![DATASPEED Inc.]

Ford Fusion Steer-By-Wire

Steering by-wire in the Lincoln MKZ and Ford Fusion/Mondeo

Features

- Computer control of steering
- Measure steering wheel position
- Driver override by grabbing the steering wheel
- CAN and USB interfaces
- No modifications to vehicle
- Signal passthrough on power off

Applications

- Driverless car research
- Advanced Driver Assist (ADAS) research

Description

The Dataspeed Inc. Steer-By-Wire interface enables computer control of the steering wheel in a safe and effective manner. This plug-in ready kit requires no modification to the factory harnessing and can be installed in minutes. Industry standard CAN and USB networks enable control and monitoring of the steering system.

Contents

DISCLAIMER:

This product is intended for research purposes only. Steps have been taken to ensure function on power or communication loss. However, in no event shall Dataspeed Inc. be liable for any direct, indirect, punitive, incidental, special consequential damages, to property or life, whatsoever arising out of or connected with the use or misuse of its products.

1   Connector Pin Description

1.1   CAN/DB9 Connector

The CAN/DB9 connector is used for power and CAN communication. Short pins 1 and 6 together to activate the digital input.

Table 1: CAN/DB9 connector pin description.

Pin	Symbol	Description
1	DIGIN	Digital Input
2	CANL	CAN Low
3	GND	Ground
4	IGNITION	Ignition (12V)
5	NC	No Connect
6	GND	Ground
7	CANH	CAN High
8	NC	No Connect
9	POWER	Power (12V)

1.2   USB Connector

The USB connector is used for introspection and firmware upgrade.

2   Electrical Characteristics

Table 2: Electrical Characteristics.

Characteristic	Min	Typ	Max	Units	Conditions
$V_{IGNITION}$ ON	9	12	16	V	
$V_{IGNITION}$ OFF	-0.3	0	2	V	
V_{POWER}	9	12	16	V	
I_{POWER}		200		mA	V_{POWER}=12V, $V_{IGNITION}$>9V
I_{POWER}			0.1	mA	V_{POWER}=12V, $V_{IGNITION}$<2V
Temperature	-40		+85	$^\circ$C	

3   Mechanical Drawings
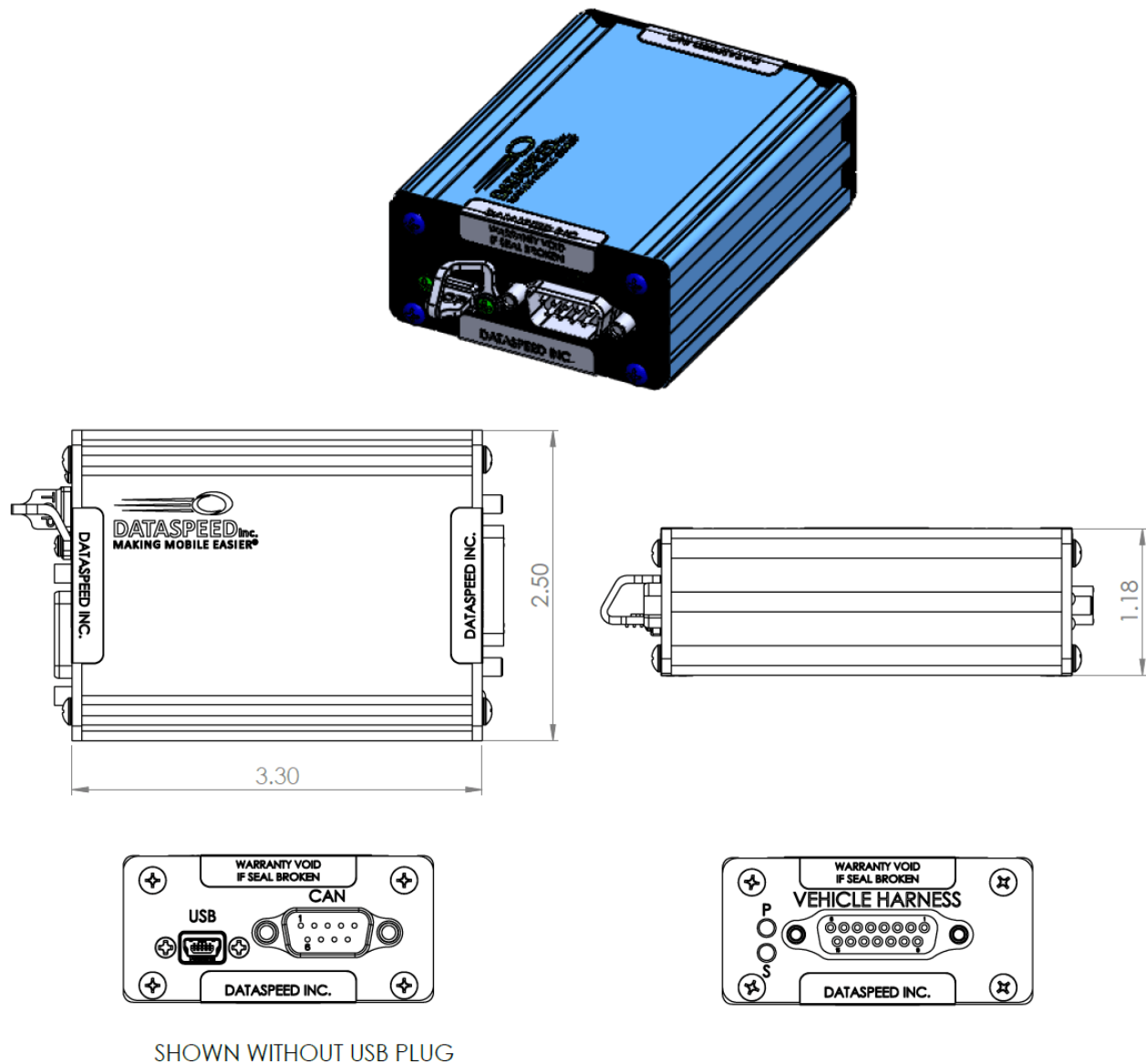
Figure 1: Mechanical Drawing

4   CAN Messages

Table 3: CAN bus configuration.

Parameter	Value	Units
Terminated	Yes	120Ω
BitRate	500	k
t_q	200	ns
SyncSeg	1	t_q
PropSeg	3	t_q
PhaseSeg1	3	t_q
PhaseSeg2	3	t_q
SyncJumpWidth	2	t_q

4.1 Steering

4.1.1 Command

Message ID: 0x064
Receive Rate: 20ms
Receive Timeout: 100ms

Table 4: Steering Command CAN Message Description.

Byte	Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	7:0	SCMD<7:0>							
1	15:8	SCMD<15:8>							
2	23:16	—	—	—	QUIET	—	IGNORE	CLEAR	EN
3	31:24	SVEL							
4	39:32	—	—	—	—	—	—	—	—
5	47:40	—	—	—	—	—	—	—	—
6	55:48	—	—	—	—	—	—	—	—
7	63:56	COUNT							

bit 0-15   **SCMD:** Steering Command
       0x125C = 470° left
       0x0001 = 0.1° left
       0x0000 = 0.0° center
       0xFFFF = 0.1° right
       0xEDA4 = 470° right
bit 16   **EN:** Enable request
       1 = enable
       0 = disable
bit 17   **CLEAR:** Clear driver override flag
       1 = request clear of driver override
       0 = normal operation
bit 18   **IGNORE:** Ignore driver override
       1 = ignore
       0 = normal
bit 19   **Unimplemented:** Set to '0'
bit 20   **QUIET:** Disable driver override audible warning
       1 = disable
       0 = normal
bit 21-23   **Unimplemented:** Set to '0'
bit 24-31   **SVEL:** Steering Velocity
       0x00 = 0°/s = 500°/s
       0x01 = 2°/s
       0x02 = 4°/s
       0xFA = 500°/s
bit 32-55   **Unimplemented:** Set to '0'
bit 56-63   **COUNT:** Optional watchdog counter

Note: The following requirements must be met to engage steering.
   Steering wheel torque: -1.5 ≤ TORQUE < 1.5
   Steering wheel angle velocity: -50°/s < VELOCITY < 50°/s

4.1.2 Report

Message ID: 0x065
Transmit Rate: 20ms

Table 5: Steering Report CAN Message Description.

Byte	Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	7:0	ANGLE<7:0>							
1	15:8	ANGLE<15:8>							
2	23:16	CMD<7:0>							
3	31:24	CMD<15:8>							
4	39:32	SPEED<7:0>							
5	47:40	SPEED<15:8>							
6	55:48	TORQUE							
7	63:56	TMOUT	FLTCAL	FLT2	FLT1	FLTWDC	FLTPWR	OVERRIDE	EN

bit 0-15   **ANGLE:** Steering wheel angle
0x125C = 470° left
0x0001 = 0.1° left
0x0000 = 0.0° center
0xFFFF = 0.1° right
0xEDA4 = 470° right

bit 16-31   **CMD:** Reported steering wheel command
0x125C = 470° left
0x0001 = 0.1° left
0x0000 = 0.0° center
0xFFFF = 0.1° right
0xEDA4 = 470° right

bit 32-47   **SPEED:** Vehicle speed
0 = 0.00 kph
1 = 0.01 kph
65535 = 655.35 kph

bit 48-55   **TORQUE:** Steering column torque
0x7F = 7.9375 Nm
0x01 = 0.0625 Nm
0x00 = 0.0000 Nm
0xFF = -0.0625 Nm
0x80 = -8.0000 Nm

bit 56   **EN:** Enabled
0 = disabled. SCMD ignored.
1 = enabled. No timeouts or overrides have occurred.

bit 57   **OVERRIDE:** Driver Override (Cleared on rising edge of EN bit in command message)
0 = No Override   (|TORQUE| < 3.5 Nm or ignored)
1 = Driver Override (|TORQUE| ≥ 3.5 Nm) (configurable)

bit 58   **FLTPWR:** Power fault: 0 = No fault, 1 = Fault
bit 59   **FLTWDC:** Watchdog Counter fault: 0 = No fault, 1 = Fault
bit 60   **FLT1:** Channel 1 fault: 0 = No fault, 1 = Fault
bit 61   **FLT2:** Channel 2 fault: 0 = No fault, 1 = Fault
bit 62   **FLTCAL:** Calibration fault: 0 = No fault, 1 = Fault
Disconnecting the vehicle battery will cause the production vehicle to lose steering calibration. Drive at least 25 mph for at least 10 seconds in a straight line (see vehicle manual).
bit 63   **TMOUT:** Timeout: 0 = Command is fresh, 1 = Command timeout after 100ms

4.2 Shifting

Note: The steer-by-wire box will not execute shift commands and generate shift report messages if there is an external module on the CAN bus handling shifting.

4.2.1 Command

Message ID: 0x066
Receive Rate: On Event

Table 6: Gear Command CAN Message Description.

Byte	Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	7:0	CLEAR	—	—	—	—	GCMD		

bit 0-2   **GCMD:** Gear Command
                0 = None
                1 = Park
                2 = Reverse
                3 = Neutral
                4 = Drive
                5 = Low
bit 3-6   **Unimplemented:** Set to '0'
bit 7   **CLEAR:** Clear driver override flag
                1 = request clear of driver override
                0 = normal operation

Note: Gear commands will be rejected if OVERRIDE=1 for any of brake/throttle/steering. See the REJECT field on the next page for more information.

4.2.2 Report

Message ID: 0x067
Transmit Rate: 50ms

Table 7: Gear Report CAN Message Description.

Byte	Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	7:0	FLTBUS	CMD			DRIVER	STATE		
1	15:8	READY	—	—	—	—	REJECT		

bit 0-2   **STATE:** Gear State
                    0 = None
                    1 = Park
                    2 = Reverse
                    3 = Neutral
                    4 = Drive
                    5 = Low
bit 3   **DRIVER:** Driver Override
                    0 = Last shift requested by-wire
                    1 = Last shift requested by driver
bit 4-6   **CMD:** Gear Command
                    0 = None
                    1 = Park
                    2 = Reverse
                    3 = Neutral
                    4 = Drive
                    5 = Low
bit 7   **FLTBUS:** CAN bus fault
                    0 = No Fault
                    1 = Fault
bit 8-10   **REJECT:** Gear rejected enumeration
                    0 = Not rejected
                    1 = Shift in progress
                    2 = Override (on brake/throttle/steering)
                    3 = Rotary shifter can't shift to Low
                    4 = Rotary shifter can't shift out of Park
                    5 = Rejected by vehicle (try pressing the brakes)
                    6 = Unsupported
                    7 = Fault
bit 10-14   **Unimplemented:** Set to '0'
bit 15   **READY:** Gear shift ready
                    0 = Not ready for shift command
                    1 = Ready for shift command

4.3 Universal Lat/Lon Controller (ULC)

4.3.1 Command

Message ID: 0x076
Receive Rate: 20ms
Receive Timeout: 100ms

Table 8: ULC Command CAN Message Description.

Byte	Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	7:0	LIN_VEL<7:0>							
1	15:8	LIN_VEL<15:8>							
2	23:16	YAW_CMD<7:0>							
3	31:24	YAW_CMD<15:8>							
4	39:32	—	—	CLEAR	PEDALS	STEER	SHIFT	PARK	CURV
5	47:40	—	—	—	—	—	—	—	—
6	55:48	—	—	—	—	—	—	—	—
7	63:56	—	—	—	—	—	—	—	—

bit 0-15   **LIN_VEL:** Desired vehicle speed
Units: m/s
Resolution: 0.0025 m/s / lsb
Type: int16
Saturated Minimum: 0xF510 = -7 m/s
Saturated Maximum: 0x4650 = 45 m/s

bit 16-31   **YAW_CMD:** Desired steering (yaw rate or curvature, depending on the CURV bit setting)
Units: rad/s if CURV == 0, 1/m if CURV == 1
Resolution: 2.5×10^{-4} rad/s / lsb if CURV == 0, 6.1×10^{-6} 1/m / lsb if CURV == 1
Type: int16
Minimum: 0x8000 (full right turn) = -8.192 rad/s if CURV == 0, -0.1999 1/m if CURV == 1
Maximum: 0x7FFF (full left turn) = 8.1915 rad/s if CURV == 0, 0.1999 1/m if CURV == 1

bit 32   **CURV:** Steering mode switch
0 = Yaw rate mode
1 = Curvature mode

bit 33   **PARK:** Enable shifting out of Park
0 = disable
1 = enable

bit 34   **SHIFT:** Enable control of the shifter
0 = disable
1 = enable

bit 35   **STEER:** Enable control of steering
0 = disable
1 = enable

bit 36   **PEDALS:** Enable control of the brake and throttle pedals to regulate speed
0 = disable
1 = enable

bit 37   **CLEAR:** Clear driver override flag
0 = normal operation
1 = request clear of driver override

bit 38-63   **Unimplemented:** Set to '0'

4.3.2 Configuration

Message ID: 0x077
Receive Rate: 200ms
Receive Timeout: 1000ms

Table 9: ULC Configuration CAN Message Description.

Byte	Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	7:0	LIN_ACCEL<7:0>							
1	15:8	LIN_DECEL<7:0>							
2	23:16	LAT_ACCEL<7:0>							
3	31:24	ANG_ACCEL<7:0>							
4	39:32	—	—	—	—	—	—	—	—
5	47:40	—	—	—	—	—	—	—	—
6	55:48	—	—	—	—	—	—	—	—
7	63:56	—	—	—	—	—	—	—	—

bit 0-7   **LIN_ACCEL:** Maximum linear acceleration
             Units: m/s^2
             Resolution: $0.025 \ m/s^2$ / lsb
             Type: uint8
             Default: 0x00 = Use built-in speed-dependent LUT to limit acceleration
             Saturated Minimum: $0x0C = 0.3 \ m/s^2$
             Saturated Maximum: $0x78 = 3.0 \ m/s^2$

bit 8-15   **LIN_DECEL:** Maximum linear deceleration
             Units: m/s^2
             Resolution: $0.025 \ m/s^2$ / lsb
             Type: uint8
             Default: $0x00 = 1.5 \ m/s^2$
             Saturated Minimum: $0x0C = 0.3 \ m/s^2$
             Saturated Maximum: $0xF0 = 6.0 \ m/s^2$

bit 16-23   **LAT_ACCEL:** Maximum lateral acceleration to limit steering angle
             Units: m/s^2
             Resolution: $0.05 \ m/s^2$ / lsb
             Type: uint8
             Default: $0x00 = 4.0 \ m/s^2$
             Saturated Minimum: $0x14 = 1.0 \ m/s^2$
             Maximum: $0xFF = 12.75 \ m/s^2$

bit 24-31   **ANG_ACCEL:** Maximum angular acceleration to limit steering rate
             Units: rad/s^2
             Resolution: $0.02 \ rad/s^2$ / lsb
             Type: uint8
             Default: $0x00 = 1 \ rad/s^2$
             Saturated Minimum: $0x19 = 0.5 \ rad/s^2$
             Maximum: $0xFF = 5.1 \ rad/s^2$

bit 32-63   **Unimplemented:** Set to '0'

4.3.3 Report

Message ID: 0x078
Transmit Rate: 20ms

Table 10: ULC Report CAN Message Description.

Byte	Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	7:0	SPEED_REF<7:0>							
1	15:8	MODE	PEDALS	TMOUT	SPEED_REF<12:8>				
2	23:16	SPEED_MEAS<7:0>							
3	31:24	CURV	STEER	OVERRIDE	SPEED_MEAS<12:8>				
4	39:32	ACCEL_REF							
5	47:40	ACCEL_MEAS							
6	55:48	—	MAX_ANG						
7	63:56	PRE_SP	PRE_ST	MAX_RATE					

bit 0-12   **SPEED_REF:** Internal speed reference being tracked
               Units: m/s   Resolution: 0.02 m/s / lsb   Type: int16

bit 13   **TMOUT:** Command timeout status
               0 = Command being received
               1 = Command timed out after 100 ms

bit 14   **PEDALS:** Status of throttle and brake signals being sent by the speed control system
               0 = Throttle and brake signals are not being sent
               1 = Throttle and brake signals are being sent

bit 15   **MODE:** Input tracking mode currently active (see ULC User's Guide for details)
               0 = Loose Tracking Mode
               1 = Tight Tracking Mode

bit 16-28   **SPEED_MEAS:** Speed control feedback value
               Units: m/s   Resolution: 0.02 m/s / lsb   Type: int16

bit 29   **OVERRIDE:** Driver override status
               0 = No driver overrides latched
               1 = One or more driver overrides latched

bit 30   **STEER:** Status of steering angle signal being sent by the steering control system
               0 = Steering signals are not being sent
               1 = Steering signals are being sent

bit 31   **CURV:** Steering mode status
               0 = Yaw rate mode
               1 = Curvature mode

bit 32-39   **ACCEL_REF:** Internal acceleration reference being tracked
               Units: m/s^2 Resolution: $0.05\ m/s^2$ / lsb   Type: int8

bit 40-47   **ACCEL_MEAS:** Acceleration control feedback value
               Units: m/s^2 Resolution: $0.05\ m/s^2$ / lsb   Type: int8

bit 48-54   **MAX_ANG:** Maximum allowed steering angle given LAT_ACCEL signal in command
               Units: degrees   Resolution: 5 degrees / lsb   Type: uint8

bit 55   **Unimplemented:** Set to '0'

bit 56-61   **MAX_RATE:** Maximum allowed steering velocity given ANG_ACCEL signal in command
               Units: deg/s   Resolution: 8 deg/s / lsb   Type: uint8

bit 62   **PRE_ST:** Steering preemption status
               0 = Not being preempted
               1 = Steering control would otherwise be active, but is being preempted

bit 63   **PRE_PD:** Pedal preemption status
               0 = Not being preempted
               1 = Speed control would otherwise be sending pedal commands, but is being preempted

4.4 Turn Signal Command

Message ID: 0x068
Receive Rate: 50ms
Receive Timeout: 200ms

Table 11: Turn Signal Command CAN Message Description.

Byte	Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	7:0	—	—	—	—	—	—	TRNCMD	

bit 0-1   **TRNCMD:** Turn Signal Command
           0 = None
           1 = Left
           2 = Right
           3 = Not Used
bit 7-2   **Unimplemented:** Set to '0'

Note: The turn-signal command will be rejected if OVERRIDE=1 for any of brake/throttle/steering. This is silent, there is no signal to report that the command was rejected.

4.5 Miscellaneous Report

Message ID: 0x069
Transmit Rate: 50ms

Table 12: Miscellaneous Report CAN Message Description.

Byte	Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	7:0	WIPER				HIBEAM		TRNSTAT	
1	15:8	RINC	CNCL	RES	OFF	ON	AMBIENT		
2	23:16	FLTBUS	LKAEN	GDEC	GINC	SDEC	SINC	RESCNCL	ONOFF
3	31:24	PABAG	PDECT	TRUNK	HOOD	DOORR	DOORL	DOORP	DOORD
4	39:32	RDEC	LDRHT	LDLFT	LDDWN	LDUP	LDOK	BELTP	BELTD
5	47:40	—	—	—	—	—	—	—	—
6	55:48	—	—	—	—	—	—	—	—
7	63:56	OTEMP							

bit 0-1	**TRNSTAT:** Turn signal status	
	0 = None	
	1 = Left	
	2 = Right	
	3 = Not Used	
bit 2-3	**HIBEAM:** High-beam status (See Table 13)	
bit 4-7	**WIPER:** Wiper status (See Table 14)	
bit 8-10	**AMBIENT:** Ambient light status (See Table 15)	
bit 11	**ON:** ACC on button: 0 = Not pressed, 1 = Pressed	
bit 12	**OFF:** ACC off button: 0 = Not pressed, 1 = Pressed	
bit 13	**RES:** ACC resume button: 0 = Not pressed, 1 = Pressed	
bit 14	**CNCL:** ACC cancel button: 0 = Not pressed, 1 = Pressed	
bit 15	**RINC:** ACC increment resume button: 0 = Not pressed, 1 = Pressed	
bit 16	**ONOFF:** ACC on/off button: 0 = Not pressed, 1 = Pressed	
bit 17	**RESCNCL:** ACC resume/cancel button: 0 = Not pressed, 1 = Pressed	
bit 18	**SINC:** ACC increment set speed button: 0 = Not pressed, 1 = Pressed	
bit 19	**SDEC:** ACC decrement set speed button: 0 = Not pressed, 1 = Pressed	
bit 20	**GINC:** ACC increment following gap button: 0 = Not pressed, 1 = Pressed	
bit 21	**GDEC:** ACC decrement following gap button: 0 = Not pressed, 1 = Pressed	
bit 22	**LKAEN:** Lane Keeping Assist (LKA) on/off button: 0 = Not pressed, 1 = Pressed	
bit 23	**FLTBUS:** CAN bus fault: 0 = No Fault, 1 = Fault	
bit 24	**DOORD:** Driver door, 0 = Closed, 1 = Open	
bit 25	**DOORP:** Passenger door, 0 = Closed, 1 = Open	
bit 26	**DOORL:** Rear left door, 0 = Closed, 1 = Open	
bit 27	**DOORR:** Rear right door, 0 = Closed, 1 = Open	
bit 28	**HOOD:** Hood , 0 = Closed, 1 = Open	
bit 29	**TRUNK:** Trunk, 0 = Closed, 1 = Open	
bit 30	**PDECT:** Passenger detect, 0 = No Passenger, 1 = Passenger	
bit 31	**PABAG:** Passenger airbag, 0 = Disabled, 1 = Enabled	
bit 32	**BELTD:** Driver seat belt, 0 = Unbuckled, 1 = Buckled	
bit 33	**BELTP:** Passenger seat belt, 0 = Unbuckled, 1 = Buckled	

bit 34   **LDOK:** Left D-Pad OK button: 0 = Not pressed, 1 = Pressed
bit 35   **LDUP:** Left D-Pad Up button: 0 = Not pressed, 1 = Pressed
bit 36   **LDDWN:** Left D-Pad Down button: 0 = Not pressed, 1 = Pressed
bit 37   **LDLFT:** Left D-Pad Left button: 0 = Not pressed, 1 = Pressed
bit 38   **LDRHT:** Left D-Pad Right button: 0 = Not pressed, 1 = Pressed
bit 39   **RDEC:** ACC increment resume button: 0 = Not pressed, 1 = Pressed
bit 40-55   **Unimplemented:** Set to '0'
bit 56-63   **OTEMP:** Outside Air Temperature:

0x00 = -40.0 °C
0x5F = -0.5 °C
0x60 = 0.0 °C
0x61 = 0.5 °C
0xFD = 86.5 °C
0xFE = Unknown
0xFF = Invalid

Table 13: Enumeration values of the **HIBEAM** signal

Value	Enum
0	NULL
1	FLASH_TO_PASS
2	HIGH
3	—

Table 14: Enumeration values of the **WIPER** signal

Value	Enum
0	OFF
1	AUTO_OFF
2	OFF_MOVING
3	MANUAL_OFF
4	MANUAL_ON
5	MANUAL_LOW
6	MANUAL_HIGH
7	MIST_FLICK
8	WASH
9	AUTO_LOW
10	AUTO_HIGH
11	COURTESY_WIPE
12	AUTO_ADJUST
13	RESERVED
14	STALLED
15	NO_DATA

Table 15: Enumeration values of the **AMBIENT** signal

Value	Enum
0	DARK
1	LIGHT
2	TWILIGHT
3	TUNNEL_ON
4	TUNNEL_OFF
5	—
6	—
7	NO_DATA

4.6 Wheel Speed

Message ID: 0x06A
Transmit Rate: 10ms

Table 16: Wheel Speed CAN Message Description.

Byte	Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	7:0	FL<7:0>							
1	15:8	FL<15:8>							
2	23:16	FR<7:0>							
3	31:24	FR<15:8>							
4	39:32	RL<7:0>							
5	47:40	RL<15:8>							
6	55:48	RR<7:0>							
7	63:56	RR<15:8>							

bit 0-15 **FL:** Front Left Wheel Speed
0x7FFF = 327.67 rad/s
0x0001 = 0.01 rad/s
0x0000 = 0.00 rad/s
0xFFFF = -0.01 rad/s
0x8000 = -327.68 rad/s

bit 16-31 **FR:** Front Right Wheel Speed
0x7FFF = 327.67 rad/s
0x0001 = 0.01 rad/s
0x0000 = 0.00 rad/s
0xFFFF = -0.01 rad/s
0x8000 = -327.68 rad/s

bit 32-47 **RL:** Rear Left Wheel Speed
0x7FFF = 327.67 rad/s
0x0001 = 0.01 rad/s
0x0000 = 0.00 rad/s
0xFFFF = -0.01 rad/s
0x8000 = -327.68 rad/s

bit 48-63 **RR:** Rear Right Wheel Speed
0x7FFF = 327.67 rad/s
0x0001 = 0.01 rad/s
0x0000 = 0.00 rad/s
0xFFFF = -0.01 rad/s
0x8000 = -327.68 rad/s

4.7   Acceleration

Message ID: 0x06B
Transmit Rate: 10ms

Table 17: Acceleration CAN Message Description.

Byte	Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	7:0	LAT$<$7:0$>$							
1	15:8	LAT$<$15:8$>$							
2	23:16	LONG$<$7:0$>$							
3	31:24	LONG$<$15:8$>$							
4	39:32	VERT$<$7:0$>$							
5	47:40	VERT$<$15:8$>$							

bit 0-15   **LAT:** Lateral acceleration
$0x7FFF = 327.67$ m/s^2
$0x0001 = 0.01$ m/s^2
$0x0000 = 0.00$ m/s^2
$0xFFFF = -0.01$ m/s^2
$0x8000 = -327.68$ m/s^2

bit 16-31   **LONG:** Longitudinal acceleration
$0x7FFF = 327.67$ m/s^2
$0x0001 = 0.01$ m/s^2
$0x0000 = 0.00$ m/s^2
$0xFFFF = -0.01$ m/s^2
$0x8000 = -327.68$ m/s^2

bit 32-47   **VERT:** Vertical acceleration
$0x7FFF = 327.67$ m/s^2
$0x0001 = 0.01$ m/s^2
$0x0000 = 0.00$ m/s^2
$0xFFFF = -0.01$ m/s^2
$0x8000 = -327.68$ m/s^2

4.8   Angular Rates

Message ID: 0x6C
Transmit Rate: 10ms

Table 18: Angular Rates CAN Message Description.

Byte	Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	7:0	ROLL<7:0>							
1	15:8	ROLL<15:8>							
2	23:16	YAW<7:0>							
3	31:24	YAW<15:8>							

bit 0-15   **ROLL:** Roll rate
                0x7FFF = 6.5534 rad/s
                0x0001 = 0.0002 rad/s
                0x0000 = 0.0000 rad/s
                0xFFFF = -0.0002 rad/s
                0x8000 = -6.5536 rad/s
bit 16-31   **YAW:** Yaw rate
                0x7FFF = 6.5534 rad/s
                0x0001 = 0.0002 rad/s
                0x0000 = 0.0000 rad/s
                0xFFFF = -0.0002 rad/s
                0x8000 = -6.5536 rad/s

4.9 GPS 1

Message ID: 0x06D
Transmit Rate: 1000ms

Table 19: GPS1 CAN Message Description.

Byte	Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	7:0	LATITUDE<7:0>							
1	15:8	LATITUDE<15:8>							
2	23:16	LATITUDE<23:16>							
3	31:24	—	LATITUDE<30:24>						
4	39:32	LONGITUDE<7:0>							
5	47:40	LONGITUDE<15:8>							
6	55:48	LONGITUDE<23:16>							
7	63:56	VALID	LONGITUDE<30:24>						

bit 0-30   **LATITUDE:** GPS Latitude
0x3FFFFFFF = 357.913941333 degrees
0x002DC6C0 = 1.00000000 degrees
0x00000001 = 3.3333333e-7 degrees
0x00000000 = 0.000000 degrees
0x7FFFFFFF = -3.3333333e-7 degrees
0xFFD23940 = -1.00000000 degrees
0x40000000 = -357.913941000 degrees

bit 31   **Unimplemented:** Set to '0'

bit 32-62   **LONGITUDE:** GPS Longitude
0x3FFFFFFF = 357.913941333 degrees
0x002DC6C0 = 1.00000000 degrees
0x00000001 = 3.3333333e-7 degrees
0x00000000 = 0.000000 degrees
0x7FFFFFFF = -3.3333333e-7 degrees
0xFFD23940 = -1.00000000 degrees
0x40000000 = -357.913941000 degrees

bit 63   **VALID:**
0 = Invalid, 1 = Valid

4.10   GPS 2

Message ID: 0x06E
Transmit Rate: 1000ms

Table 20: GPS2 CAN Message Description.

Byte	Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	7:0	—	YEAR						
1	15:8	—	—	—	—	MONTH			
2	23:16	—	—	—	DAY				
3	31:24	—	—	—	HOURS				
4	39:32	—	—	MINUTES					
5	47:40	—	—	SECONDS					
6	55:48	—	—	—	—	COMPASS			
7	63:56	—	INF	FLTGPS	PDOP				

bit 0-6   **YEAR:** UTC year (0-99)
bit 7   **Unimplemented:** Set to '0'
bit 8-11   **MONTH:** UTC month (1-12)
bit 12-15   **Unimplemented:** Set to '0'
bit 16-20   **DAY:** UTC day (1-31)
bit 21-23   **Unimplemented:** Set to '0'
bit 24-28   **HOURS:** UTC hours (0-23)
bit 29-31   **Unimplemented:** Set to '0'
bit 32-37   **MINUTES:** UTC minutes (0-59)
bit 38-39   **Unimplemented:** Set to '0'
bit 40-45   **SECONDS:** UTC seconds (0-59)
bit 46-47   **Unimplemented:** Set to '0'
bit 48-51   **COMPASS:** Compass direction
               0 = 0 degrees = North
               1 = 45 degrees = North-East
               2 = 90 degrees = East
               3 = 135 degrees = South-East
               4 = 180 degrees = South
               5 = 225 degrees = South-West
               6 = 270 degrees = West
               7 = 315 degrees = North-West
bit 52:55   **Unimplemented:** Set to '0'
bit 56-60   **PDOP:** GPS PDOP
               0x00 = 0.0
               0x01 = 0.2
               0x1F = 6.2
bit 61   **FLTGPS:** '1' = Fault, '0' = No Fault
bit 62   **INF** '0' = Actual Position, '1' = Inferred Position
bit 63   **Unimplemented:** Set to '0'

4.11 GPS 3

Message ID: 0x06F
Transmit Rate: 1000ms

Table 21: GPS3 CAN Message Description.

Byte	Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	7:0	ALTITUDE<7:0>							
1	15:8	ALTITUDE<15:8>							
2	23:16	HEADING<7:0>							
3	31:24	HEADING<15:8>							
4	39:32	SPEED							
5	47:40	—	—	—	HDOP				
6	55:48	—	—	—	VDOP				
7	63:56	NUMSAT					QUALITY		

bit 0-15   **ALTITUDE:** GPS Altitude
0x7FFF = 8191.75 m
0x0001 = 0.25 m
0x0000 = 0.00 m
0xFFFF = -0.25 m
0x8000 = -8192.00 m

bit 16-31   **HEADING:** GPS Heading
0x0000 = 0.00 degrees
0x0001 = 0.01 degrees
0xFFFF = 655.35 degrees

bit 32-39   **SPEED:** GPS Speed
0x00 = 0 MPH
0x01 = 1 MPH
0xFF = 255 MPH

bit 40-44   **HDOP:** GPS HDOP
0x00 = 0.0
0x01 = 0.2
0x1F = 6.2

bit 45:47   **Unimplemented:** Set to '0'

bit 48-52   **VDOP:** GPS VDOP
0x00 = 0.0
0x01 = 0.2
0x1F = 6.2

bit 53:55   **Unimplemented:** Set to '0'

bit 56-58   **QUALITY:** GPS Fix Quality
0 = No Fix
1 = 2D Fix
2 = 3D Fix

bit 59-63   **NUMSATS:** Number of GPS satellites

4.12 Wheel Position

Message ID: 0x070
Transmit Rate: 20ms

Table 22: Wheel Position CAN Message Description.

Byte	Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	7:0	FL<7:0>							
1	15:8	FL<15:8>							
2	23:16	FR<7:0>							
3	31:24	FR<15:8>							
4	39:32	RL<7:0>							
5	47:40	RL<15:8>							
6	55:48	RR<7:0>							
7	63:56	RR<15:8>							

bit 0-15   **FL:** Front Left Wheel Position Counts
0x7FFF = 32767
0x0001 = 1
0x0000 = 0
0xFFFF = -1
0x8000 = -32768

bit 16-31   **FR:** Front Right Wheel Position Counts
0x7FFF = 32767
0x0001 = 1
0x0000 = 0
0xFFFF = -1
0x8000 = -32768

bit 32-47   **RL:** Rear Left Wheel Position Counts
0x7FFF = 32767
0x0001 = 1
0x0000 = 0
0xFFFF = -1
0x8000 = -32768

bit 48-63   **RR:** Rear Right Wheel Position Counts
0x7FFF = 32767
0x0001 = 1
0x0000 = 0
0xFFFF = -1
0x8000 = -32768

The conversion factor was experimentally determined to be 125.5 counts per revolution. It is recommended to experimentally calculate the conversion factor for a particular vehicle by comparing wheel position counts over time with wheel speeds.

4.13 Tire Pressure

Message ID: 0x071
Transmit Rate: 500ms

Table 23: Tire Pressure CAN Message Description.

Byte	Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	7:0	FL<7:0>							
1	15:8	FL<15:8>							
2	23:16	FR<7:0>							
3	31:24	FR<15:8>							
4	39:32	RL<7:0>							
5	47:40	RL<15:8>							
6	55:48	RR<7:0>							
7	63:56	RR<15:8>							

bit 0-15   **FL:** Front Left Tire Pressure
0 = 0 kPa
1 = 1 kPa
65535 = 65535 kPa
bit 16-31   **FR:** Front Right Tire Pressure
0 = 0 kPa
1 = 1 kPa
65535 = 65535 kPa
bit 32-47   **RL:** Rear Left Tire Pressure
0 = 0 kPa
1 = 1 kPa
65535 = 65535 kPa
bit 48-63   **RR:** Rear Right Tire Pressure
0 = 0 kPa
1 = 1 kPa
65535 = 65535 kPa

4.14 Fuel Level

Message ID: 0x072
Transmit Rate: 100ms

Table 24: Fuel Level CAN Message Description.

Byte	Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	7:0	FUEL<7:0>							
1	15:8	FUEL<15:8>							

bit 0-15   **FUEL:** Fuel Level
0x0398 = 100.0000%
0x0001 = 0.108696%
0x0000 = 0.000000%
0xFFFF = -0.108696%

4.15   Surround

Message ID: 0x073
Transmit Rate: 200ms

Table 25: Surround CAN Message Description.

Byte	Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	7:0	BLISRE	BLISRA	CTARE	CTARA	BLISLE	BLISLA	CTALE	CTALA
1	15:8	SONAR01				SONAR00			
2	23:16	SONAR03				SONAR02			
3	31:24	SONAR05				SONAR04			
4	39:32	SONAR07				SONAR06			
5	47:40	SONAR09				SONAR08			
6	55:48	SONAR11				SONAR10			
7	63:56	FLTSNR	ENSNR	—	—	—	—	—	—

bit 0   **CTALA:** Cross Traffic Alert left alert
               0 = No Alert, 1 = Alert
bit 1   **CTALE:** Cross Traffic Alert left enabled
               0 = Disabled, 1 = Enabled
bit 2   **BLISLA:** Blind Spot Information System left alert
               0 = No Alert, 1 = Alert
bit 3   **BLISLE:** Blind Spot Information System left enabled
               0 = Disabled, 1 = Enabled
bit 4   **CTARA:** Cross Traffic Alert right alert
               0 = No Alert, 1 = Alert
bit 5   **CTARE:** Cross Traffic Alert right enabled
               0 = Disabled, 1 = Enabled
bit 6   **BLISRA:** Blind Spot Information System right alert
               0 = No Alert, 1 = Alert
bit 7   **BLISRE:** Blind Spot Information System right enabled
               0 = Disabled, 1 = Enabled
bit 8-11   **SONAR00:** Sonar front left side
               0x0 = Nothing Detected
               0x1 = 0.30 m
               0x2 = 0.45 m
               0xF = 2.40 m
bit 12-15   **SONAR01:** Sonar front left corner (same as SONAR00)
bit 16-19   **SONAR02:** Sonar front left center (same as SONAR00)
bit 20-23   **SONAR03:** Sonar front right center (same as SONAR00)
bit 24-27   **SONAR04:** Sonar front right corner (same as SONAR00)
bit 28-31   **SONAR05:** Sonar front right side (same as SONAR00)
bit 32-35   **SONAR06:** Sonar rear left side (same as SONAR00)
bit 36-39   **SONAR07:** Sonar rear left corner (same as SONAR00)
bit 40-43   **SONAR08:** Sonar rear left center (same as SONAR00)
bit 44-47   **SONAR09:** Sonar rear right center (same as SONAR00)
bit 48-51   **SONAR10:** Sonar rear right corner (same as SONAR00)
bit 52-55   **SONAR11:** Sonar rear right side (same as SONAR00)
bit 56:61   **Unimplemented:** Set to '0'
bit 62   **ENSNR:** Sonar Enabled
               0 = Disabled, 1 = Enabled
bit 63   **FLTSNR:** Sonar Fault
               0 = No Fault, 1 = Fault

4.16   Brake Info

Message ID: 0x074
Transmit Rate: 20ms

Table 26: BrakeInfo CAN Message Description.

Byte	Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	7:0	BRKTRQR<7:0>							
1	15:8	STATNRY	HSASTAT			BRKTRQR<11:8>			
2	23:16	BRKTRQA<7:0>							
3	31:24	PBRAKE		HSAMODE		BRKTRQA<11:8>			
4	39:32	WHLTRQ<7:0>							
5	47:40	—	—	WHLTRQ<13:8>					
6	55:48	AOG<7:0>							
7	63:56	TRACE	TRACA	STABE	STABA	ABSE	ABSA	AOG<9:8>	

bit 0-11   **BRKTRQR:** Braking Torque Request
                0x000 = 0 Nm
                0x001 = 4 Nm
                0xFFF = 16380 Nm
bit 12-13   **HSASTAT:** Hill Start Assist Status (See Table 27)
bit 14   **STATNRY:** Vehicle Stationary
                0 = Moving, 1 = Stationary
bit 16-27   **BRKTRQA:** Braking Torque Actual
                0x000 = 0 Nm
                0x001 = 4 Nm
                0xFFF = 16380 Nm
bit 28-29   **HSAMODE:** Hill Start Assist Mode (See Table 28)
bit 30-31   **PBRAKE:** Parking Brake Status (See Table 29)
bit 32-45   **WHLTRQ:** Wheel Torque Actual
                0x1FFF = 32764 Nm
                0x0001 = 4 Nm
                0x0000 = 0 Nm
                0x3FFF = -4 Nm
                0x2000 = -32768 Nm
bit 46-47   **Unimplemented:** Set to '0'
bit 48-57   **AOG:** Vehicle Acceleration Over Ground Estimate
                $0x1FF = 17.885 \ m/s^2$
                $0x001 = 0.035 \ m/s^2$
                $0x000 = 0 \ m/s^2$
                $0x3FF = -0.035 \ m/s^2$
                $0x200 = -17.92 \ m/s^2$
bit 58   **ABSA:** ABS Active, 0 = Inactive, 1 = Active
bit 59   **ABSE:** ABS Enabled, 0 = Disabled, 1 = Enabled
bit 60   **STABA:** Stability Control Active, 0 = Inactive, 1 = Active
bit 61   **STABE:** Stability Control Enabled, 0 = Disabled, 1 = Enabled
bit 62   **TRACA:** Traction Control Active, 0 = Inactive, 1 = Active
bit 63   **TRACE:** Traction Control Enabled, 0 = Disabled, 1 = Enabled

Table 27: Enumeration values of the **HSASTAT** signal

Value	Enum
0	INACTIVE
1	FINDING_GRADIENT
2	ACTIVE_PRESSED
3	ACTIVE_RELEASED
4	FAST_RELEASE
5	SLOW_RELEASE
6	FAILED
7	UNDEFINED

Table 28: Enumeration values of the **HSAMODE** signal

Value	Enum
0	OFF
1	AUTO
2	MANUAL
3	UNDEFINED

Table 29: Enumeration values of the **PBRAKE** signal

Value	Enum
0	OFF
1	TRANSITION
2	ON
3	FAULT

4.17   Throttle Info

Message ID: 0x075
Transmit Rate: 10ms

Table 30: ThrottleInfo CAN Message Description.

Byte	Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	7:0	RPM<7:0>							
1	15:8	RPM<15:8>							
2	23:16	APEDPC<7:0>							
3	31:24	—	—	—	—	—	—	APEDPC<9:8>	
4	39:32	APEDRATE							
5	47:40	—	—	—	—	—	—	—	—
6	55:48	—	—	—	—	—	—	—	—
7	63:56	—	—	—	—	—	—	—	—

bit 0-15   **RPM:** Engine RPM
                 0x0000 = 0.00 RPM
                 0x0001 = 0.25 RPM
                 0xFFFF = 16383.75 RPM
bit 16-25   **APEDPC:** Accelerator Pedal Percent
                 0x000 = 0.0 %
                 0x001 = 0.1 %
                 0x3E7 = 99.9 %
bit 26-31   **Unimplemented:** Set to '0'
bit 32-39   **APEDRATE:** Accelerator Pedal Rate
                 0x80 = -5.12 %/ms
                 0xFF = -0.04 %/ms
                 0x00 = 0 %/ms
                 0x01 = 0.04 %/ms
                 0x3F = 5.08 %/ms
bit 40-63   **Unimplemented:** Set to '0'

4.19 License

See the Dataspeed License Manager (DataspeedLM) for more information.
The bits 16-63 in the License CAN message are multiplexed with the MUX field.

MUX	Description
0x00	Feature 'Base' (base functionality)
0x80	MAC Address
0x81	Build Date string (characters 0-5)
0x82	Build Date string (characters 6-9)
0x83	VIN string (characters 0-5)
0x84	VIN string (characters 6-11)
0x85	VIN string (characters 12-16)

4.19.1 Feature: Base

Message ID: 0x07E
Transmit Rate: 250ms

Table 32: License CAN Message Description.

Byte	Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	7:0	MUX							
1	15:8	—	—	—	—	—	EXPIRED	TRIAL	READY
2	23:16	—	—	—	—	—	—	TRIAL	ENABLED
3	31:24	—	—	—	—	—	—	—	—
4	39:32	TRIALS USED<7:0>							
5	47:40	TRIALS USED<15:8>							
6	55:48	TRIALS REMAINING<7:0>							
7	63:56	TRIALS REMAINING<15:8>							

bit 0-7   **MUX:** Multiplexer field, determines representation bits 16-63
             0x00 = Feature: Base
bit 8   **READY:** License Manager ready
             0 = Waiting to resolve VIN
             1 = Ready
bit 9   **TRIAL:** Trial license
             0 = No features licensed as a trial
             1 = One or more features licensed as a trial
bit 9   **EXPIRED:** Expired license
             0 = No feature licenses expired (past firmware build date)
             1 = One or more feature licenses expired (past firmware build date)
bit 10-15   **Unimplemented:** Set to '0'
bit 16   **ENABLED:** Feature enabled
             0 = This feature not licensed
             1 = This feature successfully licensed
bit 17   **TRIAL:** Feature trial
             0 = This feature not licensed as a trial
             1 = This feature licensed as a trial (regardless of remaining trial counts)
bit 18-31   **Unimplemented:** Set to '0'
bit 32-47   **TRIALS USED:** Number of trial counts used for this feature
bit 48-63   **TRIALS REMAINING:** Number of trial counts remaining for this feature

4.19.2 MAC Address

Message ID: 0x07E
Transmit Rate: 250ms

Table 33: License CAN Message Description.

Byte	Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	7:0	MUX							
1	15:8	—	—	—	—	—	EXPIRED	TRIAL	READY
2	23:16	MAC0							
3	31:24	MAC1							
4	39:32	MAC2							
5	47:40	MAC3							
6	55:48	MAC4							
7	63:56	MAC5							

bit 0-7   **MUX:** Multiplexer field, determines representation bits 16-63
              0x80 = MAC Address
bit 8   **READY:** License Manager ready
              0 = Waiting to resolve VIN
              1 = Ready
bit 9   **TRIAL:** Trial license
              0 = No features licensed as a trial
              1 = One or more features licensed as a trial
bit 9   **EXPIRED:** Expired license
              0 = No feature licenses expired (past firmware build date)
              1 = One or more feature licenses expired (past firmware build date)
bit 10-15   **Unimplemented:** Set to '0'
bit 16-23   **MAC0:** MAC Address byte 0
bit 24-31   **MAC1:** MAC Address byte 1
bit 32-39   **MAC2:** MAC Address byte 2
bit 40-47   **MAC3:** MAC Address byte 3
bit 48-55   **MAC4:** MAC Address byte 4
bit 56-63   **MAC5:** MAC Address byte 5

4.19.3 Build Date (part 0)

Message ID: 0x07E
Transmit Rate: 250ms

Table 34: License CAN Message Description.

Byte	Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	7:0	MUX							
1	15:8	—	—	—	—	—	EXPIRED	TRIAL	READY
2	23:16	DATE0							
3	31:24	DATE1							
4	39:32	DATE2							
5	47:40	DATE3							
6	55:48	DATE4							
7	63:56	DATE5							

bit 0-7   **MUX:** Multiplexer field, determines representation bits 16-63
             0x81 = Date part 0
bit 8   **READY:** License Manager ready
             0 = Waiting to resolve VIN
             1 = Ready
bit 9   **TRIAL:** Trial license
             0 = No features licensed as a trial
             1 = One or more features licensed as a trial
bit 9   **EXPIRED:** Expired license
             0 = No feature licenses expired (past firmware build date)
             1 = One or more feature licenses expired (past firmware build date)
bit 10-15   **Unimplemented:** Set to '0'
bit 16-23   **DATE0:** Date string (character 0)
bit 24-31   **DATE1:** Date string (character 1)
bit 32-39   **DATE2:** Date string (character 2)
bit 40-47   **DATE3:** Date string (character 3)
bit 48-55   **DATE4:** Date string (character 4)
bit 56-63   **DATE5:** Date string (character 5)

4.19.4 Build Date (part 1)

Message ID: 0x07E
Transmit Rate: 250ms

Table 35: License CAN Message Description.

Byte	Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	7:0	MUX							
1	15:8	—	—	—	—	—	EXPIRED	TRIAL	READY
2	23:16	DATE6							
3	31:24	DATE7							
4	39:32	DATE8							
5	47:40	DATE9							
6	55:48	—	—	—	—	—	—	—	—
7	63:56	—	—	—	—	—	—	—	—

bit 0-7   **MUX:** Multiplexer field, determines representation bits 16-63
             0x82 = Date part 1
bit 8   **READY:** License Manager ready
             0 = Waiting to resolve VIN
             1 = Ready
bit 9   **TRIAL:** Trial license
             0 = No features licensed as a trial
             1 = One or more features licensed as a trial
bit 9   **EXPIRED:** Expired license
             0 = No feature licenses expired (past firmware build date)
             1 = One or more feature licenses expired (past firmware build date)
bit 10-15   **Unimplemented:** Set to '0'
bit 16-23   **DATE6:** Date string (character 6)
bit 24-31   **DATE7:** Date string (character 7)
bit 32-39   **DATE8:** Date string (character 8)
bit 40-47   **DATE9:** Date string (character 9)
bit 48-63   **Unimplemented:** Set to '0'

4.19.5 VIN (part 0)

Message ID: 0x07E
Transmit Rate: 250ms

Table 36: License CAN Message Description.

Byte	Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	7:0	MUX							
1	15:8	—	—	—	—	—	EXPIRED	TRIAL	READY
2	23:16	VIN00							
3	31:24	VIN01							
4	39:32	VIN02							
5	47:40	VIN03							
6	55:48	VIN04							
7	63:56	VIN05							

bit 0-7   **MUX:** Multiplexer field, determines representation bits 16-63
              0x83 = VIN part 0
bit 8   **READY:** License Manager ready
              0 = Waiting to resolve VIN
              1 = Ready
bit 9   **TRIAL:** Trial license
              0 = No features licensed as a trial
              1 = One or more features licensed as a trial
bit 9   **EXPIRED:** Expired license
              0 = No feature licenses expired (past firmware build date)
              1 = One or more feature licenses expired (past firmware build date)
bit 10-15   **Unimplemented:** Set to '0'
bit 16-23   **VIN00:** VIN string (character 0)
bit 24-31   **VIN01:** VIN string (character 1)
bit 32-39   **VIN02:** VIN string (character 2)
bit 40-47   **VIN03:** VIN string (character 3)
bit 48-55   **VIN04:** VIN string (character 4)
bit 56-63   **VIN05:** VIN string (character 5)

4.19.6 VIN (part 1)

Message ID: 0x07E
Transmit Rate: 250ms

Table 37: License CAN Message Description.

Byte	Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	7:0	MUX							
1	15:8	—	—	—	—	—	EXPIRED	TRIAL	READY
2	23:16	VIN06							
3	31:24	VIN07							
4	39:32	VIN08							
5	47:40	VIN09							
6	55:48	VIN10							
7	63:56	VIN11							

bit 0-7   **MUX:** Multiplexer field, determines representation bits 16-63
             0x84 = VIN part 1
bit 8   **READY:** License Manager ready
             0 = Waiting to resolve VIN
             1 = Ready
bit 9   **TRIAL:** Trial license
             0 = No features licensed as a trial
             1 = One or more features licensed as a trial
bit 9   **EXPIRED:** Expired license
             0 = No feature licenses expired (past firmware build date)
             1 = One or more feature licenses expired (past firmware build date)
bit 10-15   **Unimplemented:** Set to '0'
bit 16-23   **VIN06:** VIN string (character 6)
bit 24-31   **VIN07:** VIN string (character 7)
bit 32-39   **VIN08:** VIN string (character 8)
bit 40-47   **VIN09:** VIN string (character 9)
bit 48-55   **VIN10:** VIN string (character 10)
bit 56-63   **VIN11:** VIN string (character 11)

4.19.7 VIN (part 2)

Message ID: 0x07E
Transmit Rate: 250ms

Table 38: License CAN Message Description.

Byte	Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	7:0	MUX							
1	15:8	—	—	—	—	—	EXPIRED	TRIAL	READY
2	23:16	VIN12							
3	31:24	VIN13							
4	39:32	VIN14							
5	47:40	VIN15							
6	55:48	VIN16							
7	63:56	—	—	—	—	—	—	—	—

bit 0-7   **MUX:** Multiplexer field, determines representation bits 16-63
              0x85 = VIN part 2
bit 8   **READY:** License Manager ready
              0 = Waiting to resolve VIN
              1 = Ready
bit 9   **TRIAL:** Trial license
              0 = No features licensed as a trial
              1 = One or more features licensed as a trial
bit 9   **EXPIRED:** Expired license
              0 = No feature licenses expired (past firmware build date)
              1 = One or more feature licenses expired (past firmware build date)
bit 10-15   **Unimplemented:** Set to '0'
bit 16-23   **VIN12:** VIN string (character 12)
bit 24-31   **VIN13:** VIN string (character 13)
bit 32-39   **VIN14:** VIN string (character 14)
bit 40-47   **VIN15:** VIN string (character 15)
bit 48-55   **VIN16:** VIN string (character 16)
bit 56-63   **Unimplemented:** Set to '0'

4.20 Version

Message ID: 0x07F
Transmit Rate: 1000ms

Table 39: Version CAN Message Description.

Byte	Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	7:0	MODULE							
1	15:8	PLATFORM							
2	23:16	MAJOR<7:0>							
3	31:24	MAJOR<15:8>							
4	39:32	MINOR<7:0>							
5	47:40	MINOR<15:8>							
6	55:48	BUILD<7:0>							
7	63:56	BUILD<15:8>							

bit 0-7   **MODULE:** Module enumeration
           0x03 = Steering Module
           Other = Ignore, not this module
bit 8-15   **PLATFORM:** Vehicle platform enumeration
           0x00 = FORD_CD4
           Other = Ignore, not this vehicle platform
bit 16-31 **MAJOR:** Firmware version major increment
bit 32-47 **MINOR:** Firmware version minor increment
bit 48-63 **BUILD:** Firmware version build increment

5   Function

- **Modifying the Steering Signals:** The by-wire interface modifies the steering signals when power is applied and the required CAN messages are received. The vehicle steering system will function regardless of the CAN messaging and applied power to the by-wire interface.

- **Power-off State:** Without power applied, the hardware passes signals through unaltered.

- **Disabled State:** In the disabled state, steering signals are not modified. This corresponds to EN = 0. The by-wire interface does not respond to any SCMD until the enable bit (EN) is set to 1.

- **Power-up State:** The by-wire interface powers up in the disabled state. EN = 0.

- **Watchdog Timer:** If the by-wire interface does not receive a steering command message within 100ms, the by-wire interface enters the disabled state.

- **Driver Override (Steering):** If the system senses torque on the steering wheel from the driver, control is given to the driver by entering the driver override state. This corresponds to OVERRIDE = 1 and EN = 0 in the CAN steering report message. This can be cleared by toggling EN from 0 to 1, or by setting CLEAR to 1 in the CAN steering command message.

- **Driver Override (Shifting):** If the driver requests a shift, this is reported in the CAN shifting report message with DRIVER = 1. This is automatically cleared on the next by-wire shift request, but can also be cleared by setting CLEAR to 1 in the CAN shifting command message.

- **Audible Warning:** The steering module simultaneously activates the front and rear parking proximity warning chimes for one second to indicate an unintentional transition from computer control back to manual control. This is defined as a transition of the EN bit from 1 to 0 in any of the report messages for brake/throttle/steering/shifting, without a corresponding transition in the command message. An unintentional transition could be caused by an override, timeout, fault, or any other unexpected behavior. The brake and throttle report messages are received on the CAN bus from the external throttle/brake module.

6   Supported Vehicles

The Steering By-Wire interface has been tested on the Ford Fusion for model years 2013-2019, Ford Mondeo 2013-2019, and Lincoln MKZ 2013-2019.

The Ford Fusion has limitations on gear shifting if an external shift-by-wire module is not present. See section 4.2 for more details.

The Ford Mondeo uses a mechanical shift lever, and therefore will not actuate by-wire. The Ford Mondeo will only report the gear status.

7 Watchdog Counter

The watchdog counter is an optional feature enabled by incrementing the COUNT bits to assist in compliance with California autonomous vehicle requirements. This is separate from the 100ms watchdog timeout always present for each command message. Each module monitors its own state and the state of all other modules for error conditions. To clear a watchdog counter event, press the OK button on the left side of the steering wheel or cycle power to all modules.

7.1 Fault Conditions

- Count is not incremented, or count is incremented more than 3 (this allows up to 2 dropped messages)
- Command timeout after 100ms (catches main computer crash, power loss, or disconnect)
- Report timeout after 100ms (catches failure of embedded firmware)
- Transition from enabled to disabled (catches unexpected transfer of control to the driver)
  - This fault condition can be disabled with the DbwConfig GUI.
- Vehicle must be out of park or moving for any of these conditions to set off an alert

7.2 Fault Actions

- Normal driver override audible and visual alert for one second (sets off the front park aid warning)
- Apply small amount of braking until the driver takes control with the brake pedal, throttle pedal, but not the steering wheel. The applied braking value is 0.25, which corresponds to approximately 925 Nm of braking torque. The braking value can be changed with the DbwConfig GUI.
- Flash the passenger airbag ON and OFF lights until the alert is cleared to show that the watchdog is faulted
- All commands to all subsystems are ignored until the alert is cleared

APPENDIX A: REVISION HISTORY

Revision A-01 (August 2015)
Modifications:

1. Initial release of this document.

Revision A-02 (October 2015)
Modifications:

1. Added GPS, suspension height, tire pressure, and fuel level CAN messages.
2. Added product image.

Revision A-03 (December 2015)
Modifications:

1. Added steering velocity.

Revision A-04 (March 2016)
Modifications:

1. Clarified FLTCON bit and CD pins.
2. Added FLTCAL bit for steering calibration fault.
3. Removed suspension message.
4. Added doors and seat belts to Miscellaneous report.
5. Added Surround message (sonars, BLIS, and CTA).
6. Added Brake Info message.

Revision A-05 (April 2016)
Modifications:

1. Added IGNORE bit to optionally ignore driver override and periodically try and regain steering control.
2. Changed DRIVER bit to DRIVER and OVERRIDE bits (activity and enough activity for an override).
3. Added additional steering wheel buttons.
4. Added optional watchdog counter.

Revision A-06 (August 2016)
Modifications:

1. Corrected FLTSNR and ENSNR bits in surround CAN message.
2. Added Throttle Info CAN message.

Revision A-07 (November 2016)
Modifications:

1. Added QUIET bit in steering command CAN message.
2. Added version CAN message.

Revision A-08 (December 2016)
Modifications:

1. Changed wheel speeds to signed values.

Revision A-09 (August 2017)
Modifications:

1. Added license CAN message (with VIN).
2. Added steering wheel left D-Pad buttons.
3. Added Watchdog Counter applied braking value.
4. Added threshold for driver override bit in steering report.
5. Added rejected enumeration in gear report.
6. Removed driver activity bit in steering report.
7. Replaced FLTCON bit with TMOUT bit (timeout).
8. Replaced Suspension Report with Wheel Position Report.
9. Updated supported vehicle model year range to 2017.

Revision A-10 (October 2017)
Modifications:

1. Added notes about gear shift and turn-signal command rejection when an override is active.

Revision A-11 (October 2017)
Modifications:

1. Added note about requirements to engage steering.

Revision A-12 (January 2018)
Modifications:

1. Added FLTPWR bit to steering report.
2. Added wheel position conversion factor.
3. Updated audible warning to include all unintentional transitions to disabled.
4. Updated supported vehicle model year range to 2018.

Revision A-13 (June 2018)
Modifications:

1. Added RES+ and RES- cruise control buttons to miscellaneous report (RINC and RDEC).

Revision A-14 (August 2018)
Modifications:

1. Added PLATFORM field to version message.

Revision A-15 (October 2018)
Modifications:

1. Added OTEMP to miscellaneous report.
2. Updated supported vehicle model year range to 2019.
3. Removed vehicle requirement of Active Park Assist (APA). Modern firmware automatically enables APA if not already enabled.

Revision A-16 (November 2018)
Modifications:

1. Added ULC messages.

2. Added notes about parameters (overrides and watchdog counter).

3. Added mechanical drawing.

4. Updated product photo.

Revision A-17 (March 2019)
Modifications:

1. Fixed CAN termination resistance that was mistakenly changed to false.