

# ***BVCC General Meeting***

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**Computer Basics**

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## What is a Computer?

- **"Computer" now means a general-purpose, programmable electronic digital calculating machine. Today's computers evolved from:**
  - **1830's general-purpose programmable mechanical device designed by Babbage (not practical to build)**
  - **1940's electro-mechanical relay computers. 1<sup>st</sup> large-scale vacuum tube computer in US 1945**
  - **1950's basic components of commercial computers in place-- further evolution in following decades improved reliability, capacity, and speed (nuclear research & weather prediction), and reduced size and power requirements (space program)**
  - **Transistors replaced tubes (1960's), Integrated Circuits & Large-Scale Integrated Circuits replaced transistors, evolving into Intel Microprocessors and solid state memory in 1971, which made PCs possible. Since then processors and memory have evolved to be constructed with much smaller, faster, and more complex internal structures**

# Fundamental Components

- **Processor(s)** – reads and follows instructions stored in memory; reads, does arithmetic, logic & tests with data from memory, and stores results into memory; initiates input/output operations to devices
- **Memory (short-term, fast RAM)**– stores programs and data used by processor and input/output devices. All data is numeric, but depending on usage context, numbers may represent over 144K unique printable characters (unicode) from all the actively-used world languages, or represent many other objects or attributes.
- **Typical Interfaces to Input/Output devices:**
  - SATA: Internal HD, SSD, DVD drives (long-term memory)
  - HDMI, VGA, DVI, DisplayPort: monitor or display
  - USB (2.0, 3.0, 3.1, 3.2): keyboard, mouse, webcam, printer, scanner, memory sticks, external drives
  - RJ45: Ethernet
  - Stereo jack (1/8"): external mic & speakers
  - RF signal: WiFi, Bluetooth (audio devices)
- **Power Supply** – supplies other components with required DC voltages. Various physical sizes and wattage ratings..
- **Motherboard** – a circuit board that supplies the interface between all other components. Designed for a specific case size, and specific processor and memory types. May have provision for adding additional hardware interface cards (desktop), or for upgrading or adding RAM memory modules (desktop & laptop). Also contains memory holding the BIOS/UEFI program code used in the boot process and which provides consistent access to the model-specific hardware present.

# Types of Personal Computers

- **Desktop –**
  - **Separate case for processor(s), RAM, internal long-term storage, WiFi, Ethernet, connectors for external devices & Cooling fan.**
  - **greater hardware customization: change RAM, storage device, even add additional "cards"**
  - **Requires external keyboard, mouse, monitor, speakers, webcam, microphone.**



# Types of Personal Computers

- **All-In-One – minimizes desk space**
  - The monitor case is thick enough to include all the components of the typical desktop case plus includes speakers, webcam, microphone.
  - More modest hardware customization: RAM, storage device
  - Requires external keyboard, mouse
  - Typically fewer connectors for external devices because of limited space for connectors on the case.

# Types of Personal Computers

- **Laptop**

- designed for portability, small size, and low power for battery operation. Integrated keyboard, mouse, monitor, speakers, webcam, microphone; yet has standard ports to use external monitor and other external devices. Uses power-efficient processors. Upgrading RAM and Storage drive possible, but may require specialized tools and experience to partially disassemble the laptop.



# Types of Computers

- **Pads & Smart Phones**

- Different architecture than personal computers. Can't run the same program code or Operating System as personal computers, but some applications have different but similar-featured versions that run on both PCs, Pads, and Smart Phones.
- Complete replacement required to upgrade. Can only support external devices that can be connected via WiFi, Bluetooth, or charging port. All Storage is persistent, solid-state RAM memory, no storage drive. App sources constrained to standard "app stores"
- can connect to a Local network via WiFi, or connect to the Internet through cellular data service of the phone service provider
- Smaller display may make them impractical for some applications

## Other Computers

- **Many devices with complex control requirements are implemented using a computer running a fixed application that can't be changed by the user (called "embedded systems")**
  - thermostats, appliances, security systems, TVs, entertainment systems, ISP modems, routers, Ethernet switches, printers, scanners, automotive control systems, industrial control systems, etc.
  - From the user's viewpoint, more likely to be regarded as an "appliance" rather than computer.



# Processor(s)

- **Microprocessors chips – some can have billions of active "elements"**
  - **Architecture – 32-bit vs 64-bit memory address (must be 64-bit for > 4 GiB RAM memory; Win11 req 64-bit)**
  - **Physical & logical processors – more usually better**
  - **Clock speed – GHz – faster better. Win 11 minimum of 1GHz clock and 2 or more physical processor cores**
  - **Manufacturer, Family & model – e.g. Intel i7-10700**
    - **implies #processors, speed, generation (over 140 new Intel models just in last 5 yrs)**



# Processor(s)

- **Intel "Core" microprocessors**
  - Increasing performance: i3 → i5 → i7 → i9
  - Generation: higher generation number (first digits of model #, 4 – 12) is later technology, supports newer features, and probably uses less power for the same performance. Windows 11 requires generation 8 or above, available in i3 through i9 – but there are earlier generation models of i3 – i7 that do not support Win 11
  - Most users probably OK with i3 or i5; for servers, heavy 3D gaming or video editing, may need i7 or i9
- **Advanced Micro Devices (AMD) makes microprocessors that can also be used for PCs that run Windows.**
  - Totally different naming conventions for models and generations
  - Has competitive microprocessors that can run Windows 11

## Processor(s)

- **Very rough indication of relative total performance: # of physical processors times clock speed**
  - as physical processors added, benefit per processor decreases
  - Hyperthreading allows one physical processor to act like two (slower) logical processors
  - multiple logical processors allows multiple program threads to execute concurrently
  - Tasks that can only use one processor are limited by the speed of a single processor – such tasks won't directly benefit from more processors, but would see better performance from features that make each processor faster (higher clock speed, fewer clock cycles to execute instructions)

While the PC user may think he's only be doing "one" thing at a time, many things run concurrently in Windows: monitoring keyboard & mouse for new input; monitoring and responding to data received on Ethernet or WiFi connection; looking for new email, performing Anti-Virus scans; looking for downloading and installing updates to Windows and other applications; sending data to/from external devices while you work on something else; some applications like web browsers use multiple threads to download many pieces from a web page in parallel.

# Processor Clock Frequency

- Measured in GHz (billions of cycles per sec)
- Electric signals are fast but not instantaneous – best case in vacuum ~1 ft per nanosec. A certain amount of power must be transmitted to make a change in state.
- Processor moves data internally in steps in response to current program instruction and current state of the processor
  - many different electrical signals traveling internal paths of different lengths at the same time; each step takes time to insure all signals to reach their destination.
  - movement only takes place on each clock pulse to allow previous movement to reliably settle
- Running at higher than designed clock speed requires more power, generates more heat, can reduce reliability or damage processor
- Making individual elements in microprocessor smaller can reduce power and voltage requirements and make performance at higher clock frequencies practical.

# Graphics Processing Units (GPU)

- **Putting cute color graphics on a monitor screen requires much processing power and memory accesses**
  - All recent computers have a GPU of some variety. Windows 11 requires a compatible GPU.
  - GPU is designed to offload the work of projecting graphic objects on a monitor to a special processor that is optimized for video calculations
  - Cheapest way to do that is an Integrated GPU on the same microprocessor chip
  - Some motherboards use a separate GPU chip.
  - High-end gaming desktops may have plug-in board with GPU and additional memory & fans for cooling to support fast, high-res simulated-3D graphics.
  - Most computer users don't need to worry about the GPU type, as long as it is fully compatible with Windows 11. Running dxdiag from the command line should show "DirectX Version" of "12" and a "Driver Model" of WDDM 2.0 or higher. Not a problem for an Integrated GPU if the microprocessor model is supported for Windows 11.

# Ranking Microprocessor Chips

- **Typical approach: Run a "Benchmark" test**
  - **Test how fast a "benchmark" program runs**
    - Very approximate – real applications of interest may have a different mix of instructions; could be bottlenecks in other components than the processors; speed of execution of a specific instruction can be influenced by many factors.
    - <https://www.cpubenchmark.net> has results from same benchmark on many different microprocessors. Should be able to locate via google search of "*<model-number>* benchmark". Gives total vs single-CPU rating, cores vs threads
      - e.g. i5-7200u: 3405/1785 2/4 (1.9 x 1 CP)
      - i7-10700: 17188/2928 8/16 (5.9 x 1 CP)
    - Microprocessors with same clock speed and same number of physical processors can have different performance depending on internal design.

# Memory

- Measured in multiples of Bytes
  - Byte = 8 binary digits (bits), 0's & 1's
  - 1 Byte can contain 256 distinct values –e.g., 00000000 ( $0_{10}$ ,  $00_{16}$ ) through 11111111 ( $255_{10}$ ,  $FF_{16}$ )
  - Use of binary simplifies hardware design and reliability – two different voltage levels for digits "0" and "1"; transistor circuits can either be "off" or "on".
  - Depending on context consecutive bytes can represent
    - a processor machine instruction
    - larger integer values (includes 64-bit memory addresses)
    - binary-encoded decimal digits, 2 decimal digits per byte
    - binary equivalent of numbers in scientific notation (  $0.1011_2 \times 2^3$  )
    - Characters (1-4 bytes per char for UTF-8 Unicode) – e.g., "A" =  $41_{16}$ , "ß" =  $CE B2_{16}$
    - Binary data whose interpretation is defined by an application program: images, spreadsheets, formatted documents, etc.

In windows, support for arbitrary unicode chars is application specific. Both Word and Wordpad support typing the unicode char value in hex followed by pressing ALT x to toggle the hex code into the corresponding unicode character. Many Windows applications do not support this method.

In Linux support is built into the desktop.

CTRL+ALT+u followed by the unicode hex value followed by a space will work almost anywhere text input is allowed

The UTF-8 representation of the unicode character will look funny compared to the straight hex representation because extra bits are inserted to indicate when 2, 3, or 4 bytes must be interpreted as a single character

# Random Access Memory (RAM)

- **When individual bytes of memory are addressed by a binary integer value the size of the memory is always a multiple of some power of 2. For convenience  $K=2^{10}=1024$ ,  $M=2^{20}=1,048,576$ ,  $G=2^{30}=1,073,741,824$ ,  $T=2^{40}\approx 1.100\times 10^{12}$** 
  - There is actually an international standard to use Ki, Mi, Gi, and Ti instead of K, M, G, and T when powers of the binary base are intended, but it is unfortunately widely ignored.
  - Memory modules currently available with 4GiB, 8GiB, 16GiB, 32GiB, and 64GiB – motherboard design determines type, capacity, and number of modules that are allowed. Computers for home use typically support a max of 32GiB total, or less. Win 11 requires min of 4GiB, but runs better with at least 8GiB total.



# RAM Memory

- Desktop & Laptop: removable solid-state modules plug into the motherboard, whose design dictates the type of module and supported capacities.
  - size rated in GiB (1 GiB =  $2^{30}$  Bytes  $\approx$  1.07 GB) (but commonly mis-stated as GB)
  - one or more slots
    - Each slot may support several different capacities
    - Some motherboards require installation in pairs
  - Examples:
    - My laptop uses paired DDR4 2666MHz SODIMM with either 2 x 4GiB, 2 x 8GiB, or 2 x 16GiB
    - My desktop uses DDR4 2666MHz DIMM with either 2 x 4GiB, 2 x 8 GiB, or 2 x 16GiB (my desktop microprocessor will actually support up to 128GiB of DDR4-2933, but the motherboard constrains what is supported to less) (max per module  $8 \times 2.666$  GB/sec = 21.3 GB/sec)
- For pads and smart phones the memory is permanently installed
- For specialized uses in embedded systems, limited memory might even be included in the microprocessor chip to minimize cost.
- Contents of memory normally disappears when device is powered down. Exception: pads and smart phones lack separate storage drive, so must use a persistent type of RAM that retains data across a power down.
- Processors read their program instructions and data values from RAM memory and store results in RAM memory. Intermediate results may be kept in high-speed memory ("registers") within the processor itself.



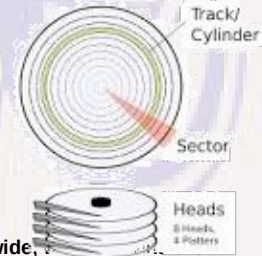
## Internal Storage Devices

- I/O devices that transfer blocks of 512 bytes ("sectors") to/from RAM memory at the direction of a processor.
- Now typically connected to motherboard via SATA cable
- Includes SSD (Solid State Drive), HD (Hard Drive), DVD/CD drive (mostly used with write-once media) – all are slower than RAM storage, but retain their contents when powered down
- Used for storage of programs and data that are not currently needed by a processor and for long-term storage of programs and data. DVD/CD media is removable and can also be used to port data to another computer or used as archival storage.

Early PC drives were 5.25" diskette drives, whose removable diskette media contained a flexible plastic surface disk coated with ferro-magnetic material. When they were replaced by much faster, higher capacity drives with fully-enclosed metal platters, read/write heads, and drive motors, the new drives were called "hard" drives because the data platters were made of rigid metal for stability at high rotation speeds.

# Hard Drives

- Mechanical hard drives – have multiple magnetic recording surfaces, an access arm with read/write heads for each magnetic recording surface that are moved together to access circular tracks of sectors from each recording surface.
- To read/write a particular sector, the access arm must be mechanically moved so that the heads are above the "cylinder" of circular tracks that contain the sector, then wait until the desired sector rotates under the read/write heads
- While each sector contains 512 ( $2^9$ ) Bytes, the total number of sectors is only related to the number of recording surfaces, physical sizes of the platters and the reliable recording density, not to any nice power of 2, so the total drive capacity in bytes has no nice relationship to  $2^{20}$ ,  $2^{30}$ , or  $2^{40}$ . Traditionally HD capacities are given in GB ( $10^9$  Bytes) and TB ( $10^{12}$  Bytes), not as GiB or TiB values.
- A mechanical HD for a desktop is 3.5" wide. Those for laptops are 2.5" wide, maximum capacity for a laptop mechanical HD is usually less than that of a comparably priced desktop HD
- A PC HD typically rotates at 5400 rpm or 7200 rpm (which gives better performance from less rotational delay)



## Desktop HD, Cover Removed



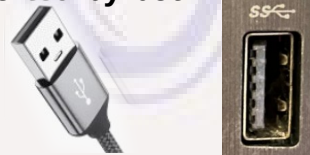
You don't want to do this to good drive. A HD is environmentally sealed to keep out dust and other contaminants. The read/write heads "float" on a cushion of air extremely close to the surfaces of the rotating platters. A particle of dust or smoke on the surface is like a boulder that can cause the head to crash into and damage the recording surface causing a track to fail and kicking up additional particles that can result in progressive failure of the drive.

# Solid State Drives (SSD)

- **An SSD emulates a mechanical HD using persistent solid state memory in place of rotating platters.**
  - **Much faster than HD: 0 time moving to a different cylinder; 0 time waiting on rotational delay; sector transfer time limited by electronics, not by HD RPM and physical recording density.**
  - **Higher cost/Byte than HD, but prices dropping (1TB now under \$100; 4 TB SSD available but may cost more than your PC)**
  - **Only available in 2.5" laptop size, but can be used in desktop disk bay with an adapter.**
  - **Can be a cheap way to upgrade a desktop or laptop that sees slow performance caused by disk drive performance bottleneck.**

# Universal Serial Bus (USB) Ports

- **Newer computers typically have both USB 2.0 & USB 3.0 ports, maybe even faster 3.1 or 3.2.**
  - **USB 2.0** more than adequate for keyboard & mouse; external USB HD for image backup should use at least **USB 3.0**
  - **USB 3.0:** 10 x speed of USB 2.0; **USB 3.1 = 2 x USB 3.0;** **USB 3.2 = 2 x USB 3.1.** USB 3.0 ports may be a different color (USB 2.0: Black; USB 3.0: Blue; USB 3.1: Red) or have "SS" label.
  - **Devices will work with different-level USB ports at the speed of the slowest protocol supported by both.**



# Ethernet & WiFi

- All desktop & laptop computers these days should support both wired Ethernet connection and WiFi connection for shared access to the Internet and other computer devices in your house.
  - Wired Ethernet is more reliable – today should be 1 Gbps rather than older 100/10 Mbps. May not be practical in older residence not wired for Ethernet unless router in same room as computer. Some older Ethernet cables may not work at 1 Gbps speeds (falling back to 100 Mbps).
  - WiFi continues to evolve in speed having gone through a progression of 802.11 standards named a, b, g, n, ac, ax. To simplify names, "ac" is now called WiFi-5, and "ax" WiFi-6. Devices frequently support more than one protocol, but for a WiFi device to talk with a WiFi router, they must both share a common protocol. As you get devices that support a faster protocol, at some point your need to upgrade your WiFi Router, and to get the benefit of devices that support a faster protocol.



# Display Monitor Interfaces

- **Not uncommon for a desktop computer to have two different monitor interfaces**

- **Two most common: HDMI, VGA; Others: DVI, Displayport.**

- **people typically choose one of those interfaces that is supported by their monitor; but there is a good chance the desktop will actually support two monitors running at the same time if you have monitors that can utilize both interfaces. Windows supports this as an extended desktop display with one monitor logically to the left of the other.**

- **Laptops generally have only one monitor interface in addition the the built-in monitor. An external monitor can be used for a largerr screen, but can also be used to interface to a digital projector.**





## Operating Systems (Windows10, Windows11, Linux, iOS...)

- **Makes writing applications possible.**
  - Handling wide varieties of hardware, storage drives, printers, graphic displays, and other I/O devices is very difficult. Even drawing a straight line of arbitrary width on a monitor is non-trivial, text characters of arbitrary size and font and images more difficult.
  - Running multiple applications at the same time impossible without some arbiter to protect applications from each other and allocate resources (processors, RAM, devices, files)
  - Operating system: a large collection of inter-related programs that make the hardware appear simpler to applications by providing common services with standard interfaces, allocating resources, providing file systems on storage devices to keep track of directories and files, and standard interfaces to access and request resources.

Some parts of the hardware would be very hazardous to allow direct access by applications: Allowing arbitrary apps direct access to control a storage drive means that a serious bug in that one app could easily destroy access to all data on the storage device! If an application program is allowed to change arbitrary parts of RAM storage that don't belong to it, it can cause failures in other applications or in the Operating System.

# How Do I Identify What I Have?

- **Save the identifying information from the original computer box – should include manufacturer, product and/or model number, serial number.**
- **Computers no longer come with printed User Guides or Recovery DVD's.**
  - **If there is no User Guide on the storage drive, search for a PDF user guide for the model number on the Internet and download it and make a copy on external media of some kind.**
  - **Use Windows to create a Recovery media/ Also good to create an image copy of your storage drive with some free utility like Macrium Reflect on an external USB drive and rely on the bootable Macrium Reflect Recovery media.**

# How Do I Identify What I Have?

- **There should also be a physical label somewhere on the computer that identifies the product and/or model number**
  - It may be difficult to find or hard to read because of low contrast – smartphone camera may be useful to enlarge
  - On desktop it usually is on back or bottom; On laptop, it may be on the bottom, inside by keyboard, or hidden under the battery.
    - On my Lenovo laptop I find: product: 20H5-0047US; Manufacturer: Lenovo; Model: E570; Series: Thinkpad. The product designation in this case is more specific than the model, as there are several options for model E570. Looking up the product identifies the specific hardware options as: 15.6" 16:9 1920x1080 display, Intel dual-core i7-7500U 2.70 GHz processor, 8 GiB DDR4 SDRAM RAM, 256 GiB SSD, Windows 10 Pro Operating System.
    - The User Guide is usually written for a specific model, or in some cases covers several closely-related models. For my laptop a search for "Lenovo E570" located the User Guide.

# How Everything Works Together

- At power-up, the processor is primed with instructions, that contain a "boot" program, which runs to find and load a "loader" program from the storage drive into RAM. That in turn runs to load the Operating System from the storage drive into RAM memory and starts running the Operating System.
- Once the Operating System is in place, its programs control the hardware and loads and runs application programs at the user's request or as scheduled, assigns them RAM memory and processors and provides supporting services for the applications.
- When a processor is executing a program, it reads instructions from memory and performs the operation requested by the instruction. There are many different instruction types, but basically each instruction tells the processor what action to perform, where to find the value(s) needed (either in the processor itself or in RAM), and where to store the result.
- Each instruction type requires a certain number of consecutive bytes in RAM and possibly several clock cycles to execute. Normally the first byte of the next instruction is the byte just after the current instruction, but some instructions (branches or jumps) are able to test a result and decide whether to go to a different RAM address for the next instruction. Certain "events" or requests for system services can also interrupt the normal sequence of instructions and return the control of a processor to programs that are part of the Operating System.
- It is the ability of a processor to make simple "decisions" based on data values and do highly repetitive actions with precision and speed with many different data values, that give it its power.

Questions?

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