1 HUD Image Brightness Function – FNV3

1.1 Functional Description

The brightness of the HUD image is determined by the dimming software algorithm. This function has two inputs: HUD background image brightness sensor and the user brightness adjustment setting as sent from the HMI.

There is a light sensor which looks at the road just in front of the bumper of the vehicle which acts as the background for the projected HUD image. The background for the image is the largest indicator for the desired image brightness in order to maintain a contrast ratio of the image to the total brightness in the eyebox. The background brightness comes to the HUD via ICAN at a periodic rate in candelas per meter squared.

The driver has the ability to choose from thirteen brightness levels: level1 to level13. The cluster menu to adjust the HUD brightness can be found under cluster "Settings" menu. When the Image Brightness selection is made, the cluster will send a request to the HUD to display the Image Brightness menu. The cluster will display a message to the driver indicating that they should look to the HUD for changing the brightness. As the user scrolls through the brightness menu selections the brightness will change in the HUD. The setting changes and is stored as soon as the HUD reacts to the Up/Down press.

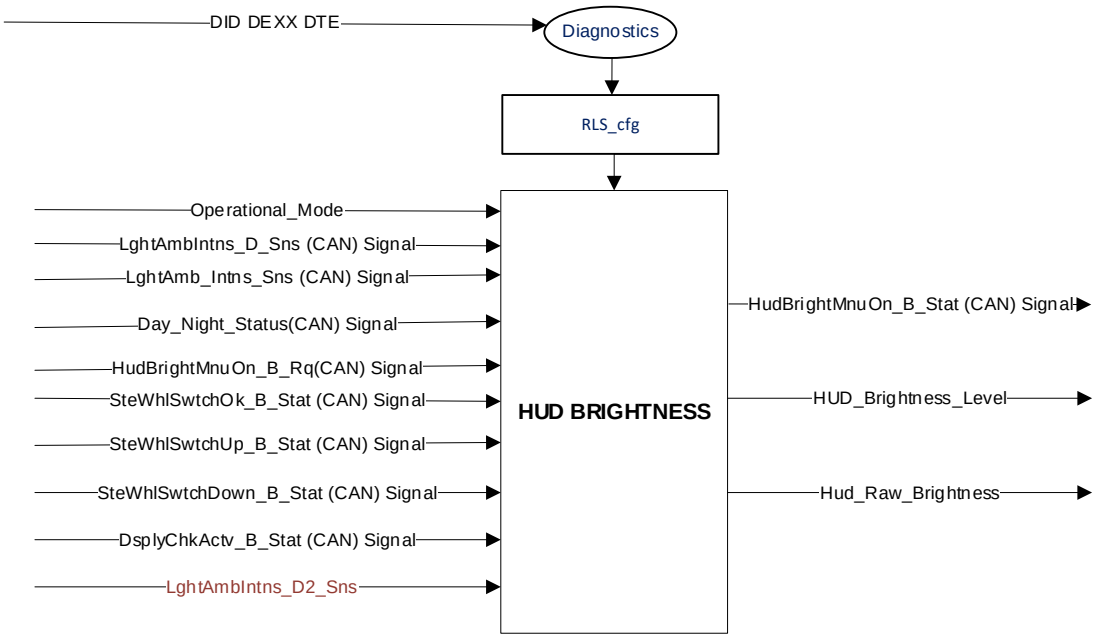
On FNV3 architecture signals would be framed gateway that is why following signals have been removed for all FNV3 and above architecture programs:
LghtAmb_Intns_Sns_UB
LghtAmbIntns_D_Sns_UB
LghtAmbIntns_D2_Sns_UB

1.2 Interfaces

1.2.1 Interface Context Diagram (I/O Block Diagram)

The HUD Brightness module has the following inputs and output signals. The signals are shown in HUD Brightness Function Context Diagram. From all input information, the module calculates the output values to control the dimming characteristics of the HUD.

HUD Brightness Function Context Diagram



1.2.2 Inputs

1.2.2.1 MUX message on the CAN Bus from IPC

1.2.2.1.1 SIG-REQ-412022/A-HudBrightMnuOn_B_Rq Signal

Signal Name	Size (bits)	Detail	Units	Res.	Offset	State Encoded	Min	Max
HudBrightMnuOn_B_Rq	1		SED	1	0		0 (0x0)	1 (0x1)
		No				0 (0x0)		
		Yes				1 (0x1)		

1.2.2.2 MUX message on the CAN Bus from GWM

1.2.2.2.1 SIG-REQ-412023/A-Day_Night_Status Signal

Signal Name	Size (bits)	Detail	Units	Res.	Offset	State Encoded	Min	Max
Day_Night_Status	2		SED	1	0		0 (0x0)	3 (0x3)
		Null				(0x0)		
		Day				(0x1)		
		Night				(0x2)		
		NotUsed				(0x3)		

1.2.2.3 MUX message on the CAN Bus from Lighting Sensor

1.2.2.3.1 SIG-REQ-412024/A-LghtAmbIntns_D_Sns

Signal Name	Size (bits)	Detail	Units	Res.	Offset	State Encoded	Min	Max
LghtAmbIntns_D_Sns	2	'0 = NULL (default out of reset until sensor CAN provide a reading, also the SCCM will use this state if the LIN signal goes missing for 5 seconds)	SED	1	0	(0x0)	0 (0x0)	3 (0x3)
		1 = Low range (brightness res: 8 cd/m^2)				(0x1)		
		2 = High range (brightness res: 80 cd/m^2)				(0x2)		
		3 = FAULT (sensor detects some sort of fault, either with sensor or HUD brightness reading).				(0x3)		

1.2.2.4 MUX message on the CAN Bus from Lighting Sensor

1.2.2.4.1 SIG-REQ-412025/A-LghtAmb_Intns_Sns

Signal Name	Size (bits)	Detail	Units	Res.	Offset	State Encoded	Min	Max
LghtAmb_Intns_Sns	8		Unitless(as per database) cd/m^2(implied)	1	0	(0x0)	0	0xFF

1.2.2.5 MUX message on the CAN Bus from Lighting Sensor

1.2.2.5.1 SIG-REQ-412027/A-LghtAmbIntns_D2_Sns

Signal Name	Size (bits)	Detail	Units	Res.	Offset	State Encoded	Min	Max
LghtAmbIntns_D2_Sns	2		SED	1	0		0 (0x0)	3 (0x3)
		Low				0(0x0)		
		Medium				1(0x1)		
		High				2(0x2)		
		Fault (default out of reset until sensor CAN provide a reading, also the SCCM will use this state if the LIN signal goes missing for 5 seconds and also sensor will send this if sensor detects some sort of fault, either with sensor or HUD brightness reading)				3(0x3)		

1.2.2.6 MUX message on the CAN Bus from SCCM

1.2.2.6.1 SteWhlSwtchY_B_Stat Signals

1.2.2.6.1.1 SIG-REQ-412029/A-SteWhlSwtchOk_B_Stat

Signal Name	Size (bits)	Detail	Units	Res.	Offset	State Encoded	Min	Max
SteWhlSwtchOk_B_Stat	1		SED	1	0		0 (0x0)	1 (0x1)
		Button_Not_Pressed				(0x0)		
		Button_Pressed				(0x1)		

1.2.2.6.1.2 SIG-REQ-412030/A-SteWhlSwtchUp_B_Stat

Signal Name	Size (bits)	Detail	Units	Res.	Offset	State Encoded	Min	Max
SteWhlSwtchUp_B_Stat	1		SED	1	0		0 (0x0)	1 (0x1)
		Button_Not_Pressed				(0x0)		
		Button_Pressed				(0x1)		

1.2.2.6.1.3 SIG-REQ-412031/A-SteWhlSwtchDown_B_Stat

Signal Name	Size (bits)	Detail	Units	Res.	Offset	State Encoded	Min	Max
SteWhlSwtchDown_B_Stat	1		SED	1	0		0 (0x0)	1 (0x1)
		Button_Not_Pressed				(0x0)		
		Button_Pressed				(0x1)		

1.2.2.6.2 SIG-REQ-412032/A-DsplyChkActv_B_Stat Signal

Signal Name	Size (bits)	Detail	Units	Res.	Offset	State Encoded	Min	Max
DsplyChkActv_B_Stat	1		SED	1	0		0 (0x0)	1 (0x1)
		Inactive				0x0		
		Active				0x1		

1.2.2.7 IR-REQ-412033/A-Internal:

- Operational_Mode
- RLS_cfg

1.2.3 Outputs

1.2.3.1 MUX message on the CAN Bus

1.2.3.1.1 SIG-REQ-412034/A-HudBrightMnuOn_B_Stat Signal

Signal Name	Size (bits)	Detail	Units	Res.	Offset	State Encoded	Min	Max
HudBrightMnuOn_B_Stat	1		SED	1	0		0 (0x0)	1 (0x1)
		No				0 (0x0)		
		Yes				1 (0x1)		

1.2.3.2 Internal

1.2.3.2.1 IR-REQ-412035/A-HUD_Raw_Brightness

1.2.3.2.2 IR-REQ-412036/A-HUD_Brightness_Level

1.3 Function/Performance

1.3.1 F-REQ-412037/A-Operational Modes

Mode	Differentiating Vehicle Conditions
Sleep Mode	HUD Brightness Function Disabled
Limited Mode	HUD Brightness Function Disabled
Crank Mode	HUD Brightness Function Enabled/Disabled
Normal Mode	HUD Brightness Function Enabled/Disabled

1.3.2 Voltage Levels

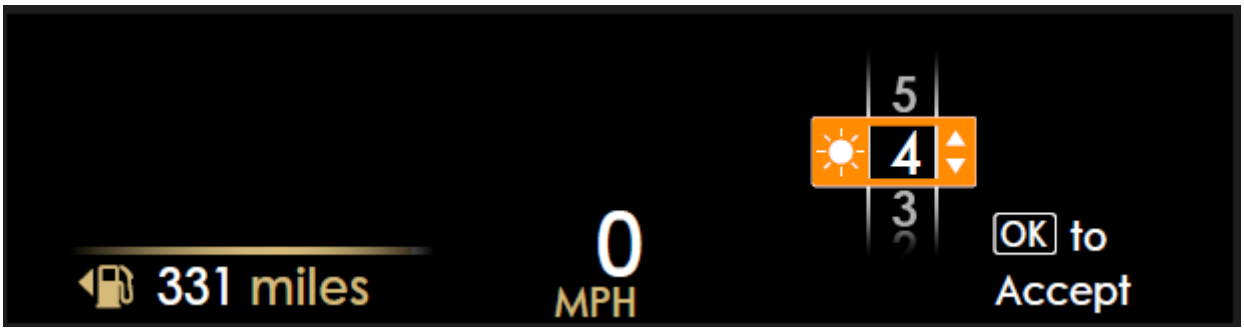
Refer to HUD Features Table located in the Operational Modes and Voltage Range Strategies section in this SPSS.

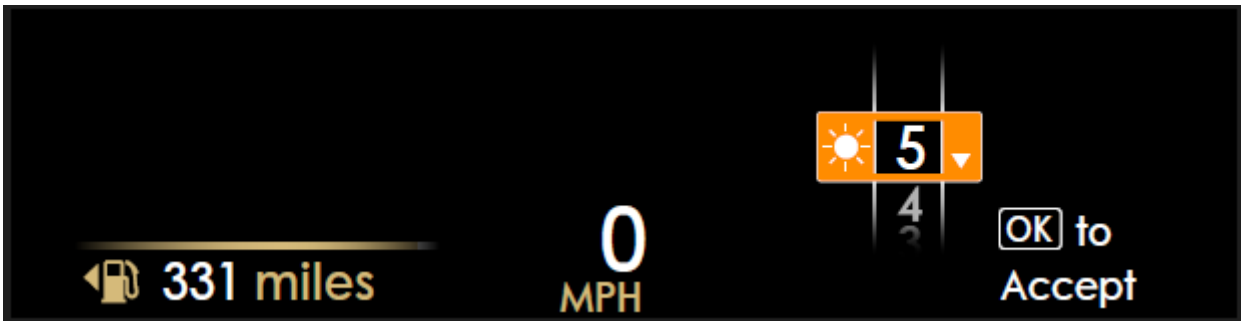
1.3.3 Human-Machine Interface

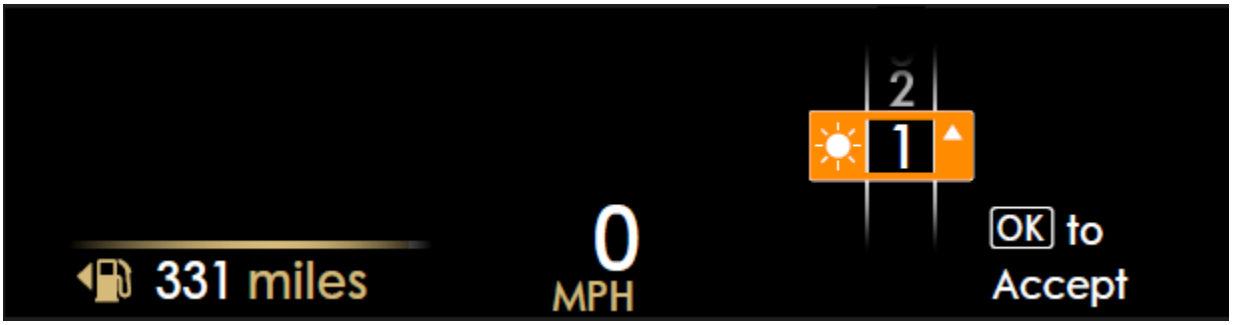
1.3.3.1 Visual

1.3.3.2 Indicator Graphics / Display Format

Refer to Graphics Section in the Master Document Section in this SPSS (HMI wall paper). Examples shown below.







1.3.3.2.1 Indicator Color Coordinates

Reference section COLOR & ILLUMINATION REQUIREMENTS (GRAPHICS)

1.3.3.2.2 Indicator Characteristics

Refer to Message Center X Display_Y Button Interface Section, where X and Y are appropriate values in this document.

1.3.3.3 Audio

None

1.3.3.4 Switch Control Logic

Consumer access to the HUD Brightness function shall be as specified in instrument cluster requirements.

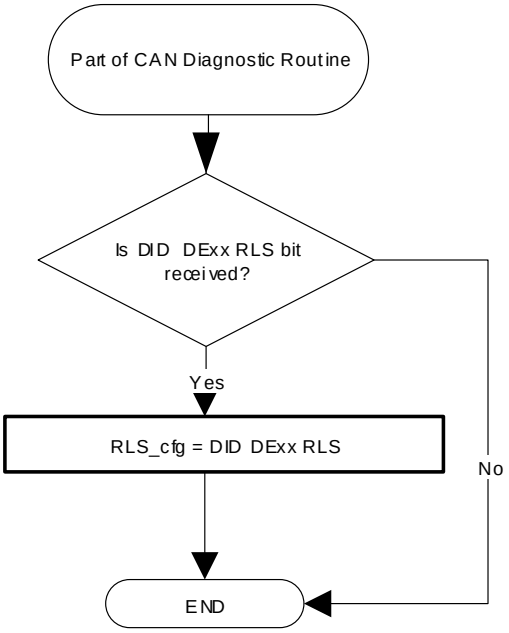
1.3.4 PFM-REQ-412038/A-System Accuracy

- Within 10ms of receiving a message that results in a change of state the brightness value shall be calculated.

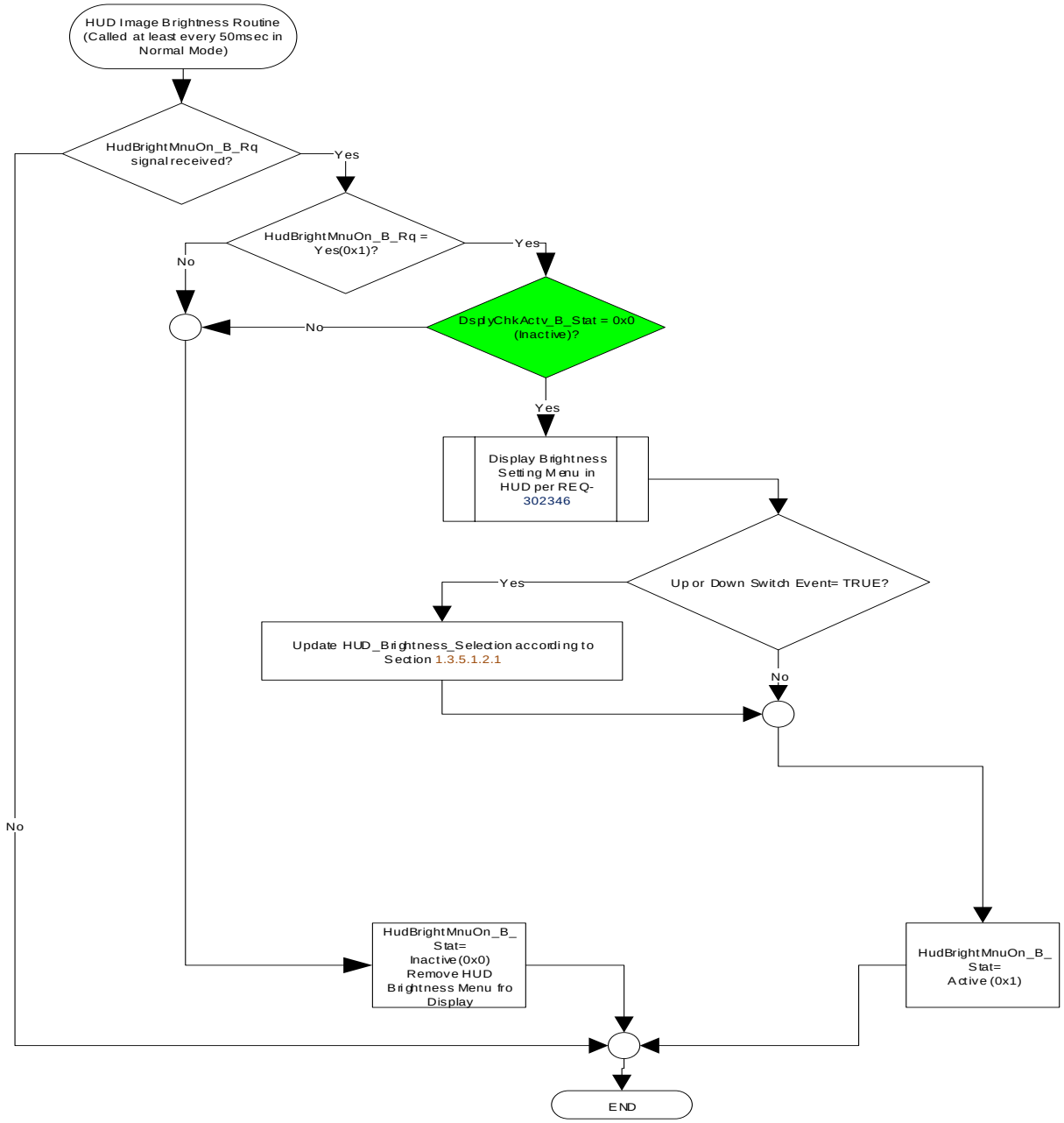
1.3.5 Operation: Performance and Functional

1.3.5.1 Subsystem Algorithm Flowchart / State Diagram

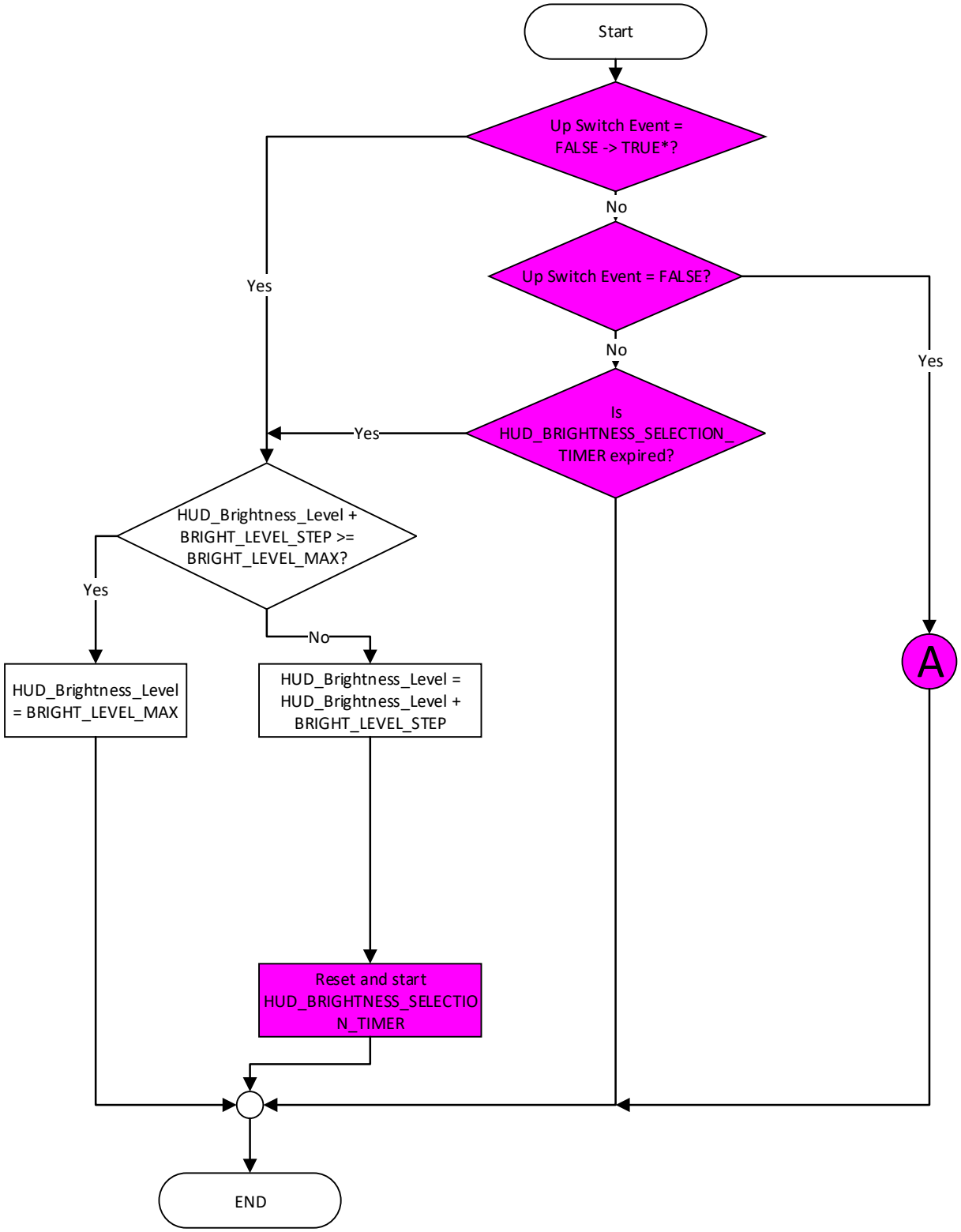
1.3.5.1.1 F-REQ-412039/A-CAN Diagnostic Routine

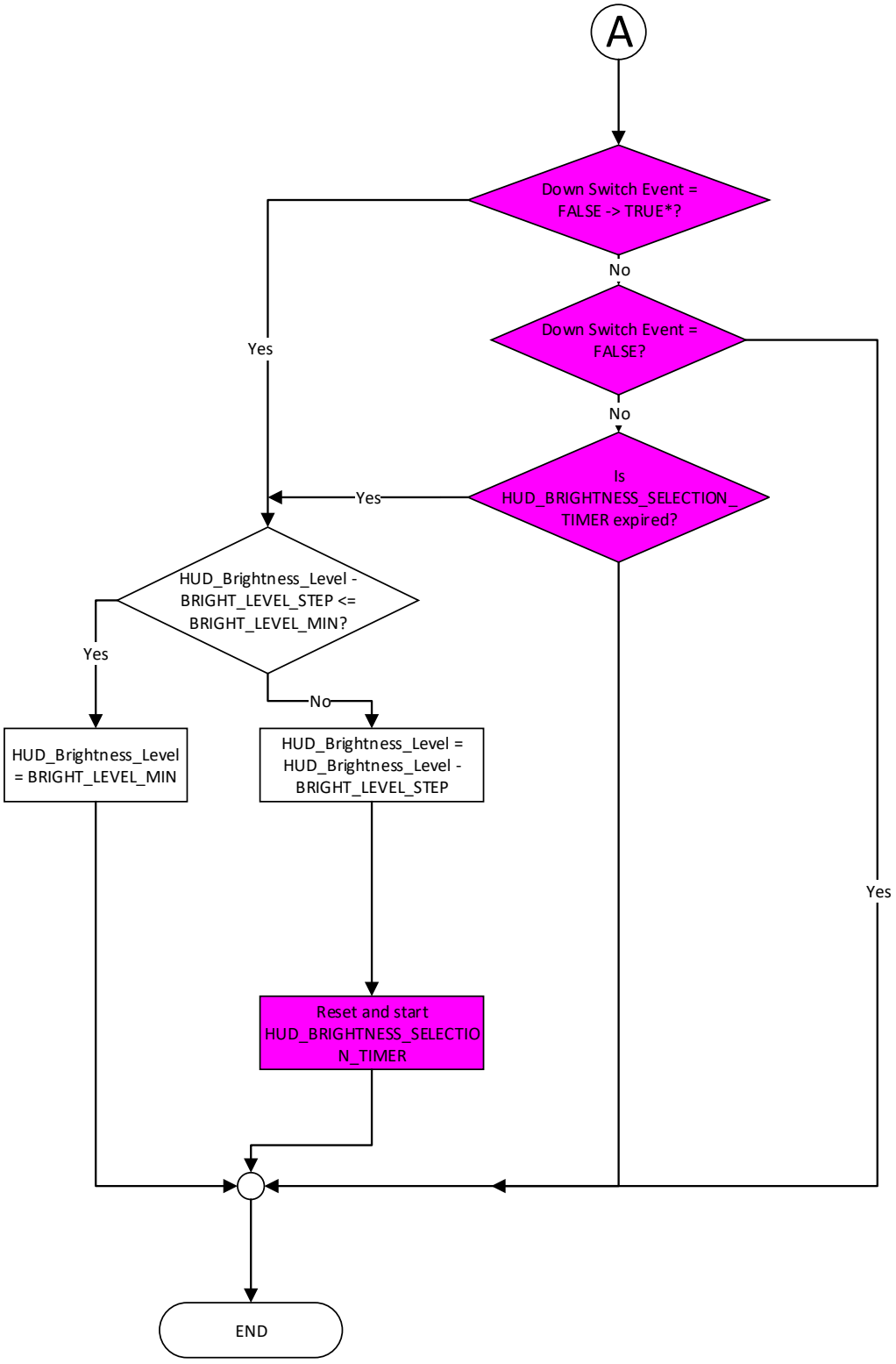


1.3.5.1.2 F-REQ-412040/A- HUD Image Brightness Selection Flowchart



1.3.5.1.2.1 F-REQ-412041/A- HUD_Brightness_Selection update Flowchart


Start
Up Switch Event = FALSE -> TRUE*?
No
Up Switch Event = FALSE?
Yes
No
Yes
Is HUD_BRIGHTNESS_SELECTION_ TIMER expired?
Yes
HUD_Brightness_Level + BRIGHT_LEVEL_STEP >= BRIGHT_LEVEL_MAX?
Yes
No
HUD_Brightness_Level = BRIGHT_LEVEL_MAX
HUD_Brightness_Level = HUD_Brightness_Level + BRIGHT_LEVEL_STEP
Reset and start HUD_BRIGHTNESS_SELECTIO N_TIMER
A
END



***Note: '→' denotes 'transition to'.**

1.3.5.1.2.2 F-REQ-412042/A- HUD Brightness Display Menu based on HUD_Brightness_Level

HUD_Brightness_Level (current setting)	Display Menu	5-Button Switch Selection Event	HUD_Brightness_Level (new setting)
0xC (Level13)	☑ 13 ☐ 12 ☐ .. ☐ 2 ☐ 1	Down (To Select 12,11..,2,1)	If 12 selected (Level12 (0xB)) If 11selected (Level 11 (0xA)) .. If 2 selected (Level2 (0x1)) If 1 selected (Level1 (0x0))
0xB (Level12))	☐ 13 ☑ 12 ☐ 11 ☐ .. ☐ 1	Up/Down (To Select 13,11..4,3,2,1)	If 13 selected (Level13 (0xC)) If 11 selected (Level11 (0xA)) … If 2 selected (Level2 (0x1)) If 1 selected (Level1 (0x0))
0xA(Level 11) to 0x2(Level 3) similar to the settings listed	Level 11 to Level 3 similar to the settings listed	Level 11 to Level 3 similar to the settings listed	Level 11 to Level 3 similar to the settings listed
0x1 (Level2)	☐ 13 ☐ .. ☐ 3 ☑ 2 ☐ 1	Up/Down (To Select 13,12..5,4,3,1)	If 13 selected (Level13 (0xC)) … If 4 selected (Level4 (0x3)) If 3 selected (Level3 (0x2)) If 1 selected (Level1 (0x0))
0x0 (Level1)	☐ 13 ☐ 12 ☐ .. ☐ 2 ☑ 1	Up (To Select 13,12,..5,4,3,2)	If 13 selected (Level13 (0xC)) … If 4 selected (Level4 (0x3)) If 3 selected (Level3 (0x2)) If 2 selected (Level2 (0x1))

Note: HUD_Brightness_Level user setting can have 13 settings. In level 13 if Up button pressed new setting is not changed and in level1 if Down button pressed new setting is not changed as the settings are limited between level 1 to level 13.

1.3.5.2 Operation Description (supports algorithm flowchart/state diagram)

1.3.5.2.1 F-REQ-412043/A-Image Brightness

- The HUD shall show the Image Brightness adjustment menu as long as it is request by CAN signal from the cluster. As the user navigates to each setting, the HUD shall change the image brightness in order to display to the user what the brightness level would look like. Upon an OK Switch event (press of the OK button), the cluster will request the HUD to remove the Image Brightness Adjustment Menu from the HUD Display.

1.3.5.2.2 F-REQ-412044/A-Ambient Light Sensor Readings

The ambient light sensor will transmit a value (LghtAmb_Intns_Sns) and a range (LghtAmbIntns_D_Sns and LghtAmbIntns_D2_Sns) to HUD. Heads Up display shall use these signals to calculate the Background_Image_Sensor_Reading and based on this, HUD shall output the HUD Raw Brightness as specified in Section 1.3.5.2.5.

The ambient light sensor will support two different configurations:

1. A two-piece-wise linear interpolation of the logarithm brightness curve (RLS_cfg =0x0 in HUD).
2. A logarithm brightness curve (RLS_cfg =0x1 in HUD)

HUD shall have two different brightness dimming algorithms to support both sensor configurations.

1.3.5.2.2.1 F-REQ-412045/A-Background_Image_Sensor_Reading for RLS_cfg= 0

If RLS_cfg = 0x0 (2-piece-wise linear approximation):

The HUD Background_Image_Sensor_Reading shall be calculated as follows:

- If LghtAmbIntns_D_Sns = 0x0 (LOW) → Background_Image_Sensor_Reading = LghtAmb_Intns_Sns* 8cd/m^2
- If LghtAmbIntns_D_Sns = 0x1 (HIGH) → Background_ Image_Sensor_Reading = LghtAmb_Intns_Sns* 80cd/m^2

The ambient light sensor will transmit LghtAmbIntns_D_Sns as "LOW" (8cd/m^2) for a 0-2040 cd/m^2 background and "HIGH" (80cd/m^2) for a 2048-20400cd/m^2 background.

HUD shall ignore LghtAmbIntns_D2_Sns, if "RLS_cfg = 0x0" since it will not contain a valid reading from the sensor if "RLS_cfg =0x0".

1.3.5.2.2.2 F-REQ-412046/A-Background_Image_Sensor_Reading for RLS_cfg =1

If RLS_cfg =0x1 (logarithm curve):
HUD should use the lookup tables in section 1.8 to find the Background_Image_Sensor_Reading value corresponding to the two input signals, LghtAmbIntns_D2_Sns and LghtAmb_Intns_Sns.

Note: Signal LghtAmbIntns_D2_Sns corresponds to the 2 highest bits and the LghtAmb_Intns_Sns corresponds to the 8 lowest bits of the 10bit value.

HUD shall ignore LghtAmbIntns_D_Sns, if RLS_cfg = 0x1 since it will not contain a valid reading from the sensor if RLS_cfg =0x1.

1.3.5.2.2.3 F-REQ-412047/A-Background Luminance

Content removed

1.3.5.2.3 F-REQ-412048/A-Signal information

LghtAmbIntns_D_Sns signal:

- Use only when RLS_cfg =0x0
- Determines whether the background brightness value is in the low or high range of the 2-piece-wise linear interpolation of the logarithmic brightness curve.
- Also communicates 'fault' or 'NULL'.
- LghtAmb_Intns_Sns signal from Rain Light Sensor Module (RLSM) represents value of the HUD image back brightness (on road); centered at 19.2° down from horizontal (from RLSM); 50% drop at ±4° from nominal beam

LghtAmbIntns_D2_Sns:

- Used only when RLS_cfg =0x1

- It is used for the logarithm implementation as the 9th and 10th highest bit of the 10bits log reading from the sensor (see section 1.8 for details).
- Also communicates 'fault'.
- Note: There is NO NULL state
- LghtAmb_Intns_Sns and LghtAmbIntns_D2_Sns signals from Rain Light Sensor Module (RLSM) represents value of the HUD image back brightness (on road); centered at 19.2° down from horizontal (from RLSM); 50% drop at ±4° from nominal beam

1.3.5.2.4 F-REQ-412049/A-Automatic dimming

- The automatic dimming adjustment based on the ambient light sensor input shall follow Tables in REQ 302354 below which defines the nominal (median) user brightness setting. Interpolation should be used to obtain any values in between the provided points.
- The HUD_Raw_Brightness values should be included as a DID -User Level 7 Brightness Curve Table so they can be tuned and calibrated during the VP build.
- Note that Table in REQ 302354 below shall be the **initial** value for this DID prior to in-vehicle calibration
- HUD shall follow the dimming curve indicated in REQ 302354 until it reaches its maximum brightness capability.
- If the HUD maximum brightness capability for a specific HUD unit is below the theoretical brightness for any User Level corresponding to the ambient sensor input signals, then the brightness at that User Level setting & above shall be clipped to HUD maximum brightness capability. For example: If HUD maximum brightness capability is X nits, HUD should follow the dimming curve indicated in REQ 302354 until it reaches its maximum brightness capability X as it is shown in REQ344154
- HUD shall have a DID to store its maximum brightness capability.

1.3.5.2.5 F-REQ-412050/A- Lookup for HUD_Raw_Brightness for User Median Brightness selection, Initial Values

Level	User Brightness Setting	Background_Image Sensor_Reading (cd/m^2)	HUD_Raw_Brightness (User Level 7) (cd/m^2)
7	Level7 (0x6) – median brightness setting	0	34
		8	199
		32	796
		88	2088
		216	4475
		496	6962
		1000	10625
		2000	15470
		3440	19338

		6000	23205
		10000	26520
		15040	29835
		20400	32598

The HUD_RAW BRIGHTNESS of each user brightness level should be derived by applying USER_BRIGHTNESS_LEVEL_RANGE to User Level 7 (UL7) brightness curve based on the calculation described below.

HUD_RAW_BRIGHTNESS (User Level Z) =
(HUD_RAW_BRIGHTNESS (User Level 7) * (1 + ((USER_BRIGHTNESS_LEVEL_RANGE/100) *(Z-7)/6))

Note:
a) Z defines the User Brightness Level, 1≤ Z ≤13
b) The constant 7 in the formula represents the median curve which is User Brightness Level 7
c) The constant 6 in the formula represents the number of curves above and below User Brightness Level 7

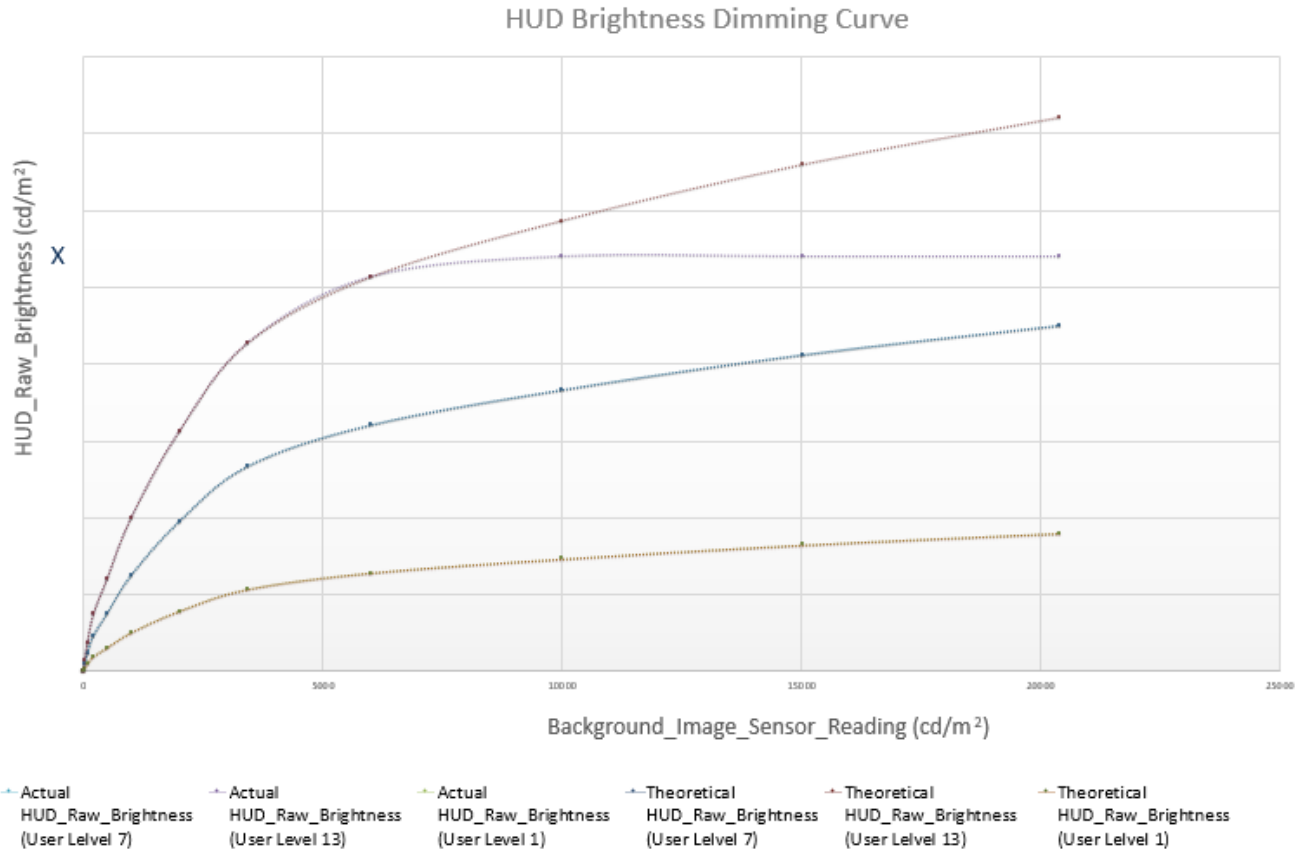
An example of this application is shown in REQ-302355

Note: Table in REQ-302355 is **NOT** a lookup table, but rather an example of the application of this USER_BRIGHT_LEVEL_RANGE PERCENTAGE on HUD_Raw_Brightness

The USER_BRIGHT_LEVEL_RANGE shall be included as a DID so that it can be tuned and calibrated during VP build.

Note: Initial value for USER_BRIGHT_LEVEL_RANGE = 60%

1.3.5.2.6 F-REQ-412051/A-HUD Brightness Dimming Curve Example



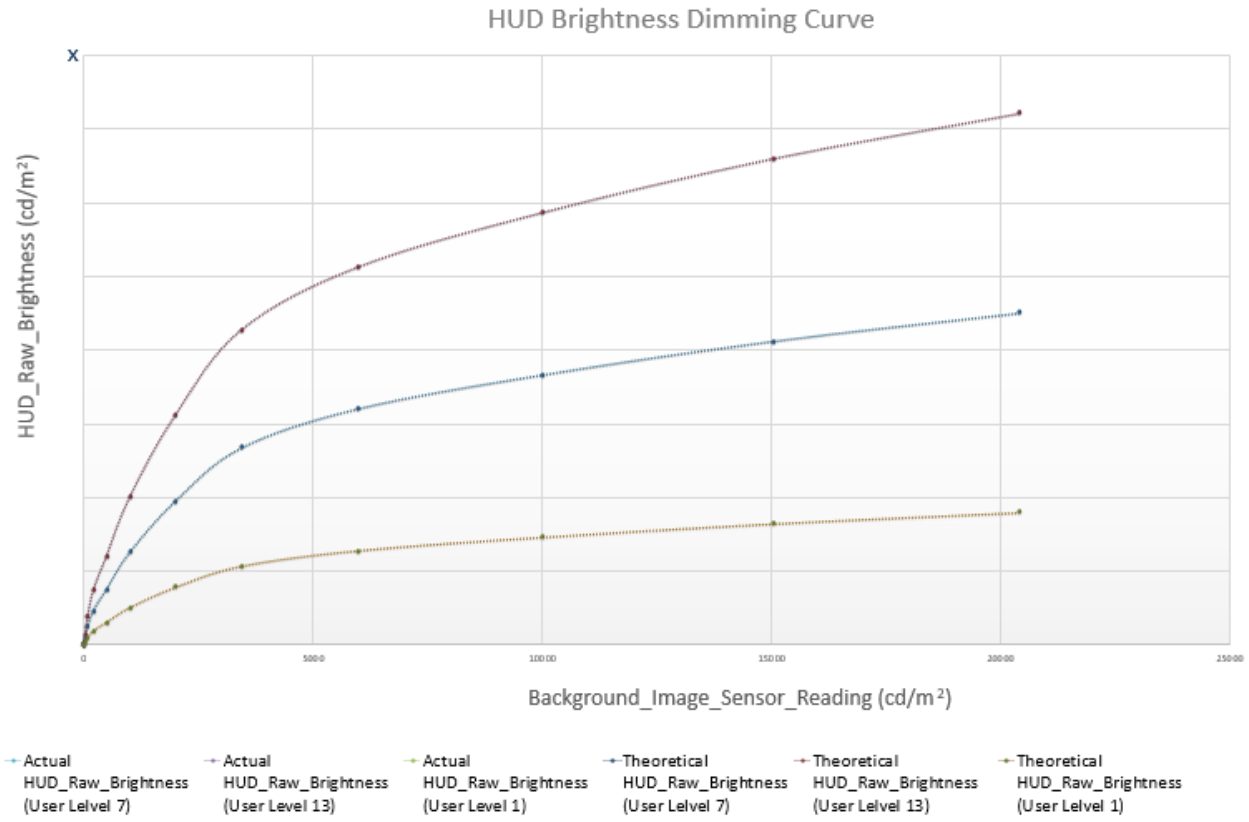
In the above graph, the Actual HUD_Raw_Brightness is the actual brightness output from the Heads Up Display which depends on the HUD Maximum Brightness Capability (X) for a specific HUD. The Theoretical HUD_Raw_Brightness curve is the calculated brightness curve based on requirement REQ-302354

In this example, HUD Maximum Brightness Capability (X) is less than the Theoretical HUD_Raw_Brightness User Level 13 curve (high end of the curve) therefore, the Actual HUD Raw_Brightness is clipped at "X".

Note:

- For simplicity purposes, the image above only shows HUD Brightness Dimming Curves for User Level 1, User Level 7, and User Level 13 but all other user levels should behave in the same manner.
- The Actual HUD_Raw_Brightness User Level 1 curve overlaps with the Theoretical HUD_Raw_Brightness User Level 1 curve
- The Actual HUD_Raw_Brightness User Level 7 curve overlaps with the Theoretical HUD_Raw_Brightness User Level 7 curve
- The Actual HUD_Raw_Brightness User Level 13 curve is clipped at the HUD Maximum Brightness Capability "X".

1.3.5.2.7 F-REQ-412052/A-HUD Brightness Dimming Curve Example for UL7, UL1, and UL13



In this example of application, X is greater than the Theoretical HUD_Raw_Brightness User Level 13 curve highest point therefore, the Actual HUD_Raw_Brightness curve shall overlap the Theoretical HUD_Raw_Brightness curve for all user levels (1-13).

Note: The image above only shows HUD Brightness Dimming Curves for User Level 1, User Level 7, and User Level 13 but all other user levels should behave in the same manner.

1.3.5.2.8 F-REQ-412054/A-HUD_Raw Brightness Example of Application of USER_BRIGHT_LEVEL_RANGE

Level (Z)	User Brightness Setting	Background_Image Sensor_Reading (cd/m²)	USER_BRIGHT_ LEVEL_RANGE PERCENTAGE	HUD_Raw_Brightness (User Level Z) (cd/m2) (HUD_RAW_BRIGHTNESS (User Level 7) * (1 + ((USER_BRIGHTNESS_LEVEL_RANGE/100) *(Z-7)/6))
1	Level1 (0x0) –	0	60%	13.6
		8		79.6
		32		318.4

	brightness setting	88		835.2
		216		1790
		496		2784.8
		1000		4250
		2000		6188
		3440		7735.2
		6000		9282
		10000		10608
		15040		11934
		20400		13039.2
2	Level2 (0x1) – brightness setting	0	60%	17
		8		99.5
		32		398
		88		1044
		216		2237.5
		496		3481
		1000		5312.5
		2000		7735
		3440		9669
		6000		11602.5
		10000		13260
		15040		14917.5
		20400		16299
3	Level3 (0x2) – brightness setting	0	60%	20.4
		8		119.4
		32		477.6
		88		1252.8
		216		2685
		496		4177.2
		1000		6375
		2000		9282
		3440		11602.8
		6000		13923
		10000		15912
		15040		17901
		20400		19558.8
4	Level4 (0x3) – brightness setting	0	60%	23.8
		8		139.3
		32		557.2
		88		1461.6
		216		3132.5
		496		4873.4
		1000		7437.5
		2000		10829
		3440		13536.6
		6000		16243.5
		10000		18564
		15040		20884.5
		20400		22818.6

5	Level5 (0x4) – brightness setting	0	60%	27.2
		8		159.2
		32		636.8
		88		1670.4
		216		3580
		496		5569.6
		1000		8500
		2000		12376
		3440		15470.4
		6000		18564
		10000		21216
		15040		23868
		20400		26078.4
6	Level6 (0x5) – brightness setting	0	60%	30.6
		8		179.1
		32		716.4
		88		1879.2
		216		4027.5
		496		6265.8
		1000		9562.5
		2000		13923
		3440		17404.2
		6000		20884.5
		10000		23868
		15040		26851.5
		20400		29338.2
7	Level7 (0x6) – Median brightness setting	0	60%	34
		8		199
		32		796
		88		2088
		216		4475
		496		6962
		1000		10625
		2000		15470
		3440		19338
		6000		23205
		10000		26520
		15040		29835
		20400		32598
8	Level8 (0x7) – brightness setting	0	60%	37.4
		8		218.9
		32		875.6
		88		2296.8
		216		4922.5
		496		7658.2
		1000		11687.5
		2000		17017
		3440		21271.8

		6000		25525.5
		10000		29172
		15040		32818.5
		20400		35857.8
9	Level9 (0x8) – brightness setting	0	60%	40.8
		8		238.8
		32		955.2
		88		2505.6
		216		5370
		496		8354.4
		1000		12750
		2000		18564
		3440		23205.6
		6000		27846
		10000		31824
		15040		35802
		20400		39117.6
10	Level10 (0x9) – brightness setting	0	60%	44.2
		8		258.7
		32		1034.8
		88		2714.4
		216		5817.5
		496		9050.6
		1000		13812.5
		2000		20111
		3440		25139.4
		6000		30166.5
		10000		34476
		15040		38785.5
		20400		42377.4
11	Level11 (0xA) – brightness setting	0	60%	47.6
		8		278.6
		32		1114.4
		88		2923.2
		216		6265
		496		9746.8
		1000		14875
		2000		21658
		3440		27073.2
		6000		32487
		10000		37128
		15040		41769
		20400		45637.2
12	Level12 (0xB) – brightness setting	0	60%	51
		8		298.5
		32		1194
		88		3132
		216		6712.5

		496		10443
		1000		15937.5
		2000		23205
		3440		29007
		6000		34807.5
		10000		39780
		15040		44752.5
		20400		48897
13	Level13 (0xC) – brightness setting	0	60%	54.4
		8		318.4
		32		1273.6
		88		3340.8
		216		7160
		496		11139.2
		1000		17000
		2000		24752
		3440		30940.8
		6000		37128
		10000		42432
		15040		47736
		20400		52156.8

Note:

- These values may change in future based on the results in field.
- The above table is NOT a lookup table; it is an example of the application of USER_BRIGHT_LEVEL_RANGE.
- HUD should follow the dimming curves for all User Levels until it reaches its maximum brightness capability (X).

1.3.5.2.9 F-REQ-412055/A-HUD_Raw_Brightness Minumun

- HUD shall be able to achieve a HUD_Raw_Brightness minimum value of 3 cd/m^2 (or lower)

1.3.5.2.10 F-REQ-412056/A-HUD_Raw_Brightness Maximun

- HUD shall be able to achieve a maximum HUD_Raw_Brightness of at least 15000cd/m^2 (average)

1.3.5.2.11 HUD Dimming module

Content deleted

1.3.5.2.12 F-REQ-412057/A-Dimming Handling

The speed of change of HUD brightness as a function of the Ambient brightness shall be determined by a Low Pass Filter, for which there shall be a different time constant for Increasing (AMB_BRIGHTNESS_TAU_INCR) and Decreasing (AMB_BRIGHTNESS_TAU_DECR) brightness.

The brightness output shall also be controlled by a LPF whose time constant is determined by USER_BRIGHTNESS_LEVEL_DIMMING_TAU when the user brightness level is changed.

1.3.5.2.13 FCW Warning Handling

1.3.5.2.13.1 F-REQ-412058/A-FCW Warning Handling with Ambient brightness

- The HUD_Raw_Brightness values for FCW should be included as a DID -User Level 7 Brightness Curve Table so they can be tuned and calibrated during the VP build.
- Note that Table in "REQ-302364" below shall be the **initial** value for this DID prior to in-vehicle calibration.

1.3.5.2.13.2 F-REQ-412059/A-FCW HUD Raw Brightness for User Median Brightness Selection, Initial Values for FCW Warning

level	User Brightness Setting	Background Image Sensor Reading (cd/m^2)	HUD_Raw_Brightness for FCW (cd/m2))
7	Level7 (0x6) – median brightness setting	0	34
		8	199
		32	796
		88	2088
		216	4475
		496	6962
		1000	10625
		2000	15470
		3440	19338
		6000	23205
		10000	26520
		15040	29835
		20400	32598

The HUD_RAW_BRIGHTNESS for FCW of each User brightness level should be derived by applying USER_BRIGHTNESS_LEVEL_RANGE_FCW to User Level 7 FCW brightness curve based on the calculation described below.

HUD_RAW_BRIGHTNESS (User Level Z) for FCW =
(HUD_RAW_BRIGHTNESS for FCW (User Level 7) * (1 +
((USER_BRIGHTNESS_LEVEL_RANGE_FCW/100) *(Z-7)/6))

Note:

a) Z defines the User Brightness Level, 1 ≤Z≤ 13
b) The constant 7 in the formula represents the median curve which is User Brightness Level 7
c) The constant 6 in the formula represents the number of curves above and below User Brightness Level 7

1.3.5.2.13.3 F-REQ-412060/A-FCW Warning Handling without Ambient brightness

1.3.5.2.13.3.1 F-REQ-412062/A-FCW Warning Handling without Ambient Brightness and RLS_cfg =0x1

1) If ((LghtAmbIntns_D2_Sns = 0x3[FAULT] OR IS NOT Received) for greater than 5s) AND (Day_Night_Status signal is Valid AND Active FCW Warning)
THEN,
If (Day_Night_Status = Day), THEN HUD_Raw_Brightness = TBL_HUD_BRIGHTNESS_FCW_ACT_DAYTIME
If (Day_Night_Status = Night), THEN HUD_Raw_Brightness = TBL_HUD_BRIGHTNESS_FCW_ACT_NIGHTTIME

2) If ((LghtAmbIntns_D2_Sns = 0x3[FAULT] OR IS NOT Received) for greater than 5s) AND (Day_Night_Status signal is missing for greater than 5s AND Active FCW Warning)
THEN,
HUD_Raw_Brightness = TBL_HUD_BRIGHTNESS_FCW_ACT_NIGHTTIME

3) If ((LghtAmbIntns_D2_Sns = 0x3[FAULT] OR IS NOT Received) for greater than 5s) AND ((Day_Night_Status = 0x0[NULL] OR 0x3[NotUsed]) AND Active FCW Warning))
THEN,
HUD_Raw_Brightness = TBL_HUD_BRIGHTNESS_FCW_ACT_NIGHTTIME

Note: TBL_HUD_BRIGHTNESS_FCW_ACT_DAYTIME & TBL_HUD_BRIGHTNESS_FCW_ACT_NIGHTTIME are applied to User median brightness selection (Level 7, 0x6).
The brightness for any other user level setting shall be calculated based on the USER_BRIGHT_LEVEL_RANGE_FCW for that particular user level setting.

Note: If (LghtAmbIntns_D2_Sns = 0x3[FAULT] OR 0x0[NULL] OR IS NOT Received within 5s) OR (Day_Night_Status = 0x0 [NULL] OR 0x3[NotUsed] OR IS NOT Received within 5s) then HUD will retain the last received brightness value until reach to the 5s criteria

1.3.5.2.13.3.2 F-REQ-412061/A-FCW Warning Handling without Ambient Brightness and RLS_cfg =0x0

1) If (((LghtAmbIntns_D_Sns = 0x3[FAULT] OR 0x0[NULL] OR IS NOT Received) for greater than 5s) AND (Day_Night_Status signal is Valid AND Active FCW Warning))
THEN,
If (Day_Night_Status = Day), THEN HUD_Raw_Brightness = TBL_HUD_BRIGHTNESS_FCW_ACT_DAYTIME
If (Day_Night_Status = Night), THEN HUD_Raw_Brightness = TBL_HUD_BRIGHTNESS_FCW_ACT_NIGHTTIME

2) If (((LghtAmbIntns_D_Sns = 0x3[FAULT] OR 0x0[NULL] OR IS NOT Received) for greater than 5s) AND (Day_Night_Status signal is missing for greater than 5s AND Active FCW Warning)
THEN,
HUD_Raw_Brightness = TBL_HUD_BRIGHTNESS_FCW_ACT_NIGHTTIME

3) If (((LghtAmbIntns_D_Sns = 0x3[FAULT] OR 0x0[NULL] OR IS NOT Received) for greater than 5s) AND ((Day_Night_Status = 0x0 [NULL] OR 0x3[NotUsed]) AND Active FCW Warning)
THEN,
HUD_Raw_Brightness = TBL_HUD_BRIGHTNESS_FCW_ACT_NIGHTTIME

Note: TBL_HUD_BRIGHTNESS_FCW_ACT_DAYTIME & TBL_HUD_BRIGHTNESS_FCW_ACT_NIGHTTIME are applied to User median brightness selection (Level

7, 0x6). The brightness for any other user level setting shall be calculated based on the USER_BRIGHT_LEVEL_RANGE_FCW for that particular user level setting.

Note: If (LghtAmbIntns_D_Sns = 0x3[FAULT] OR 0x0[NULL] OR IS NOT Received within 5s) OR (Day_Night_Status = 0x0 [NULL] OR 0x3[NotUsed] OR IS NOT Received within 5s) then HUD will retain the last received brightness value until reach to the 5s criteria

1.3.5.2.14 F-REQ-412063/A-Missing Signal / Fault for Non-FCW condition

1.3.5.2.14.1 F-REQ-412064/A-Missing Signal /Fault for RLS_cfg =0

1) If ((LghtAmbIntns_D_Sns = 0x3[FAULT] OR 0x0[NULL] OR IS NOT Received)for greater than 5s) AND Day_Night_Status signal is Valid

   THEN
   If (Day_Night_Status = Day), THEN HUD_Raw_Brightness = TBL_HUD_BRIGHTNESS_DAYTIME_DEFAULT
   If (Day_Night_Status = Night), THEN HUD_Raw_Brightness = TBL_HUD_BRIGHTNESS_NIGHTTIME_DEFAULT

2) If ((LghtAmbIntns_D_Sns = 0x3[FAULT] OR 0x0[NULL] OR IS NOT Received) for greater than 5s) AND Day_Night_Status signal is missing for greater than 5s

   THEN
   HUD_Raw_Brightness = TBL_HUD_BRIGHTNESS_NIGHTTIME_DEFAULT

3) If ((LghtAmbIntns_D_Sns = 0x3[FAULT] OR 0x0[NULL] OR IS NOT Received) for greater than 5s) AND (Day_Night_Status = 0x0[NULL] OR 0x3[NotUsed]) THEN

   HUD_Raw_Brightness = TBL_HUD_BRIGHTNESS_NIGHTTIME_DEFAULT

   Note: TBL_HUD_BRIGHTNESS_DAYTIME_DEFAULT & TBL_HUD_BRIGHTNESS_NIGHTTIME_DEFAULT are applied to User median brightness selection (Level 7, 0x6).-The brightness for any other user level setting shall be calculated based on the USER_BRIGHT_LEVEL_RANGE for that particular user level setting.

   Note: If (LghtAmbIntns_D_Sns = 0x3[FAULT] OR 0x0[NULL] OR IS NOT Received within 5s) OR (Day_Night_Status = 0x0 [NULL] OR 0x3[NotUsed] OR IS NOT Received within 5s) then HUD will retain the last received brightness value until reach to the 5s criteria

1.3.5.2.14.2 F-REQ-412065/A-Missing Signal/ Fault for RLS_cfg =1

1) If ((LghtAmbIntns_D2_Sns = 0x3[FAULT] OR IS NOT Received) for greater than 5s) AND Day_Night_Status signal is Valid

   THEN
   If (Day_Night_Status = Day), THEN HUD_Raw_Brightness = TBL_HUD_BRIGHTNESS_DAYTIME_DEFAULT
   If (Day_Night_Status = Night), THEN HUD_Raw_Brightness = TBL_HUD_BRIGHTNESS_NIGHTTIME_DEFAULT

2) If ((LghtAmbIntns_D2_Sns = 0x3[FAULT] OR IS NOT Received) for greater than 5s) AND Day_Night_Status signal is missing for greater than 5s

THEN
HUD_Raw_Brightness = TBL_HUD_BRIGHTNESS_NIGHTTIME_DEFAULT

3) If ((LghtAmbIntns_D2_Sns = 0x3[FAULT] OR IS NOT Received) for greater than 5s) AND (Day_Night_Status = 0x0[NULL] OR 0x3[NotUsed])

THEN
HUD_Raw_Brightness = TBL_HUD_BRIGHTNESS_NIGHTTIME_DEFAULT

Note: TBL_HUD_BRIGHTNESS_DAYTIME_DEFAULT & TBL_HUD_BRIGHTNESS_NIGHTTIME_DEFAULT are applied to User median brightness selection (Level 7, 0x6).
The brightness for any other user level setting shall be calculated based on the USER_BRIGHT_LEVEL_RANGE_FCW for that particular user level setting.

Note: If (LghtAmbIntns_D2_Sns = 0x3[FAULT] OR IS NOT Received within 5s) OR (Day_Night_Status = 0x0 [NULL] OR 0x3[NotUsed] OR IS NOT Received within 5s) then HUD will retain the last received brightness value until reach to the 5s criteria

1.3.5.3 FS-REQ-412066/A-Function Safety Classification (EMC)

Class A

1.3.5.4 NVM-REQ-412067/A-Memory Storage

Parameter Name	Description	Value at Battery connect	Value at Module Wake-up	Initial Design Value
HUDBrghtMenu_St signal	CAN signal used to transmit HUD Image Brightness Menu status to the cluster	Inactive (0x0)	Inactive(0x0)	
Operational_Mode	4 State indicator for HUD operational mode	Limited	Limited or Normal or Crank	
HUD_Brightness_Level	The attribute that determines the HUD Brightness level. State Indicator to identify which text is currently being displayed on the HUD display.	0x6	Do not Init	0x6
BRIGHT_LEVEL_STEP	The step to increment Brightness Level on each UP/Down press	0x1	0x1	
BRIGHT_LEVEL_MIN	Minimum value for Brightness Level	0x0	0x0	

BRIGHT_LEVEL_MAX	Maximum value for Brightness Level	12(0xC)	12(0xC)	
HUD_Raw_Brightness	Calculated value of the brightness based on sensor reading as well as user setting (HUD_Brightness_Level) in Image Brightness Menu	Stored in EEPROM	Use stored value	
TBL_HUD_BRIGHTNESS_DAYTIME_DEFAULT	Suggested storage of HUD Daytime Brightness default value when input CAN signal is missing or invalid. This is applied to User Median brightness selection(Level 7, 0x6)	Stored in EEPROM	Use stored value	7000 cd/m2
TBL_HUD_BRIGHTNESS_NIGHTTIME_DEFAULT	Suggested storage of HUD Nighttime Brightness default value when input CAN signal is missing or invalid. This is applied to User Median brightness selection(Level 7, 0x6)	Stored in EEPROM	Use stored value	65 cd/m2
TBL_HUD_BRIGHTNESS_FCW_ACT_DAYTIME	Suggested storage of HUD Daytime Brightness default value when FCW warning RED image is Active	Stored in EEPROM	Use stored value	10,000Cd/m2
TBL_HUD_BRIGHTNESS_FCW_ACT_NIGHTTIME	Suggested storage of HUD Nighttime Brightness default value when FCW warning RED image is Active	Stored in EEPROM	Use stored value	1,200Cd/m2
USER_BRIGHT_LEVEL_RANGE	RANGE for Customer adjusted Brightness Level. This is a +/- range.	Stored in EEPROM	Use stored value	60%
USER_BRIGHT_LEVEL_RANGE_FCW	RANGE of Luminance Ratio for Customer adjusted Brightness Level when FCW warning is Active. This is a +/- range.	Stored in EEPROM	Use stored value	60%
AMB_BRIGHTNESS_TAU_INCR	Suggested storage for LPF Time constant for increasing brightness in AmbientBrightnessHandling sub-component	Stored in EEPROM	Use stored value	300msec
AMB_BRIGHTNESS_TAU_DECR	Suggested storage for LPF Time constant for decreasing brightness in AmbientBrightnessHandling sub-component	Stored in EEPROM	Use stored value	50msec
CUST_DIMMING_TAU	Suggested storage for LPF Time constant for brightness in CustomerDimmingOutput Handling sub-component	Stored in EEPROM	Use stored value	10ms

DsplyChkActv_B_Stat CAN Signal	0x0 (Inactive) 0x1 (Active)	0x0 (Inactive)	0x0 (Inactive)	0x0 (Inactive)

Timer Name	Duration	Description	Min	Max	Resolution
HUD_BRIGHTNESS_SELECTION_TIMER	600 msec	Duration of the time the Up or Down switch is pressed & held before scrolling up or scrolling down the Image brightness user level selection.	150 msec	5000 msec	25 msec

1.3.5.5 Prove Out

No

1.3.5.6 Reconfigurable Telltale

No

1.3.5.7 Message Center Msg

See Program Specific Menu Structure and Translation files from Ford HMI for Message Center text.

1.4 Error Handling

1.4.1 Missing Message Strategy

1.4.1.1 Missing Signal Reference:

The signals will be declared missing as per the Diagnostics section of this SPSS.

If 'HUD_RLS_cfg = 0x0', HUD shall ignore LghtAmbIntns_D2_Sns, therefore there is no missing strategy for these signals and no DTCs shall be logged against these signals for this HUD configuration.

If 'HUD_RLS_cfg = 0x1', HUD shall ignore LghtAmbIntns_D_Sns, therefore there is no missing strategy for these signals and no DTCs shall be logged against these signals for this HUD configuration.

1.4.1.2 States & History

DTCs states and history will be determined as per the Diagnostics section of this SPSS.

1.5 Diagnostics

1.5.1 Self Test

None

1.5.2 Engineering Test Mode

1.5.3 Part II Performance

1.5.3.1 DTC-REQ-412068/A-Supported Diagnostic Trouble Codes (DTCs)

DTC	Description
TBD	HUD PGU Error
C21200	Lost Communication with SCCM
C42981	Invalid data received from SCCM

1.5.3.2 DCR-REQ-412069/A-Supported DID DExx

DID DExx

Block Num	Block Description	Size (bits)	Type	Byte(s)	Bits	State: Description	"0"	"1"	Default	Comments/ Information
PACKETED BLOCKS										
$xx	Option Content (B&A)	1	1	*	*	RLS_cfg	2-piece linear	Logarithm	2-piece linear	
*Byte and bit location to be identified in Part II Specification for this HUD										

1.5.3.3 DID-REQ-412070/A-Supported Diagnostic DIDs (Service $22 and $2E)

Number	DID / CommonID Name	DID Type	Comments
$606B	Head Up Display User Brightness Range	Unsigned Numeric	This DID is linked with parameter "USER_BRIGHT_LEVEL_RANGE". This DID is used to define percentage range of Head Up Display user level brightness. It is fixed-point integer value.
$606A	Head Up Display Forward Collision Warning User Brightness Level Range	Unsigned Numeric	This DID is linked with parameter "USER_BRIGHT_LEVEL_RANGE_FCW". RANGE of Luminance Ratio for Customer adjusted Brightness Level when Forward Collision Warning is Active. This is a +/- range.
$606D	Head Up Display Brightness Daytime Default Value	Unsigned Numeric	This DID is linked with parameter "TBL_HUD_BRIGHTNESS_DAYTIME_DEFAULT" and is used for reading/writing EEPROM parameter. This defines Head Up Display Daytime Brightness default value when input CAN signal is missing or invalid. This is applied to user median brightness selection (Level 7, 0x6).
$606C	Head Up Display Brightness Nighttime Default Value	Unsigned Numeric	This DID is linked with parameter "TBL_HUD_BRIGHTNESS_NIGHTTIME_DEFAULT" and it is used for reading/writing EEPROM parameter. This defines Head Up Display Nighttime Brightness default value when input CAN signal is missing or invalid. This is applied to user median brightness selection (Level 7, 0x6)
$6069	Head Up Display Forward Collision Warning Active Daytime	Unsigned Numeric	This DID is linked with parameter "TBL_HUD_BRIGHTNESS_FCW_ACT_DAYTIME" and this is used for reading/writing EEPROM parameter. Head Up

	Brightness Default Value		Display Daytime Brightness default value when Forward Collision Warning RED image is Active.
$6066	Head Up Display Brightness Forward Collision Active Warning Nighttime Default Value	Unsigned Numeric	This DID is linked with parameter "TBL_HUD_BRIGHTNESS_FCW_ACT_NIGHTTIME" and it is used for reading/writing EEPROM parameter. This DID defines Head Up Display Nighttime Brightness default value when Forward Collision Warning RED image is Active.
$6068	Head Up Display Ambient Brightness Time Constant Increment Value	Unsigned Numeric	This DID is linked with parameter "AMB_BRIGHTNESS_TAU_INCR" and it is used for reading/writing EEPROM parameter. This DID defines the LPF Time Constant for increasing brightness in AmbientBrightnessHandling sub-component.
$6067	Head Up Display Ambient Brightness Time Constant Decrement Value	Unsigned Numeric	This DID is linked with parameter "AMB_BRIGHTNESS_TAU_DECR" and it is used for reading/writing EEPROM parameter. This DID define the LPF Time Constant for decreasing brightness in AmbientBrightnessHandling sub-component.
$6065	Head Up Display Ambient Brightness Time Constant	Unsigned Numeric	This DID is linked with parameter "CUST_DIMMING_TAU" and it is used for reading/writing EEPROM parameter. LPF Time Constant for brightness in AmbientBrightnessHandling sub-component. This DID define the transition time from Daytime to Nighttime for Ambient Brightness handling.
$6061	Head Up Display User Level 7 Brightness Curve Table	Packeted	User level 7 brightness curve table is defined based on HUD Image Brightness Function STSS. It is used to read/write User Level 7 brightness curve table. NOTE: The output string for DID follows the Little Endian format. The 'X' and 'Y' values cannot be correctly decoded by MDX when reading via the Diagnostic Engineering Tool.
$605E	Head Up Display User Level 7 Forward Collision Warning Dimming Curve Table	Packeted	User level 7 FCW Dimming curve table is defined based on HUD Image Dimming Function STSS. It is used to read/write User Level 7 Dimming curve table. NOTE: The output string for DID follows the Little Endian format. The 'X' and 'Y' values cannot be correctly decoded by MDX when reading via the Diagnostic Engineering Tool.
$605D	Head Up Display Maximum Brightness	Packeted	This DID is defined to determine Head Up Display maximum brightness during white-point calibration. It is being used by dimming algorithm to set brightness values above its value to 100%.

1.5.3.4 DID-REQ-412071/A-Supported Diagnostic DIDs (Service $22 and $2F)

Number	DID / CommonID Name	DID Type	Comments
$6060	Head Up Display User Brightness Adjustments Level	State Encoded	This DID is linked with parameter "HUD_Brightness_Level". This DID is defined to control the Head Up Display User Brightness levels from Level 1 to Level 13 according to the user selection from steering wheel switch.
$6063	Head Up Display Ambient Light Sensor Values	Packeted	This DID is defined to override all input CAN signals to this subsystem. Following inputs will be received through the Diag command: 1. One byte for LghtAmbIntns_D_Sns, 2. One byte for LghtAmbIntns_D2_Sns, 3. One byte for LghtAmb_Intns_Sns

$605F	Head Up Display Brightness Output	Unsigned Numeric	This DID is used for Head Up Display Brightness expected output value. Head Up Display should perform calculations on the basis of ambient light sensor and User brightness level input and show brightness output accordingly with this DID. This DID is used for "HUD_Raw_Brightness".

Note: During Diagnostics HUD will not take any input from any other module including steering wheel switch. After Diagnostic session ends up, HUD will go back to the previous state where it was before going to the Diagnostics.
If HUD User Level Brightness settings, HUD Positional settings (Vertical/Rotational), HUD On/Off settings, HUD Density Settings or HUD DAT feature Display Status settings are active before diagnostic then during diagnostic, HUD will ignore those settings and HUD will not show any Brightness settings on display during diagnostic session. HUD will go back to the previous state where it was before going to the Diagnostics.

1.5.3.5 DID-REQ-412072/A-Supported Diagnostic DIDs (Service $22)

Number	DID / CommonID Name	DID Type	Comments
$606F	Head Up Display Image Background Brightness	Unsigned Numeric	This DID read the Image Background Brightness (cd/m2) value seen by the module. Note this will be a read only DID. The Background Image Sensor signal will be reported based on the description present in the HUD_Image_Brightness_Function_CGEA1.3_v1.15 12-01-2020.docm spec. This DID will provide the Image Brightness output calculated value on the basis of "Rain Light Sensor config" and respective signals LghtAmbIntns_D_Sns, LghtAmbIntns_D2_Sns and LghtAmb_Intns_Sns.

1.6 Reference Specification

1.7 Appendix

1.7.1 Lookup Tables

1.7.1.1 F-REQ-412073/A-LOW Range Lookup Table for Background_Image_Sensor_Reading

LOW RANGE TABLE (only for RLS_cfg =1)				
LghtAmbIntns_ D2_Sns (2bits)	**LghtAmb_Intns_Sns (8bits)**	**Combine Signal (10bits)**	**Combined Signal 10-bit value (DEC)**	**Background_ Image_Sensor_ Reading (cd/m²)**
00	00000000	0000000000	0	0.000
00	00000001	0000000001	1	0.100
00	00000010	0000000010	2	0.102
00	00000011	0000000011	3	0.104
00	00000100	0000000100	4	0.106
00	00000101	0000000101	5	0.107
00	00000110	0000000110	6	0.109
00	00000111	0000000111	7	0.111
00	00001000	0000001000	8	0.113
00	00001001	0000001001	9	0.116
00	00001010	0000001010	10	0.118
00	00001011	0000001011	11	0.120
00	00001100	0000001100	12	0.122

00	00001101	0000001101	13	0.124
00	00001110	0000001110	14	0.126
00	00001111	0000001111	15	0.129
00	00010000	0000010000	16	0.131
00	00010001	0000010001	17	0.133
00	00010010	0000010010	18	0.136
00	00010011	0000010011	19	0.138
00	00010100	0000010100	20	0.141
00	00010101	0000010101	21	0.143
00	00010110	0000010110	22	0.146
00	00010111	0000010111	23	0.149
00	00011000	0000011000	24	0.151
00	00011001	0000011001	25	0.154
00	00011010	0000011010	26	0.157
00	00011011	0000011011	27	0.160
00	00011100	0000011100	28	0.163
00	00011101	0000011101	29	0.166
00	00011110	0000011110	30	0.169
00	00011111	0000011111	31	0.172
00	00100000	0000100000	32	0.175
00	00100001	0000100001	33	0.178
00	00100010	0000100010	34	0.181
00	00100011	0000100011	35	0.185
00	00100100	0000100100	36	0.188
00	00100101	0000100101	37	0.191
00	00100110	0000100110	38	0.195
00	00100111	0000100111	39	0.198
00	00101000	0000101000	40	0.202
00	00101001	0000101001	41	0.206
00	00101010	0000101010	42	0.209
00	00101011	0000101011	43	0.213
00	00101100	0000101100	44	0.217
00	00101101	0000101101	45	0.221
00	00101110	0000101110	46	0.225
00	00101111	0000101111	47	0.229
00	00110000	0000110000	48	0.233
00	00110001	0000110001	49	0.238
00	00110010	0000110010	50	0.242
00	00110011	0000110011	51	0.246
00	00110100	0000110100	52	0.251
00	00110101	0000110101	53	0.255
00	00110110	0000110110	54	0.260
00	00110111	0000110111	55	0.265
00	00111000	0000111000	56	0.270
00	00111001	0000111001	57	0.275
00	00111010	0000111010	58	0.280
00	00111011	0000111011	59	0.285
00	00111100	0000111100	60	0.290
00	00111101	0000111101	61	0.295
00	00111110	0000111110	62	0.300
00	00111111	0000111111	63	0.306

00	01000000	0001000000	64	0.312
00	01000001	0001000001	65	0.317
00	01000010	0001000010	66	0.323
00	01000011	0001000011	67	0.329
00	01000100	0001000100	68	0.335
00	01000101	0001000101	69	0.341
00	01000110	0001000110	70	0.347
00	01000111	0001000111	71	0.353
00	01001000	0001001000	72	0.360
00	01001001	0001001001	73	0.366
00	01001010	0001001010	74	0.373
00	01001011	0001001011	75	0.380
00	01001100	0001001100	76	0.387
00	01001101	0001001101	77	0.394
00	01001110	0001001110	78	0.401
00	01001111	0001001111	79	0.408
00	01010000	0001010000	80	0.416
00	01010001	0001010001	81	0.423
00	01010010	0001010010	82	0.431
00	01010011	0001010011	83	0.439
00	01010100	0001010100	84	0.447
00	01010101	0001010101	85	0.455
00	01010110	0001010110	86	0.463
00	01010111	0001010111	87	0.472
00	01011000	0001011000	88	0.480
00	01011001	0001011001	89	0.489
00	01011010	0001011010	90	0.498
00	01011011	0001011011	91	0.507
00	01011100	0001011100	92	0.516
00	01011101	0001011101	93	0.526
00	01011110	0001011110	94	0.535
00	01011111	0001011111	95	0.545
00	01100000	0001100000	96	0.555
00	01100001	0001100001	97	0.565
00	01100010	0001100010	98	0.575
00	01100011	0001100011	99	0.586
00	01100100	0001100100	100	0.596
00	01100101	0001100101	101	0.607
00	01100110	0001100110	102	0.618
00	01100111	0001100111	103	0.629
00	01101000	0001101000	104	0.641
00	01101001	0001101001	105	0.653
00	01101010	0001101010	106	0.664
00	01101011	0001101011	107	0.677
00	01101100	0001101100	108	0.689
00	01101101	0001101101	109	0.701
00	01101110	0001101110	110	0.714
00	01101111	0001101111	111	0.727
00	01110000	0001110000	112	0.740
00	01110001	0001110001	113	0.754
00	01110010	0001110010	114	0.768

00	01110011	0001110011	115	0.782
00	01110100	0001110100	116	0.796
00	01110101	0001110101	117	0.810
00	01110110	0001110110	118	0.825
00	01110111	0001110111	119	0.840
00	01111000	0001111000	120	0.855
00	01111001	0001111001	121	0.871
00	01111010	0001111010	122	0.887
00	01111011	0001111011	123	0.903
00	01111100	0001111100	124	0.919
00	01111101	0001111101	125	0.936
00	01111110	0001111110	126	0.953
00	01111111	0001111111	127	0.970
00	10000000	0010000000	128	0.988
00	10000001	0010000001	129	1.006
00	10000010	0010000010	130	1.024
00	10000011	0010000011	131	1.043
00	10000100	0010000100	132	1.062
00	10000101	0010000101	133	1.081
00	10000110	0010000110	134	1.101
00	10000111	0010000111	135	1.121
00	10001000	0010001000	136	1.141
00	10001001	0010001001	137	1.162
00	10001010	0010001010	138	1.183
00	10001011	0010001011	139	1.205
00	10001100	0010001100	140	1.227
00	10001101	0010001101	141	1.249
00	10001110	0010001110	142	1.272
00	10001111	0010001111	143	1.295
00	10010000	0010010000	144	1.319
00	10010001	0010010001	145	1.343
00	10010010	0010010010	146	1.367
00	10010011	0010010011	147	1.392
00	10010100	0010010100	148	1.417
00	10010101	0010010101	149	1.443
00	10010110	0010010110	150	1.469
00	10010111	0010010111	151	1.496
00	10011000	0010011000	152	1.523
00	10011001	0010011001	153	1.551
00	10011010	0010011010	154	1.579
00	10011011	0010011011	155	1.608
00	10011100	0010011100	156	1.637
00	10011101	0010011101	157	1.667
00	10011110	0010011110	158	1.697
00	10011111	0010011111	159	1.728
00	10100000	0010100000	160	1.760
00	10100001	0010100001	161	1.792
00	10100010	0010100010	162	1.824
00	10100011	0010100011	163	1.858
00	10100100	0010100100	164	1.891
00	10100101	0010100101	165	1.926

00	10100110	0010100110	166	1.961
00	10100111	0010100111	167	1.996
00	10101000	0010101000	168	2.033
00	10101001	0010101001	169	2.070
00	10101010	0010101010	170	2.107
00	10101011	0010101011	171	2.146
00	10101100	0010101100	172	2.185
00	10101101	0010101101	173	2.225
00	10101110	0010101110	174	2.265
00	10101111	0010101111	175	2.306
00	10110000	0010110000	176	2.348
00	10110001	0010110001	177	2.391
00	10110010	0010110010	178	2.435
00	10110011	0010110011	179	2.479
00	10110100	0010110100	180	2.524
00	10110101	0010110101	181	2.570
00	10110110	0010110110	182	2.617
00	10110111	0010110111	183	2.664
00	10111000	0010111000	184	2.713
00	10111001	0010111001	185	2.762
00	10111010	0010111010	186	2.812
00	10111011	0010111011	187	2.864
00	10111100	0010111100	188	2.916
00	10111101	0010111101	189	2.969
00	10111110	0010111110	190	3.023
00	10111111	0010111111	191	3.078
00	11000000	0011000000	192	3.134
00	11000001	0011000001	193	3.191
00	11000010	0011000010	194	3.249
00	11000011	0011000011	195	3.308
00	11000100	0011000100	196	3.368
00	11000101	0011000101	197	3.430
00	11000110	0011000110	198	3.492
00	11000111	0011000111	199	3.556
00	11001000	0011001000	200	3.620
00	11001001	0011001001	201	3.686
00	11001010	0011001010	202	3.753
00	11001011	0011001011	203	3.822
00	11001100	0011001100	204	3.891
00	11001101	0011001101	205	3.962
00	11001110	0011001110	206	4.034
00	11001111	0011001111	207	4.107
00	11010000	0011010000	208	4.182
00	11010001	0011010001	209	4.258
00	11010010	0011010010	210	4.336
00	11010011	0011010011	211	4.415
00	11010100	0011010100	212	4.495
00	11010101	0011010101	213	4.577
00	11010110	0011010110	214	4.660
00	11010111	0011010111	215	4.745
00	11011000	0011011000	216	4.831

00	11011001	0011011001	217	4.919
00	11011010	0011011010	218	5.009
00	11011011	0011011011	219	5.100
00	11011100	0011011100	220	5.193
00	11011101	0011011101	221	5.287
00	11011110	0011011110	222	5.384
00	11011111	0011011111	223	5.482
00	11100000	0011100000	224	5.581
00	11100001	0011100001	225	5.683
00	11100010	0011100010	226	5.786
00	11100011	0011100011	227	5.892
00	11100100	0011100100	228	5.999
00	11100101	0011100101	229	6.108
00	11100110	0011100110	230	6.219
00	11100111	0011100111	231	6.332
00	11101000	0011101000	232	6.448
00	11101001	0011101001	233	6.565
00	11101010	0011101010	234	6.684
00	11101011	0011101011	235	6.806
00	11101100	0011101100	236	6.930
00	11101101	0011101101	237	7.056
00	11101110	0011101110	238	7.185
00	11101111	0011101111	239	7.315
00	11110000	0011110000	240	7.448
00	11110001	0011110001	241	7.584
00	11110010	0011110010	242	7.722
00	11110011	0011110011	243	7.863
00	11110100	0011110100	244	8.006
00	11110101	0011110101	245	8.151
00	11110110	0011110110	246	8.300
00	11110111	0011110111	247	8.451
00	11111000	0011111000	248	8.605
00	11111001	0011111001	249	8.761
00	11111010	0011111010	250	8.921
00	11111011	0011111011	251	9.083
00	11111100	0011111100	252	9.248
00	11111101	0011111101	253	9.417
00	11111110	0011111110	254	9.588
00	11111111	0011111111	255	9.762

1.7.1.2 F-REQ-412074/A-MEDIUM Range Lookup Table for Background_Image_Sensor_Reading

MID RANGE TABLE (Only for RLS_cfg =1)				
LghtAmbIntns_ D2_Sns(2bits)	**LghtAmb_ Intns_Sns (8bits)**	**Combine Signal (10bits)**	**Combined Signal 10-bit value (DEC)**	**Background_Image _Sensor_Reading (cd/m²)**
01	00000000	0100000000	256	9.940
01	00000001	0100000001	257	10.121
01	00000010	0100000010	258	10.305
01	00000011	0100000011	259	10.493

01	00000100	0100000100	260	10.684
01	00000101	0100000101	261	10.878
01	00000110	0100000110	262	11.076
01	00000111	0100000111	263	11.278
01	00001000	0100001000	264	11.483
01	00001001	0100001001	265	11.692
01	00001010	0100001010	266	11.905
01	00001011	0100001011	267	12.121
01	00001100	0100001100	268	12.342
01	00001101	0100001101	269	12.567
01	00001110	0100001110	270	12.795
01	00001111	0100001111	271	13.028
01	00010000	0100010000	272	13.265
01	00010001	0100010001	273	13.507
01	00010010	0100010010	274	13.752
01	00010011	0100010011	275	14.003
01	00010100	0100010100	276	14.258
01	00010101	0100010101	277	14.517
01	00010110	0100010110	278	14.781
01	00010111	0100010111	279	15.050
01	00011000	0100011000	280	15.324
01	00011001	0100011001	281	15.603
01	00011010	0100011010	282	15.887
01	00011011	0100011011	283	16.176
01	00011100	0100011100	284	16.471
01	00011101	0100011101	285	16.770
01	00011110	0100011110	286	17.076
01	00011111	0100011111	287	17.386
01	00100000	0100100000	288	17.703
01	00100001	0100100001	289	18.025
01	00100010	0100100010	290	18.353
01	00100011	0100100011	291	18.687
01	00100100	0100100100	292	19.027
01	00100101	0100100101	293	19.373
01	00100110	0100100110	294	19.726
01	00100111	0100100111	295	20.085
01	00101000	0100101000	296	20.451
01	00101001	0100101001	297	20.823
01	00101010	0100101010	298	21.202
01	00101011	0100101011	299	21.588
01	00101100	0100101100	300	21.980
01	00101101	0100101101	301	22.380
01	00101110	0100101110	302	22.788
01	00101111	0100101111	303	23.203
01	00110000	0100110000	304	23.625
01	00110001	0100110001	305	24.055
01	00110010	0100110010	306	24.493
01	00110011	0100110011	307	24.938
01	00110100	0100110100	308	25.392
01	00110101	0100110101	309	25.854
01	00110110	0100110110	310	26.325

01	00110111	0100110111	311	26.804
01	00111000	0100111000	312	27.292
01	00111001	0100111001	313	27.788
01	00111010	0100111010	314	28.294
01	00111011	0100111011	315	28.809
01	00111100	0100111100	316	29.333
01	00111101	0100111101	317	29.867
01	00111110	0100111110	318	30.411
01	00111111	0100111111	319	30.964
01	01000000	0101000000	320	31.528
01	01000001	0101000001	321	32.102
01	01000010	0101000010	322	32.686
01	01000011	0101000011	323	33.281
01	01000100	0101000100	324	33.886
01	01000101	0101000101	325	34.503
01	01000110	0101000110	326	35.131
01	01000111	0101000111	327	35.770
01	01001000	0101001000	328	36.421
01	01001001	0101001001	329	37.084
01	01001010	0101001010	330	37.759
01	01001011	0101001011	331	38.446
01	01001100	0101001100	332	39.146
01	01001101	0101001101	333	39.859
01	01001110	0101001110	334	40.584
01	01001111	0101001111	335	41.323
01	01010000	0101010000	336	42.075
01	01010001	0101010001	337	42.840
01	01010010	0101010010	338	43.620
01	01010011	0101010011	339	44.414
01	01010100	0101010100	340	45.222
01	01010101	0101010101	341	46.045
01	01010110	0101010110	342	46.883
01	01010111	0101010111	343	47.737
01	01011000	0101011000	344	48.605
01	01011001	0101011001	345	49.490
01	01011010	0101011010	346	50.391
01	01011011	0101011011	347	51.308
01	01011100	0101011100	348	52.242
01	01011101	0101011101	349	53.192
01	01011110	0101011110	350	54.160
01	01011111	0101011111	351	55.146
01	01100000	0101100000	352	56.150
01	01100001	0101100001	353	57.172
01	01100010	0101100010	354	58.212
01	01100011	0101100011	355	59.272
01	01100100	0101100100	356	60.350
01	01100101	0101100101	357	61.449
01	01100110	0101100110	358	62.567
01	01100111	0101100111	359	63.706
01	01101000	0101101000	360	64.865
01	01101001	0101101001	361	66.046

01	01101010	0101101010	362	67.248
01	01101011	0101101011	363	68.471
01	01101100	0101101100	364	69.718
01	01101101	0101101101	365	70.986
01	01101110	0101101110	366	72.278
01	01101111	0101101111	367	73.594
01	01110000	0101110000	368	74.933
01	01110001	0101110001	369	76.297
01	01110010	0101110010	370	77.685
01	01110011	0101110011	371	79.099
01	01110100	0101110100	372	80.539
01	01110101	0101110101	373	82.005
01	01110110	0101110110	374	83.497
01	01110111	0101110111	375	85.017
01	01111000	0101111000	376	86.564
01	01111001	0101111001	377	88.139
01	01111010	0101111010	378	89.743
01	01111011	0101111011	379	91.377
01	01111100	0101111100	380	93.040
01	01111101	0101111101	381	94.733
01	01111110	0101111110	382	96.457
01	01111111	0101111111	383	98.213
01	10000000	0110000000	384	100.000
01	10000001	0110000001	385	101.820
01	10000010	0110000010	386	103.673
01	10000011	0110000011	387	105.560
01	10000100	0110000100	388	107.481
01	10000101	0110000101	389	109.437
01	10000110	0110000110	390	111.429
01	10000111	0110000111	391	113.457
01	10001000	0110001000	392	115.522
01	10001001	0110001001	393	117.624
01	10001010	0110001010	394	119.765
01	10001011	0110001011	395	121.944
01	10001100	0110001100	396	124.164
01	10001101	0110001101	397	126.423
01	10001110	0110001110	398	128.724
01	10001111	0110001111	399	131.067
01	10010000	0110010000	400	133.452
01	10010001	0110010001	401	135.881
01	10010010	0110010010	402	138.354
01	10010011	0110010011	403	140.872
01	10010100	0110010100	404	143.436
01	10010101	0110010101	405	146.046
01	10010110	0110010110	406	148.704
01	10010111	0110010111	407	151.411
01	10011000	0110011000	408	154.166
01	10011001	0110011001	409	156.972
01	10011010	0110011010	410	159.829
01	10011011	0110011011	411	162.738
01	10011100	0110011100	412	165.699

01	10011101	0110011101	413	168.715
01	10011110	0110011110	414	171.786
01	10011111	0110011111	415	174.912
01	10100000	0110100000	416	178.095
01	10100001	0110100001	417	181.337
01	10100010	0110100010	418	184.637
01	10100011	0110100011	419	187.997
01	10100100	0110100100	420	191.419
01	10100101	0110100101	421	194.902
01	10100110	0110100110	422	198.450
01	10100111	0110100111	423	202.061
01	10101000	0110101000	424	205.739
01	10101001	0110101001	425	209.483
01	10101010	0110101010	426	213.296
01	10101011	0110101011	427	217.177
01	10101100	0110101100	428	221.130
01	10101101	0110101101	429	225.154
01	10101110	0110101110	430	229.252
01	10101111	0110101111	431	233.424
01	10110000	0110110000	432	237.673
01	10110001	0110110001	433	241.998
01	10110010	0110110010	434	246.402
01	10110011	0110110011	435	250.887
01	10110100	0110110100	436	255.453
01	10110101	0110110101	437	260.102
01	10110110	0110110110	438	264.836
01	10110111	0110110111	439	269.656
01	10111000	0110111000	440	274.563
01	10111001	0110111001	441	279.560
01	10111010	0110111010	442	284.648
01	10111011	0110111011	443	289.828
01	10111100	0110111100	444	295.103
01	10111101	0110111101	445	300.474
01	10111110	0110111110	446	305.942
01	10111111	0110111111	447	311.510
01	11000000	0111000000	448	317.180
01	11000001	0111000001	449	322.952
01	11000010	0111000010	450	328.830
01	11000011	0111000011	451	334.814
01	11000100	0111000100	452	340.908
01	11000101	0111000101	453	347.112
01	11000110	0111000110	454	353.430
01	11000111	0111000111	455	359.862
01	11001000	0111001000	456	366.411
01	11001001	0111001001	457	373.080
01	11001010	0111001010	458	379.870
01	11001011	0111001011	459	386.783
01	11001100	0111001100	460	393.822
01	11001101	0111001101	461	400.990
01	11001110	0111001110	462	408.287
01	11001111	0111001111	463	415.718

01	11010000	0111010000	464	423.284
01	11010001	0111010001	465	430.988
01	11010010	0111010010	466	438.831
01	11010011	0111010011	467	446.818
01	11010100	0111010100	468	454.950
01	11010101	0111010101	469	463.230
01	11010110	0111010110	470	471.660
01	11010111	0111010111	471	480.244
01	11011000	0111011000	472	488.984
01	11011001	0111011001	473	497.884
01	11011010	0111011010	474	506.945
01	11011011	0111011011	475	516.171
01	11011100	0111011100	476	525.565
01	11011101	0111011101	477	535.130
01	11011110	0111011110	478	544.869
01	11011111	0111011111	479	554.786
01	11100000	0111100000	480	564.883
01	11100001	0111100001	481	575.163
01	11100010	0111100010	482	585.631
01	11100011	0111100011	483	596.289
01	11100100	0111100100	484	607.141
01	11100101	0111100101	485	618.191
01	11100110	0111100110	486	629.442
01	11100111	0111100111	487	640.897
01	11101000	0111101000	488	652.561
01	11101001	0111101001	489	664.438
01	11101010	0111101010	490	676.530
01	11101011	0111101011	491	688.843
01	11101100	0111101100	492	701.379
01	11101101	0111101101	493	714.144
01	11101110	0111101110	494	727.141
01	11101111	0111101111	495	740.375
01	11110000	0111110000	496	753.849
01	11110001	0111110001	497	767.569
01	11110010	0111110010	498	781.539
01	11110011	0111110011	499	795.762
01	11110100	0111110100	500	810.245
01	11110101	0111110101	501	824.991
01	11110110	0111110110	502	840.005
01	11110111	0111110111	503	855.293
01	11111000	0111111000	504	870.859
01	11111001	0111111001	505	886.708
01	11111010	0111111010	506	902.846
01	11111011	0111111011	507	919.277
01	11111100	0111111100	508	936.008
01	11111101	0111111101	509	953.043
01	11111110	0111111110	510	970.387
01	11111111	0111111111	511	988.048

1.7.1.3 F-REQ-412075/A-HIGH Range Lookup Table for Background_Image_Sensor_Reading

HIGH RANGE TABLE (Only for RLS_cfg =1)				
LghtAmbIntns_D2_Sns (2bits)	**LghtAmb_Intns_Sns (8bits)**	**Combine Signal (10bits)**	**Combined Signal 10-bit value (HEX)**	**Background_Image_Sensor_Reading (cd/m²)**
10	00000000	1000000000	512	1006.030
10	00000001	1000000001	513	1024.339
10	00000010	1000000010	514	1042.982
10	00000011	1000000011	515	1061.964
10	00000100	1000000100	516	1081.291
10	00000101	1000000101	517	1100.970
10	00000110	1000000110	518	1121.007
10	00000111	1000000111	519	1141.409
10	00001000	1000001000	520	1162.182
10	00001001	1000001001	521	1183.333
10	00001010	1000001010	522	1204.869
10	00001011	1000001011	523	1226.797
10	00001100	1000001100	524	1249.125
10	00001101	1000001101	525	1271.858
10	00001110	1000001110	526	1295.005
10	00001111	1000001111	527	1318.574
10	00010000	1000010000	528	1342.571
10	00010001	1000010001	529	1367.005
10	00010010	1000010010	530	1391.884
10	00010011	1000010011	531	1417.216
10	00010100	1000010100	532	1443.009
10	00010101	1000010101	533	1469.271
10	00010110	1000010110	534	1496.011
10	00010111	1000010111	535	1523.238
10	00011000	1000011000	536	1550.960
10	00011001	1000011001	537	1579.186
10	00011010	1000011010	538	1607.927
10	00011011	1000011011	539	1637.191
10	00011100	1000011100	540	1666.987
10	00011101	1000011101	541	1697.325
10	00011110	1000011110	542	1728.216
10	00011111	1000011111	543	1759.668
10	00100000	1000100000	544	1791.693
10	00100001	1000100001	545	1824.301
10	00100010	1000100010	546	1857.503
10	00100011	1000100011	547	1891.309
10	00100100	1000100100	548	1925.730
10	00100101	1000100101	549	1960.777
10	00100110	1000100110	550	1996.462
10	00100111	1000100111	551	2032.797
10	00101000	1000101000	552	2069.793
10	00101001	1000101001	553	2107.462
10	00101010	1000101010	554	2145.817
10	00101011	1000101011	555	2184.870

10	00101100	1000101100	556	2224.634
10	00101101	1000101101	557	2265.121
10	00101110	1000101110	558	2306.345
10	00101111	1000101111	559	2348.319
10	00110000	1000110000	560	2391.058
10	00110001	1000110001	561	2434.574
10	00110010	1000110010	562	2478.882
10	00110011	1000110011	563	2523.997
10	00110100	1000110100	564	2569.932
10	00110101	1000110101	565	2616.704
10	00110110	1000110110	566	2664.327
10	00110111	1000110111	567	2712.816
10	00111000	1000111000	568	2762.188
10	00111001	1000111001	569	2812.459
10	00111010	1000111010	570	2863.644
10	00111011	1000111011	571	2915.761
10	00111100	1000111100	572	2968.827
10	00111101	1000111101	573	3022.858
10	00111110	1000111110	574	3077.873
10	00111111	1000111111	575	3133.889
10	01000000	1001000000	576	3190.924
10	01000001	1001000001	577	3248.997
10	01000010	1001000010	578	3308.128
10	01000011	1001000011	579	3368.334
10	01000100	1001000100	580	3429.636
10	01000101	1001000101	581	3492.054
10	01000110	1001000110	582	3555.608
10	01000111	1001000111	583	3620.318
10	01001000	1001001000	584	3686.206
10	01001001	1001001001	585	3753.294
10	01001010	1001001010	586	3821.602
10	01001011	1001001011	587	3891.153
10	01001100	1001001100	588	3961.970
10	01001101	1001001101	589	4034.076
10	01001110	1001001110	590	4107.495
10	01001111	1001001111	591	4182.249
10	01010000	1001010000	592	4258.364
10	01010001	1001010001	593	4335.865
10	01010010	1001010010	594	4414.775
10	01010011	1001010011	595	4495.122
10	01010100	1001010100	596	4576.931
10	01010101	1001010101	597	4660.230
10	01010110	1001010110	598	4745.044
10	01010111	1001010111	599	4831.401
10	01011000	1001011000	600	4919.331
10	01011001	1001011001	601	5008.860
10	01011010	1001011010	602	5100.019
10	01011011	1001011011	603	5192.837
10	01011100	1001011100	604	5287.344
10	01011101	1001011101	605	5383.572
10	01011110	1001011110	606	5481.550

10	01011111	1001011111	607	5581.312
10	01100000	1001100000	608	5682.889
10	01100001	1001100001	609	5786.315
10	01100010	1001100010	610	5891.624
10	01100011	1001100011	611	5998.848
10	01100100	1001100100	612	6108.025
10	01100101	1001100101	613	6219.188
10	01100110	1001100110	614	6332.374
10	01100111	1001100111	615	6447.621
10	01101000	1001101000	616	6564.964
10	01101001	1001101001	617	6684.444
10	01101010	1001101010	618	6806.098
10	01101011	1001101011	619	6929.965
10	01101100	1001101100	620	7056.088
10	01101101	1001101101	621	7184.505
10	01101110	1001101110	622	7315.260
10	01101111	1001101111	623	7448.394
10	01110000	1001110000	624	7583.952
10	01110001	1001110001	625	7721.976
10	01110010	1001110010	626	7862.513
10	01110011	1001110011	627	8005.607
10	01110100	1001110100	628	8151.305
10	01110101	1001110101	629	8299.655
10	01110110	1001110110	630	8450.705
10	01110111	1001110111	631	8604.504
10	01111000	1001111000	632	8761.102
10	01111001	1001111001	633	8920.550
10	01111010	1001111010	634	9082.900
10	01111011	1001111011	635	9248.205
10	01111100	1001111100	636	9416.518
10	01111101	1001111101	637	9587.894
10	01111110	1001111110	638	9762.390
10	01111111	1001111111	639	9940.061
10	10000000	1010000000	640	10120.965
10	10000001	1010000001	641	10305.162
10	10000010	1010000010	642	10492.711
10	10000011	1010000011	643	10683.674
10	10000100	1010000100	644	10878.112
10	10000101	1010000101	645	11076.089
10	10000110	1010000110	646	11277.668
10	10000111	1010000111	647	11482.917
10	10001000	1010001000	648	11691.901
10	10001001	1010001001	649	11904.688
10	10001010	1010001010	650	12121.348
10	10001011	1010001011	651	12341.951
10	10001100	1010001100	652	12566.569
10	10001101	1010001101	653	12795.275
10	10001110	1010001110	654	13028.143
10	10001111	1010001111	655	13265.249
10	10010000	1010010000	656	13506.670
10	10010001	1010010001	657	13752.486

10	10010010	1010010010	658	14002.775
10	10010011	1010010011	659	14257.619
10	10010100	1010010100	660	14517.101
10	10010101	1010010101	661	14781.306
10	10010110	1010010110	662	15050.319
10	10010111	1010010111	663	15324.227
10	10011000	1010011000	664	15603.121
10	10011001	1010011001	665	15887.091
10	10011010	1010011010	666	16176.229
10	10011011	1010011011	667	16470.629
10	10011100	1010011100	668	16770.387
10	10011101	1010011101	669	17075.600
10	10011110	1010011110	670	17386.368
10	10011111	1010011111	671	17702.792
10	10100000	1010100000	672	18024.975
10	10100001	1010100001	673	18353.021
10	10100010	1010100010	674	18687.038
10	10100011	1010100011	675	19027.134
10	10100100	1010100100	676	19373.419
10	10100101	1010100101	677	19726.006
10	10100110	1010100110	678	20085.010
10	10100111	1010100111	679	20450.549
10	10101000	1010101000	680	20822.739
10	10101001	1010101001	681	21201.704
10	10101010	1010101010	682	21587.565
10	10101011	1010101011	683	21980.449
10	10101100	1010101100	684	22380.483
10	10101101	1010101101	685	22787.797
10	10101110	1010101110	686	23202.525
10	10101111	1010101111	687	23624.800
10	10110000	1010110000	688	24054.761
10	10110001	1010110001	689	24492.547
10	10110010	1010110010	690	24938.300
10	10110011	1010110011	691	25392.165
10	10110100	1010110100	692	25854.291
10	10110101	1010110101	693	26324.828
10	10110110	1010110110	694	26803.927
10	10110111	1010110111	695	27291.747
10	10111000	1010111000	696	27788.444
10	10111001	1010111001	697	28294.181
10	10111010	1010111010	698	28809.122
10	10111011	1010111011	699	29333.435
10	10111100	1010111100	700	29867.290
10	10111101	1010111101	701	30410.861
10	10111110	1010111110	702	30964.325
10	10111111	1010111111	703	31527.862
10	11000000	1011000000	704	32101.654
10	11000001	1011000001	705	32685.890
10	11000010	1011000010	706	33280.758
10	11000011	1011000011	707	33886.453
10	11000100	1011000100	708	34503.171

10	11000101	1011000101	709	35131.113
10	11000110	1011000110	710	35770.483
10	11000111	1011000111	711	36421.489
10	11001000	1011001000	712	37084.344
10	11001001	1011001001	713	37759.262
10	11001010	1011001010	714	38446.463
10	11001011	1011001011	715	39146.172
10	11001100	1011001100	716	39858.614
10	11001101	1011001101	717	40584.023
10	11001110	1011001110	718	41322.633
10	11001111	1011001111	719	42074.686
10	11010000	1011010000	720	42840.427
10	11010001	1011010001	721	43620.103
10	11010010	1011010010	722	44413.969
10	11010011	1011010011	723	45222.283
10	11010100	1011010100	724	46045.308
10	11010101	1011010101	725	46883.311
10	11010110	1011010110	726	47736.566
10	11010111	1011010111	727	48605.350
10	11011000	1011011000	728	49489.945
10	11011001	1011011001	729	50390.639
10	11011010	1011011010	730	51307.726
10	11011011	1011011011	731	52241.503
10	11011100	1011011100	732	53192.275
10	11011101	1011011101	733	54160.350
10	11011110	1011011110	734	55146.044
10	11011111	1011011111	735	56149.677
10	11100000	1011100000	736	57171.575
10	11100001	1011100001	737	58212.072
10	11100010	1011100010	738	59271.505
10	11100011	1011100011	739	60350.219
10	11100100	1011100100	740	61448.566
10	11100101	1011100101	741	62566.901
10	11100110	1011100110	742	63705.591
10	11100111	1011100111	743	64865.003
10	11101000	1011101000	744	66045.517
10	11101001	1011101001	745	67247.515
10	11101010	1011101010	746	68471.389
10	11101011	1011101011	747	69717.537
10	11101100	1011101100	748	70986.364
10	11101101	1011101101	749	72278.284
10	11101110	1011101110	750	73593.716
10	11101111	1011101111	751	74933.088
10	11110000	1011110000	752	76296.836
10	11110001	1011110001	753	77685.403
10	11110010	1011110010	754	79099.242
10	11110011	1011110011	755	80538.813
10	11110100	1011110100	756	82004.582
10	11110101	1011110101	757	83497.028
10	11110110	1011110110	758	85016.636
10	11110111	1011110111	759	86563.900

10	11111000	1011111000	760	88139.323
10	11111001	1011111001	761	89743.419
10	11111010	1011111010	762	91376.708
10	11111011	1011111011	763	93039.723
10	11111100	1011111100	764	94733.003
10	11111101	1011111101	765	96457.101
10	11111110	1011111110	766	98212.576
10	11111111	1011111111	767	100000.000

1.8 Revision History

STSS Module Revision History

Revision Level	Name	Change Description	Date
DRAFT	Anil Katakam	Initial Draft to Ford	10/23/2014
DRAFT	Anil Katakam	Changed operational modes, updated limiting algorithm for brightness level, provided more break points for interpolation curve as per review comments with Ford engineers.	10/26/2014
DRAFT	Anil Katakam	Updated Luminance ratio and HUD_Raw_Brightness values for different brightness levels.	10/27/2014
DRAFT	Anil Katakam	Updated Luminance ratio and HUD_Raw_Brightness values for different brightness levels as per Anthony comments to make Luminance ratios between 2 to 5.	10/30/2014
1.1	James Raj Asirvatham	Updated sec 1.3.1 to allow Brightness functionality in Crank. Changes highlighted in RED	02/26/2015
1.2	James Raj Asirvatham	Changes highlighted in RED -Updated sec 1.3.4(System accuracy) -Updated Table 1.8 & 1.9 as per Anthony's suggestions -Updated sec 1.3.5.2.1 to handle HUD brightness for FCW warning -Updated sec 1.3.5.4 by adding 2 DIDs for HUD brightness for FCW warning	03/12/2015
1.3	James Raj Asirvatham	Changes highlighted in RED based on directions from Anthony & Florian Oefelein - Updated the numbering of Tables - Updated Table 1.9. Added Luminance ratio factor - Updated comments on Table 1.10. This table is now only an example, and not a look-up table - Updated sec 1.3.5.2.1. Added numbering to HUD dimming sub-components - Updated sec 1.3.5.2.1 by introducing DIDs to control Time constants in the sub-components - Updated Missing signal/Fault section(sec 1.3.5.2.3) to apply the values of TBL_HUD_BRIGHTNESS_DAYTIME_DEFAULT & TBL_HUD_BRIGHTNESS_NIGHTTIME_DEFAULT to User Median brightness selection(Level 7 0x6) - Updated sec 1.3.5.4 by adding the following EEPROM parameters: USER_BRIGHT_LEVEL_RANGE, AMB_BRIGHTNESS_TAU_INCR AMB_BRIGHTNESS_TAU_DECR CUST_DIMMING_TAU	03/27/2015

		- Updated sec 1.3.5.4 by updating description for TBL_HUD_BRIGHTNESS_DAYTIME_DEFAULT & TBL_HUD_BRIGHTNESS_NIGHTTIME_DEFAULT - Updated sec 1.3.5.4 by deleting TBL_HUD_LUMINANCE_RATIOS[10]. Changed the name of HUD_RAW_BRIGHTNESS[] to TBL_HUD_BACKGRND_IMAGE_LUMIN_RATIO	
1.4	James Raj Asirvatham	Changes highlighted in RED based on directions from Anthony -Added sec 1.3.5.2.2.1. This introduces HUD brightness values for Active FCW warning with Table 1.11 when Ambient sensor is available. - Added sec 1.3.5.2.2.2 -Updated sec 1.3.5.4. Added DIDs TBL_HUD_BACKGRND_IMAGE_LUMIN_RATIO_FCW & USER_BRIGHT_LEVEL_RANGE_FCW to handle brightness when FCW warning is Active.	04/10/2015
1.5		Changes highlighted in Green. Update required to allow active HUD Image Brightness to return after IPC warning is cleared. Page 1 **Figure 1.1** – Add DsplyChkActv_B_Stat (CAN) Signal. Page 3 **Table 1.6** – New table for DsplyChkActv_B_Stat (CAN) Signal. Page 7 **Figure 1.2** – Add DsplyChkActv_B_Stat decision. Page 19 **Section 1.3.5.4** – Add DsplyChkActv_B_Stat (CAN) Signal	DRAFT
1.6		Change highlighted in Yellow. Updated Fig 1.2 - No action is required to be taken by HUD against no user action after displaying the brightness menu on HUD.	10/13/2017
1.7	P.Denduku	Initial VSEM RM Release	03/20/2018
1.8	llopezla	Changes highlighted in Pink Updated Fig 1.2.1. Introduced HUD_BRIGHTNESS_SELECTION_TIMER for Push & hold feature for the Up & Down keys during Image brightness user selection. Updated sec 1.3.5.4. Added HUD_BRIGHTNESS_SELECTION_TIMER.	1/28/18
1.9	ilopezla	Updated section 1.1 (Functional Description) to remove HUD hard switch statement since there is not HUD hardswitch for future HUD programs. Added the following singals/variables to the Interfece Context Diagram in section 1.2.1 to support the new ambient light sensor which supports a logarithm reading. 1. RLS_cfg 2.LhgtAmbIntns_D2_Sns 3.LhtAmbIntns_D2_Sns_UB 4.LhtAmbIntns_D_Sns_UB Removed Details from Section 1.2.2.4.1 LghtAmb_Intns_Sns signal Added input signals in section 1.2.2.2	2/13/2019

		2.LhgtAmbIntns_D2_Sns 3.LhtAmbIntns_D2_Sns_UB 4.LhtAmbIntns_D_Sns_UB Updated Section 1.2.2.9.2 with a new table (1.2.2.9.2.2) to support the new sensor signals. Also, updated table 1.2.2.9.2.1 with the correct requirement reference (REQ 302354) Added 1.3.5.1.1 Diagnostic Rotine for RLS_cfg needed for new sensor Updated flow chart in section 1.3.5.1.2 with correct REQ reference (REQ 302346) since it was wrong. Updated section 1.3.5.2.2 with information for new sensor configurations Added Section 1.3.5.2.2.1 for Background_Image_Sensor_Reading calculation when RLS_cfg =0 Added Section 1.3.5.2.2.2 for Background_Image_Sensor_Reading calculation when RLS_cfg =1 Updated Section 1.3.5.2.3 Signal Information with LghtAmbIntns_D2_Sns for new sensor Removed HUD_Raw_Brightness formula since it does not apply anylonger and added description for auto dimming. Removed section 1.3.5.2.5 since it is not appliable Removed note in section 1.3.5.2.5 about the Luminance ratio since it is not applicable Updated Table in Section 1.3.5.2.6 with the following: 1. Remove Luminance Ratio Column since is not applicable 2. Remove Formula for HUD_Raw_Brightness since it is not applicable 3. Updated values for HUD_Raw_Brightness 4. Removed note for Luminance Ratio Added section 1.3.5.2.7 Updated Talble in section 1.3.5.2.8 as follows: 1. Remove Formula for HUD_Raw_Brightness since it is not applicable 2. Updated values for HUD_Raw_Brightness 3. Removed note for Luminance Ratio 4. Added statement about HUD maximun capability Added Section 1.3.5.2.9 Updated Section 1.3.5.2.12.1 with the following: 1. Remove Luminance Ratio statement 2. Added User Level 7 brightness curve Table DID requirement for FCW warning brightness Updated Table in Section 1.3.5.2.12.2 with the following: 1. Remove Luminance Ratio Column since is not applicable 2. Remove Formula for HUD_Raw_Brightness since it is not applicable 3. Updated values for HUD_Raw_Brightness	

		4. Added USER_BRIGHT_LEVEL_RANGE_FCW requeriment Updated Section 1.3.5.2.12.3 so it takes into account the RLS_cfg input and new signals for new sensor. Also, removed information about Luminance factor statement Updated Section 1.3.5.2.13.1 so it takes into account the RLS_cfg input and new signals for new sensor. Also, removed information about Luminance factor statement In Section 1.3.5.4 Removed TBL_HUD_BACKGRND_IMAGE_LUMIN_RATIO & TBL_HUD_BACKGRND_IMAGE_LUMIN_RATIO_FCW since it is n/a Updated AMB_BRIGHTNESS_TAU_INCR --->300msec AMB_BRIGHTNESS_TAU_DECR --->10msec CUST_DIMMING_TAU --> 10ms Added Section 1.5.3.2 Supported DID DExx for RLS_cfg Added Section 1.8 for Lookup tables for Background Image Sensor Reading when RLS_cfg =1	
1.10	ilopeza	Updated name for signals below LhgtAmbIntns_D2_Sns → LhgtAmbIntns2_D_Sns LhtAmbIntns_D2_Sns_UB → LhtAmbIntns2_D_Sns_UB	2/18/2019

1.11	llopezla	• Section 1.2.1-Removed
		  ○ DimSpTechnicalR (SPI) signal
		  ○ DimSpTechnical G (SPI) signal
		  ○ DimSpTechnicalB (SPI) signal.
		• Removed SIG-REQ-302327/A-HudBri
		• Removed SIG-REQ-302329/A-Amblight
		• Removed- "The following are the internal signals used by the dimming algorithm" statement in REQ-302334/A
		• Moved SIG-REQ-302328/B-HUD_Raw_Brightness from input to output section 1.2.3
		• Added paragraph "634557-Internal"
		• Added SIG-REQ-346714/A-HUD_Brightness_Level
		• Change REQ type from "SIG" to "IR" for REQ-344268 & REQ-344269 since it is an internal req.
		• Removed 521040/A-PWM Output Signals
		  ○ SIG-REQ-302322/A-DimSPtechnicalR
		  ○ SIG-REQ-302323/A-DimSPtechnicalG
		  ○ SIG-REQ-302324/A-DimSPtechnicalB
		• Changed REQ-302328 type from SIG to IR since it is an internal requirement.
		• Removed -F-REQ-302347/A-HUD Dimming Handling overview
		• Section 1.3.5.2.4- Added text in brown
		• Section 1.3.5.2.5
		  ○ Removed USER_BRIGHTNSS_LEVEL_RANGE_PERCENTAGE Column from LookUp table
		  ○ Replaced paragraph for USER_BRIGHT_LEVEL_RANGE_PERCENTAE with formula for HUD_RAW_BRIGHNTESS(User Level Z). Text in brown
			4/23/2019

		• Updated Dimming Curve in REQ-344154 so there is no numbers in the Y-axis also added a note.
		• Updated Dimming Curve for REQ 344155
		• Corrected values in brown in REQ 302355 and also corrected UL8 value from 103 to 10.
		• Removed reference to section 1.3.5.2.9
		• Removed section 1.3.5.2.10 HUD Dimming Module
		• In Section 1.3.5.2.11 removed:
		  ○ REQ-302359-InputErrorHandling
		  ○ REQ-302360-CustomerBrightnessHandling
		  ○ REQ-202361-AmbientBrihtnessHandling
		  ○ REQ-302362-CustomerDimmingOuputHandling
		• Updated REQ-302341 Updated values for USER_BRIGHT_LEVEL_RANGE and USER_BRIGHT_LEVEL_RANGE_FCW to 60%
		• In Section 1.3.5.2.12.2, the following changes were performed:
		• Removed USER_BRIGHT_LEVEL_RANGE_FCW
		• Removed paragraph about USER_BRIGHT_LEVEL_RANGE_FCW
		• Added paragraph in brown text for USER_BRIGHT_LEVEL_RANGE_FCW Calculation
		• Removed OK Switch Event from REQ-302348
		• Updated Functional Description to remove sentence about PWM
		• Removed "2=High range (brightness res:80 cd/m^2) from second row in SIG-REQ-302325 since that was an error
		• Deleted IR-REQ-302335 since it should not be a requirement
		• Added text in brown in REQ-346714
		• Updated REQ-344266 flow chart
		• Updated REQ-302348 flow chart (text in brown)
		• Updated REQ 302350 text in brown
		Updated RQ 344273 text in brown
		• Added text in brown to REQ 302351
		• Updated REQ 302351 (text in brown)
		• Corrected typo in section 1.3.5.2.12.3 for RLS configuration from RLS_resolution_cfg to RLS_cfg.
		• Removed paragraph from REQ 3302363 to 1.4.1.1 section
		• Removed paragraph from REQ 344275 to 1.4.1.1 section
		• Changed TBL_HUD_BRIGHTNESS_NIGHTIME_DEFAULT from 5cd/m2 to 30cd/m2	

		• Updated description for USER_BRIGHT_LEVEL_RANGE_FCW in section 1.3.5.3 • Updated DefaultNightValue from 4cd/m2 to 30cd/m2 • Removed Details and comments from section 1.2.3.2.1.1 for FAULT and NULL state and added that to section 1.3.5.2.12.3 • Removed REQ344268 and REQ 344269 since logic for HUD_RAW_Brightness ouput is covered in section 1.3.5.2.6 • Modified Title for REQ302402 from "Missing Signal/Fault" to "Missing Signal/Fault for Non-FCW condition" • Added text in brown to REQ 302363 • Updated REQ 302349 (text in brown) since HUD will not check for OK switch event anymore. • Replaced Reference "Section 1.3.5.2.7" with "REQ 344154" in REQ 302352 • Removed Min and Max requirements from REQ 302355 and created two new requirements, one for Minimum Brightness (REQ-347582) and one for Maximum (REQ-347582) • Updated Reference in REQ-302401 from "section 1.3.5.12.2" to "REQ-302364" • Split REQ-302402 into REQ-344274 & REQ-344275 • Change Value at module wake up state to inactive for HUDBrghtMenuOn_B_Stat signal • Replaced paragraph 521076 with REQ350583	
1.12	F. Sethi	• Correct Signal name from "LghtAmbIntns2_D_Sns" to "LghtAmbIntns_D2_Sns"	10/9/2019
1.13	F. Sethi	• Update column name from "Background_ Image_Sensor_ Reading cd/m²" to "Background_ Image_Sensor_ Reading (cd/m²)" in all Lookup Tables and update whole column: "Background_ Image_Sensor_ Reading (cd/m²)" in "F-REQ-344254/C-LOW Range Lookup Table for Background_Image_Sensor_Reading" with up to 3 decimal values. • Update column name from "Combined Signal 10 bit value" to "Combined Signal 10-bit value (DEC)" • Correct Signal name from "LghtAmbIntns2_D_Sns" to "LghtAmbIntns_D2_Sns" in following Lookup Tables: ▪ F-REQ-344254/C-LOW Range Lookup Table for Background_Image_Sensor_Reading ▪ F-REQ-344255/C-MEDIUM Range Lookup Table for Background_Image_Sensor_Reading ▪ F-REQ-344256/C-HIGH Range Lookup Table for Background_Image_Sensor_Reading	1/30/2020
1.14	F. Sethi	Correct "RSL_cfg" config name to "RLS_cfg" under DCR-REQ-344267/A-Supported DID DExx requirement section Correct "RSL_cfg" config name to "RLS_cfg" under F-REQ-344272/D requirement section. Correct "RSL_cfg" config name to "RLS_cfg" under F-REQ-344273/D requirement section.	6/9/2020

		Correct DTC number from “C21287” to “C21200” for “Lost Communication with SCCM” under DTC-REQ-302408/A requirement section	
1.15	F. Sethi	Added new requirement “DID-REQ-403683/A-Supported Diagnostic DIDs (Service $22 and $2E)” while adding below DIDs: • $606B • $606A • $606D • $606C • $6069 • $6066 • $6068 • $6067 • $6065 • $6061 • $605E • $605D Added new requirement “DID-REQ-403684/A-Supported Diagnostic DIDs (Service $22 and $2F)” while adding below DIDs: • $6060 • $6063 • $605F Added note,” **Note**: During Diagnostics HUD will not take any input from any other module including steering wheel switch. After Diagnostic session ends up, HUD will go back to the previous state where it was before going to the Diagnostics. If HUD User Level Brightness settings, HUD Positional settings (Vertical/Rotational), HUD On/Off settings, HUD Density Settings or HUD DAT feature Display Status settings are active before diagnostic then during diagnostic, HUD will ignore those settings and HUD will not show any Brightness settings on display during diagnostic session. HUD will go back to the previous state where it was before going to the Diagnostics.” Added new requirement “DID-REQ-404575/A-Supported Diagnostic DIDs (Service $22)” while adding below DID: • $606F Updated Requirement “SIG-REQ-302333/B-Day_Night_Status Signal”, while modifying Signal size from “1” bits to “2” bits. Corrected typo mistakes by updating “cluster” with “HUD” on DCR-REQ-344267/B-Supported DID DExx”, “NVM-REQ-302341/D-Memory Storage” Operational_Mode Description and Switch Control Logic. This Spec is applicable for CGEA1.3 and above architectures.	01/06/2021
1.16	F. Sethi	This Spec version is released for FNV3 architecture vehicle programs.	3/22/2021

		On FNV3 architecture signals would be framed gateway that is why following signals have been removed for all FNV3 and above architecture programs: LghtAmb_Intns_Sns_UB LghtAmbIntns_D_Sns_UB LghtAmbIntns_D2_Sns_UB Following requirements are modified: 879555/A-Functional Description 879557/A-Interface Context Diagram (I/O Block Diagram) F-REQ-412059/A-FCW HUD Raw Brightness for User Median Brightness Selection, Initial Values for FCW Warning F-REQ-412061/A-FCW Warning Handling without Ambient Brightness and RLS_cfg =0x0 F-REQ-412062/A-FCW Warning Handling without Ambient Brightness and RLS_cfg =0x1 F-REQ-412064/A-Missing Signal /Fault for RLS_cfg =0 F-REQ-412065/A-Missing Signal/ Fault for RLS_cfg =1	