Technical White Paper

Automotive qualified electromagnetic compliant 3.3V CAN FD transceivers

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ABSTRACT

Modern-day automobiles perform a plethora of functions to improve vehicle safety, performance and comfort. From powertrain to advanced driver assistance systems (ADAS), from body electronics and lighting to infotainment and safety, a large number of electronic control units (ECUs) deployed in vehicles perform these electromechanical functions. ECUs exchange control and data-log information through in-vehicle network buses. Among Controller Area Network (CAN), Local Interconnect Network (LIN), FlexRay and Ethernet, the CAN bus remains the most popular choice given its ease of use, good common-mode noise rejection, priority-based messaging, bitwise arbitration to handle bus contention, and error detection and recovery.

Until now, almost all CAN transceivers deployed in vehicles are based on 5V driver/receiver supply. This is because the CAN physical layer ISO11898-2:2024 and CAN component level electromagnetic compliance (EMC) standard IEC62228-3 provides specifications and pass/fail limits only for 5V supplied CAN transceivers. There are sub-systems which need 5V power rail only for the CAN transceiver. A 3.3V supplied CAN transceiver can simplify power stage design of ECU’s by eliminating 5V rail needed, while being fully interoperable with 5V CAN transceivers on same network bus and meeting strict automotive EMC requirements. This article introduces Texas Instruments TCAN3403-Q1 and TCAN3404-Q1, the industry’s first automotive qualified and EMC certified 3.3V CAN FD transceivers.

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1 Introduction

With the electrification of vehicles happening at a rapid pace, multiple ECU's are deployed all through the vehicle. These sub-systems talk to each other via CAN network.

Figure 1-1 shows a CAN network.

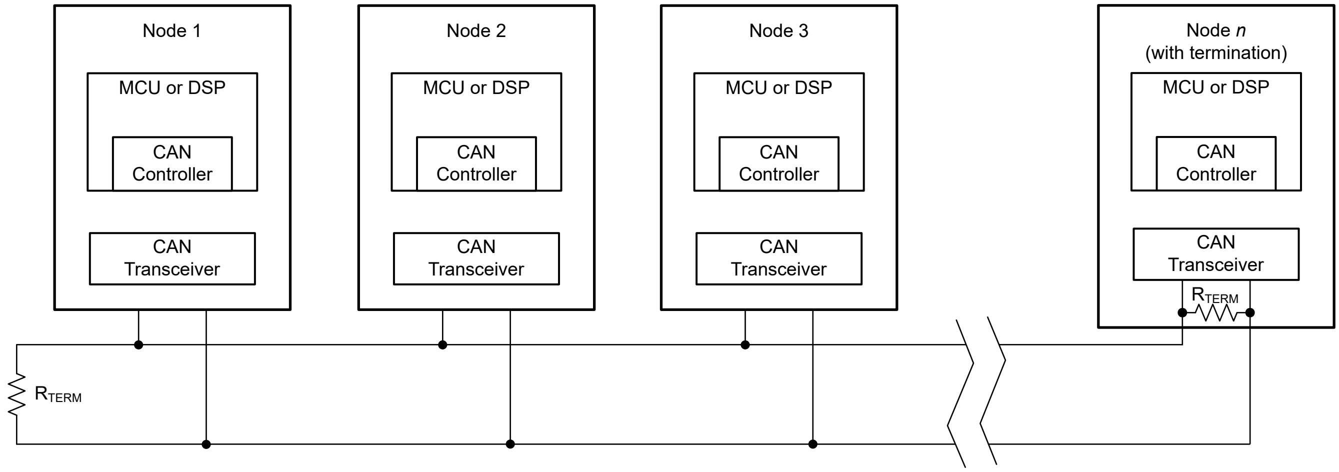

Figure 1-1. Typical CAN Network

Each CAN node consists of at least three components: a CAN transceiver, a microcontroller (MCU) or microprocessor (MPU) with embedded CAN protocol controller and power device (DC-DC converter or Linear regulator) that converts automotive battery voltage to 5V. Additionally, in case the MCU/MPU I/O voltage is 3.3V, separate 3.3V power device is used on ECU PCB. Figure 1-2 shows a simplified schematic.

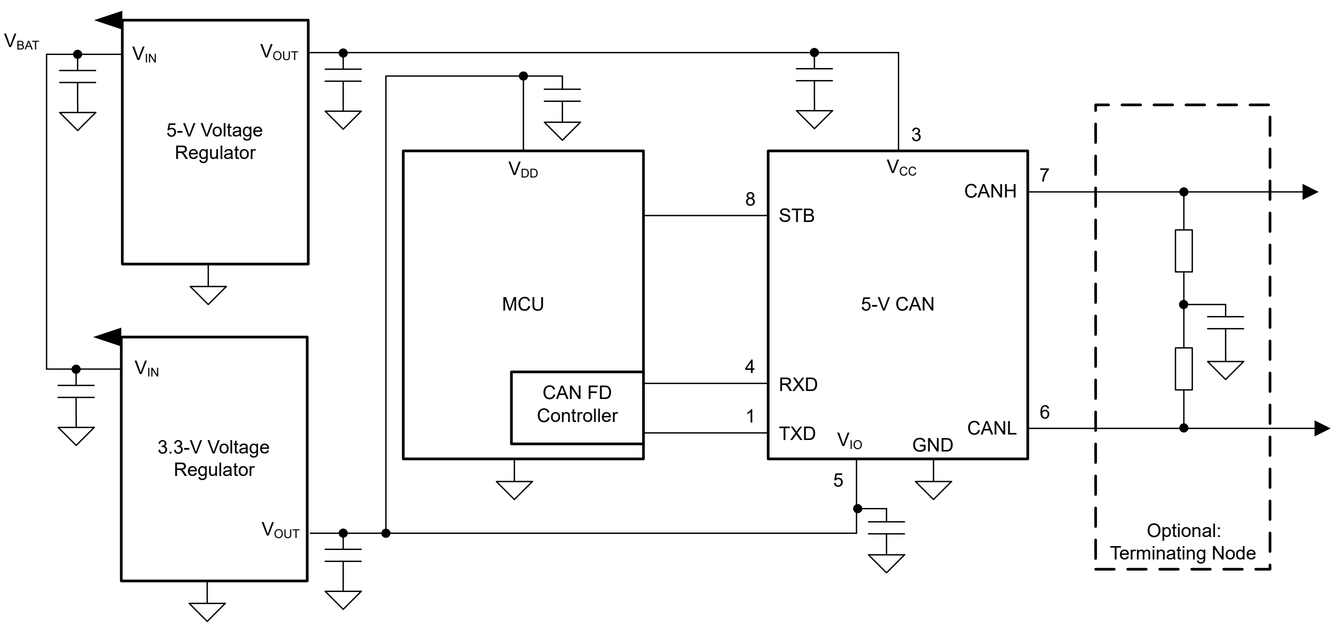

Figure 1-2. Application Schematic of a 5V CAN Transceiver

Typical CAN bus signals consist of dominant and recessive phases. CAN driver produces differential signal of at least 1.5V across a 60Ω load during the dominant phase, whereas the driver weakly biases the bus to common mode 2.5V level during the recessive phase. This signaling is designed for bitwise arbitration and device with highest priority ID (CAN frame Identification field with most dominant bits) takes control of the bus since dominant (strong drive) is able to overcome recessive (weak biasing). The receiving nodes monitor CANH-CANL differential signal and are able to decode the CAN message, as long as the signal is above 900mV (dominant threshold) or below 500mV (recessive threshold).

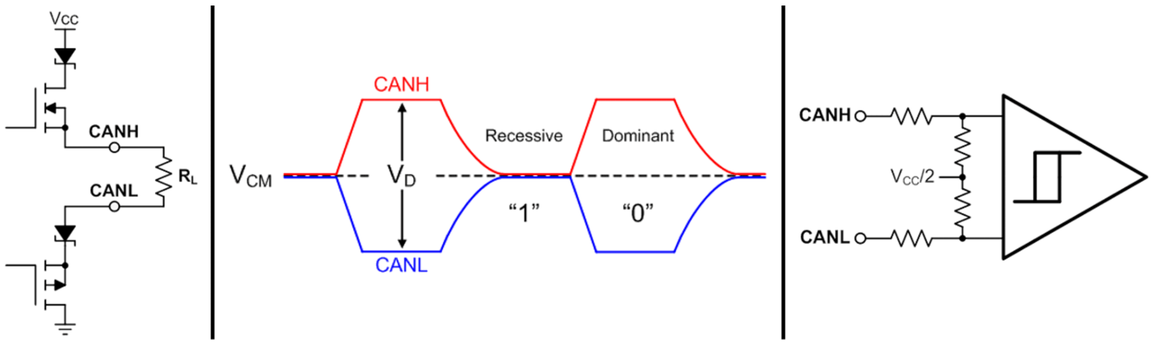

Figure 1-3. CAN Signaling, Diver and Receiver Representation

$V_D = V_{CANH} – V_{CANL}$

For driver: $V_{OD(DOM)} \geq 1.5V$ @ 60 Ω load

For receiver: $V_{ID(DOM)} \geq 900mV$, $V_{ID(rec)} \leq 500mV$

CAN wiring harness is spread throughout the vehicle. Any common mode disturbance generated by CAN transceiver can result in emissions that can impact functionality of other automotive sub-systems. Similarly, the harness is susceptible to pick-up electromagnetic interference from other modules. Thus, electromagnetic compliance is a key requirement for any automotive CAN transceiver. Additionally, different sub-systems can have CAN transceivers from different semiconductor vendors, and hence interoperability is another strict requirement needed for any CAN transceiver to be used in mainstream vehicle network.

2 5V CAN Transceiver

As seen from the functional block diagram of 5V CAN transceiver below, for the driver to be able to produce minimum differential voltage of 1.5V across CANH-CANL terminals, high side and low side transistors (highlighted in dotted red rectangle in Figure 2-1) have to be sized appropriately so that maximum drop across them is 3V when operating from 4.5V supply (since main 5V supply can vary by ±10%).

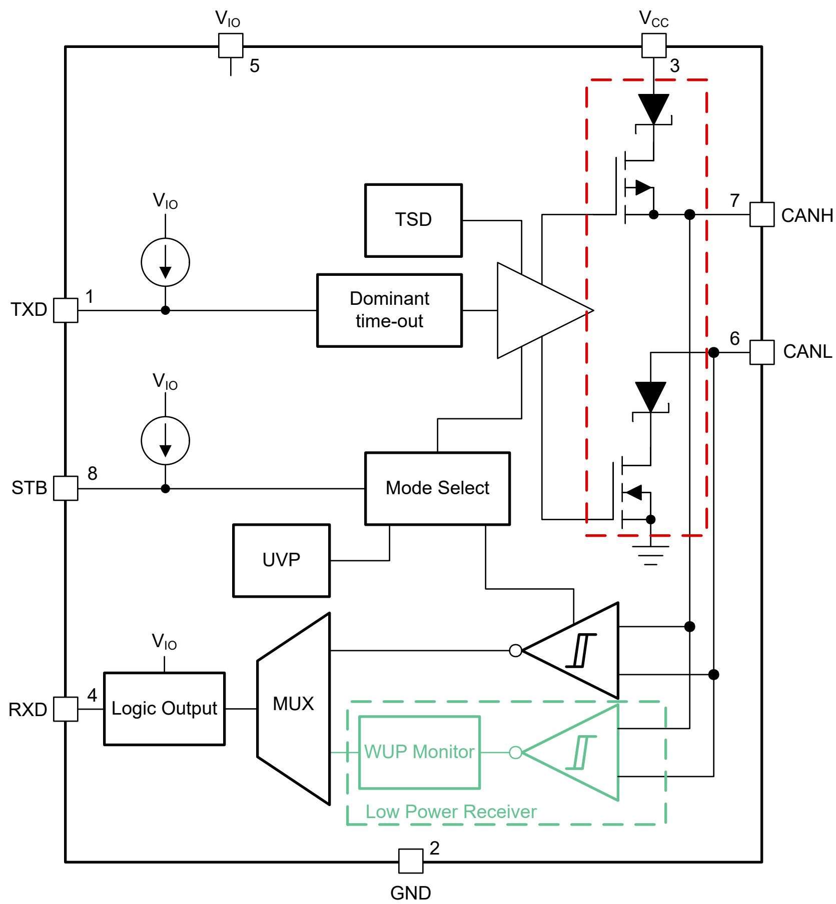

Figure 2-1. CAN Transceiver Block Diagram

Correspondingly the specifications for CANH and CANL with respect to GND are specified in the physical layer standard as shown in Table 2-1.

Table 2-1. 5V CAN Transceiver Specifications

Parameter	Conditions	Min (V)	Max (V)
V_{CANH}	Dominant output, Bus load 50 Ω ≤ R_L ≤ 65 Ω	2.75	4.5
V_{CANL}		0.5	2.25

The CAN bus transceiver can be the only 5V component in the sub-system. With the modern MCU's I/O supply going down to 3.3V, there is a possibility to eliminate the 5V rail altogether resulting in power stage simplification and cost saving by BOM reduction and PCB space reduction.

A high bus-fault tolerant CAN bus transceiver that is footprint compatible to standard 5V CAN transceivers, and that operates from a single 3.3V supply can help simplify the design and reduce cost by eliminating the need for a dedicated 5V supply.

3 TI's TCAN3403-Q1, TCAN3404-Q1 3.3V CAN FD Transceivers

Texas Instruments has released the industry's first automotive qualified and EMC certified 3.3V CAN FD transceivers. This family has 2 devices: TCAN3403-Q1 and TCAN3404-Q1 with below differences between them: shown in Table 3-1.

Table 3-1. TCAN340x-Q1 Family of Devices

Part Number	Pin 5	Pin 8
TCAN3403-Q1	Ultra-low power shutdown mode	Low power standby mode with remote wakeup
TCAN3404-Q1	Low voltage I/O support	

Few key things to note about TCAN3403-Q1, TCAN3404-Q1 family:

- Even with 3V minimum supply (since 3.3V main supply can vary by ±10%), device is designed for minimum 1.5V of differential output voltage with 50Ω bus load. This maintains compliance to V_{OD} spec of ISO11898-2(2024).
- Receiver thresholds are exactly same as standard 5V CAN transceivers and maintains compliance to ISO11898-2 (2024).
- Single ended specifications are as below, which is a slight deviation from CAN physical layer standard ISO11898-2(2024):

Table 3-2. 3.3V CAN Transceiver Specifications

Parameter	Conditions	Min (V)	Max (V)
V_{CANH}	Dominant output, Bus load 50 Ω ≤ R_L ≤ 65 Ω	2.25	V_{CC}
V_{CANL}		0.5	1.25
V_{CANH}, V_{CANL}	Recessive	1.9 V (typical)	

Driver transistors (highlighted in dotted red rectangle in Figure 2-1) have to be sized so that drop across the high side and low side combined is 1.5V maximum at 3V operating bus supply. This reduction in minimum operating supply mandates device recessive biasing to be positioned at 1.9V as opposed to 2.5V for standard 5V CAN transceivers. CAN being a differential interface, single-ended voltages in dominant and recessive state are not crucial for proper operation or communication. This means the TCAN340x-Q1 family of devices is compatible with ISO11898-2 (2024).

Figure 3-1 is an application diagram with TCAN3404-Q1 demonstrating single 3.3V supply regulator to run the MCU and the CAN transceiver, thereby eliminating the 5V regulator that was needed for standard 5V CAN transceivers.

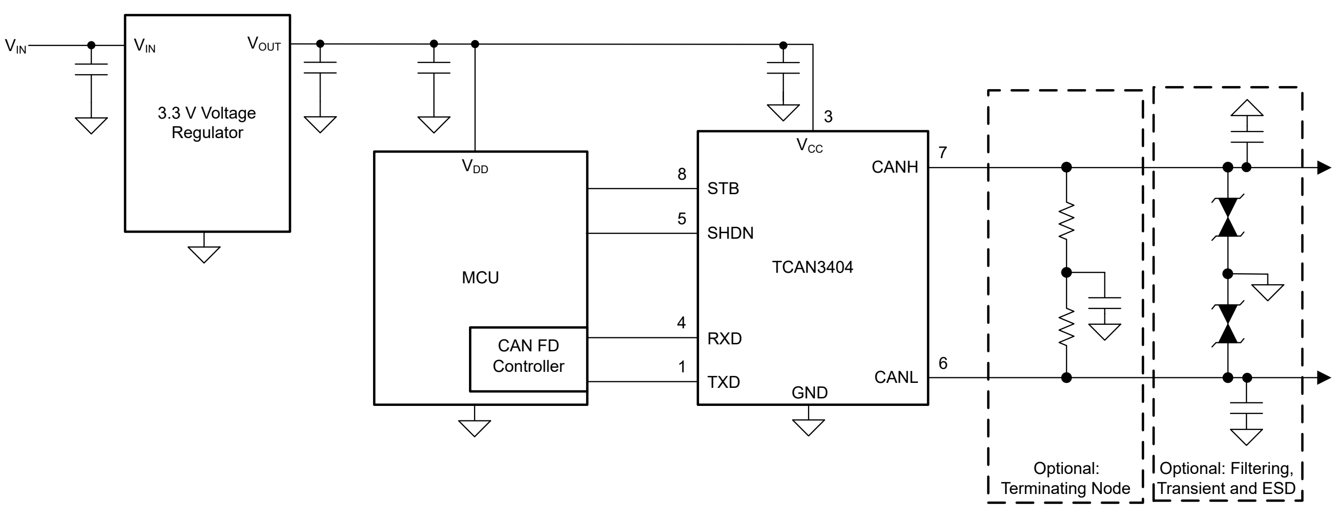

Figure 3-1. Application Schematic of a 3.3V CAN Transceiver

Figure 3-2 compares single device level waveforms between TCAN340x-Q1 and standard 5V CAN.

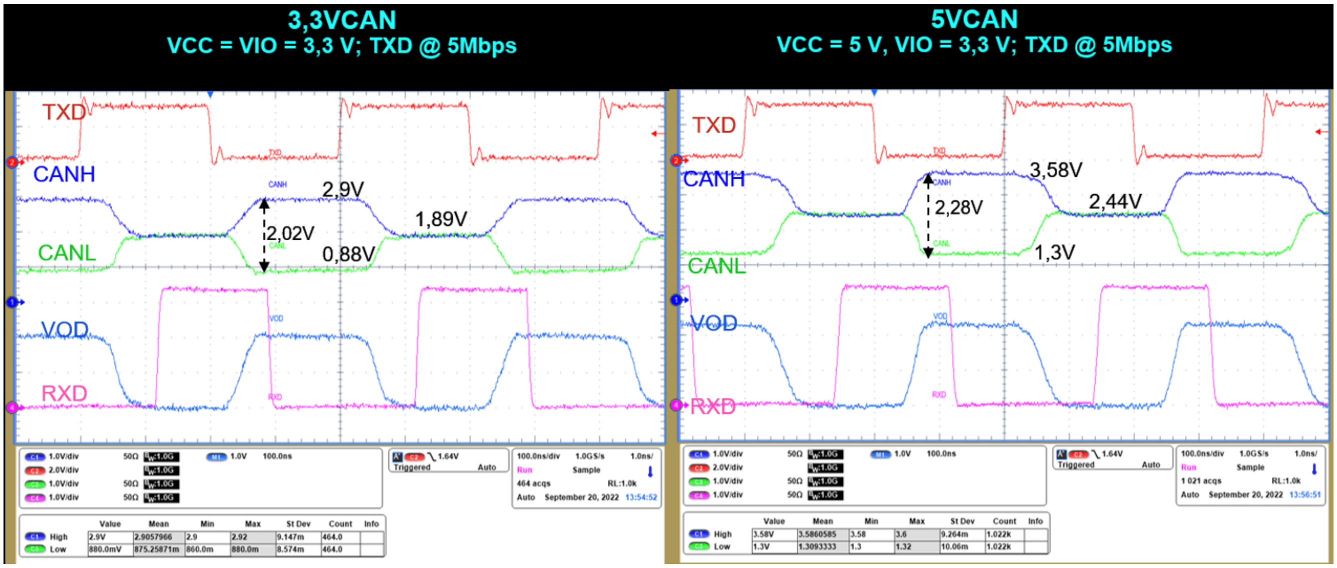

Figure 3-2. Waveform Comparison of a 5V CAN and 3.3V CAN Transceiver

When TCAN340x-Q1 is combined with 5V CAN transceivers on the same bus network, slight recessive bias mismatch can have an impact on emissions. But proprietary design techniques implemented in TCAN3403-Q1/TCAN3404-Q1 maintains EMC compliance per IEC 62228-3 in homogeneous (both nodes in network as TCAN340x-Q1) and heterogeneous (one node is TCAN340x-Q1, other node is standard 5V CAN) network conditions.

Other key features of TCAN340x-Q1 are:

- Robust high bus fault tolerance up to ±58V that maintains no device damage in the events of miswiring faults for 12V and 24V battery applications.
- Extended common mode operating voltage range of ±30V maintains TCAN340x-Q1 receiver continues to receive data without disruption even in the presence of large ground potential difference or voltage interference.
- Devices are footprint compatible to standard 5V CAN transceivers while also having shutdown feature that reduces supply current consumption to < 5uA, enabling seamless upgradeability.
- Devices are offered in 3 package options (leaded SOIC-8, leadless VSON-8 with wettable flanks and ultra-small leaded package SOT-23) to match the needs of various applications.

Many 3.3V CAN transceivers were already available in the market, but none met both auto qualification and EMC certification requirement. TCAN340x-Q1 offers a great solution to automotive designers looking for a fully interoperable and robust 3.3V CAN transceiver which overcomes EMC challenges in heterogeneous networks.

4 Interoperability (IOPT) of TCAN340x-Q1

As stated in previous section, TCAN340x-Q1 recessive biasing of CANH and CANL terminals is 1.9V. This minor shift in common mode voltage (compared to 2.5V for standard 5V CAN transceivers) falls within the common mode voltage range of −12V to +12V specified in the ISO11898-2 (2024) standard. Also, this minor shift in recessive bias level is inconsequential to the extended ±30V common mode voltage range of the TCAN340x-Q1 when operating at 3.3V, allowing the TCAN340x-Q1 to communicate seamlessly with any other ISO11898-2 compliant transceivers. The TCAN340x-Q1 is fully interoperable with other transceivers on the same bus that are powered by 5V supply.

TI’s TCAN340x-Q1 3.3VCAN transceiver family has been successfully tested by the internationally recognized 3rd party communications and systems group (C&S) to the Interoperability test specification for high-speed CAN transceiver. TCAN340x-Q1 devices have successfully passed homogeneous and heterogeneous network testing, and certificates are available upon request.

In the C&S IOPT tests, TCAN340x-Q1 was tested in a 16-node linear network with all nodes TCAN340x-Q1 (homogeneous network) at 2Mbps and also tested in 8-node homogeneous linear network at 5Mbps. Additionally, 16 node 2Mbps network testing was done under heterogeneous condition (4 nodes being TCAN340x-Q1 and 12 nodes being golden reference 5V CAN transceivers). Similarly, 8 node 5Mbps network was also tested in heterogeneous condition (2 nodes being TCAN340x-Q1 and 6 nodes as golden reference 5V CAN transceivers). Under all network conditions, failures such as CAN bus short to GND, CAN short to battery, ground shift between nodes and disconnection of nodes is intentionally introduced in the network on startup, then failure is removed and communication integrity is checked.

Additionally, TI performed internal testing for various different networks (multi-node complex star topologies) with and without arbitration, and TCAN340x-Q1 passes IOPT under all network conditions.

Below are two waveforms during arbitration for homogeneous (all 5V nodes) and heterogeneous (three TCAN340x-Q1 and 8 standard 5V CAN nodes) 11-node complex triple star network tested at 2Mbps data rate (with 500kbps arbitration). Waveforms clearly demonstrate RXD is received without any errors. Even though bus common mode V_{CM} movement happens during the frame for heterogeneous condition, differential bus and RXD waveforms remain undisturbed and comparable to all 5V homogeneous network condition.

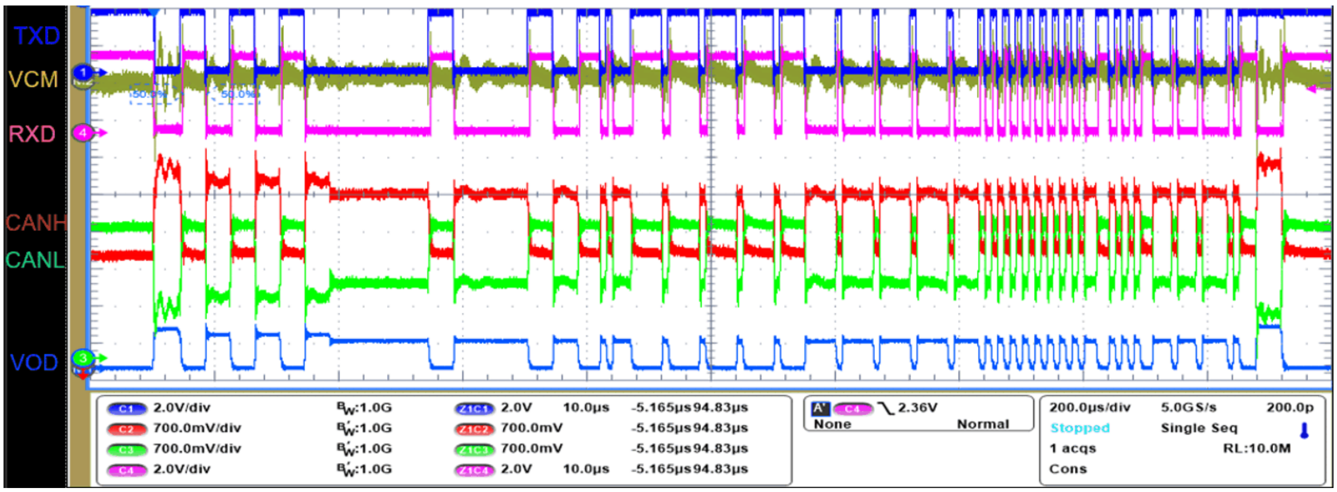

Figure 4-1. 5V Homogeneous Network CAN FD Frame Waveform

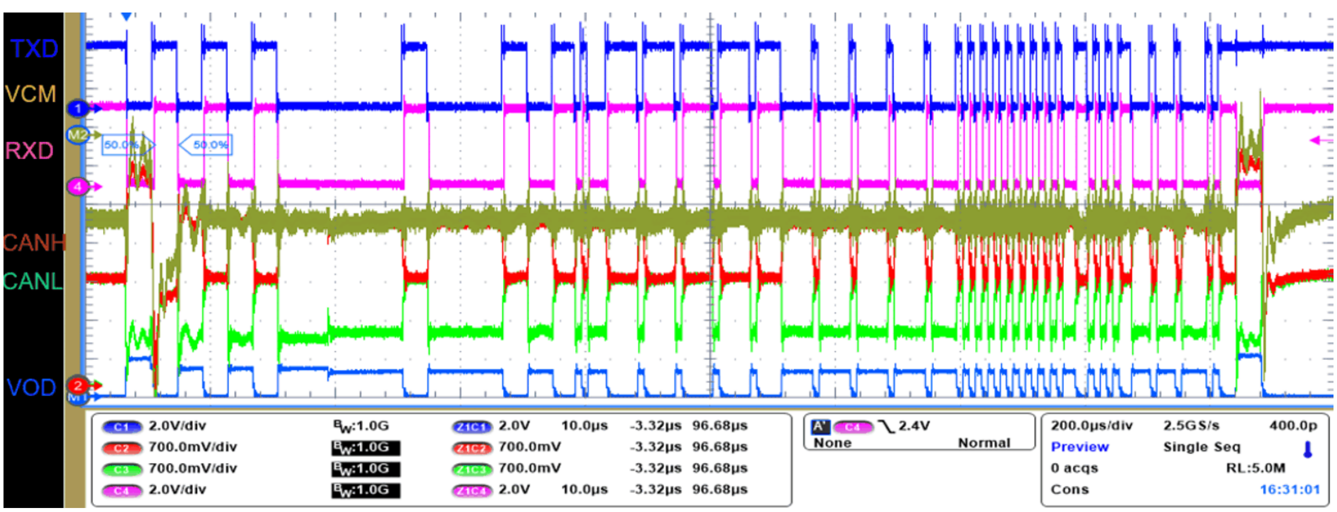

Figure 4-2. 3.3V and 5V Heterogeneous Network CAN FD Frame Waveform

5 EMC of TCAN340x-Q1

As stated in previous sections, meeting component level EMC is a strict requirement to get CAN transceiver qualified at major car makers. One standard that is used to test and qualify CAN transceivers for EMC is IEC62228-3:2019. This standard tests CAN transceivers for conducted emissions and conducted immunity in a 2-node setup, and for ISO10605 ESD and Pulse transients.

CAN being a differential interface, electromagnetic energy due to differential signals largely gets cancelled out, but any common mode mismatch can show up on cable harnesses and result in significant system level emissions. To meet EMC, significant design effort has been made in TCAN340x-Q1 to keep switching symmetry between CANH and CANL during rising and falling bus transitions. Additionally, proprietary design techniques are implemented in TCAN340x-Q1 that dynamically adjusts the bus common mode while driving and receiving CAN data to meet emissions specifically in heterogeneous networks. Emissions in homogeneous network (where all nodes on CAN bus are 3.3V) is easier to meet compared to the stricter heterogeneous network (mix of 3.3V and 5V CAN node on same bus) because of the movement of common mode during recessive condition.

TCAN340x-Q1 meets strict EMC requirements per IEC 62228-3:2019 under both homogeneous and heterogeneous network conditions and passing reports are available upon request.

6 Benefits of TCAN340x-Q1 over competition 3.3V CAN offerings

Table 6-1. Feature Comparison of TCAN340x-Q1 Against Competition 3.3V CAN Devices

Parameter	Competition A	Competition B	Competition C	TCAN340x-Q1	System Implication
Automotive qualified	No	No	No	Yes	Only TI is automotive qualified
EMC certified	No	No	No	Yes	Only TI is automotive EMC certified
CAN bus standoff	±36V	±40V	±60V	±58V	TI is able to work for 12V and 24V automotive battery sub-systems
Receiver common mode voltage range	±25V	±25V	±36V	±30V	TI has extended operating common mode range
Maximum data rate	1Mbps	5Mbps	4Mbps	8Mbps	Operation guaranteed to CAN FD data rates and beyond
Supply current standby mode	600μA	60μA	NA	17μA	Lower standby current consumption reduces battery voltage drain

7 Conclusion

Texas Instruments EMC certified 3.3V CAN transceiver TCAN340x-Q1 offers a compelling alternate to automotive designers against a standard 5V CAN transceiver. It is footprint compatible, and fully interoperable with 5V CAN transceivers while being compatible with physical layer ISO11898-2:2024 specifications. TCAN340x-Q1 helps reduce CAN solution cost by 25% (eliminates automotive 5V LDO) and PCB space by 70%. TCAN340x-Q1 marks the beginning of a new era in 3.3V CAN FD transceivers helping to remove the 5V supply rail traditionally needed in an application only for the 5V CAN transceiver and reducing the BOM cost and PCB size.