

# Ford Transit Connect Steer-By-Wire

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## Steering by-wire in the Ford Transit Connect

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### 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.



# Ford Transit Connect Steer-By-Wire

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## Contents

<b>1</b>	<b>Connector Pin Description</b>	<b>3</b>
1.1	CAN/Power Connector . . . . .	3
1.2	USB Connector . . . . .	3
<b>2</b>	<b>Electrical Characteristics</b>	<b>3</b>
<b>3</b>	<b>Mechanical Drawings</b>	<b>4</b>
<b>4</b>	<b>CAN Messages</b>	<b>5</b>
4.1	Steering . . . . .	6
4.1.1	Command . . . . .	6
4.1.2	Report . . . . .	7
4.2	Version . . . . .	9
<b>5</b>	<b>Function</b>	<b>10</b>
<b>6</b>	<b>Supported Vehicles</b>	<b>10</b>
<b>7</b>	<b>Watchdog Counter</b>	<b>11</b>
7.1	Fault Conditions . . . . .	11
7.2	Fault Actions . . . . .	11

# Ford Transit Connect Steer-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/Power Connector

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

Table 1: CAN/DB9 connector pin description.

Pin	Symbol	Description
1	POWER	Power (12V)
2	GND	Ground
3	DBW-CANH	Drive-By-Wire CAN High
4	DBW-CANL	Drive-By-Wire CAN Low
5	IGNITION	Ignition (12V)
6	GND	Ground
7	VEH-CANH	Vehicle CAN High
8	VEH-CANL	Vehicle CAN Low

### 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		50		mA	VPOWER=12V, VIGNITION>9V
IPOWER			0.1	mA	VPOWER=12V, VIGNITION<2V
Temperature	-40		+85	°C	

# Ford Transit Connect Steer-By-Wire

## 3 Mechanical Drawings

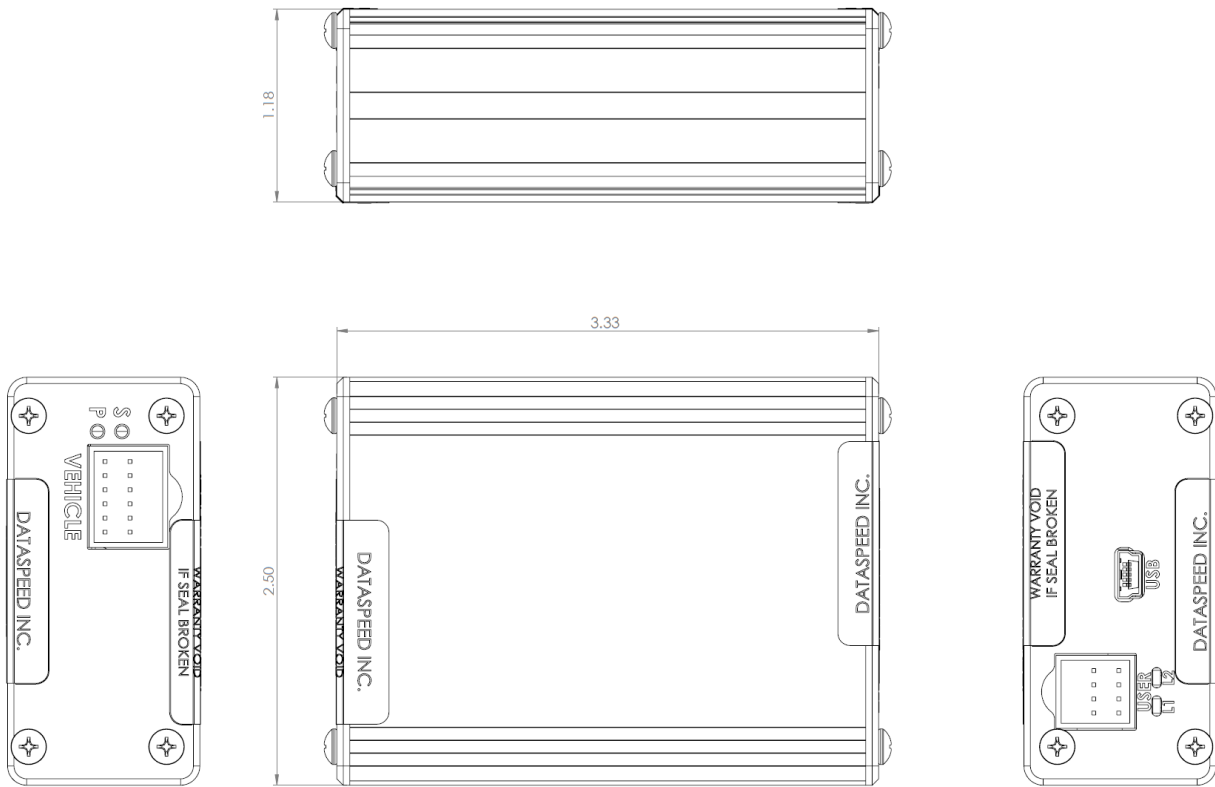


Figure 1: Mechanical Drawing

## 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	$t_q$

# Ford Transit Connect Steer-By-Wire

## 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	CMD_TYPE	—	—	QUIET	—	IGNORE	CLEAR	EN
3	31:24	SVEL							
4	39:32	—	—	—	—	—	—	—	—
5	47:40	—	—	—	—	—	—	—	—
6	55:48	—	—	—	—	—	—	—	—
7	63:56	COUNT							

bit 0-15	<b>SCMD:</b> Steering Command
	<b>Angle Mode</b> (CMD_TYPE = 0):
	0x12C0 = 480° left
	0x0001 = 0.1° left
	0x0000 = 0.0° center
	0xFFFF = 0.1° right
	<b>Torque Mode</b> (CMD_TYPE = 1):
	0x0400 = 8.0 Nm left
	0x0001 = 0.0078125 Nm left
	0x0000 = 0.0 Nm
	0xFFFF = -0.0078125 Nm right
	0xFC00 = -8.0 Nm right
bit 16	<b>EN:</b> Enable request 0 = disable 1 = enable
bit 17	<b>CLEAR:</b> Clear driver override flag 0 = normal operation 1 = request clear of driver override
bit 18	<b>IGNORE:</b> Ignore driver override 0 = normal 1 = ignore
bit 19	<b>Unimplemented:</b> Set to '0'
bit 20	<b>QUIET:</b> Disable driver override audible warning 0 = normal 1 = disable
bit 21-22	<b>Unimplemented:</b> Set to '0'
bit 23	<b>CMD_TYPE:</b> Steering command type 0 = angle 1 = torque
bit 24-31	<b>SVEL:</b> Steering Velocity 0x00 = 0°/s = 500°/s 0x01 = 4°/s 0x02 = 8°/s 0xFA = 1000°/s
bit 32-55	<b>Unimplemented:</b> Set to '0'
bit 56-63	<b>COUNT:</b> Optional watchdog counter

# Ford Transit Connect Steer-By-Wire

## 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	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  
                  0x12C0 = 480° left  
                  0x0001 = 0.1° left  
                  0x0000 = 0.0° center  
                  0xFFFF = 0.1° right  
                  0xED40 = 480° right  
                  0x8000 Unknown

bit 16-30      **CMD:** Reported steering wheel command  
                  **Angle Mode** (TMODE = 0):      **Torque Mode** (TMODE = 1):  
                  0x12C0 = 480° left      0x0400 = 8.0 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  
                  0x6D40 = 480° right      0x7C00 = -8.0 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  
                  0xFFFF = 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| < 6.0 Nm, or IGNORE == 1)  
                  1 = Driver Override (|TORQUE| ≥ 6.0 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

# Ford Transit Connect Steer-By-Wire

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- 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



# Ford Transit Connect Steer-By-Wire

## 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  
                 0x07 = EPS Steering Module  
                 Other = Ignore, not this module

bit 8-15     **PLATFORM:** Vehicle platform enumeration  
                 0x02 = FORD\_C1  
                 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.

## 6 Supported Vehicles

The Steering By-Wire interface has been tested on the Ford Transit Connect for model year 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 1 m/s<sup>2</sup>. 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-00 (May 2019)

Modifications:

1. Initial release of this document.

### Revision A-01 (February 2020)

Modifications:

1. Added enumeration for "unknown" for many signals.
2. Updated supported vehicle model year range to 2020.
3. Updated Dataspeed logo.

### Revision A-02 (August 2020)

Modifications:

1. Increased torque override threshold.