

# Polaris GEM Throttle-By-Wire

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## Throttle by-wire in the Polaris GEM

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### Features

- Computer control of throttle and brake
- Measure throttle and brake pedal positions
- Driver override by pressing either pedal
- 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. Brake-Throttle Combination By-Wire interface enables computer control of the braking and throttle systems 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 throttle and brake systems.



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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/DB9 Connector

The CAN/DB9 connectors are used for power and CAN communication. The two connectors have the same pin descriptions. Connecting either of the CAN/DB9 connectors will provide power and CAN to both the throttle and brake. Power from both connectors is merged with a diode OR circuit, so power on each connector does not need to be the same voltage. The digital inputs on the two connectors are separate. 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	GND	Ground
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
VIGNITION ON	9	12	16	V	
VIGNITION OFF	-0.3	0	2	V	
VPOWER	9	12	16	V	
IPower		125	300	mA	VPOWER=12V, VIGNITION>9V
IPower			0.2	mA	VPOWER=12V, VIGNITION<2V
Temperature	-40		+85	°C	

## 3 Mechanical Drawings

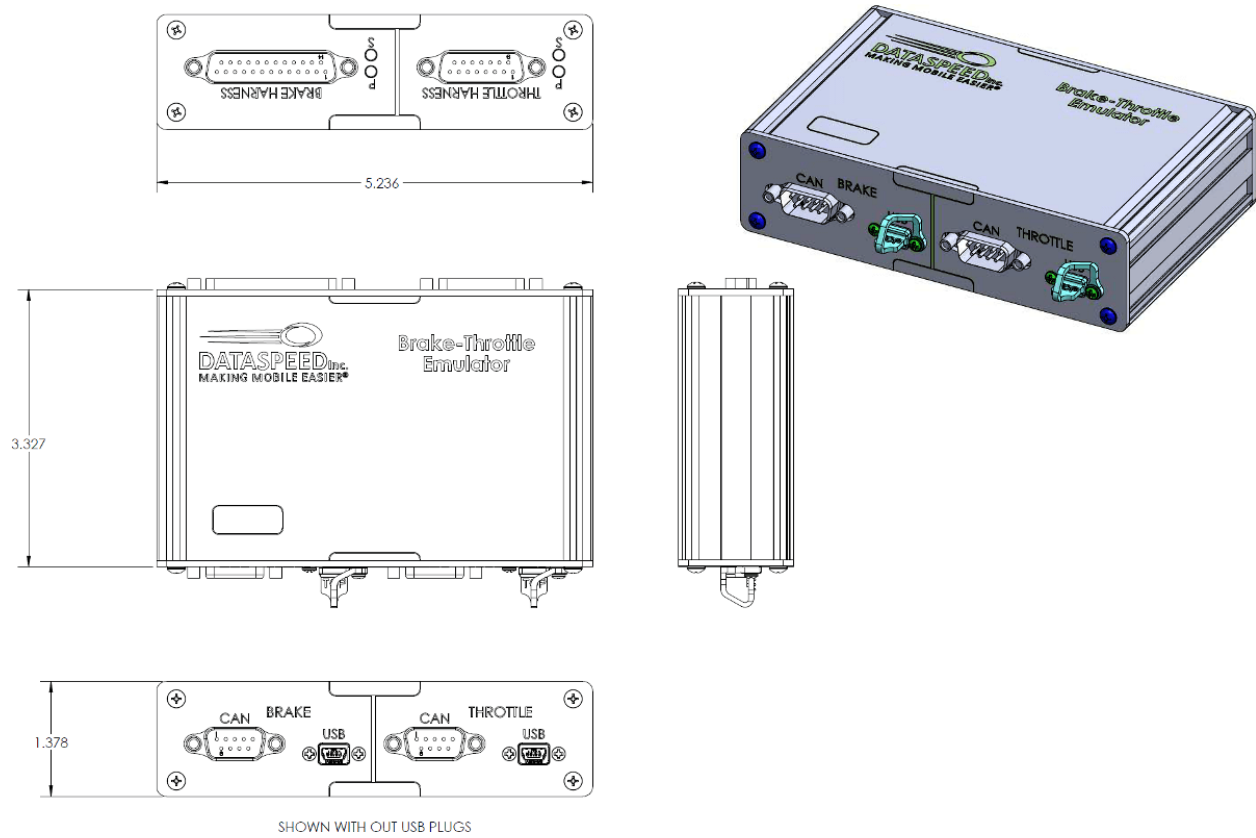


Figure 1: Mechanical Drawing

## 4 CAN Messages

Table 3: CAN bus configuration.

Parameter	Value	Units
Terminated	No	
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	$t_q$

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## 4.1 Throttle

### 4.1.1 Command

Message ID: 0x062  
Receive Rate: 20ms  
Receive Timeout: 100ms

Table 4: Throttle 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	RES2	—	—	—	IGNORE	CLEAR	EN
4	39:32	—	—	—	—	—	—	—	—
5	47:40	—	—	—	—	—	—	—	—
6	55:48	—	—	—	—	—	—	—	—
7	63:56	COUNT							

bit 0-15      **PCMD:** Pedal Command<sup>1</sup>  
                 0x0000 = 0%  
                 0xFFFF = 100%

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

bit 20-23     **CMD\_TYPE:** Command Type  
                 0 = NONE  
                 1 = PEDAL (raw pedal position)  
                 2 = PERCENT (percent of maximum throttle)

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 27-29     **Unimplemented:** Set to '0'

bit 30        **RESERVED:** Set to '0'

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

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

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

<sup>1</sup> Ramp limited to 20% per 20ms

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## 4.1.2 Report

Message ID: 0x063  
Transmit Rate: 20ms

Table 5: Throttle 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				—	—	—	—
7	63:56	TMOUT	FLTPWR	FLT2	FLT1	FLTWDC	DRIVER	OVERRIDE	EN

bit 0-15      **PI:** Pedal Input from the physical pedal  
                  0x0000 = 0%  
                  0xFFFF = 100%

bit 16-31     **PC:** Pedal Command from the command message  
                  0x0000 = 0%  
                  0xFFFF = 100%

bit 32-47     **PO:** Pedal Output is the maximum of PI and PC  
                  0x0000 = 0%  
                  0xFFFF = 100%

bit 48-51     **Unimplemented:** Set to '0'

bit 52-55     **WDCSRC:** Watchdog counter source (See Table 7)

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 ≤ 30%, or IGNORE == 1)  
                  1 = Driver Override (PI > 30% for 100ms) (configurable)

bit 58        **DRIVER:** Driver Activity  
                  0 = No Activity    (PI ≤ 18%)  
                  1 = Driver Activity (PI > 18% 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

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## 4.2 Version

Message ID: 0x07F  
Transmit Rate: 1000ms

Table 6: 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  
              0x02 = Throttle 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 Function

- **Modifying the Pedal Signals:** The pedal emulator hardware enables adding to the amount requested by each pedal, but not subtracting. The physical pedal will function normally regardless of the CAN messaging and applied power.
- **Power-off State:** Without power applied, the hardware passes each pedal signal through unaltered.
- **Disabled State:** In the disabled state, the emulator passes the pedal input to the output. This corresponds to PCMD = 0 or EN = 0. The emulator does not respond to any PCMD until the enable bit (EN) is set to 1.
- **Power-up State:** The emulator powers up in the disabled state. PCMD = 0 and EN = 0.
- **Watchdog Timer:** If the emulator does not receive a command message within 100ms, the emulator enters the disabled state.
- **Driver Override:** If the driver presses either pedal, both pedals enter the driver override state. This corresponds to OVERRIDE = 1 and EN = 0 in the CAN report messages. If the pedals are enabled when the driver presses either pedal, the driver override state is latched. This can be cleared by toggling EN from 0 to 1 in the CAN command messages. The driver override state can also be cleared by setting the CLEAR bit to 1 in either CAN command message.

## 6 Supported Vehicles

The Brake-Throttle Combination By-Wire interface has been tested on the Polaris GEM e2 for model years 2016-2020.

## 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 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

### 7.3 Fault Source Enumeration

Table 7: 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. Add RES2 bit in throttle command message.