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DATA COMMUNICATION OVER THE TELEPHONE NETWORK

ELECTRICAL CHARACTERISTICS FOR UNBALANCED DOUBLE-CURRENT INTERCHANGE CIRCUITS OPERATING AT DATA SIGNALLING RATES NOMINALLY UP TO 100 kbit/s

ITU-T Recommendation V.10

(Previously "CCITT Recommendation")

FOREWORD

The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of the International Telecommunication Union. The ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Conference (WTSC), which meets every four years, established the topics for study by the ITU-T Study Groups which, in their turn, produce Recommendations on these topics.

ITU-T Recommendation V.10 was revised by the ITU-T Study Group XVII (1988-1993) and was approved by the WTSC (Helsinki, March 1-12, 1993).

NOTES

1 As a consequence of a reform process within the International Telecommunication Union (ITU), the CCITT ceased to exist as of 28 February 1993. In its place, the ITU Telecommunication Standardization Sector (ITU-T) was created as of 1 March 1993. Similarly, in this reform process, the CCIR and the IFRB have been replaced by the Radiocommunication Sector.

In order not to delay publication of this Recommendation, no change has been made in the text to references containing the acronyms "CCITT, CCIR or IFRB" or their associated entities such as Plenary Assembly, Secretariat, etc. Future editions of this Recommendation will contain the proper terminology related to the new ITU structure.

2 In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

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ELECTRICAL CHARACTERISTICS FOR UNBALANCED DOUBLE-CURRENT INTERCHANGE CIRCUITS OPERATING AT DATA SIGNALLING RATES NOMINALLY UP TO 100 kbit/s[1) 2)]

(Geneva, 1976; amended at Geneva, 1980, at Melbourne, 1988 and Helsinki, 1993)

1 Introduction

This Recommendation deals with the electrical characteristics of the generator, receiver and interconnecting leads of an unbalanced interchange circuit employing a differential receiver.

In the context of this Recommendation an unbalanced interchange circuit is defined as consisting of an unbalanced generator connected to a receiver by an interconnecting lead and a common return lead.

Annexes and appendices are provided to give guidance on a number of application aspects as follows:

Annex A Compatibility with other interfaces

Annex B Considerations for coaxial cable applications - V.10 COAXIAL

Appendix I Waveshaping

Appendix II Cable guidelines

NOTE – Generator and load devices meeting the electrical characteristics of this Recommendation need not operate over the entire data signalling rate range specified. They may be designed to operate over narrower ranges to satisfy specific requirements more economically, particularly at lower data signalling rates.

The interconnecting cable is normally not terminated, but the matter of terminating coaxial interconnecting cable is dealt with in Annex B. Where the interchange circuit incorporates the special provisions for coaxial applications with cable termination this shall be referred to as "complying with Recommendation V.10 (COAXIAL)".

Reference measurements are described which may be used to verify certain of the recommended parameters but it is a matter for individual manufacturers to decide what tests are necessary to ensure compliance with this Recommendation.

2 Field of application

The electrical characteristics specified in this Recommendation apply to interchange circuits operating with data signalling rates up to 100 kbit/s.

This Recommendation is not intended to apply to equipment implemented in discrete component technology, for which the electrical characteristics covered by Recommendation V.28 are more appropriate.

Typical points of application are illustrated in Figure 1.

Whilst the unbalanced interchange circuit is primarily intended for use at the lower data signalling rates, its use should be avoided in the following cases:

1) where the interconnecting cable is too long for proper unbalanced circuit operation;
2) where extraneous noise sources make unbalanced circuit operation impossible;
3) where it is necessary to minimize interference with other signals.

Whilst a restriction on maximum cable length is not specified, guidelines are given with respect to conservative operating distance as a function of data signalling rates (see Appendix II).

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1) This Recommendation is also designated as X.26 in the X-Series Recommendations.

2) Signalling rates above the suggested 100 kbit/s may also be employed, but the maximum suggested operating distances should be shortened accordingly (see Figure II-1).

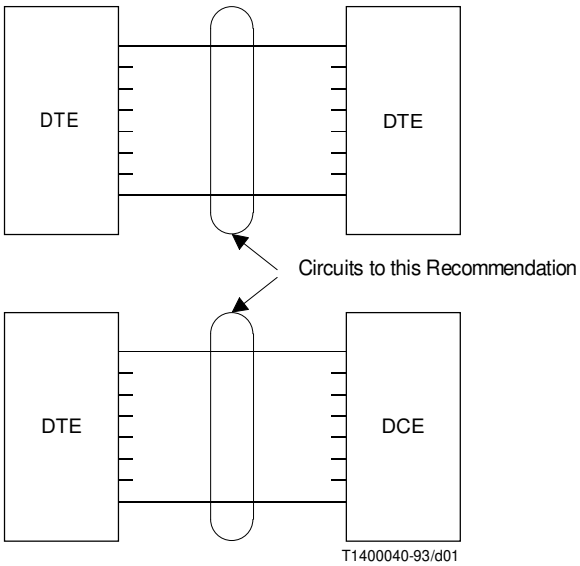


FIGURE 1/V.10

Typical applications of unbalanced interchange circuits

3 Symbolic representation of an interchange circuit

See Figure 2.

For data transmission applications, it is commonly accepted that the interface cabling is provided by the DTE. This introduces the line of demarcation between the DTE plus cable and the DCE. This line is also called the interchange point and physically implemented in the form of a connector. The applications also require interchange circuits in both directions. This leads to an illustration as shown in Figure 3.

4 Generator polarities and receiver significant levels

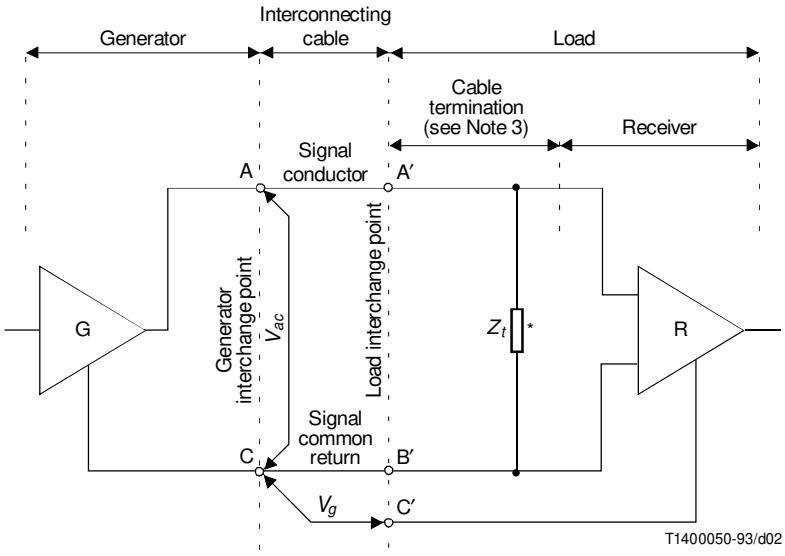
4.1 Generator

The signal conditions for the generator are specified in terms of the voltage between output points A and C shown in Figure 2.

When the signal condition 0 (space) for data circuits, or ON for control and timing circuits, is transmitted the output point A is positive with respect to point C. When the signal condition 1 (mark) for data circuits, or OFF for control and timing circuits, is transmitted the output point A is negative with respect to point C.

4.2 Receiver

The receiver significant levels are shown in Table 1, where $V_{A'}$ and $V_{B'}$ are respectively the voltage at points A' and B' relative to point C'.



* This terminating resistor is only used with "V.10-COAXIAL", see Annex B.

V_{ac} Generator output voltage
V_g Ground potential difference
Z_t Cable termination impedance
A Generator active interchange point
C Generator common return point
A′ Load active interchange point
B′ Load common return point
C′ Receiver zero reference point

NOTES

1 Two interchange points are shown. The output characteristics of the generator, excluding any interconnecting cable, are defined at the "generator interchange point". The electrical characteristics to which the receiver must respond are defined at the "load interchange point".

2 The connection of the signal common return is dealt with in 10 below. Points C and C´ may be connected to protective ground if required by national regulations.

3 The interconnecting cable is normally not terminated. The termination of coaxial interconnecting cable is dealt with in Annex B.

FIGURE 2/V.10

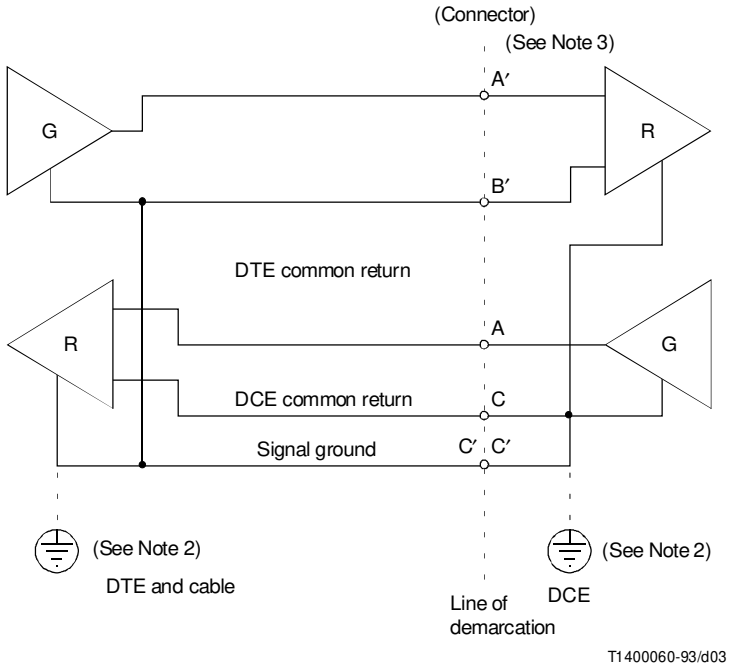
Symbolic representation of an unbalanced interchange circuit

5 Generator[3)]

5.1 Output impedance

The total dynamic output impedance of the generator shall be equal to or less than 50 ohms.

3) For test purposes other than specified in this Recommendation (e.g. signal quality measurement), a transmitter test load of 450 ohms may be used.



NOTES

1 The zero volt reference interchange points C´ may be interconnected via the signal ground conductor.

2 Signal ground may be further connected to external protective ground if national regulations require.

3 The type of connector with this electrical characteristic specification depends on the application. ISO specifies, for data transmission over telephone type facilities, a 37-pin connector in ISO 4902.

FIGURE 3/V.10

Practical representation of the interface

TABLE 1/V.10

Receiver significant levels

	$V_{A'} - V_{B'} \leq -0.3$ V	$V_{A'} - V_{B'} \geq +0.3$ V
Data circuits	1	0
Control and timing circuits	OFF	ON

5.2 Static reference measurements

The generator characteristics are specified in accordance with measurements illustrated in Figure 4 and described in 5.2.1 to 5.2.4.

5.2.1 Open circuit measurement

See Figure 4a).

The open circuit voltage measurement is made with a 3900-ohm resistor connected between points A and C. In both binary states, the magnitude of the signal voltage (V_0) shall be equal to or greater than 4.0 volts but not greater than 6.0 volts.

5.2.2 Test termination measurement

See Figure 4b).

With a test load of 450 ohms connected between output points A and C, the magnitude of the output voltage (V_t) in both binary states shall be equal to or greater than 0.9 of the magnitude of V_0.

5.2.3 Short-circuit measurement

See Figure 4c).

With the output points A and C short-circuited the current (I_s) flowing through point A in both binary states shall not exceed 150 milliamperes.

5.2.4 Power-off measurements

See Figure 4d).

Under power-off condition, with a voltage ranging between +0.25 volt and –0.25 volt applied between the output point A and point C, the magnitude of the output leakage current (I_x) shall not exceed 100 microamperes.

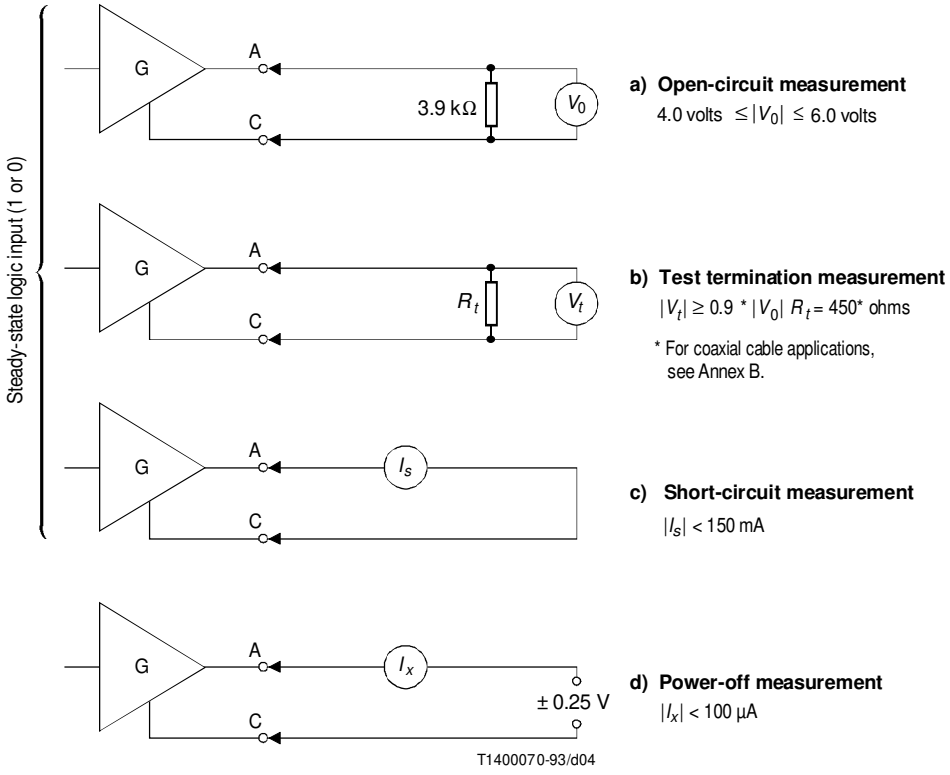


FIGURE 4/V.10

Generator parameter reference measurements

5.3 Generator output rise-time measurement

See Figure 5.

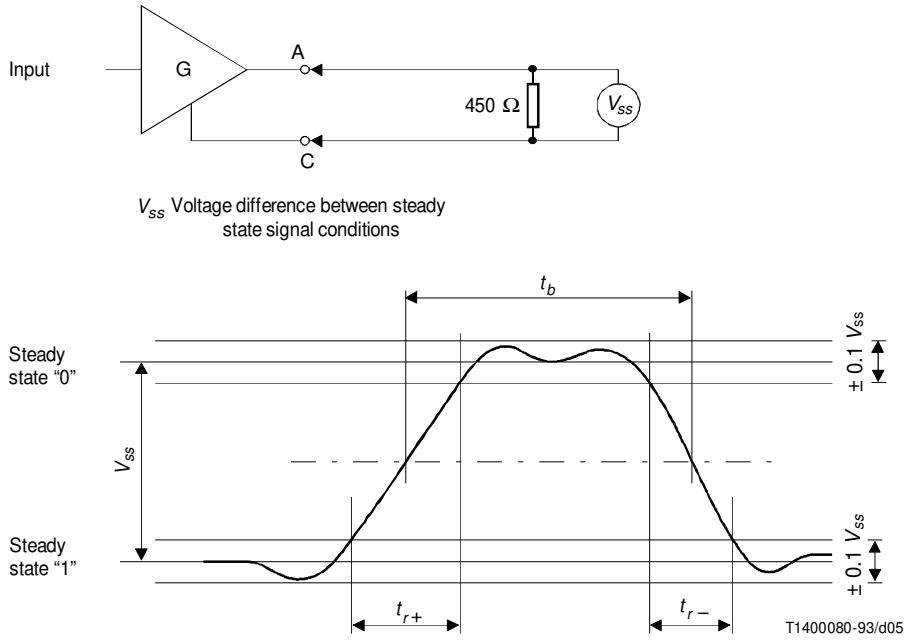


FIGURE 5/V.10

Generator output rise-time measurement

5.3.1 Waveform

The measurement will be made with a resistor of 450 ohms connected between points A and C. A test signal, with a nominal signal element duration t_b and composed of alternate ones and zeros, shall be applied to the input. The change in amplitude of the output signal during transitions from one binary state to the other shall be monotonic between 0.1 and 0.9 of V_{ss}.

5.3.2 Waveshaping

Waveshaping of the generator output signal shall be employed to control the level of interference (near-end crosstalk) which may be coupled to adjacent circuits in an interconnection. The rise time (t_r) of the output signal shall be controlled to ensure the signal reaches 0.9 V_{ss} between 0.1 and 0.3 of the duration of the unit interval (t_b) at signalling rates greater than 1 kbit/s, and between 100 and 300 microseconds at signalling rates of 1 kbit/s or less. The method of waveshaping is not specified but examples are given in Appendix I.

6 Load

6.1 Characteristics

The load consists of a receiver (R) as shown in Figure 2. The electrical characteristics of the receiver are specified in terms of the measurements illustrated in Figures 6, 7 and 8 and described in 6.2, 6.3 and 6.4 below. A circuit meeting these requirements results in a differential receiver having a high input impedance, a small input threshold transition region between –0.3 and +0.3 volts differential, and allowance for an internal bias voltage not to exceed 3 volts in magnitude.

The receiver is electrically identical to that specified for the balanced receiver in Recommendation V.11.

6.2 Receiver input voltage – Current measurements

See Figure 6.

With the voltage V_{ia} (or V_{ib}) ranging between –10 volts and +10 volts, while V_{ib} (or V_{ia}) is held at 0 volt, the resultant input current I_{ia} (or I_{ib}) shall remain within the shaded range shown in Figure 6. These measurements apply with the power supply of the receiver in both the power-on and power-off conditions.

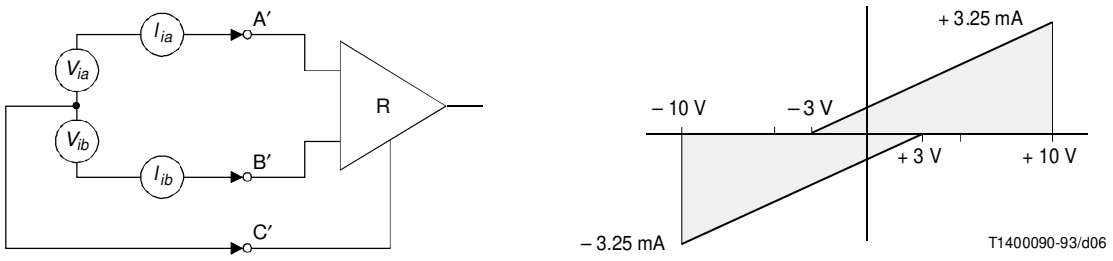


FIGURE 6/V.10

Receiver input voltage-current measurements

6.3 DC input sensitivity measurements

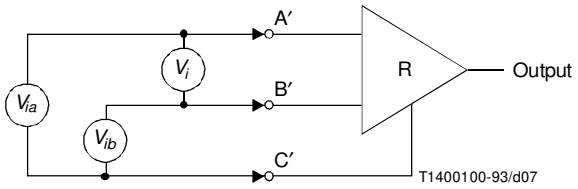
See Figure 7.

Over the entire common-mode voltage (V_{cm}) range of +7 volts to –7 volts, the receiver shall not require a differential input voltage (V_i) of more than 300 millivolts to assume correctly the intended binary state. Reversing the polarity of V_i shall cause the receiver to assume the opposite binary state.

The maximum voltage (signal plus common-mode) present between either receiver input and receiver ground shall not exceed 10 volts nor cause the receiver to malfunction. The receiver shall tolerate a maximum differential voltage of 12 volts applied across its input terminals without being damaged.

In the presence of the combinations of input voltages V_{ia} and V_{ib} specified in Figure 7, the receiver shall maintain the specified output binary state and shall not be damaged.

NOTE – Designers of equipment should be aware that slow signal transitions with noise present may give rise to instability or oscillatory conditions in the receiving equipment; therefore, appropriate techniques should be implemented to prevent such behaviour. For example, adequate hysteresis may be incorporated in the receiver to prevent such conditions.



Applied voltages		Resulting input voltage V_i	Output binary state	Purpose of measurement
V_{ia}	V_{ib}			
–12 V 0 V +12 V 0 V	0 V –12 V 0 V +12 V	–12 V +12 V +12 V –12 V	(Not specified)	To ensure no damage to receiver inputs
+10 V + 4 V –10 V – 4 V	+ 4 V +10 V – 4 V –10 V	+6 V –6 V –6 V +6 V	0 1 1 0	To guarantee correct operation at V_i = 6 V (maintain correct logic state)
				300 mV threshold measurement -
+0.30 V 0 V	0 V +0.30 V	+0.3 V –0.3 V	0 1	} V_{cm} = 0 V
+7.15 V +6.85 V	+6.85 V +7.15 V	+0.3 V –0.3 V	0 1	} V_{cm} = +7 V
–7.15 V –6.85 V	–6.85 V –7.15 V	–0.3 V +0.3 V	1 0	} V_{cm} = –7 V

FIGURE 7/V.10

Receiver input sensitivity measurement

6.4 Input balance test

See Figure 8.

The balance of the receiver input resistances and internal bias voltages shall be such that the receiver shall remain in the intended binary state under the conditions shown in Figure 8 and described as follows:

a) with V_i = +720 millivolts and V_{cm} varied between –7 and +7 volts;

b) with V_i = –720 millivolts and V_{cm} varied between –7 and +7 volts;

c) with V_i = +300 millivolts and V_{cm} a 1.5 volt peak-to-peak square wave at the highest applicable data signalling rate (this condition is provisional and subject to further study);

d) with V_i = –300 millivolts and V_{cm} a 1.5 volt peak-to-peak square wave at the highest applicable data signalling rate (this condition is provisional and subject to further study).

NOTE – The values of V_i are provisional and are the subject of further study.

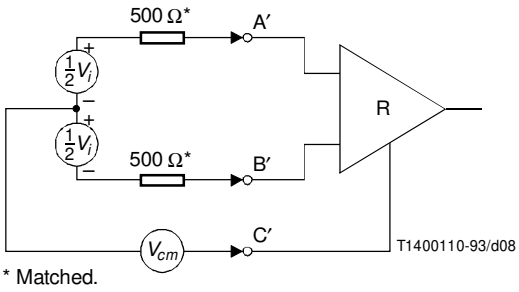


FIGURE 8/V.10

Receiver input balance test

7 Environmental constraints

In order to operate an unbalanced interchange circuit at data signalling rates ranging between 0 and 100 kbit/s, the following conditions apply:

1) The total peak differential noise measured between the points A' and B' at the load interchange point (with the generator interchange point connected to a 50-ohm resistor substituted for the generator) shall not exceed the expected amplitude of the received signal minus 0.3 volts (provisional value).

2) The worst-case combination of generator-receiver ground potential difference (V_g, Figure 2) and longitudinally induced peak random noise voltage measured between the receiver points A' or B' and C' with the generator ends of the cable A and C joined together shall not exceed 4 volts.

8 Circuit protection

Unbalanced generator and load devices complying with this Recommendation shall not be damaged under the following conditions:

1) generator open circuit;

2) short-circuit between the conductors of the interconnecting cable;

3) short-circuit between the conductors and Point C or C'.

The above faults 2) and 3) might cause power dissipation in the interchange circuit devices to approach the maximum power dissipation that may be tolerated by a typical integrated circuit (IC) package. The user is therefore cautioned that where multiple generators and receivers are implemented in a single IC package, only one such fault per package might be tolerable at any one time without damage occurring.

The user is also cautioned that the generator and receiver devices complying with this Recommendation might be damaged by spurious voltages applied between their input or output points and points C and C' (Figure 2). In those applications where the interconnecting cable may be inadvertently connected to other circuits or where it may be exposed to a severe electromagnetic environment, protection should be employed.

9 Category 1 and category 2 receivers

In order to provide flexibility in the choice of generator (V.10 or V.11), two categories of receiver are defined as follows:

Category 1 – Receivers shall have both input terminals A' and B' connected to individual terminals at the load interchange point, independent of all other receivers, as shown in Figure 9, and as applied in Figure A.1.

Category 2 – Receivers shall have one terminal connection for each A' input terminal at the load interchange point, and all B' input terminals shall be connected together within the DCE or DTE and shall be brought to one common B' input terminal as shown in Figure 10.

The specification of the category to be used in any application is part of the appropriate DCE Recommendation, using this type of interface electrical characteristics.

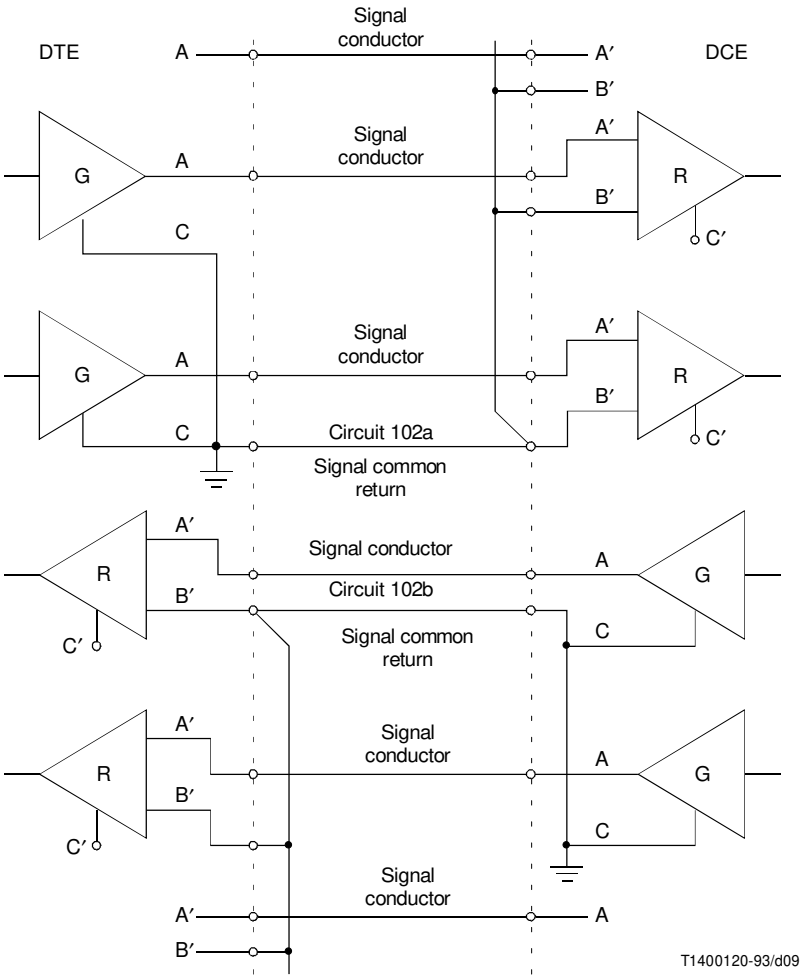


FIGURE 9/V.10

Interconnection of signal common return for category 1 receivers

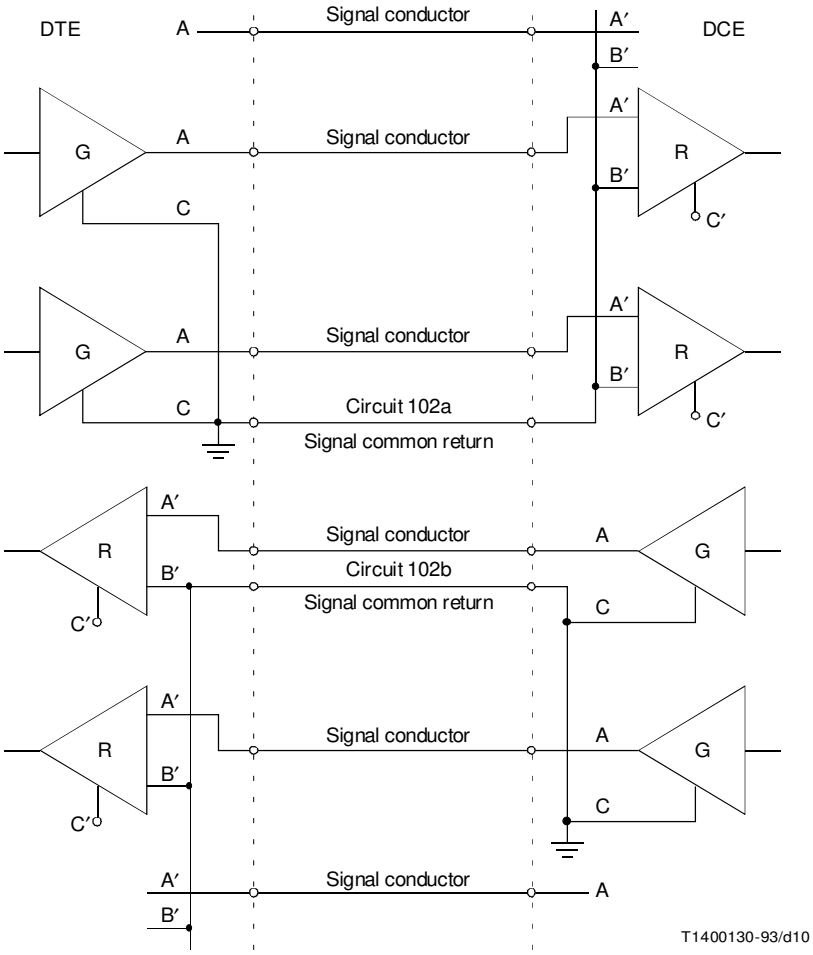


FIGURE 10/V.10

Interconnection of signal common return for category 2 receivers

10 Signal common return

The interconnection between the generator and the load interchange points in Figure 2 shall consist of a signal conductor for each circuit and one signal common return for each direction as shown in Figures 9 and 10. Signal common return may be implemented by more than one lead, where required to accomplish interworking, as described in A.2 and as shown in Figure A.1.

To minimize the effects of ground potential difference V_g and longitudinally-coupled noise on the signal at the load interchange point, the signal common return shall be connected to ground only at the C terminal of the generator interchange point. For example, the B' terminal of all the receivers in DTE which interconnect with unbalanced generators in DCE shall connect to signal common return circuit 102b, which is connected to ground only in DCE. Signal common return circuit 102a is used to interconnect terminal B' of the receivers in DCE with the grounded terminal C of the unbalanced generators in DTE, as in Figures 9 and 10.

11 Detection of generator power-off or circuit failure

Certain applications require detection of various fault conditions in the interchange circuits, e.g.:

1) generator power-off condition;

2) receiver not interconnected with a generator;

3) open-circuited interconnecting cable;

4) short-circuited interconnecting cable;

5) input signal to the load remaining within the transition region (± 300 millivolts) for an abnormal period of time.

When detection of one or more fault conditions is required by specific applications, additional provisions are required in the load and the following items must be determined:

a) which interchange circuits require fault detection;

b) what faults must be detected;

c) what action must be taken when a fault is detected, e.g. which binary state must the receiver assume?

The interpretation of a fault condition by a receiver (or load) is application dependent. Each application may use a combination of the following classification:

Type 0 – No interpretation. A receiver or load does not have fault detection capability.

Type 1 – Data circuits assume a binary 1 state. Control and timing circuits assume an OFF condition.

Type 2 – Data circuits assume binary 0 state. Control and timing circuits assume an ON condition.

Type 3 – Special interpretation. The receiver or load provides a special indication for interpreting a fault condition. This special indication requires further study.

The association of the circuit failure detection to particular interchange circuits in accordance with the above types is a matter of the functional and procedural characteristics specification of the interface.

The interchange circuits monitoring circuit fault conditions in the general telephone network interfaces are indicated in Recommendation V.24.

The interchange circuits monitoring circuit fault conditions in data network interfaces are indicated in Recommendation X.24 [1].

The receiver fault detection type required is specified in the relevant DCE Recommendations.

12 Measurements at the physical interchange point

The following information provides guidance for measurements when maintenance persons examine the interface for proper operation at the interchange point.

12.1 Listing of essential measurements

– open-circuit measurements;

– test-termination measurement;

– short-circuit measurement;

– generator output rise time;

– d.c. input sensitivity measurements.

12.2 Listing of optional measurements

– the total generator resistance between points A and C shall be equal to or less than 50 ohms;

– power-off measurements;

– receiver input voltage espace-espace current measurements;

– input balance test;

– check of the required circuit fault detection (clause 11).

The parameters defined in this Recommendation are not necessarily measurable at the physical interchange point. This is for further study.

Annex A

Compatibility with other interfaces

(This annex forms an integral part of this Recommendation)

A.1 Compatibility of Recommendation V.10 and Recommendation V.11 interchange circuits in the same interface

The electrical characteristics of Recommendation V.10 are designed to allow the use of balanced (see Recommendation V.11) and unbalanced circuits within the same interface. For example, the balanced circuits may be used for data and timing whilst the unbalanced circuits may be used for associated control circuit functions.

A.2 Recommendation V.10 interworking with Recommendation V.11

The differential receiver specifications of this Recommendation and Recommendation V.11 are electrically identical. It is therefore possible to interconnect an equipment using Recommendation V.10 receivers and generators on one side of the interface with an equipment using Recommendation V.11 generators and receivers on the other side of the interface. Such interconnection would result in interchange circuits according to Recommendation V.11 in one direction and interchange circuits according to this Recommendation in the other direction. Where such interworking is contemplated, the following technical considerations must be taken into account.

A.2.1 Interconnecting cable lengths are limited by performance of the circuits working to the Recommen-dation V.10 side of the interface.

A.2.2 The optional cable termination resistance (Z_t), if implemented, in the equipment using Recommendation V.11 must be removed.

A.2.3 V.10-type receivers shall be of category 1 (see Figure A.1).

A.3 Recommendation V.10 interworking with Recommendation V.28

The unbalanced electrical characteristics of this Recommendation have also been designed to permit limited interworking, under certain conditions, with generators and receivers to Recommendation V.28. Where such interworking is contemplated, the following technical limitations must be considered:

A.3.1 Separate DTE and DCE signal return paths will not be available at the Recommendation V.28 side of the interface.

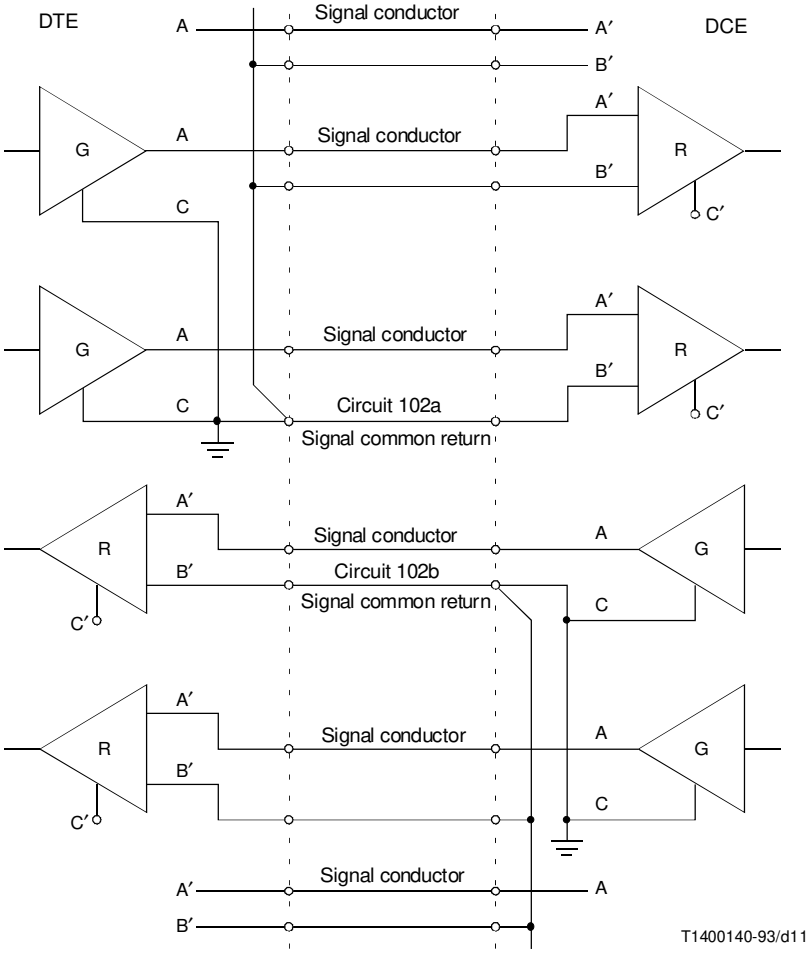


FIGURE A.1/V.10

Interconnection of signal common return by more than one conductor in order to accomplish interoperation of V.10 generators with category 1 receivers

A.3.2 Data signalling-rate limitations according to Recommendation V.28 shall apply.

A.3.3 Interconnecting cable lengths are limited by the Recommendation V.28 performance restrictions.

A.3.4 Probability of satisfactory operation will be enhanced by providing the maximum generator voltage possible on the Recommendation V.10 side of the interface within the limitations stipulated in this Recommendation.

A.3.5 There may be equipment in the field where the V.28 type generators use potentials in excess of 12 volts and up to 25 volts. Where connection to this type of equipment is envisaged, adequate protection for the V.10 receivers is advised.

A.3.6 Power-off detectors in Recommendation V.28 receivers may not necessarily work with Recommendation V.10 generators.

Annex B

Considerations for coaxial cable applications – V.10 COAXIAL[4)]

(This annex forms an integral part of this Recommendation)

It is recognized that where coaxial cables are used for interconnecting purposes it may be desirable to include a terminating resistance at the receiver end of the cable. This is considered to be a special case for which special generator characteristics are required. The terminating resistance shall in no case be less than 50 ohms and the reference measurements under 5.2.2 and 5.3 shall be made with a 50-ohm test termination[5)]. Use of this special application will require appropriate agreement with the proper authority.

The alternative set of electrical characteristics applied in the coaxial cable case is the following.

5.2.2 *bis* Test termination measurement

See Figure 4b)**.**

With a test load (R_t) of 50 ohms connected between output points A and C, the magnitude of the output voltage (V_t) shall be equal to or greater than 0.5 of the magnitude of V_0.

5.3.1 *bis* Waveform

See Figure 5**.**

The measurement will be made with a resistor of 50 ohms connected between points A and C. A test signal, with a nominal signal element duration t_b and composed of alternate ones and zeros, shall be applied to the input. The change in amplitude of the output signal during transitions from one binary state to the other shall be monotonic between 0.1 and 0.9 of V_{ss}.

5.3.2 *bis* Waveshaping

Waveshaping is not normally required for coaxial cable applications.

10 *bis* Signal common return

In applications where coaxial cables are used, the screen of the coaxial cable shall be connected to ground only at point C at the generator end as shown in Figure B.1.

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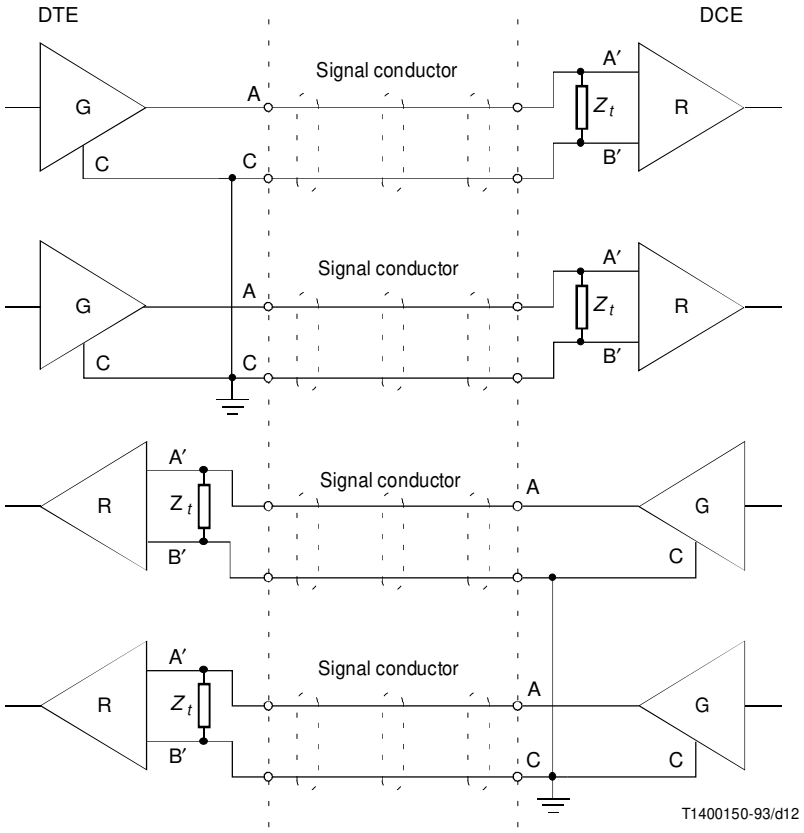
4) All the electrical characteristics specified in Recommendation V.10 other than those set down in this annex are applicable to the coaxial cable case with a cable case with a cable termination.

5) For test purposes other than specified in this Recommendation (e.g. signal quality measurement), a transmitter test load of 50 ohms may be used.



Z_t Optional termination impedance

FIGURE B.1/V.10

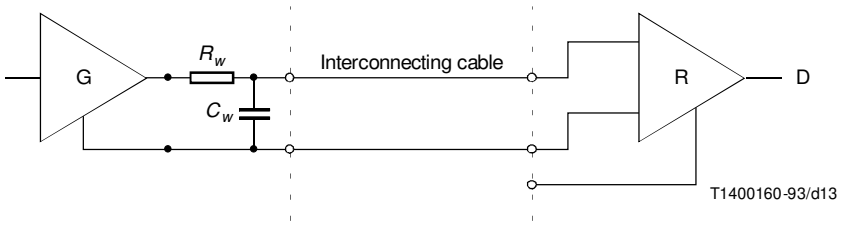
Interconnection with coaxial cable

Appendix I

Waveshaping

(This appendix does not form an integral part of this Recommendation)

The required waveshaping may be accomplished either by providing a slew-rate control in the generator or by inserting an RC filter at the generator interchange point. A combination of these methods may also be employed. An example of the RC filter method is shown in Figure I.1. Typical values of capacitance C_w, with the value of R_w selected so that $R_w + R_d$ is approximately 50 ohms, are given for typical cable with an interconductor shunt capacitance of approximately 0.05 microfarads per kilometre.



R_d Generator internal resistance
R_w 50 ohms – R_d

C_w (microfarads)	Data signalling rate range (kbit/s)
1.0	de 0 - 2.5
0.47	de 2.5 - 5
0.22	de 5 - 10
0.1	de 10 - 25
0.047	de 25 - 50
0.022	de 50 - 100

FIGURE 1.1/V.10

Example method of waveshaping

Appendix II

Cable Guidelines

(This appendix does not form an integral part of this Recomendation)

No electrical characteristics of the interconnection cable are specified in this Recommendation. However, guidance is given herein concerning operational constraints imposed by cable length and near-end crosstalk.

The maximum operating distance for the unbalanced interchange circuit is primarily a function of the amount of interference (near-end crosstalk) coupled to adjacent circuits in the equipment interconnection. Additionally the unbalanced circuit is susceptible to exposure to differential noise resulting from any imbalance between the signal conductor and signal common return at the load interchange point. Increasing the physical separation and interconnection cable length between the generator and load interchange points might increase the exposure to common-mode noise and the degree of near-end crosstalk. Accordingly, users are advised to restrict the cable length to a minimum consistent with the generator-load physical separation requirements.

The curve of cable length versus data signalling rate given in Figure II.1 may be used as a conservative guide. This curve is based upon calculations and empirical data using twisted-pair telephone cable with a shunt capacitance of 0.052 microfarads per kilometre, a 50-ohm source impedance, a 6-volt source signal and maximum near-end crosstalk of 1-volt peak. The rise time (t_r) of the source signal at signalling rates below 1000 bit/s is 100 microseconds and above 1000 bit/s is 0.1 t_b (see Figure 5).

The user is cautioned that the curve given in Figure II-1 does not account for common-mode noise or near-end crosstalk levels beyond the limits specified, that may be introduced between the generator and load by exceptionally long cables. On the other hand operation within the signalling-rate and distance bounds of Figure II.1 will usually ensure that the distortion of the signal appearing at the receiver input will be acceptable. Many applications, however, can tolerate greater levels of signal distortion, and correspondingly greater cable lengths can be employed. The generation of near-end crosstalk can be reduced by increasing the amount of waveshaping employed.

Experience has shown that in most practical cases the operating distance at the lower data signalling rates may be extended to several kilometres.

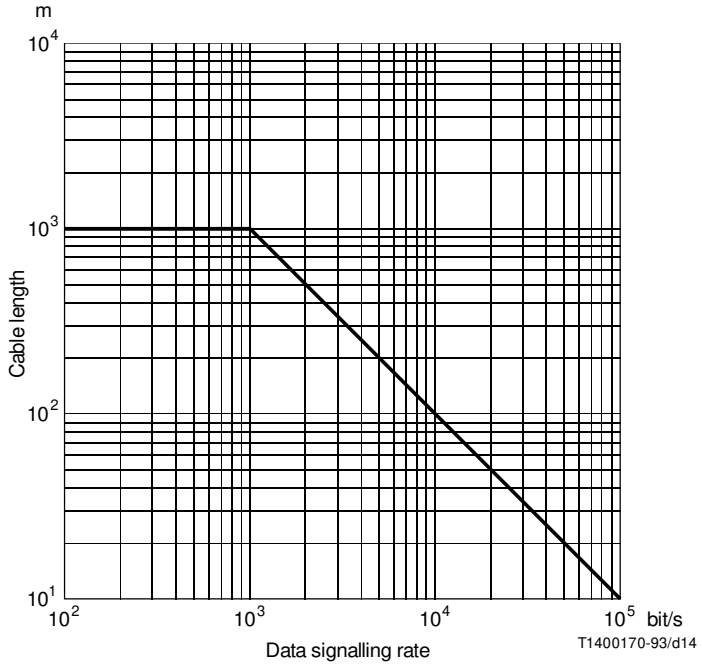


FIGURE II.1/V.10

Data signalling rate vs cable length for unbalanced interchange circuit

Reference

[1] CCITT Recommendation *List of definitions for interchange circuits between data terminal equipment (DTE) and data circuit-terminating equipment (DCE) on public data networks*, Vol. VIII, Rec. X.24.