC_hi_batt_OCV_V_table_x_SOC | <1x10> | % | High-voltage battery OCV calculation MAP<br>x-axis: SOC |
| BT_PNT_Hi_ocv_SOC_hi_batt_OCV_V_table | <1x10> | V | High-voltage battery OCV calculation MAP<br>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 |

5.3.16.5 Other information

None

## 5.3.17. [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.

### 5.3.17.1 Overview

The outline of this system is shown below.

① Modeling target
High-voltage electrical load modelfor 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

### 5.3.17.2 Data flow diagram

The data flow diagram of this system is shown below.

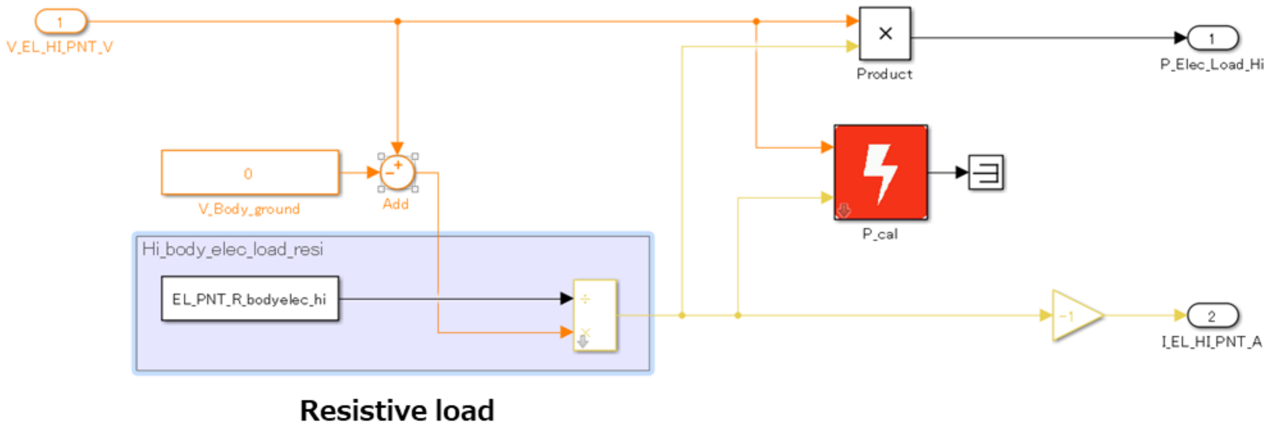



**Fig. 5.3.17 Data flow diagram：3rd layer EL_HI_PNT system**

5.3.17.3 Input/Output specifications

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

| Inputs | | | |
|---|---|---|---|
| Name | Unit | Scope | Explanation |
| 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 |

5.3.17.4 Parameter specifications

The parameter specifications of this system are shown below.

| Variable name | Set value | Unit | Explanation |
|---|---|---|---|
| EL_PNT_R_bodyelec_hi | 5800 [*1] | Ω | High-voltage side electrical load resistance |

[*1] 5800(Ω) = 290(V) / 0.05(A) Resistance value at which a current of 0.05A is flows when a 290V voltage is applied

5.3.17.5 Other information

None

## 5.3.18. [B34P: DCDC_PNT] system functional specifications

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

### 5.3.18.1 Overview

The outline of this system is shown below.

① Modeling target

Buck converter model

② Scope of modeling / degree of abstraction

Voltage drops from high-voltage side to low-voltage side

③ Modeled functions

Function to drop the voltage from the high voltage side to the low voltage side considering conversion efficiency

### 5.3.18.2 Data flow diagram

The data flow diagram of this system is shown below.

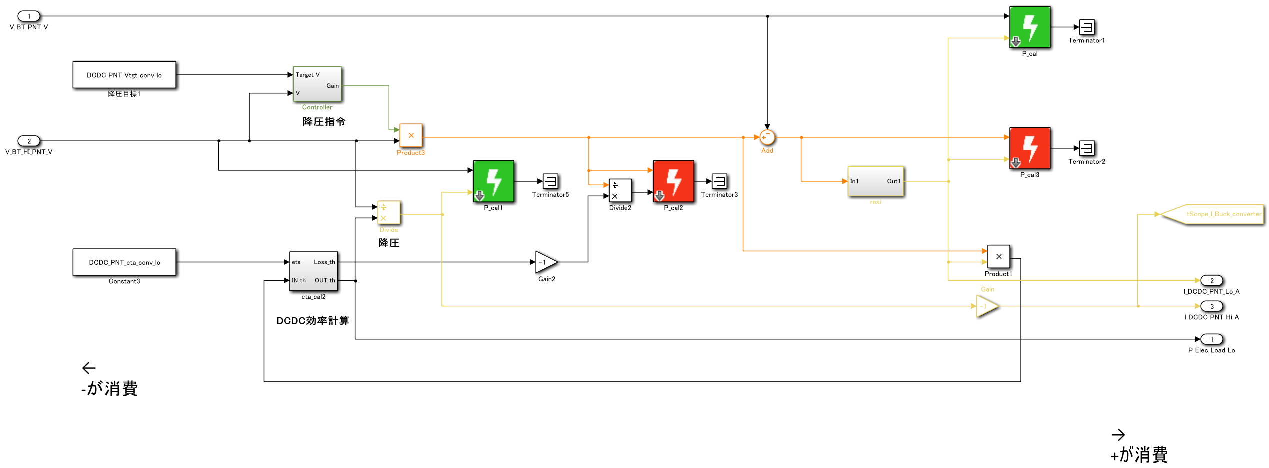



**Fig. 5.3.18 Data flow diagram：3rd layer DCDC_PNT system**

5.3.18.3 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 |

5.3.18.4 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 | Ω | Buck converter resistance value |
| DCDC_PNT_Vtgt_conv_lo | 14.0 | V | Target buck converter voltage value |

5.3.18.5 Other information

None

## 5.3.19. [B35P:BT_PNT] system functional specifications

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

### 5.3.19.1 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

### 5.3.19.2 Data flow diagram

The data flow diagram of this system is shown below.

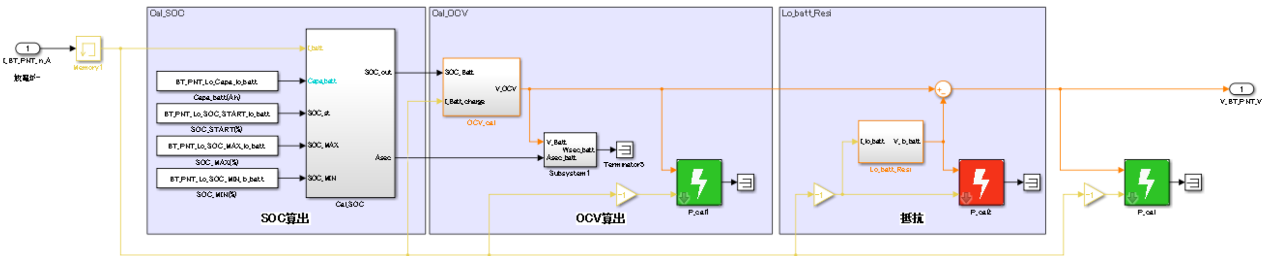



**Fig. 5.3.19 Data flow diagram：3rd layer BT_PNT system**

5.3.19.3 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 |

5.3.19.4 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 | Ω | Battery internal resistance value |

5.3.19.5 Other information

None

## 5.3.20. [B36P: EL_PNT] system functional specifications

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

### 5.3.20.1 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

### 5.3.20.2 Data flow diagram

The data flow diagram of this system is shown below.

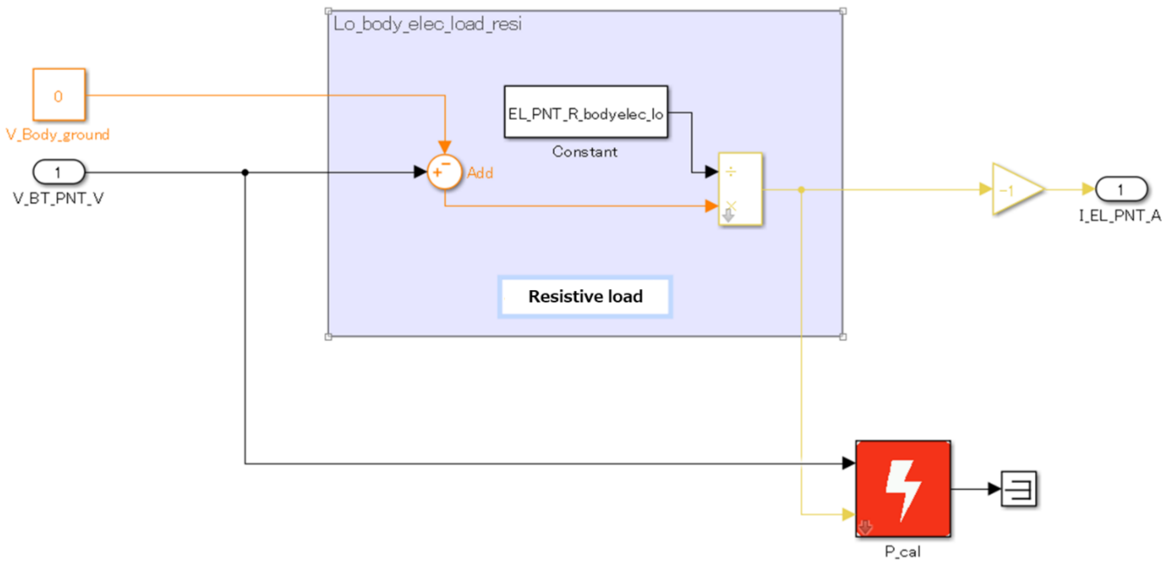



**Fig. 5.3.20 Data flow diagram：3rd layer EL_PNT system**

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 |
| Outputs | | | |
| Name | Unit | Scope | Explanation |
| I_EL_PNT_A | A | TBD | Low-voltage side current value |

5.3.20.4 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] | Ω | Low-voltage side electrical load resistance |

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

5.3.20.5 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 | | | |
| | | | Vehicle Plant | VehicleBody | VB | Engine | Engine | ENG_PNT | | | |
| | | | | | | Transmission | Transmission | TM_PNT | Flywheel | Flywheel | FW_PNT |
| | | | | | | | | | Gear | Gear | RG_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 | | | |
| | | | | | | 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.

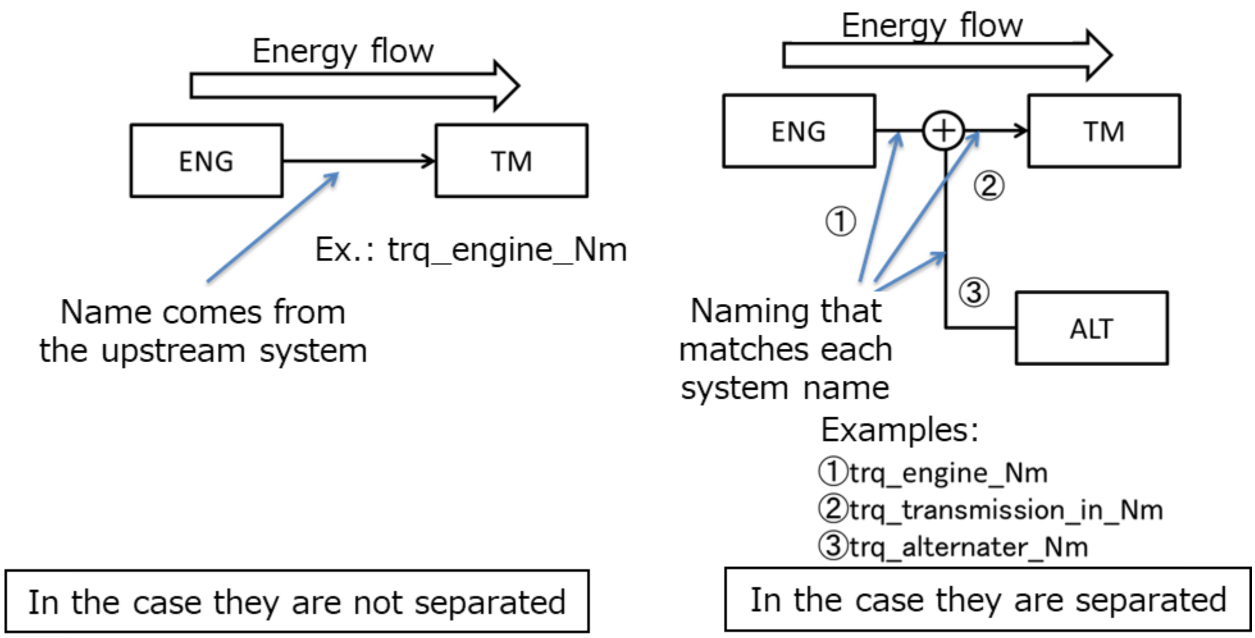



**Fig. 6.4.1 Signal naming methods**

### 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.

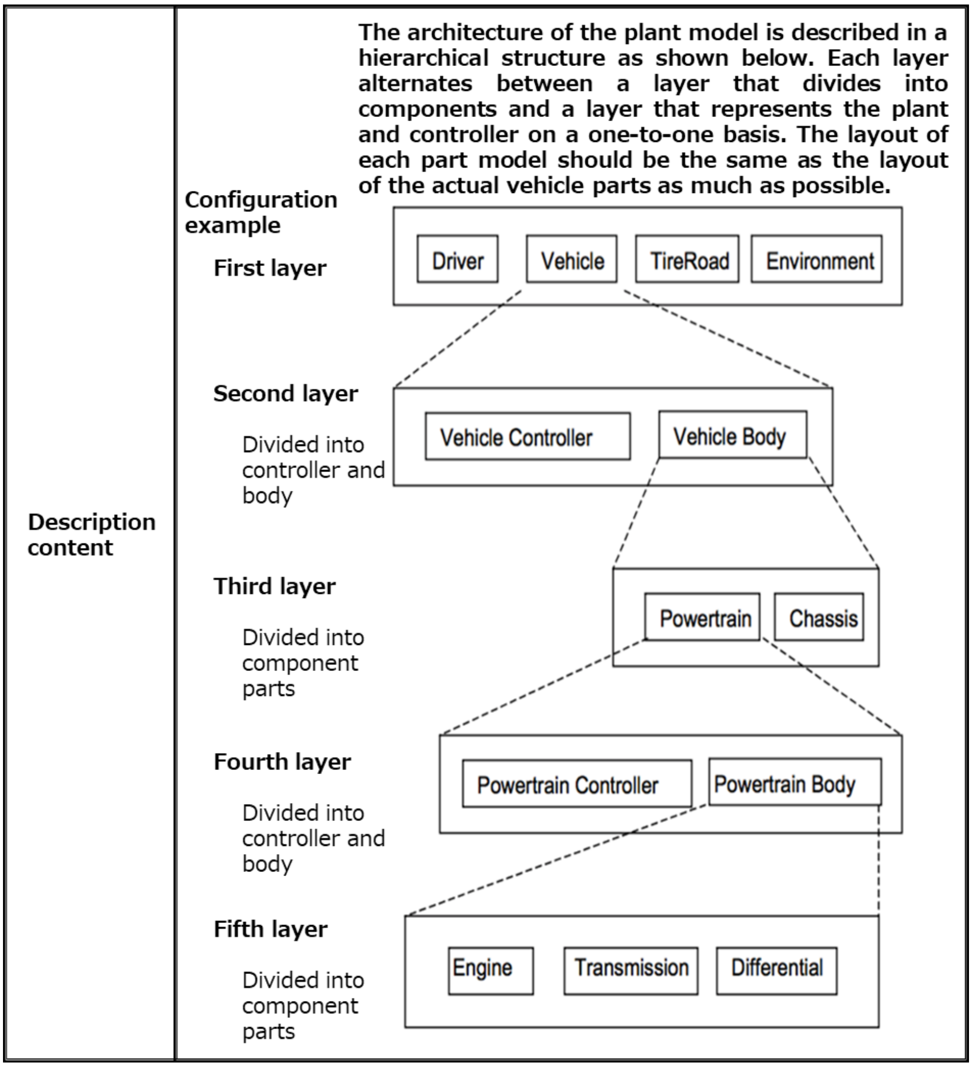



**Fig. 6.5.1 JP3001 "plant structure"**

<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.

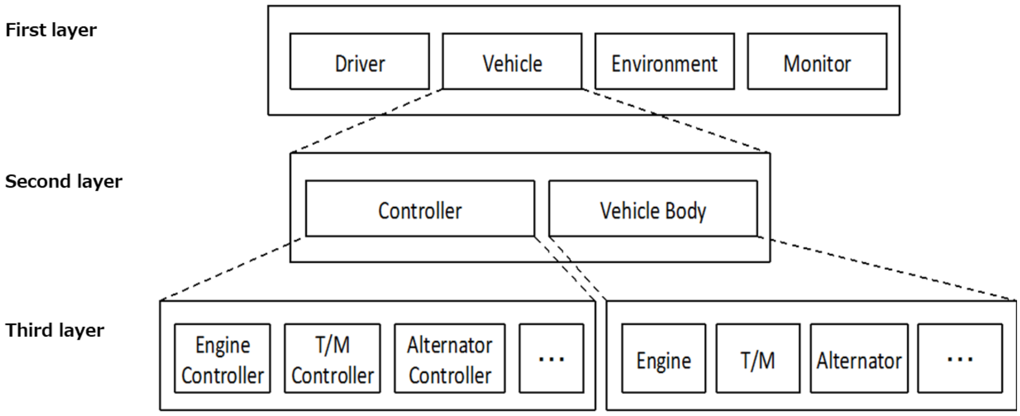



**Fig. 6.5.2 Structure in which control and plant are largely separated in the same layer**

## 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.

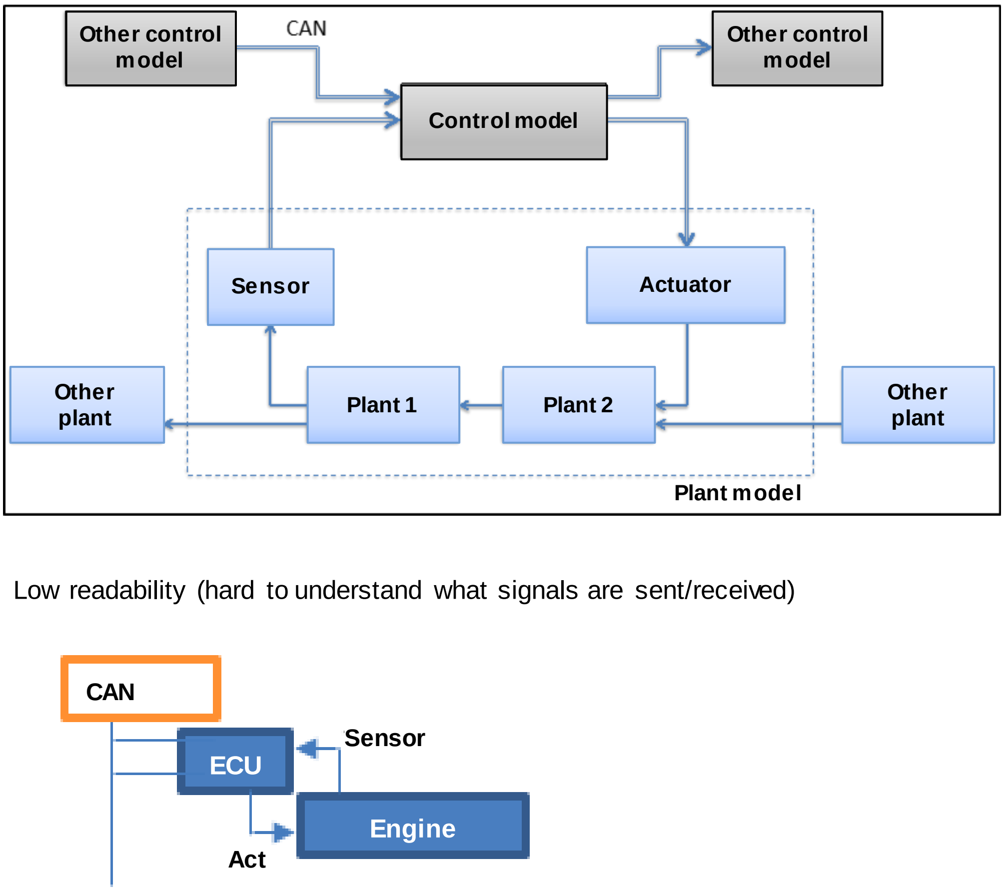



**Fig. 6.6.1 I/F Types and description methods**

### 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 spaghettified. 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.

①Plant 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.
②Control 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 | Ω | ohm |
| celsius temperature | celsius degree | ℃ | 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