
Drive-by-wire in the Polaris GEM

Features

- Computer control of braking
- Computer control of steering
- Computer control of shifting
- Driver override by grabbing the steering wheel
- Driver override by pressing the brake pedal
- CAN and USB interfaces
- Manual control on power off

Applications

- Driverless car research

Description

The Dataspeed Inc. Drive-By-Wire interface enables computer control of the brake/throttle/steering/shifting in a safe and effective manner.

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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/Power Connector

The CAN/Power connector is used for power and CAN communication.

Table 1: CAN/Power connector pin description.

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

1.2 Ethernet Connector

The Ethernet connector is unused at this time.

- **1 meter cable:** [09482612749010](#).
- **2 meter cable:** [09482612749020](#).
- **3 meter cable:** [09482612749030](#).

1.3 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
VIGNITION ON	9	12	32	V	
VIGNITION OFF	-0.3	0	2	V	
VPOWER	9	12	30	V	
IPOWER		200		mA	VPOWER=12V, VIGNITION>9V
IPOWER			0.1	mA	VPOWER=12V, VIGNITION<2V
Temperature	-40		+85	°C	

3 Mechanical Drawings

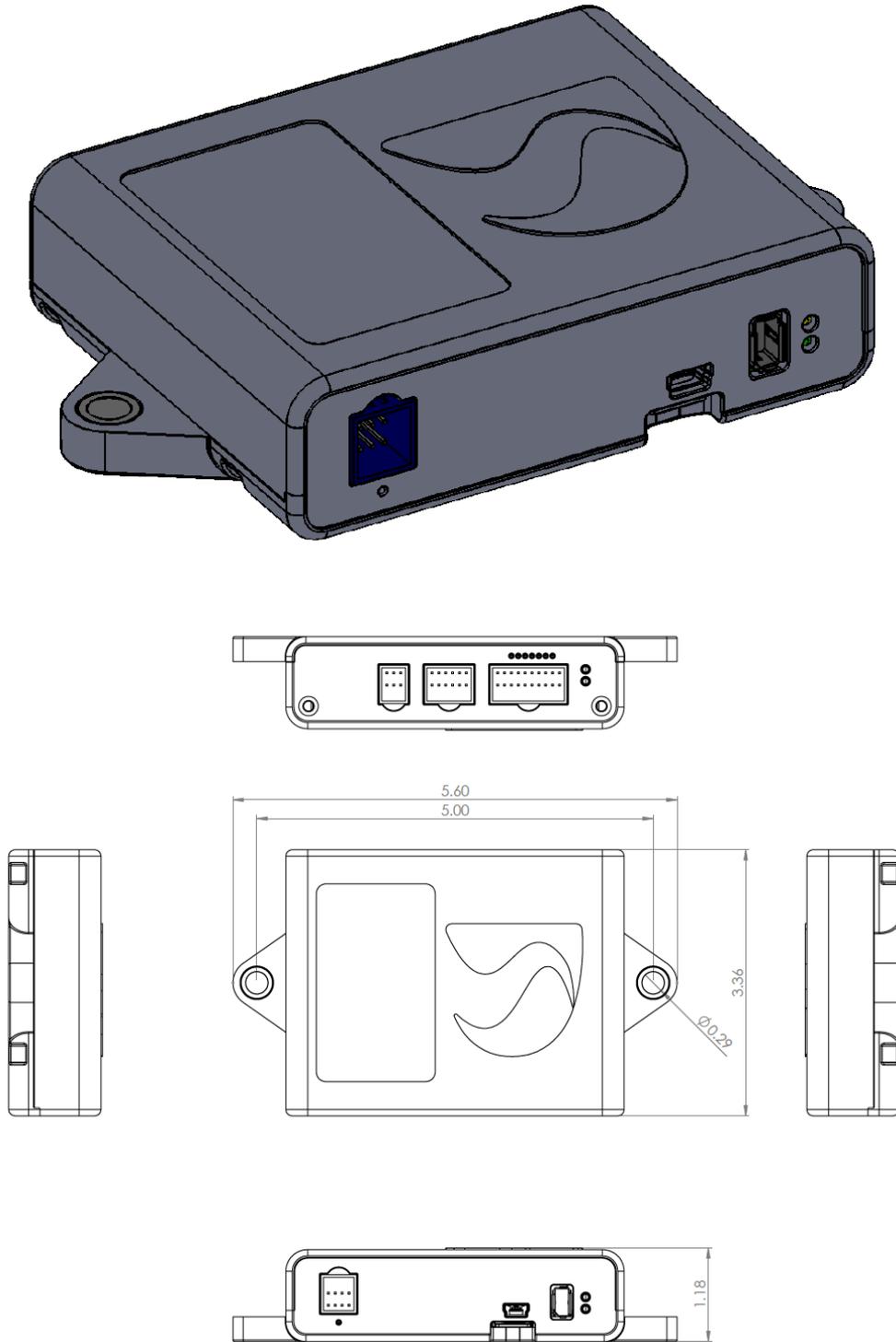


Figure 1: Mechanical Drawing

4 CAN Messages

Table 3: CAN bus configuration.

Parameter	Value	Units
Terminated	Yes	120 Ω
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 Brake

4.1.1 Command

Message ID: 0x060
 Receive Rate: 20ms
 Receive Timeout: 100ms

Table 4: Brake 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	PCMD<7:0>							
1	15:8	PCMD<15:8>							
2	23:16	CMD_TYPE				—	—	—	—
3	31:24	RES1	—	—	—	—	IGNORE	CLEAR	EN
4	39:32	—	—	—	—	—	—	—	—
5	47:40	—	—	—	—	—	—	—	—
6	55:48	—	—	—	—	—	—	—	—
7	63:56	COUNT							

bit 0-15 **PCMD:** Pedal Command
 Percent (CMD_TYPE = 2):
 0x0000 = 0%
 0xFFFF = 100%
 Torque Mode (CMD_TYPE = 3 or 4):
 0x0000 = 0 N-m
 0x0001 = 1 N-m
 0xFFFF = 65535 N-m

bit 16-19 **Unimplemented:** Set to '0'

bit 20-23 **CMD_TYPE:** Command Type
 0 = NONE
 1 = not implemented on this platform
 2 = PERCENT (percent of maximum torque)
 3 = TORQUE (integer open-loop braking torque)
 4 = TORQUE_RQ (integer closed-loop braking torque)
 5 = not implemented on this platform
 6 = not implemented on this platform

bit 24 **EN:** Enable request
 0 = disable
 1 = enable

bit 25 **CLEAR:** Clear driver override flag
 0 = normal operation
 1 = request clear of driver override

bit 26 **IGNORE:** Ignore driver override
 0 = normal
 1 = ignore

bit 27-30 **Unimplemented:** Set to '0'

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

bit 32-55 **Unimplemented:** Set to '0'

bit 56-63 **COUNT:** Optional watchdog counter

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4.1.2 Report

Message ID: 0x061
 Transmit Rate: 20ms

Table 5: Brake 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	PI<7:0>								
1	15:8	PI<15:8>								
2	23:16	PC<7:0>								
3	31:24	PC<15:8>								
4	39:32	PO<7:0>								
5	47:40	PO<15:8>								
6	55:48	WDCSRC				WDCBRK		—	—	BTYPE
7	63:56	TMOUT	FLTPWR	FLT2	FLT1	FLTWDC	DRIVER	OVERRIDE	EN	

- bit 0-15 **PI:** Pedal Input from the physical pedal
 0 = 0 Nm
 1 = 1 Nm
- bit 16-31 **PC:** Pedal Command from the command message
 0 = 0 Nm
 1 = 1 Nm
- bit 32-47 **PO:** Pedal Output to the vehicle
 0 = 0 Nm
 1 = 1 Nm
- bit 48 **BTYPE:** Brake type is set to '1', otherwise the message was not generated by this module
- bit 49-50 **Unimplemented:** Set to '0'
- bit 51 **WDCBRK:** Watchdog counter is applying brakes
- bit 52-55 **WDCSRC:** Watchdog counter source (See Table 23)
- bit 56 **EN:** Enabled
 0 = disabled. PCMD 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 (PI ≤ 1000Nm, or IGNORE == 1)
 1 = Driver Override (PI > 1000Nm for 100ms) (configurable)
- bit 58 **DRIVER:** Driver Activity
 0 = No Activity (PI ≤ 50Nm)
 1 = Driver Activity (PI > 50Nm for 20ms)
- 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 **FLTPWR:** Power fault: 0 = No fault, 1 = Fault
- bit 63 **TMOUT:** Timeout
 0 = Command is fresh
 1 = Command timeout after 100ms

4.2 Steering

4.2.1 Command

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

Table 6: 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	CMD_TYPE	—	RES1	QUIET	CAL	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
 Angle Mode (CMD_TYPE = 0): **Torque Mode** (CMD_TYPE = 1):
 0x1770 = 600° left 0x1E00 = 60.0 Nm left
 0x0001 = 0.1° left 0x0001 = 0.0078125 Nm left
 0x0000 = 0.0° center 0x0000 = 0.0 Nm
 0xFFFF = 0.1° right 0xFFFF = -0.0078125 Nm right
 0xE890 = 600° right 0xE200 = -60.0 Nm right

bit 16 **EN:** Enable request
 0 = disable
 1 = enable

bit 17 **CLEAR:** Clear driver override flag
 0 = normal operation
 1 = request clear of driver override

bit 18 **IGNORE:** Ignore driver override
 0 = normal
 1 = ignore

bit 19 **CAL:** Calibrate angle sensor
 0 = no action
 1 = set angle measurement to value in SCMD

bit 20 **QUIET:** Disable driver override audible warning
 0 = normal
 1 = disable

bit 21 **RESERVED:** Set to '0'

bit 22 **Unimplemented:** Set to '0'

bit 23 **CMD_TYPE:** Steering command type
 0 = angle
 1 = torque

bit 24-31 **SVEL:** Steering Velocity
 0x00 = 0°/s = 500°/s
 0x01 = 4°/s
 0x02 = 8°/s
 0xFA = 1000°/s

bit 32-55 **Unimplemented:** Set to '0'

bit 56-63 **COUNT:** Optional watchdog counter

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4.2.2 Report

Message ID: 0x065
 Transmit Rate: 20ms

Table 7: 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	TMODE	CMD<14:8>						
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
 0x1770 = 600° left
 0x0001 = 0.1° left
 0x0000 = 0.0° center
 0xFFFF = 0.1° right
 0xE890 = 600° right
 0x8000 = Unknown
- bit 16-30 **CMD:** Reported steering wheel command
Angle Mode (TMODE = 0): **Torque Mode** (TMODE = 1):
 0x1770 = 600° left 0x1E00 = 60.0 Nm left
 0x0001 = 0.1° left 0x0001 = 0.0078125 Nm left
 0x0000 = 0.0° center 0x0000 = 0.0 Nm
 0x7FFF = 0.1° right 0x7FFF = -0.0078125 Nm right
 0x6890 = 600° right 0x6200 = -60.0 Nm right
 0x4000 = Unknown 0x4000 = Unknown
- bit 31 **TMODE:** Steering torque mode: 0 = angle, 1 = torque
- bit 32-47 **SPEED:** Vehicle speed
 0x0000 = 0.00 kph
 0x0001 = 0.01 kph
 0xFFFFE = 655.34 kph
 0xFFFF = Unknown
- bit 48-55 **TORQUE:** Steering column torque
 0x7F = 7.9375 Nm
 0x01 = 0.0625 Nm
 0x00 = 0.0000 Nm
 0xFF = -0.0625 Nm
 0x81 = -7.9375 Nm
 0x80 = Unknown
- 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| < 4.5 Nm, or IGNORE == 1)
 1 = Driver Override (|TORQUE| ≥ 4.5 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

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- bit 62 **FLTCAL:** Calibration fault: 0 = No fault, 1 = Fault, see CAL bit in steering command message to recalibrate.
- bit 63 **TMOUT:** Timeout: 0 = Command is fresh, 1 = Command timeout after 100ms

4.3 Shifting

4.3.1 Command

Message ID: 0x066
Receive Rate: On Event

Table 8: 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	RES1	—	—	—	GCMD		

bit 0-2 **GCMD:** Gear Command

0 = None
2 = Reverse
3 = Neutral
4 = Drive

bit 3-5 **Unimplemented:** Set to '0'

bit 6 **RESERVED:** Set to '0'

bit 7 **CLEAR:** Clear driver override flag

0 = normal operation
1 = request clear of driver override

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.

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4.3.2 Report

Message ID: 0x067
Transmit Rate: 50ms

Table 9: 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
 2 = Reverse
 3 = Neutral
 4 = Drive
- 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
 2 = Reverse
 3 = Neutral
 4 = Drive
- 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 = Manually shift to neutral before auto-shift
 4 = RESERVED
 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

4.4 Acceleration

Message ID: 0x06B
 Transmit Rate: 10ms

Table 10: 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/s²
 0x0001 = 0.01 m/s²
 0x0000 = 0.00 m/s²
 0xFFFF = -0.01 m/s²
 0x8001 = -327.67 m/s²
 0x8000 = Unknown

bit 16-31 **LONG:** Longitudinal acceleration
 0x7FFF = 327.67 m/s²
 0x0001 = 0.01 m/s²
 0x0000 = 0.00 m/s²
 0xFFFF = -0.01 m/s²
 0x8001 = -327.67 m/s²
 0x8000 = Unknown

bit 32-47 **VERT:** Vertical acceleration
 0x7FFF = 327.67 m/s²
 0x0001 = 0.01 m/s²
 0x0000 = 0.00 m/s²
 0xFFFF = -0.01 m/s²
 0x8001 = -327.67 m/s²
 0x8000 = Unknown

4.5 Angular Rates

Message ID: 0x06C
 Transmit Rate: 10ms

Table 11: 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>							
4	39:32	PITCH<7:0>							
5	47:40	PITCH<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
 0x8001 = -6.5534 rad/s
 0x8000 = Unknown

bit 16-31 **YAW:** Pitch rate
 0x7FFF = 6.5534 rad/s
 0x0001 = 0.0002 rad/s
 0x0000 = 0.0000 rad/s
 0xFFFF = -0.0002 rad/s
 0x8001 = -6.5534 rad/s
 0x8000 = Unknown

bit 32-47 **PIATCH:** Yaw rate
 0x7FFF = 6.5534 rad/s
 0x0001 = 0.0002 rad/s
 0x0000 = 0.0000 rad/s
 0xFFFF = -0.0002 rad/s
 0x8001 = -6.5534 rad/s
 0x8000 = Unknown

4.6 Universal Lat/Lon Controller (ULC)

4.6.1 Command

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

Table 12: 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)

CURV: spec:	0	1
Units	rads/sec	1/m
Resolution	2.5×10^{-4}	6.1×10^{-6}
Type	int16	int16
Min = 0x8000 (full right)	-8.192	-0.1999
Max = 0x7FFF (full left)	8.1915	0.1999

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'

4.6.2 Configuration

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

Table 13: 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/s²
 Resolution: 0.025 m/s² / lsb
 Type: uint8
 Default: 0x00 = Use built-in speed-dependent LUT to limit acceleration
 Saturated Minimum: 0x0C = 0.3 m/s²
 Saturated Maximum: 0x78 = 3.0 m/s²

bit 8-15 **LIN_DECEL:** Maximum linear deceleration Units: m/s²
 Resolution: 0.025 m/s² / lsb
 Type: uint8
 Default: 0x00 = 1.5 m/s²
 Saturated Minimum: 0x0C = 0.3 m/s²
 Saturated Maximum: 0xF0 = 6.0 m/s²

bit 16-23 **LAT_ACCEL:** Maximum lateral acceleration to limit steering angle
 Units: m/s²
 Resolution: 0.05 m/s² / lsb
 Type: uint8 Default: 0x00 = 4.0 m/s²
 Saturated Minimum: 0x14 = 1.0 m/s²
 Maximum: 0xFF = 12.75 m/s²

bit 24-31 **ANG_ACCEL:** Maximum angular acceleration to limit steering rate
 Units: rad/s²
 Resolution: 0.02 rad/s² / lsb
 Type: uint8 Default: 0x00 = 1 rad/s²
 Saturated Minimum: 0x19 = 0.5 rad/s² Maximum: 0xFF = 5.1 rad/s²

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

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4.6.3 Report

Message ID: 0x078
 Transmit Rate: 20ms

Table 14: 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/s² Resolution: 0.05 m/s² / lsb Type: int8
- bit 40-47 **ACCEL_MEAS:** Acceleration control feedback value
 Units: m/s² Resolution: 0.05 m/s² / 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

4.7 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)

4.7.1 Feature: Base

Message ID: 0x07E
Transmit Rate: 250ms

Table 15: 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

4.7.2 MAC Address

Message ID: 0x07E
 Transmit Rate: 250ms

Table 16: 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

4.7.3 Build Date (part 0)

Message ID: 0x07E
 Transmit Rate: 250ms

Table 17: 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)

4.7.4 Build Date (part 1)

Message ID: 0x07E
 Transmit Rate: 250ms

Table 18: 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'

4.7.5 VIN (part 0)

Message ID: 0x07E
 Transmit Rate: 250ms

Table 19: 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)

4.7.6 VIN (part 1)

Message ID: 0x07E
 Transmit Rate: 250ms

Table 20: 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)

4.7.7 VIN (part 2)

Message ID: 0x07E
 Transmit Rate: 250ms

Table 21: 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'

4.8 Version

Message ID: 0x07F
 Transmit Rate: 1000ms

Table 22: 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 = CAN Gateway Module
 Other = Ignore, not this module

bit 8-15 **PLATFORM:** Vehicle platform enumeration
 0x80 = POLARIS_GEM
 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 Calibration

- **Steering Wheel Angle:** The user must provide the steering wheel angle calibration. Send a steering command CAN message with the CAL bit set and the desired value in the SCMD field. This value will update the SteeringCalOffset parameter and set the SteeringCal to true. The calibration is stored in flash, persists across firmware updates, and only needs to be done one time.
- **Brake Pedal Positions:** The drive-by-wire module automatically moves the brake pedal to record the correlation between brake pedal position and brake pressure. The process takes approximately one minute. This happens automatically when the vehicle speed is zero, the vehicle is in park, and the throttle pedal is not pressed. The calibration is stored in flash, persists across firmware updates, and only needs to be done one time. The calibration can be cleared to trigger a new calibration with the BrakeCalClear parameter.

6 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.

7 Supported Vehicles

The Drive-By-Wire Gateway interface has been tested on the Polaris GEM e2 for model years 2016-2020.

8 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.

8.1 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

8.2 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 1000 Nm. 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

8.3 Fault Source Enumeration

Table 23: Enumeration values of the **WDCSRC** signal

Value	Enum	Description
0	NONE	None
1	OTHER_BRAKE	Determined by brake module
2	OTHER_THROTTLE	Determined by throttle module
3	OTHER_STEERING	Determined by steering module
4	BRAKE_COUNTER	Brake command counter failed to increment (user error)
5	BRAKE_DISABLED	Brake module disabled without override when in gear or moving
6	BRAKE_COMMAND	Brake command timeout (CAN bus overload or user error)
7	BRAKE_REPORT	Brake report timeout (CAN bus overload or module failure)
8	THROTTLE_COUNTER	Throttle command counter failed to increment (user error)
9	THROTTLE_DISABLED	Throttle module disabled without override when in gear or moving
10	THROTTLE_COMMAND	Throttle command timeout (CAN bus overload or user error)
11	THROTTLE_REPORT	Throttle report timeout (CAN bus overload or module failure)
12	STEERING_COUNTER	Steering command counter failed to increment (user error)
13	STEERING_DISABLED	Steering module disabled without override when in gear or moving
14	STEERING_COMMAND	Steering command timeout (CAN bus overload or user error)
15	STEERING_REPORT	Steering report timeout (CAN bus overload or module failure)

APPENDIX A: REVISION HISTORY

Revision A-01 (August 2020)

Modifications:

1. Initial release of this document.

Revision A-02 (November 2020)

Modifications:

1. Added IMU messages (accel/gyro).
2. Added reserved bit in steering and gear command messages.
3. Added calibration section.