

# RS-232

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(Redirected from [Rs232](#))



Female RS-232 plug.

In [telecommunications](#), **RS-232** (Recommended Standard 232) is a standard for [serial](#) binary data signals connecting between a *DTE* ([Data terminal equipment](#)) and a *DCE* ([Data Circuit-terminating Equipment](#)). It is commonly used in [computer serial ports](#). A similar [ITU-T](#) standard is **V.24**.

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## Scope of the standard

The [Electronic Industries Alliance](#) (EIA) standard RS-232-C<sup>[1]</sup> as of 1969 defines:

- Electrical signal characteristics such as voltage levels, signaling rate, timing and [slew-rate](#) of signals, voltage withstand level, [short-circuit](#) behavior, and maximum load [capacitance](#).
- Interface mechanical characteristics, pluggable connectors and pin identification.
- Functions of each circuit in the interface connector.
- Standard subsets of interface circuits for selected telecom applications.

The standard does not define such elements as

- [character encoding](#) (for example, [ASCII](#), [Baudot](#) or [EBCDIC](#))
- the framing of characters in the data stream (bits per character, start/stop bits, [parity](#))
- protocols for error detection or algorithms for data compression
- bit rates for transmission, although the standard says it is intended for [bit rates](#) lower than 20,000 bits per second. Many modern devices support speeds of 115,200 bit/s and above
- power supply to external devices.

Details of character format and transmission bit rate are controlled by the [serial port](#) hardware, often a single [integrated circuit](#) called a [UART](#) that converts data from parallel to serial form. A typical [serial port](#) includes specialized driver and receiver integrated circuits to convert between internal logic levels and RS-232 compatible signal levels.

# History

The original DTEs were electromechanical [teletypewriters](#) and the original DCEs were (usually) [modems](#). When [electronic terminals](#) (smart and dumb) began to be used, they were often designed to be interchangeable with teletypes, and so supported RS-232. The C revision of the standard was issued in 1969 in part to accommodate the electrical characteristics of these devices.

Since application to devices such as computers, printers, test instruments, and so on was not considered by the standard, designers implementing an RS-232 compatible interface on their equipment often interpreted the requirements idiosyncratically. Common problems were non-standard pin assignment of circuits on connectors, and incorrect or missing control signals. The lack of adherence to the standards produced a thriving industry of breakout boxes, patch boxes, test equipment, books, and other aids for the connection of disparate equipment. A common deviation from the standard was to drive the signals at a reduced voltage: the standard requires the transmitter to use +12V and -12V, but requires the receiver to distinguish voltages as low as +3V and -3V. Some manufacturers therefore built transmitters that supplied +5V and -5V and labeled them as "RS-232 compatible."

Later [personal computers](#) (and other devices) started to make use of the standard so that they could connect to existing equipment. For many years, an RS-232-compatible port was a standard feature for [serial communications](#), such as modem connections, on many computers. It remained in widespread use into the late 1990s. While it has largely been supplanted by other interface standards in computer products, it is still used to connect older designs of peripherals, industrial equipment (such as based on [PLCs](#)), and [console](#) ports, and special purpose equipment such as a cash drawer for a cash register.

The standard has been renamed several times during its history as the sponsoring organization changed its name, and has been variously known as EIA RS 232, EIA 232, and most recently as TIA 232. The standard continues to be revised and updated by the [EIA](#) and since 1988 the [Telecommunications Industry Association](#) (TIA)<sup>[2]</sup>. Revision C was issued in a document dated August 1969. Revision D was issued in 1986. The current revision is *TIA-232-F Interface*

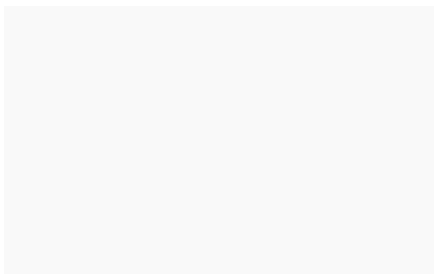
*Between Data Terminal Equipment and Data Circuit-Terminating Equipment Employing Serial Binary Data Interchange*, issued in 1997. Changes since Revision C have been in timing and details intended to improve harmonization with the [CCITT](#) standard V.24, but equipment built to the current standard will interoperate with older versions.

## Limitations of the standard

Because the application of RS-232 has extended far beyond the original purpose of interconnecting a terminal with a modem, successor standards have been developed to address the limitations. Issues with the RS-232 standard include:

- The large voltage swings and requirement for positive and negative supplies increases power consumption of the interface and complicates power supply design. The voltage swing requirement also limits the upper speed of a compatible interface.
- Single-ended signaling referred to a common signal ground limits the noise immunity and transmission distance.
- Multi-drop (meaning a connection between more than two devices) operation of an RS-232 compatible interface is not defined; while multi-drop "work-arounds" have been devised, they have limitations in speed and compatibility.
- Asymmetrical definitions of the two ends of the link make the assignment of the role of a newly developed device problematic; the designer must decide on either a DTE-like or DCE-like interface and which connector pin assignments to use.
- The [handshaking](#) and control lines of the interface are intended for the setup and takedown of a [dial-up](#) communication circuit; in particular, the use of handshake lines for [flow control](#) is not reliably implemented in many devices.
- No method for sending power to a device, while a small amount of current can be extracted from the DTR and RTS lines this can only be used for low power devices such as mice.
- While the standard recommends a 25-way connector and its [pinout](#), the connector is large by current standards.

## Role in modern personal computers





PCI Express x1 card with one RS-232 port

In the book *PC 97 Hardware Design Guide*<sup>[3]</sup>, Microsoft deprecated support for the RS-232 compatible serial port of the original IBM PC design. Today, RS-232 is gradually being superseded in personal computers by USB for local communications. Compared with RS-232, USB is faster, has lower voltage levels, and has connectors that are simpler to connect and use. Both standards have software support in popular operating systems. USB is designed to make it easy for device drivers to communicate with hardware. However, there is no direct analog to the terminal programs used to let users communicate directly with serial ports. USB is more complex than the RS 232 standard because it includes a protocol for transferring data to devices. This requires more software to support the protocol used. RS 232 only standardizes the voltage of signals and the functions of the physical interface pins. Serial ports of personal computers are also often used to directly control various hardware devices, such as relays or lamps, since the control lines of the interface could be easily manipulated by software. This isn't feasible with USB which requires some form of receiver to decode the serial data.

As an alternative, USB docking ports are available which can provide connectors for a keyboard, mouse, one or more serial ports, and one or more parallel ports. Corresponding device drivers are required for each USB-connected device to allow programs to access these USB-connected devices as if they were the original directly-connected peripherals. Devices that convert USB to RS 232 may not work with all software on all personal computers.

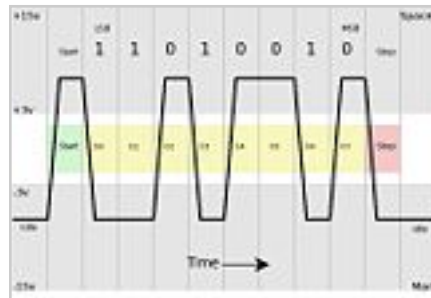
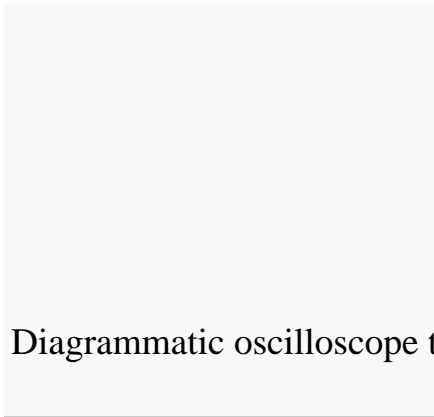
Personal computers may use the control pins of a serial port to interface to devices such as uninterruptible power supplies. In this case, serial data is not sent, but the control lines are used to

signal conditions such as loss of power, or low battery alarms.

## Standard details

In RS-232, data is sent as a time-series of bits. Both synchronous and asynchronous transmissions are supported by the standard. In addition to the data circuits, the standard defines a number of control circuits used to manage the connection between the DTE and DCE. Each data or control circuit only operates in one direction, that is, signaling from a DTE to the attached DCE or the reverse. Since transmit data and receive data are separate circuits, the interface can operate in a full duplex manner, supporting concurrent data flow in both directions. The standard does not define character framing within the data stream, or character encoding.

## Voltage levels



Diagrammatic oscilloscope trace of voltage levels for ASCII "K" character (0x4b) with 1 start bit, 8 data bits, 1 stop bit

The RS-232 standard defines the voltage levels that correspond to logical one and logical zero levels. Valid signals are plus or minus 3 to 15 volts. The range near zero volts is not a valid RS-232 level; logic one is defined as a negative voltage, the signal condition is called marking, and has the functional significance of OFF. Logic zero is positive, the signal condition is spacing, and has the function ON. The standard specifies a maximum open-circuit voltage of 25 volts; signal levels of  $\pm 5$  V,  $\pm 10$  V,  $\pm 12$  V, and  $\pm 15$  V are all commonly seen depending on the power supplies available within a device. RS-232 drivers and receivers must be able to withstand indefinite short circuit to ground or to any voltage level up to  $\pm 25$  volts. The slew rate, or how fast the signal changes between levels, is also controlled.

Because the voltage levels are higher than logic levels typically used by integrated circuits, special intervening driver circuits are required to translate logic levels. These also protect the device's internal circuitry from short circuits or transients that may appear on the RS-232 interface, and provide sufficient current to comply with the slew rate requirements for data transmission.

Because both ends of the RS-232 circuit depend on the ground pin being zero volts, problems will occur when connecting machinery and computers where the voltage between the ground pin on one end, and the ground pin on the other is not zero. This may also cause a hazardous ground loop.

Unused interface signals terminated to ground will have an undefined logic state. Where it is necessary to permanently set a control signal to a defined state, it must be connected to a voltage source that asserts the logic 1 or logic 0 level. Some devices provide test voltages on their interface connectors for this purpose.

## Connectors

RS-232 devices may be classified as Data Terminal Equipment (DTE) or Data Communications Equipment (DCE); this defines at each device which wires will be sending and receiving each signal. The standard recommended but did not make mandatory the D-subminiature 25 pin connector. In general and according to the standard, terminals and computers have male connectors with DTE pin functions, and modems have female connectors with DCE pin functions. Other devices may have any combination of connector gender and pin definitions. Many terminals were manufactured with female terminals but were sold with a cable with male connectors at each end; the terminal with its cable satisfied the recommendations in the standard.

Presence of a 25 pin D-sub connector does not necessarily indicate an RS-232C compliant interface. For example, on the original IBM PC, a male D-sub was an RS-232C DTE port (with a non-standard current loop interface on reserved pins), but the female D-sub connector was used for a parallel Centronics printer port. Some personal computers put non-standard voltages or signals on some pins of their serial ports.

The standard specifies 20 different signal connections. Since most devices use only a few signals, smaller connectors can often be used. For example, the 9 pin DE-9 connector was used by most IBM-compatible PCs since the IBM PC AT, and has been standardized as TIA-574. More recently, modular connectors have been used. Most common are 8 pin RJ-45 connectors. Standard EIA/TIA 561 specifies a pin assignment, but the "Yost Serial Device Wiring Standard" invented by Dave Yost (and popularized by the Unix System Administration Handbook) is common on Unix computers and newer devices from Cisco Systems. Many devices don't use either of these standards. 10 pin RJ-50 connectors can be found on some devices as well. Digital Equipment Corporation defined their own DECconnect connection system which was based on the Modified Modular Jack connector. This is a 6 pin modular jack where the key is offset from the center position. As with the Yost standard, DECconnect uses a symmetrical pin layout which enables the direct connection between two DTEs. Another common connector is the DH10 header connector common on motherboards and add-in cards which is usually converted via a cable to the more standard 9 pin DE-9 connector (and frequently mounted on a free slot plate or other part of the housing).

## Pinouts (DTE relative)

The following table lists the commonly used RS-232 signals and common pin assignments

Signal Type	Abbr.	Dir.	<u>DB- 25</u>	<u>DE-9</u> ( <u>TIA- 574</u> )	<u>EIA/ TIA 561</u>	Yost	<u>RJ- 50</u>	<u>MMJ</u>	Cisco RJ-45	Hirschmann RJ-45	Alternates
Common Ground	G	–	7	5	4	4,5	6	3,4	4,5	4	
Transmitted Data	TxD	Out	2	3	6	3	8	2	3	3	
Received Data	RxD	In	3	2	5	6	9	5	6	5	
Data Terminal Ready	DTR	Out	20	4	3	2	7	1	2	-	

Data Set Ready	DSR	In	6	6	1	7	5	6	7	-	
Request To Send	RTS	Out	4	7	8	1	4	-	1 (Aux only)	-	Ready To Receive (RTR)
Clear To Send	CTS	In	5	8	7	8	3	-	8 (Aux only)	-	
Carrier Detect	DCD	In	8	1	2	7	10	-	-	-	
Ring Indicator	RI	In	22	9	9	-	2	-	-	-	

The signals are labeled from the standpoint of the DTE device; TD, DTR, and RTS are generated by the DTE and RD, DSR, CTS, DCD, and RI are generated by the DCE. The ground signal is a common return for the other connections; it appears on two pins in the Yost standard but is the same signal. Connection of pin 1 (protective ground) and pin 7 (signal reference ground) is a common practice but not recommended. Use of a common ground is one weakness of RS-232. If the two pieces of equipment are far enough apart or on separate power systems, the ground will degrade between them and communications will fail; this is a difficult condition to trace.

Note that EIA/TIA 561 combines DSR and RI, and the Yost standard combines DSR and DCD.

## Signals

Commonly-used signals are:

### Transmitted Data (TxD)

Data sent from DTE to DCE.

### Received Data (RxD)

Data sent from DCE to DTE.

### Request To Send (RTS)

Asserted (set to 0) by DTE to prepare DCE to receive data. This may require action on the part of the DCE, e.g. transmitting a carrier or reversing the direction of a half-duplex channel. For the modern usage of "RTS/CTS handshaking," see the [section of that name](#).

### Ready To Receive (RTR)

Asserted by DTE to indicate to DCE that DTE is ready to receive data. If in use, this signal

appears on the pin that would otherwise be used for Request To Send, and the DCE assumes that RTS is always asserted; see [RTS/CTS handshaking](#) for details.

#### Clear To Send (CTS)

Asserted by DCE to acknowledge RTS and allow DTE to transmit. This signaling was originally used with half-duplex modems and by slave terminals on multidrop lines: The DTE would raise RTS to indicate that it had data to send, and the modem would raise CTS to indicate that transmission was possible. For the modern usage of "RTS/CTS handshaking," see the [section of that name](#).

#### Data Terminal Ready (DTR)

Asserted by DTE to indicate that it is ready to be connected. If the DCE is a modem, this may "wake up" the modem, bringing it out of a power saving mode. This behaviour is seen quite often in modern PSTN and GSM modems. When this signal is de-asserted, the modem may return to its standby mode, immediately hanging up any calls in progress.

#### Data Set Ready (DSR)

Asserted by DCE to indicate the DCE is powered on and is ready to receive commands or data for transmission from the DTE. For example, if the DCE is a modem, DSR is asserted as soon as the modem is ready to receive dialing or other commands; DSR is not dependent on the connection to the remote DCE (see Data Carrier Detect for that function). If the DCE is not a modem (e.g. a [null modem](#) cable or other equipment), this signal should be permanently asserted (set to 0), possibly by a jumper to another signal.

#### Data Carrier Detect (DCD)

Asserted by DCE when a connection has been established with remote equipment.

#### Ring Indicator (RI)

Asserted by DCE when it detects a ring signal from the telephone line.

## Cables

Since the standard definitions are not always correctly applied, it is often necessary to consult documentation, test connections with a breakout box, or use trial and error to find a cable that works when interconnecting two devices. Connecting a fully-standard-compliant DCE device and DTE device would use a cable that connects identical pin numbers in each connector (a so-called "straight cable"). "[Gender changers](#)" are available to solve gender mismatches between cables and connectors. Connecting devices with different types of connectors requires a cable that connects the corresponding pins according to the table above. Cables with 9 pins on one end and 25 on the other are common. Manufacturers of equipment with RJ-45 connectors usually provide a cable with either a DB-25 or DE-9 connector (or sometimes interchangeable connectors so they can work with multiple devices). Poor-quality cables can cause false signals by [crosstalk](#) between data and control lines ( such as Ring Indicator).

## Conventions

For functional communication through a serial port interface, conventions of bit rate, character framing, communications protocol, character encoding, data compression, and error detection, not defined in RS 232, must be agreed to by both sending and receiving equipment. For example, consider the [serial ports](#) of the original [IBM PC](#). This implementation has an integrated circuit [UART](#), often [16550 UART](#), using [asynchronous start-stop](#) character formatting with 7 or 8 data bits per frame, usually [ASCII](#) character coding, and data rates programmable between 75 bits per second and 115,200 bits per second. Data rates above 20,000 bits per second are out of the scope of the standard, although higher data rates are sometimes used by commercially manufactured equipment. In the particular case of the IBM PC, baud rates were programmable with arbitrary values, so that a PC could be connected to, for example, [MIDI](#) music controllers (31,250 bits per second) or other devices not using the rates typically used with [modems](#). Since most devices do not have [automatic baud rate detection](#), users must manually set the baud rate (and all other parameters) at both ends of the RS-232 connection.

## RTS/CTS handshaking

In older versions of the specification, RS-232's use of the RTS and CTS lines is asymmetric: The DTE asserts RTS to indicate a desire to transmit to the DCE, and the DCE asserts CTS in response to grant permission. This allows for half-duplex modems that disable their transmitters when not required, and must transmit a synchronization preamble to the receiver when they are re-enabled. This scheme is also employed on present-day RS-232 to [RS-485](#) converters, where the RS-232's RTS signal is used to ask the converter to take control of the RS-485 bus - a concept that doesn't otherwise exist in RS-232. There is no way for the DTE to indicate that it is unable to accept data from the DCE.

A non-standard symmetric alternative, commonly called "RTS/CTS handshaking," was developed by various equipment manufacturers: CTS indicates permission from the DCE for the DTE to send data to the DCE (and is controlled by the DCE independent of RTS), and RTS indicates

permission from the DTE for the DCE to send data to the DTE. This was eventually codified in version RS-232-E (actually TIA-232-E by that time) by defining a new signal, "RTR (Ready to Receive), which is CCITT V.24 circuit 133. TIA-232-E and the corresponding international standards were updated to show that circuit 133, when implemented, shares the same pin as RTS (Request to Send), and that when 133 is in use, RTS is assumed by the DCE to be ON at all times.

[4]

Thus, with this alternative usage, one can think of RTS asserted (logic 0) meaning "ready to receive characters" from the DTE, rather than a "request to send" to the DCE.

### **3-wire and 5-wire RS-232**

A minimal "3-wire" RS-232 connection consisting only of transmit data, receive data, and ground, is commonly used when the full facilities of RS-232 are not required. Even a two-wire connection (data and ground) can be used if the data flow is one way (for example, a digital postal scale that periodically sends a weight reading, or a GPS receiver that periodically sends position, if no configuration via RS-232 is necessary). When only flow control is required in addition to two-way data, the RTS and CTS lines are added in a 5-wire version.

### **Seldom used features**

The EIA-232 standard specifies connections for several features that are not used in most implementations. Their use requires the 25-pin connectors and cables, and of course both the DTE and DCE must support them.

### **Signal rate selection**

The DTE or DCE can specify use of a "high" or "low" signaling rate. The rates as well as which device will select the rate must be configured in both the DTE and DCE. The prearranged device selects the high rate by setting pin 23 to ON.

### **Loopback testing**

Many DCE devices have a [loopback](#) capability used for testing. When enabled, signals are echoed back to the sender rather than being sent on to the receiver. If supported, the DTE can signal the local DCE (the one it is connected to) to enter loopback mode by setting pin 18 to ON, or the remote DCE (the one the local DCE is connected to) to enter loopback mode by setting pin 21 to ON. The latter tests the communications link as well as both DCE's. When the DCE is in test mode it signals the DTE by setting pin 25 to ON.

A commonly used version of loopback testing doesn't involve any special capability of either end. A hardware loopback is simply a wire connecting complementary pins together in the same connector. See [loopback](#).

Loopback testing is often performed with a specialized DTE called a Bit Error Rate Tester ([BERT](#)).

## Timing signals

Some synchronous devices provide a [clock signal](#) to synchronize data transmission, especially at higher data rates. Two timing signals are provided by the DCE on pins 15 and 17. Pin 15 is the transmitter clock, or send timing (ST); the DTE puts the next bit on the data line (pin 2) when this clock transitions from OFF to ON (so it is stable during the ON to OFF transition when the DCE registers the bit). Pin 17 is the receiver clock, or receive timing (RT); the DTE reads the next bit from the data line (pin 3) when this clock transitions from ON to OFF.

Alternatively, the DTE can provide a clock signal, called transmitter timing (TT), on pin 24 for transmitted data. Again, data is changed when the clock transitions from OFF to ON and read during the ON to OFF transition. TT can be used to overcome the issue where ST must traverse a cable of unknown length and delay, clock a bit out of the DTE after another unknown delay, and return it to the DCE over the same unknown cable delay. Since the relation between the transmitted bit and TT can be fixed in the DTE design, and since both signals traverse the same cable length, using TT eliminates the issue. TT may be generated by looping ST back with an appropriate phase change to align it with the transmitted data. ST loop back to TT lets the DTE

use the DCE as the frequency reference, and correct the clock to data timing.

## Secondary channel

Data can be sent over a secondary channel (when implemented by the DTE and DCE devices), which is equivalent to the primary channel. Pin assignments are described in following table:

Signal	Pin
Common Ground	7 (same as primary)
Secondary Transmitted Data (STD)	14
Secondary Received Data (SRD)	16
Secondary Request To Send (SRTS)	19
Secondary Clear To Send (SCTS)	13
Secondary Carrier Detect (SDCD)	12

## Related standards

Other serial signaling standards may not interoperate with standard-compliant RS-232 ports. For example, using the TTL levels of near +5 and 0 V puts the mark level in the undefined area of the standard. Such levels are sometimes used with NMEA 0183-compliant GPS receivers and depth finders.

20 mA current loop uses the absence of 20 mA current for high, and the presence of current in the loop for low; this signaling method is often used for long-distance and optically isolated links. Connection of a current-loop device to a compliant RS-232 port requires a level translator; current-loop devices are capable of supplying voltages in excess of the withstand voltage limits of a compliant device. The original IBM PC serial port card implemented a 20 mA current-loop interface, which was never emulated by other suppliers of plug-compatible equipment.

Other serial interfaces similar to RS-232:

- RS-422 (a high-speed system similar to RS-232 but with differential signaling)
- RS-423 (a high-speed system similar to RS-422 but with unbalanced signaling)

- [RS-449](#) (a functional and mechanical interface that used RS-422 and RS-423 signals - it never caught on like RS-232 and was withdrawn by the EIA)
- [RS-485](#) (a descendant of RS-422 that can be used as a bus in multidrop configurations)
- [MIL-STD-188](#) (a system like RS-232 but with better impedance and rise time control)
- [EIA-530](#) (a high-speed system using RS-422 or RS-423 electrical properties in an EIA-232 pinout configuration, thus combining the best of both; supersedes RS-449)
- [TIA-574](#) (standardizes the 9-pin D-subminiature connector pinout for use with EIA-232 electrical signalling, as originated on the IBM PC/AT)

## See also

- [Asynchronous start-stop](#)
- [List of device bandwidths](#)
- Paul Horowitz and Winfield Hill, *The Art of Electronics Second Edition*, Cambridge University Press, Cambridge MA, 1989, [ISBN 0-521-37095-7](#), pages 723-726 for discussion of RS 232 limitations and application issues.

## References

1. <sup>^</sup> Electronics Industries Association, "EIA Standard RS-232-C Interface Between Data Terminal Equipment and Data Communication Equipment Employing Serial Data Interchange", August 1969, reprinted in Telebyte Technology *Data Communication Library*, Greenlawn NY, 1985, no ISBN
2. <sup>^</sup> [TIA Web site](#)
3. <sup>^</sup> (1997) *PC 97 Hardware Design Guide*. Redmond, Washington, USA: Microsoft Press. [ISBN 1-57231-381-1](#).
4. <sup>^</sup> ca...@gauss.llnl.gov (Casey Leedom) (1990-02-20 00:24:17 GMT). "[<49249@lln-winken.LLNL.GOV> Re: EIA-232 full duplex RTS/CTS flow control standard proposal](#)". [comp.dcom.modems](#). (Web link). Retrieved on [2008-04-30](#).

## External links

Wikibooks' [Serial Programming](#) has more about this subject:

[\*Serial Programming:RS-232 Connections\*](#)

- [RS-232 tutorial](#)
- [Yost Serial Device Wiring Standard](#)
- [Serial Port Basics](#)

- [RS232 serial port info](#)
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