Electronic Industries Association (EIA) RS-232-C Interface Standard

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Synopsis

Editor's Note

The subject of this report is considered as a mature standard. No significant developments are anticipated, but because of its importance in the industry, coverage is being continued.

Copies of the RS-232-C standard can be obtained from the Electronic Industries Association, Engineering Department, 2001 I Street NW, Washington, DC 20006. A companion publication, "Application Notes for EIA Standard RS-232-C," is also available.

Report Highlights

RS-232-C is a set of specifications that applies to the transfer of data between data terminal equipment (DTE) and data circuit-terminating equipment (DCE). It defines the interface circuit functions and their corresponding connector pin assignments. It is the most common DTE to DCE interface used in the United States. Full- or half-duplex operations are supported for synchronous or asynchronous transmissions at speeds up to 20K bps.

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Analysis

The Electronic Industries Association (EIA) Standard RS-232-C defines the electrical and mechanical characteristics of the interface for connecting data terminal equipment (DTE) and data circuit-terminating equipment (DCE) using serial binary data communications. In the United States, RS-232-C is the most widely used DTE to DCE interface. It applies to all classes of service: private line, dial-up, point-to-point, multipoint, switched, nonswitched, two-wire, and four-wire service. Asynchronous and synchronous data transmission is supported at speeds up to 20K bps in full- or half-duplex mode. RS-232-C is a single-ended or unbalanced interface; all of the interchange signals share a common electrical ground.

RS-232-C is functionally compatible with the International Telegraph and Telephone Consultative Committee (CCITT) Recommendation V.24. Another similar interface, ISO IS2110, has been adopted by the International Organization for Standardization (ISO). Both the EIA RS-232-C and the ISO IS2110 specify a 25-pin connector. Pin incompatibilities exist, however, because of the diagnostic features outlined in RS-232-C.

RS-232-C coexists with another EIA standard for DTE to DCE interface, RS-449, which specifies requirements for expanded transmission speeds, longer cable lengths, and additional functions. Equipment meeting RS-232-C standards can be made compatible with equipment meeting RS-449 standards by using an interface converter.

As the terms relate to this interface, data terminal equipment (DTE) is business machine hardware such as teleprinters, CRTs, front-end ports, CPUs, etc.; data circuit-terminating equipment (DCE) is hardware such as modems, limited distance data sets, or the data service units (DSUs).

Mechanical Characteristics

The physical connection between DTE and DCE is made through plug-in, 25-pin connectors. The connectors are keyed with 13 pins on the top row and 12 pins on the bottom row to prevent improper connection. The male connector is always associated with the DTE, and the female is always associated with the DCE. The cable is provided by the DTE. The use of short cables, each less than 50 feet or 15 meters, is recommended. Use of longer cables is permissible, however, provided that load capacity requirements are met. Longer cables are used with the length restricted by the data rate (in synchronous applications, the clock leads generally run twice as fast as the data leads), and by the environment. Proximity to heavy rotating machinery or other noisy/radiating devices will limit the practical cable length.

Pin assignments are explicit and unalterable, unless unassigned. Special functions not specifically defined should be allotted to unassigned pins. For example, pin 25 (unassigned) is sometimes used to "busy out" a connected modem that is associated with a switched application. This causes the modem to go "off hook," thus preventing an incoming call from being connected/answered. Because some pins are unassigned, and because all the functions defined by RS-232-C are not necessarily required for a specific application, all 25 pins are not usually used. Contact the DTE vendor to determine the specific configuration.

Interchange Circuits

An interchange circuit is defined as a circuit between the data terminal equipment and the data circuit-terminating equipment. RS-232-C describes the four categories of interchange circuits that apply generally to all systems. They are ground or common return, data, control, and timing circuits. Twenty-two circuits are specified by possible functions, and three are unassigned. See Table 1.

Ground Circuits

The ground interchange circuits are *Protective Ground (AA)* and *Signal Ground (AB)*. Protective Ground is electrically bonded to the equipment frame; it can be connected to an external ground (e.g., the ground pin of an electrical power plug). Signal Ground establishes a common reference for all interchange circuits, except Protective Ground.

Data Circuits

Two types of data circuits are described. A **primary channel** is a data transmission channel that has the

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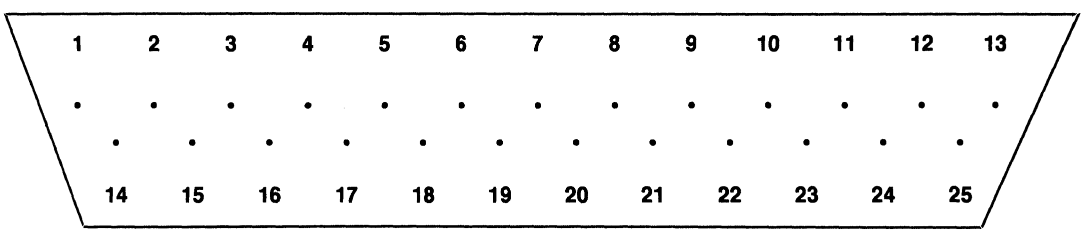
Table 1. EIA RS-232-C Interface Connector Pin Assignments

Pin Number	Function	Circuit	Data Signal from DCE	Data Signal from DTE	Control Signal from DCE	Control Signal from DTE	Timing Signal from DCE	Timing Signal from DTE	CCITT Equivalent*
1	Protective ground	AA							101
2	Transmitted data	BA		X					103
3	Received data	BB	X						104
4	Request to send	CA				X			105
5	Clear to send	CB			X				106
6	Data set ready	CC			X				107
7	Signal ground/common return	AB							102
8	Received line signal detector	CF			X				109
9	Reserved for data set testing								
10	Reserved for data set testing								
11	Unassigned								
12	Secondary received line signal detector	SCF			X				122
13	Secondary clear to send	SCB			X				121
14	Secondary transmitted data	SBA		X					118
15	Transmission signal element timing (DCE)	DB					X		114
16	Secondary received data	SBB	X						119
17	Receiver signal element timing (DCE)	DD					X		115
18	Unassigned								
19	Secondary request to send	SCA				X			120
20	Data terminal ready	CD				X			108.2
21	Signal quality detector	CG			X				110
22	Ring indicator	CE			X				125
23	Data signal rate selector	CH/CI			X	X			111/112
24	Transmit signal element timing (DTE)	DA						X	113
25	Secondary clear to send	SCB			X				

DCE = Data Communication Equipment **DTE = Data Terminal Equipment**

Pin Number Assignments



Equivalents are outlined in CCITT Recommendation V.24.

highest signaling rate of all channels sharing a common interface connector.

The **secondary channel** has a lower signaling rate than the primary channel in a system where two channels share a common interface connector. RS-232-C defines two types of secondary channels: *auxiliary*, whose direction of transmission is independent of the primary channel and is controlled by the appropriate set of secondary control interchange circuits; and *backward*, whose direction of transmission must always be opposite that of the primary channel.

Secondary channels are established because in some communications systems, greater channel efficiency can be achieved by using a lower speed subchannel to carry control responses. Signals usually flow in opposite directions to one another: primary in one direction at a higher speed, and secondary in the reverse direction at a lower speed.

RS-232-C accommodates primary and secondary arrangements with separately defined secondary interchange circuits for Transmitted Data, Received Data, Request to Send, Clear to Send, and Received Line Signal Detector. Secondary circuits may be independent of other interchange circuits in terms of direction and speed. The secondary interchange circuits, however, are additional circuits that function in the same manner as their basic counterparts and follow the same conditions that govern corresponding basic circuits (see Tables 1, 2, and 3). For the DTE to transmit data on the secondary channel, an ON condition must

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be present on the following four circuits: SCA (Secondary Request to Send); SCB (Secondary Clear to Send); CC (Data Set Ready); and CD (Data Terminal Ready).

When the data circuits are idle, they are in a mark hold condition (binary "ones"). Data is transferred in bipolar fashion. A binary "one" (mark) is represented by a voltage more negative than −3 volts; a binary "zero" (space) is represented by a voltage more positive than +3 volts.

Control Circuits

Control signals are used to enable and disable data transmission and reception, and to indicate the operational status and condition of the DTE and DCE. A control function is considered to be in the ON condition when the voltage is more positive than +3 volts; it is considered to be in the OFF condition when the voltage is more negative than −3 volts. These control circuits include *Request to Send (RTS)*, *Clear to Send (CTS)*, *Data Set Ready (DSR)*, *Data Terminal Ready (DTR)*, *Received Line Signal Detector (carrier detect, CD)*, and *Ring (RI)*. Assuming a half-duplex transmission between DTE/DCE-1 and DTE/DCE-2 is run over the public switched network, the control sequence might be as follows:

1. All control circuits OFF.
2. DTE/DCE-1 places a call to DTE/DCE-2; DCE-1 turns DSR ON to DTE-1, DTE-1 turns DTR ON to DCE-1.
3. DCE-2 turns RI ON to DTE-2.
4. DTE-2 turns DTR ON to DCE-2.
5. DCE-2 goes "off hook" and turns DSR ON to DTE-2.
6. DTE-2 turns RTS ON to DCE-2.
7. DCE-2 turns CTS ON to DTE-2 (ENQ transmitted), DTE/DCE-2 turns OFF RTS and CTS.
8. DCE-1 turns CD ON to DTE-1.
9. DTE-1 decodes ENQ, turns ON RTS.
10. DCE-1 turns ON CTS; DTE-1 transmits response.

The four basic control signals relating to transmission are:

1. Request to Send (RTS)—Circuit CA

- Conditions the local DCE for data transmission.
- Controls the direction of transmission on half-duplex channels, maintains transmit, and inhibits receive.
- Maintains the DCE in the transmit mode on duplex or one-way only channels; otherwise, holds it in nontransmit.
- RTS transition (OFF to ON) causes the DCE to enter transmit mode and turn CTS ON.
- RTS transition (ON to OFF) causes the DCE to complete the data transmission, enter the receive or nontransmit mode, and turn CTS OFF.

2. Clear to Send (CTS)—Circuit CB

- Indicates to the DTE that data can be transmitted (CTS ON) or cannot be transmitted (CTS OFF).
- CTS ON is delayed until the remote DCE is initialized.
- When RTS is not implemented, CTS must be ON continuously.

3. Data Set Ready (DSR)—Circuit CC

- Indicates the local data set status.
- ON indicates that the data set is connected to the communications channel ("Off Hook" or switched service) and is not in test, talk (alternative voice/data), or dial mode. The ON condition of this circuit should not be interpreted as either the status of any remote station equipment or an indication that a communication channel has been established to a remote data station.
- ON indicates completed timing functions, if any, required for call establishment (switched service).
- ON indicates completed transmission of a discreet answer tone, the duration of which is controlled by the local data set.
- OFF, occurring during transmission, indicates that the connection has been lost. A new transmission must be originated.

4. Data Terminal Ready (DTR)—Circuit CD

- Used to control switching of the DCE to the communications channel.

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- The ON condition prepares the data set to connect and maintain connection to the communications channel.
- With automatic answering equipment, connection to the communications channel occurs when both the Data Terminal Ready and the Ring Indicator circuit are in the ON condition. The OFF condition of the Data Terminal Ready circuit does not disable the Ring Indicator signal.
- In switched systems, Data Set Ready must be OFF before Data Terminal Ready is turned ON again.

Other control interchange circuits include the following.

The *Ring Indicator, Circuit CE,* indicates that a ring (call) signal is being received on the communications channel through the switched network. The circuit is in an ON condition during ringing and in an OFF condition between rings or when ringing is not present.

The *Received Line Signal Detector, Circuit CF,* presents an ON condition to indicate that data signals are being received, and that they are acceptable for demodulation. An OFF condition indicates that data signals are not being received, or that they are not acceptable for demodulation. The OFF condition causes the Received Data (Circuit BB) to be held in a binary one (marking) condition.

The *Signal Quality Detector, Circuit CG,* indicates whether there is a high probability of error in received data. The ON condition is maintained, unless a high probability of error has occurred. Probable error is indicated by the OFF condition. This condition can be used to effect retransmission.

Data Signal Rate Detector, Circuit CH or *CI,* is used to select between two signaling rates when the data set or data terminal accommodates dual rates. The ON condition selects the higher rate or range of rates. Circuit CH indicates that the data terminal provides the selection signal. Circuit CI indicates that the data set provides the selection signal. Selection is between two asynchronous rates or between two synchronous rates.

Timing Circuits

Two circuits are used to provide **Transmitter Signal Element Timing**.

Circuit DA provides signal element timing information to the transmitting signal converter, the DCE. The ON-OFF transition indicates the occurrence of the center of the data element. The DTE normally provides timing information on this circuit when the DTE is powered ON. If Circuit CA (Request to Send) is OFF, timing information on Circuit DA may be withheld by the DTE for short periods.

Circuit DB provides signal element timing to the DTE. A data signal on Circuit BA (Transmitted Data) is provided from the DTE in which the transition between signal elements occurs at the time of the OFF-ON transition in Circuit DB. If Circuit CC (Data Set Ready) is OFF, it is permissible for the DCE to withhold timing information for short periods. The performance of maintenance tests within the DCE, for example, may require the withholding of timing information.

Receiver Signal Element Timing, Circuit DD, provides timing to the data terminal from the data set. The ON-OFF transition indicates the center of the received data elements.

Standard Interfaces for Selected Configurations

EIA RS-232-C describes a selected set of data transmission configurations or interfaces. A provision is made for the addition of custom configurations. Determining factors in the selection of an interface type are whether the DTE transmits, receives, or does both; whether the mode of operation is half or full duplex; and whether a secondary channel is used. The interface designations do not relate to which terminal originates or answers the call, but rather to the data transmitted.

RS-232-C defines selected interface types by letter designation. These types are described in Table 2, where the direction of data transfer pertaining to the interface is stated (function), and the use of Request to Send and Received Line Signal Detector interchange circuits is stipulated (comment). This list indicates that interfaces A and B, which are one-way only transmissions, differ only in terms of the use of RTS. Interface D is normally employed with half-duplex operation using RTS, and interface E is normally employed with full-duplex operation without using RTS. When interface D is used in full-duplex operation, however, RTS is used with special significance.

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Table 2. Selected Configuration Interfaces

Interface Type	Function	Comment
A	Transmits only	RTS not used
B	Transmits only	RTS used
C	Receives only	RLSD used
D	Transmits or Receives (HDX)	RTS used*; RLSD used
D	Transmits and Receives (FDX)	RTS not used: RLSD used
F	Primary Transmits only	RTS used*
	Secondary Receives only	Secondary RLSD used
G	Secondary Transmits only	Secondary RTS used*
	Primary Receives only	RLSD used
H	Primary Transmits only	RTS not used
	Secondary Receives only	Secondary RLSD used
I	Secondary Transmits only	Secondary RTS not used
	Primary Receives only	RLSD used
J	Primary Transmits only	RTS used*
	Secondary Transmits or Receives (HDX)	Secondary RTS and RLSD used
K	Primary Receives only	RLSD used
	Secondary Transmits or Receives (HDX)	Secondary RTS and RLSD used
L	Primary Transmits or Receives (HDX)	RTS used; RSLD used
	Secondary Transmits or Receives (HDX)	Secondary RTS used
L	Primary Transmits or Receives (FDX)	RTS used*; RSLD used
	Secondary Transmits or Receives (FDX)	Secondary RTS used*
M	Primary Transmits or Receives (FDX)	RTS not used; RLSD used
	Secondary Transmits or Receives (FDX)	Secondary RTS not used; Secondary RLSD used
Z	Circuits specified by suppliers	

HDX—Half-duplex channel.
FDX—Full-duplex channel.
RTS—Request to Send signal.
RLSD—Received Line Signal Detector.

Indicates the Request to Send Circuit in a one-way (transmit) of duplex arrangement where RTS might not ordinarily be expected. It might be used to indicate a nontransmit mode to the DCE or to permit the DCE to remove a line signal or to send synchronization signals as required.

Interfaces E, F, G, and H define two-way transmission, where both the primary and secondary directions are one-way only.

Interfaces J, K, L, and M define less restrictive primary and secondary arrangements.

Interface Z simply allows a special arrangement to be established.

The complete relationship of interchange circuits to standard interface types is depicted in Tables 3a, 3b, and 3c.

Summary of Electrical Characteristics

The EIA RS-232-C standard prescribes bipolar-voltage serial data transmission between communicating devices. Within the EIA RS-232-C standard, transmitted data is represented by the mark condition for binary one and the space condition for binary zero. A data signal on an interchange circuit is in the mark condition when the voltage at the interface point is more negative than -3 volts with respect to signal ground (Circuit AB). When the data signal at the interface point is more positive than $+3$ volts, with respect to signal ground, the data signal is in the space condition. The area between -3 and $+3$ volts is the transition region. In the transition region, the signal state is not defined.

On timing or control interchange circuits, the signal is considered OFF when the voltage at the interface point is more negative than -3 volts with respect to signal ground. It is considered ON if the voltage at the interface point is more positive than $+3$ volts with respect to signal ground. The function is not defined for voltages in the transition region between -3 and $+3$ volts.

Mandatory Interchange Circuit conditions follow (see Figure 1):

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Table 3a. Required Interchange Circuits for Standard Interface Types A, B, C, D, and E

Interchange Circuit		Interface Type				
		A	B	C	D	E
AA	Protective Ground					
AB	Signal Ground	b	b	b	b	b
BA	Transmitted Data	b	b		b	b
BB	Received Data			b	b	b
CA	Request to Send		b		b	
CB	Clear to Send	b	b		b	b
CC	Data Set Ready	b	b	b	b	b
CD	Data Terminal Ready	s	s	s	s	s
CE	Ring Indicator	s	s	s	s	s
CF	Received Line Signal Detector			b	b	b
CG	Signal Quality Detector					
CH/CI	Data Rate Selector					
DA/DB	Transmitter Timing	t	t		t	t
DD	Receiver Timing			t	t	t

b—Basic interchange circuits required.
s—Required for switched network operation.
t—Required for synchronous operation.

Table 3b. Required Interchange Circuits for Standard Interface Types F, G, H, and I

Interchange Circuit		Interface Type			
		F	G	H	I
AA	Protective Ground				
AB	Signal Ground	b	b	b	b
BA	Transmitted Data	b		b	
BB	Received Data		b		b
SBA	Secondary Transmitted Data		b		b
SBB	Secondary Received Data	b		b	
CA	Request to Send	b			
SCA	Secondary Request to Send		b		
CB	Clear to Send	b		b	
SCB	Secondary Clear to Send		b		b
CC	Data Set Ready	b	b	b	b
CD	Data Terminal Ready	s	s	s	s
CE	Ring Indicator	s	s	s	s
CF	Received Line Signal Detector		b		b
SCF	Secondary RLSD	b		b	
CG	Signal Quality Detector				
CH/CI	Data Rate Selector				
DA/DB	Transmitter Timing	t		t	
DD	Receiver Timing		t		t

b—Basic interchange circuits required.
s—Required for switched network operation.
t—Required for synchronous operation.

- Open circuit driver voltage (VO), with respect to signal ground, must not exceed 25 volts with respect to ground.
- The potential at the interface point must not be less than 5 volts nor more than 15 volts in magnitude when the terminator resistance (RL) is between 3000 and 7000 ohms, and the terminator open voltage (EL) is zero.
- The effective shunt capacitance (CL), associated with the terminator, must not exceed 2500 picofarads at the interface point.

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Table 3c. Required Interchange Circuits for Standard Interface Types J, K, L, and M

Interchange Circuit		Interface Type			
		J	K	L	M
AA	Protective Ground				
AB	Signal Ground	b	b	b	b
BA	Transmitted Data	b		b	b
BB	Received Data		b	b	b
SBA	Secondary Transmitted Data	b	b	b	b
SBB	Secondary Received Data	b	b	b	b
CA	Request to Send	b		b	
SCA	Secondary Request to Send	b	b	b	
CB	Clear to Send	b		b	b
SCB	Secondary Clear to Send	b	b	b	b
CC	Data Set Ready	b	b	b	b
CD	Data Terminal Ready	s	s	s	s
CE	Ring Indicator	s	s	s	s
CF	Received Line Signal Detector				
SCF	Secondary RLSD	b	b	b	b
CG	Signal Quality Detector				
CH/CI	Data Rate Selector				
DA/DB	Transmitter Timing	t	t	t	t
DD	Receiver Timing		t	t	t

b—Basic interchange circuits required.
s—Required for switched network operation.
t—Required for synchronous operation.

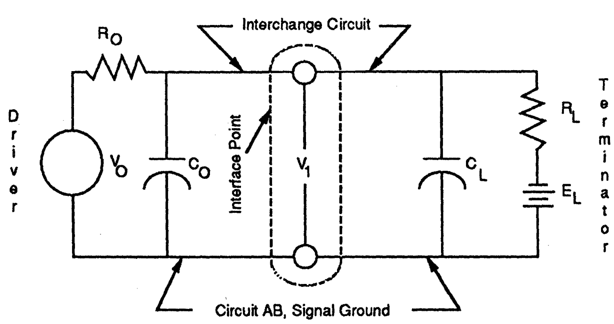
- The open circuit terminator voltage (EL) must not exceed 2 volts.

Request to Send (CA), Data Set Ready (CC), Data Terminal Ready (CD), and Secondary Request to Send (SCA), where implemented, are used to detect the power-off condition or the disconnection of the interconnecting cable.

Certain limitations apply to all interchange signals (data, control, and timing):

- All interchange signals entering transition must proceed to the opposite signal state, and may not reenter the transition region until the next significant change in signal condition.
- The direction of voltage must not change while in the transition region.
- The time required for a control signal to pass through the transition region must not exceed one millisecond.
- The time required for a data or timing signal to pass through the transition region must not exceed one millisecond or 4 percent of the normal duration of a signal element on that interchange circuit, whichever is the lesser.
- The maximum instantaneous rate of voltage must not exceed 30 volts per microsecond. ■

Figure 1.
Interchange Equivalent Circuit



V_O — Open circuit driver voltage.
R_O — Driver internal DC resistance.
C_O — Total effective capacitance associated with the driver.
V_1 — Voltage at interface point.
C_L — Total effective capacitance associated with the terminator.
R_L — Terminator load DC resistance.
E_L — Open circuit terminator voltage (bias).

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