Module Interface Specification for Mechatronics

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Revision History

Date	Version	Notes
January 18, 2023	1.0	First Version

Symbols, Abbreviations and Acronyms

See SRS Documentation here.

Contents

1 Introduction

The following document details the Module Interface Specifications for the vehicle controls system for the McMaster Formula Electric Vehicle.

Complementary documents include the System Requirement Specifications and Module Guide. The full documentation and implementation can be found here.

2 Notation

The structure of this MIS has been reformatted to reflect the model-based design principles that our system is based on, in the form of Simulink. This environment is composed of blocks (black-box modules), each responsible for managing a specific subsystem/function, and input and output signals between other blocks. This inherently frames the software system as modularized, with defined IO interactions and hidden implementations.

Each MIS details these critical elements - inputs, outputs, and states & transitions if a state manager is present in the module. An MIS has been defined for all 5 of our main subsystems.

3 Module Decomposition

The following table is taken directly from the Module Guide document for this project.

Level 1	**Level 2**
Hardware-Hiding	Plant Model
Behaviour-Hiding	Driver Interface Vehicle Dynamics Motor Interface Battery Monitor
Software Decision	Governor

Table 1: Module Hierarchy

4 Governor MIS

The previously referenced as MSR (Mode-selection-ring) in our SRS, is now named Governor. The Governor is responsible for controlling and monitoring the Battery Monitor, Vehicle Dynamics, Motor Interface, and Driver Interface subsystems. Governor uses the state of each module to determine an overall vehicle status, and coordinate state changes between these modules.

4.1 Alias Name

GOV

4.2 Uses

Driver Interface, Motor Interface, Battery Monitor, Vehicle Dynamics

4.3 Variables

4.3.1 Inputs

Variable	GOV_e_bmSts
Description	Battery monitoring module statuses.
Data Type	Enumeration
Scope	Local
Origin	System

Variable	GOV_e_diSts
Description	Driver interface module statuses.
Data Type	Enumeration
Scope	Local
Origin	System

Variable	GOV_e_miSts
Description	Motor interface module statuses.
Data Type	Enumeration
Scope	Local
Origin	System

Variable	GOV_e_vdSts
Description	Vehicle dynamics module statuses.
Data Type	Enumeration
Scope	Local
Origin	System

4.3.2 Outputs

Variable	GOV_e_bmCmd
Description	State transition command issued to the battery monitoring module.
Data Type	Enumeration
Scope	Global
Origin	System

Variable	GOV_e_miCmd
Description	State transition command issued to the motor interface module.
Data Type	Enumeration
Scope	Global
Origin	System

Variable	GOV_e_diCmd
Description	State transition command issued to the driver interface module.
Data Type	Enumeration
Scope	Global
Origin	System

Variable	GOV_e_vdCmd
Description	State transition command issued to the vehicle dynamics module.
Data Type	Enumeration
Scope	Global
Origin	System

4.4 States and Transitions

State	Level	Transition Condition	Destination State
Initialize outputs	N/A	True (exit after 1 execution)	HV startup
STARTUP	Parent	BM reports startup error	HV startup error
-	-	MI reports error AND motor start count ≥ 5	Motor faulted
-	-	MI reports error AND motor start count < 5	Error reset
-	-	DI reports error	Driver Interface error
STARTUP $\gg$ HV startup	Child	BM reports running	Command motor startup
STARTUP $\gg$ Command motor startup	Child	MI reports running AND DI reports driver requested start	Send readyToDrive
STARTUP $\gg$ Send readyToDrive	Child	DI reports running	RUNNING
RUNNING	N/A	BM reports running error	HV run error
-	-	MI reports error	Motor run error
STARTUP ERROR	Parent	None	None
STARTUP ERROR $\gg$ HV startup error	Child	None	None
STARTUP ERROR $\gg$ Error reset	Child	MI reports off	STARTUP
STARTUP ERROR $\gg$ Motor faulted	Child	None	None
RUNNING ERROR	Parent	None	None
RUNNING ERROR $\gg$ HV run error	Child	None	None
RUNNING ERROR $\gg$ Motor run error	Child	None	None

5 Driver Interface MIS

The Driver Interface module reads environment signals from the driver (eg. pedal, steering input), and processes these signals for use elsewhere in the control system.

5.1 Alias Name

DI

5.2 Uses

Governor

5.3 Variables

5.3.1 Inputs

Variable	GOV_e_diCmd
Description	Driver interface module command from Governor.
Data Type	Enumeration
Scope	Local
Origin	System

Variable	DI_V_BrakePedalPos
Description	Brake pedal position as a percentage.
Data Type	Voltage
Scope	Local
Origin	System

Variable	DI_b_DriverButton
Description	Driver button.
Data Type	Boolean
Scope	Local
Origin	System

Variable	DI_V_AccelPedalPos1
Description	Accelerator pedal position sensor 1 as a percentage.
Data Type	Voltage
Scope	Local
Origin	System

Variable	DI_V_AccelPedalPos2
Description	Accelerator pedal position sensor 2 as a percentage.
Data Type	Voltage
Scope	Local
Origin	System

Variable	DI_V_SteeringAngle
Description	Steering angle.
Data Type	Voltage
Scope	Local
Origin	System

5.3.2 Outputs

Variable	GOV_e_diSts
Description	Driver interface status output to Governor.
Data Type	Enumeration
Scope	Global
Origin	System

Variable	GOV_e_TorqueRequest
Description	Torque request output to vehicle dynamics module.
Data Type	Single
Scope	Global
Origin	System

State	Level	Transition Condition	Destination State
Initialization	Parent	N/A	Running
Running	Parent	N/A	Driver interface error or vehicle coasting
Waiting for driver	Child	Initialization complete	Driver requested start
Driver requested start	Child	Drive button pushed	Ready to drive
Ready to drive	Child	Governor commanded state transition	Speaker on
Speaker on	Stepchild	N/A	Speaker off
Speaker off	Stepchild	2 second timer	N/A
Driver interface error	Parent	Drive interface error detected	N/A
Vehicle coasting	Parent	Governor commanded state transition	N/A

6 Vehicle Dynamics MIS

The Vehicle Dynamics module is the medium between the Driver Interface, and the Motor interface. It takes processed inputs from both the Driver Interface and AMK motors, and uses them to calculate appropriate motor torque requests based on factors like available electrical power and component temperatures.

6.1 Alias Name

VD

6.2 Uses

Driver Interface, Governor

6.3 Variables

6.3.1 Inputs

Variable	DI_p_driverTorqueRequest
Description	Filtered potentiometer value from the driver accelerator pedal.
Data Type	Single
Scope	Global
Origin	System

Variable	DI_p_brakePedalPosition
Description	Filtered potentiometer value from the driver brake pedal.
Data Type	Single
Scope	Global
Origin	System

Variable	DI_p_steeringAngle
Description	Filtered steering angle sensor input value.
Data Type	Single
Scope	Global
Origin	System

Variable	ptCAN_AMK_ActualValues1_Left
Description	Incoming CAN messages from the left-side inverter.
Data Type	Enumeration
Scope	Local
Origin	Environment

Variable	ptCAN_AMK_ActualValues1_Right
Description	Incoming CAN messages from the right-side inverter.
Data Type	Enumeration
Scope	Local
Origin	Environment

6.3.2 Outputs

Variable	VD_n_RightMotorSpeedRequest
Description	Right Motor Speed Request in RPM.
Data Type	Single
Scope	Global
Origin	System

Variable	VD_T_RightMotorTorqueLimitPositive
Description	Positive Right Motor Torque Limit in Nm.
Data Type	Single
Scope	Global
Origin	System

Variable	VD_T_RightMotorTorqueLimitNegative
Description	Negative Right Motor Torque Limit in Nm.
Data Type	Single
Scope	Global
Origin	System

Variable	VD_n_LeftMotorSpeedRequest
Description	Left Motor Speed Request in RPM.
Data Type	Single
Scope	Global
Origin	System

Variable	VD_T_LeftMotorTorqueLimitPositive
Description	Positive Left Motor Torque Limit in Nm.
Data Type	Single
Scope	Global
Origin	System

Variable	VD_T_LeftMotorTorqueLimitNegative
Description	Negative Left Motor Torque Limit in Nm.
Data Type	Single
Scope	Global
Origin	System

6.4 States and Transitions

None

7 Motor Interface MIS

The Motor Interface monitors and controls the state of each of the 2 AMK motors. As the name implies, it serves as the interface between higher level system modules and the motors.

7.1 Alias Name

MI

7.2 Uses

Governor, Vehicle Dynamics

7.3 Variables

7.3.1 Inputs

Variable	GOV_e_miCmd
Description	State transition command issued to the motor interface module.
Data Type	Enumeration
Scope	Global
Origin	System

Variable	ptCAN_AMK_ActualValues1_Right
Description	Incoming CAN messages from the right-side inverter.
Data Type	Enumeration
Scope	Local
Origin	Environment

Variable	ptCAN_AMK_ActualValues2_Right
Description	Incoming CAN messages from the right-side inverter.
Data Type	Enumeration
Scope	Local
Origin	Environment

Variable	VD_n_RightMotorSpeedRequest
Description	Right Motor Speed Request in RPM.
Data Type	Single
Scope	Global
Origin	System

Variable	VD_T_RightMotorTorqueLimitPositive
Description	Positive Left Motor Torque Limit in Nm.
Data Type	Single
Scope	Global
Origin	System

Variable	VD_T_RightMotorTorqueLimitNegative
Description	Negative Right Motor Torque Limit in Nm.
Data Type	Single
Scope	Global
Origin	System

Variable	ptCAN_AMK_ActualValues1_Left
Description	Incoming CAN messages from the left-side inverter.
Data Type	Enumeration
Scope	Local
Origin	Environment

Variable	ptCAN_AMK_ActualValues2_Left
Description	Incoming CAN messages from the left-side inverter.
Data Type	Enumeration
Scope	Local
Origin	Environment

Variable	VD_n_LeftMotorSpeedRequest
Description	Left Motor Speed Request in RPM.
Data Type	Single
Scope	Global
Origin	System

Variable	VD_T_LeftMotorTorqueLimitPositive
Description	Positive Left Motor Torque Limit in Nm.
Data Type	Single
Scope	Global
Origin	System

Variable	VD_T_LeftMotorTorqueLimitNegative
Description	Negative Left Motor Torque Limit in Nm.
Data Type	Single
Scope	Global
Origin	System

7.3.2 Outputs

Variable	GOV_e_vdSts
Description	Internal status of the vehicle dynamics module, for use by Governor.
Data Type	Enumeration
Scope	Global
Origin	System

Variable	VD_T_RmotorTorqueReq
Description	Right wheel torque request computed from the Vehicle Dynamics module and sent to Motor Interface module
Data Type	Single
Scope	Global
Origin	System

7.4 States and Transitions

State	Level	Transition Condition	Destination State
Motor off/Waiting for Governor	Parent	N/A	AMK Startup
AMK Startup	Parent	N/A	AMK running or error state
Waiting for system ready	Child	Governor issued state command	Toggle AMK DC on or error state
Toggle AMK DC on	Child	AMK system ready	Enforce set points zero
Enforce set points zero	Child	AMK DC on and AMK quit DC on	Command AMK on
Command AMK on	Child	After 1 second	Error or AMK running
AMK running	Parent	AMK inverter on and AMK quit inverter on	AMK shutdown or error state
AMK shutdown	Parent	Governor commanded state transition	Motor off/Waiting for governor
Enforce set points zero	Child	Governor commanded state transition	Command off
Command off	Child	AMK inverter off	Toggle DC off
Toggle DC off	Child	AMK inverter quit off	Motor off waiting for governor
AMK error detected	Parent	Error detected (in any child or parent)	AMK error reset
AMK error reset	Parent	Governor issued state command	Motor off wait for governor
Enforce set points zero	Child	Governor issued state command	Toggle AMK enable
Toggle AMK enable	Child	AMK inverter off	Send reset
Send reset	Child	500ms timer	Toggle reset
Toggle reset	Child	500ms timer	AMK system ready

8 Battery Monitor MIS

The Battery Monitor reads the battery's three high voltage contactor states (closed or open), and determines & reports if the battery is in an operating state.

8.1 Alias Name

BM

8.2 Uses

None

8.3 Variables

8.3.1 Inputs

Variable	GOV_e_bmCmd
Description	Battery monitoring module command.
Data Type	Enumeration
Scope	Local
Origin	System

Variable	BM_b_prechrgContactorSts
Description	Battery monitoring precharge contactor status.
Data Type	Boolean
Scope	Local
Origin	System

Variable	BM_b_HVposContactorSts
Description	Battery monitoring high voltage positive contactor status.
Data Type	Boolean
Scope	Local
Origin	System

Variable	BM_b_HVnegContactorSts
Description	Battery monitoring high voltage negative contactor status.
Data Type	Boolean
Scope	Local
Origin	System

8.3.2 Outputs

Variable	GOV_e_bmCSts
Description	Battery monitoring module status.
Data Type	Enumeration
Scope	Local
Origin	System

8.4 States and Transitions

State	Level	Transition Condition	Destination State
Initial State	Parent	All BM contactors open	Startup State 1
Initial State	Parent	precharge contactor closed, HV negative and HV positive contactors open	Error Precharge Closed State
Initial State	Parent	All BM contactors closed	Error All Closed State
Initial State	Parent	HV positive contactor closed, precharge and HV negative contactors open	Error HV Positive
Initial State	Parent	precharge and HV negative contactors closed, HV positive contactor open	Precharge State
Initial State	Parent	HV negative and positive contactors closed, precharge contactor open	Running State
Startup State 2	Parent	HV negative contactor closed, precharge and HV positive contactors open	Startup State
Startup State	Parent	Precharge and HV negative contactor closed, HV positive contactor open	Initialize Precharge State
Startup State	Parent	After 1 second	Error Startup State
Initialize Precharge State	Parent	All contactors closed	Precharge state
Initialize Precharge State	Parent	After 1 second	Error Initialize Precharge state
Precharge State	Parent	HV positive and negative contactors closed, precharge contactor open	Running State
Precharge State	Parent	After 1 second	Error Precharge State
Running State	Parent	HV positive contactor closed, precharge and HV negative contactor closed	Running state
Running State	Parent	After 1 second	Error Running State