

19z604 Embedded Systems

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Serial Communication

Asynchronous Data Transfer

- Data can be transmitted intermittently
- The receiver must have a way to distinguish between valid data and noise
- special start bit and stop bit at the beginning and end of each piece of data
- asynchronous communication a.k.a called start-stop transmission

RS-232

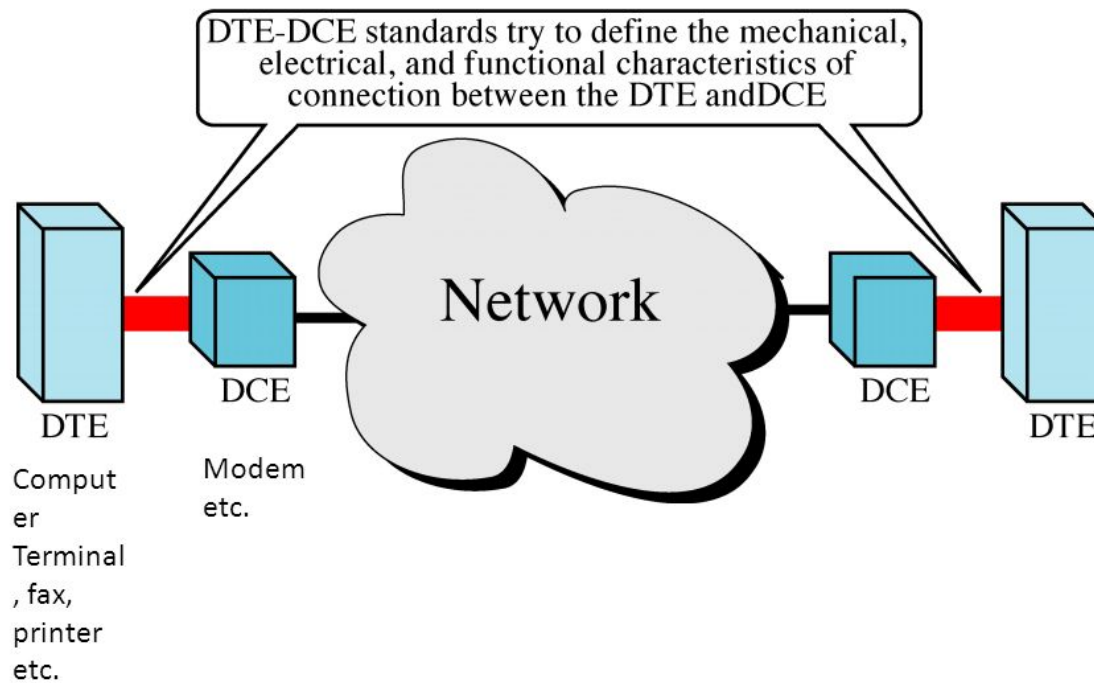
- A standard interface approved by the Electronic Industries Association (EIA) for connecting serial devices
- Defined it originally for teletypewriter devices
- RS-232 is the specification used by the computer to talk to and exchange data with your modem and other serial devices

DTE and DCE Devices

- DTE – Data Terminal Equipment (e.x: Computer)
- DCE – Data Communication Equipment (e.x: Modem)
- RS-232 (Recommended Standard – 232)
 - Electrical Interface between DTE and DCE
 - Variants include RS-232C, RS-232D, V.24,V.28, V.10
- Asynchronous Data Transfer

DTE-DCE Interface

DTE-DCE interface



RS-232 on DB-9 pin

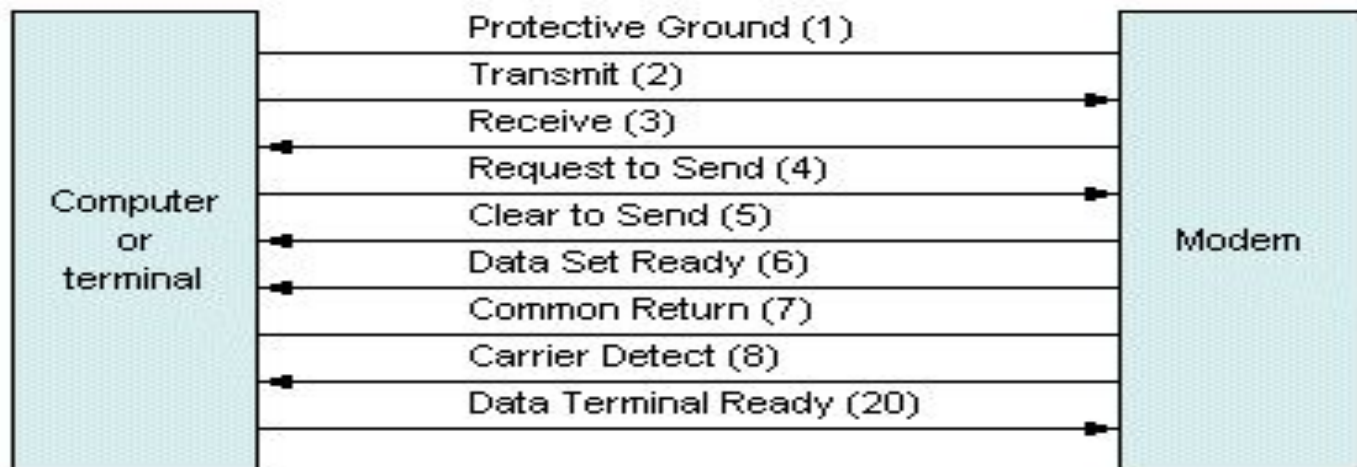
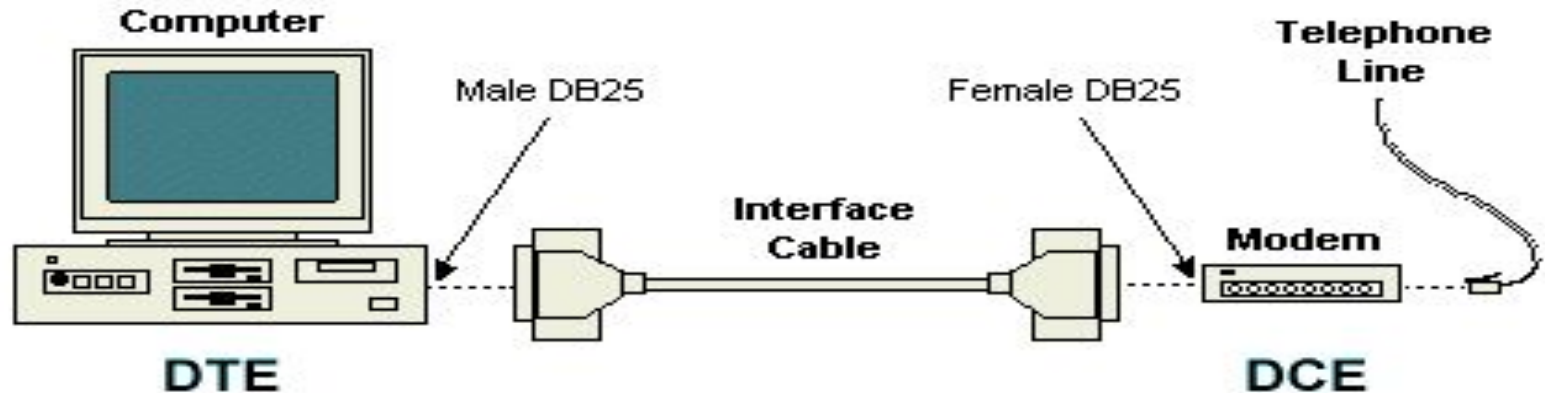
Pin Number	Signal	Description
1	DCD	Data carrier detect
2	RxD	Receive Data
3	TxD	Transmit Data
4	DTR	Data terminal ready
5	GND	Signal ground
6	DSR	Data set ready
7	RTS	Ready to send
8	CTS	Clear to send
9	RI	Ring Indicator

- PCs are equipped with male D type connectors having only 9 pins
- normal cable limitation of 50 feet can be extended to several hundred feet with high-quality cable.

RS-232 on DB-25, RJ-45

- DB-25 pin
- RJ-45 pin
 - RJ-45 (Registered Jack-45) is an eight-wire connector used commonly to connect computers onto local-area networks (LAN), especially Ethernets

DTE-DCE Communication



Signal Description

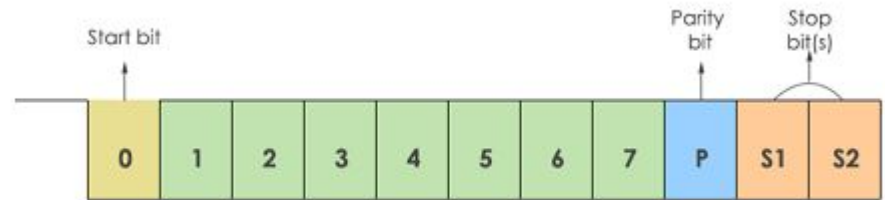
- TxD
 - This pin carries data from the computer to the serial device
- RXD
 - This pin carries data from the serial device to the computer
- DTR signals
 - DTR is used by the computer to signal that it is ready to communicate with the serial device like modem. In other words, DTR indicates to the Dataset (i.e., the modem or DSU/CSU) that the DTE (computer) is ON.
- DSR
 - Similarly to DTR, Data set ready (DSR) is an indication from the Dataset that it is ON.
- DCD
 - Data Carrier Detect (DCD) indicates that carrier for the transmit data is ON.
- RTS
 - This pin is used to request clearance to send data to a modem
- CTS
 - This pin is used by the serial device to acknowledge the computer's RTS Signal. In most situations, RTS and CTS are constantly on throughout the communication session.
- CD
 - CD stands for Carrier Detect. Carrier Detect is used by a modem to signal that it has made a connection with another modem, or has detected a carrier tone.
- RI
 - RI stands for Ring Indicator. A modem toggles (keystroke) the state of this line when an incoming call rings your phone.

RS-232 vs UART

- RS-232 is a standard for Serial Communication
- RS-232 is a specification that describe the physical, mechanical, electrical characteristics for serial communication
- The bits are transmitted serially.
- Full Duplex
- UART – Universal Asynchronous Receiver/Transmitter
- UART and RS-232 are not the same
- UART interface is responsible for sending and receiving a sequence of bits

RS-232 Communication Parameters

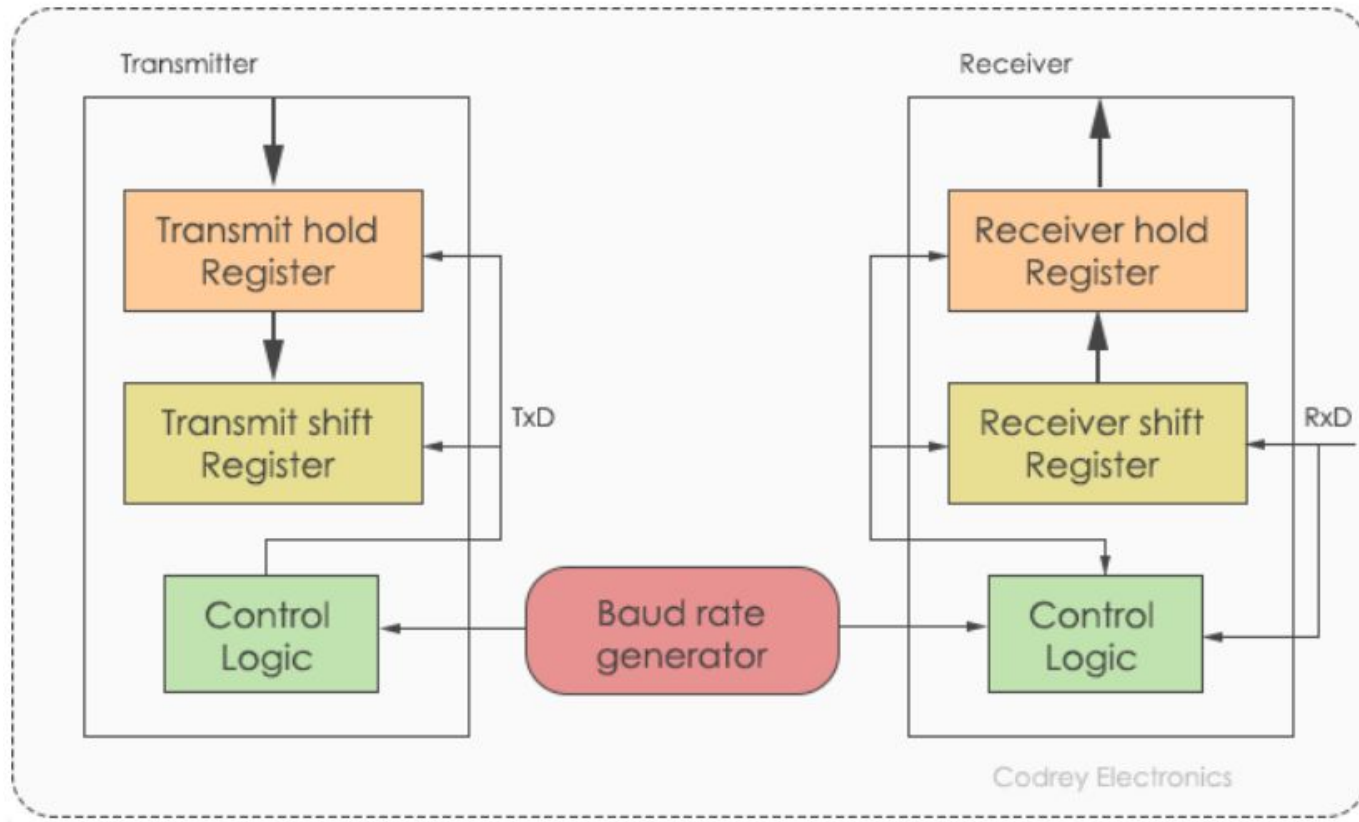
- Data bits
 - Characters can have 5,6,7 or 8 bits
 - For sending ASCII character, no. Of bits is 7
- Data rate
 - 50, 150,300,1200,2400,9600,38400,57600,115200bps
- Start bit (1 bit)
 - indicate beginning of a character
- Stop bit (1 or 1.5 or 2)
 - End of character
- Parity bit
 - Error checking
 - Odd or even parity
 - Odd Parity: total number of bits odd
- Flow Control (stop/resume data transmission)
 - Device A send at a faster rate; Device B can't absorb the data at that rate
 - Handshaking
 - Handshaking signals (RTS/CTS – hardware flow control)
 - Software Flow Control – (Ctrl + S, Ctrl + Q) – a.k.a. XON/XOFF



UART

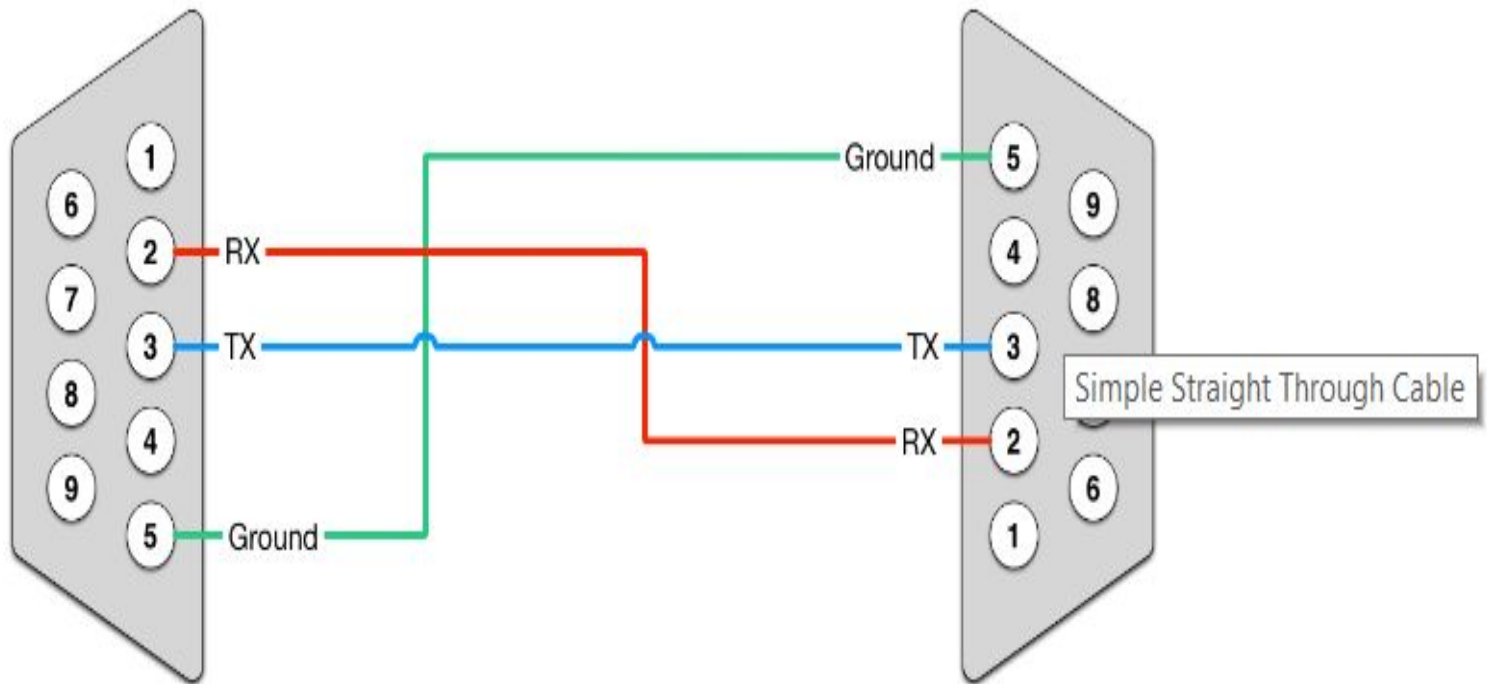
- Universal Asynchronous Receiver Transmitter
- It is a peripheral that is present inside a microcontroller (UART chip)
- Function:
 - Receives data in Serial format, converts to Parallel format and gives it to processor
 - Transmission: Convert Parallel format to serial format

UART block Diagram

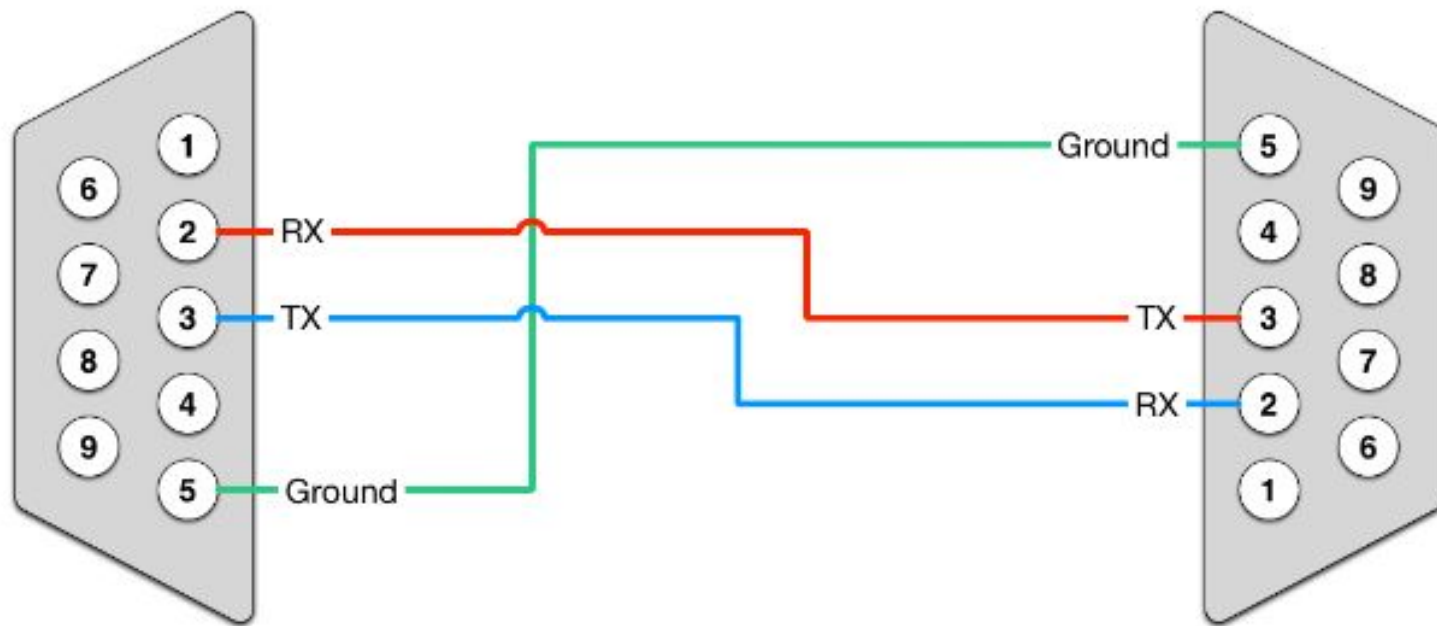


- Baud rate generator - generates the speed at which the transmitter and receiver have to send/receive the data
- A read or write control logic is provided to tell when to read/write

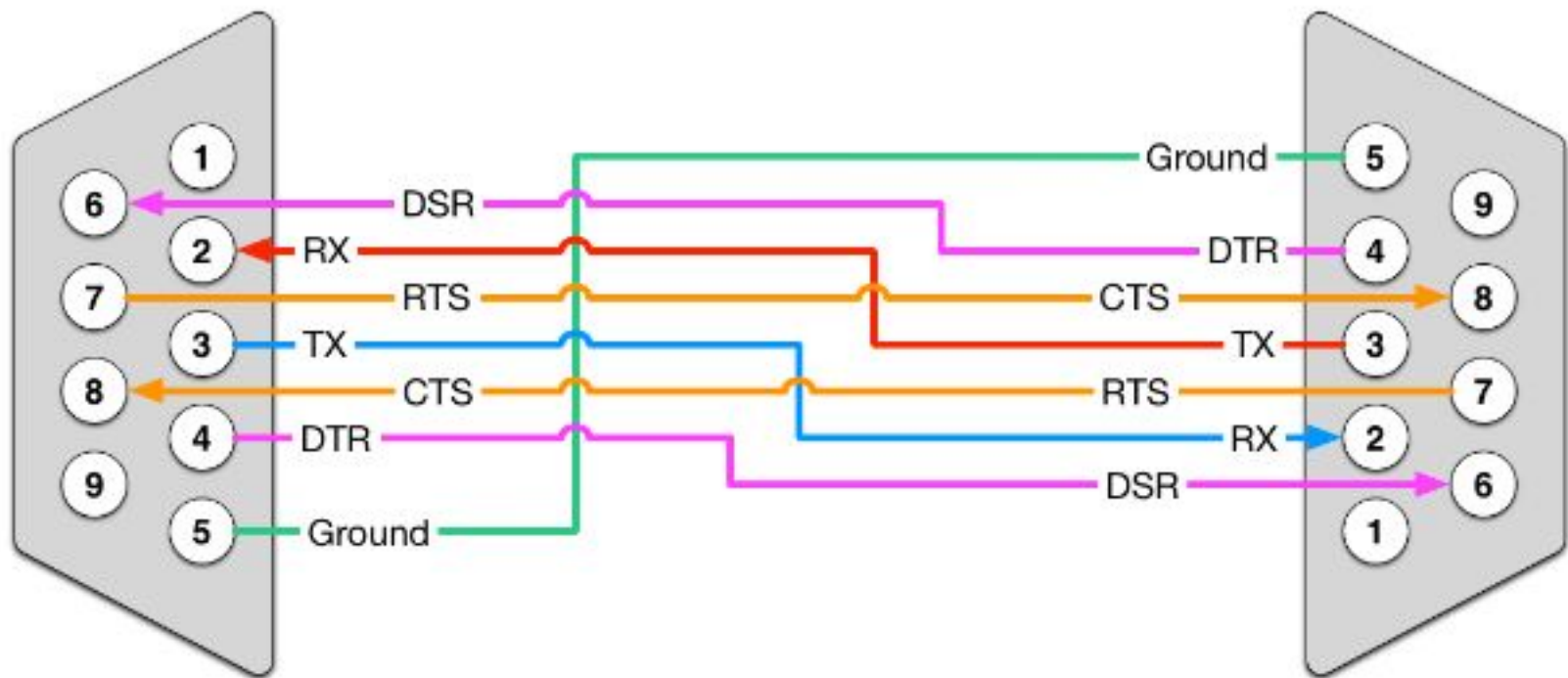
Simple Straight Cable Connection



Simple Null Modem Cable Connection



Null Modem Cable with Handshaking



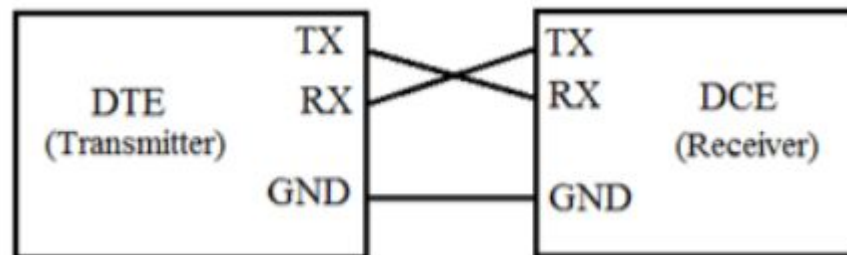
a.k.a Cross over cable

Difference between DTR and RTS

- DTR means Data Terminal Ready and indicates that the connected device is ready to receive data
- RTS means Request To Send and indicates to the connected device that it wants to send data
- DTR is used to indicate the presence of some equipment
- RTS is one half of hardware flow control (along with CTS) to start and stop communication.

RS-232 Standard

- RS232 is a standard protocol used for serial communication
- It is used for connecting computer and its peripheral devices to allow serial data exchange between them.
- As it obtains the voltage for the path used for the data exchange between the devices. It is used in serial communication up to 50 feet with the rate of 1.492kbps.
- As EIA defines, the RS232 is used for connecting **Data Transmission Equipment (DTE)** and **Data Communication Equipment (DCE)**.



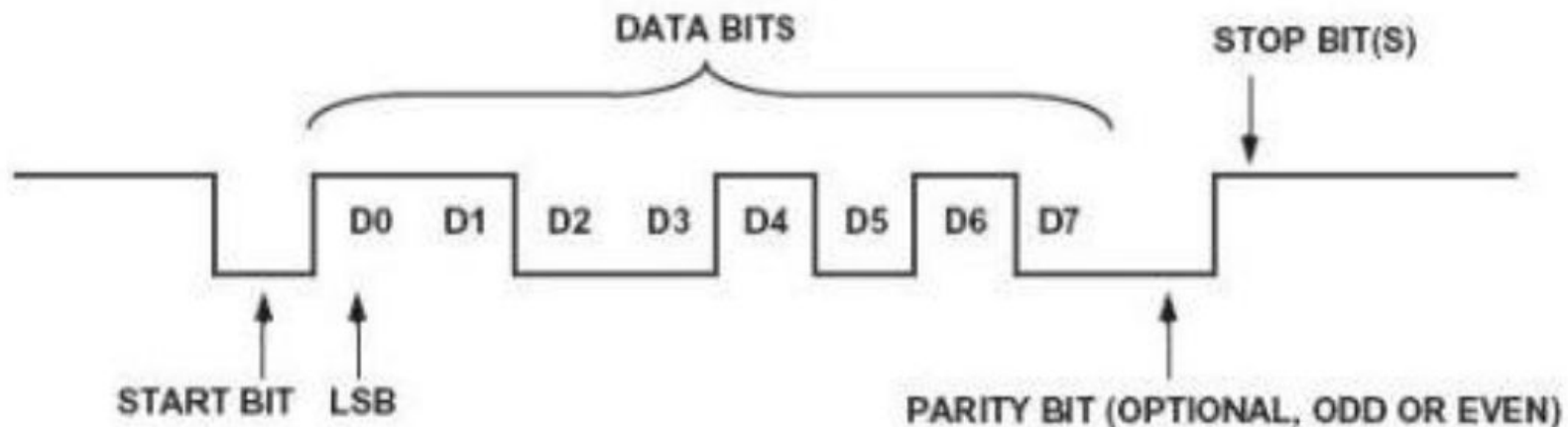
Electrical Specification of RS-232

- **Voltage Levels:** RS232 also used as ground & 5V level. Binary 0 works with voltages up to +5V to +15Vdc. It is called as 'ON' or spacing (high voltage level) whereas Binary 1 works with voltages up to -5V to -15Vdc. It is called as 'OFF' or marking (low voltage level).
- **Received signal voltage level:** Binary 0 works on the received signal voltages up to +3V to +13 Vdc & Binary 1 works with voltages up to -3V to -13 Vdc.
- **Line Impedances:** The impedance of wires is up to 3 ohms to 7 ohms & the maximum cable length are 15 meters, but new maximum length in terms of capacitance per unit length.
- **Operation Voltage:** The operation voltage will be 250v AC max.
- **Current Rating:** The current rating will be 3 Amps max.
- **Dielectric withstanding voltage:** 1000 VAC min.
- **Slew Rate:** The rate of change of signal levels is termed as Slew Rate. With its slew rate is up to 30 V/microsecond and the maximum bitrate will be 20 kbps.

How RS-232 Works ?

- Full – duplex - RS232 works on the two-way communication that exchanges data to one another.
- There are two devices connected to each other, **(DTE) Data Transmission Equipment & (DCE) Data Communication Equipment** which has the pins like **TXD, RXD, and RTS & CTS**.
- Now, from **DTE** source, the **RTS** generates the *request to send* the data. Then from the other side **DCE**, the **CTS**, clears the path for receiving the data.
- After clearing a path, it will give a signal to **RTS** of the **DTE** source to send the signal.
- Then the bits are transmitted from **DTE** to **DCE**.
- Now again from **DCE** source, the request can be generated by **RTS** and **CTS** of **DTE** sources clears the path for receiving the data and gives a signal to send the data.
- This is the whole process through which data transmission takes place.

RS-232 Communication Parameters



Asynchronous Transmission: UART data transfers are asynchronous. The transmitter transmits each bit (of the word being transmitted) for a fixed duration (defined by baud rate).

UART

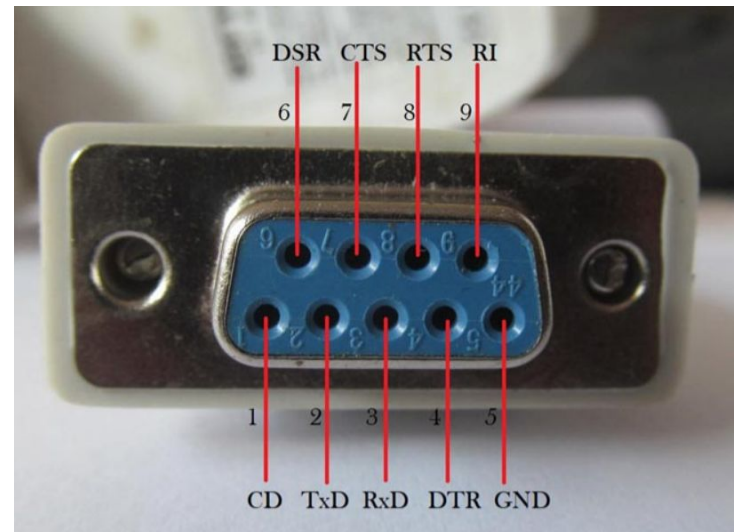
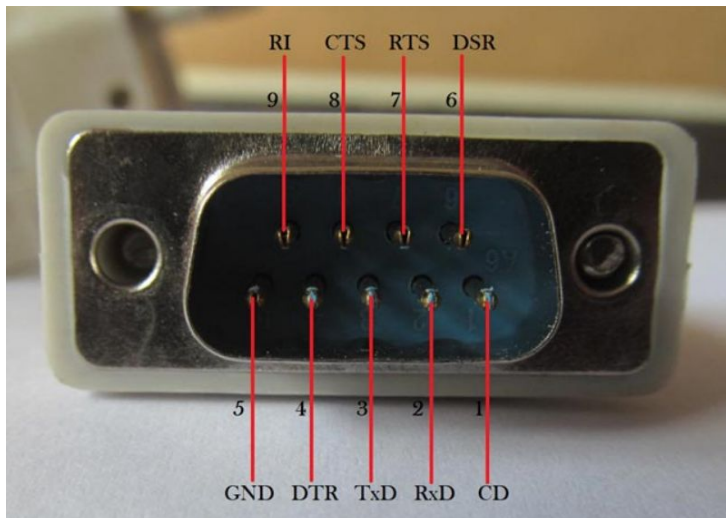
- **Universal Asynchronous Data Receiver & Transmitter (UART)** used in connection with RS232 for transferring data between printer and computer. The microcontrollers are not able to handle such kind of voltage levels, connectors are connected between RS232 signals.

RS-232 port and cable



Mechanical Specification

- Two types of connectors that is **DB-25** and **DB-9**.
- In DB-25, there are 25 pins available which are used for many of the applications, but some of the applications didn't use the whole 25 pins.
- DB-9 Male and Female connectors

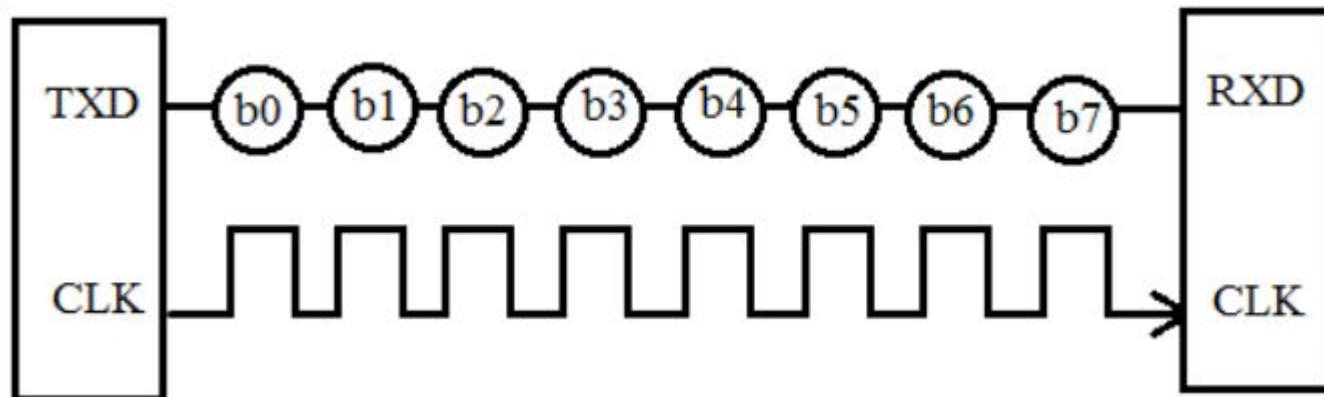


Pin Description

PIN No.	Pin Name	Pin Description
1	CD (Carrier Detect)	Incoming signal from DCE
2	RD (Receive Data)	Receives incoming data from DTE
3	TD (Transmit Data)	Send outgoing data to DCE
4	DTR (Data Terminal Ready)	Outgoing handshaking signal
5	GND (Signal ground)	Common reference voltage
6	DSR (Data Set Ready)	Incoming handshaking signal
7	RTS (Request to Send)	Outgoing signal for controlling flow
8	CTS (Clear to Send)	Incoming signal for controlling flow
9	RI (Ring Indicator)	Incoming signal from DCE

Serial Communication

- In telecommunication, the process of sending data sequentially over a computer bus is called as **serial communication**, which means the data will be transmitted bit by bit. While in parallel communication the data is transmitted in a byte (8 bit) or character on several data lines or buses at a time.



Modes of Transfer

- **Asynchronous Data Transfer** – The mode in which the bits of data are not synchronized by a clock pulse. Clock pulse is a signal used for synchronization of operation in an electronic system.
- **Synchronous Data Transfer** – The mode in which the bits of data are synchronized by a clock pulse.

Characteristics of Serial Communication

- **Baud rate** is used to measure the speed of transmission. It is described as the **number of bits passing in one second**. For example, if the baud rate is 200 then 200 bits per Sec passed. In telephone lines, the baud rates will be **14400, 28800 and 33600**.
- **Stop Bits** are used for a single packet to stop the transmission which is denoted as "T". Some typical values are **1, 1.5 & 2 bits**.
- **Parity Bit** is the simplest form of checking the errors. There are of four kinds, i.e., even odd, marked and spaced. **For example**, If 011 is a number the parity bit=0, i.e., even parity and the parity=1, i.e., odd parity.

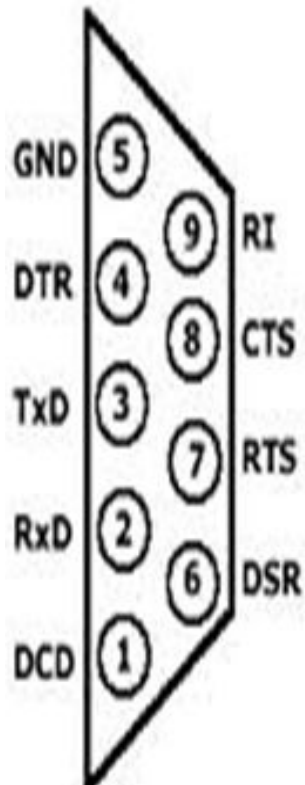
Handshaking

There are **3 types of handshaking processes**:

- No Handshaking
 - If there is no handshaking, then DCE reads the already received data while DTE transmits the next data. All the received data stored in a memory location known as receiver's buffer.
- Hardware Handshaking
 - It uses specific serial ports, i.e., RTS & CTS to control data flow.
- Software Handshaking
 - In this process, there are two forms, i.e., X-ON & X-OFF. Here, 'X' is the transmitter.
 - X-ON is the part in which it resumes the data transmission.
 - X-OFF is the part in which it pauses the data transmission.

RS-232 pins

RS-232 DB-9 Male Pinout



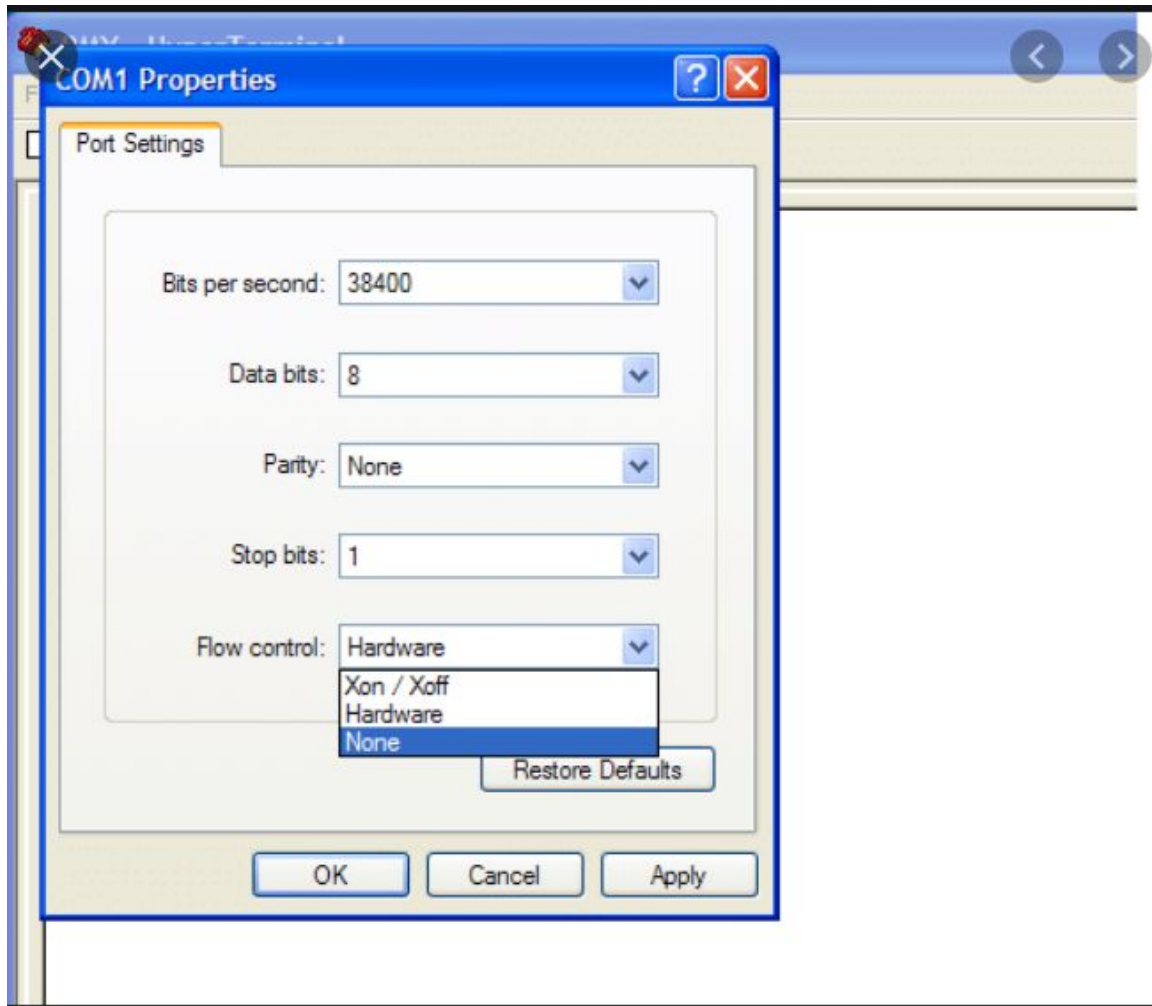
- PIN 1: Data Carrier Detect
- PIN 2: Receive Data
- PIN 3: Transmit Data
- PIN 4: Data Terminal Ready
- PIN 5: Signal Ground
- PIN 6: Data Set Ready
- PIN 7: Request to Send
- PIN 8: Clear to Send
- PIN 9: Ring Indicator

RS232 Pinout on DB25



- 2 Transmit Data (TxD)
- 3 Receive Data (RxD)
- 4 Request to Send (RTS)
- 5 Clear to Send (CTS)
- 6 Dataset ready (DSR)
- 7 Signal Ground
- 8 Data Carrier Detect (DCD)
- 15 Transmit Clock
- 17 Receive Clock
- 20 Data Terminal Ready (DTR)
- 24 Auxiliary Clock

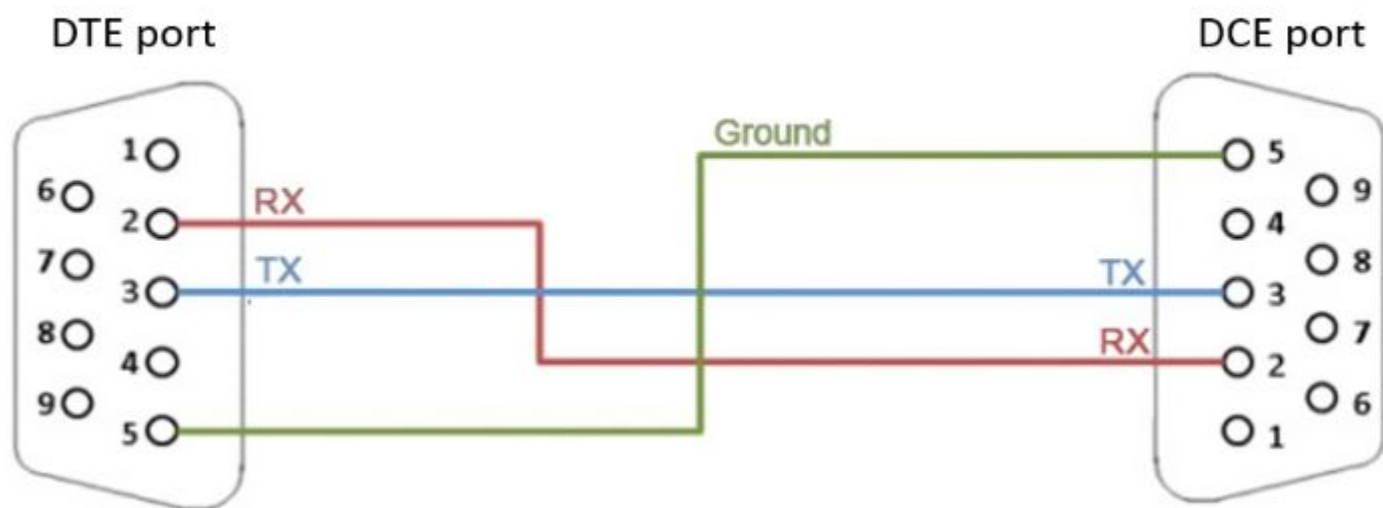
Hyperterminal



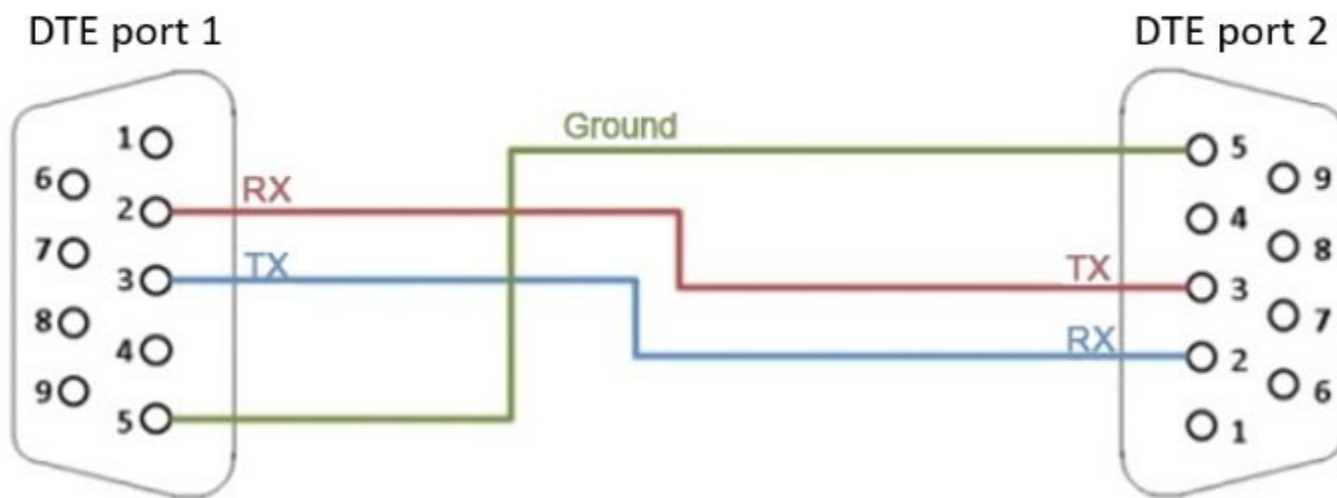
Types of Cable

- Straight Cable
- Crossover Cable or Null modem cable

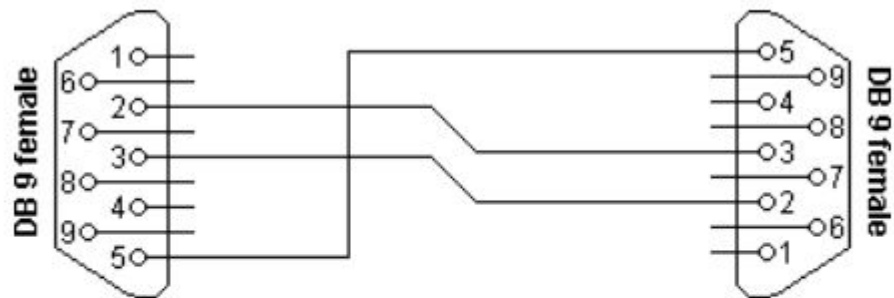
Simple Straight Through Cable Route



Simple Null Modem Cable Route

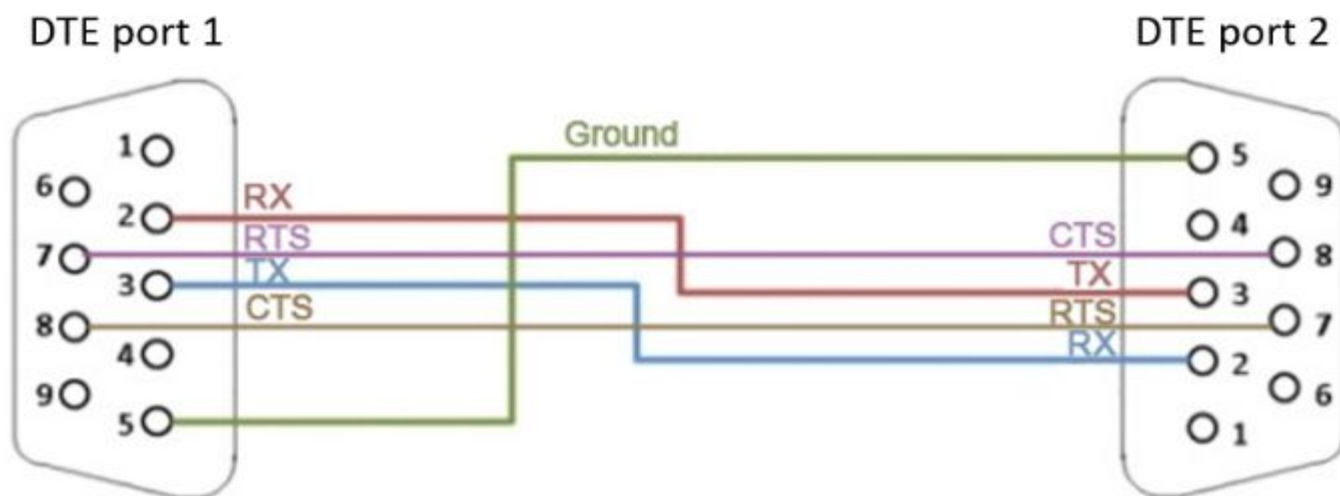


Simple null modem without handshaking

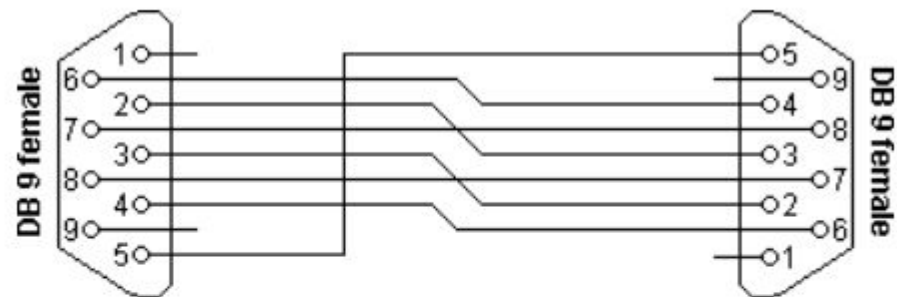


Connector 1	Connector 2	Function
2	3	Rx ← Tx
3	2	Tx → Rx
5	5	Signal ground

Null Modem Cable with Handshaking Route



Null modem with full handshaking



Connector 1	Connector 2	Function
2	3	Rx ← Tx
3	2	Tx → Rx
4	6	DTR → DSR
5	5	Signal ground
6	4	DSR ← DTR
7	8	RTS → CTS
8	7	CTS ← RTS

References

- <https://www.lammertbies.nl/comm/info/rs-232-null-modem>
- <https://circuitdigest.com/article/rs232-serial-communication-protocol-basics-specifications>