

RS-485 Transceivers

RS-485 Transceivers in J1708 Physical Layer Applications of Heavy Duty Vehicles

AN1990
Rev.0.00
Feb 7, 2018

Abstract

In 1986 the Society of Automotive Engineers (SAE) issued the recommended practice J1708, which defines a bidirectional, multi-master network that enables the communication between Electronic Control Units (ECUs) in heavy duty vehicles. The standard specifies a data rate of 9.6kbps and was intended to be replaced by the much faster (250kbps) Controller Area Network (CAN) a decade later.

Still, J1708 remains alive and well, not only in refurbished networks of older vehicles, but also as a diagnostic bus in modern heavy duty vehicles. Here it coexists with CAN, which is predominantly used for the exchange of high-speed data ([Figure 1](#)).

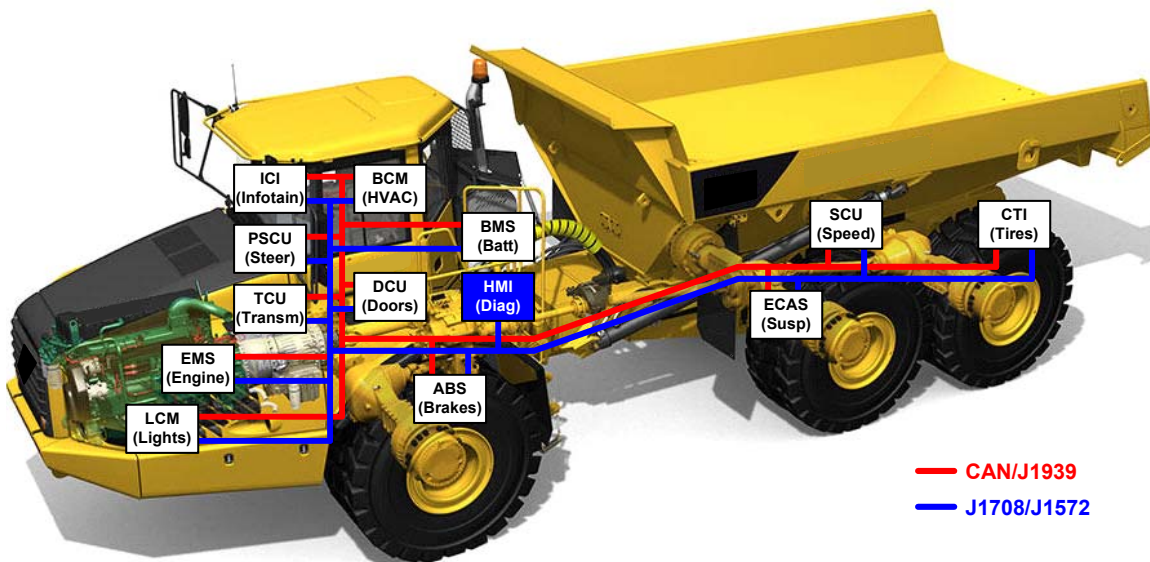


Figure 1. Electronic Control Unit Network in Heavy Duty Vehicles

This application note gives an overview of the hardware design aspects of a J1708 network. It explains the configuration and operating mode of RS-485 transceivers in J1708 applications, and introduces a highly robust bus node design that is immune to overvoltages of $\pm 60V_{DC}$ and $\pm 80V$ transients, while operating over a wide common-mode voltage range of $\pm 20V$.

Contents

1.	Network Parameters	2
2.	Bus Node Interface Circuit	3
3.	Data Formats	4
4.	Message Priority and Buss Access Time	5
5.	Collision Detection and Bus Access	6
6.	Fault-Protected Bus Node Solution	7
7.	Signal Waveforms	10
8.	Conclusion	12
9.	Revision History	13

1. Network Parameters

SAE J1708 defines a serial communication link for the exchange of data between standalone microcomputer-based modules, known as Electronic Control Units (ECUs), in heavy duty vehicle applications.

The topology of a J1708 network is that of a common or global bus, supporting a minimum of 20 bus nodes. The transmission medium is an 18-gauge twisted-pair cable. Although there is no restriction in cable length between nodes, the total length of the data link (A+B+C+D+E+F) shall not exceed 40m. The applied data rate is 9.6kbps, which translates into a bit time of ($t_B = 104.17\mu s$).

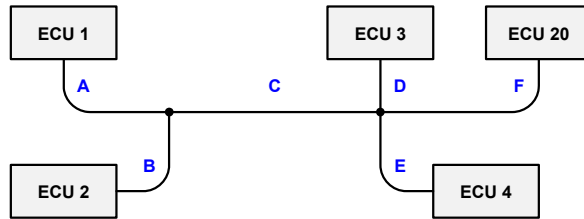


Figure 2. J1708 Network Topology

2. Bus Node Interface Circuit

Each bus node interface consists of an RS-485 transceiver and a resistor-capacitor network, known as the load (Figure 3). Thus, J1708 networks do not have bus termination resistors as referenced in EIA-485.

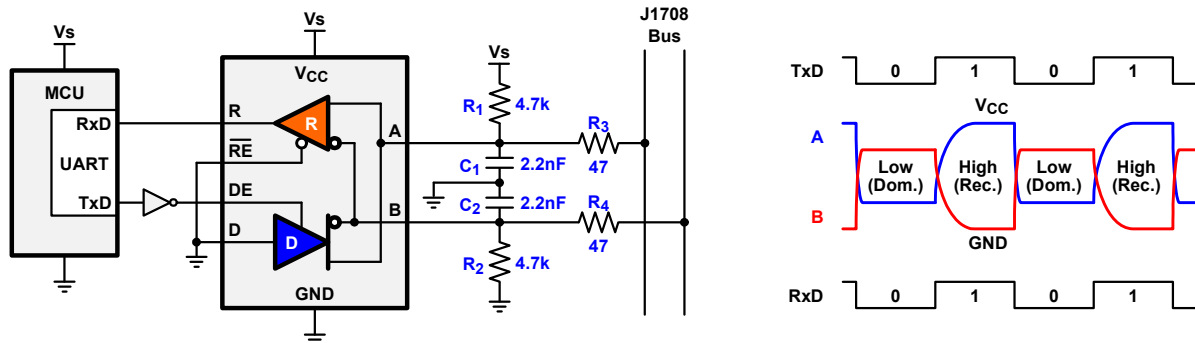


Figure 3. Bus Node Interface Circuit

The receiver stage within the RS-485 transceiver is always enabled through the fixed connection of the receiver enable pin (RE) to local ground. This allows for monitoring the data traffic on the bus, as well as the detection of bus collisions.

The driver is configured to operate in the dominant/recessive mode. Its data input (D) is fixed to ground while its enable pin (DE) is used as the new data input. A high at DE enables the driver, driving the low potential at D onto the bus. A low at DE disabled the driver, making its outputs high-impedance. In this case, bus line A is pulled up towards Vs through R₁, and bus line B is pulled down to ground using R₂. This condition constitutes a bus-high. To ensure the UART output and the differential output of the driver have the same signal polarity, a logic inverter is inserted between TxD and DE.

Because the actively driven low-state always overwrites a passively generated high-state on the bus, the low becomes the dominant, and the high becomes the recessive bus state. This operating mode enables bus nodes to detect idle lines and bus contentions, both of which are important conditions, used for synchronizing the network, prioritizing bus access, and aborting transmissions.

The remaining components of the load circuits serve as low-pass filters. R₃ and R₄ in combination with C₁ and C₂ form a 1.6MHz receive low-pass filter for EMI suppression. The driver output impedance together with C₁ and C₂ form a 6MHz transmit low-pass filter for EMI and transient suppression.

3. Data Formats

A J1708 message consists of three types of characters:

- (1) **Message Identification character (MID):** Used to identify the transmitter sending the information, and to establish message priority and collision detection.
- (2) **Data characters:** Used to convey the intelligence of a message to the receiver, such as data type, size, and scaling factor.
- (3) **Checksum:** Required to prevent invalid data from being used.

The message length can range from a minimum of 2 up to a maximum of 21 characters, including the checksum ([Figure 4](#)).

Each character consists of 10 bits: one start bit (logic low level), eight data bits, and 1 stop bit (logic high-level). This conversion is consistent with the standard UART transmission scheme, 8-N-1 (8 data bits, no parity, 1 stop bit), with the data bits being transmitted Least Significant Bit (LSB) first.

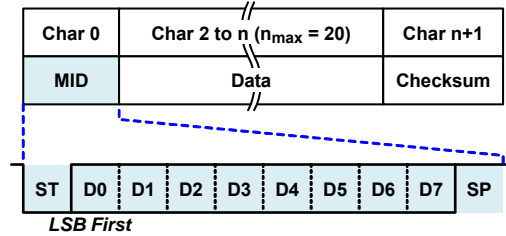


Figure 4. J1708 Message and Character Formats

4. Message Priority and Bus Access Time

Each message is assigned a priority between one and eight by the module manufacturer’s defining application document. Classes of message priorities and their assignments as specified in J1708 are listed in [Table 1](#).

Table 1. Priority Classes

Priority	Message Assignment
1 2	Messages requiring immediate bus access
3 4	Messages preventing mechanical damage
5 6	Messages controlling economy and efficiency
7 8	All other messages

Before a transceiver attempts to access the bus, it must have detected an idle-line condition, which consists of 10 consecutive high bits. After that, the transceiver must continue to wait until its priority delay (P_D) has passed. This delay is transceiver specific as it depends on the message priority. P_D is calculated using [Equation 1](#):

$$(EQ. 1) \quad P_D = P \cdot 2 \cdot t_B$$

where P is the message priority and t_B the bit time of 104.17 μ s.

The sum of idle-line duration (t_I) and priority delay is known as the bus access time (t_A).

$$(EQ. 2) \quad t_A = t_I + P_D$$

Thus, the bus access time is the time a transceiver must wait, after being synchronized or returning from a collision detection, before trying to access the bus again. [Table 2](#) lists the resulting priority delays and bus access times in numbers of bits (multiples of t_B). As can be seen, messages of higher priorities have shorter bus access times than low-priority messages.

Table 2. Priority Delays and Access Times

Priority	P_D (Bits)	t_A (Bits)
1	2	12
2	4	14
3	6	16
4	8	18
5	10	20
6	12	22
7	14	24
8	16	26

5. Collision Detection and Bus Access

If two or more nodes gain bus access at the same time, data collision is inevitable. [Figure 5](#) presents a collision example between a transmission and a diagnostics ECU.

ECU	MID	D0	D1	D2	D3	D4	D5	D6	D7	P	P_D (Bits)
Transmission	24	0	0	0	1	1	0	0	0	2	4
Diagnostics	48	0	0	0	0	1	1	0	0	3	6

↑ ↑
 1st 2nd
 Collision

Figure 5. Collision Detection between Electronic Control Units

Both ECUs drive their MIDs onto the bus, which are instantaneously verified through the corresponding receivers. At the fourth MID bit (D3) the transmission ECU detects a collision as it transmits a 1 onto the bus, but reads back a 0 instead, which occurred due to the diagnostics ECU pulling the bus low. Both ECUs continue transmitting, the diagnostics ECU because it did not detect a collision, and the transmission ECU because it entered the collision-retry procedure.

Then, at bit D5 a second collision occurs. This time the diagnostics ECU detects the collision and enters the collision-retry procedure. Because of the detected collisions, both ECUs relinquish the bus after sending the first character (MID), only to reengage into a new, subsequent bus access attempt ([Figure 6 on page 5](#)).

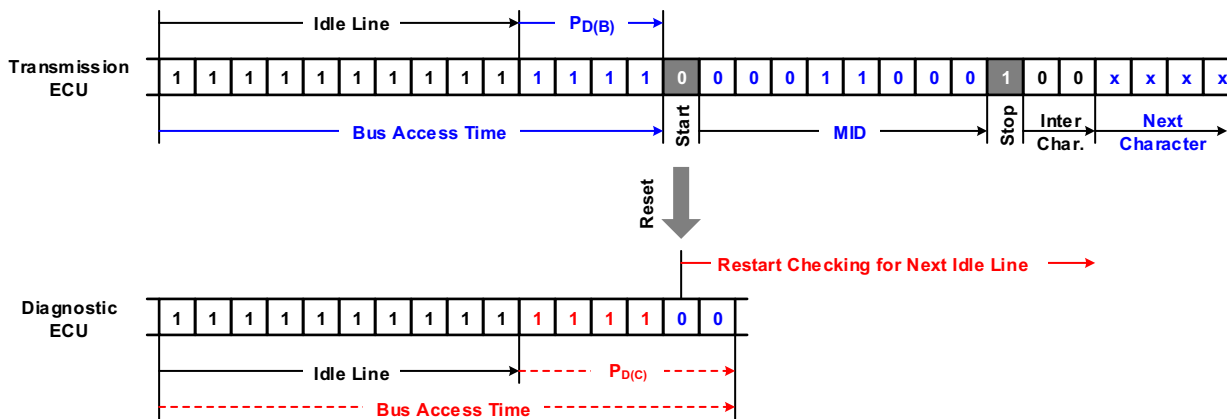


Figure 6. Simultaneous Bus Access Attempts of ECUs

Both ECUs begin checking the bus for an idle-line condition. Because the transmission ECU has the higher priority (see Figure 5 on page 4), its priority delay is only 4 bit times and thus, shorter than the 6 bit PD of the diagnostics ECU.

After passing a total bus access time of 14 bits ($t_1 + P_{D(B)}$), the transmission ECU begins transmitting its entire message. At the same time, the diagnostics ECU, still waiting for two more high bits to receive, is reset by the low-level start bit from the transmission ECU. The diagnostics ECU must now restart checking for the next idle-line condition before trying to regain bus access. The next idle-line however, can only occur after the transmission ECU has completed sending its entire message (for example, 2 to 21 characters).

6. Fault-Protected Bus Node Solution

Today's modern microcontrollers, such as the Renesas RL78 family of MCUs, provide the programmable inversion of an embedded UART output in form of a /TxD signal (Figure 7). This eliminates the need for an external inverter gate or a modified RS-485 transceiver with inverted DE input, and ensures that designers can choose from a wide variety of standard RS-485 transceivers.

The transceiver of choice for J1708 applications is the ISL32455E. This is due to many customers requiring high immunity to overvoltages (DC and transients), as well as reliable data transmission over a significantly wider Common-Mode Voltage Range (CMVR) than specified in EIA-485.

The ISL32455E has bus I/O stages with high, symmetric stand-off capability of up to $\pm 60V$, thus providing protection against high DC potentials and transient voltages within that range (Figure 8 on page 6).

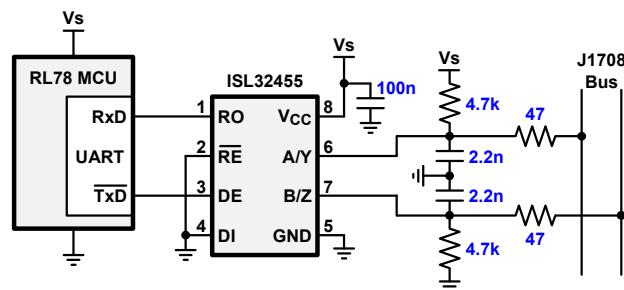


Figure 7. Robust J1708 Interface with ISL32455

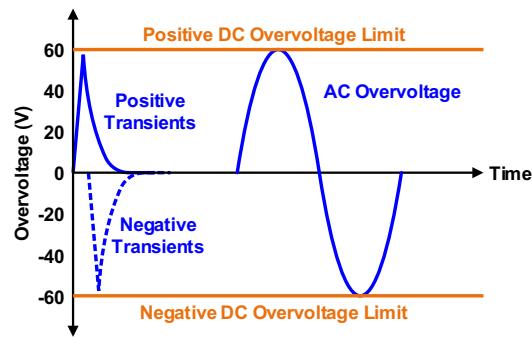


Figure 8. Stand-off Voltage Range of ISL32455E

The transceiver also supports a wide CMVR of up to $\pm 20V$. To limit the power consumption of the active driver during a fault event, while maintaining reliable operation across the wide CMVR, its internal current limiter has a dual fold-back characteristic (Figure 9).

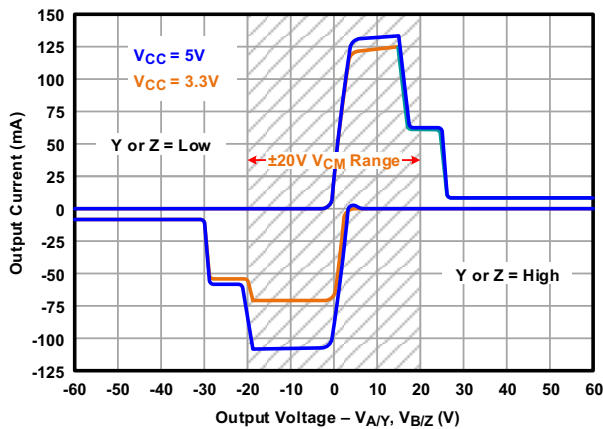


Figure 9. Dual Fold-Back Characteristic of the Current Limiter

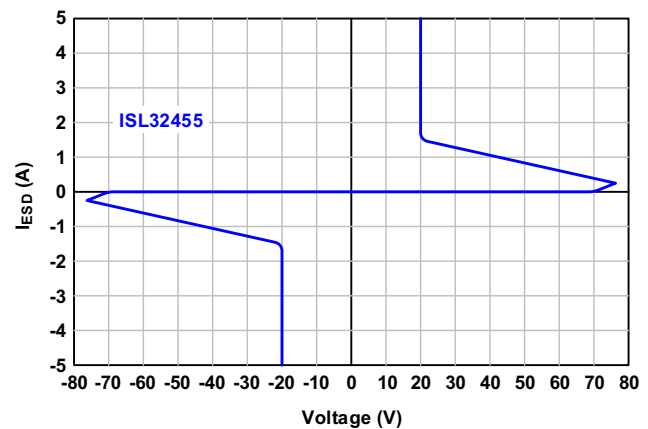


Figure 10. V-I Characteristic of the On-Chip ESD Protection

Here the first fold-back current level ensures that the driver never folds back when driving loads within the entire 40V common-mode voltages. The very low second fold-back current setting minimizes power dissipation if the driver is enabled when a fault occurs.

In the event of a major short-circuit condition, the ISL32455E also provides a thermal shutdown function that disables the driver whenever the die temperature becomes excessive. This eliminates any power dissipation and allows the die to cool. The driver automatically re-enables after the die temperature drops by 15°C. If the fault condition persists, the thermal shutdown/re-enable cycle repeats until the fault is cleared. The receiver stays operational during thermal shutdown, and fault-protection is active, whether the driver is enabled or disabled, and even if the IC is powered down.

The ISL32455E provides high ESD protection of up to $\pm 16kV$. To prevent the transceiver's on-chip ESD protection circuits from being triggered by low-level (60V) overvoltages, the ESD trigger threshold lies far outside the $\pm 60V$ operating range (Figure 10). The symmetric protection range of the ISL32455E presents another major benefit for surge protection designs, as it allows designers to choose from a vast range of symmetrically clamping Transient Voltage Suppressors (TVS).

Further device features of the ISL32455E are:

- A wide supply voltage range from 3.0V to 5.5V, allowing an easy interfacing to low-voltage controllers.
- Low supply current of only 2.1mA, which is 1/20th of the supply current of some legacy transceivers previously used in J1708 applications.
- ¼ UL rating, to ensure the maximum common-mode loading of 20UL for a fully loaded J1708 network supporting 20 nodes is never exceeded.
- Full-failsafe receiver inputs to maintain the receiver output high if the inputs are open or shorted, thus easing the detection of bus failures.

[Table 3](#) lists the key parameters of the ISL32455E compared to competitive devices used in legacy J1708 designs.

Table 3. ISL32455E Key Parameters

Parameters	ISL32455E	ISL81487	DS36277
Fault Protection: DC (Transients referenced in EIA-485)	±60V (±80V)	-8V to +13V	-8V to +13V
Common-Mode Voltage Range	±20V	-7V to +12V	-7V to +12V
Supply Voltage Range	3.0V to 5.5V	4.5V to 5.5V	4.75V to 5.25V
Supply Current (Driver disabled, no Load)	2.1mA	0.35mA	24mA
Unit Load	0.25	0.125	1.5
Failsafe	Open/Short	Open/Short	Open/Short
Driver Enable to Output Low Delay (t_{ZL})	300ns	70ns	60ns
Receiver Input-to-Output Delay (t_{PHL})	200ns	150ns	90ns
ESD Protection (HBM)	±16.5kV	±7kV	±7kV
Operating Temperature Range	-40 to +85°C	-40 to +85°C	-40 to +85°C

The two delay times, t_{ZL} and t_{PHL} , are of utmost importance because they ensure J1708 compliance during the fast HIGH to LOW (recessive-to-dominant) transition on the bus. Here, J1708 specifies a transition time of 600ns for a bus with two nodes and 2.3µs for a fully loaded bus with 20 nodes.

[Table 3](#) lists the maximum values for t_{ZL} and t_{PHL} with 300ns and 200ns respectively, thus assuring a maximum HIGH to LOW or Recessive-to-Dominant transition time (t_{RD}) of 500ns is never exceeded. Note, these numbers hold true over the entire supply and temperature range.

7. Signal Waveforms

Figures 11 to 14 show the signal waveforms at the transceiver bus terminals and the transition times (t_{RD}) for networks with 2 and 20 nodes, when the transceiver supply is 5V. Figures 15 to 18 show similar waveforms for a transceiver supply of 3.3V.

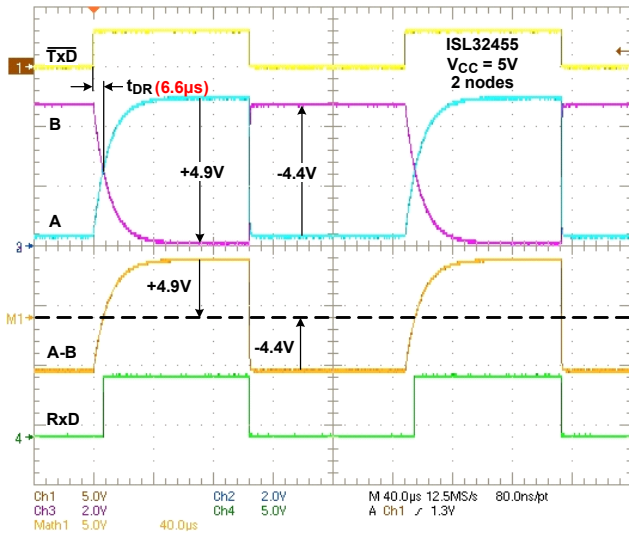


Figure 11. Transceiver Signal Waveforms: 2 Nodes, $V_{CC} = 5.0V$

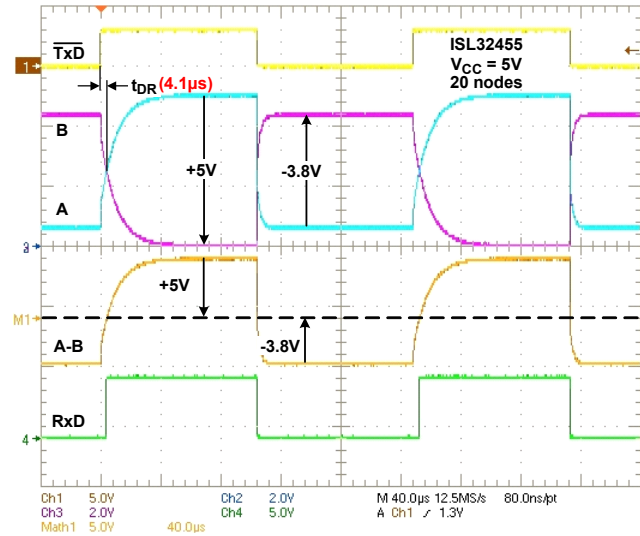


Figure 12. Transceiver Signal Waveforms: 20 Nodes, $V_{CC} = 5.0V$

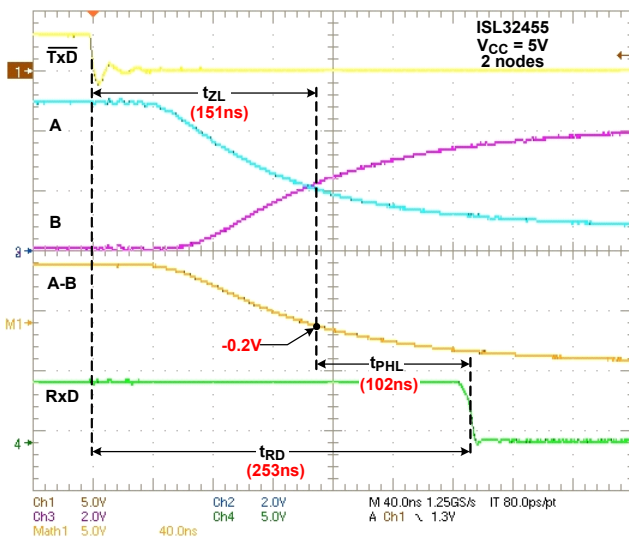


Figure 13. HIGH to LOW Transition: 2 Nodes, $V_{CC} = 5.0V$

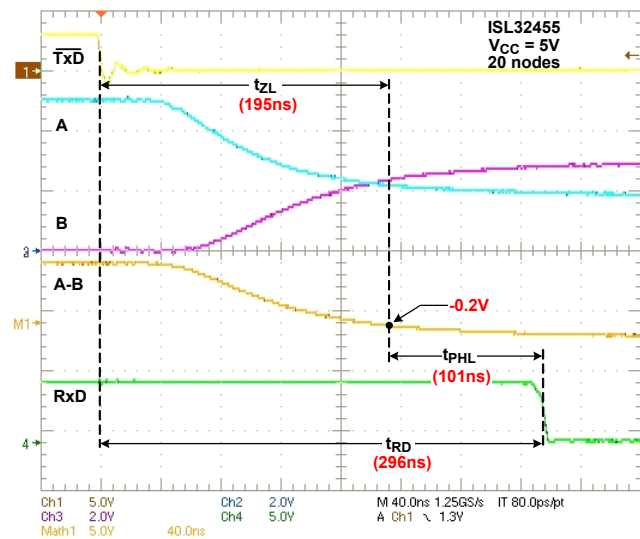


Figure 14. HIGH to LOW Transition: 20 Nodes, $V_{CC} = 5.0V$

RS-485 Transceivers

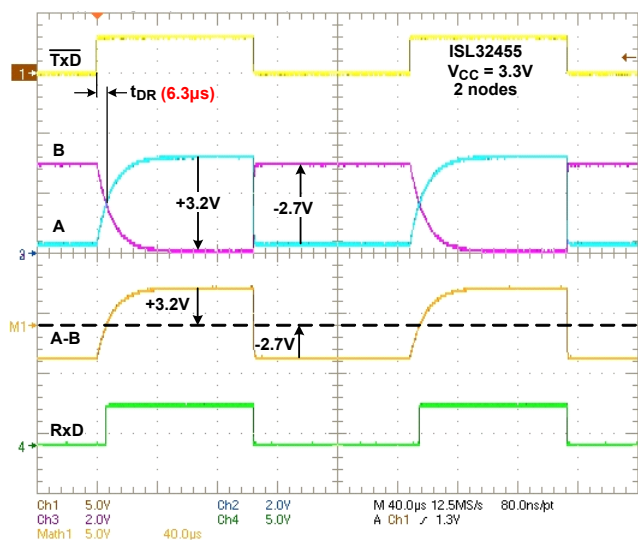


Figure 15. Transceiver Signal Waveforms: 2 Nodes, $V_{CC} = 3.3V$

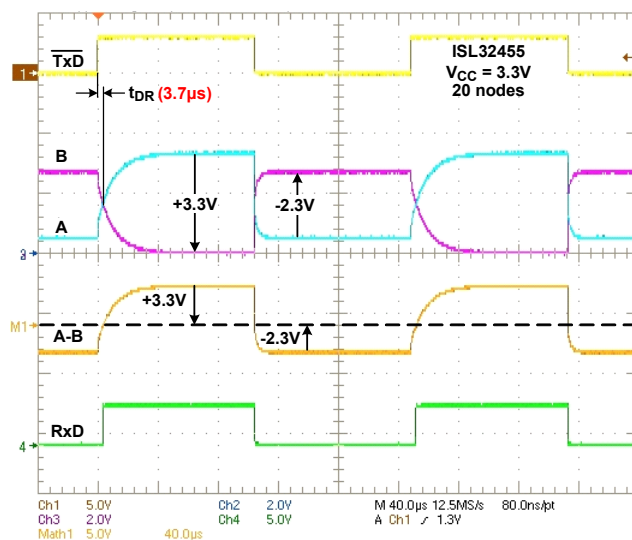


Figure 16. Transceiver Signal Waveforms: 20 Nodes, $V_{CC} = 3.3V$

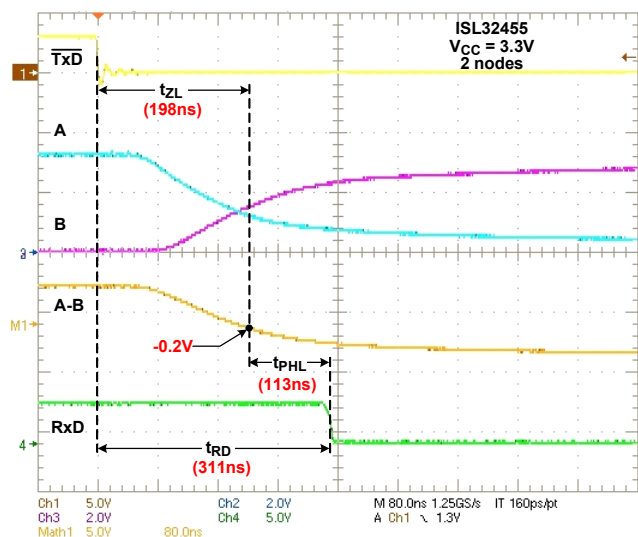


Figure 17. HIGH to LOW Transition: 2 Nodes, $V_{CC} = 3.3V$

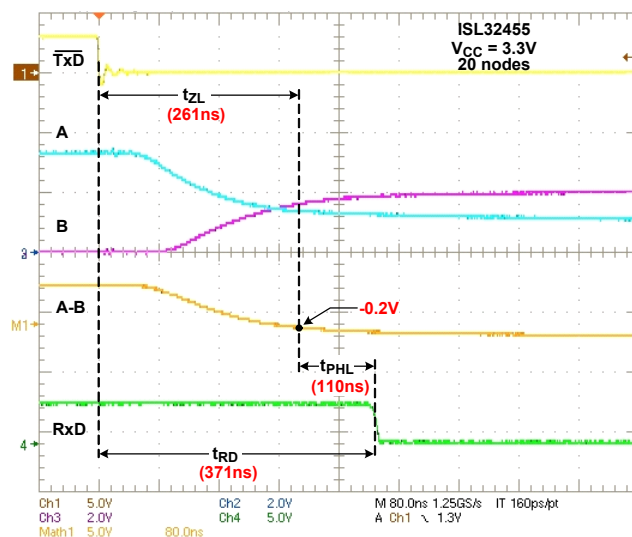


Figure 18. HIGH to LOW Transition: 20 Nodes, $V_{CC} = 3.3V$

8. Conclusion

The combination of Renesas microcontrollers and RS-485 transceivers not only simplifies the design of J1708 bus nodes, but also ensures reliable data transmission over a wide common-mode range while protecting your bus node against high overvoltages.

9. Revision History

Rev.	Date	Description
0.00	Feb 7, 2018	Initial release

Notice

1. Descriptions of circuits, software and other related information in this document are provided only to illustrate the operation of semiconductor products and application examples. You are fully responsible for the incorporation or any other use of the circuits, software, and information in the design of your product or system. Renesas Electronics disclaims any and all liability for any losses and damages incurred by you or third parties arising from the use of these circuits, software, or information.
2. Renesas Electronics hereby expressly disclaims any warranties against and liability for infringement or any other claims involving patents, copyrights, or other intellectual property rights of third parties, by or arising from the use of Renesas Electronics products or technical information described in this document, including but not limited to, the product data, drawings, charts, programs, algorithms, and application examples.
3. No license, express, implied or otherwise, is granted hereby under any patents, copyrights or other intellectual property rights of Renesas Electronics or others.
4. You shall not alter, modify, copy, or reverse engineer any Renesas Electronics product, whether in whole or in part. Renesas Electronics disclaims any and all liability for any losses or damages incurred by you or third parties arising from such alteration, modification, copying or reverse engineering.
5. Renesas Electronics products are classified according to the following two quality grades: "Standard" and "High Quality". The intended applications for each Renesas Electronics product depends on the product's quality grade, as indicated below.
"Standard": Computers; office equipment; communications equipment; test and measurement equipment; audio and visual equipment; home electronic appliances; machine tools; personal electronic equipment; industrial robots; etc.
"High Quality": Transportation equipment (automobiles, trains, ships, etc.); traffic control (traffic lights); large-scale communication equipment; key financial terminal systems; safety control equipment; etc.
Unless expressly designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not intended or authorized for use in products or systems that may pose a direct threat to human life or bodily injury (artificial life support devices or systems; surgical implantations; etc.), or may cause serious property damage (space system; undersea repeaters; nuclear power control systems; aircraft control systems; key plant systems; military equipment; etc.). Renesas Electronics disclaims any and all liability for any damages or losses incurred by you or any third parties arising from the use of any Renesas Electronics product that is inconsistent with any Renesas Electronics data sheet, user's manual or other Renesas Electronics document.
6. When using Renesas Electronics products, refer to the latest product information (data sheets, user's manuals, application notes, "General Notes for Handling and Using Semiconductor Devices" in the reliability handbook, etc.), and ensure that usage conditions are within the ranges specified by Renesas Electronics with respect to maximum ratings, operating power supply voltage range, heat dissipation characteristics, installation, etc. Renesas Electronics disclaims any and all liability for any malfunctions, failure or accident arising out of the use of Renesas Electronics products outside of such specified ranges.
7. Although Renesas Electronics endeavors to improve the quality and reliability of Renesas Electronics products, semiconductor products have specific characteristics, such as the occurrence of failure at a certain rate and malfunctions under certain use conditions. Unless designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not subject to radiation resistance design. You are responsible for implementing safety measures to guard against the possibility of bodily injury, injury or damage caused by fire, and/or danger to the public in the event of a failure or malfunction of Renesas Electronics products, such as safety design for hardware and software, including but not limited to redundancy, fire control and malfunction prevention, appropriate treatment for aging degradation or any other appropriate measures. Because the evaluation of microcomputer software alone is very difficult and impractical, you are responsible for evaluating the safety of the final products or systems manufactured by you.
8. Please contact a Renesas Electronics sales office for details as to environmental matters such as the environmental compatibility of each Renesas Electronics product. You are responsible for carefully and sufficiently investigating applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive, and using Renesas Electronics products in compliance with all these applicable laws and regulations. Renesas Electronics disclaims any and all liability for damages or losses occurring as a result of your noncompliance with applicable laws and regulations.
9. Renesas Electronics products and technologies shall not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable domestic or foreign laws or regulations. You shall comply with any applicable export control laws and regulations promulgated and administered by the governments of any countries asserting jurisdiction over the parties or transactions.
10. It is the responsibility of the buyer or distributor of Renesas Electronics products, or any other party who distributes, disposes of, or otherwise sells or transfers the product to a third party, to notify such third party in advance of the contents and conditions set forth in this document.
11. This document shall not be reprinted, reproduced or duplicated in any form, in whole or in part, without prior written consent of Renesas Electronics.
12. Please contact a Renesas Electronics sales office if you have any questions regarding the information contained in this document or Renesas Electronics products.
(Note 1) "Renesas Electronics" as used in this document means Renesas Electronics Corporation and also includes its directly or indirectly controlled subsidiaries.
(Note 2) "Renesas Electronics product(s)" means any product developed or manufactured by or for Renesas Electronics.

(Rev.4.0-1 November 2017)



SALES OFFICES

Renesas Electronics Corporation

<http://www.renesas.com>

Refer to "<http://www.renesas.com/>" for the latest and detailed information.

Renesas Electronics America Inc.
1001 Murphy Ranch Road, Milpitas, CA 95035, U.S.A.
Tel: +1-408-432-8888, Fax: +1-408-434-5351

Renesas Electronics Canada Limited
9251 Yonge Street, Suite 8309 Richmond Hill, Ontario Canada L4C 9T3
Tel: +1-905-237-2004

Renesas Electronics Europe Limited
Dukes Meadow, Millboard Road, Bourne End, Buckinghamshire, SL8 5FH, U.K
Tel: +44-1628-651-700, Fax: +44-1628-651-804

Renesas Electronics Europe GmbH
Arcadiastrasse 10, 40472 Düsseldorf, Germany
Tel: +49-211-6503-0, Fax: +49-211-6503-1327

Renesas Electronics (China) Co., Ltd.
Room 1709 Quantum Plaza, No.27 ZhichunLu, Haidian District, Beijing, 100191 P. R. China
Tel: +86-10-8235-1155, Fax: +86-10-8235-7679

Renesas Electronics (Shanghai) Co., Ltd.
Unit 301, Tower A, Central Towers, 555 Langao Road, Putuo District, Shanghai, 200333 P. R. China
Tel: +86-21-2226-0888, Fax: +86-21-2226-0999

Renesas Electronics Hong Kong Limited
Unit 1601-1611, 16/F., Tower 2, Grand Century Place, 193 Prince Edward Road West, Mongkok, Kowloon, Hong Kong
Tel: +852-2265-6688, Fax: +852-2886-9022

Renesas Electronics Taiwan Co., Ltd.
13F, No. 363, Fu Shing North Road, Taipei 10543, Taiwan
Tel: +886-2-8175-9600, Fax: +886-2-8175-9670

Renesas Electronics Singapore Pte. Ltd.
80 Bendemeer Road, Unit #06-02 Hyflux Innovation Centre, Singapore 339949
Tel: +65-6213-0200, Fax: +65-6213-0300

Renesas Electronics Malaysia Sdn.Bhd.
Unit 1207, Block B, Menara Amcorp, Amcorp Trade Centre, No. 18, Jln Persiaran Barat, 46050 Petaling Jaya, Selangor Darul Ehsan, Malaysia
Tel: +60-3-7955-9390, Fax: +60-3-7955-9510

Renesas Electronics India Pvt. Ltd.
No.777C, 100 Feet Road, HAL 2nd Stage, Indiranagar, Bangalore 560 038, India
Tel: +91-80-67208700, Fax: +91-80-67208777

Renesas Electronics Korea Co., Ltd.
17F, KAMCO Yangjae Tower, 262, Gangnam-daero, Gangnam-gu, Seoul, 06265 Korea
Tel: +82-2-558-3737, Fax: +82-2-558-5338