

IEEE Guide for Power System Protective Relay Applications Over Digital Communication Channels

IEEE Power and Energy Society

Sponsored by the
Power System Relaying Committee

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IEEE Guide for Power System Protective Relay Applications Over Digital Communication Channels

Sponsor

Power System Relaying Committee
of the
IEEE Power and Energy Society

Approved 6 March 2013

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Abstract: Guidance for the power system user in applying, installing and operating digital communication channels for the purpose of protective relaying is provided in this guide.

Keywords: ac pilot wire, alarm, asynchronous, audio Tone, channel, current differential, data communication equipment, data terminal equipment, DCE, DDS, digital data service, direct under-reaching transfer trip, DTE, DUTT, Ethernet, FC connector, fiber optic, GOOSE, Ground Potential Rise, IEEE C37.94™, IEEE C37.236™, jitter, LC connector, loopback, microwave, MT-RJ connector, multiplexer, phase comparison, radio frequency interference, RFI, RS-232, RS-422, RS-449, RS-530, signal attenuation, SONET, TDM, telecommunication, teleprotection, time division multiplex, transfer trip, tunneling, V.35, zone

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Introduction

This introduction is not part of IEEE Std C37.236-2013, IEEE Guide for Power System Protective Relay Applications Over Digital Communication Channels.

This is a guide for the application of digital communication for protective relaying systems and schemes. This document is intended to guide the power system user in applying, installing and operating digital communication channels for the purpose of protective relaying. This guide covers the topics including transmitting and receiving equipment, digital channels, application principals, performance, installation, troubleshooting, testing and maintenance.

There are several standards, environmental and otherwise, while not mandatory for the use of this document, are highly recommended and are listed in the bibliography.

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1. Overview

1.1 Scope

This is a guide for the application of digital communication for protective relaying systems and schemes, including transmitting and receiving equipment, digital channels, application principals, performance, installation, troubleshooting, testing and maintenance. Reflected in this guide are the knowledge and experience of equipment manufacturers and power utility users. This guide is not intended to supplant specific or general instructions contained in manufacturers’ books nor any contractual agreements.

1.2 Purpose

The primary purpose of this document is to guide the power system user in applying, installing and operating digital communication channels for the purpose of protective relaying. The guide is prepared not only for those considering digital communication relaying for the first time, but also as a reference for the experienced user.

2. Definitions and acronyms

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.¹

2.1 Definitions

asynchronous communications: A transmission method in which each data terminal equipment (DTE) transmits messages without regard for the rate at which messages are received. A Start bit is used to identify the beginning of each message byte, and a stop bit is generally used to identify the end of the message byte. A dwell time generally exists between the end of one byte and the transmission of the next message byte.

bidirectional line switched ring (BLSR): BLSR does not send redundant copies from ingress to egress. BLSRs switch at the line layer. The ring nodes adjacent to a failure reroute the traffic “the long way” around the ring.

central-directional: Clock signals supplied on different wires from a centralized clock.

channel addressing: A technique used in digital teleprotection in which specific transmitters and receivers have matched addresses that are sent with data.

channel delay: The sum of the communication electronics and the communication path delays.

channel hopping: Where frame alignment is off by exactly one-channel time.

co-directional: Data and timing sent in the same direction over the same two twisted pair of wires.

communication configurations: *See: linear drop; insert and star.*

contra-directional: There are always 8-wires, two pairs for clock signals, and two for data.

current differential schemes: This scheme compares remotely measured values of either current samples or computed current phasors (magnitudes and angles) with locally measured time-aligned samples or phasors. The time delay associated with communicating samples or phasor quantities must be determined by test, or automatically computed by the terminal devices to provide proper time-alignment of local and remote signals.

digital data service (DDS): Also known as dataphone digital service or digital data system. A non-switched (dedicated) digital service network for data rates up to 56 000 bps.

digital telephone hierarchy (T1): A digital carrier signal designed to carry speech or data at the DS1 rate, which is 1.544 Mbps.

direct digital interface (DDI): A direct digital interface in a multiplexer or channel bank is an electrical interface from an Intelligent Electronic Device operating at 56 kbps or 64 kbps.

directional comparison blocking scheme: This scheme requires overreaching tripping and blocking functions. The transmitter normally sends a GUARD signal or is off for quiescent conditions and signals a

¹IEEE Standards Dictionary Online subscription is available at:
http://www.ieee.org/portal/innovate/products/standard/standards_dictionary.html.

TRIP by operation of any one of the blocking functions. Receipt of a remote terminal signal applies the NOT input to the local comparator to BLOCK it from producing an output.

directional comparison hybrid scheme: The overreaching tripping functions or the remote terminal initiates a TRIP signal, but with no concurrent output of the blocking functions at the local terminal.

directional comparison unblocking scheme: This scheme utilizes the power line as a communication media and requires a permissive overreaching directional comparison scheme. When a remote signal is lost, the local unblocking logic will produce a TRIP output that will last for 150 ms to 300 ms. If a fault exists, at least one of the RO permissive trip function will be picked up, and tripping will be initiated. If no trip functions are picked up, the channel will lock itself out in 150 ms to 300 ms after the remote signal is lost.

dual-phase comparison: In dual-phase comparison, the logic compares during both half-cycles of the power system sine wave.

extrinsic fiber losses: The losses are caused by external influences on the fiber, such as bending.

ferrule connector (FC): This connector has a threaded body. Datacom and telecom connections.

fiber attenuation: Fiber losses, either intrinsic, or extrinsic. *See:* **extrinsic fiber losses; intrinsic fiber losses.**

fiber optic interfaces: *See:* **ferrule connector (FC); little connector (LC); mechanical transfer registered jack; square connector (SC); sub miniature A (SMA); straight tip (ST).**

fiber optic splicing: *See* **fusion fiber optic splicing; mechanical fiber optic splicing.**

fusion fiber optic splicing: Splicing by melting fiber ends together using an electric arc.

intrinsic fiber losses: This is caused by impurities in the fiber.

little connector: Snaps into place. High density connections.

linear drop and insert: Capability to drop off specific DSO channels between any two points or nodes, and insert DSO channels into vacated time slots.

loss of frame: In the reception of framed data, a loss of frame is an interruption in data output, causing data to be mis-framed for the time it takes to detect the loss of frame and the time to reframe.

mechanical fiber optic splicing: Splicing with the use of connectors.

mechanical transfer registered jack (MT-RJ): Snaps into place. Duplex multimode connections.

message acknowledgment and retransmission (Ack/Nak): To improve reliable communications, packet switched network protocols have the receiver acknowledge receipt of data, or they will notify the sender which packets were received incorrectly and may have to be retransmitted.

optical fiber interface (OFIF): An optical fiber interface in a multiplexer or channel bank from a intelligent electronic device has a channel operating at 64 kbps or at multiples up to 12.

packet switching networks: Networks that route messages from origin to destination in which the message is broken up into segments of limited length called packets.

phase comparison schemes: *See* **dual-phase comparison; single-phase comparison.**

pink noise: Pink noise or $1/f$ noise is a signal with a frequency spectrum such that the power spectral density is proportional to the reciprocal of the frequency.

resynchronism: In a synchronous optical network (SONET), circuit switching can require the network to resynchronize, thus delaying messages for a period of time.

single-phase comparison: In single-phase comparison, the relay compares the local square wave and the received remote square wave in one half-cycle.

square connector (SC): Snaps into place. Datacom and telecom connections. *Syn:* **stick and click**.

star: Communication network comprised of multiple point-to-point systems, all with one common point.

straight tip (ST): Multimode and single-mode connections. *Syn:* **straight tip; square tip; stab and twist**.

submarine A (SMA): Screws into place. Multimode and single-mode telecom connections.

synchronous communications: A transmission method of synchronizing bits to a clock.

Synchronous Optical Network (SONET) rings: SONET path switched ring, line switched rings. See: **bidirectional line switched ring (BLSR); unidirectional path switched ring (UPSR)**.

teleprotection: Communications used by the relaying industry for sending discrete contact logic signals from point-to-point with a high degree of security and dependability.

total internal reflection (TIR): Optical phenomenon that occurs when a ray of light strikes a medium boundary at an angle larger than the critical angle with respect to the normal to the surface.

transfer trip: A form of remote trip in which a communication channel is used to transmit a trip signal from the relay location to a remote location.

unidirectional path switched ring (UPSR): Two redundant (path level) copies of protected traffic are sent in either direction around a ring. A selector at the egress node determines the higher quality copy and decides to use the best copy.

yellow alarm: An alarm signal sent back towards the source of a failed signal due to the presence of an alarm indication signal (AIS) or out of service (OOS).

2.2 Acronyms and abbreviations

Ack/Nak	mechanical acknowledgment and transmission
ADSL	Asymmetric Digital Subscriber Line
A/D	analog-to-digital
AGC	automatic gain control
AIS	alarm indication signal
BER	bit error rate
BERT	bit error rate transfer
BLSR	bidirectional line switched ring
D/A	digital-to-analog

DCB	directional comparison blocking
DCE	data communications equipment
DDI	direct digital interface
DDS	digital data service
DIF	digital interface
DSSS	direct-sequence spread spectrum
DTE	data terminal equipment
DUTT	direct under-reaching transfer trip
EDFA	erbium doped fiber amplifiers
EMI	electromagnetic interference
FC	ferrule connector
FEF	Far End Fault
FHSS	frequency-hopping spread spectrum
FSK	frequency shift keying
GVD	group-velocity dispersion
HDSL	high-bit-rate digital subscriber line
LAN	Local Area Network
LC	little connector
MT-RJ	mechanical transfer registered jack
NMS	network management systems
NLD	non-linear distortion
OFDM	orthogonal frequency-division multiplexing
OFIF	optical fiber interface
OOS	out of service
PCM	pulse-code modulation
PLC	power line carrier
POTT	permissive over-reaching transfer trip
PTT	permissive transfer trip
PUTT	permissive under-reaching transfer trip
SC	square connector
SDH	synchronous digital hierarchy
SFF	small form factor
SMA	sub miniature A

SNR	signal-to-noise ratio
SOA	semiconductor optical amplifiers
ST	straight tip
TDM	time division multiplex
TIR	total internal reflection
TLP	transmission level points
VT	virtual tributary
UPSR	unidirectional path switched ring

3. Types of digital teleprotection equipment

Teleprotection equipment plays a critical role in the protection of the power network, by helping isolate faults and preventing outages and blackouts.

At first, analog protection systems such as audio-tone were used, and these are still well-suited for analog systems such as analog radio and microwave. The noise detection systems implemented in audio-tone teleprotection and power-line carrier are best suited for the noise that will affect these signals, not digital channels (described in 6.8). Digital teleprotection equipment became popular when communications systems themselves became digital. However, sending analog signals over a digital transport is inefficient and problematic. For example, the digital communications system first converts the analog signal into a digital signal (A-to-D) and at the other end needs to convert it back to analog (D-to-A). These additional steps cause increased latency delays and more opportunities to introduce errors, and change the characteristics of the channel noise.

It is therefore most efficient to send digital signals through a digital communications system, as these signals are natively compatible with the transport system. Rather than looking at signal to noise ratios and analog noise energies to detect channel problems, they can directly detect bit errors. Using available error detection algorithms, it is easy to design these systems to be secure from misoperations due to data errors.

Digital teleprotection systems send two types of serial data through the digital network: synchronous and asynchronous data. Examples of synchronous data channels include ANSI/TIA/EIA-422-B-1994², [B4]³ ITU-T.703 [B26] and ITU-T V.35 [B28]. Examples of asynchronous data channels include ANSI/TIA-232-F-1997⁴ [B3], X.21 and Ethernet⁵. Connection details for these are shown in 4.2.

Digital teleprotection can be supplied in several configurations, described below in 3.1, 3.2 and 3.3. All of these methods are in use and provide viable solutions. The chosen method is up to the user, and should be selected based on system design, convenience, and the attributes of the individual manufacturers' performance of their teleprotection per the application.

3.1 Standalone teleprotection systems

Standalone teleprotection systems are used to convert contact or data inputs and outputs from protective relays into communications messages compatible with a digital communications system, as shown in Figure 1.

² Referred to as RS-422 for the remainder of this guide.

³ The numbers in brackets correspond to those of the bibliography in Annex A.

⁴ Referred to as RS-232 for the remainder of this guide.

⁵ IEEE 802.3™ is referred to as Ethernet in this guide.

The digital teleprotection system encodes the input from a protection device into a digital bit stream. These digital teleprotection systems typically encode information from multiple inputs. The input data is encoded with other information used to detect data errors and synchronize the remote receiver. This synchronization is used to determine the message's beginning and end.

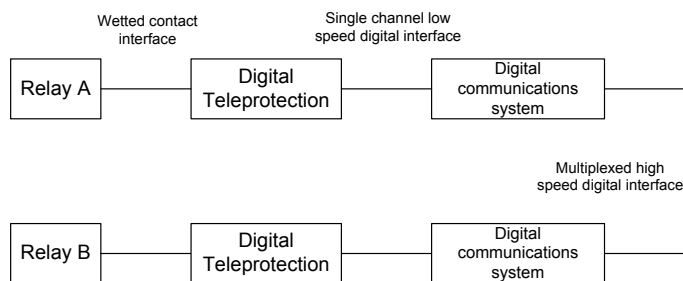


Figure 1—Typical standalone teleprotection system

At the remote end, the data is decoded and converted back into contact or data outputs for use by the remote protection device.

3.2 Teleprotection integrated with relay devices

The digital teleprotection function has become integrated with many relay devices. In place of contact inputs and outputs connected to standalone teleprotection devices, these relay communications ports can be used to provide teleprotection functionality. Certain types of relays, such as current differential relays, require their own dedicated communications channels.

Figure 2 shows a typical integrated teleprotection system.

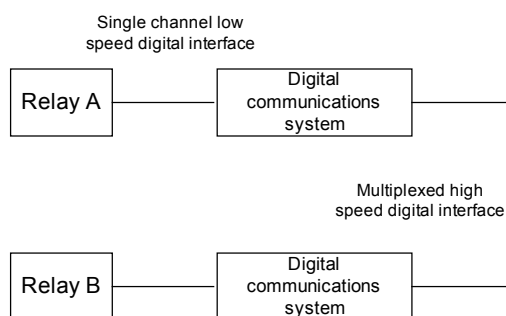


Figure 2—Typical teleprotection integrated with relay devices

Many forms of communications interfaces are currently used in these systems, ranging from direct fiber optic connections, to RS-232 and Ethernet.

3.3 Teleprotection integrated with multiplexed communication devices

Digital multiplexers designed specifically for use in power utility protection applications can also provide integrated digital teleprotection functionality. Multiplexers use specialized interface modules to connect to

various voice and data devices. In these specialized products, interfaces that provide teleprotection functionality have been made available as well. These modules use contact or data input and output information from the protective relays, like the standalone teleprotection systems described in 3.1.

Figure 3 shows the interface between a protective relay and a multiplexer with integrated teleprotection functionality.

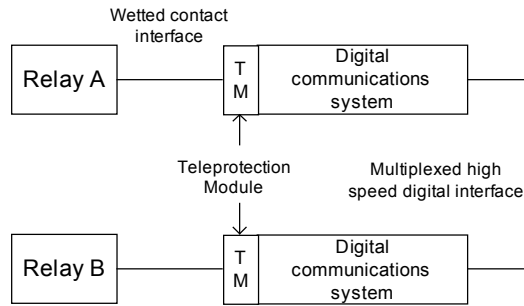


Figure 3—Typical teleprotection integrated with multiplexed communication devices

4. Communications infrastructure

Clause 4 discusses hazards to effective digital communications, connections and interfaces.

Digital communication reliability depends on the network reacting to bit errors. These errors can be caused by noise and radio frequency interference, which are discussed in 4.1.

Ground potential rise, which occurs when a large current flows to earth through an earth grid impedance, is a major concern to exposed copper wire communication wires. This phenomenon, along with signal attenuation, is discussed in 4.1.

Electrical, fiber and audio-to-digital interfaces, including connector pin layouts, are discussed in 4.2.

Signal attenuation, which refers to any reduction in the strength of a signal that may occur with digital or analog signals, is discussed in 4.3.

Radio frequency interference, a disturbance that affects an electrical circuit due to either electromagnetic induction or electromagnetic radiation from an external source, is discussed in 4.4.

Connections to non-substation hardened equipment are discussed in 4.5.

Finally, an overview of environmental standards is discussed in 4.6.

4.1 Noise

The reliability of a protection command sent over a channel that is entirely digital (bits in = bits out) is related to bit errors. If the digital teleprotection equipment is connected to a communication system free from bit errors, its performance will be at the highest security and dependability that the equipment is capable of handling.

Bit errors occur when sent data bits are not equal to received bits (bits in $\neq$ bits out). These can be caused by the transportation media and/or transmitting or receiving equipment problems. The received signal strength, its level, its noise content, and signal jitter are directly related to resultant bit error rate. Bit errors will result in the protective communication equipment detecting incorrect information. The way that this affects the protective communication equipment's output depends greatly on the equipment design, communication transport system, and the end-to-end communication protocol used, but in most cases, the equipment will ignore erroneous bits. If bit errors occur during the transmission of a command, this can result in a delayed or missed signal. If the bit errors become excessive, the likelihood of false operation (false trip) increases. All equipment should state the probability of false operation and lack of operation based on various bit error rates (BER) in the form of security and dependability ratings.

BER is the number of bit errors divided by the total number of bits sent. A BER of 1 bit error per 1 000 000 bits sent is commonly expressed 10^{-6} . Many manufacturers will state their security and dependability ratings based on average bit error rates. It is advantageous to have security and dependability ratings at multiple BER as performance can be adversely affected and vary greatly as bit error rates increase.

An analog protective relaying channel, namely audio tone, is rarely connected directly to its companion at the other end of the line. The audio tone can be used in both leased circuit applications and over a utility's own in-house communications systems. The aspects of a digital channel and its effect on analog audio tone can have unique implications on the protection performance, see 6.8.

Noise on metallic wires can be generated by several mechanisms, and can affect either analog or digital communication on the circuit. The use of fiber optic cable is preferred as it can eliminate many of these issues but it is not immune from environmental factors increasing BER.

4.1.1 Power system coupled noise

Subclause 4.1.1 discusses noise that can be induced onto the communications system by the power system.

4.1.1.1 Inductively coupled noise

Inductively coupled noise relates to current, in parallel distribution, transmission circuits or control cables in the substation yard. Typically, noise is at increased levels when the loading is higher on the power system. Twisting of pairs and increasing the distance from the noise sources are solutions. Noise is typically heard as hum at multiples of the power system frequency. Noise at 180 Hz is typically due to three-phase imbalance.

4.1.1.2 Capacitively coupled noise

Capacitively coupled noise relates to the electrostatic coupling related to voltage. The higher the voltage, the higher the noise. Keeping sufficient distance from the noise source and shielding helps. This noise is generally detected audibly as a sizzling sound, although it can cause a measurable circulating current in the shield, depending on the drainage connections.

4.1.1.3 Fault noise

Noise during non-fault conditions is an indicator of coupling. Power system coupled noise will increase during faults, and since the protection equipment is often required to operate during faults, this is the worst situation possible. The equipment design can tolerate a certain amount of fault noise, but at some level, the channel will become unreliable. Reducing or eliminating noise during non-fault conditions is the best method for increasing equipment reliability during faults.

4.1.2 Noise generated by the communication systems

Subclause 4.1.2 discusses noise that can come from the communications system.

4.1.2.1 Analog to digital conversion noise

The levels at the analog-to-digital (A/D) conversion points need to be properly adjusted. If the analog levels drive the A/D converter too high, clipping will occur, resulting in harmonic distortion and intermodulation products. Typical operating levels are 13 dB below the clip point. If the analog levels are too low into the A/D converter, quantizing noise will be produced, resulting in a general signal to noise increase. Higher operating levels on the “wire” are desired so that the signal to noise ratio is less should fault noise be present.

4.1.2.2 Bit error noise

Digital noise in the form of bit errors can come from the electronic devices themselves because of sampling errors, processor errors, and circuitry glitches. However, modern equipment, adjusted properly and used within its environmental ratings, will produce very low bit errors. A momentary error can go unnoticed in the analog domain, but when several bit errors occur in a short amount of time, the noise can become audible. In fact, noise due to bit errors can result in communication channel dropouts. It is important that the protection engineer understands the relationship of when these errors can occur related to events on the power system. When errors occur, they do so randomly and are unrelated to any event on the power system. Therefore, the chance of the channel dropout occurring when the communications is called upon to operate is low.

4.1.2.3 Timing noise

Digital communication systems can rely on timing signals that must be synchronized at various points along the communication path. Loss of synchronism can result in timing “slips” and timing “resynchronizations.” The behavior of the digital-to-analog (D/A) equipment supplying the analog signal to the relay communications receiver during slips and resynchronizations will greatly affect both security and dependability of the connected protection equipment. Since the data during a slip or resync is not usable, the best scenario is for the path to mute, which will shut down the audio tone. If the path produces noise, it will be up to the performance of the audio tone receiver to restrain from misoperation. During a resync, there can be a rapid phase change. If the audio tone uses quadrature amplitude modulation detection, the phase change may be incorrectly detected as a command, resulting in a misoperation. Properly setting noise detectors and timers can reduce the risk of a misoperation.

Noise resulting from clock synchronization issues can sometimes be recognized from audio tone channel alarms being generated at periodic intervals, rather than at random. Jitter is due to a small variation in timing (either random or predictable), and results in a decreased level of the audio tone being sent, as well as an increased level in sidebands. This may be detected using an oscilloscope or a bit error rate tester (BERT) with jitter analysis.

4.1.2.4 Noise detection

Test equipment or diagnostic capabilities built into the communication equipment will detect, alarm, and log noise on a digital system. Examples of test equipment typically used for would be a BER tester for digital communication channels or a spectrum analyzer for analog communications. Although there is always some level of noise on an analog pair, this noise is often noticeable only when the noise is high enough to disrupt the communication path. Ground potential rise

Wire-line telecommunication facilities serving electric supply locations often require special high voltage protection against the effects of fault-produced ground potential rise or induced voltages, or both. Some of the telecommunication services used for control and protective relaying purposes are called upon to perform critical operations at times of power system faults. This presents a major challenge in the design and protection of the telecommunication system, because power system faults can result in the introduction of interfering voltages and currents into the telecommunication circuit at the very time when the circuit is most urgently required to perform its function. Even when critical services are not involved, special high-voltage protection may be required for both personnel safety and plant protection at times of power system faults. Effective protection of any wire-line telecommunication circuit requires coordinated protection on all circuits provided over the same telecommunication cable.

Refer to IEEE Std 487-2007 [B14] further information. The Wire-Line Subcommittee of the Power Systems Communications Committee of the IEEE Power Engineering Society has prepared this recommended practice. This standard represents the consensus of both power and communications engineers.

4.2 Connections

Subclause 4.2 covers both electrical and mechanical connections.

4.2.1 Digital electrical interfaces

Several electrical communication interface standards—both asynchronous and synchronous—exist to permit the interconnection of equipment from different manufactures. Asynchronous data transmission does not utilize a master clock, allowing each terminal to generate its own timing. Asynchronous communications are used primarily for slower speed data and are not as efficient as synchronous data transmission, since framing (or start) and stop bits are required for every data byte.

Synchronous communications require a common clock source, generally provided by the data communications equipment (DCE), to which the data terminal equipment (DTE) synchronizes. While synchronous communications systems require more precise clock circuitry, they allow faster data transfer rates than asynchronous methods, since start and stop bits are not required to mark the beginning and end of each data byte.

DCE devices are digital devices that connect to a communications line for the purpose of data transfer, without regard to its content (e.g., a modem). DTE devices are digital devices that transmit or receive data and require communications equipment for the data transfer. Figure 4 shows some simple relationships between DCE and DTE devices.

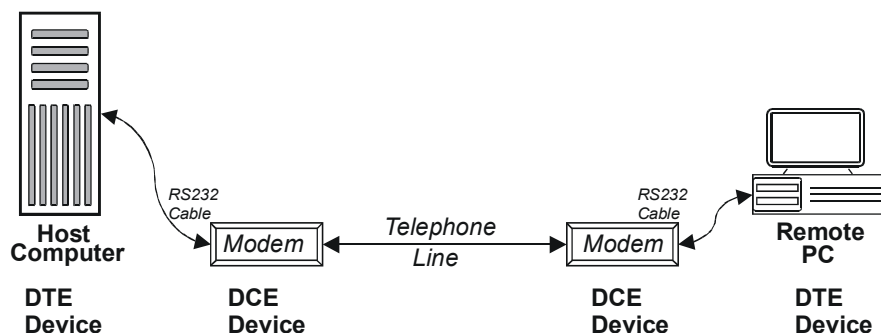


Figure 4—DTE and DCE devices

Signal names are in reference to the terminal DTE device. For example, TX data is an output from the DTE device, transmitted to the DCE device. DTE devices usually use a male plug connector and DCE devices a female connector. There are many styles of the connectors.

4.2.1.1 RS-232 electrical interface

The RS-232 standard was designed to allow DTE devices to connect directly to DCE devices with a straight-through cable. The RS-232 connector is usually a 9-pin DB9 connector that is actually specified by EIA/TIA-574 [B10] or a 25-pin DB25 connector defined by the RS-232 standard, see Figure 5 for connector drawing and Table 1 for pinouts.



Figure 5—Typical RS-232 connectors

RS-232 is an unbalanced interface that uses signals with reference to ground, making the interface susceptible to ground potential differences. Isolated dc power supplies and interface circuits are often used to overcome this problem. RS-232 data is typically sent at irregular intervals with variable time between characters, which requires either hardware or software flow control to prevent the receiver data buffers from being overrun. The RS-232 interface is rated to operate up to 20 kbps. The maximum cable length is not defined, but the maximum line capacitance is; at 2500 pF, with a load impedance of 3K Ω to 7K Ω . This produces a maximum cable length of something less than 20 m.

Table 1—TD-232 pinouts

DB25 Pin #	DB9 Pin #	Signal Name	Description	Direction (Ref DTE)
1		–	Shield / Gnd	–
2	3	TXD	Transmit Data	Out
3	2	RXD	Receive Data	In
4	7	RTS	Request to Send	Out
5	8	CTS	Clear to Send	In
6	6	DSR	Data Set Ready	In
7	5	S-GND	System Ground	–
8	1	CD	Carrier Detect	In
9		–	Reserved	–
10		–	Reserved	–

DB25 Pin #	DB9 Pin #	Signal Name	Description	Direction (Ref DTE)
11		–	Unassigned	–
12		Sec CD	SecondaryCarrier detect	In
13		Sec CTS	Secondary Clear to Send	In
14		Sec TXD	Secondary Transmit Data	Out
15		DB	Transmit Clock	Out
16		Sec RXD	Secondary Receive Data	In
17		DD	Receive Clock	In
18		LL	Local Loopback	–
19		Sec RTS	Secondary Request to Send	Out
20	4	DTR	Data Terminal Ready	Out
21		RL/SQ	Signal Quality / Remote Loopback	–
22	9	RI	Ring Indicator	In
23		CH / CI	Sig Rate Select	Out
24		DA	Auxiliary clock	–
25		–	Unassigned	–

4.2.1.2 RS-449 electrical interface

Developed to overcome RS-232 speed and distance limitations, the RS-449 interface is a high-speed digital interface that can support data rates of 100 kbps at 1,219.20 m (4000 ft), or 10 Mbps at 12.19 m (40 ft). The EIA RS-449 standard specifies the functional and mechanical characteristics of the RS-449 interconnection between the DTE in the DCE complying to TIA electrical interface standards RS-422 for balanced signals, and RS-423 for unbalanced signals, see Figure 6 for the connector drawing and Table 2 for pinouts.

Unlike RS-232, which uses signals with reference to ground, RS-449 receivers look for the difference between two wires. By twisting the two wires and making a "twisted pair," any stray noise picked up on one wire will be picked up on the other. Because both wires pick up the same noise, the RS-449 differential interface just shifts in voltage level with reference to ground, but does not change with respect to each wire. The receivers only look at the difference in voltage level of each wire to the other, and not to ground. While RS-449 is less susceptible to noise, the interface may be compromised, if a ground potential rise event were to occur as the differential line drivers and receivers are connected to ground. Some manufacturers may

take additional steps to protect the interface against ground potential rise. It is advised to check with the manufacturer on their interface design.

The differential signals for RS-449 are labeled as either “A and B” or “+ and –”. Wire A always connects to A, and Wire B connects to B (or Wire + connects to Wire +, and Wire – connects to Wire –). Wire crossing occurs when Wire A connects to Wire B or Wire + connects to Wire –. If crossing does occur, the data or clock in the interface will be inverted.



Figure 6—RS-449 connectors

Table 2—RS 449 connectors

Pin	Signal	Abbr.	DTE	DCE	Pin	Signal	Abbr.	DTE	DCE
1	Shield				20	Receive	RC		
2	Signal	S	Out	In	21	Unassigned			
3	Unassigned				22	Send Data	SD+	Out	In
4	Send Data	SD-	Out	In	23	Send	ST+	In	Out
5	Send	ST-	In	Out	24	Receive	RD+	In	Out
6	Receive	RD-	In	Out	25	Request	RS+	Out	In
7	Request	RS-	Out	In	26	Receive	RT+	In	Out
8	Receive	RT-	In	Out	27	Clear To	CS+	In	Out
9	Clear To	CS-	In	Out	28	Terminal	IS	Out	In
10	Local	LL	Out	In	29	Data	DM+	In	Out
11	Data	DM-	In	Out	30	Terminal	TR+	Out	In
12	Terminal	TR-	Out	In	31	Receiver	RR+	In	Out
13	Receiver	RR-	In	Out	32	Select	SS	In	Out
14	Remote	RL	Out	In	33	Signal	SQ	In	Out
15	Incoming	IC	In	Out	34	New	NS	Out	In
16	Signal	SF/SR+	In/Out	Out/In	35	Terminal	TT+	Out	In
17	Terminal	TT-	Out	In	36	Standby	SB	In	Out
18	Test Mode	TM-	In	Out	37	Send	SC		
19	Signal	SG							

NOTE—Signals in **boldface** are commonly used in the majority of applications.

4.2.1.3 V.35 electrical interface

The V.35 interface specifies a connector type, pin allocation and signal level used for synchronous communications interfaces. Most commonly used for 56 kbps and 64kbps data rates, V.35 is a partially balanced, partially single-ended interface specification. The data leads and clock leads are balanced and the handshake leads are single-ended, see Figure 7 for the connector drawing and Table 3 for pinouts.

V.35 uses differential interfaces for the clock and data signals, which are the only signals requiring high switching speeds for high-speed communications. Throughput of up to 10 Mbps is typical, and is dependent