Unit 9 Digital Equipments

Structure:

9.1 Introduction

In the previous unit you studied about some real world logic circuits like traffic signal systems, tennis scoring system, switches, temperature & weather forecast systems and their design. Multiplexing equipment used by the news services in the year 1920s are not commonly counted in the history of modems as the modem function was incidental to the multiplexing function. In 1940, George Stibitz connected a new Hampshire teletype to a computer system in New York City through phone lines. In United States, modems were part of the SAGE air-defense system in 1950s for connecting terminals to various radar sites, airbases and command-and-control centers to the SAGE director present all over the US and Canada. SAGE had dedicated lines for communication, but the terminal devices at every end were installed with a king of today's modem.

Later, when CEO of American Airlines and a region manager of IBM had a chance of meeting; this led to the development of "mini-SAGE" as an automatic airline ticketing system. It worked in the lines as sage like ticket office scattered across the nation had the terminals which are tied to the central computer that took care of availability and scheduling. This system known as SABRE is the primitive version of today's Sabre system.

AT&T maintained a monopoly in the US for many years by letting only AT&T devices to be connected to the network. AT&T introduced two digital sub-sets in 1958 for the growing group of computers – Wideband device and low-speed modem.

Data-phone was introduced in 1960 to replace the term digital subset. The 202 Data-phone which was market extensively in 1960 was a half-duplex asynchronous service. The 201A operated half-duplex at 2000 bit/s over normal phone lines, while the 201B provided full duplex 2400 bit/s service on four-wire leased lines, they sent and received channels running on their own set of two wires each.

In 1962, the famous 103A was introduced. Over the normal phone lines, it provided full-duplex service up to 300 baud. Call originators transmitting at 1070 or 1270 Hz and the answering device transmitting at 2025 or 2225 Hz used Frequency-shift keying. The readily available 103A2 gave an important boost to the use of remote low-speed terminals such as the KSR33, the ASR33, and the IBM 2741. By introducing the originate-only 113D and answer-only 113B/C modems, AT&T reduced modem costs considerably.

As radio receivers and vacuum tube electronic devices became more common in 1920s, multimeters were invented. Multimeter became more complex or may be supplemented by more specialized equipment in technician’s toolkit as the modern systems became more complex. A modern technician uses a hand-held analyzer to test several parameters in order to verify the performance of a network cable, where a general-purpose mulitmeter can test only short-circuits, conductor resistance and measure of insulation quality.

DVD (also known as "Digital Versatile Disc" or "Digital Video Disc") – is a popular optical disc storage media format. Its main uses are video and data storage. In this unit you will study about the some digital equipments. Here you will mainly study MODEM, Digital Multi-meter and Digital Versatile Disks

Objectives:

By the end of Unit 9, the learners are able to:

- explain the function of MODEM.
- explain the working of Digital Multi-meter
- list the uses of DVD

9.2 MODEM

MODEM stands for modulator-demodulator. It is a device which modulates an analog carrier signal for encoding digital information and performs the function of demodulating such a carrier signal to decipher the digital information encoded in it. The goal is the generation of a signal that can easily be transmitted and decoded to regenerate the actual digital data. Modems can be used over any means of transmitting analog signals, from light emitting diodes to radio. Voice band modem is one example that converts digital 0s and 1s from a personal computer into sound signals which could be transmitted over telephone lines of Plain Old Telephone Systems (POTS) which on the other side receives the sound signal and converts it back to the corresponding digital information.

Classification of modems is done on the basis of rate of data transmission, normally measured in bits/second or bps. Classification can also be done based on the rate at which the modem switches its transmission speed per second, termed Baud. Baud is measured in symbols/sec. Based on the modulation technique used, baud rate changes. A state change of 300 times/sec was observed in original Bell 103 modems. If a modem transmitted 1-bit every baud, it's a 300bit/sec modem or 300-baud modem. Only modem whose bit rate matched with the baud rate is 300 bits/sec. A modem that switches its state 600 times/sec and for each baud if it transmits 4 bits, it is said to be a 2400 bit/sec modem.

Cable modems and Asymmetric digital subscriber line (ADSL) modems are some faster modems used by internet users daily. Repeating frames of data is transmitted at very high rates over microwave radio links in "radio modems" used in telecommunications. There are modems that transmit more than hundred million bits/sec. Optical modems use optical fibers to transmit data. Undersea optical fibers are used in most of the present intercontinental data links. Optical modems consistently have data rates in excess of a billion bits/sec. One kilobit/sec in this context refers to 1000bits/sec and not 1024bits/sec. For example, a 48k modem transfers data at rates up to 48,000 bits (6kB)/sec.

The Smartmodem and the rise of Bulletin Board Systems

Smartmodem introduced by Hayes Communications in 1981 is the next major breakthrough in modems. It is a standard 103A 300-bits/sec modem, along with a controller; because of which computer can send commands to it and enable it use the phone line. Picking up and hanging up calls, dialing numbers etc. can be done through commands. Most of the modern modems still use the basic Hayes command set.

Modems before the Hayes Smartmodem required a two-step sequence to activate the connection: primarily, the user will have to dial the number on the standard phone and the then secondarily, phone is plugged into an acoustic coupler. In order to emulate dialing a handset, hardware add-ons like dialers are used in special circumstances.

Using Smartmodem, computer can directly dial the phone using corresponding commands. Hence the separate phone and acoustic coupler is no more required. Smartmodem is plugged directly into the phone line. This reduced the setup and operation effort significantly. Terminal programs that stored a list of phone numbers and sending commands to dial became common.

Bulletin board systems (BBSs) spread was aided by the Smartmodem and its clones. Previously on the client side, call-only, acoustically coupled models were used. Whereas on the server side, more expensive answer-only models are were employed. Smartmodem works in any mode depending on the computer sent out commands. Currently, there are low-cost server-side modems available in the market and BBSs flourished.

Soft modem (dumb modem)

During the second half of the 1990s, GeoPort modem released by Apple was similar one. Even though the theory is a clever one, i.e. enabling creation of powerful telephony application, in reality only programs developed were mere answering-machine and fax software, little improvised than their physical-world counterparts and more prone to error. The software was fussy and consumed majority of processor time and is no more operates in the present operating systems.

Most of the present day modems works secondarily as fax machine as well. In 1980's when digital faxes were introduced, an image format was sent over a high-speed modem (9600/1200 bit/sec). Computer can convert an image into fax-format which was then sent through modem. Once, this function was just an add-on, but it has become universal now.

Softmodem or winmodem is a stripped-down modem that takes up most of the tasks in to software, which was traditionally performed in hardware. Here, modem acts a digital signal process that creates sounds or voltage fluctuations on the telephone line. Because of the lesser hardware components, it is cheaper than traditional modems. Software generating the modem tones is complex and the performance of the computer as a whole gets affected when it is used. This is one disadvantage. This is becomes a real concern when it comes to online gaming. Lack of portability to operating systems(Oss) like Linux which may not have equivalent driver to operate the modem is another down-side. If the driver is incompatible with later version of windows, Winmodem may not work properly then.

Narrowband/phone-line dialup modems

Modems that are used currently are composed of an analog part and a digital part - analog part for generating signals and operating the phone, whereas the digital part for setup and control. Both the components are incorporated into a single chip even though there is division theoretically. Modem essentially works in two modes – command mode and data mode. Command mode is the one wherein the modem accepts the commands from the system and executes them. In data mode, data is sent to and from the computer over the phone lines. After powering up, modem enters command mode and then system sends it the command for dialing a number. Once the connection is established with the remote modem, it can switch to data mode and then send and receive data. When the user is done with data transfer, an escape sequence “+++” followed by a break of about one second is sent to the modem to let it know and return it to command mode, and the command ATH to hang up the phone is sent.

The commands themselves are typically from the Hayes command set, although that term is somewhat misleading. Only for the operations which work at 300 bps Hayes commands are used and for 1200bps operations these commands are extended. As new commands are required for faster speeds of operation, in 1990 there was rapid growth of command sets. By second half of 1990s, chip sets are used to construct the modem. We call this the Hayes command set even today, although it has three or four times the numbers of commands as the actual standard.

Increasing speeds (V.21 V.22 V.22bis)

In order to send the data using 300bps modems, frequency shift keying is used. In the above systems, the sounds which can be transmitted easily on phone lines is generated from the stream of 1s and 0s. In Bell 103 system, 1070 Hz and 1270 Hz tones are played to send 0s and 1s respectively from the originating modem, and 0s and 1s are putted on to 2025 Hz and

2225 Hz respectively. As these frequencies are not harmonics to each other and can suffer from the distortion on the system, they should be chosen very carefully.

Phase shift keying is used in the systems whose speed is equal to or more than 1200bps. Similar to 300bps systems, same frequencies are used to send the tones, but these signals will be out of phase with each other. The values of the stream can be determined by comparing the phases of the two signals, An 90 degree out of phase signals represent “1,0”, and an 180 degree out of phase signals represent “1, 1”. It can be observed that instead of one digit, two digits are represented by using above method.

In mid 1980s, 300bps (V.21) and 1200bps (V.22) modems are used in voiceband modems. A different version of V.22b is 2400bps is introduced in Europe, but a system which is similar to Bell 212 (1200bps) is introduced in US. 2400bps modems operations became common by late 1980s and they could support all the standards.

Increasing speeds (one-way proprietary standards)

In order to use low speed channels and high speed channels for transmitting and receiving, many standards have been introduced. In the French Minitel systems, 1200bps and 75bps have been used for receiving and transmitting respectively.

By introducing high speed versions of above concept 2 companies in US became famous. The Trailblazer modem which has been introduced by Telebit, can send the data at a rate of 1800 bps. The direction of the communication can be changed by the modem depending upon how much data is waiting on each side; this was done by an additional single channel which is connected in reverse direction. The UUCP “g” protocol which is used to send e-mail on Unix systems can spoofed by the special feature on Trailblazer modem and because of the there was tremendous amount of speed up. As the speed was improved, till 1990s Trailblazer became common on Unix systems.

HST modems which was for larger backchannels supplied only 9600bps was introduced by U.S. Robotics (USR). Instead of offering spoof, for fast file transfers USR offered its modem to BBs sysops (system operators) at lower price to create a large market. Similar to Telebit’s PEP, Express 96 was introduced by Hayes which used 9600 bps standard. These modems which are high speed were rare, because neither spoofing nor sysop discounts was not offered by Hayes.

4800 and 9600 (V.27ter, V.32)

Another major advancement in the modem design was Echo cancellation. In order to receive and send the data, same wires are used by the telephone lines, because of which the amount of bouncing back will be small. But the modem can get confused by this signal. Is the signal it is "hearing" a data transmission from the remote modem, or its own transmission bouncing back? In earlier systems, in order to originate and answer, the signal frequencies are split into two so that modem can avoid hearing its own originating frequencies; the speed of the modems has been limited to its half speed because of splitting of the bandwidth.

Echo cancellation got around this problem. The modems were able to decide whether the signal is from remote modem or from itself by measuring the delays and magnitudes of the echo and cancel the signals if it is from itself. By cancelling the echoes, the speed of the modems was increased and was able to send and receive the data at full speed which led to the development of 9600bps and 4800bps modems.

A complicated theory of communication has been used to increase the speed of modems. PSK technique was used in 2400 bps and 1200bs modems where 2 or 3 bits per symbol can be transmitted. Then Quadrature Amplitude Modulation (QAM) is used to get the combination of phase and amplitude by encoding four bits. A constellation diagram can be used for the best visualization, this diagram has two coordinates x(real) and y (quadrature) and the bits which are transmitted over the carrier are mapped on to the points on the graph. The new V.27ter and V.32 standards were able to transmit 4 bits per symbol, at a rate of 1200 or 2400 baud, giving an effective bit rate of 4800 or 9600 bits per second. The carrier frequency was 1650 Hz.

Error correction and compression

The limitation of the phone lines has been increased because of operations at high speeds which resulted in high error rates. In order to reduce the error rates, modems with inbuilt error corrections mechanism has been built and became famous with Micorcom's MNP systems. By minimizing overheads, the effective data rate has been increased from 75% (in MNP1) to 95% (MNP 4) the data rate in MNP 5 has been further increased by introducing the data compression mechanism to the systems. Generally the user could expect an MNP5 modem to transfer at about 130% the normal data rate of the modem. MNP was later "opened" and became popular on a series of 2400-bit/s modems, and ultimately led to the development of V.42 and V.42bis ITU standards. V.42 and V.42bis were non-compatible with MNP but were similar in concept: Error correction and compression.

In high speed modems, the concept of fallback is the used very commonly. Because of this concept high speed modem can speak to a modem which is less capable. At the time of call initiation, modem would wait for the response from remote modem once after sending a series of signals into the telephone line. During this process, till the modem hears from remote modem, it would reduce its speed progressively. Because of above method at a speed of 9600bps 2 USR modems were able to communicate, but the 2400bps modem would fall back to its normal speed. As the HST and V.32 modems used different standard at 9600bps, they also fall back to its normal standard (2400 bps), if the above method is employed. The same applies to V.32bis and 14400 bit/s HST modem.

Breaking the 9.6k barrier

In 1980 Gottfried Ungerboeck from IBM Zurich Research Laboratory applied powerful channel coding techniques to search for new ways to increase the speed of modems. His results were astonishing but only conveyed to a few colleagues. Finally in 1982, he agreed to publish what is now a landmark paper in the theory of information coding. By applying powerful parity check coding to the bits in each symbol, and mapping the encoded bits into a two dimensional "diamond pattern", Ungerboeck showed that it was possible to increase the speed by a factor of two with the same error rate. The new technique was called "mapping by set partitions" (now known as trellis modulation).

The industry was galvanized into new research and development. More powerful coding techniques were developed, commercial firms rolled out new product lines, and the standards organizations rapidly adopted to new technology. The "tipping point" occurred with the introduction of the SupraFAXModem 14400 in 1991. Rockwell had introduced a new chipset supporting not only V.32 and MNP, but the newer 14,400 bit/s V.32bis and the higher-compression V.42bis as well and even included 9600 bit/s fax capability. Supra, then known primarily for their hard drive systems, used this chip set to build a low-priced 14,400 bit/s modem which cost the same as a 2400 bit/s modem from a year or two earlier (about US$300). The product was a runaway best-seller, and it was months before the company could keep up with demand.

V.32bis was so successful that the older high-speed standards had little to recommend them. USR fought back with a 16,800 bit/s version of HST, while AT&T introduced a one-off 19,200 bit/s method they referred to as V.32ter (also known as V.32 terbo), but neither non-standard modem sold well.

V.34 / 28.8k and 33.6k

An ISA modem manufactured to conform to the V.34 protocol. Any interest in these systems was destroyed during the lengthy introduction of the 28,800 bit/s V.34 standard. While waiting, several companies decided to "jump the gun" and introduced modems they referred to as "V.FAST". In order to guarantee compatibility with V.34 modems once the standard was ratified (1994), the manufacturers were forced to use more "flexible" parts, generally a DSP and microcontroller, as opposed to purpose-designed "modem chips".

Today the ITU standard V.34 represents the culmination of the joint efforts. The most powerful coding techniques are employed including channel encoding and shape encoding. From 4 bits per symbol (9.6 kbit/s), the new standards used the functional equivalent of 6 to 10 bits per symbol, plus increasing baud rates from 2400 to 3429, to create 14.4, 28.8, and 33.8 kbit/s modems. This rate is near the theoretical Shannon limit. When calculated, the Shannon capacity of a narrowband line is Bandwidth * log2(1 + Pu / Pn), with Pu / Pn the signal-to-noise ratio. Narrowband phone lines have a bandwidth from 300-3100 Hz, so using Pu / Pn = 100,000: capacity is approximately 35 kbit/s.

Without the discovery and eventual application of trellis modulation, maximum telephone rates would have been limited to 3429 baud * 4 bits/symbol = approximately 14 kilobits per second using traditional QAM.

Using digital lines and PCM (V.90/92)

In the late 1990s Rockwell and U.S. Robotics introduced new technology based upon the digital transmission used in modern telephony networks. The standard digital transmission in modern networks is 64 kbit/s but some networks use a part of the bandwidth for remote office signaling (eg to hang up the phone), limiting the effective rate to 56 kbit/s Digital Signal 0 (DS0). This new technology was adopted into ITU standards V.90 and is common in modern computers. The 56 kbit/s rate is only possible from the central office to the user site (downlink) and in the United States; government regulation limits the maximum power output to only 53.3 kbit/s. The uplink (from the user to the central office) still uses V.34 technology at 33.6k.

Later in V.92, the digital PCM technique was applied to increase the upload speed to a maximum of 48 kbit/s, but at the expense of download rates. For example a 48 kbit/s upstream rate would reduce the downstream as low as 40 kbit/s, due to echo on the telephone line. To avoid this problem, V.92 modems offer the option to turn off the digital upstream and instead use a 33.6 kbit/s analog connection, in order to maintain a high digital downstream of 50 kbit/s or higher. V.92 also adds two other features. The first is the ability for users who have a call waiting to put their dial-up Internet connection on hold for extended periods of time while they answer a call. The second feature is the ability to "quick connect" to one's ISP. This is achieved by remembering the analog and digital characteristics of the telephone line, and using this saved information to reconnect at a fast pace.

Using compression to exceed 56k

Today's V.42, V.42bis and V.44 standards allow the modem to transmit data faster than its basic rate would imply. For instance, a 53.3 kbit/s connection with V.44 can transmit up to 53.3*6 == 320 kbit/s using pure text. However, the compression ratio tends to vary due to noise on the line, or due to the transfer of already-compressed files (ZIP files, JPEG images, MP3 audio, MPEG video). At some points the modem will be sending compressed files at approximately 50 kbit/s, uncompressed files at 160 kbit/s, and pure text at 320 kbit/s, or any value in between.

In such situations a small amount of memory in the modem, a buffer, is used to hold the data while it is being compressed and sent across the phone line, but in order to prevent overflow of the buffer, it sometimes becomes necessary to tell the computer to pause the data stream. This is accomplished through hardware flow control using extra lines on the modem–computer connection. The computer is then set to supply the modem at some higher rate, such as 320 kbit/s, and the modem will tell the computer when to start or stop sending data.

Compression by the ISP

As telephone-based 56k modems began losing popularity, some Internet Service Providers (ISPs) such as Netzero and Juno started using pre-compression to increase the throughput & maintain their customer base. As an example, the Netscape ISP uses a compression program that squeezes images, text, and other objects at the server, just prior to sending them across the phone line. The server-side compression operates much more efficiently than the "on-the-fly" compression of V.44-enabled modems. Typically website text is compacted to 4% thus increasing effective throughput to approximately 1300 kbit/s. The accelerator also precompresses Flash executables and images to approximately 30% and 12%, respectively.

The drawback of this approach is a loss in quality, where the graphics become heavily compacted and smeared, but the speed is dramatically improved such that web pages load in less than 5 seconds, and the user can manually choose to view the uncompressed images at any time. The ISPs employing this approach advertise it as "DSL speeds over regular phone lines" or simply "high speed dial-up".

List of dialup speeds

Note that the values given are maximum values, and actual values may be slower under certain conditions (for example, noisy phone lines). For a complete list see the companion article List of device bandwidths.

Connection	Bitrate
Modem 110 baud	0.1 kbit/s
Modem 300 (300 baud) (Bell 103 or V.21)	0.3 kbit/s
Modem 1200 (600 baud) (Bell 212A or V.22)	1.2 kbit/s
Modem 2400 (600 baud) (V.22bis)	2.4 kbit/s
Modem 2400 (1200 baud) (V.26bis)	2.4 kbit/s
Modem 4800 (1600 baud) (V.27ter)	4.8 kbit/s
Modem 9600 (2400 baud) (V.32)	9.6 kbit/s

Modem 14.4 (2400 baud) (V.32bis)	14.4 kbit/s
Modem 28.8 (3200 baud) (V.34)	28.8 kbit/s
Modem 33.6 (3429 baud) (V.34)	33.8 kbit/s
Modem 56k (8000/3429 baud) (V.90)	56.0/33.6 kbit/s
Modem 56k (8000/8000 baud) (V.92)	56.0/48.0 kbit/s
Bonding Modem (two 56k modems)) (V.92)	112.0/96.0kbit/s
Hardware compression (variable) (V.90/V.42bis)	56.0-220.0kbit/s
Hardware compression (variable) (V.92/V.44)	56.0-320.0 kbit/s
Server-side web compression(variable) (Netscape ISP)	100.0-1000.0 kbit/s

Radio modems

Direct broadcast satellite, WiFi, and mobile phones all use modems to communicate. Modern telecommunications and data networks also make extensive use of radio modems where long distance data links are required. Such systems are an important part of the PSTN, and are also in common use for high-speed computer network links to outlying areas where fiber is not economical.

Even where a cable is installed, it is often possible to get better performance or make other parts of the system simpler by using radio frequencies and modulation techniques through a cable. Coaxial cable has a very large bandwidth; however signal attenuation becomes a major problem at high data rates if a digital signal is used. By using a modem, a much larger amount of digital data can be transmitted through a single piece of wire. Digital cable television and cable Internet services use radio frequency modems to provide the increasing bandwidth needs of modern households. Using a modem also allows for frequency-division multiple access to be used, making full-duplex digital communication with many users possible using a single wire.

Wireless modems come in a variety of types, bandwidths, and speeds. Wireless modems are often referred to as transparent or smart. They transmit information that is modulated onto a carrier frequency to allow many simultaneous wireless communication links to work simultaneously on different frequencies.

Transparent modems operate in a manner similar to their phone line modem cousins. Typically, they were half duplex, meaning that they could not send and receive data at the same time. Typically transparent modems are polled in a round robin manner to collect small amounts of data from scattered locations that do not have easy access to wired infrastructure. Transparent modems are most commonly used by utility companies for data collection.

Smart modems come with a media access controller inside which prevents random data from colliding and resends data that is not correctly received. Smart modems typically require more bandwidth than transparent modems, and typically achieve higher data rates.

WiFi and WiMax

The WiFi and WiMax standards use wireless mobile broadband modems operating at microwave frequencies.

Mobile modems & Routers

Mobile modems are the modems which use mobile phone lines like GPRS, UMTS, EVDO, etc. For a laptop or any appliance, these modems can be embedded inside them. Datacards and cellular routers are the external modems which can be connected to any appliance. The datacard is a PC card or ExpressCard which slides into a PCMCIA/PC card/ExpressCard slot on a computer. AirCard made by Sierra Wireless is the most famous brand of modem datacards. Instead of PC cards, now a day's USB modems are used to connect to the laptop. An external datacard may or may not be present in the cellular router. The cellular modem is usually made for single connection and but multiple people are allowed to connect to a cellular routers.

There will be integrated SIM cardholder for the GSM based cellular router i.e., Huawei E220, Sierra 881, etc, but the CDMA routers will not use SIM cards, instead they use Electronic Serial Numbers. From region to region, there is a variation in the cost of using the modems. For unlimited data transfers some providers implement a flat rate, whereas some have maximum limit on the data transfers in a month. Some countries charge per Megabyte or Kilobyte of downloaded data. The faster data rates of the newest cellular modem technologies (UMTS, HSPA, EVDO, WiMax) are also considered to be "Broadband Cellular Modems" and compete with other Broadband modems below.

Broadband

ADSL modem

ADSL (asymmetric digital subscriber line) modems, a more recent development, are not limited to the telephone's "voiceband" audio frequencies. Some ADSL modems used discrete multi-tone(DMT) also called coded orthogonal frequency division modulation (COFDM)

A range of frequencies which are intended to carry radio frequency TV channels can be used by cable modems. The same frequency band can be used by many cable modems which are connected to a single cable, in order to allow multiple cable modems to work together within the channel, a low level media access protocol can be used. By using FDMA, up and down signal are kept apart.

Power line modems and double way satellite modems are new types of latest broadband modems.

As the broadband modems uses complex waveform to carry the data, they are still called as modems. When compared to the normal dial up modems, these broadband modems are more advanced. Broadband modems can modulate or demodulate 100s of channels. Many functions of a router and features like DHCP, firewall features and NAT are included in broadband modems.

Since consumers were unfamiliar with routers and networking when the technology of broadband was introduced manufacturers instead of selling broadband devices as adapter or transceivers, they started selling with the term modem. Before a broadband modem using a router, they should be configured in a bridge mode.

Deep-space telecommunications

Many modern modems have their origin in deep space telecommunications systems from the 1960s. Differences between deep space telecom modems and landline modems digital modulation include:

- digital modulation formats that have high doppler immunity are typically used
- waveform complexity tends to be low-typically binary phase shift keying
- error correction varies mission to mission, but is typically much stronger than most landline modems

Voice modem

The recording or playing audio over the telephone line can be done using a voice modem and are used in telephony applications. This type of modem can be used as FXO card for Private branch exchange systems.

9.3 Digital Multi-meter

Digital multi meter (DMM) or multitester is a measuring device which combines multiple functions in one unit. It is also known as VOM (Volt-Ohm meter). Generally the voltage, current and resistance measuring features are included in the multimeter. The figure 9.1 shows the digital multimeter.

Figure 9.1: Digital multimeter

Analog multimeters and digital multimeters are the two categories of the multimeters. Digital multimeters are abbreviated as DMM or DVOM.

A multimeter can be used to find the faults, field work service with high accuracy and for troubleshooting of both household and industrial devices.

Quantities measured

Many of the following quantities can be measured using multimeters. The common ones are:

- Voltage (both Alternating and Direct) in Volts.
- Current(both Alternating and Direct) in amperes
- Resistance in ohms

- Capacitance in farads.
- Conductance in siemens.
- Decibels for audio signal levels
- Duty cycle as a percentage.
- Frequency in hertz.
- Inductance in henrys.

Digital multimeters may also include circuits for:

- Continuity that beeps when a circuit conducts.
- Diodes and Transistors

Various sensors can be attached to multimeters to take measurements such as:

- light level
- Acidity/Alkalinity(pH)
- Wind speed
- Relative humidity

Resolution

The resolution of a multimeter is the smallest part of the scale which can be shown and is a scale dependent.

Digital

The resolution of a multimeter is often specified in the number of decimal digits resolved and displayed. For example, the term 5½ digit refers to the number of digits displayed on the readout of a multimeter.

A number greater than 1 and less than 9 can be displayed using 3 quarters digit and only zero or one can be displayed by a half digit. Maximum value of 3 or 5 can be referred to a three quarters digit. The most significant digit in the display is always the fractional digit. In a 5½ digit multimeter values from 0 to 9 can be represented using 5 full digits, and only zero or one can be displayed using half digit. Thus a 5½ digit multimeter can have range from 0 to 199999 to show the positive or negative values. Depending the manufacturing company, values from 0 to 3999 or 5999 can be displayed using a 3¾ digit meter. If the analog portion of the multimeter is not designed with proper care and calibration, the extra digits which are used to extend the precision will not have any value. A good traceability of the calibration, good controllability of the measurement conditions, and goof understanding of the specification of the instruments are required for high resolution measurements.

The resolution can be also specified using another way called “display counts”. The largest number that can be displayed by multimeter can be determined from the display counts and these display counts ignore the decimal separator. For example, a 5½ digit multimeter can also be specified as a 199999 display count or 200000 display count multimeter. In multimeter specification the display count is just referred as count.

Analog

The width of the scale pointer, accuracy of scales, zero calibration, no of ranges, pointer vibration and errors because of non-horizontal usage of display limits the analog multiplier’s resolution. Accuracy of readings obtained is also often compromised by miscounting division markings, errors in mental arithmetic, parallax observation errors, and less than perfect eyesight. In order to improve the resolution, a large meter movements and mirrored scales are used; the resolution of two and half to 3 digits is sufficient.

The resistance measurement circuit compress the scale at higher resistances, because of this of the precision of the circuit is low.

Accuracy

The accuracy of the digital multimeters is better when compared to the analog meters. The accuracy of the digital multimeters is 0.5% on current scales and DC voltage; whereas the analog meters have accuracy of 3 to 5%.The accuracy up to ±0.01% can be achieved by using mainstream bench top multimeters. The accuracy of Laboratory grade instruments will be in parts of million.

Sensitivity and input impedance

The accuracy of the mutlimeter can be affected by testing the current load. Precise measurements are required to calculate the small current drawn. A multimeter can get damaged with too much of current load or with improper usage of device.

The digital and analog meters, which performs the amplification using transistor, has high input impedance so that it will not disturb the most circuits. The input impedance will be in order of million or ten million ohms.

The range of direct current measurement can be done up to tens of thousands of volts by using the standard input impedance.

The analog meters are said to be unbuffered if they are of moving pointer type and in order to deflect the meter it will draw the current circuit which is being tested. Depending upon the selected range of the meter and its sensitivity, the impedance of the meter varies. The impedance will be 2,000,000 ohms for the meter whose sensitivity is 20,000 ohm/volt. In testing of power circuits (where meter impedance > source impedance) – a low sensitivity meters are used. The meter impedance should not be load in measuring the signal circuits which requires high sensitivity.

Occasionally resolution of the meter confused with the sensitivity of the meter. The general purpose meters should have a 100 millivolts AC or DC in the full scale range, but the meter should have 100 milliamps in current's full scale range. The accuracy of measurements below few tens of ohms by the general purpose meters will be low because, these meters have a two wire resistance measurements and the effect of the lead wire resistance is not compensated. Depending upon the manufacturers the upper end of measurement range varies; a specialized test instrument is required for measurements ove 10 amps, 100 megaohms or 1000 volts.

Alternating current sensing

In order to measure alternating current, an AC to DC converter is included in the multimeter. To calculate the average value of the sine wave, a rectifier circuit can be included in the meter and can be calibrated to evaluate the value. In order to determine the correct RMS value for average responding meter, correction factors for simple waveforms will be given in meter's user guide. To calculate the RMS values of a waveform, few meters include an AC to DC conversion circuit, but these meters will be expensive. For non-sinusoidal quantities like audio signals, the measurement of RMS sensing is required.

Digital Multimeters (DMM or DVOM)

Many features are provided in the digital meters with inclusion of wide variety of solid state electronics. Commonly available measurement enhancements include:

- Auto-ranging, which selects the correct range for the quantity under test so that the most significant digits are shown. For example, a four-digit multimeter would automatically select an appropriate range to display 1.234 instead of 0.012, or overloading. Auto-ranging meters usually include a facility to 'freeze' the meter to a particular range, because a measurement that causes frequent range changes is distracting to the user.

- Auto-polarity for direct-current readings, shows if the applied voltage is positive (agrees with meter lead labels) or negative (opposite polarity to meter leads).
- Sample and hold, which will latch the most recent reading for examination after the instrument is removed from the circuit under test.
- Current-limited tests for voltage drop across semiconductor junctions. While not a replacement for a transistor tester, this facilitates testing diodes and a variety of transistor types.
- A graphic representation of the quantity under test, as a bar graph. This makes go/no-go testing easy, and also allows spotting of fast-moving trends.
- A low-bandwidth oscilloscope.
- Automotive circuit testers, including tests for automotive timing and dwell signals.
- Simple data acquisition features to record maximum and minimum readings over a given period, or to take a number of samples at fixed intervals.
- A miniature digital multimeter integrated with tweezers for surface-mount technology.

By using RS232 cables, or by IrDA links or USB or an instrument bus, a personal computer can be connected to the modern meters. Thus the recording of the measurements can be done using personal computers. Few digital multimeters can first store the measurements when are made and later upload them to a computer. In 1955, Non Linear systems manufactured the first DMM.

Analog Multimeters

Even though the analog multimeters are used commonly, the cost of a quality analog instrument will be same as that of DMM. The analog multimeters cannot have the same accuracy as that of DMM because of the limitations on precision and reading accuracy. The figure 9.2 shows the analog multimeter with galvanometer needle display.

Figure 9.2: Analog multimeter with galvanometer needle display.

Sometimes for better detection of rate of change of a reading, an analog meter can be used; fast responding bar graph display is used in few DMM's to detect the rate of change of reading. When compared to DMM the analog multimeters are less susceptible to radio frequency interference.

The basic part of analog meter is called a meter movement. The meter movement in a moving pointer analog multimeter is practically always a moving-coil galvanometer of the d'Arsonval type, using either jeweled pivots or taut bands to support the moving coil. Generally the analog multimeters draw the current from the circuit being measured in order to deflect the pointer and the coil; reducing the current drawn from the circuit being tested will be an advantage. The unit for sensitivity of an analog meter is ohms/v. The sensitivity the inexpensive analog meter at full scale measure voltage can be 100ohms/v, which can draw 1mA from a circuit. The sensitivity of the expensive analog meter at full scale measure voltage can be 20,000 ohms/v or more, and the upper limit for general purpose, portable and non-amplified meters is 50,000 ohms/v.

An amplifier is inserted between the meter movement and the measuring circuit in order to minimize the current drawn for meter movement and avoid loading on the circuit. But the adding of an amplifier increased the complexity and cost of the meter and power supply which is required by the amplifier., Independent of the current required to meter movement, the input resistance can be made high by using vaccum tubes and Field Effect Transistors. Such amplified multimeters are called VTVM (vacuum tube voltmeters) TVM (transistor volt meter), FET-VOM, and similar names.

Probes

In order to connect the circuit to a multimeter, different kinds of probes can be used. The most 3 commons probes used are pointed probes, crocodile clips, and retractable hook clips. The connectors are attached to flexible, thickly-insulated leads that are terminated with connectors appropriate for the meter. Shrouded or recessed banana jacks are used for handheld multimeters, but BNC connectors or banana jacks can be used for benchtop meters. Occasionally binding posts and 2mm plugs are also used.

For accuracy and for safety, non-contact attachment mechanism is used in meter which measures high currents or high voltages. To determine the current flowing through the conductor, a coil that clamps around it is provided by the clamp multimeters.

Safety

In order to prevent the damage to the multimeter when it is overloaded, a fuse is provided by few multimeters. But fuses usually protect only high current range on the meter. During the operations, setting the meter to measure the current or resistance and then connecting to a voltage source which has low impedance would damage the meter and sometimes it can explode the device.

Depending upon the intended application of the digital meters DMM are categorized into 4 types:

- Category I: used where current levels are low.
- Category II: used on residential branch circuits.

- Category III: used on permanently installed loads such as distribution panels, motors, and appliance outlets.
- Category IV: used on locations where current levels are high, such as service entrances, main panels, and house meters.

For selected measuring range in the DMM, maximum transient voltages are also specified for each category. Protection from over current faults is provided by the category based meters.

9.4 Digital Versatile Disks

Digital versatile disk (DVD) is a digital optical disc storage format, invented and developed by Philips, Sony, Toshiba, and Panasonic in 1995. Most DVDs are of the same dimensions as compact discs (CDs) but store more than six times as much data.

The figure 9.3 shows the typical DVD.

Figure 9.3: DVD- read/write side

DVD was never defined in the original DVD specification. Now-a-days the most common usages are “DVD”, “Digital Versatile Disc”, and “Digital Video Disc”. A DVD can store video’s, audio and other data and access all on one disc. Variations of the term DVD often describe the way data is stored on the discs: For example in DVD-ROM, data can only be read and not written, DVD-R and DVD+R can only record data once and then function as a DVD-ROM. DVD-RW, DVD+RW and DVD-RAM can both record and erase data multiple times. The wavelength used by standard DVD lasers is 650 nm, and thus has a red color. The types of DVD are referred by its storage capacity. The table 9.1 shows the capacity of DVD along with nomenclature.

Table 9.1: Capacity of DVD and nomenclature

Designation	Sides	Layers (total)	Diameter (cm)	Capacity (GB)	Capacity (GiB)
DVD-1 SS SL	1	1	8	1.46	1.36
DVD-2 SS DL	1	2	8	2.66	2.47
DVD-3 DS SL	2	2	8	2.92	2.72
DVD-4 DS DL	2	4	8	5.32	4.95
DVD-5 SS SL	1	1	12	4.70	4.37
DVD-9 SS DL	1	2	12	8.54	7.95
DVD-10 DS SL	2	2	12	9.40	8.74
DVD-14DS DL/SL	2	3	12	13.24	12.32
DVD-18DS DL	2	4	12	17.08	15.90

SS = single-sided, DS = double-sided, SL = single-layer, DL = dual-layer

Standard DVD is of 12cm and mini DVD is of 8cm. These are the same sizes as a standard CD and a mini-CD, respectively. The capacity by surface (MiB/cm²) differs from 6.92MiB/cm² in the DVD-1 to 18.0 MiB/cm² in the DVD-18.

Note: The capacity of DVD is represented by symbol GB (gigabyte). In order to show the distinction, Kilobyte, Megabyte and Gigabyte are the labels used to represent the files sizes in present day computers.

Among 2418 bytes of data that is contained in a sector of DVD, the user data will be 2048 bytes. There is a small difference in storage space between '+' and '-' formats. Capacity differences of writable DVD formats is shown in table 9.2.

Table 9.2: Capacity differences of writable DVD formats

Type	Sectors	Bytes	GB	GiB
DVD−R SL	2,298,496	4,707,319,808	4.71	4.384
DVD+R SL	2,295,104	4,700,372,992	4.70	4.378
DVD−R DL	4,171,712	8,543,666,176	8.54	7.957
DVD+R DL	4,173,824	8,547,991,552	8.55	7.961

Technology

Internal mechanism of a DVD-ROM Drive.

CD's uses 780nm wavelength laser diode light, HD-DVD uses 405nm wavelength laser diode light and DVD uses 650nm wavelength laser diode light. As DVD uses lesser wavelength laser diode light than CD, on the media surface it is possible to etch a smaller pit.

The writing speed of the first media and the drive model was 1x (1318 KiBps) and the recent models have the speed of 18x or 20x. The writing speed of CD is 1x (153.6 KiBps) and it is 9 times slower than DVD.

DVD drive speeds

Drive speed	**Data rate**		**~Write time (min)**	
	(Mibit/s)	**(MB/s)**	**SL**	**DL**
1×	10.55	1.35	61	107
2×	21.09	2.70	30	54
2.6×	27.43	3.51	24	42
4×	42.19	5.40	15	27
6×	63.30	8.10	11	18
8×	84.38	10.80	8	14
12×	126.60	16.20	6	11
16×	168.75	21.60	4	7
18×	189.90	24.30	3	5
20×	211.00	27.00	3	4

DVD recordable and rewritable

In order to store the information for transport and back up, a recordable DVD was developed by HP.

For the purpose of video and audio recording, the recordable DVD's are used. DVD-RAM, DVD-R/RW (minus), and DVD+R/RW (plus) are the three formats for recording purpose.

Dual layer recording

Storing of more data in DVD-R and DVD+R disc can be done by using dual layer recording. With this method data up to 8.5 GB per side can be stored on a disc. But with single layer recording, only 4.7GB of data can be stored. Pioneer Corporation developed DVD-R DL for DVD forum, Philips and

Mitsubishi Kagaku Media (MKM) developed DVD+R DL for DVD+RW Alliance.

When compared to the usual DVD a dual layer disc has a second physical layer in it. By shining the laser though the first semitransparent layer second layer can be accessed by the drive. The noticeable pause in DVD players indicate the change of layer in the disc, some DVD players will pause for several seconds. Because of this effect, viewers were worried that their discs are defective or damaged., as a result on dual layer packed discs the messages were listed explaining the pausing effect due to layer change DVD recordable discs supporting this technology are backward compatible with some existing DVD players and DVD-ROM drives. Now a day the dual layer technology is supported by the modern DVD, and even though the empty disc is expensive, the cost of both single layer drives and dual layer drives are comparable. But dual layer drive recording speed is well below the recording speed of single layer drive.

For dual layer orientation, Parallel track path (PTP) and outer track path (OTP) are the two modes. With PTP, inside diameter (ID) will be beginning point for both layers and with lead out at outer diameter (OD) both layers end. With OTP, at ID lower layer begins and at OD the upper layer begins, the lead in and lead out are shared at the point where the other layer ends.

DVD-Video

IDVD-Video is a standard for storing and distributing video/audio content on DVD media. In 1997, the sale of DVD players and videos was started in U.S. Now a day for worldwide distribution of home video, DVD video is used as dominant form. Either 16:9 aspect ratio MPEG 2 video or 4:3 aspect ratio is used in many DVD-video discs, which are stored at 720x576 (PAL) or 720x480 (NTSC) at 25 FPS or 29.97 FPS. Audio is commonly stored using the Dolby Digital (AC-3) or Digital Theater System (DTS) formats, ranging from 16-bits/48 kHz to 24-bits/96 kHz format with monaural to 7.1 channel "Surround Sound" presentation, and/or MPEG-1 Layer 2. Almost all possible formats are supported by the current DVD players even though there audio and video requirement specification changes from region to region. Different features like multiple camera angles, and audio tracks, different subtitles which can be selectable and menus are supported by the DVD video.

DVD-Audio

In order to deliver high quality audio content, DVD audio format is used. At various frequencies (up to 192 kHz), many channel configuration options are offered. Higher audio quality and more music can be included in the higher capacity DVD audio when compared with CD.

Despite DVD-Audio's superior technical specifications, there is debate as to whether the resulting audio enhancements are distinguishable in typical listening environments. DVD-Audio currently forms a niche market, probably due to the very sort of format war with rival standard SACD that DVD-Video avoided.

Security

DVD-Audio discs employ a copy prevention mechanism, called Content Protection for Prerecorded Media (CPPM) developed by the 4C group (IBM, Intel, Matsushita, and Toshiba).

To date, CPPM has not been "broken" in the sense that DVD-Video's CSS has been broken, but ways to circumvent it have been developed. By modifying commercial DVD(-Audio) playback software to write the decrypted and decoded audio streams to the hard disk, users can, essentially, extract content from DVD-Audio discs much in the same way they can from DVD-Video discs.

Self Assessment Questions

1. ____________was introduced in 1960 to replace the term digital subset.
2. ___________________ is a device which modulates an analog carrier signal for encoding digital information and performs the function of demodulating such a carrier signal to decipher the digital information encoded in it.
3. POTS stands for__________________________.
4. The WiFi and WiMax standards use wireless mobile broadband modems operating at ___________________frequencies.
5. ADSL stands for __________________________.
6. _________________is a measuring device which combines multiple functions in one unit.
7. The resolution of a multimeter is often specified in the number of decimal digits resolved and displayed (True or False).
8. The unit for sensitivity of an analog meter is________________.

9. The meter movement in a moving pointer digital multimeter is always a moving-coil galvanometer of the d'Arsonval type (True or False?).
10. A _______________can store video's, audio and other data and access all on one disc.
11. __________________is a standard for storing and distributing video/audio content on DVD media.
12. CPPM stands for ___________________________________.

9.5 Summary

Let us recapitulate the important concepts discussed in this unit.

- Modem which stands for modulator-demodulator. It is a device which modulates an analog carrier signal for encoding digital information.
- Cable modems and Asymmetric digital subscriber line (ADSL) modems are some faster modems used by internet users daily.
- Softmodem or winmodem is a stripped-down modem that takes up most of the tasks in to software, which was traditionally performed in hardware.
- In order to send the data using 300bps modems, frequency shift keying is used.
- Modern telecommunications and data networks also make extensive use of radio modems where long distance data links are required.
- Digital cable television and cable Internet services use radio frequency modems to provide the increasing bandwidth needs of modern households.
- Mobile modems are the modems which use mobile phone lines like GPRS, UMTS, EVDO, etc.
- Digital multi meter (DMM) or multitester is a measuring device which combines multiple functions in one unit. It is also known as VOM (Volt-Ohm meter).
- The resolution of a multimeter is the smallest part of the scale which can be shown and is a scale dependent.
- When compared to DMM the analog multimeters are less susceptible to radio frequency interference.

- A DVD can store video's, audio and other data and access all on one disc.
- The recordable DVD's are used for the purpose of video and audio recording.
- DVD-RAM, DVD-R/RW (minus), and DVD+R/RW (plus) are the three formats for recording purpose.

9.6 Terminal Questions

1. Explain the working of MODEM.
2. Write a note on smartmodem.
3. Explain the functioning of Digital Multi-meter.
4. Write a short note on Digital Versatile Disk.

9.7 Answers

Self Assessment Questions

1. Data-phone
2. MODEM
3. Plain Old Telephone Systems
4. Microwave
5. Asymmetric digital subscriber line
6. Digital multi meter (DMM)
7. True
8. Ohms/v
9. False
10. DVD
11. IDVD-Video
12. Content Protection for Prerecorded Media

Terminal Questions

1. Refer to section 9.2
2. Refer to section 9.2
3. Refer to section 9.3
4. Refer to section 9.4