Application Note

RS-232 Glossary and Selection Guide

Parker Dodson

Transceiver Interface

ABSTRACT

RS-232 is a long-standing communication standard. This document gives an overview on the RS-232 standard, provides explanations of key electrical and timing specifications of RS-232 transceivers, and includes a selection guide to help choose the correct RS-232 for a specific application.

Table of Contents

List of Figures

List of Tables

Trademarks

All trademarks are the property of their respective owners.

1 Introduction

RS-232 is a common point-to-point communication interface for various peripheral devices to enable communication between a host and a peripheral. RS-232 conforms to the TIA-232 and EIA-232 standards. To understand how to choose the correct RS-232 device for a system, a brief overview of the RS-232 standard as well key specifications for the transceivers is discussed in the following sections.

2 RS-232 Standard Overview

The RS-232 standard covers three areas of interest: electrical, functional, and mechanical. The electrical specifications include the physical electrical layer standard definitions.

2.1 Electrical Overview

The RS-232 standard defines multiple key electrical characteristics. RS-232 is a single ended point-to-point communication protocol – which means each data signal travels along one wire (as opposed to differential which uses two wires for one data signal) and there are only two nodes at each end of the communication bus. The nature of this bus is inherently unbalanced. The bus operates in a full duplex manner – which means that the bus can transmit and receive data simultaneously. Older versions of the standard required a data-rate of 19.2Kbps at a cable length of 50 feet; however, since there is variation between many cables with respect to their electrical properties modern revisions of the RS-232 standard now requires a minimum data-rate of 19.2Kbps with a capacitive load of 2500 pF – where the bus length is limited by capacitance per unit length. RS-232 transceivers can go up to 1Mbps. The signal levels are defined as such: a logic one from a transmitter is between –5 V and –15 V and logic 0 from the transmitter is between 5 V and 15 V. For a transceiver to be compliant, the device must recognize a voltage from –3 V to –15 V as logic 1 and voltages between 3 V and 15 V to be a logic 0 – the receivers can be more sensitive depending on the specific device chosen. The maximum output current can be up to 500 mA by standard, but generally most ICs are designed well below this level. Finally, the input impedance of a receiver is nominally 5 kΩ but can be as low as 3 kΩ.

Table 2-1. RS-232 Interface Overview

Specification	Definition
Wiring	Single ended
Topology	Point to point (2 communication nodes)
Duplex	Full
Minimum Data Rate	19.2Kbps at 2500-pF load
Output Signal Levels	–15 V to –5 V for Logic 1; 5 V to 15 V for Logic 0
Receiver Sensitivity	±3 V
Receiver Input Impedance	5 kΩ (nominal); 3 kΩ (minimum)
Maximum Output Current Allowed	500 mA (but many ICs are limited much lower)

2.2 Functional Overview

Beyond the electrical specifications, RS-232 includes functional definitions of 24 different signals; however, common usage uses 8 or less of the defined signals. This document covers the eight most commonly-used signals in RS-232. The signals can be broken up into four different categories: Common, Data, Timing, and Control signals; however, most signals fall into the *Control* category. *Timing Signals* are rather rare in RS-232 interfaces and have limited use and are not used in standard 8, or less, signal RS-232 interfaces which TI transceivers primarily support. The RS-232 standard defines a Data Terminal Equipment (DTE) which acts as the host and controller and a Data Communication Equipment (DCE) which acts as the peripheral to the host and controller.

The *Common* category is just the name for the ground wire between two RS-232 devices and has no purpose beyond providing a ground reference.

The Data signals are the lines that receive and transmit data – two data signals are common in RS-232. The TD signal refers to the Transmitted Data signal and the RD signal refers the received data line. The TD signal line is defined as the transmitted data by the DTE to the DCE, where the RD line is defined as the received data from the DCE to the DTE. Even though both nodes are transmitting and receiving data, the TD and RD lines are specific to the host node in the system not the peripheral.

The *Control* signals are used to control flow of data between the two nodes in an RS-232 system. This gives a higher layer of control beyond what can be done in the physical layer alone and allows for a more directed focus on implementing the firmware for RS-232 systems. There are 2 to 6 common control signals that are used for handshaking between two nodes before data transmission occurs. In applications that require some handshaking, a common use case is to use the two data signals + two control signals. These control signals are Ready to Send (RTS) and Clear to Send (CTS). The RTS signal is asserted when the DTE has data that is ready to transmit to the DCE through the TD signal; while the CTS signal is asserted after the RTS signal has been received and the peripheral is letting the host know it is ready to receive data. However, this simple version of handshaking is not the only common handshaking signal used when using RS-232 and systems such as modems. Modems typically add an additional 4 control signals on top of RTS and CTS. Along with RTS and CTS, common control signals also include Data Terminal Ready (DTR), Data Set Ready (DSR), Data Carrier Detect (DCD), and Ring Indicator (RI). The DTR signal is asserted by the DTE to the DCE that it is ready to transmit or receive data while the DSR signal is asserted by the DCE to the DTE after the DTR signal to let the DTE know that it is connected to the communications line. The DCD signal is a signal from the DCE to DTE to show that there is a valid connection between the DTE and the DCE. Finally, the RI signal is a signal from the DCE sent to the DTE to show that there is a ringing on the communication line – or more simply that the DCE wants to communicate with the DTE itself – by which the DTE responds by asserting the DTR signal.

2.3 Mechanical Overview

The final portion of the RS-232 standard focuses on the mechanical interface for RS-232 connections. The two commonly-used connectors are DB25 and DB9S. The DB25 connector allows the RS-232 functional signal to each have a connection point. The more common DB9S connector supports the eight most common functional RS-232 signals (as previously discussed) plus a common ground connection.

3 RS-232 Transceiver Key Specification Overview

When planning an RS-232 based communication system, there are many different transceiver options to choose from. To be able to quickly navigate to parts that are designed for a specific use case or application there are a few key specifications along with some optional features that are common to RS-232 compliant devices. These areas of interest can be broken down into three categories: electrical characteristics, timing and switching characteristics, and optional features that can be present in RS-232 compliant devices.

3.1 Electrical Characteristics

The electrical specifications of RS-232 complaint devices include non-timing related specifications such as signal levels, leakage currents, power, and input thresholds for the device. The following list includes common specifications and where to find them in TI RS-232 compliant transceivers.

- *Supply Voltage (V_{CC}, V_{SS}*, V+*, V–*, and V_L*)*:

  Supply voltage is the power source for the transceiver; however, due to the large voltage swings possible in many RS-232 applications there are multiple supply voltage ratings that all mean slightly different things. The * denotes a pin that may or may not be present on an RS-232 device.
- V_{CC} is the positive power supply – this is generally 3.3 V – 5 V for most modern RS-232 devices (but can be up to 15 V depending on the device). V_{CC} has three main uses that it can occupy in a common RS-232 device. The first is providing the bias for the controller side and bus side pins directly allowing positive voltage swings to be generated- in these devices a negative supply pin - V_{SS} - is also included to provide a negative supply voltage to provide negative voltage swings. The second is bias the controller side pins and to act as a input voltage for the integrated charge pump to generate the bus voltage swings. Finally, V_{CC} can also be used to just feed the charge pump in devices with separate logic voltage supply pins available.
- V+ and V– are the charge pump output pins when seen on a device and in the data sheet they represent the voltage ratings of these pins. If these pins exist on the device, the pins are usually connected only to an external capacitor. These output pins have ratings on the absolute maximum and recommended operating conditions table as well – but no external voltage is applied to this pin. These supplies are used to provide drive strength to the bus pins.
- V_L is the power supply for separate logic pin supply voltages in devices with separate bus and logic supply. This power supply allows a lower control voltage to interact with the console side pins as the interface with low voltage (< 3.3 V) controllers (down to 1.8 V). This information is found in the same data sheet sections as the other supply voltage parameters.
- *Supply Current (I_{CC})*:

  Supply current or I_{CC} is the quiescent current of the device while active with no loading to give a baseline power consumption for the device. This specification is important to understand if power savings is important to the application. Supply current is usually found in the data sheet either under Electrical Specifications or Electrical Specifications-Power.
- *Common Driver Electrical Characteristics (V_{OH}, V_{OL}, V_{IH}, V_{IL}, I_{IL}, I_{IH}, I_{OS}, R_O, and I_{OZ})*:

  Many RS-232 devices separate most of the driver electrical characteristics into independent sections in the data sheet – except for V_{IH} and V_{IL} which is typically found in the recommended operating conditions.

  – V_{IL} and V_{IH} are the console-side input thresholds and stand for Voltage, Input Low Threshold and Voltage, Input High Threshold, respectively. These values are applied to enable, driver input, or special feature pins that can register a logic low or logic high state. If an input voltage with respect to device ground is ≥ than V_{IH} (min), the pin state is registered a logic high and if the input voltage with respect to device ground is ≤ V_{IL} (max), the pin state is registered a logic low. On many devices V_{IL} (max) and V_{IH} (min) are rated to 0.8 V and 2 V, respectively, but on devices with a separate logic supply voltage or devices without internal charge pumps, these values can deviate from the most common threshold levels. Holding the input voltage between the V_{IL} (max) and V_{IH} (min) thresholds can cause large shoot-through currents and can lead to oscillations at output due to LC parasitics on the power line for the device.

  – I_{IL} and I_{IH} are the resulting current draw into a console side pin when the voltage applied with respect to ground is a logic low for I_{IL} and logic high for I_{IH}. These specifications are used to help size pullup and pulldown resistors to provide proper default state operation.

  – I_{OS} is the output short-circuit current from a driver output to device ground. This value gives the maximum expected short-circuit current and potentially also provides a typical short-circuit current value. The

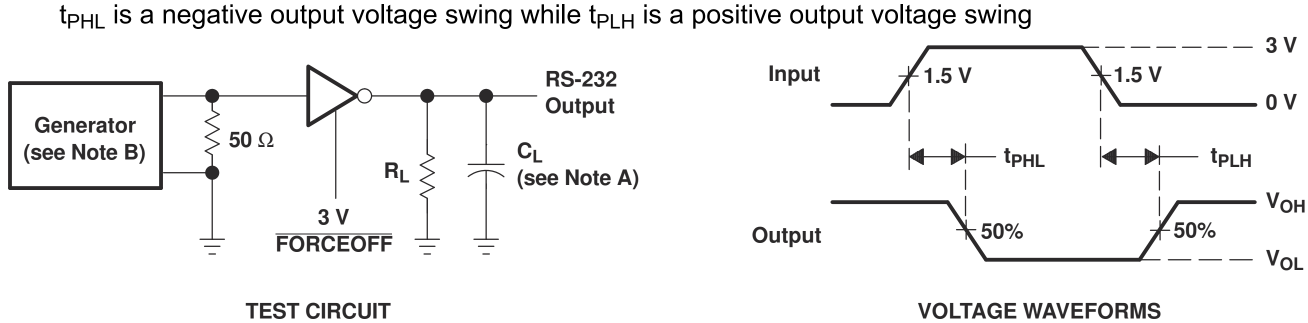
designer must control the short-circuit duration to prevent too much power being dissipated over the device. Repeated power overages can lead to premature part failure. Typically only one output is allowed to be shorted at a time. See the specific device data sheet for more information.

  - R_O is the output resistance of the driver. Generally this is when the supply voltage is disconnected from the device. The minimum of this specification is usually 300 Ω but many devices have a typical value in the KΩ to MΩ range. This specification gives an idea on how the driver loads the bus when unpowered.
  - I_{OZ}, also called I_{OFF}, is the leakage current from the driver when the driver is disabled. This is the amount of current that can be sourced or sunk from the driver pin when disabled. This helps characterize the bus loading when the driver is inactive.
- *Common Receiver Electrical Specifications (V_{OH}, V_{OL}, V_{IT+}, $V_{IT–}$, V_{HYS}, R_I, and I_{OZ})*
  - V_{OH} and V_{OL} are the output high-level voltage and output low-level voltage, respectively, on the console side pins. When an RS-232 device receives data on one of the RX bus pins, the corresponding output voltage on the console side is V_{OH} for a logic high and V_{OL} for a logic low. These values are used to provide accurate communication between the RS-232 transceiver and controller.
  - V_{IT+} and $V_{IT–}$ are the positive-going and negative-going input voltage thresholds, respectively, for the RS-232 device RX bus pins. These voltage thresholds function similar to the console-side logic input thresholds V_{IH} and V_{IL}, but are dependent on current state. If the device is receiving a logic low when the input signal crosses the V_{IT+} (max) boundary, a logic high is read at the RX bus pin. Whereas the inverse is true of the $V_{IT–}$ (min) boundary. These voltage thresholds are used to help determine how much attenuation the system is able to handle from driver to receiver.
  - V_{HYS} is the hysteresis voltage between the V_{IT+} and $V_{IT–}$ thresholds. This parameter is used to determine the noise margin allowed between the input thresholds to provide error-free communication between driver and receiver.
  - R_I is the input resistance of the bus-facing RX pins on the RS-232 device. R_I acts a resistor to ground. The RS-232 standard requires a minimum input resistance of 3 kΩ – with many devices having a possible range of input resistance of 3 kΩ to 7 kΩ; however, some devices can be higher than 7 kΩ.
  - I_{OZ} is the console-side receiver output pin leakage current. I_{OZ} is the same parameter as I_{OZ} on the driver, but specifies the console-side RX output.

3.2 Switching and Timing Characteristics

This section defines the switching characteristics and timing characteristics of common drivers and receivers.

- *Common Driver Switching Characteristics and Timing Characteristics (DR, t_{PHL}, t_{PLH}, $t_{sk(p)}$, and SR(tr))*
  - DR refers to the maximum data rate of the transceiver. RS-232 only requires 20Kbps, however many devices can go up to 1Mbps. This value is specified with a resistor and capacitor representing 50 feet of cabling + a resistor to model the input impedance of the RS-232 device RX bus pin. For best performance limit the maximum speed of application to the minimum data rate listed in the device data sheet.
  - t_{PHL} and t_{PLH} are the propagation delay times from high to low and low to high, respectively. This value measures the time from an input signal reaching 50% of its value to the output reaching 50% of its value. t_{PHL} is a negative output voltage swing while t_{PLH} is a positive output voltage swing

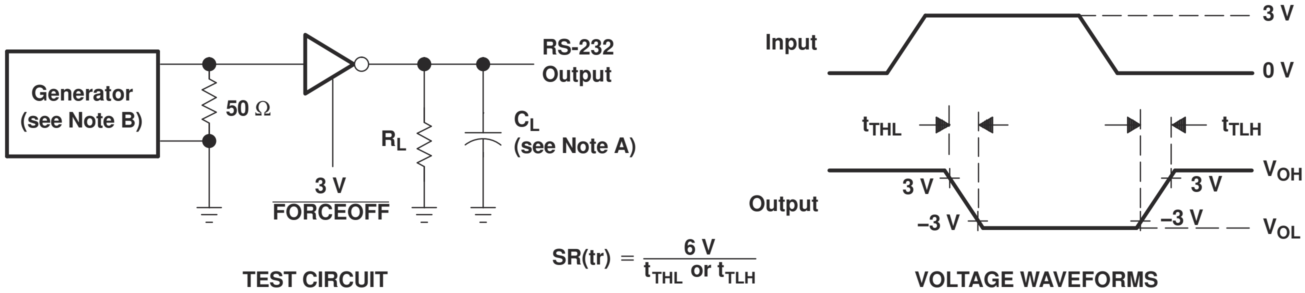


NOTES: A. C_L includes probe and jig capacitance.
B. The pulse generator has the following characteristics: PRR = 1 Mbit/s, Z_O = 50 Ω, 50% duty cycle, $t_r \leq 10$ ns, $t_f \leq 10$ ns.

Figure 3-1. Example TPHL and TPLH Test Setup from the TRSF3243E Data Sheet

  - $t_{sk(p)}$ is the pulse skew of the driver. Figure 3-1 looks at the magnitude of difference between t_{PHL} and t_{PLH} - since in real devices these times typically only vary slightly. The higher the skew is in the system, the more additive jitter exists in the system because skew changes the periodicity of the data signal.

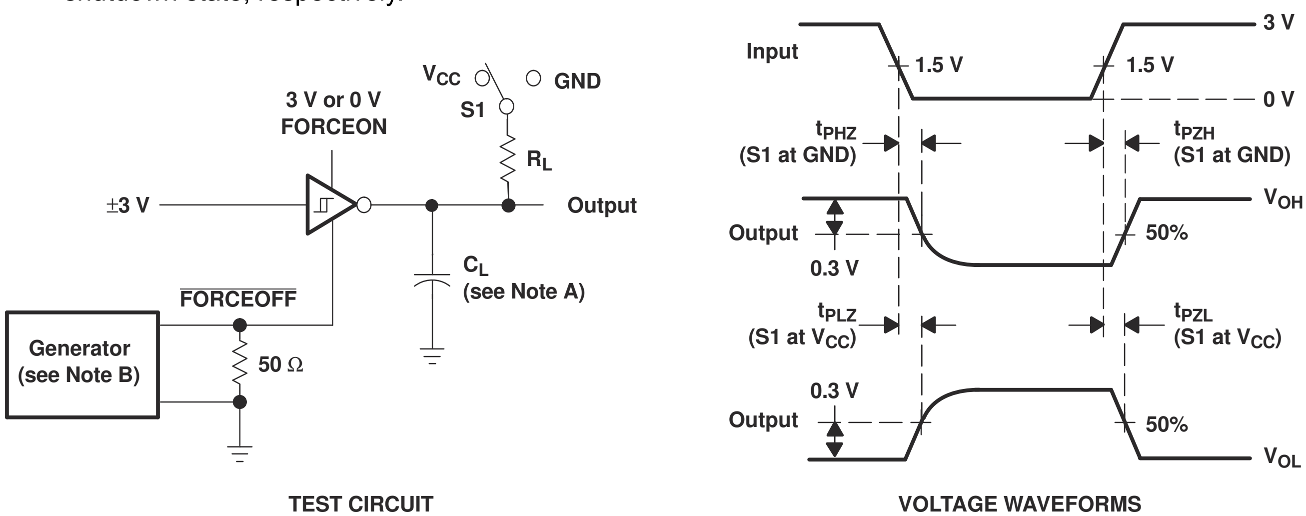
– SR(tr) is the slew rate during the transition region of the driver output. SR(tr) measures the voltage output per microsecond of the device in the linear region of operation (typically 10% to 90% of signal value). SR(tr) gives an idea of how fast the transition speed is and can help determine what frequency content is generated during switching. The change in voltage magnitude divided by the duration of the change is the slew rate.



NOTES: A. C_L includes probe and jig capacitance.
B. The pulse generator has the following characteristics: PRR = 1 Mbit/s, Z_O = 50 Ω, 50% duty cycle, $t_r \leq 10$ ns, $t_f \leq 10$ ns.

Figure 3-2. Slew Rate Test Setup Example from TRSF3243E Data Sheet

- *Common Receiver Switching Characteristics and Timing Characteristics (TPHL, TPLH, Tsk(p), Ten, and Tdis)*
  – t_{PHL}, t_{PLH}, and $t_{sk(p)}$ are all the same characteristics as described in the previous section on driver timing and switching characteristics. The only difference is that these parameters are measured from the input on RX bus pins to the output on RX console output pins.
  – t_{en} and t_{dis} refer to the enable time and disable time of the device. These specifications determine how long it takes the device to become active from a shutdown state or how long to put the device into a shutdown state, respectively.



NOTES: A. C_L includes probe and jig capacitance.
B. The pulse generator has the following characteristics: Z_O = 50 Ω, 50% duty cycle, $t_r \leq 10$ ns, $t_f \leq 10$ ns.
C. t_{PLZ} and t_{PHZ} are the same as t_{dis}.
D. t_{PZL} and t_{PZH} are the same as t_{en}.

Figure 3-3. Enable and Disable Time Test Setup Example from the TRSF3243E Data Sheet

3.3 Additional Features on Select TI RS-232 Transceivers

This section details a few features which are additional to RS-232 devices that are included on select TI RS-232 devices.

- *Integrated Charge Pump*

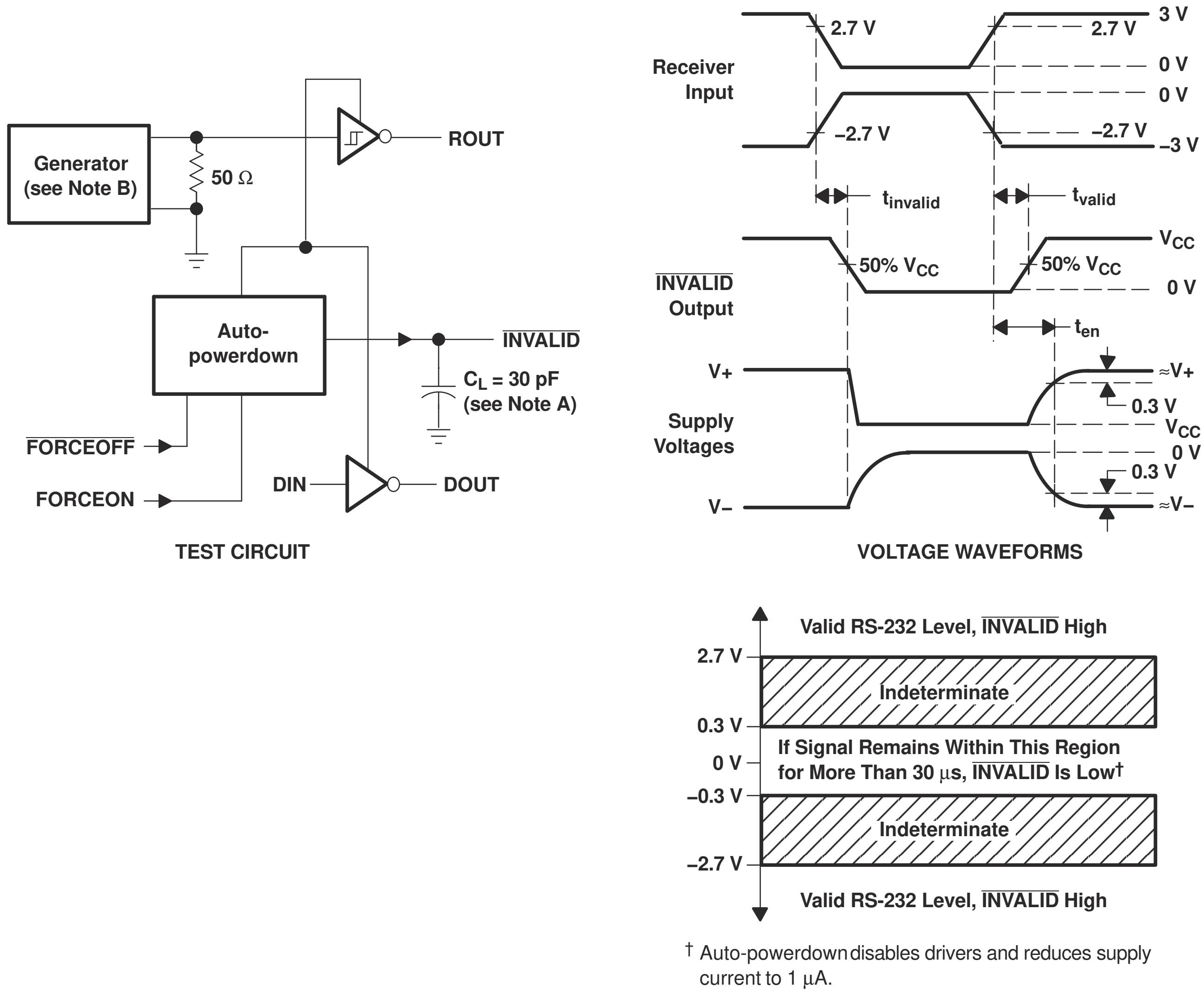
  The vast majority of TI RS-232 devices use an integrated charge pump that requires external capacitors for charge pump operation. This allows the device to create the necessary RS-232 compliant output voltage swings from a single supply voltage (typically 3.3 V to 5 V). Some older devices do not have this feature and require dual supplies for RS-232 compliant operation.

- *Slew Rate Control*

  One device, the SN55188, has an additional feature name *slew rate control* where there is a measured relationship between the output capacitor and the device slew rate. Most devices have a decrease in slew rate for an increase in output capacitance, the only difference is that this device gives a relationship to allow the customer to externally control the slew rate. For lower slew-rate requirements, picking a device with a lower data rate is generally a best practice.
- *Power Down*

  Power down as a feature just allows the device to be controlled via enable signals, thus allowing the device to be enabled and disabled as needed throughout system operation. The power down feature allows for more flexible control over power usage in the system.
- *Auto Power -Down and Auto Power-Down +*

  The Auto Power-Down and Auto Power-Down+ feature allows the device to go into a disabled state (charge pump inactive) after no transitions have occurred on the TX or RX inputs. The difference in delay time is typically 30 µs for Auto Power-Down Parts and 30 s for Auto Power-Down+ parts. These parts include a flag pin, $\overline{\text{INVALID}}$, that goes low when the data on the RX bus is not within the valid range.



NOTES: A. C_L includes probe and jig capacitance.
B. The pulse generator has the following characteristics: PRR = 5 kbit/s, Z_O = 50 Ω, 50% duty cycle, $t_r \le 10$ ns, $t_f \le 10$ ns.

Figure 3-4. Auto-Power-Down Test Setup Example From TRSF3243E Data Sheet

4 RS-232 Transceiver Selection Guide

Table 4-1 highlights the key RS-232 devices and their most important functional specifications and features.

Table 4-1. TI RS-232 Transceiver Selection

Device	Configuration	V_{CC}	VL (MIN)	MAX Data Rate	Output Voltage	Temperature Range	Package Options	Features
MAX3227E	1TX 1RX	3.3 V, 5 V	N/A	1Mbps	±5.4 V	0°C to 70°C, –40°C to 85°C	16-SSOP	Auto-Power Down Plus
TRSF3221	1TX 1RX	3.3 V, 5 V	N/A	1Mbps	±5.4 V	0°C to 70°C	16-SSOP	Auto-Power Down
SN75155	1TX 1RX	5 V, 12 V	N/A	400Kbps	±9.7 V	0°C to 70°C	8-SOIC, 8-PDIP	N/A
TRS3221E	1TX 1RX	3.3 V, 5 V	N/A	250Kbps	±5.4 V	0°C to 70°C, –40°C to 85°C	16-VQFN, 16-SSOP, 16-TSSOP	Auto-Power Down
TRS3122E	2TX 2RX	1.65 V to 5.5 V	1.65V	1Mbps	±5.4 V	–40°C to 85°C	24-VQFN	Auto-Power Down Plus
MAX3222E	2TX 2RX	3.3 V, 5 V	N/A	500Kbps	±5.4 V	0°C to 70°C, –40°C to 85°C	20-SOIC, 20-SSOP, 20-TSSOP	Power Down
TRS3223-Q1	2TX 2RX	3.3 V, 5 V	N/A	250Kbps	±5.4 V	–40°C to 125°C	20-TSSOP	Auto-Power Down
TRS202E	2TX 2RX	5 V	N/A	120Kbps	±9 V	0°C to 70°C, –40°C to 85°C	16-SOIC, 16-PDIP, 16-TSSOP	N/A
TRS3243E	3TX 5RX	3.3 V, 5 V	N/A	1Mbps	±5.4 V	–40°C to 85°C	28-TSSOP, 32-VQFN	Auto-Power Down
MAX3243E	3TX 5RX	3.3 V, 5 V	N/A	500Kbps	±5.4 V	0°C to 70°C, –40°C to 85°C	28-SOIC, 28-TSSOP, 28-SSOP, 32-VQFN	Auto-Power Down
MAX3243-EP	3TX 5RX	3.3 V, 5 V	N/A	250Kbps	±5.4 V	–55°C to 125°C	28-TSSOP, 28-SSOP	Auto-Power Down

5 References

1. Texas Instruments, *TRSF3243E 3-V to 5.5-V Multichannel RS-232 Compatible Line Driver and Receiver with ±15-kV IEC ESD protection Data Sheet*
2. Texas Instruments, *MC1488, SN55188, SN75188 Quadruple Line Drivers Data Sheet*