

# Throttle-Brake Combination By-Wire

## Throttle and brake by-wire in the Ford Fusion and Lincoln MKZ Hybrid vehicles

### 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. Throttle-Brake Combination By-Wire interface enables computer control of the throttle and braking 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 are merged with a diode OR circuit, so power on each connector does not need to be the same voltage. Optionally short both CD pins together.

Table 1: CAN/DB9 connector pin description.

| Pin | Symbol   | Description      |
|-----|----------|------------------|
| 1   | CD       | Connector Detect |
| 2   | CANL     | CAN Low          |
| 3   | GND      | Ground           |
| 4   | IGNITION | Ignition (12V)   |
| 5   | NC       | No Connect       |
| 6   | CD       | Connector Detect |
| 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   |
|---------------------------|------|-----|-----|-------|--|
| V <sub>IGNITION ON</sub>  | 9    | 12  | 16  | V     |  |
| V <sub>IGNITION OFF</sub> | -0.3 | 0   | 2   | V     |  |
| V <sub>POWER</sub>        | 9    | 12  | 16  | V     |  |
| I <sub>POWER</sub>        |      | 125 | 300 | mA    | V <sub>POWER</sub> =12V, V <sub>IGNITION</sub> >9V |
| I <sub>POWER</sub>        |      |     | 0.2 | mA    | V <sub>POWER</sub> =12V, V <sub>IGNITION</sub> <2V |
| Temperature               | -40  |     | +85 | °C    |  |

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## 3 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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## 3.1 Brake

### 3.1.1 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 | —          | —     | —     | —     | —     | —      | —     | BCMD  |
| 3    | 31:24 | —          | —     | —     | —     | —     | 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>  
65535 = 100%  
0 = 0%

bit 16        **BCMD:** BOO Command<sup>23</sup>  
1 = on  
0 = off

bit 17-23     **Unimplemented:** Set to '0'

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

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

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

bit 27-55     **Unimplemented:** Set to '0'

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

<sup>1</sup>Ramp limited to 40% per 20ms

<sup>2</sup>Changes limited to 150ms from the last change

<sup>3</sup>Brake On Off (BOO), turn on brake lights, enable shift out of park, and cancel cruise control

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## 3.1.2 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 | BI     | BC       | BO    |
| 7    | 63:56 | TMOUT    | FLTPWR | FLT2  | FLT1  | FLTWDC | DRIVER | OVERRIDE | EN    |

bit 0-15      **PI:** Pedal Input from the physical pedal  
65535 = 100%  
0 = 0%

bit 16-31    **PC:** Pedal Command from the command message  
65535 = 100%  
0 = 0%

bit 32-47    **PO:** Pedal Output is the maximum of PI and PC  
65535 = 100%  
0 = 0%

bit 48       **BI:** BOO Input from the physical pedal<sup>1</sup>  
1 = on, 0 = off

bit 49       **BC:** BOO Command from the command message<sup>1</sup>  
1 = on, 0 = off

bit 50       **BO:** BOO Output is the maximum of BI and BC<sup>1</sup>  
1 = on, 0 = off

bit 51       **WDCBRK:** Watchdog counter is applying brakes

bit 52-55    **WDCSRC:** Watchdog counter source (See Table 9)

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 ≤ 22% or ignored)  
1 = Driver Override (PI > 22% for 100ms)

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

<sup>1</sup> Brake On Off (BOO), turn on brake lights, enable shift out of park, and cancel cruise control

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## 3.2 Throttle

### 3.2.1 Command

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

Table 6: 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 | —          | —     | —     | —     | —     | —      | —     | —     |
| 3    | 31:24 | —          | —     | —     | —     | —     | 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>  
65535 = 100%  
0 = 0%

bit 16-23    **Unimplemented:** Set to '0'

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

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

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

bit 27-55    **Unimplemented:** Set to '0'

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

<sup>1</sup>Ramp limited to 40% per 20ms

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## 3.2.2 Report

Message ID: 0x063  
Transmit Rate: 20ms

Table 7: 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  
65535 = 100%  
0 = 0%

bit 16-31    **PC:** Pedal Command from the command message  
65535 = 100%  
0 = 0%

bit 32-47    **PO:** Pedal Output is the maximum of PI and PC  
65535 = 100%  
0 = 0%

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

bit 52-55    **WDCSRC:** Watchdog counter source (See Table 9)

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 ignored)  
1 = Driver Override (PI > 30% for 100ms)

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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## 3.3 Version

Message ID: 0x07F  
Transmit Rate: 1000ms

Table 8: 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  | —           | —     | —     | —     | —     | —     | —     | —     |
| 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  
             0x01 = Brake module  
             0x02 = Throttle module  
             Other = Ignore, not this module  
  
bit 8-15     **Unimplemented:** Set to '0'  
bit 16-31    **MAJOR:** Firmware version major increment  
bit 32-47    **MINOR:** Firmware version minor increment  
bit 48-63    **BUILD:** Firmware version build increment

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## 4 Function

- **Modifying the Throttle Signal:** 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.

## 5 Supported Vehicles

The Throttle-Brake Combination By-Wire interface has been tested on the Ford Fusion for model years 2013-2018, and Lincoln MKZ 2013-2018. The hybrid model is required for the brake to function.

## 6 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.

### 6.1 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)
- Vehicle must be out of park or moving for any of these conditions to set off an alert

### 6.2 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 925 Nm of braking torque.
- 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

### 6.3 Fault Source Enumeration

Table 9: 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 (July 2015)

#### Modifications:

1. Initial release of this document.

### Revision A-02 (August 2015)

#### Modifications:

1. Added CLEAR bit for clearing of driver override.

### Revision A-03 (December 2015)

#### Modifications:

1. Added IGNORE bit to ignore driver override on throttle only.

### Revision A-04 (March 2016)

#### Modifications:

1. Clarified FLTCON bit and CD pins.

### Revision A-05 (April 2016)

#### Modifications:

1. Added IGNORE for brake. Previously this was only available for throttle.
2. Changed DRIVER bit to DRIVER and OVERRIDE bits (activity and enough activity for an override).
3. Added optional watchdog counter.

### Revision A-06 (November 2016)

#### Modifications:

1. Added version CAN message.

### Revision A-07 (December 2016)

#### Modifications:

1. Added footnotes about pedal command ramp limits.

### Revision A-08 (August 2017)

#### Modifications:

1. Added Watchdog Counter applied braking value.
2. Added thresholds for driver override and driver activity bits in brake/throttle reports.
3. Replaced FLTCON bit with TMOUT bit (timeout).
4. Updated supported vehicle model year range to 2017.

### Revision A-09 (January 2018)

#### Modifications:

1. Added FLTPWR bit to throttle report.
2. Replaced FLTBOO with FLTPWR bit in brake report.
3. Updated supported vehicle model year range to 2018.