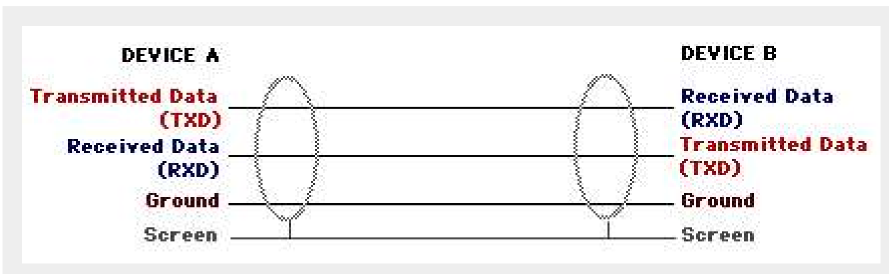
RS-232 and RS-422

The elderly *RS-232* and *RS-422* standards define the physical and electrical characteristics of many serial interfaces. Unlike modern serial buses, they only accommodate a simple connection between two devices. As with any *asynchronous interface*, data is sent in short bursts, usually one byte in length. This avoids the need for a precise timing reference at the receiver, a simple crystal oscillator being perfectly adequate. Each *byte* consists of *8 bits*, the least significant byte being sent first. Whenever 7-bit data is transmitted the last bit is available as a *parity bit* for simple *error detection*.

Data is transferred between each port and the processor itself via a chip that's commonly known as a *Universal Asynchronous Receiver and Transmitter (UART)* or an *Asynchronous Communications Interface Adaptor (ACIA)*. The basic form of this kind of interface is shown below:-



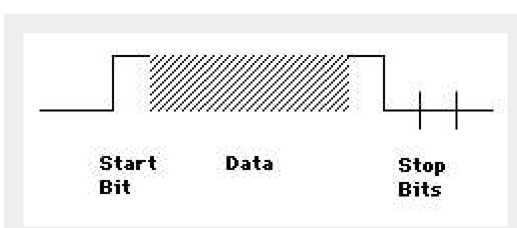
Depending on the type of interface, the `TXD` and `RXD` circuits may consist of pair of wires. Several other connections, known as *control circuits*, may also be provided.

Data Representation

In this kind of interface the signal is usually at a positive or negative voltage. Unfortunately, some devices only use positive 3 or 5 volt *transistor-transistor logic (TTL)* levels, causing compatibility problems with other equipment. The *RS-232* standard permits any voltage in the range of 5 to 15 volts, although 12 volts is commonly used, whilst some interfaces employ between 0.2 and 6 volts. In most instances a negative voltage is called a *mark* whilst a positive voltage is a *space*.

The *RS-422* standard is slightly different in that it applies 5 volts alternately to one of two wires to represent the logical states. This can make it incompatible with RS-232, although it often works with low-cost interfaces that use TTL signals.

Each burst of data in a serial interface is generated as shown below:-



When at *rest*, when sending a *logical 0* or when sending *stop bits* (at the end of each burst), the signal wire is at the negative voltage. When sending a *logical 1* or a *start bit* (at the beginning of a data burst) the signal wire is at the positive voltage.

As for the data itself, the *least significant bit (LSB)* is always sent first.

Speed

The speed of an interface is given in bits per second (bit/s or bps), which is often confused with a modem's *baud rate*. As a rough approximation, the bit rate divided by ten equals the byte rate in bytes per second (byte/s). For example, 9.6 kbit/s is roughly equivalent to 960 byte/s. Higher speeds are usually given in KB per second (KB/s) or MB per second (MB/s)

Common bit rates for RS-232 and RS-422 include:-

bit/s	**50**	**75**	**110**	**134**	**150**	
kbit/s	**1.2**	**1.8**	**2.0**	**3.6**	**4.8**	**7.2**
kbit/s	**9.6**	**14.4**	**19.2**	**28.8**	**38.4**	

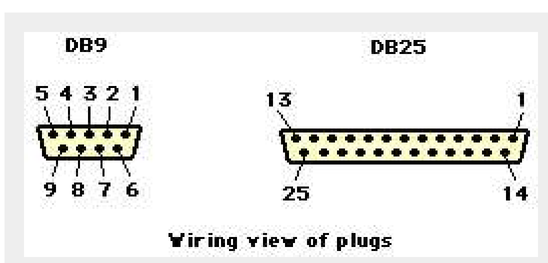
as well as the many other rates that are employed for modems.

In older equipment, 9.6 kbit/s is often used as a default speed. Fortunately, this slightly faster than the speed of older dot matrix printers that were originally connected to this kind of port.

RS-232C

This interface is also known as *CCITT V.24*. Although data is sent along a single wire, with another for any data going in the opposite direction, there are also several *control circuits*.

A computer is normally configured as *data terminal equipment (DTE)* and is commonly fitted with a *25-way D plug (DB25)*, although more modern machines come with a *9-way plug (DB9)*. Both types of connector are illustrated below.



A *modem* should be configured as *data circuit-terminating* or *data communication equipment (DCE)* and usually has a DB25 or DB9 *socket*. The connection between modem and computer therefore consists of a *plug-to-socket cable* with *pin-for-pin* connections.

A *printer* is usually configured as DTE, with a DB25 or DB9 *plug*, although some printers have a DB25 socket. In most instances, a computer and a printer, both of which are DTE devices, can be connected using a *socket-to-socket cable* with *swapped-pin* connections. This is often known as *null-modem cable*, since a modem isn't involved in the circuit.

The pin connections for DTE fitted with a DB25 connector are as follows:-

Pin	Code	Function	I/O
1	-	Screen	
2	TXD	Transmitted data	Output
3	RXD	Received data	Input
4	RTS	Request to send	Output
5	CTS	Clear to send	Input
6	DSR	Data set ready	Input
7	Gnd	Signal ground	
8	DCD	Data carrier detect	Input
9	-	+volts	
10	-	-volts	
11	-	Spare	
12	SDCD	Secondary DCD	Input
13	SCTS	Secondary CTS	Input
14	STXD	Secondary TXD	Output
15	DCE	Transmitter signal element timing	Output
16	SRXD	Secondary RXD	Input
17	-	Receiver signal element timing	Input
18	-	Spare	
19	SRTS	Secondary RTS	Output
20	DTR	Data terminal ready	Output
21	SQD	Signal quality detector	Input
22	RI	Ring indicator	Input
23	-	Data signal rate detector	Input
24	DTE	Transmitter signal element timing	Input
25	-	Spare	

Spare pins may be used for extra circuits on some devices

The following wiring is used for DTE fitted with a DB9 connector:-

Pin	Code	Function	I/O
1	-	Spare	
2	RXD	Received data	Input
3	TXD	Transmitted data	Output
4	DTR	Data terminal ready	Output
5	Gnd	Signal ground	
6	-	Spare	
7	RTS	Request to send	Output
8	CTS	Clear to send	Input
9	-	Spare	

The DB25 and DB9 connections for DCE is identical to DTE, except that the roles of input and output pins are reversed. In other words, the circuits are the same but inputs become outputs and vice versa.

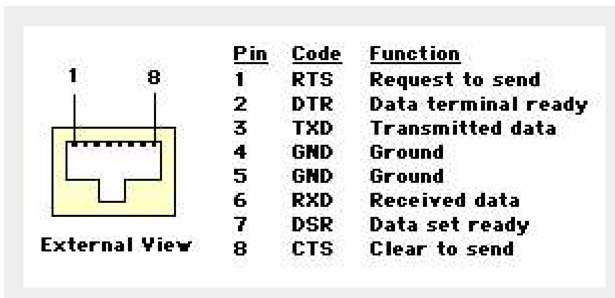
The serial port on an RS-423 device can be tested using a *loop test* plug. For DTE this can consist of a 25-way socket with links wired as follows:-

Pin	Code	Pin	Code
2	TXD	3	RXD
4	RTS	5	CTS
8	DCD	11	SSD
20	DTR	6	DSR

or as a 9-way socket linked as shown below:-

Pin	Code	Pin	Code
3	TXD	2	RXD
7	RTS	8	CTS
20	DTR	8	CTS

Some equipment uses an *RJ45 connector* for RS-232 ports, as shown below:-



RS-232 Interconnecting Cables

Connecting DTE to DCE

A cable between DTE and DCE must be wired *pin-for-pin*, usually with a plug at both ends, although some devices require a socket. The cable *screen* (acting as an electrical shield around the other wires) and the *signal ground* (`Gnd`) circuits are usually connected at both ends.

A cable with conductors wired will always work but can be expensive. Varieties that only uses 5 or 8 wires are cheaper and are often satisfactory. The basic form of wiring consists of connections for `TXD`, `RXD`, `RTS`, `CTS`, `DSR`, `DCD`, `DTR`, as well as `Gnd` and shield wires. For a link that use *software handshaking* (see below) you only need three wires; `TXD`, `RXD` and `Gnd`.

Connecting Two DTEs or Two DCEs

This is slightly more complicated since you'll need a cable in which the data circuits are *swapped*. Always remember that terms such as `TXD` and `RXD` refer to the function of the circuit as used in a conventional DTE to DCE link, not the roles of circuits as inputs and outputs. In other words you can have `TXD` inputs as well as outputs and `RXD` outputs as well as inputs!

For two DTEs the `TXD` output connection (pin 2 on a DB25) of one device must be joined to the `RXD` input (pin 3 on a DB25) of the second device, and similarly in the opposite direction.When connecting two DCEs each `RXD` output (pin 3) must be joined to each `TXD` input (pin 2).

RS-423A

Also known as *CCITT V.10*, this is similar to RS-232 but with the common wire connected to a *differential input* instead of ground. This prevents a data current following to ground, allowing the interface it to work at 1 Mbit/s over 1,000 metres of cable or at 100 kbit/s over 10 metres. The lower transition voltage of 4 to 6 volts is usually compatible with RS-232.

RS-422

This *balanced interface* applies 5 volts alternately to one of two wires to indicate its logical state. It can operate at 10 Mbit/s over 10 metres of cable or at 100 kbit/s over 1,000 metres. This form of interface usually appears on a *9-way D connector (DB9)* or *37-way D connector (DB37)*. The table below shows the connections for a 37-way D connector fitted to a printer:-

Pin	Code	Function	I/O
1	Gnd	Signal ground	
3	SSD+	Supervisory send data*	Output
21	SSD-	Supervisory send data*	Output
4	TXD+ (SD+)	Send data	Output
22	TXD- (SD+)	Send data	Output
6	RXD+ (RD+)	Receive data	Input
24	RXD- (RD-)	Receive data	Input
7	RTS+ (RS+)	Request to send*	Output
25	RTS- (RS-)	Request to send*	Output
9	CTS+ (CS+)	Clear to send (reply to RTS)	Input
27	CTS- (CS-)	Clear to send (reply to RTS)	Input
11	DM+	Data mode (indicates data can be sent)	Input
29	DM-	Data mode (indicates data can be sent)	Input
12	TR+	Terminal ready*	Output
30	TR-	Terminal ready*	Output
19	Gnd	Signal ground	

* Sometimes indicates printer cannot receive data (Ready/Busy protocol)
Pins 2, 5, 8, 10, 13 to 18, 20, 23, 26, 28, 31,32 to 37 not used

The port on an RS-422 device can be tested using a *loop test* plug, consisting of a 37-way plug with links wired as follows:-

Pin	Code	Pin	Code
4	SD+	6	RD+
22	SD-	24	RD-
7	RS+	9	CS+
25	RS-	27	CS-

13	RR+	3	SSD+
31	RR-	21	SSD-
12	TR+	11	DM+
30	TR-	29	DM-

Note that the original *Macintosh* computers had an RS-422 interface on a *9 way D connector (DB9)* wired as follows:-

Pin	Code	Function	I/O
1	Shield	Screen	
2	+5V	For external device	Output
3	Gnd	Signal ground	
4	TXD+	Transmitted data	Output
5	TXD-	Transmitted data	Output
6	+12V	For external device	Output
7	CTS	Clear to send	Input
8	RXD+	Received data	Input
9	RXD-	Received data	Input

A standard RS-422 port doesn't accept negative voltages and therefore can't provide a reliable interconnection with RS-232 devices, unless the latter uses TTL voltages. However, although the 'classic' *Mac* port shown here conforms to the RS-422 standard, it also accommodates an RS-232 signal whenever the positive wire of an input pair is linked to ground.

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20 mA Loop Interface

This older type of interface is used for connecting a *teleprinter* or *Telex* machine. *Logic 1* is represented by a *flow* of current, *logic 0* is indicated by *no current* flowing.

- You'll need an interface box to connect a 20 mA loop device to normal serial ports.

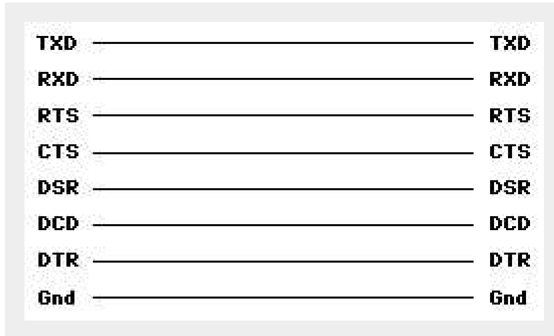
Handshaking

Handshaking is a recognised *protocol* that allows two asynchronous devices to communicate their intention to send or ability to receive data. In other words, handshaking provides *flow control* for the transfer of data. Two systems are used: hardware handshaking and software handshaking.

Hardware handshaking uses extra *handshake wires* between the two devices. This is essential for the connection between a computer and a serial *modem* when working at 9.6 kbit/s or higher. Common hardware handshaking methods include *RTS*, *CTS* and *DTR*, as described below:-

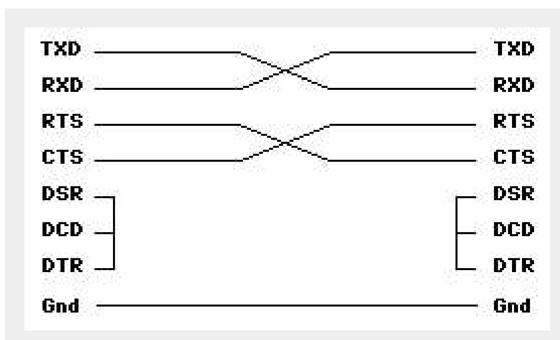
Request to Send (RTS) and Clear to Send (CTS)

This provides the standard form of flow control for a DTE to DCE link. In this situation all the circuits in the interconnecting cable should be wired *pin-for-pin*, as shown below:-



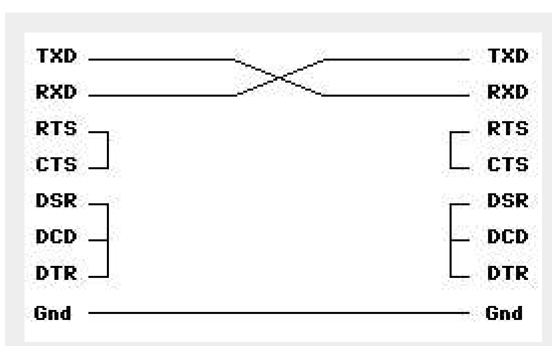
- This type of cable is sometimes known as a *straight-through* cable.

The cable that connects two DTEs is known as a *null-modem cable* since no modem is used. Several types of null-modem adaptor or cable are available. The one below employs *RTS/CTS handshaking*, implemented by exchanging the `RTS` (output) and `CTS` (input) lines. The `DTR` outputs are linked to the `DSR` and `DCD` inputs to disable *DTR handshaking* (see below).

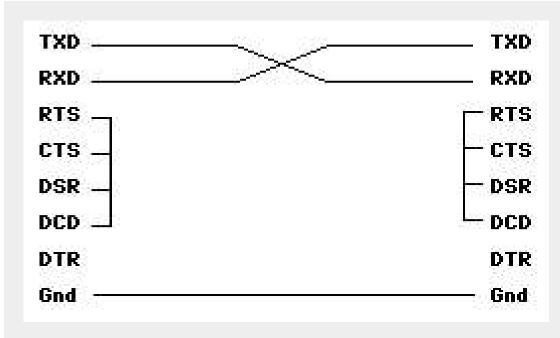


- This type of cable is sometimes known as a *crossover cable*.

The null-modem cable shown below works with *software handshaking* (see below), so the `RTS` and `CTS` circuits are ‘linked out’ to defeat their operation. Once again the `DTR` outputs are linked to the `DSR` and `DCD` inputs to defeat DTR handshaking.

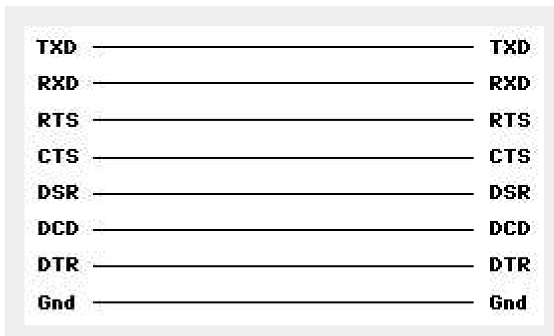


The next null-modem cable is again intended for software handshaking, in this instance with devices that lack `DTR` outputs. In this example the `CTS` outputs are used to set all three inputs:-

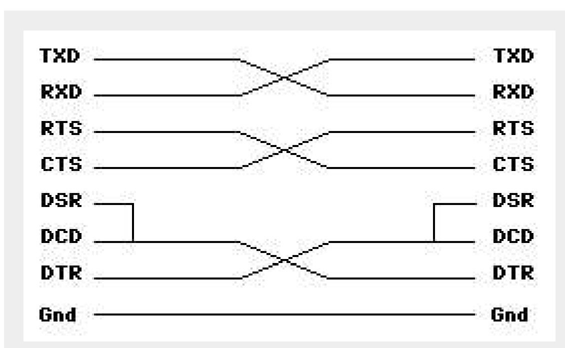


Data Terminal Ready (DTR)

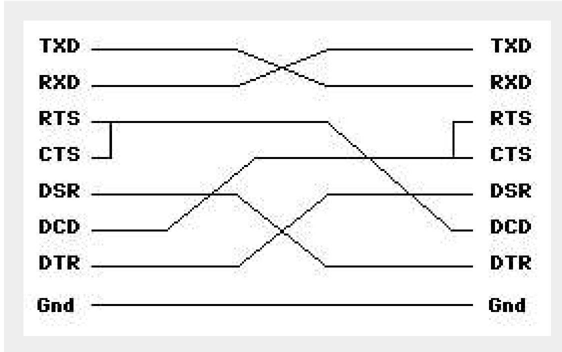
This kind of handshaking is used for flow control as an alternative to *CTS handshaking*. A high level on a `DTR` output indicates that DTE is ready to accept data. In a standard DTE to DCE link all the circuits in the interconnecting cable are wired pin-for-pin as shown below:-



The following *null-modem* cable, for joining DTE to DTE, provides both CTS/RTS and DTR handshaking. The `DTR` outputs feed both the `DSR` and `DCD` inputs of the other device:-



The next cable configuration can be used where RTS/CTS handshaking isn’t used, usually when *software handshaking* is in operation, but where DTR control is still necessary. The `RTS` outputs are ‘linked out’ to the `CTS` inputs of each device and to the other device’s `DCD` inputs:-



Software handshaking uses *additional codes* within the data to control the actual data flow. Since these instructions must be handled by software some timing delays are inevitable. Software handshaking may be used in conjunction with hardware handshaking (see above) or on its own.

Common software handshaking includes *XON/XOFF* and *ENQ/ACK*, as described below:-

XON/XOFF

This is the most common system. However, to make it work it may be necessary to 'link out' some hardware handshake lines. Usually this involves joining `CTS` to `RTS`, and, in some instances, to the `DTR` inputs. A *null modem* cable used for connecting two DTEs often has such links.

`XOFF`, represented by an ASCII control code called `DC3` (hex 14, `Control-S`), tells the sender to suspend transmission, whilst `XON`, also known as `DC1` (hex 11, `Control-Q`) lets it resume. Most printers send out an `XOFF` message when the printer's interface *buffer* is nearly full.

Enquire/Acknowledge (ENQ/ACK)

This is an alternative system that's rarely encountered. The two devices must be set up to work with the same *block size* and the transmitter then checks that the receiver is ready to accept data.

When the sender's ready to transmit it puts out a control code called `ENQ` (hex 05, `Control-E`). If the receiver can accept a full data block it replies with `ACK` (hex 06, `Control-F`).