



EMBEDDED MODEM FUNDAMENTALS AND GLOSSARY

INTRODUCTION

The world of high technology is full of jargon that sometimes seems to make our lives unnecessarily complex. Fortunately most of these concepts are not hard to understand if explained in simple terms. This document will attempt to de-mystify some of the concepts involved in the areas of modem telephony.

Even if we do not use a computer and modem to transmit data to another computer and modem, we probably use modems every day without realizing it.

- An embedded modem is used in a point-of-sale terminal when using a credit card or debit card to purchase goods
- An embedded modem is sometimes used when ordering a movie at home, using a cable or satellite television set-top box
- Electricity or water usage may be monitored several times during the day and transmitted to the utility company via an embedded modem

A modem serves to:

- Interface to the phone line
- Seize control of the phone line (go “off-hook”)
- Dial a phone number
- Negotiate a common “language” or protocol with another modem
- Convert digital data to an analog form that can be sent over the analog phone network, and convert that analog information back to digital on the other end
- Transmit and/or receive that data
- End the modem session (go “on-hook”)

For the modem session to complete successfully, the control messages between the “calling” and “called” modems must exchange information accurately and at the appropriate times in each direction. The three main culprits waiting to defeat this process are network delay, network echo, and signal levels. A modem solves these potential problems, usually quite successfully. The purpose of this document is to introduce basic concepts of telephone networks and modems, and to help provide a better understanding of each.

MODEM FUNCTIONAL BLOCKS

Every modem includes four basic functional blocks. Though these functional blocks can be partitioned in different ways, depending on the implementation, these four functions are always performed in modems.

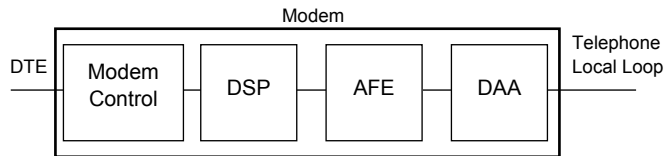


Figure 1. Modem Functional Blocks

Data Access Arrangement

The Data Access Arrangement, or **DAA**, interfaces the modem to the phone network. This interface is required by the **FCC** and **PTT**'s throughout the world to provide safety protection both to the end user and to the telephone switching lines. DAA's usually consist of discrete components and provide many features, including voltage isolation, detect **Caller ID** signals, detect ring signals, and perform on-hook and off-hook functions.

DAA's usually consist of discrete components such as relays and a transformer; however, there are new programmable silicon implementations that perform the DAA function. These solid state DAA's typically reduce component count, board area, and power consumption, but may be too expensive for cost-sensitive low speed modem applications.

Analog Front End

The Analog Front End (**AFE**) performs both analog-to-digital conversion (ADC) and digital-to-analog conversion (DAC). The AFE is sometimes called the modem **codec**, or Coder/Decoder. Particular data protocols and data rates

(speed) of the modem signal determine the precision or signal resolution characteristics of the AFE.

Digital Signal Processor

The Digital Signal Processor (**DSP**) is usually a specialized microprocessor that performs highly complex math functions. In the modem world, DSP techniques improve the accuracy and reliability of digital communications. Sometimes called the modem data pump, it is where the real magic is performed in a modem.

A DSP is able to differentiate between orderly data signals and noise, which is inherently chaotic. **Noise** is the bane of communications engineers, who are always striving to find new ways to improve the signal-to-noise (S/N) ratio in communications systems. Traditional methods of optimizing S/N ratio include increasing the transmitted signal power and increasing the receiver sensitivity. Digital signal processing dramatically improves the sensitivity of a receiving unit.

If an incoming signal is analog, (for example, a standard modem), the signal is first converted to digital form by the AFE. The resulting digital signal has two or more levels. Ideally, these levels are always predictable, exact voltages, or currents. However, because the incoming signal contains noise, the levels are not always at the standard values. The DSP circuit adjusts the levels so they are at the correct values, which practically eliminates the noise.

DSP techniques are also used to **modulate** data onto a carrier signal, and demodulate that data from the carrier signal. Thus, the derivation for the name **modem**: MODulator/DE-Modulator.

Modem Control

The Modem Control function regulates the actions of the modem DSP, interprets AT commands, and performs error control and data compression on the signal. In embedded systems, the modem controller is usually an 8-bit microprocessor.

TELEPHONE NETWORK BASICS

The telephone network that we use every day has several different names. The Plain Old Telephone Service (**POTS**) and **PSTN** (Public Switched Telephone Network) are the most common names, although the term **GSTN** is sometimes used (General Switched Telephone Network). The GSTN is a network that was originally designed to carry voice traffic; however, it now carries both voice and data traffic. The phone network typically consists of analog signaling, over the ubiquitous medium of twisted-pair copper wiring.

One purpose of a modem is to convert data, in its common digital form, to an **analog signal**, for transmitting over a phone network, then convert the data back to digital form

at the other end. This digital data is modulated (encoded) onto an analog **carrier wave**.

The typical telephone **subscriber line**, or local loop, connects the subscriber to the network backbone, through the Central Office switch. Physically, the line is made of copper wires, with connection distances ranging from less than 1 km (in cities) to 10 km (in rural areas).

These lines are powered by a 48-volt battery, which is located at the **Central Office** (CO). This battery allows the telephone line to be used at all times, even during times of power outage.

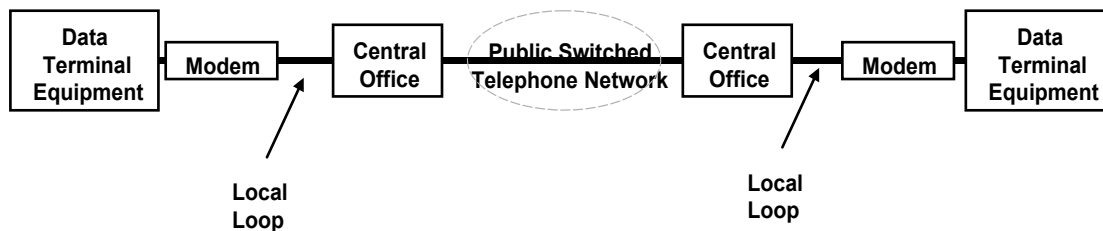


Figure 2. Typical Phone Network

CALL PROGRESS

Call progress signals indicate the state of a particular telephone call. These include Dial tone, Ring tone, Busy Tone, and **DTMF** tone.

Off-Hook

The **Off-Hook** state is determined when a person or telephony device (for example, a modem) completes the connection between tip and ring by picking up the telephone handset or closing a relay in a modem. This activity causes a relay in the Central Office to close, completing the local loop and causing a dial tone to be returned to the calling party. The completed connection creates a “hold-in” current to flow between the subscriber and the Central Office.

Dial Tone

The dial tone can be significantly different from country to country. Certain country dial tones are steady tones with no break, while other countries have dial tones that are on/off cadences of some arrangement or another. The tone frequencies differ as well.

For example, a dial tone in the U.K. is comprised of a 350-400 Hz tone that is “on” for 0.75 seconds, and “off” for 0.75 seconds. The dial tone in France is similar, except it can be in the range of 315 Hz to 455 Hz; that is, a continuous tone with no “off” period. The Dial tone in North America is a continuous tone in the range of 245 to 650 Hz.

Dialing

Once a dial tone has been established, dialing can begin. Dialing can be performed in one of two ways, either tone dialing or pulse dialing.

Tone dialing, also called Dual Tone, Multiple Frequency (DTMF) dialing, involves sending simultaneous tone pairs to the Central Office, where the tones are decoded. Table 1 indicates the tone pair frequencies associated with DTMF dialing. Notice the matrix also shows the corresponding number (1, 2, 3, etc.), which is represented by the tone pairs. In order to dial a “5” for example, DTMF dialing specifies that a 770-Hz low tone and a 1336-Hz high tone are transmitted simultaneously.

Table 1. DTMF Tone Pair Frequencies

High Band/ Low Band	1209 Hz	1336 Hz	1477 Hz	1633 Hz
697 Hz	1	2	3	A
770 Hz	4	5	6	B
852 Hz	7	8	9	C
941 Hz	*	0	#	D

Pulse dialing interrupts the “hold-in” current a certain number of times equal to the “number” being dialed, which is detected at the Central Office. Old-style rotary dial phones use the pulse dialing method. Phone networks have to be able to recognize both tone dialing and pulse dialing.

Ringling

If the called party is not using the telephone line, the Central Office returns a ring signal (or ring-back tone) to the calling party. This signal is comprised of a tone and a cadence (on-time, off-time) for certain countries. The ring-back tone in France is “on” for 1.5 seconds and “off” for 3.5 seconds. The ring-back tone in North America is “on” for 2 seconds and “off” for 4 seconds.

Call Completion

When the receiving party takes the phone off-hook, the circuit is completed between the calling party and receiving party, allowing the call to proceed.

Negotiation, Training, Handshake

Once the receiving modem takes the line off-hook, the **negotiation** phase can begin. This is the process whereby each modem will transmit certain information to the other modem in an attempt to agree on common protocols, speeds, etc. The initial **training** session is conducted to probe the line for configuration of the modems (equalization, nonlinear coding, pre-emphasis, pre-coding, shaping, mapping, etc.).

After a successful negotiation, the modems handshake—that is, they exchange control characters in addition to the data that was transmitted after a successful link negotiation. The handshake signifies readiness to receive, acknowledgment of data sent, and acceptance of sent data.

Negotiation times are different for different protocols. V.32bis modems, for example, can send data much faster (up to 14,400 bps), but they are much more costly, much larger, and the handshake time for that type of modem is much slower than for V.22bis modems. A V.22bis modem can dial, handshake, transfer small amounts of data, and disconnect in a much shorter time than a V.32bis modem. Table 2 indicates the ITU specs for handshake times:

Table 2. Handshake Times

Handshake Range	Minimum	Maximum
V.22bis 7.0 sec ±1.1 sec	5.9 sec	8.1 sec
V.32bis 12.5 sec ±5.3 sec	7.2 sec	17.8 sec
	22% longer	120% longer

V.29QC Line Turnaround

V.29 Quick Connect is a ZiLOG proprietary method that allows the host to quickly reverse the direction of communication in half duplex communications. Combined with a suitable communication protocol in a host CPU, V.29 Quick Connect allows a 9600-bps data transmission in alternating directions within a single telephone connection, giving the appearance of a full duplex connection. Line turn-around (training) time is improved from the ITU V.29 standard of 253msec to around 50msec.

Fallback and Retrain

Sometimes, the quality of the telephone line is not sufficient to allow reliable communications over the full bandwidth expected by the modem. In such a case, most high-speed modems incorporate “fallback” abilities. When the top speed does not work, the modem attempts to communicate at lower speeds that are less critical to telephone line quality. The pair of modems might first attempt a 9600-bps con-

nection and be unsuccessful; they might then try 4800 bps, then 2400, and so on, until reliable communications are established.

Either modem can request a retrain, but the retrain will only occur if the other modem grants it. During the several seconds of retraining, no data can flow. For this reason, the modems should be required to retrain only when truly necessary. Though line conditions may change significantly and permanently, this phenomenon is usually rare.

Busy Tone

If the receiving party is using the telephone line (“off-hook”), the Central Office returns a busy signal to the calling party. As with the dial tone, the busy signal can be a steady tone or a cadence. The busy tone in both North America and France is “on” for 0.5 seconds and “off” for 0.5 seconds.

TELEPHONE TECHNICAL BASICS

Simplex, Duplex, and Symmetrical Data Transmission

Data can be transmitted and received in one of three ways:

Simplex. Data is sent in one direction only.

Half Duplex. Data is sent in one of two directions, but only one direction at any time. In other words, the signal alternates transmission direction.

Full Duplex. Data is sent in two directions simultaneously. In other words, simultaneous transmission and reception of signals.

Symmetrical modulation protocols transmit data at the same speed in both directions. **Asymmetrical** modulation protocols transmit data at different speeds in either direction.

Mark and Space

A **Mark** is a signal on a data circuit which indicates a binary “one”. A **Space** is a signal on a data circuit which indicates a binary “zero.”

Bits and Baud

The terms **baud** and bit rate are often used interchangeably; however, this interpretation is incorrect. The two terms describe fundamentally different properties of the communication channel.

The baud of a communication channel is an expression of its primary electrical signaling rate. Baud is defined as the number of potential state changes that can occur in the channel per unit of time—regardless of the number of states or their interpretation. As such, baud rate is a physical characteristic of the signal itself, and bears no fixed relationship to the data being transmitted by the signal. Each potential change of state is called a symbol or event, and the baud of a channel is expressed in symbols per second (1 baud = 1 symbol/sec).

In contrast, the bit rate of a channel is the number of bits of information the channel can carry, expressed in bits per second (bps). The bit rate measures a fundamentally different characteristic, in that a single symbol can represent more than one bit.

Consider, for example, a modulation scheme that defines four possible states for a single symbol. Each state is then assigned to one of the four possible combinations of a pair of bits. Using this encoding scheme, a 600-baud channel could carry 2400 bps. Similarly, a system that defined 16 symbol states could encode four bits per symbol and achieve a bit rate of 9600 bps over the same channel. The baud of a channel is numerically equal to its bit rate only when one bit is encoded per symbol (from *Programmer’s*

Technical Reference: Data and Fax Communications by Robert L. Hummel, published by Ziff Davis Press; 1993).

Modulation

Modulation is a method to represent information on a carrier signal by varying the signal’s frequency, amplitude, or phase. Examples are:

Amplitude Modulation (AM). Symbols are represented by a difference in signal amplitude.

Differential Phase Shift Keying (DPSK). Symbols are represented by the phase difference between the current and the previous carrier phase.

Frequency Modulation (FM). Symbols are represented by a difference in signal frequency.

Frequency Shift Keying (FSK). A method using two different frequencies to distinguish between a mark and a space. Used at 1200 bps or slower.

Phase Modulation (PM). Symbols are represented by a difference in signal phase.

Phase Shift Keying (PSK). This method uses the differences in phase angle between two symbols to encode information. PSK is more bandwidth-efficient than FSK.

Quadrature Amplitude Modulation (QAM). Sometimes pronounced “kwam.” Symbols are represented by a combination of signal amplitude and phase. QAM is used in modems that are compliant with V.22bis and higher.

Trellis Coded Modulation (TCM). Defined as QAM with forward error correction. Used in higher modem speeds such as V.32bis.

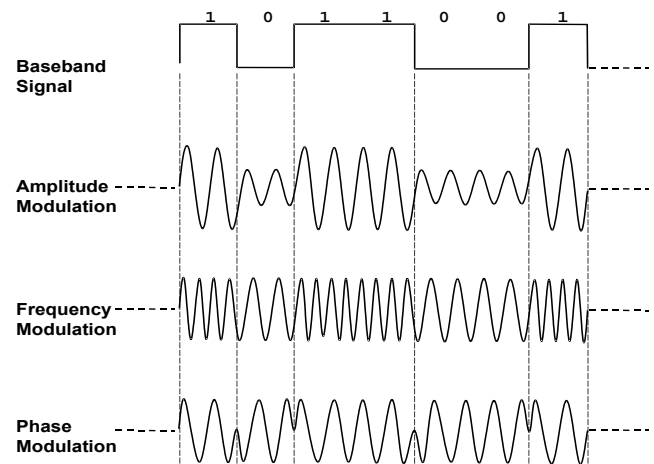


Figure 3. Fundamental Modulation Types

AT Command Set

A command line is a string of characters starting with the “A” and “T” characters, and ending with a special end of line character, <CR>, or carriage return. “AT” stands for “attention”, and configures the modem in particular ways, determined by the user or the modem designer. The modem uses these characters to determine the data rate and parity of data from the terminal.

Most **AT commands** follow the attention characters with one letter that specifies the family of the command and another character that indicates the nature of the command. For example, H stands for Hook. H0 means put the phone “on-hook” or hang up. H1 indicates that the modem should take the phone “off-hook.”

Several commands and their modifiers can be combined on a single line after an initial attention command. For example, to command a modem to dial information on a tone-dialing line, the sequence of commands would read: ATDT9,14085588500. The “AT” is the attention signal, D is the dial command, the T tells the modem to use tone dialing, 9 dials an outside phone line, the comma (“,”) initiates a pause to access the outside line, and the 4085588500 is the number of the called modem.

All AT commands must be followed by a carriage return. The modem waits for the carriage return which signals that the modem has sent the complete command. From that point, the modem should start processing the signal.

S-Registers

S-registers are storage locations for values that configure the modem when it makes calls or talks to another modem. S-registers can change the number rings before a modem auto-answers, change the time duration of a DTMF tone, set transmit levels, and set the highest modem speed.

Response Codes

Response codes are responses the modem provides after being issued an AT command. These can be either numeric or verbose responses. Verbose responses can be one or more words long and are more descriptive of the response to the AT command. Examples are “CONNECT 2400”, to indi-

cate you have connected at 2400 bps, or “OK” to signify that a command was received and acted upon.

Eye Pattern or Constellation

The modem signal can be represented on an X-Y oscilloscope as dots which fall into four quadrants (+/+, -/+, -/-, and +/-). Each dot represents an amplitude and a phase of the signal at a given point in time. The resultant display is called the **constellation**, or **eye pattern**.

The eye pattern is used as a visual way of determining the quality of a modem’s signal. Sharp, steady dots on an oscilloscope represent a “clean” modem signal. A modem signal that is less than ideal may be seen as fuzzy dots that move around quite a bit, and a constellation may be rotated.

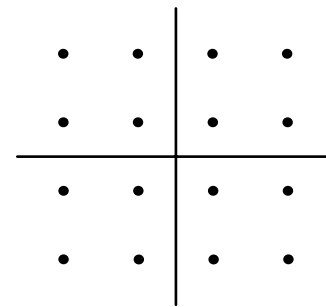


Figure 4. V.22bis 2400bps Constellation

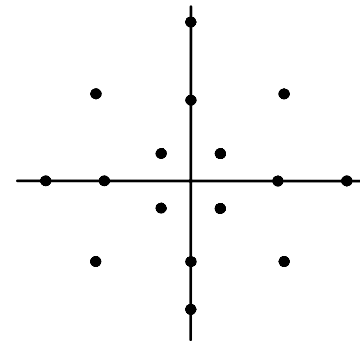


Figure 5. V.29 9600bps Constellation

MODEM PROTOCOLS AND STANDARDS

Standard ¹	Data Rate (bps)		Modulation	Baud Rate	Sync/Async	Constellation Points
Bell 103	300	Full Duplex	FSK	300	Async	—
Bell 202	1200	Half Duplex	FSK	1200	Async	—
Bell 212A	1200		DPSK	600	Sync	4
ITU V.21	300	Full Duplex	FSK	300	Async	—
ITU V.22	1200	Full Duplex	DPSK	600	Both	4
ITU V.22bis	2400	Full Duplex	QAM	600	Both	16
ITU V.23	1200	Half Duplex	FSK	300	Both	—
	75	Half Duplex	FSK	75	Async	—
ZiLOG V.29QC ²	9600	Half Duplex	QAM	2400	Sync	16
ITU V.26bis	2400	Half Duplex	DPSK	1200	Sync	
ITU V.32	9600	Full Duplex	TCM	2400	Sync	32
ITU V.32bis	14,400	Full Duplex	TCM	2400	Sync	128
ITU V.34	28,800/33,600	Full Duplex	TCM	Variable	Sync	Variable
ITU V.90	56,000 ³ downstream, V.34 upstream	Full Duplex	TCM	Variable	Sync	Variable
MNP2	Microcom Networking Protocol. Error Control, Asynchronous, full duplex					
MNP3	Error correction, synchronous. ~20% improvement over MNP2					
MNP4	Error correction which rides on top of MNP2 or 3 to improve throughput.					
MNP5	Simple data compression, about 2:1.					
V.42	Error correction protocol that uses LAP-M (Link Access Protocol for Modems) as the primary approach and MNP4 as the alternate scheme.					
V.42bis	Data Compression. The commonly accepted maximum compression ratio for V.42bis is 4:1 but higher rates (maybe as high as 10:1) are possible. Requires V.42.					

Notes:

1. Bell = Bellcore (www.bellcore.com); ITU = International Telecommunications Union
2. ZiLOG proprietary.
3. Restricted to 53Kbps in some areas.

MODEM GLOSSARY

A/D Converter. Converts an analog signal to digital data.

AFE. Analog Front End, refers to the analog-to-digital and digital-to-analog converters in a modem. Resides between the modem DSP and transformer. Also called codec.

Amplitude. The difference between the maximum and minimum voltages of a waveform expressed as a “peak-to-peak” voltage.

Amplitude modulation. Method of encoding information on a signal by varying the signal’s amplitude.

Analog signal. A signal in the form of a continuously varying value; for example, a sine wave.

ANSI. American National Standards Institute.

ASCII. Acronym for American Standard Code for Information Interchange. ASCII is an ANSI character set. The standard ASCII character set consists of 128 decimal numbers (0–127) for letters of the alphabet, numerals, punctuation marks, and common special characters. The extended ASCII character set extends to 255 characters, and contains special mathematical, graphics, and foreign characters.

Asymmetrical Modulation. A signal modulation scheme which permits high speed data flow in one direction, and low speed data flow in the other. V.23 is an example of an asymmetrical protocol.

Asynchronous transmission. The random transfer of data in bytes, usually with “start” and “stop” identifying bits. An event is asynchronous if it can happen at any time; in other words, not related to a clock signal. See Synchronous transmission.

AT command set. A set of commands provided to the modem to control certain functions. AT stands for “attention.” Example is ATDT, which calls for tone dialing.

Attenuation. A decrease in the power of a received signal caused by loss through transmission lines, equipment, or other transmission devices. Usually measured in decibels (dB).

Autobaud. An automatic detection of the bit rate of a modem and other forms of data communication, by measuring the length of the start bit of the first character.

BABT. British Approvals Board for Telecommunications. BABT is a private, independent company. BABT operates internationally, and in addition to its regulatory role, offers a wide range of services and practical consultancy in telecom and other industries.

Bandpass filter. A filter which allows a certain range of frequencies to pass through a circuit. Also describes the dif-

ference between the highest and lowest frequencies of a transmission channel.

BAPT. Bundesamt für Post und Telekommunikation. BAPT is the German Federal Office for Post and Telecommunications, responsible for ensuring compliance with electromagnetic compatibility regulations.

Baseband. A signal not changed from its original form through modulation.

Baud. The speed at which a modem can transmit data. Baud rate measures the number of events, or signal changes, that occur in one second. Because one event can actually encode more than one bit in high-speed digital communications, baud rate and bits per second are not always synonymous. The baud rate does not always equal the bit rate, especially at speeds above 2400bps.

BBS. Bulletin Board Service, usually a dial-up service.

BER. See Bit Error Rate.

BERT. Acronym for Bit Error Rate Test.

Bit. Binary Digit. The smallest unit of data processing information in a binary system. A bit assumes the value of either “1” or “0”. Abbreviated “b”.

Bit Error Rate. A test for checking the quality of data transmission that compares the data received to the data transmitted. Typically, a low bit error rate is better over a given transmission line with known line impairments.

Blacklisting. Call blocking capability for specific phone numbers.

BLER. Block Error Rate.

Block. A unit of transferred data, measured in bytes, such as 64, 128, or 256. Blocks have identifying headers and footers to distinguish them, and to include protocol information for error control and decoding of data compression.

Blind Dialing. An automated process whereby the modem goes off-hook and dials without waiting for a dial tone. This is prohibited in many countries.

BPS. Bits per second; a measurement of transmission speed.

BT. British Telecom.

Byte. A unit of information comprised of multiple bits. Each byte in an asynchronous transmission is ten bits (not eight), including a start bit, eight data bits, and a stop bit. Abbreviated “B”.

Call Progress. Network signals that allow for call monitoring. A common term to describe the busy tone, dial tone, ring-back tone, etc.

Caller ID (CID). A method to decode the calling party's identification to the receiving party. Information such as phone number of the calling party can be received. Sometimes called Caller Identifier (CLID).

Carrier Wave. A Carrier Wave can be used to carry modulated signals. Program signals are impressed on the carrier by frequency modulation (FM) or amplitude modulation (AM). The carrier wave is usually kept at a fixed frequency by the transmitter, and is detected in the receiver by a resonant circuit at the carrier frequency. A message is sent by changing the carrier wave's amplitude or its phase proportional to the desired transmission signal.

CCITT. Comite Consultatif International de Telephonie et de Telegraphie. A Consultative Committee for International Telephone and Telegraph. Now called the ITU-T. This organization continues to recommend and publish worldwide communications standards.

Central Office (C.O.). An office in a locality to which subscriber home and business lines are connected on what is called a local loop. The Central Office has switching equipment that can switch calls locally or to long-distance carrier phone offices.

CID. Caller identification, or caller ID.

Clock. A timing signal generated by an oscillating circuit which is used to synchronize data transmissions.

Codec. Coder/decoder. Another name for the modem analog front end (see AFE). Performs analog-to-digital conversion and digital-to-analog conversion.

Constellation. Also called eye pattern. Visual representation of the modem signal quality, usually on an X-Y oscilloscope. Each dot of the display represents a signal's phase and amplitude. A "clean" modem signal is shown as a clear dot with little or no movement.

Controller. A function inside a modem that performs AT command set handling, error handling, and data compression.

Controllerless. Refers to the type of modem where the controller function is performed inside the host processor, such as a Pentium in personal computers, or in a higher performance RISC processor in embedded applications.

Country certifications. End product manufacturers are required to obtain approval of the telecommunications certification body in the particular country their products will be sold. This certification refers to electrical certification (transmit level, voltage isolation, etc.), and certification for specific call progress requirements.

CPE. Customer premises equipment.

CPS. Characters per second.

CRC. Cyclical Redundancy Check. An error-detection method which uses a polynomial to generate a series of check characters to represent a block of data. The CRC characters are included in the transmission frame and checked at the receiving end for errors. CRC errors usually indicate a bad phone line, but occasionally result from having your DTE speed set higher than the equipment can handle.

DAC. Digital-to-analog converter. Converts digital data to an analog signal. See [Codec](#).

DAA. Data Access Arrangement. Circuitry that connects the modem, fax, or voice circuit to the PSTN. DAA circuits must be approved by the government agency that oversees the PSTN in various countries. A DAA isolates any device from phone lines and their associated equipment.

Data Compression. In modems, a bit encoding process that removes redundancy, resulting in fewer bits to transmit.

Data Mode. The modem is in data mode when a connection has been established with a remote modem, sending a CONNECT response to confirm the connection. User data may then be transmitted or received.

Data Pump. The signal processing core of a modem, usually performed on a digital signal processor (DSP).

dB. Decibel. A measure of the relative strength of a signal such as power or voltage. $dB = 20 \times \log_{10}$ of the ratio of the power of two signals.

DB-25. The 25-pin plug that connects an RS-232C cable to an RS-232 port.

DCE. Data Circuit-terminating Equipment. Connects data terminal equipment (DTE) to a data circuit. A modem is a DCE.

Dial Modifier. Dial modifiers are special characters appended to the ATD command which instruct the modem how to place a call.

Dibit. A sequence of two bits associated with one signal element.

Digital Line. A Digital Line carries discrete, non-varying signals, as opposed to continuous but varying waveforms. Many telephone systems in office settings use digital lines to a central switching system (e.g. PBX), which are unsuitable for analog modems.

Downstream. The direction of data transmission, usually from the Central Office to the user modem.

DPSK. Differential Phase Shift Keying, a modulation technique that uses successive relative phase changes of the carrier to encode data.

DQPSK. Differential Quadrature Phase Shift Keying, a modulation technique that encodes information by using the changes in phase relative to the previous phase.

DSP. Digital Signal Processing. A specialized microprocessor that is tailored to perform high repetition math processing and improve signal quality.

DSR signal. Data Set Ready signal.

DTE. Data Terminal Equipment. Equipment that sends and receives data.

DTMF. Dual Tone Multiple Frequency tone generation and detection. A method of representing digits with tone frequencies. In the PSTN, the DTMF is used for call initiation (dialing).

DTR signal. Data Terminal Ready signal. Originated by the DTE, the DTR instructs the DCE to prepare to connect to the communications channel.

Echo. A signal reflected back to the transmission point by impedance mismatches in the transmission path.

Echo Cancellation. A technique to reduce or eliminate echo by placing a signal that is equal but opposite to the echo signal on the signal's return path.

EEPROM. Electronically Erasable Programmable Read Only Memory. A type of non-volatile memory.

EIA. Electronics Industries Association, a private U.S. standards organization that sets electronic interface standards. For example, the EIA is responsible for the RS-232 standards: RS-232C (the interface between DTE and data interchange communication) and RS-232D (equipment using serial binary data).

EMI. Electro-Magnetic Interference. Occurs when a modem is positioned too closely to a high-output energy source, such as computer monitor, or a building's main power transformer. Legitimate commands and responses between the computer and modem will become garbled at the receiving end. EMI causes errors occurring randomly after legitimate AT commands or sporadic reinitialization attempts.

EPROM. Erasable Programmable Read Only Memory. A type of non-volatile memory.

Equalization. Compensation for signal distortion introduced by transmission facilities. Equalization compensates for amplitude and/or delay distortion when a modem adjusts its transmit level for different frequencies. This activity accounts for the greater loss at certain frequencies over the phone line.

Error Control. The ability of a modem to notice errors in transmission and resend any incorrect data. See ECM.

Escape Sequence. Also referred to as the escape command. This special command is entered as three "plus" symbols (+++) and places the modem in command mode, interrupting user data transmission. However, the escape

sequence does not terminate the data connection. Command mode allows the entering of commands while the connection is maintained.

ETSI. European Telecommunications Standards Institute.

Eye pattern. See Constellation.

Factory default settings. A modem includes register settings that are set upon power up. Typical AT commands to return to factory default settings are ATZ or AT&F; however, a power OFF followed by a power ON will provide the same result.

Fallback. Ability of a modem that can operate at different speeds to fall back to its next lower speed if line conditions can not support the higher speed. To work, both sending and receiving modems must shift to the lower rate.

FCC. Federal Communications Commission in the U.S. From www.fcc.gov, "...the FCC develops and implements policy concerning interstate and international communications by radio, television, wire, satellite, and cable."

FCC Part 15. Governs the terms and conditions under which "intentional or unintentional or incidental" radiator of radio emissions can be sold and used in the United States. Part 15 Class A digital devices are those marketed for use in a commercial, industrial, or business environment. Part 15 Class B digital devices are those marketed for use in residential environments.

FCC Part 68. Governs the terms and conditions under which customer-provided terminal equipment may be connected to the telephone network without causing harm to the public switched network.

FDM. Frequency-Division Multiplexing. The most common and simplest technique supporting full-duplex transmission.

Flow control. Compensates for the difference between the rate at which data reaches a device and the rate at which the device processes and transmits. The two common types of flow control are RTS/CTS signaling (a hardware based method, employing an electrical signal) and XON/XOFF (a software-based method using standard ASCII control characters to pause or resume transmission). See XON/XOFF.

Frequency Modulation (FM)/Frequency Shift Keying (FSK). A modulation method that uses two different frequencies to distinguish between a mark ('1') and a space ('0'). Used at 1200bps or slower.

Full Duplex. Simultaneous transmission and reception of signals.

GPIO. General Purpose Input/Output.

GSTN. General Switched Telephone Network. Also called PSTN (Public Switched Telephone Network) and POTS (Plain Old Telephone System).

Guard Tone. An option of V.22 and V.22bis that prevents the high-band data signal from interfering with the operation of billing equipment in certain countries. Guard tones are employed in the United Kingdom and other countries, but are not used in the U.S. This circumstance requires that the modem transmit an 1800-Hz tone after it sends an answer tone.

Half Duplex. Alternating transmission or reception of signals at one time.

Handshake. Exchange of control characters in addition to the data transmitted after successful link negotiation. A handshake involves synchronization and negotiation by the exchange of predefined, mutually-recognized control codes. A handshake signifies readiness to receive, acknowledgment of data sent, and acceptance of sent data. It is also used to describe the negotiation process itself.

HDLC. High-level Data Link Control framing. A transmission protocol used at the data link layer (layer 2) of the OSI seven layer model for data communications. The HDLC protocol embeds information in a data frame that allows devices to control data flow and correct errors. HDLC is an ISO standard developed from the Synchronous Data Link Control (SDLC) standard proposed by IBM in the 1970's.

Homologation. See Country Certification.

Host-based. See Controllerless, Software Modem.

Initialize. To establish start-up parameters, typically involving clearing all of some part of the device's memory space.

ISO. International Standardization Organization.

Isolation Barrier. Electrical barrier to voltage spikes in modems to prevent voltage spikes from harming the phone network.

ITU. International Telecommunications Union. A special agency of the United Nations based in Geneva, which is the parent organization of the CCITT. The ITU-T is responsible for telecom standards recommendations such as the "V." series and "X." series.

ITU-TSS. International Telecommunications Union-Telecommunications Standardization Sector.

Kbps. Kilobits per second. One thousand bits per second.

LAP-M. Link Access Procedure for Modems, an error detection and correction method.

Leased Line. Also referred to as a private line. A leased line is obtained from a communications company (carrier) to provide a transmission medium between two points. The

line consists of a permanent dedicated circuit between two points, or to a set of previously arranged points. This is in contrast to switched or dial-up lines, which can be connected to any point on the network. Leased lines are preferable to standard dial-up lines under certain conditions, due in part to improved signal quality which is the result of bypassing switching equipment.

Line Conditioning. An option offered by the telephone company for their leased, voice-grade lines. The service provides a careful balance of line enhancements to improve the frequency response and to reduce distortion.

Line Simulator. Equipment that simulates different conditions found on real-world phone lines. Allows testing of telephone equipment under controlled conditions.

Local Loop. A communications link between a telephone subscriber's location and the local exchange. Also called Subscriber Line or Subscriber Loop.

Loopback Tests. There are four types of loopback tests which are as follows:

1. The local digital loopback tests the operation of the DTE, including whether or not data is leaving the terminal or computer port;
2. The local analog loopback tests the digital and analog circuits of the modem;
3. The remote digital loopback checks the operating condition of the line and remote modem;
4. The remote analog loopback tests the line to the remote modem.

Make/Break Ratio. The &P command controls the ratio of the off-hook (make) to on-hook (break) interval used by the modem when it pulse dials. For example, a 39%/61% make/break ratio is used in the U.S, while a 33%/67% make/break ratio is used in the United Kingdom and Hong Kong.

Mark. A signal on a data circuit indicating a binary "one".

MCU. Micro Controller Unit.

MNP. Microcom Networking Protocol. Early standard for error correction and data compression in dial-up modems. Among its more popular classes are an error detection and correction method (MNP 2-4), data compression (MNP 5 & 7), and enhanced capability (MNP 10 for adverse channel reliability commonly used in wireless communications).

Modem. A modulator-demodulator device for converting transmissions from digital signals to analog signals, intended for transmission over analog telecommunications lines. At the destination, these transmissions are converted back from analog to digital. A modem also performs dialing and call progress monitoring.

Modulation. Represents information on a carrier signal by varying the signal's frequency, amplitude, or phase. Provides a method to transmit digital data over an analog medium.

MPU. Micro Processor Unit. Serves as the modem controller.

Negotiation. Initial part of a modem session that establishes a common set of protocols, speeds, etc. between two modems. The modems compare mutual capabilities to determine the best communication level. Each unit bargains for the best obtainable speed on the phone line (carrier), best error-control method, and best form of data compression.

Noise. Undesirable energy in a communication medium that interferes with the transmission of a signal.

Normal Mode. A mode of operation without error correction active.

Off-hook. When a modem has “captured” the modem signal. This activity creates a DC current between Tip and Ring, causing a line connection between a phone or modem and Central Office.

On-hook. When the modem is not active and is ready to receive a call. The DC current is removed from between Tip and Ring, disconnecting the subscriber from the Central Office.

Parity Bit. An extra bit attached to each byte of synchronous data that allows detection of transmission errors.

Part 15. See FCC Part 15.

Part 68. See FCC Part 68.

PBX or PABX. Private Branch Exchange or Private Automatic Branch Exchange. Telephone switching equipment usually found on a customer's premises.

Phase modulation. A method of modifying an analog signal to allow information to be carried. The signal's phase is changed in accordance with the information to be transmitted.

POTS. Plain Old Telephone System. See PSTN.

Protocol. A formal set of communications procedures governing the format and control between two communications devices. A protocol determines the type of error checking to be used, the data compression method, if any, how the sending device will indicate that it has finished sending a message, and how the receiving device will indicate that it has received a message.

Phase Shift Keying (PSK). Phase Shift Keying modulation method, a more bandwidth-efficient method than FSK. PSK contrasts the differences in phase angle between two symbols to encode information. See also DPSK.

PSTN. Public Switched Telephone Network. A mixture of analog and digital lines. Refers to the ordinary telephone system which includes subscriber lines, local exchanges and the complete system of trunks, and the exchange hierarchy which makes up the network.

PTT. Post, Telephone, and Telegraph. Agency in many countries that is responsible for providing telecommunication approvals.

Pulse Dialing. Also referred to as rotary dialing (dialing with the older-style rotary dial wheel). The dial modifier, ATDP, sets the modem to pulse dialing, which is the default method, as opposed to tone dialing which is enabled with ATDT. All telephone exchanges will accept older-style pulse dialing, and most exchanges will accept modern-tone dialing. Tone dialing is faster and more reliable, since mechanical relays and their inherent failure mechanisms are avoided.

QAM. Quadrature Amplitude Modulation method, which, of practical modulation techniques, has the best bandwidth efficiency per information symbol (baud).

Quick Connect. A short handshake used by transaction processing applications where the amount of data sent is small. This method reduces the overhead (time) associated with the handshake. ZiLOG's V.29QC handshake (sub-50 milliseconds) is a shortened form of the V.29 handshake, but does not conform to the ITU standard.

REN. US FCC Ringer Equivalence Number. This number determines how many devices may be connected to the same line and still ring properly.

Result Code. A response sent by the modem after executing a command. The response reports the modem's status, or the progress of a call, and can take the form of either digits (numeric) or words (verbose). Example: “OK” (word), or “0” (numeric) indicates that the modem successfully executed a command.

Retrain. An adjustment process performed when one of the modems detects signal distortion or line noise, which can threaten data integrity.

Ringback tone. The tone you hear at the originating end, when the phone being called “rings”.

RJ11. Short for Registered Jack-11, a four-wire connector used commonly to connect telephone equipment.

RJ45. Short for Registered Jack-45, an eight-wire connector used commonly to connect computers onto a local-area network (LAN), especially Ethernet. RJ-45 connectors look similar to the ubiquitous RJ-11 connectors used for connecting telephone equipment; however, these connectors are wider.

RS232C. The standard interface between modems and PCs for serial port communications. Its international equivalent is V.24.

RTS/CTS. Request to Send/Clear to Send. A hardware method of flow control. RTS and CTS are two control signal lines between the modem (DCE) and terminal (DTE), which allow the terminal to control the flow of information. See also flow control.

Scrambler/Descrambler. A defined method for modifying a data stream in order to make the altered data stream appear random. A descrambler reverses the effect of the scrambler to recover the original data stream. An element of modem handshakes, as defined by handshake protocols.

SDLC. Synchronous Data Link Control. SDLC was invented by IBM to replace the older Bisynchronous protocol for wide area connections between IBM equipment. A variation of the ISO HDLC protocol, called HDLC Normal Response Mode (NRM), is essentially the same as SDLC.

Sigma Delta. An advanced, highly linear, low-noise analog-to-digital conversion technique using oversampling and digital filtering.

Simplex. Data is sent in one direction only.

SNR. Signal-to-Noise Ratio. The relative power of a signal as compared to the power of noise on a line.

Software modem. A modem implemented entirely in software. Software modems rely on an application's powerful processor to perform modulation, demodulation, filtering, modem control, error control, and data compression.

Space. A binary “zero”; opposite of “mark”.

S-registers. Registers that store modem status and configuration data.

Start/Stop bits. A bit used in asynchronous communications to indicate the beginning and the end of a character.

Subscriber Line, Subscriber Loop. See Local Loop.

Symmetrical Modulation. A modulation scheme which transmits data at the same rate in either direction.

Synchronous transmission. The transfer of data in batches timed by a clock. See Asynchronous. Synchronous transmission makes higher speeds possible in the presence of noise and line distortion.

Technical Basis for Regulation (TBR). TBR21, for example, specifies requirements for pan-European approval for connecting terminal equipment to the PSTN via 2-wire access. This regulation is intended to ensure that terminal equipment (e.g., modem) will not damage the PSTN and to ensure interworking between the network and its terminal equipment.

Trellis Coded Modulation (TCM). Similar to QAM, but also includes forward error correction.

Touch-Tone Dialing. Push-button tone dialing as used on contemporary phone sets. The dial modifier ATDT sets the modem to “tone” mode. Tone dialing is faster and more reliable than older-style pulse dialing.

Training. See Handshake.

TransPro™. ZiLOG's modem solution for transaction processing applications which include the Quick Connect handshakes. Part number Z02922. See Quick Connect.

Trellis Coded Modulation (TCM). An encoding technique for the bit stream sequence in the transmission signal. At speeds over 2400bps, TCM protects high-speed transmissions from noise. Trellis coding permits transmitted data to travel through twice the amount of line disturbance as conventional (QAM) modulation. Trellis coding decreases the number of CRC errors and retransmissions.

Twist. A term that describes the difference between standard DTMF tone power levels, where one tone is transmitted at a higher power level than the other.

Twisted Pair Wiring. A type of cabling with one or more pairs of insulated wires wrapped around each other. An inexpensive wiring method used for LAN and telephone connections, also called UTP wiring.

UART. Universal Asynchronous Receiver/Transmitter. Component or functional block that handles asynchronous communications. Converts the data from the parallel format in which it is stored, to the serial format for transmission.

Upstream. The direction of data transmission, usually from the user modem to the Central Office.

USART. Universal Synchronous/Asynchronous Receiver Transmitter. Can handle synchronous as well as asynchronous transmissions.

UTP. Unshielded twisted pair wiring.

V.24. CCITT recommendation that specifies the logical characteristics of RS-232 interface.

V.29QC. See Quick Connect, Transpro™.

V.42. Error-correction procedures for DCE's using, CCITT, Dial-up modems, and asynchronous-to-synchronous conversion.

V.42bis. Data compression procedures for DCE's using error-correction procedures.

Waveform Coding. A type of voice compression that attempts to preserve the input waveform in the recovered (decompressed) speech. See DPCM, ADM and ADPCM.

Word. Refers to the amount of data a processor can hold in its registers and process at one time. A DSP word is often

16 bits. Given the same clock rate, a 16-bit controller processes four bytes in the same time it takes an 8-bit controller to process two.

XMODEM. An asynchronous file-transfer protocol. XMODEM programs typically use both the older version (checksum) and the newer version (CRC method) to detect errors. If CRC is not present at the other end of a file transfer, it will use checksum.

XON/XOFF. A software method of flow control. The XOFF character is set to stop further characters, and XON is sent to resume them. This method is inferior to hardware flow

control, using RTS and CTS, because it means that XON and XOFF characters cannot be freely used in the data.

YMODEM. An asynchronous file transfer protocol that improves speed by transmitting 1,024-byte (1K) blocks and batch file transfer.

ZMODEM. An asynchronous file transfer protocol that is more efficient than XMODEM. It sends file name, date, and size first and responds well to changing line conditions, due to its variable-length blocks. ZMODEM protocol uses CRC error correction.

ABOUT ZILOG

ZiLOG creates embedded and integrated technologies that improve the performance of everyday applications. Our engineers immerse themselves into all aspects of specific markets so we can deliver appropriate, feature-rich solutions at

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