Understanding Power Requirements in RS-232 Applications

Introduction

As the popularity of asynchronous serial communication became widely accepted by the industry, the RS-232 standard gained very wide acceptance. The use of this standard is visible in almost all Industrial, Portable, Desktop, Data Acquistion and Test Measurement applications using a serial port for communication. Even though the standard specifies a maximum data rate for RS-232 of 20 kbps, some applications need for higher speed is overwhelming. More and more applications today require at least 120 kbps to support Laplink®, a popular communication software used by Laptop/Desktop computers for fast file transfer between two computers. RS-232 type Drivers and Receivers must also support this higher data rate to be Laplink compatible.

This application note covers the RS-232 circuit functions, an explanation of hardware handshaking, a step by step analysis of the hardware handshaking between a local and remote terminal, and power requirements/dissipation of the DS14C335.

RS-232 Handshaking Circuits

In a Terminal (DTE-Data Terminal Equipment) to Modem (DCE-Data Circuit Terminating Equipment) application, as shown in *Figure 2*, commonly only eight dedicated lines are required. Even though the standard defines a 25 pin connection, the de-facto 9 pin connector is very popular. These lines are DCD, RXD, TXD, DTR, DSR, RTS, CTS, RI and GND and are shown in *Figure 1*. Lets take a quick look at these dedicated lines along with their respective functions. Note that ON is defined as a positive voltage and OFF is a negative voltages on the cable.
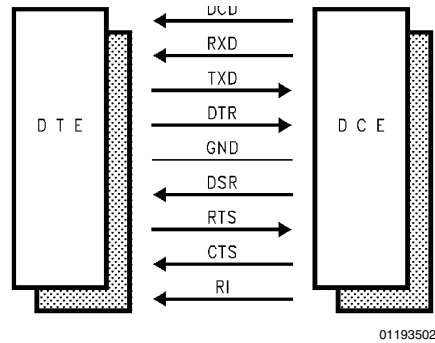

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FIGURE 1. Direction of Flow from DTE/DCE

DCD: Data Carrier Detect (DCE to DTE)

When this circuit is OFF locally, it indicates to the local terminal that the remote DTE has not switched its RTS circuit ON yet and the local terminal can gain control over the carrier line if needed. When this circuit is ON locally, it indicates to the local terminal that the remote modem has received a RTS ON condition from its terminal and the remote DTE is in control over the carrier line.

RXD: Receive Data (DCE to DTE)

Receive data circuit from modem to DTE.

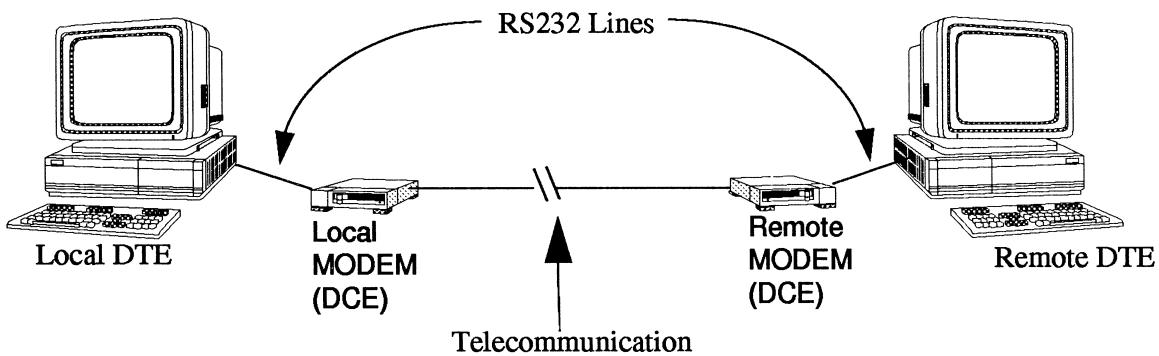## TXD: Transmit Data (DTE to DCE)

Transmit data circuit from DTE to modem.

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FIGURE 2. DTE to DCE Interface

DTR: Data Terminal Ready (DTE to DCE)

The DTR pin is generally ON when the terminal is ready to establish communication channel through its modem. By keeping the DTR circuit ON the DTE lets an *"auto answer"* modem accept the call unattended. The DTR circuit is OFF, only when the DTE does not want its modem to accept calls from remote locations. This is known as *local mode*.

DSR: Data Set Ready (DCE to DTE)

Both modems switch their DSR circuit ON when a communication path has been established between the two sites (local and remote modem).

RTS: Request To Send (DTE to DCE)

When a terminal is ready to transmit data, it switches the RTS circuit ON, indicating to the local modem that it is ready to transmit data. This information also gets passed to the remote modem. The RTS line controls the direction of data transmission. During transmit mode, the line is ON and during receive mode it's OFF.

CTS: Clear To Send (DCE to DTE)

When CTS swicthes ON, the local modem is ready to receive data from its DTE and the local modem has control over the telephone lines for data transmission.

RI: Ring Indicator (DCE to DTE)

When the modem receives a call, the RI circuit switches ON/OFF in sequence with the phone ringing informing the DTE that a call is coming in. This indicates that a remote modem is requesting a dial-up connection.

GND

Ground, signal common.

Hardware Handshake Flow

A step by step analysis of handshaking illustrates how each circuit is used to establish communication between a local and a remote site. To keep the subject simple, assumption has been made that transmission is from Local to Remote only.

1. Local DTE switches DTR ON and local modem dials the phone number of the remote modem.

2. If DTR at remote location is ON, the remote modem's RI turns ON/OFF in sequence with the phone ringing, indicating a call coming in.

3. The remote modem returns an answer-back tone to the local modem. Upon detection of this tone, the local modem and the remote modem establishes the on-line connection. At this point both modems switch their DSR pins ON indicating that a connection has been established.

4. The local DTE switches RTS ON indicating that it is ready to send data. This signal gets passed on to the remote modems DCD circuit.

5. The local modem checks to make sure that local DCD is OFF, which indicates that the remote modem is not in control of the carrier line.

6. The local modem then switches CTS ON to the local DTE to inform that it can start sending data. Locally the DCD circuit stays OFF. On the remote modem DCD stays ON. RTS is held ON by the local DTE throughout the duration of the connection.

7. The local DTE sends data through TXD to modem for transmittal.

8. The remote modem receives the data and sends the data to its terminal via the RXD circuit.

9. When data transmittal is finished, local DTE drops RTS, which drops the DCD at remote modem and CTS at local modem. Transmission of data can be discontinued by hanging up the phone line, by the DTE dropping its DTR circuit, by disconnecting the modem cable from the DTE.

10. Now, either DTE is ready to start all over again and gain control of the telecommunication line.
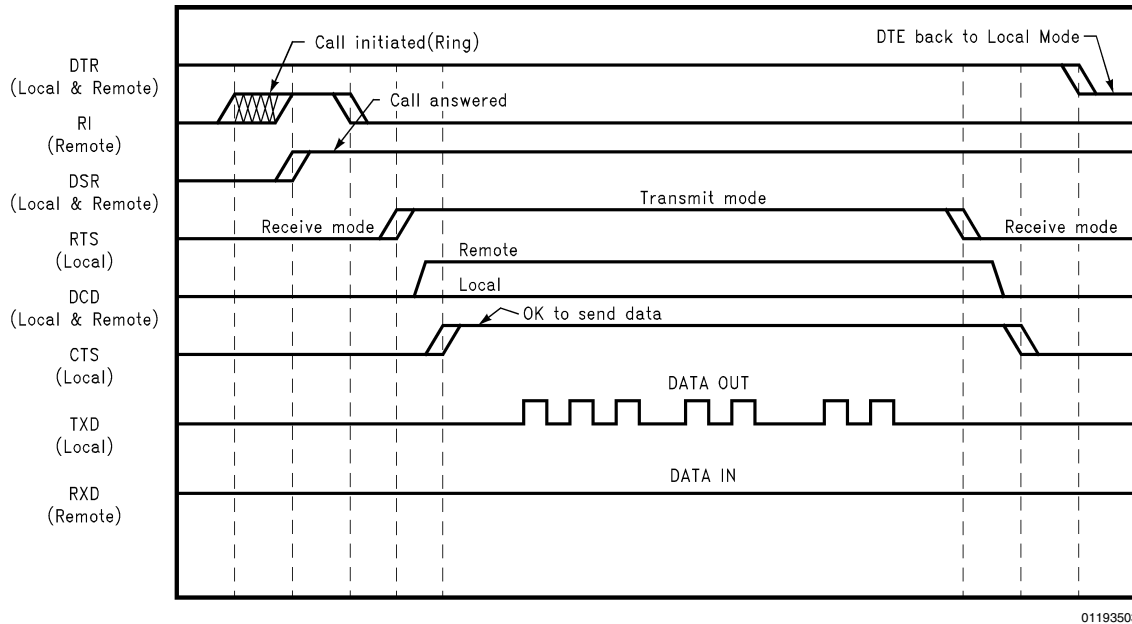
Hardware Handshake Flow (Continued)

FIGURE 3. Graphical Illustration of Hardware Handshaking

From the above explanations, in half-duplex communication, we can derive that in transmit mode, only one driver (TXD) is switching (up to 120 kbps) while the other drivers/receivers are at some known steady state (not switching). Similarly, on a receive mode, only one receiver (RXD) is switching while other lines maintain known steady state levels.

Power Consumption

Based on the above observations, lets determine how I_{CC}, frequency, internal/external capacitance and load resistance play a role in power consumption for the DS14C335. Total power consumption is the static and the dynamic power combined. CMOS devices typically consume minimal power in a static condition. This can be calculated simply by multiplying I_{CC} with V_{CC}.

Under a loaded condition, the external loading of the driver directly effects the power dissipation of the device and application. The RS-232 driver is normally connected to a cable and a receiver at the far end. Since the transition time of the driver is set to be substantially longer than the cable delay, the cable load represents a lumped capacitive load and a series resistance. The series resistance on short cables (< 200 feet) can be neglected since it is very small compared to the receiver input resistance. This means the cable may be modeled as a lumped capacitive load equal to the capacitance per unit length multiplied by the length of the cable. 1000 pF is commonly used to represent a 20 foot cable, and 2500 pF is used as the maximum specified cable load. The receiver input resistance is specified to be between 3 kΩ and 7 kΩ, 5 kΩ is used as a typical, and 3 kΩ is the worst case from a power point of view. This equivalent load is illustrated in *Figure 4*.
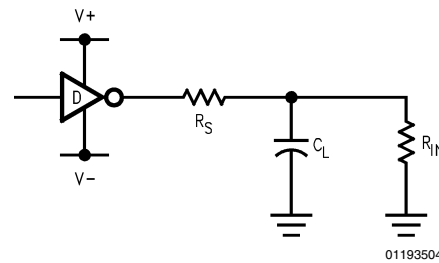

FIGURE 4. Load Seen by the Driver

Where: R_S = Cable series resistance.

C_L = Cable load capacitance.

R_{IN} = Input resistance of the Receiver.

A channel that is in a steady state is loaded by the receivers input impedance since the cable capacitance has charged up. The output current of the driver is determined by the output voltage of the driver (V_{OH} or V_{OL}) divided by the input resistance of the receiver. For example, a 7V level, across the 3 kΩ load, requires 2.3 mA.

Dynamic power consumption has three major components. The switching current (spike current, also commonly called Conduction Overlap Current) during transitions, external load resistance and external load capacitance transient dissipation.

When the voltages to an NMOS/PMOS pair are in transition, both transistors turn on partially, creating a relatively low impedance path between the supply rails (V+ and V−). This

Power Consumption (Continued)

is known as simultaneous conduction and is illustrated in *Figure 5*. As input frequency increases, the period decreases. At some point the output transistors fail to charge and discharge fully causing both upper and lower output transistor to stay on momentarily. This simultaneous conduction increases I_{CC} as the input signal's frequency is increased.

The charging and discharging of the large load capacitance C_L contributes to power consumption as well. The external load capacitance increases power in the same manner as the internal capacitance. A channel that is switching at speed is affected by all the components described previously. These new components contribute to the increased output current sourced or sunk by the driver to charge or discharge the capacitive load. This component of the load current will increase if the external capacitance is increased and also if the switching rate of the device is increased.
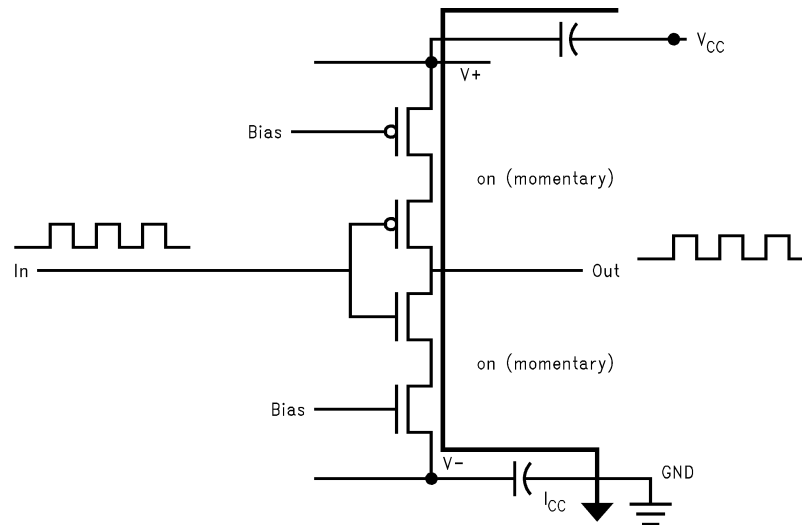
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FIGURE 5. Simultaneous Conduction and I_{CC}

DS14C335 and Power Consumption

National's DS14C335 is a 3 X 5 Driver/Receiver combination providing a one-chip solution for a 9 pin RS-232 DTE application. *Figure 6* shows a worst case situation where all 3 drivers and 5 receivers are switching under different loading conditions. Under this worst case condition, at 10 kHz (20 kbps), supply current is 30 mA (2500 pF). Under a no load condition, supply current stays relatively flat. *Figure 7* shows a true RS-232 application where one driver (TXD) is switching while the other two are driver (DTR and RTS) remain High (loaded) as shown in *Figure 3*. At 10 kHz, supply current reads 26 mA (2500 pF), under this real world RS-232 application. Decreasing the capacitive load also decreases the supply current as shown in *Figure 7*. *Figure 8* illustrates one receiver (RXD) switching. Supply current is almost constant under this operating condition.

DS14C335 and Power Consumption (Continued)

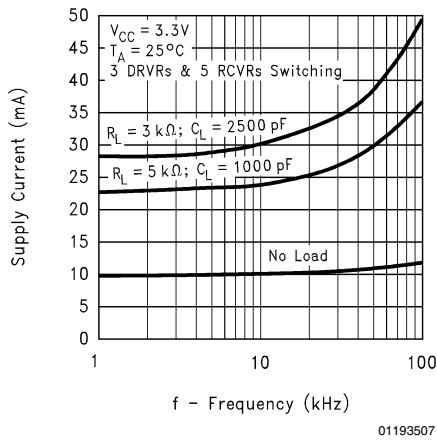**DS14C335 Supply Current vs Frequency vs Driver Loads**

V_CC = 3.3V
T_A = 25°C
3 DRVRs & 5 RCVRs Switching

R_L = 3 kΩ; C_L = 2500 pF
R_L = 5 kΩ; C_L = 1000 pF

No Load

f – Frequency (kHz)

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FIGURE 6. All Driver and Receiver Switching

DS14C335 Supply Current vs Frequency vs Driver Loads

V_CC = 3.3V T_A = 25C
One Driver(TXD) switching (Loaded)
Two drivers(DTR, RTS) High(Loaded)

R_L = 3k, C_L = 2500 pF
R_L = 3k, C_L = 1000 pF
R_L = 5k, C_L = 1000 pF

f – Frequency (kHz)

ON
DTR
ON
RTS
TXD DATA

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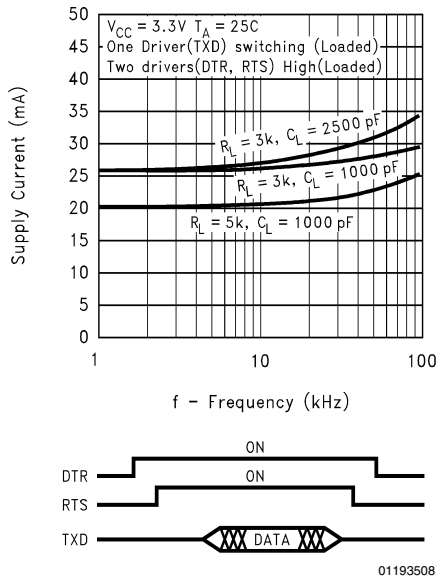
FIGURE 7. One Driver (TXD) Switching

DS14C335 Supply Current vs Frequency (Receiver)

V_CC = 3.3V T_A = 25C
One RCVR(RXD) switching
All Drivers Loaded
4 Receivers at steady state

No load on RCVRS
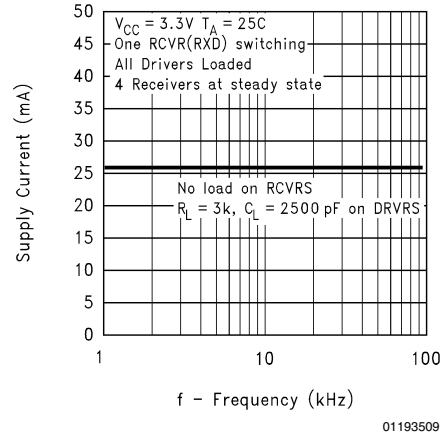R_L = 3k, C_L = 2500 pF on DRVRS

f – Frequency (kHz)

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FIGURE 8. One Receiver (RXD) Switching

Looking at the Supply Power vs Data Rate (*Figure 9*) we can see that under multiple driver switching and at a maximum data rate of 120 kbps, the supply power is 120 mW (2500 pF load). With one driver switching and the other two driver output at High (RS-232 Application), the supply power at maximum data rate of 120 kbps drops to 103 mW (2500 pF load).
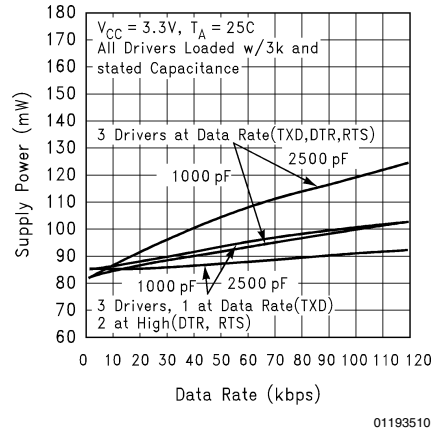
DS14C335 Supply Power vs Data Rate

V_CC = 3.3V, T_A = 25C
All Drivers Loaded w/3k and stated Capacitance

3 Drivers at Data Rate(TXD,DTR,RTS)
2500 pF
1000 pF

1000 pF 2500 pF
3 Drivers, 1 at Data Rate(TXD)
2 at High(DTR, RTS)

Data Rate (kbps)

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FIGURE 9. Supply Power vs Data Rate

The DS14C335 also offers a SHUTDOWN (SD) feature where the device can be de-activated by applying a logic High on the SD pin. This will lower the supply current to less than 1 µA (typical). In addition, in this mode one receiver (R5) remains active to monitor RI (Ring Indicator). This active receiver can sense incoming calls and inform the power management circuit to activate the device. SHUT-DOWN mode saves battery life when the serial port is not used. In this mode, power dissipation is only 3.3 µW allowing battery charge to be used by other active circuitry.

Other Industry Standards (RS-232)

RS-562 is another standard that is gaining popularity in the Industry. RS-562 is compatible to RS-232, however, there are some trade-offs. *Table 1* illustrates a comparison and the major differences between the two standards.

Other Industry Standards (RS-232) (Continued)

TABLE 1. Comparison and Major Differences between RS-232 and RS-562

Specifications	RS-232	RS-562
Mode of Operation	Single-ended	Single-ended
Receiver Input Resistance (Ω)	3 kΩ to 7 kΩ	3 kΩ to 7 kΩ
Receiver Sensitivity	±3V	±3V
Driver Output Current (Powered Off, ±2V)	±6.67 mA (300Ω)	±6.67 mA (300Ω)
Driver Output Short Circuit Current Limit	**≤100 mA**	**≤60 mA**
Number of Drivers and Receivers Allowed	1 Driver 1 Receiver	1 Driver 1 Receiver
Max Cable Length	~50' (2500 pF)	2500 pF (20 kbps) 1000 pF (64 kbps)
Max Data Rate	**20 kbps**	**64 kbps**
Driver Output	**±5V Min** **±15V Max**	**±3.7V Min** **±13.2V Max**
Driver Load	3 kΩ to 7 kΩ	3 kΩ to 7 kΩ
Driver Slew Rate	≤30 V/μs	≤30 V/μs

Even though RS-562 standard specifies data rates greater than RS-232, the DS14C335 (RS-232) far exceeds the 64 kbps of RS-562. The most significant difference between the two standards is the noise margin. As shown in *Figure 10*, RS-232 devices have a noise margin of 2V or greater. Typically for DS14C335, the noise margin is 4.5V (7.5V − 3V) whereas RS-562 has a noise margin as low as 700 mV (3.7V − 3V). A lower noise margin (RS-562) means limited rejection of external noise, crosstalk and ground potential differences which can all commonly occur in RS-232 type communication.
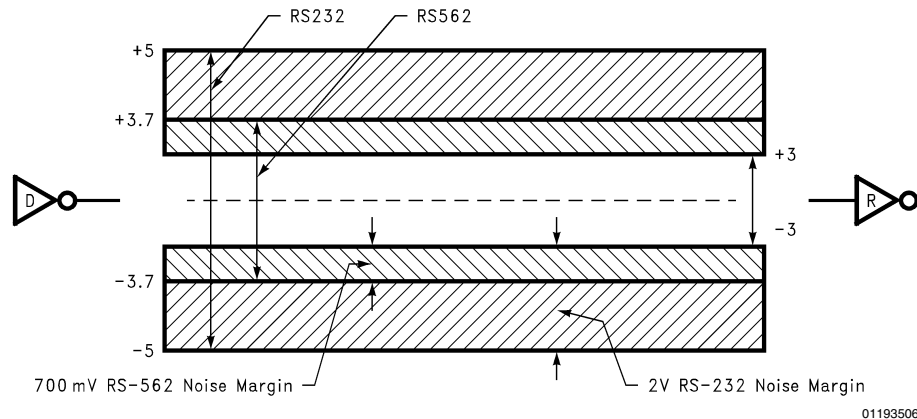

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FIGURE 10. Noise Margin Comparison

Conclusion

Design Engineers are plagued with ground shift, noise problems and a noise margin of only 700 mV is not acceptable in many applications. RS-232 guarantees a 2V noise margin and Nationals DS14C335 is the preferred choice for applications requiring data rates pushing 120 kbps. Also, we have observed that in a half-duplex RS-232 DTE to DCE application, the supply current of the device is lower than simultaneous switching of all drivers and receivers as the application only requires one driver (TXD) or one receiver (RXD) switching at a time while the rest of the drivers/receivers maintain known steady state levels. Along with the power dissipation calculations, a discussion of the SHUTDOWN feature was also presented. This SHUTDOWN mode is highly desirable for any application that is battery powered, as it saves battery charge when the serial port is inactive.

References

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