Common Information



RS-485 Drivers and Receivers

Functional Principles of RS-485 Drivers and Receivers

Abstract

The RS-485 standard specifies the electrical characteristics of differential drivers and receivers in multi-point networks but does not explain their functional principles. This document explains how the differential line signals are generated by the driver and processed by the receiver.

Contents

1.	Drive	r Functional Principle	2
2.	Rece	iver Functional Principle	3
3.	Revis	sion History	4
List o	of Fig	gures	
Figure	1.	Driver with Drive Logic and H-Bridge Output	2
Figure	2.	Driver Differential and Common-Mode Output Voltages	2
Figure	3 .	Mixed, Differential, and Common-Mode Representations of an RS-485 Driver	3
Figure	4 .	Input Voltage Divider with Comparator	3
-		Input Voltage Attenuation and Biasing	

1. Driver Functional Principle

An RS-485 driver consists of a drive logic and four output transistors (Q1 to Q4) in an H-bridge configuration. The drive logic becomes active when the driver enable pin (DE) is asserted high.

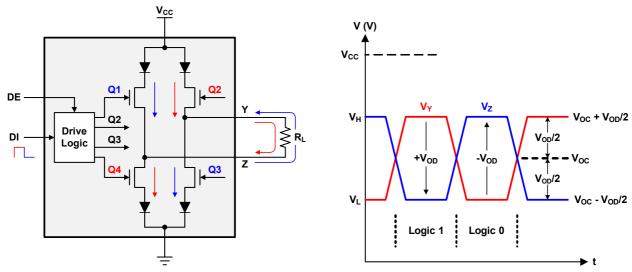


Figure 1. Driver with Drive Logic and H-Bridge Output

Figure 2. Driver Differential and Common-Mode
Output Voltages

A high applied to the data input (DI) turns on Q2 and Q4 and disables Q1 and Q3. This configuration causes current to flow through R_L from Output Y to Output Z. A low applied to DI turns Q2 and Q4 off and enables Q1 and Q3, which causes the current to flow in the opposite direction, from Z to Y.

Each transistor has a diode in series to prevent reverse leakage current from flowing into the transistor if the bus voltage either rises above V_{CC} or drops below ground. When a driver drives a loaded bus, the forward voltages of the diodes and the voltage drops across the $r_{DS(ON)}$ resistance of the transistors causing the output voltages, V_Y and V_Z , to never reach the supply rails. Instead, both outputs switch alternately between the high and low voltage levels, V_H and V_L (Figure 2).

In general, the differential output voltage, V_{OD}, is the difference between the high and low-level output voltages:

(EQ. 1)
$$V_{OD} = V_H - V_L$$

However, in practice V_{OD} is defined as $V_Y - V_Z$, so V_Y is referenced to V_Z . For $V_Y > V_Z$, V_{OD} is positive and represents a binary 1 or logic high at DI. For $V_Y < V_Z$, V_{OD} is negative and indicates a binary 0 or logic low at DI.

As both outputs switch within the positive voltage range, the DC-component is common to both outputs. This voltage is the driver output common-mode voltage, V_{OC} , and is defined in Equation 2:

(EQ. 2)
$$V_{OC} = \frac{V_H + V_L}{2}$$

Inserting <u>Equation 1</u> into <u>Equation 2</u> presents the output voltages in their common-mode and differential components:

(EQ. 3)
$$V_H = V_{OC} + \frac{V_{OD}}{2}$$
 and $V_L = V_{OC} - \frac{V_{OD}}{2}$

The driver can therefore be shown as a common-mode voltage source superimposed by two complementary, differential voltages:

(EQ. 4)
$$V_Y = V_{OC} \pm \frac{V_{OD}}{2}$$
 and $V_Z = V_{OC} \mp \frac{V_{OD}}{2}$

These depictions will come in handy when evaluating a driver's output drive capability, or explaining the removal of common-mode voltages through galvanic isolation (<u>Figure 3</u>).

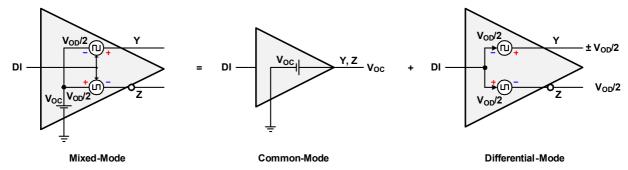


Figure 3. Mixed, Differential, and Common-Mode Representations of an RS-485 Driver

2. Receiver Functional Principle

An RS-485 receiver must be able to detect small differential bus signals as small as ±200mV in the presence of large common-mode voltages that range from -7V to +12V. To detect these signals, the receiver consists of an input voltage divider with biasing stage, followed by a differential comparator. Its simplified equivalent circuit diagram is shown in Figure 1 on page 2.

Here the voltage divider action between the input resistor, R_{IN} , and the biasing resistors, R_{B} , attenuate the line voltage by a gain factor of about 1/10 to 1/12. The attenuated input signal is then biased or level-shifted to approximately $V_{CC}/2$. This level-shift is necessary to enable the single-supply comparator to process large negative voltages.

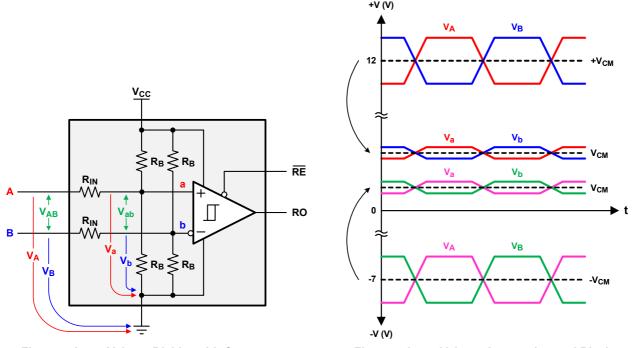


Figure 4. Input Voltage Divider with Comparator

Figure 5. Input Voltage Attenuation and Biasing

<u>Figure 5</u> shows how large positive and negative line voltages are attenuated and then level-shifted into the positive operating voltage range of the comparator. Expressing the line voltages V_A and V_B through their common-mode and differential components: $V_A = V_{CM} + V_D/2$ and $V_B = V_{CM} - V_D/2$ respectively, the internal comparator input voltages are:

$$(EQ. 5) \qquad V_a = \left(V_{CM} + \frac{V_D}{2}\right) \bullet G_1 + V_{CC} \bullet G_2 \ \ \text{and} \ \ V_b = \left(V_{CM} - \frac{V_D}{2}\right) \bullet G_1 + V_{CC} \bullet G_2$$

where G_1 is the gain factor of the voltage divider and G_2 is the gain factor of the biasing stage.

The comparator input voltage is $V_{ab} = V_a - V_b = V_D \cdot G_1$, which is purely differential. Because the comparator only reacts to differential inputs, all common-mode and biasing voltage components are rejected.

Note: Internal biasing references the receiver input voltages to receiver ground, so it is not necessary to connect the driver and a remote receiver with a ground wire.

RS-485 is therefore known as a true 2-wire bus.

3. Revision History

Rev.	Date	Description
1.00	Jun.25.19	Updated equations 3 and 5. Updated disclaimer. Applied new format.
0.00	Apr.26.17	Initial release

Notice

- 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; willtary 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.
- (Note1) "Renesas Electronics" as used in this document means Renesas Electronics Corporation and also includes its directly or indirectly controlled subsidiaries.
- (Note2) "Renesas Electronics product(s)" means any product developed or manufactured by or for Renesas Electronics.

(Rev.4.0-1 November 2017)

Corporate Headquarters

TOYOSU FORESIA, 3-2-24 Toyosu, Koto-ku, Tokyo 135-0061, Japan

Trademarks

Renesas and the Renesas logo are trademarks of Renesas Electronics Corporation. All trademarks and registered trademarks are the property of their respective owners.

Contact Information

For further information on a product, technology, the most up-to-date version of a document, or your nearest sales office, please visit: