Serial Interfaces

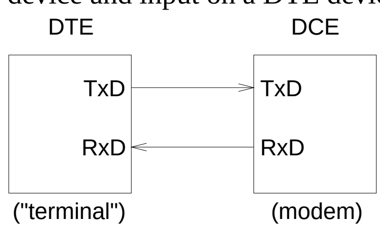
Serial interfaces are typically used to connect computer systems and low-speed external peripherals such as modems and printers.
You should be able to describe the operation and format of data and handshaking signals on an RS-232 interface.

RS-232 Interface

The most widely used peripheral interface is the "RS-232" serial interface. This interface is available on most general-purpose microcomputers.

DTE and DCE

The serial interface was originally designed to connect modems (Data Communications Equipment - DCE) to computer terminals (Data Terminal Equipment - DTE). In its simplest form the interface has two signal lines, Transmit Data (TxD or TD) and Receive Data (RxD or RD), and a ground reference. The TxD signal is an output on a DTE device and an input on a DCE device. Similarly, RxD is an output on a DCE device and input on a DTE device.

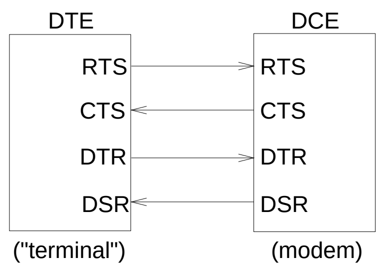


Exercise: Is the "Transmit Data" (TxD) signal an input or an output? How about "Receive Data" (RxD)? Is a computer a 'modem' or a 'terminal'?

The standard RS-232 connector is a 25-pin D-style connector called a "DB-25". Pin 2 is TxD, pin 3 is RxD and pin 7 is signal ground. When two serial devices are connected together they are connected pin-to-pin (RxD is connected to RxD and TxD is connected to TxD). This means that RxD must be an input on one device and an output on the other device. Thus the terms RxD and TxD *do not* say whether a pin is an input or output but are instead names for pins on the connector. Typically DTE connectors are male and DCE connectors are female.

In addition to the two data lines, most RS-232 devices implement additional handshaking pins. Of these, the most useful are called RTS (Request To Send) and CTS (Clear To Send). The CTS pin is a DCE output and is used by the DCE to indicate that it can accept data on the TxD line. The RTS line is an output on a DTE and is used to indicate that the DTE wants to send (RTS was originally used to control half-duplex modems – these are rarely seen today).

Since these signals are used to control the flow of data from the DTE (and optionally from the DCE) these pins are called [hardware] "flow control" signals.



The second set of control signals are DTR (Data Terminal Ready) and DSR (Data Set Ready). These signals indicate that the DTE and DCE devices respectively are connected and operational (typically, simply that the power is turned on). Some modems can use DTR to force a reset and DSR as a replacement for CD (see below).

A number of other handshaking signals are available but are less widely used. Carrier Detect (CD) is asserted by modem-type DCEs when a carrier signal is present. This signal is typically used by system software to indicate the start and end of a dial-up session. Another signal pin is Ring Indicator (RI) which is used by modem-type DCEs to indicates that the attached phone is ringing. This signal is seldom used. The RS-232 specification defines a number of other signals (e.g. a secondary serial interface) but they are almost never used.

In addition to the standard DB-25 serial connector, there are a number of smaller connectors that are widely used. These connectors are physically smaller and carry a subset of the RS-232 pins. The most common are the DB-9 connectors popular on IBM PC-AT clones, the round DIN connectors (popular on Apple computers), and the inexpensive telephone-style "RJ-11" (6-pin) and "RJ-45" (8-pin) connectors (popular on devices with many serial interfaces).

Adapters are often used not only to convert between different styles of connectors but also to convert between male and female connectors (a "gender adapter" which allows two males or two females to be connected together) and to switch between DCE and DTE pinouts (a "null modem" which allows two DCEs or two DTEs to be connected together).

Interface Voltages

The serial interface voltage levels are bipolar with respect to ground. The table below summarizes the relationship between voltage level, logical meaning on handshaking lines and data bit value (values on TxD and RxD lines).

Signal Level	Line State	For Handshaking	For Data
negative	mark	false	1
positive	space	true	0

The received signal must be greater than +3 volts to be considered positive and less than -3 volts for negative. Intermediate values are considered invalid. This allows disconnected pins to be detected.

Note: *The data lines (TxD and RxD) are asserted when* **negative***. The control lines (e.g. CTS) are asserted when* **positive***.*

Character Format

Data is transferred over the serial interface one bit at a time. A **positive** (zero) bit (the "start bit") is sent to indicate the start of the character being sent. This is followed by the bits in the character, from LS to MS bit. After sending the 7 (for plain ASCII) or 8 (for arbitrary bytes) bits, an optional parity bit (even or odd) can be sent, followed by a one "stop" bit.

Exercise: Draw the waveform used to send the ASCII character 'e' (hex 65) at 9600 bps with no parity.

The start bit allows a receiver to re-synchronize itself at the start of each character. This allows for small variations between transmitter and receiver timing.

Exercise: What happens if the receiver's clock is running faster than the transmitter clock?

The stop bit guarantees that there will be a transition at the start of each character. It also allows a receiver to re-synchronize to a character boundary in the middle of a continuous data stream. If the receiver does not see a 'one' stop bit (called a "framing error") it knows it is unsynchronized and treats that bit as a start bit. Eventually the receiver will synchronize to an actual start bit.

Exercise: What would happen if the receiver was expecting 8-bit characters and the transmitter was sending 7-bit characters? What about the reverse case?

There are a number of standard bit rates, typically powers of two times 1200 bps (1200, 2400, 4800 bps etc). The RS-232 standard specifies maximum bit rates, distances, etc but these are usually ignored in practical applications. For short distances it's possible to send in excess of 100 kbps.

Other Serial Interfaces

The RS-422 serial interface specification uses a similar signaling scheme but uses differential signals (opposite voltages on two signal lines) to increase immunity to noise and increase maximum transmission distance. Data rates up to 1 Mbps are common. RS-422 is common in industrial applications because of its improved noise immunity.

There are also two relatively new high-speed serial interfaces: USB and IEEE 1394.

The Universal Serial Bus (USB) serial interface is designed to connect desktop PC peripherals such as keyboards and printers. It uses a four-wire cable that carries power and data and operates at 1.5 or 12

Mbps. Data is transmitted in packets and each packet is is sent with a CRC (cyclic redundancy check) parity checksum. The data may be isochronous (constant rate, e.g. speech) or bursty. The USB protocol supports multiple devices on each bus and allows devices to be dynamically added and removed from the bus. Each device has both a socket and a plug which allows dozens of devices to be daisy-chained (assuming electrical specifications are met).

IEEE 1394 ("Firewire") is a high-speed (100 to 400 Mbps) serial interface designed to connect high-speed devices such as digital video cameras, digital video disks and hard disks. The network consists of a "tree" of short (4.5 m maximum) point-to-point links between devices.

It remains to be seen whether either of these two interfaces will become popular enough to displace the traditional RS-232 and SCSI standards.