



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.



Throttle-Brake Combination By-Wire

Contents

1	Connector Pin Description	3
1.1	CAN/DB9 Connector	3
1.2	USB Connector	3
2	Electrical Characteristics	3
3	CAN Messages	4
3.1	Brake	5
3.1.1	Command	5
3.1.2	Report	6
3.2	Throttle	7
3.2.1	Command	7
3.2.2	Report	8
3.3	Version	9
4	Function	10
5	Supported Vehicles	10
6	Watchdog Counter	11
6.1	Fault Conditions	11
6.2	Fault Actions	11
6.3	Fault Source Enumeration	11

Throttle-Brake Combination By-Wire

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 _{IGNITION ON}	9	12	16	V	
V _{IGNITION OFF}	-0.3	0	2	V	
V _{POWER}	9	12	16	V	
I _{POWER}		125	300	mA	V _{POWER} =12V, V _{IGNITION} >9V
I _{POWER}			0.2	mA	V _{POWER} =12V, V _{IGNITION} <2V
Temperature	-40		+85	°C	

Throttle-Brake Combination By-Wire

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

Throttle-Brake Combination By-Wire

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	CMD_TYPE				—	—	ABOO	BCMD
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 Command¹
65535 = 100%
0 = 0%

bit 16 **BCMD:** BOO Command²³
1 = on
0 = off

bit 17 **ABOO:** Auto BOO (Automatically set BOO from PCMD)
1 = on
0 = off

bit 18-19 **Unimplemented:** Set to '0'

bit 20-23 **CMD_TYPE:** Command Type
0 = NONE
1 = PEDAL (raw pedal position)
2 = PERCENT (percent of maximum torque)
3 = TORQUE (integer open-loop braking torque)
4 = TORQUE_RQ⁴ (integer closed-loop braking torque)

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

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

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

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

¹Ramp limited to 40% per 20ms

²Changes limited to 150ms from the last change

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

⁴The BRKTRQR field in the BrakelInfo CAN message from the steering module is the feedback for closed-loop control

Throttle-Brake Combination By-Wire

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 pedal¹
1 = on, 0 = off
- bit 49 **BC:** BOO Command from the command message¹
1 = on, 0 = off
- bit 50 **BO:** BOO Output is the maximum of BI and BC¹
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

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

Throttle-Brake Combination By-Wire

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	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 Command¹
65535 = 100%
0 = 0%

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

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

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

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

¹Ramp limited to 40% per 20ms

Throttle-Brake Combination By-Wire

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

Throttle-Brake Combination By-Wire

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	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
 0x01 = Brake module
 0x02 = Throttle 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

Throttle-Brake Combination By-Wire

4 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.

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.

Throttle-Brake Combination By-Wire

Revision A-10 (August 2018)

Modifications:

1. Added ABOO bit to brake command.
2. Added RESERVED bit to brake and throttle commands.
3. Added CMD_TYPE to brake and throttle commands.
4. Added PLATFORM field to version message.