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Chapter 1

Introduction

In this chapter

- Definition of informatics
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By definition, **informatics** is the science of computer informational systems. It is a broad academic field, encompassing computer science, the study of human-computer interaction, information science, information technology and algorithms. Informatics studies the structure, algorithms, behavior, and interactions of natural and artificial systems which store, process, access, and communicate information. Based on the above, informatics should never be confused with computer programming, which is a process that leads from an original formulation of a computing problem to executable computer programs.

Etymology

In 1957 the German computer scientist Karl Steinbuch coined the word "Informatik" by publishing a paper called "Informatik: Automatische Informationsverarbeitung" ("Informatics: Automatic Information Processing"). The English term Informatics is sometimes understood as meaning the same as computer science. The German word "Informatik" is usually translated to English as computer science.

The French term "informatique" was coined in 1962 by Philippe Dreyfus together with various translations – "informatics" (English), also proposed independently and simultaneously by Walter F. Bauer and associates who co-founded Informatics Inc., and "informatica" (Italian, Spanish, Romanian, Portuguese, Dutch), referring to the application of computers to store and process information.

The term was coined as a combination of "information" and "automatic" to describe the science of automating information interactions. The morphology – informat-ion + -ics – uses "the accepted form

for names of sciences, as conics, linguistics, optics, or matters of practice, as economics, politics, tactics", and so, linguistically, the meaning extends easily to encompass both the science of information and the practice of information processing.

A practitioner of informatics may be called an "informatician" or an "informaticist".

Definitions

Data – values of qualitative or quantitative variables, belonging to a set of items. Data can be measured, collected, reported and then later analyzed. For example, measuring the height of individuals in sample group of people is collecting the process of collecting the quantitative variable *height*. Sending the set of measurements to a statistician is the process of reporting the data. The statistician calculating averages, standard deviations and such is the process of analyzing the data. The process of representing data can be achieved by creating graphs and charts based on the measurements.

Quantitative data can be usually expressed in absolute values and can be accompanied by a unit of measurement. For instance, height measured in centimeters, the resistance of a resistor measured in kiloohms and the speed of travel measured in kilometers-per-hour are all quantitative data.

Qualitative data cannot be expressed in absolute values and is often the result of more subjective evaluation or measurement process. For example, saying that a flower is beautiful is a subjective, qualitative observation related to the value of "beauty" of a flower. Since "beauty is in the eyes of the beholder", the evaluation is both subjective and also cannot be expressed in an absolute value.

Information – a sequence of symbols that can be interpreted as a message. It can be recorded as signs or transmitted as signals. Information is sequences of data and at its most fundamental, is any propagation of cause and effect within a system. The role of information is to resolve uncertainty, to answer a question.

Information system – an ensemble of elements involved in the process of collecting, transmitting and processing information. This can be a network of people, computers, other electronic devices or all these in a mixed system.

The four main components of any informational systems are:

- ✓ Transmitter – [compulsory] the element that is transmitting the information
- ✓ Receiver – [compulsory] the element that is receiving the information
- ✓ Channel – [compulsory] the medium through which the information is being transmitted
- ✓ Information – [optional] sequences of data being transmitted, also called message

Any information system needs to have at least three components. If the element that sends the message is missing, then the system is not transmitting information, therefore is not an informational system. If the system is transmitting information, but there is no one listening then the information is

lost, and therefore still no transfer of knowledge is taking place. Moreover, the transfer of information needs to be done over a transfer medium.

In any information system it is important that both the transmitter and receiver are able to "understand" or decode the message. If the message sent by the transmitter is not understood by the receiver, then no actual information exchange is taking place. The receiver should be able to interpret, react to or store the message being transmitted. For example, two foreigners who do not speak the same language, although can talk to each other, no information exchange will take place. No information exchange might also happen if the two communication sides do understand each other, however no information is being transmitted at a given point. This is called silence of transmission.

Figure 1.1. Computer network

Figure 1.2. Human-computer interaction

In informatics the two major information systems are computer networks (Figure 1.1) and the human-computer interaction (Figure 1.2).

In a computer network, the server can be both the transmitter, when it is serving information to a request and the receiver, when it is receiving request from any computer on the network. The same principle applies to any device connected to the network. When both communicating parties can be both transmitters and receivers simultaneously, the communication is called full duplex. Half duplex communication is defined as both communication parties being able to be both transmitters and receivers but can only take one role at a time. In a simplex communication protocol, there are well defined transmitters and receivers, and they cannot change roles.

In the case of the computer network, the transmission medium can be a coaxial or UTP cable, a fiber optics cable or radio waves, in case of wireless transmissions. In the case of the human-computer interaction, the transmission media are the wires running from any input device (keyboard, mouse, touchscreen, etc.) to the component on the motherboard that processes the given signals.

Computer – an informational system that can be programmed to carry out a set of arithmetic or logical operations. In other words, it is an electronic device that manipulates information or data with the ability to store, retrieve, and process data. Since a sequence of operations can be readily changed, the computer can solve more than one kind of problem (i.e.: you can both solve complex equations using dedicated programs, model electronic circuits, as well as play games).

Chapter 2

Hardware Concepts

In this chapter

- Personal computers
- Desktop PCs, laptop PCs, embedded devices
- Architecture of a PC
- How to build your own PC from scratch:
  - Description of hardware components
  - Component selection and compatibility

Computer hardware is defined as a collection of physical elements that constitutes a computer system. Basically, everything that is around a computer, which is tangible, is referred as hardware. These can vary in shape and size and usually vary by functionality. They include, but are not limited to the input devices of the computer (keyboard, mouse, touch screen, etc.), the output devices (monitors, speakers, printers, and such) and the main case of the computer to which all these devices, called peripherals connect, and which does the actual computing. Inside the case more components can be found, which will be detailed later.

Generally, **personal computers** vary in shapes and sizes, however, based on their portability, two main categories are distinguished. Stationary computers, often called desktop computers, have multiple computers which are installed on a desk top (hence the name), while laptop computers are the portable version of these. The main differences between these two are their size, performances and the way they are powered. While desktop computers are bulkier, they are easier to upgrade by switching older components with new generation ones, and due to better cooling policies, have usually higher performances than laptop computers. Stationary computers are powered directly from mains electricity and therefore cannot run without a direct connection to a power source. On the other hand, laptop computers are equipped with battery packs which can be recharged and can power the computer for a limited time without the need of connection to mains power. The time it takes the battery of the laptop to go from a full charge to a full discharge is called *autonomy* and is measured in

hours. Autonomy can vary greatly with the type of battery used, its size, as well as the workload of the laptop.

Personal computers come in two main styles: PC and Mac. Both are fully functional, but they have a different look and feel, and many people prefer one or the other.

PCs began with the original IBM PC that was introduced in 1981. Other companies began creating similar computers, which were called IBM PC Compatible (often shortened to PC). Today, this is the most common type of personal computer, and it typically includes the Microsoft Windows operating system.

Figure 2.1. A Serioux Advantage V2 desktop PC

Figure 2.2. A Toshiba Satellite laptop PC

Figure 2.3. An Apple Mac Pro desktop computer

Figure 2.4. An Apple Macbook Air laptop computer

The Macintosh computer (**Mac –** for short) was introduced in 1984, and it was the first widely sold personal computer with a graphical user interface, or GUI. All Macs are made by one company, Apple Inc., and they almost always use the Mac OS X operating system. Both PCs and Macs come in desktop and laptop form, as presented in the figures above.

More portable, but lower performance variant of the laptop computers are **tablets** and **smartphones**. Tablet computers (or tablet) are handheld computers that instead of a keyboard or touchpad use a touch-sensitive screen for typing and navigation.

Tablets can't necessarily do anything a laptop or a desktop can do, so you may still want a desktop or laptop to run programs or create documents. But if you just want to be able to play low to medium-end games, check email and social media, or stream music and videos, a tablet may be a good computer replacement. Smartphones, tablets, and other smart devices are generally referred to as **embedded devices** in electronics.

On the other hand, **servers** are a more powerful, not-at-all portable variants of desktop computer. Servers are computers that serve up information to other computers on a network. Many businesses have file servers where employees can use to store and share files. A server can look like a regular desktop computer, or it can be much larger, however servers which function in average to large networks are regularly very powerful computer configurations or clusters of such computer configurations.

Servers also play an important role in making the Internet work: They are where webpages are stored. When you use your browser to click a link, a web server delivers the page you requested.

General architecture

The template for all modern computers is **the Von Neumann architecture** (Figure 2.5), detailed in a 1945 paper by Hungarian mathematician John von Neumann. This describes a design architecture for an electronic digital computer with subdivisions of a processing unit consisting of an arithmetic logic unit (ALU) and processor registers, a control unit containing an instruction register and program counter, a memory to store both data and instructions, external mass storage, and input and output devices The meaning of the term has evolved to mean a stored-program computer in which an instruction fetch and a data operation cannot occur at the same time because they share a common bus. This is referred to as the Von Neumann bottleneck and often limits the performance of the system.

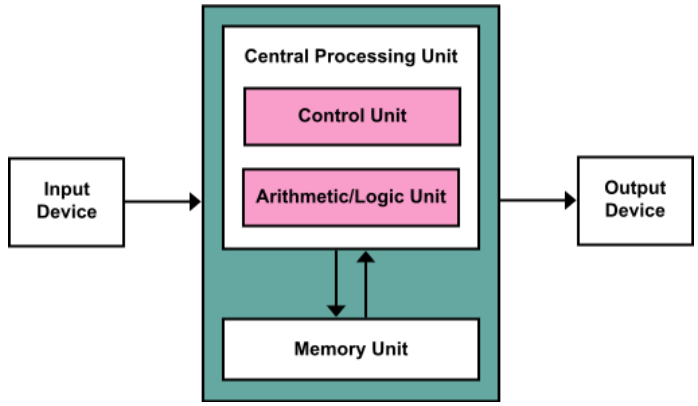


Figure 2.5. Simplified von Neumann architecture scheme

An exploded view of a general desktop computer is presented in Figure 2.6. Here the parts can be identified as presented in the following table.

Part number	Part name
1	Monitor
2	Motherboard
3	Central processing unit (CPU)
4	Random access memory (RAM)
5	Expansion cards (video card, USB hubs, etc.)
6	Power source

7	Optical unit (CD/DVD/Blu-ray)
8	Hard disk (HDD)
9	Keyboard
10	Mouse

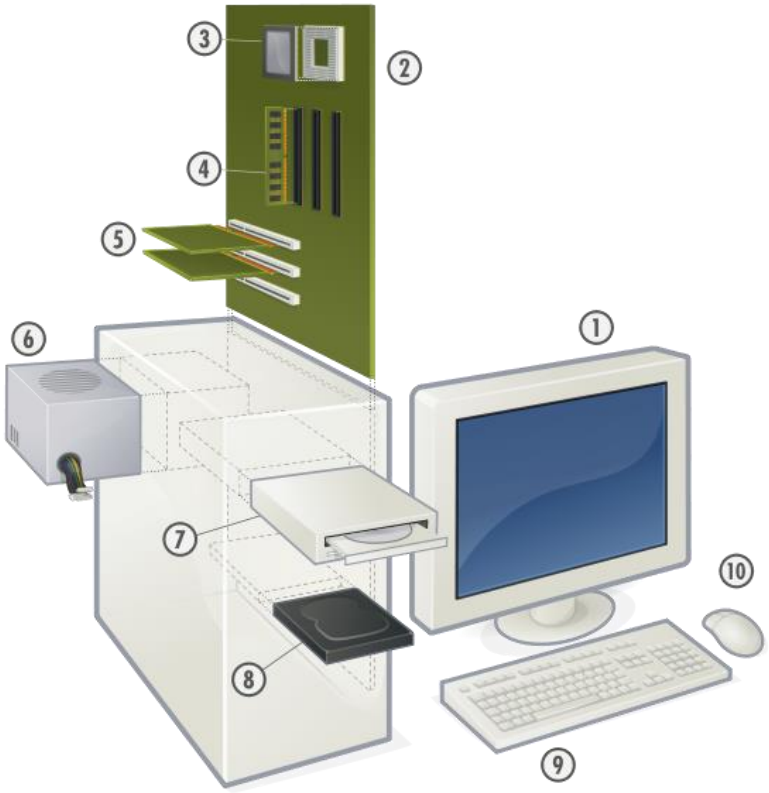


Figure 2.6. Exploded view of a general desktop computer

In the following pages, each component will be explored in detail, to aid in better understanding the functionality of each and how components interact with each other to build one integrated computation system.

Computer case

The computer case is the metal and plastic box that contains the main components of the computer. It houses the motherboard, central processing unit (CPU), power supply, and more.

Computer cases come in different shapes and sizes. A desktop case lies flat on a desk, and the monitor usually sits on top of it. A tower case is tall and sits next to the monitor or on the floor. The front of the case usually has an on/off switch and one or more optical drives.

Figure 2.7. Tower case vs. desktop case vs. caseless PC

Most of the personal computers you can purchase today include tower cases rather than desktop cases; however, some computers are being made with all of the internal components built into the monitor (caseless PCs), which eliminates the need for a tower, the most popular and widely used these being Macs manufactured by Apple.

Motherboard

A motherboard (sometimes alternatively known as the mainboard, system board, planar board, or logic board, or colloquially, a mobo) is the main printed circuit board (PCB) found in computers and other expandable systems. It holds and ensures communication between the crucial electronic components of a system, such as the central processing unit (CPU) and memory and provides connectors for other peripherals.

A motherboard provides the electrical connections by which the other components of the system communicate. A typical desktop computer has its microprocessor, main memory, and other essential components connected to the motherboard. Other components such as external storage, controllers for video display and sound, and peripheral devices may be attached to the motherboard as plug-in cards or via cables, in modern computers it is increasingly common to integrate some of these peripherals into the motherboard itself.

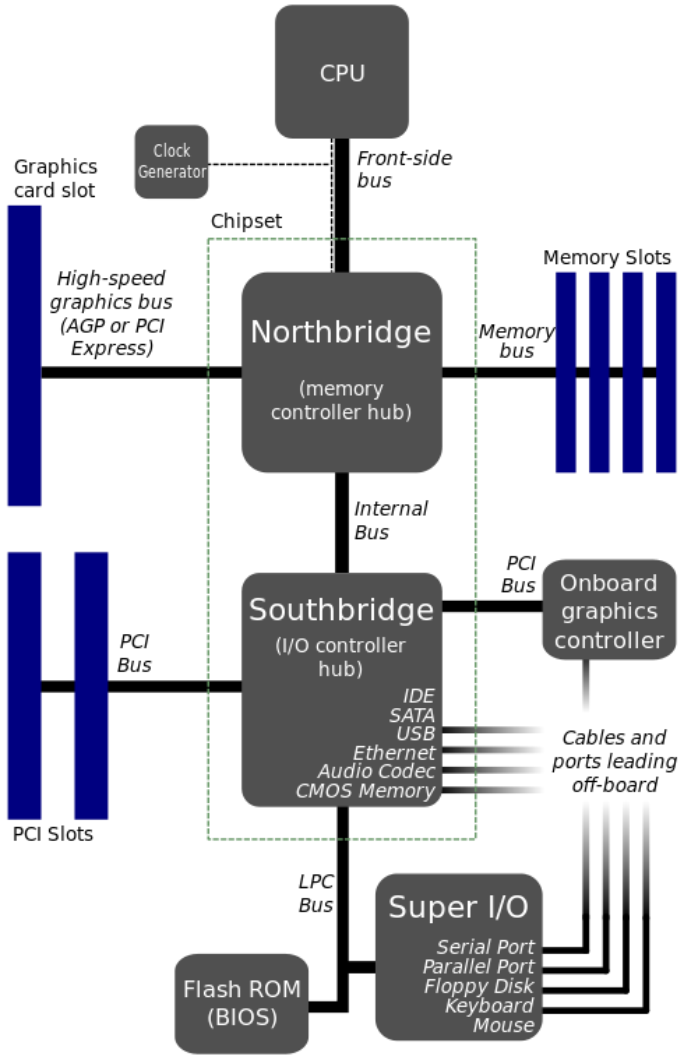


Figure 2.8. Block diagram of a motherboard

An important component of a motherboard is the microprocessor's supporting chipset, which provides the supporting interfaces between the CPU and the various buses and external components. This chipset determines, to an extent, the features and capabilities of the motherboard.

The block diagram of a modern motherboard can be seen in Figure 2.8. As can be seen, every motherboard is divided into two main functional blocks: the Northbridge and the Southbridge.

The **Northbridge**, also called the memory controller hub or host bridge, is usually a controller chip that is directly connected to the CPU and RAM memory, as well as most expansion slots. Therefore, the Northbridge is responsible for the tasks that require the highest performance. Some Northbridges also contain integrated video controllers, also known as a Graphics and Memory Controller Hub (GMCH) in

Intel systems. Because different processors and RAM require different signaling, a given Northbridge will typically work with only one or two classes of CPUs and generally only one type of RAM.

The **Southbridge** typically implements the slower capabilities of the motherboard. It handles all of a computer's I/O functions, such as USB, audio, serial, the system BIOS, the ISA bus, the interrupt controller and the IDE channels.

Due to the push for system-on-a-chip (SoC) processors, modern devices increasingly have the Northbridge integrated into the CPU die itself (ex.: Intel's Sandy Bridge and AMD's Fusion processors, both released in 2011). The Southbridge became redundant and it was replaced by the Platform Controller Hub (PCH) architecture introduced with the Intel 5 Series chipset in 2008. All Southbridge features and remaining I/O functions are managed by the PCH which is directly connected to the CPU via the Direct Media Interface (DMI)

The two main controller chips of the Northbridge and Southbridge (excluding all other connectors and slots) are also referred to as the **Chipset** of the Motherboard.

It is beyond the scope of this book to analyze every technical aspect and characteristic of a motherboard. However, next the most important characteristics that the reader needs to know about when shopping for a motherboard for a custom-built PC will be presented. To illustrate this, the full technical specifications, as offered by most online retailers, of a Gigabyte motherboard are presented in Table 2.1.

Figure 2.9. Gigabye GA-Z97-SOC motherboard

Table 2.1. Gigabyte GZ-Z97-SOC Motherboard technical specifications (www.newegg.com)

Model	
Brand	GIGABYTE
Model	GA-Z97X-SOC Force
Supported CPU	
CPU Socket Type	LGA 1150
CPU Type	Core i7 / i5 / i3 / Pentium / Celeron (LGA1150)
Chipsets	
Chipset	Intel Z97
Memory	
Number of Memory Slots	4×240pin
Memory Standard	DDR3 3300(OC)/3200(OC)/3100(OC)/3000(OC)/2933(OC)/2800(OC)/2666(OC)/2600(OC)/2500(OC)/2400(OC)/2200(OC)/2133(OC)/2000(OC)/1866(OC)/1800(OC)/1600/1333
Maximum Memory Supported	32GB
Channel Supported	Dual Channel
Expansion Slots	
PCI Express 3.0 x16	1 (x16) 1 (x8) 1 (x4)
PCI Express x16	1 (x4)
PCI Express x1	1 x PCI Express x1
PCI Slots	2 x PCI Slots
Storage Devices	
SATA 6Gb/s	6 x SATA 6Gb/s
SATA Express	1 x SATA Express

SATA RAID	0/1/5/10
Onboard Video	
Onboard Video Chipset	Supported only by CPU with integrated graphic
Onboard Audio	
Audio Chipset	Realtek ALC1150
Audio Channels	7.1 Channels
Onboard LAN	
LAN Chipset	Qualcomm Atheros Killer E2201
Max LAN Speed	10/100/1000Mbps
Rear Panel Ports	
PS/2	1 x PS/2 keyboard/mouse port
Video Ports	1 x DVI-D 1 x VGA 1 x DisplayPort
HDMI	1 x HDMI
RJ45	1 x RJ45
USB 3.0	4 x USB 3.0
USB 1.1/2.0	4 x USB 2.0
S/PDIF Out	1 x Optical
Internal I/O Connectors	
Onboard USB	2 x USB 3.0 + 4 x USB 2.0
Other Connectors	1 x 24-pin ATX main power connector 1 x 8-pin ATX 12V power connector 1 x 4-pin ATX 12V power connector 1 x OC PEG power connector 1 x CPU fan header 1 x water cooling fan header (CPU_OPT) 6 x system fan headers 1 x front panel header 1 x front panel audio header 1 x S/PDIF Out header

	1 x serial port header 1 x Clear CMOS jumper 1 x power button 1 x reset button 1 x Clear CMOS button 1 x Gear button 1 x OC Turbo button 1 x OC Tag button 1 x OC Trigger switch 1 x CPU BCLK Down button 1 x CPU BCLK Up button 1 x CPU Ratio Down button 1 x CPU Ratio Up button 1 x Memory Safe button 1 x Settings Lock button 1 x Direct to BIOS button 1 x OC DIMM switch 1 x OC PCIe switch 1 x OC Ignition button 1 x Clear Battery button 2 x BIOS switches 1 x onboard voltage measurement module
Physical Spec	
Form Factor	ATX
Dimensions (W x L)	12.0" x 9.6"
Power Pin	24 Pin
Features	
Features	Supports 4th and 5th Generation Intel Core processors Premium 4-way CrossFire support with OC Brace Precise digital CPU power design SATA Express support for 10 Gb/s data transfer Exclusive GIGABYTE OC Features Killer E2200 gaming networking 2x copper PCB design Realtek ALC1150 115dB SNR HD Audio with Built-in rear audio amplifier New Heatsink design with 8 onboard fan connectors Long lifespan Durable Black Solid caps APP Center including EasyTune and Cloud Station utilities GIGABYTE UEFI DualBIOS

At first glance, such a large table, with so many technicalities might seem frightening and as a result put off most users from the adventures of custom computer building. But fear not, most are not that difficult to grasp, you do not even need to understand each and every one, and a couple are just irrelevant things that the manufacturer likes to "brag" with.

First, there are the **manufacturer** name and the **name** of the motherboard itself, which may seem irrelevant, however, once you narrowed down your decision to a few choices, it is always a good idea to hit up the site of a few well known electronics retailers and read customer reviews, or at least see the customer satisfaction score. You may be surprised to find that one of your choices suffers from overheating problems, for example, while another one has audio problems. Of course, this is rarely the case, but being well informed before buying can still save you time and money.

The **CPU socket** actually represented the type of connector mounted on the motherboard, in which you can plug in your CPU. This is a vital piece of information since the CPU you choose must have the same socket (a.k.a. must be compatible with the motherboard). Most manufacturers also list the compatible CPUs and bear in mind that your choice is limited to these and *only* these CPUs. If you prefer a CPU type that is not listed here, you *must* choose another motherboard.

The next relevant pieces of information are related to **memory**. Specifically, the number of memory slots, the type of memory supported and supported memory speeds (in MHz). The number of slots is relevant so as to inform you on how to distribute your memory. For instance, if you have 4 memory slots and want to install 16 GB of RAM, you can buy 4 pieces of 4 GB RAM memory cards. However, if you have only 2 slots, you will need to buy 2 pieces of 8 GB RAM memory cards. It is good to know that higher capacity memory cards are usually a little bit more expensive.

Also, a relevant piece of information is the maximum memory that you can install. The general rule of thumb is that the more, the better. Based on the main activity of the PC your building, you might not need to install the maximum accepted memory (maybe ever) but take into consideration that a well maintained system might last you up to 5-7 or even 10 years, over which you may want to upgrade. Currently, general systems for office use work well with 8 GB of memory. Higher usage systems, like those used in engineering with specialized computer aided design (CAD) tools might require from 12 to 16 GB, while the most memory hungry applications are high end games.

Expansion slots give you the opportunity to add extra functionality to the motherboard. Most common usage for these is to install dedicated video cards, sound cards, USB cards and other specialized data acquisition cards for engineering. Take a note of what expansion card slots are available because any card that you want to install will have to be compatible with the available slots. The speed of these slots is from highest to lowest: PCI Express 3.0 → PCI Express → (simple) PCI

Next, the **storage device** (a.k.a. hard disk drive and optical drive) **connectors**. The industry standard connector on all modern motherboards is the SATA connector, which replaced the old parallel ATA connector. Being the only connector currently widely used for connecting storage devices to motherboards, all you need to know is that the 6 GB/s SATA is faster than the Express version. Make sure that if your motherboard has the faster version, so does the hard disk that you buy. The

connectors are compatible for all versions, however, the transfer limit will always be imposed by the slowest device.

Most motherboards come with **onboard video** and **audio** options. These allow to connect at least one monitor and one pair of speakers/headphones, without the need of expansion cards. While for connecting multiple monitors or for high-end graphics a dedicated video card is necessary, for a low to medium end system, such as those used for productivity and office tasks, the onboard video provided will do just fine.

On the audio part, most motherboards (like the one presented) are able to connect even to advanced audio systems and as a result, using a dedicated audio card is only needed for music fanatics or people actually working in the music industry.

When it comes to networking, the main characteristic of the onboard LAN connection (also called a NIC – network interface controller) is the maximum transfer speed. With internet speeds getting ever higher, it is a good idea to get a card that supports Gigabit speed – that is it has 1000 Mbps (or 1 Gbps) in its speed rating.

Video ports are also of major importance if you want to connect directly to the onboard video card. Always make sure that the motherboard and that the monitor you intend to buy have the same type of connector. Otherwise, you may end up buying sometimes expensive adapters and sacrificing picture quality.

A two-in-one solution for both video and audio is the **HDMI connector**, which allows the connection of both picture and sound through the same cable. Look for this type of connector if you want to link your system to a smart TV through a single cable.

The **RJ45** connector refers to the industry standard connector used to connect to the internet via a wired connection. If the motherboard has onboard LAN, it will definitely have an RJ45 connector.

The last connector type you should look for are the **USB connectors**. Bear in mind that USB 3.0 is faster than older generation 2.0 connectors. However, USB 3.0 is only used for data transfer to USB flash (pen) drives, external hard drives, etc. USB 2.0 is just fine for connecting peripheral devices (keyboards, mice, printers, etc.).

Finally, in the **other connectors** section, you should always check that the power connectors of the motherboard are compatible with the connectors offered by the power supply you intend to buy.

And with that, you know everything there is to when buying a motherboard for a custom-built PC. Now that wasn't so hard, was it?

BIOS and UEFI

Besides its physical role of connecting components amongst each other, the motherboard also has the vital role of storing and executing the Basic Input/Output System (BIOS). The BIOS is basically a piece of software code (often referred to as firmware) that is stored in a non-volatile memory of the computer and is basically the first program to execute when your computer is powered on.

The most important role of the BIOS is to initialize and test the system hardware components and to start the boot loader which then loads the operating system. In addition to this it also offers a layer of abstraction for the hardware, a consistent way for application programs and operating systems to interact with peripheral hardware in particular.

Every BIOS version is specifically designed to work with a given computer or motherboard model, because it is heavily hardware dependent, given that it needs to interface with the various devices that make up the complementary chipset.

In recent computers, the BIOS is replaced by the UEFI (Unified Extensible Firmware Interface), which extends the functionalities of the BIOS. The UEFI is a specification that defines a software interface between an operating system and platform firmware. UEFI can support remote diagnostics and repair of computers, even without another operating system.

The boot order, boot priority or boot sequence are always defined using the BIOS/UEFI. Via this setting the user can define where and in what order devices are searched for a bootable application, to which the BIOS/UEFI can hand over control. Devices that can store bootable applications are called boot devices, and these can be a hard disk drive, optical media (CDs, DVDs), flash drivers or network interface controllers (which don't actually store data, but can offer access to it via a network).

The boot priority is especially important when you want to install or reinstall your operating system or are having difficulties booting starting your current operating system. In case your system does not boot from the desired location, check and modify as necessary the boot settings of your system.

Most systems also offer a quick boot menu, which you can access by pressing a designated key (usually F12 or TAB) on your keyboard during the startup process. This key is shown on the interface that displays on startup. This boot menu can be used to boot from a desired media one time, after which the boot order is respected by the BIOS/UEFI on the next startup.

For a faster startup of your system, you should always set your hard disk drive that contains the operating system as your primary boot device. This way, you avoid the time it takes the computer to look for bootloaders on the optical media and/or flash drives that might be present in your computer.

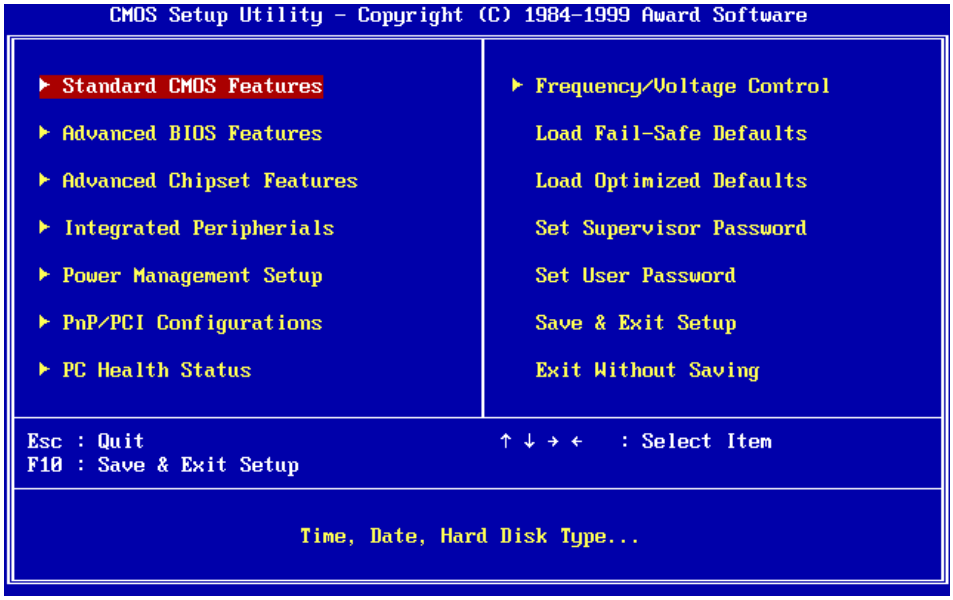


Figure 2.10. Typical BIOS graphical user interface with menu

Figure 2.11. UEFI graphical user interfaces

Access to the BIOS/UEFI menu is usually done by pressing a special key (usually F2, Delete, Esc, but can be other) during the computer startup process for computers running Windows 7 or later. If you are running Windows 8 or later on a system with UEFI, especially with solid state drives, this method does not work. In this case you need to perform one of the following to perform a reboot into the UEFI menu:

- ✓ Under "PC Settings" go to "General" and under "Advanced startup" select "Restart now"
- ✓ Hold down the Shift key while clicking "Restart" in the "Power" menu
- ✓ Run the following command line from a command shell: "`shutdown /r /o`"

Troubleshooting

As mentioned before, during system startup the BIOS/UEFI does a system test to make sure everything is functioning according to their intended purpose, before handing over the control to the operating system. If this self-test fails for whatever reason, the computer may not start the operating system and instead will report the error to the user.

The most obvious way of reporting an error is displaying a message stating the encountered problem on the screen. However, sometimes a display may not be connected to the computer or there might be a problem with the graphics, preventing the BIOS/UEFI to display messages to the user. For this reason, the computer also has two other mechanisms for notifying the user of the error that occurred: by using a number of diagnostic LEDs on the back pane and via a series of beep codes.

Diagnostic LEDs are usually found on the back pane of a computer and consist of a series of LEDs, like those in Figure 2.12, that light up in different configurations if an error occurred. These might not light up at all in case of no error or might light green if the system test passed. They may only light up if the system test failed or might change their color if so.

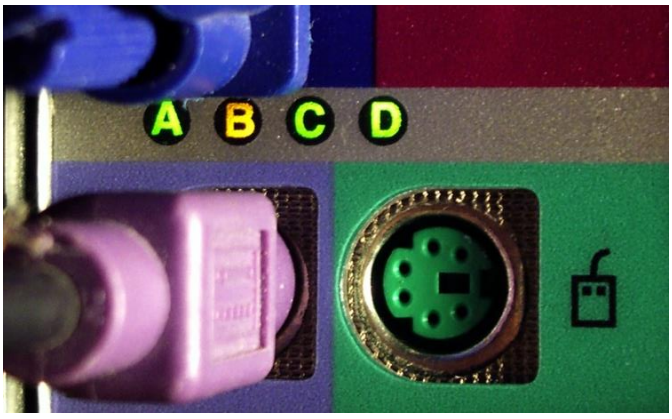


Figure 2.12. Diagnostic LEDs on the back pane of a PC

There is no one standard, each manufacturer can define its own, and even with the same manufacturer, the codes might differ from one model to the other. However, these codes and their meanings are always defined in the Service Manual of the computer, so a quick search on the Internet (we are assuming that you have long lost the service manual that came with your computer) should always provide you with the necessary explanations.

In Figure 2.12 an excerpt from a Dell Optiplex 990 desktop computer Service Manual is shown. The figure explains the error code represented by the first two diagnostic LEDs off and the next two on means that the RAM memory modules are detected in their respective slots but cannot be powered. Then, steps to solve the issue are provided.

Assembling/disassembling a computer is not that hard and should be a fairly straightforward task. However, before opening the case always shut down/power off the computer, put all power buttons in the off position and disconnect all power cables from the plugs and from the case. Moreover, you should wait at least 30 seconds before handling any components as some capacitors may take time to discharge.

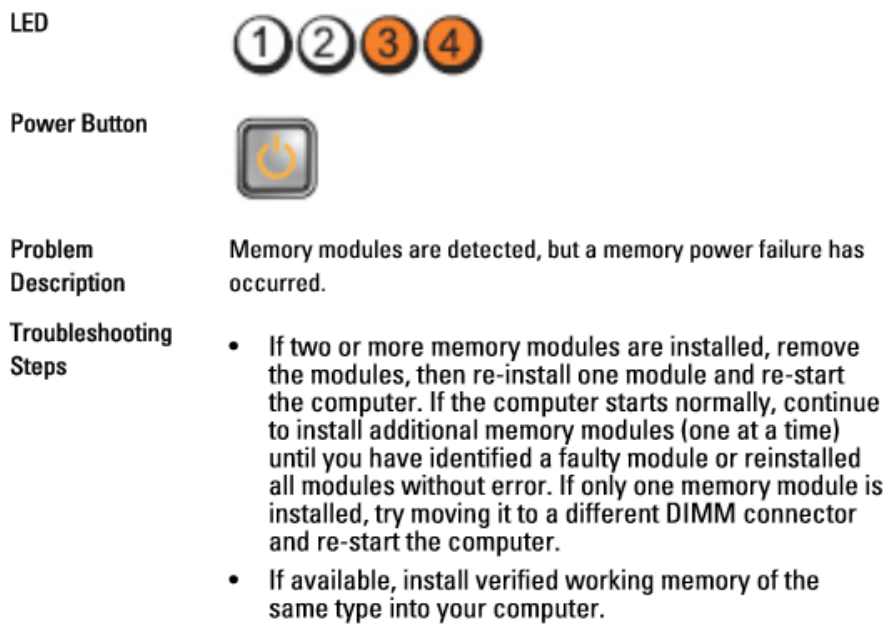


Figure 2.13. Example of diagnostics LED code

Another alternative way of communicating errors to the user are **beep codes**. During the startup process if errors are detected the computer will beep a sequence of short or long sounds, which also represent an error code. As show in Figure 2.14, the interpretation of these can also be found in the Service Manual.

Code	1-1-2
Cause	Microprocessor register failure
Code	1-1-3
Cause	NVRAM
Code	1-1-4
Cause	ROM BIOS checksum failure
Code	1-2-1
Cause	Programmable interval timer

Figure 2.14. Examples of beep diagnostic codes

Central Processing Unit (CPU)

Remember 10 pages ago, when we set off to build our own computer? We took the long way around, didn't we? Well, it's time to get back on the main road and head towards our goal again.

The central processing unit (CPU) is practically the "brain" of the computer. Even though it cannot function without a motherboard and other components it connects to, nor can other components function without the CPU (seen in Figure 2.15).

Figure 2.15. A CPU: Intel Core i5 750 (top and bottom view)

By definition the CPU is the electronic circuitry within a computer that carries out the instructions of a computer program by performing the basic arithmetic, logical, control and input/output (I/O)

operations specified by the instructions. The term has been used in the computer industry at least since the early 1960s. Traditionally, the term CPU refers to a processor, more specifically to its processing unit and control unit (CU), distinguishing these core elements of a computer from external components such as main memory and I/O circuitry.

Table 2.2. Intel Core i7-4790K Haswell specifications (www.newegg.com)

Model	
Brand	Intel
Processors Type	Desktop
Series	Core i7
Name	Core i7-4790K
Model	BX80646I74790K
CPU Socket Type	
CPU Socket Type	LGA 1150
Details	
Core Name	Devil's Canyon
# of Cores	Quad-Core
# of Threads	8
Operating Frequency	4.0GHz
Max Turbo Frequency	4.4GHz
L2 Cache	4 x 256KB
L3 Cache	8MB
Manufacturing Tech	22nm
64-Bit Support	Yes
Hyper-Threading Support	Yes
Virtualization Technology Support	Yes
Integrated Graphics	Intel HD Graphics 4600
Graphics Base Frequency	350 MHz
Graphics Max Dynamic Frequency	1.25 GHz

PCI Express Revision	3.0
Max Number of PCI Express Lanes	16
Cooling Device	Heatsink and fan included

Fortunately, Table 2.2, which presents the technical specifications of CPUs as you would find them on a retailer's website isn't as long as the one for the motherboard. However, here to, there are key parameters you should always check before buying a CPU and some information that can be totally neglected.

The name and the brand of the processor are important only if you are a fan of one particular brand. Some prefer Intel, others prefer AMD based on their previous experiences, but there is no real winner here. Well, actually there is, Intel, who has about 70% percent of the market share, however, this should never impact your decision, because it does not impact performance.

The model name of the CPU may be important if the motherboard specifically states that it is compatible with such a CPU. If not, the most important factor when pairing motherboard to CPU is the CPU socket type. We already talked about this when discussing the motherboard, remember? Yes, they should definitely be the same both on the CPU as well as on the motherboard.

The core name is of no importance at all, it is just something with which marketing people at the manufacturer's HQ can play around giving them code names such as Vishera, Haswell-E or Devil's Canyon (Uuuh! Fearsome!)

What you should pay attention is the number of cores. This will mainly determine the power of your processor. Dual-core means two cores, quad-core means four, octa-core means eight, etc. This is basically a quantification of how many independent tasks can a processor perform in parallel.

The "# of threads" (number of threads) is the number of tasks the processor can execute (almost, but not quite) in parallel. This is sometimes expressed as threads per core. This allows a single physical processor core to act like multiple logical cores. Our example processor has four cores and eight threads and simple math leads us to two threads per core. General rule of thumb for both cores and threads per core: the higher, the better.

The operating frequency is basically the clock rate at which your processor runs. What is clock rate? Take a year of digital electronics, come back, and I'll explain, at which point you won't need me because you had already found out. Let's just agree that it the speed at which your processor cores run, and like running, the faster, the better.

If the clock frequency is like running, the maximum turbo frequency is like a short sprint for the CPU. Just like any jogger, to keep itself cool (electronics don't like heat), the CPU prefers to run at its

designed frequency (or at a lower one), however, should the need arise (an application requires instant results for large amounts of data) the CPU can go for a short sprint, when it increases its clock frequency to the maximum turbo frequency. This increase can only be maintained for short bursts of time (until the heat management algorithm determines that it's close to overheating), after which the CPU would return to its normal operating frequency.

L2 and L3 cache sizes are the size of memories close (built in) to the CPU. The more you have, the less the CPU will need to write to the RAM memory, so operation speed will increase.

The manufacturing technology is supposed to define the size of the transistors used in the CPU, however, this is a marketing lie. A 22 nm processor does not really use 22 nm transistors. However, on a general note, the smaller this number, the newer the manufacturing technology of the processor.

Every processor manufactured currently (for computers, at least) supports a 64-bit architecture, so this is nothing to worry about.

You should glimpse at the maximum number of PCI Express Lanes supported. This is the maximum number of expansion cards you can add to your system, but I highly doubt you'll ever need more than the manufacturer provides.

Heat is the killer of electronics, especially for delicate devices like microprocessors. These can usually run at temperatures only up to around 105-125°C, until irreversible damage occurs. These devices usually dissipate more than 100W, so their small surface area can get quite hot very rapidly. This is why installing a cooler and heat-sink for your microprocessor is very important. These are usually aided in extracting heat from the device by a fan.

Whenever you observe significant decreases in the response times of your computer, or you hear the fan constantly running at high speeds, you should always check the state of the heat sinking elements on the processor. The general causes of such behavior are dust accumulations on the processor or the drying out of the thermal paste between the processor and the heatsink. Disassemble the heatsink and fan from the processor. Clean both components (do not use water or solvents!) and apply a fresh layer of thermal paste (the best ones are with silver or gold particles) between the CPU and heatsink and mount everything back to its place. It will not only make your PC much more silent, it will also boost its performance and prolong its life. Repeat this about once a year.

In order to protect the CPU to prolonged exposures to high temperatures, the motherboard is equipped with a temperature sensor underneath the CPU which constantly measures the heat dissipated by the processing unit. This sensor is constantly monitored by the operating system, which is also aware of the maximum accepted temperature of your CPU, depending on the model. This temperature is always defined in the datasheet of the CPU and is referred to as the maximum junction temperature (T_{jmax}). T_{jmax} ranges from 95°C to about 125°C for different types of processors.

Figure 2.16. CPU thermal management

Although these temperatures might seem quite high, if, for whatever reason, your cooling elements are not dissipating heat efficiently, the CPU can reach its maximum junction temperature in a matter of seconds when subjected to high loads. Should this situation ever occur, the operating system will prevent prolonged heat exposure to the CPU by performing a **thermal shutdown**. In other words, when the OS sees your CPU temperatures getting dangerously close to T_{jmax}, it will halt the system. This can be quite scary to the user, because the PC simply stops without any warning, message or without a shut down. Even more scary is the fact that the BIOS will then not allow you to turn your computer back on until the CPU has cooled down sufficiently.

So, if your PC ever goes blank during high loads (e.g.: gaming, video processing, etc.) and will not turn back on immediately, let it cool down and attempt to restart it afterwards. If the problem persists, you need to take action to clean your CPU cooling system, as described earlier on in this chapter.

In Figure 2.17 you can see an application called Core Temp running on Windows 7 and providing temperature data for an Intel Core i5 2500 processor. As it can be seen from the figure, this processor has a T_{jmax} of 98°C and at the time of the screenshot being captured, all four cores had temperatures between 39°C and 46°C. As it can be observed, there can be differences of several degrees between different cores, depending on their load. A thermal shutdown will occur when any of them is near critical temperature.

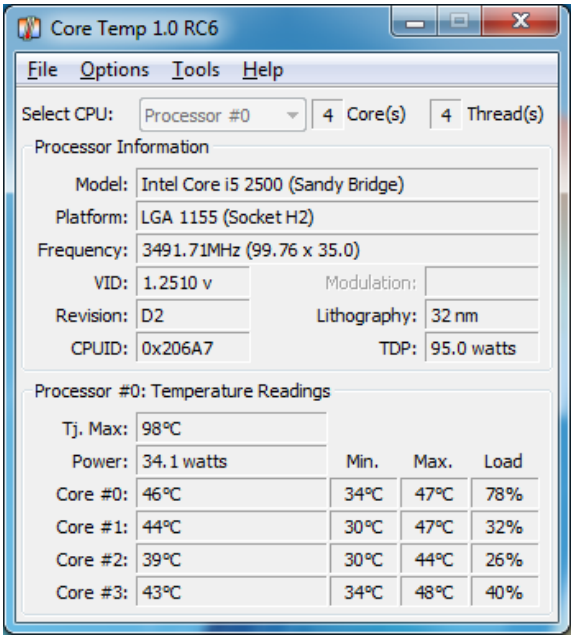


Figure 2.17. Core Temp application showing CPU temperatures

Random Access Memory (RAM)

Right, getting back to building our computer. We have the "brains" and now we need somewhere to store the information that the CPU is spewing out at a very high speed. As a result, we need a means of fast storage in order to collect that information. And this is where the Random-Access Memory (RAM) comes in.

A random-access memory device allows data items to be accessed (read or written) in almost the same amount of time irrespective of the physical location of data inside the memory. In contrast, with other direct-access data storage media such as hard disks, CD-RWs and DVD-RWs, the time required to read and write data items varies significantly depending on their physical locations on the recording medium, due to mechanical limitations such as media rotation speeds and arm movement.

Today, random-access memory takes the form of integrated circuits. RAM is normally associated with **volatile** types of memory (such as DRAM memory modules), where stored information is lost if power is removed, although many efforts have been made to develop non-volatile RAM chips.

In Table 2.3 the main characteristics of a RAM memory kit are presented, as they are usually described by most retailers. The two most important characteristics are the type of memory and the size installed.

Figure 2.18. RAM memory: Kingston FURY Beast DDR4

The type of memory is important because it must match the type of memory supported by your motherboard. The newest, and most common type of RAM memory used is the DDR SDRAM (Double Data Rate Synchronous Dynamic Random-Access Memory) of which an earlier version (DDR4) is still in use, however the newest technology commercially available[1] is DDR5. Usually, different types of memories will only fit in the motherboard if they are the same technology as the motherboard accepts, so bear this in mind when purchasing RAM memory.

Table 2.3. Kingston FURY Beast characteristics (newegg.com)

Model	
Brand	Kingston
Series	FURY Beast
Model	KF432C16BBK2/16
Details	
Capacity	16GB (2 x 8GB)
Type	288-Pin PC RAM
Speed	DDR4 3200
CAS Latency	16 ns
Timing	16-18-18
Voltage	1.35V
Multi-channel Kit	Dual Channel Kit

[1] at the time of editing this book (July 2024)

After the CPU characteristics, the size of RAM memory installed on a system is the second most important feature which greatly impacts the performance and speed of the PC. General rule of thumb is that the more RAM memory a system has, the better it will perform, however, exaggerating can be a waste of money. 4 to 8 GB should be enough for a typical general-purpose computer (office applications, internet browsing, etc.), while a computer used for engineering should have around 12-16 GB of RAM (when used for simulations, modelling, etc.). High end PCs (used for video/photo editing, gaming, etc.) should have 16 to 32 GB of RAM.

To be noted however, that each motherboard only supports limited amount of RAM memory (i.e.: 32 GB for the motherboard presented in Table 2.1). Also, as seen in Figure 2.18, RAM memory comes in sticks which need to be installed in slots on the motherboard. A typical motherboard may have usually 2 or 4 RAM slots, so attention must be paid to ensure that enough slots are available to accommodate the number of RAM sticks to be installed.

The number of memory channels on a system is another important feature of RAM that can impact the computer's data transfer speed. RAM modules communicate with the CPU through a memory controller, which uses a bus to transfer data between the CPU and memory. Some memory controllers support multiple channels, allowing data to travel on several paths simultaneously, which boosts data exchange rates. Channel configurations vary, with some memory controllers supporting single, dual, or quad-channel setups, while others offer six or eight channels, the latter two primarily designed for server environments. To fully utilize multi-channel memory architecture, RAM modules need to be installed in groups matching the system's channel configuration—two modules for dual channel, four for quad channel.

If you are very nerdy about your RAM memory being fast, then you might also want to take a look at the CAS latency. Column Access Strobe (CAS) latency is the delay time between the moment a memory controller tells the memory module to access a particular memory column on a RAM module, and the moment the data from the given array location is available on the module's output pins. It is usually measured in nanoseconds, and the lower the latency, the faster the RAM memory.

Hard Disk Drive (HDD)

Since RAM memory is a volatile means of storage, a computer also generally needs non-volatile (that is permanent) storage. Permanent storage can store data almost indefinitely, even if the device is not powered. A hard disk drive (HDD) is a good example of such a storage medium.

Nowadays, HDDs come in three types: classical (mechanical) hard disks, solid-state drives (SSDs) and hybrid hard disks (SSHD).

Mechanical (or classical) hard disks are data storage devices used for storing and retrieving digital information using one or more rigid ("hard") rapidly rotating disks (platters) coated with magnetic material. The platters are paired with magnetic heads arranged on a moving actuator arm, which read

and write data to the platter surfaces. Data is accessed in a random-access manner, meaning that individual blocks of data can be stored or retrieved in any order and not only sequentially. As a result, their performance is limited by two factors: the speed at which the mechanical patters spin and the speed at which the reading head is able to travel across the plates to read information. Due to their mechanical nature, these hard disks are much slower than the new technology SSDs.

Figure 2.19. Classical hard disk (left) vs. solid state hard disk (right)

As of 2016, the primary competing technology for secondary storage is flash memory in the form of solid-state drives (SSDs), which have higher data transfer rates, better reliability and significantly lower latency and access times, but HDDs remain the dominant medium for secondary storage due to advantages in price per bit and per-device recording capacity. However, SSDs are replacing HDDs where speed, power consumption and durability are more important considerations.

Hybrid drives (SSHDs) are a logical or physical storage device that combines NAND flash solid-state drive (SSD) with hard disk drive (HDD) technology, with the intent of adding some of the speed of SSDs to the cost-effective storage capacity of traditional HDDs. The purpose of the SSD in a hybrid drive is to act as a cache for the data stored on the HDD, improving the overall performance by keeping copies of the most frequently used data on the SSD.

There are two main technologies used for implementing hybrid drives: dual-drive hybrid systems and solid-state hybrid drives. In dual-drive hybrid systems, separate SSD and HDD devices are installed in the same computer, having the data placement optimization performed either manually by the end user, or automatically by the operating system through the creation of a "hybrid" logical device. In solid-state hybrid drives, SSD and HDD functionalities are built into the same physical storage device, by adding a certain amount of NAND flash storage (usually somewhere between 8 to 16 GB) to a hard

disk drive. The data placement decisions are performed either entirely by the device (self-optimized mode), or through placement "hints" supplied by the operating system (host-hinted mode).

When choosing a storage device, once you have decided on the technology you desire, the next decision should be regarding its form factor, or simply said, its size. All hard disk drives come in two sizes: the smaller 2.5" (inch) for laptops and the larger 3.5" for desktop PCs. However, SSDs are often produced only in a 2.5" form factor and sold with adaptor kits (some hinges and screws) to extend their size for desktop PC cases.

Of course, the available storage space (capacity) is then the most important factor that you will take into account. The higher the capacity of the drive, the more information you will be able to store.

To be noted, that the cost per storage unit for SSDs is about 1.5 to 2 times higher[2] than for classical HDDs. For example, the classical HDD presented in Table 2.4 costs $53, while the SSD is $79.

Table 2.4. HDD and SSD characteristics (www.newegg.com)

Model		
Type	**HDD**	**SSD**
Brand	Western Digital	Mushkin Enhanced
Series	Blue	Reactor
Model	WD10EZEX	MKNSSDRE1TB
Performance		
Interface	SATA 6.0Gb/s	SATA III
Capacity	1 TB	1 TB
RPM	7200	n/a
Cache	64 MB	n/a
Dimensions		
Form factor	3.5"	2.5"

For mechanical hard drive, the rotation speed (measured in rotations per minute, RPM) is a factor that should also be taken into account. These are generally either 5400 RPM or 7200 RPM, the later one being obviously faster.

[2] at the time of editing this book (July 2024)

Connecting any hard drive to a motherboard should not be an issue, the only type of connector being commercially available for consumer use being the SATA interface, with its fasters variant being the 6 Gb/s version. A compact connector used in modern SSDs, supporting both SATA and NVMe protocols is the M.2 connector.

Video Card

A video card (also called a video adapter, display card, graphics card, graphics board, display adapter, graphics adapter or frame buffer) is an expansion card (and therefor optional) which generates a feed of output images to a display (such as a computer monitor). Frequently, these are advertised as discrete or dedicated graphics cards, emphasizing the distinction between these and integrated graphics.

Figure 2.20. MSI GeForce GTX 960 video card

The video card contains a specialized processor called a graphical processing unit (GPU) and video RAM. The performance of the video card will be mainly limited by these two components. The faster the GPU clock speed and the more video RAM the card has installed, the better performances you can expect.

Two other aspects which should also be noted are the maximum resolution supported and the ports the video card has. These two factors will limit the choice of monitors which you can connect to your PC. Mainly, the higher the supported resolution, the better the displayed image will be. Regarding the ports, the monitor and the video card should have the same type of connector in order to be compatible with each other.

Also important is the fact that the video card needs to be compatible with at least one of the expansion slots available on the motherboard. Video cards usually connect to the motherboard via a PCI Express interface, however, the versions of these should match.

Table 2.5. MSI GeForce GTX 960 characteristics (www.newegg.com)

Model	
Brand	MSI
Model	GTX 960 GAMING 4G
Interface	
Interface	PCI Express 3.0 x16
Chipset	
Chipset manufacturer	NVIDIA
GPU	GeForce GTX 960
Core clock	1241 MHz
Boost clock	1304 MHz
Memory	
Effective memory clock	7010 MHz
Memory size	4 GB
Memory interface	128-bit
Memory type	GDDR5
Ports	
HDMI	1 x HDMI 2.0
Multi-monitor support	4
DisplayPort	3 x DisplayPort 1.2
DVI	1 x Dual-link DVI-I
Maximum Resolution	4096 x 2160

Monitor

A computer monitor or a computer display is an electronic visual display for computers. A monitor usually comprises the display device, circuitry, casing, and power supply. The display device in modern monitors is typically a thin film transistor liquid crystal display (TFT-LCD) or a flat panel LED display, while older monitors used cathode ray tubes (CRT). It can be connected to the computer via VGA, DVI, HDMI, DisplayPort or other proprietary connectors and signals.

As stated before, the connector of the display should match where the display will be connected: either the video port on the motherboard or on the video card.







VGA connector | DVI connector | HDMI connector | DisplayPort connector

Other characteristics that should be taken into account when choosing a display are the:

- Size
- Resolution
- Refresh rate
- Number of colors displayed
- Contrast ratio
- Response time

The screen size (or display size) is the physical size of the area where pictures and videos are displayed. The size of a screen is usually described by the length of its diagonal (usually in inches), which is the distance between opposite corners.

All LCD screens are built with a fixed quantity and size of display pixels (as seen in Figure 2.21). This fixed quantity and size of pixels is called native resolution, equivalent to the recommended resolution or the maximum resolution. The recommended resolution uses all of the pixels in the LCD screen exactly as it was engineered.

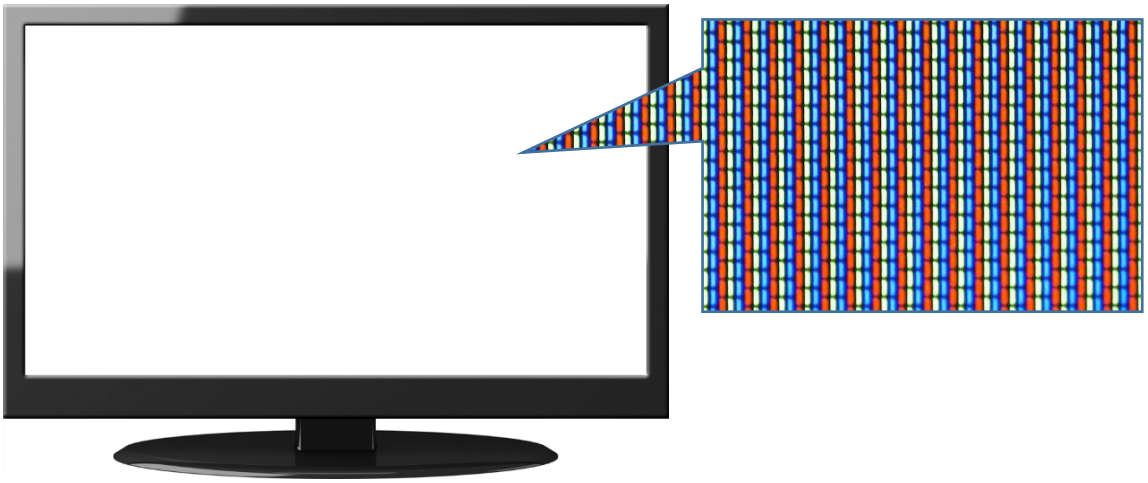


Figure 2.21. LED monitor: pixels zoomed in

To display moving images, a monitor must change the displayed image at least 24 times per second to be perceived smoothly by the human eye. This is what we mean when we say the television refreshes the image - it has to draw images in pixels so quickly that the human eye can't detect the process. Refresh rate is the number of times per second in which the display draws the data it is being given. For example, a television with refresh rate of 60 hertz means the screen displays an image 60 times every second. The more often it does this, the more fluent the motion can be. However, a refresh rate higher than 100-150 Hz can be overkill and a waste of money, as at higher frequencies the human eye will no longer tell the differences.

The contrast ratio is the measure of a display system, defined as the ratio of the luminance of the brightest color (white) to that of the darkest color (black) that the system is capable of producing. The higher the contrast ratio, the more brilliant the display.

The response time is the amount of time a pixel in an LCD monitor takes to go from black to white, and back to black again, measured in milliseconds. Typically, lower numbers mean faster transitions, and therefore fewer visible image artifacts. The black-white-black is the typical response time for an LCD display and is the ISO standard for this specification. The GTG response time, which means grey to grey, is far more common in practice.

Keyboard and Mouse

The keyboard and mouse are the two most popular devices used to input data into a personal computer.

A computer keyboard is a typewriter-style device which uses an arrangement of buttons or keys to act as a mechanical lever or electronic switch. It typically has characters engraved or printed on the keys

and each press of a key typically corresponds to a single written symbol. However, to produce some symbols requires pressing and holding several keys simultaneously or in sequence. While most keyboard keys produce letters, numbers or signs (characters), other keys or simultaneous key presses can produce actions or execute computer commands.

Figure 2.22. Cooler Master CM Storm Octane Gaming Keyboard and Mouse Bundle

Despite the development of alternative input devices, such as the mouse, touchscreen, pen devices, character recognition and voice recognition, the keyboard remains the most commonly used device for direct (human) input of alphanumeric data into computers.

In normal usage, the keyboard is used as a text entry interface to type text and numbers into a word processor, text editor or other programs. In a modern computer, the interpretation of key presses is generally left to the software. A computer keyboard distinguishes each physical key from every other and reports all key presses to the controlling software. Keyboards are also used for computer gaming, either with regular keyboards or by using keyboards with special gaming features, which can expedite frequently used keystroke combinations.

A computer mouse is a pointing device (hand control) that detects two-dimensional motion relative to a surface. This motion is typically translated into the motion of a pointer on a display, which allows for a fine control of the graphical user interface.

Physically, a mouse consists of an object held in one's hand, with one or more buttons. Mice often also feature other elements, such as touch surfaces and "wheels", which enable additional control and dimensional input.

Figure 2.23. PS/2 connectors (violet - keyboards, green - mouse) and USB connectors below

Choosing a keyboard and a mouse is most of all a personal preference and as a result will be not discussed in detail. However, important aspects when choosing a keyboard are its layout and language, while the selection of a mouse is often guided by its sensitivity (measured in dots per inch, DPI). Older keyboards and mice connect on a PS/2 interface, while new designs often connect via USB.

Power Supply Unit (PSU)

A power supply unit (PSU) converts mains AC to low voltage regulated DC power for the internal components of a computer. Modern personal computers universally use a switched-mode power supply. Some power supplies have a manual selector for input voltage (110V/230V), while others automatically adapt to the supply voltage.

Most modern desktop personal computer power supplies conform to the ATX specification, which includes form factor and voltage tolerances. While an ATX power supply is connected to the mains supply, it always provides a 5 V standby (5VSB) voltage so that the standby functions on the computer and certain peripherals are powered. ATX power supplies are turned on and off by a signal from the motherboard. They also provide a signal to the motherboard to indicate when the DC voltages are in specification, so that the computer is able to safely power up and boot.

Figure 2.24. An ATX power supply unit with the cover removed

The most important factor when selecting a power supply is calculating the power needs of your computer at peak usage and then adding a safety overhead. This means adding together the peak power consumption of all the components powered from the PSU: motherboard, CPU, GPU, etc. (however, not the monitor, which is always powered separately) and then adding to that about a 50% safety margin. The resulting power rating is the minimum power rating for the PSU that is needed for the given system. Most power supplies range from 400W to a staggering 1200W.

Final considerations

Now that we know what each component does, how to select it to be compatible with our assembly and what to pay attention to in order to achieve top performance, all we need to do is mount the components together in order to obtain our desktop PC. This should be a fairly straightforward task and if the components are compatible, everything should fit snugly together.

At this point your PC should power on, all the fans should be spinning, and if everything is connected correctly a message should appear on the monitor saying, "`Missing operating system`" or "`Operating system not found`." This is because, in this chapter we only took care of the hardware, however we have not yet installed an operating system (or anything in fact) on our newly built PC.

Figure 2.25. Assembled PC (side cover removed)

Although generally not recommended, powering up a custom-built PC for the first time should be done with the case open. This way you can make sure that all fans are spinning, and the processor is being cooled. If the system powers on but the fans are not spinning, safely power off the system as quickly as possible by pressing and holding the power button. Then check again if your fans are correctly connected to the PSU. **Do not run your system without working fans as this may damage your processor!**

Also, do not place your hand inside the case, attach or remove components as long as the computer is powered on and the mains cable in connected. **Always unplug the mains cable from the PSU before handling components!**

In this chapter we have learnt what are personal computers, how their architecture is structured and what are the components that go inside a PC. We have also studied each component in depth, taking a look at their most important characteristics. We studied how to get the most out of our hardware performance and how to always ensure compatibility between the components.

In the next chapter we will take a look at how an operating system works, how to install and configure it and how to troubleshoot most common problems.

Chapter 3

Operating Systems

In this chapter

- General presentation of operating systems
- Operating system types
- Functions and components of the operating system
- Installing an operating system
- Troubleshooting tricks and tips

An operating system, commonly referred to as OS, is a collection of software that manages computer hardware resources and provides common services for computer programs. For hardware functions such as input and output and memory allocation, the operating system acts as an intermediary between programs and the computer hardware, although the application code is usually executed directly by the hardware and frequently makes system calls to an OS function or is interrupted by it. Operating systems are found on many devices that contain a computer – from cellular phones and video game consoles to web servers and supercomputers.

The most widely used operating systems are produced by Microsoft and are marketed under the brand name “Microsoft Windows”. The most common versions of this OS are Windows 10 (support ends October 2025), (less popular but still present in some systems), Windows 10 (widely used in both personal and business environments) and the most recent version, Windows 11. Initially, Microsoft announced that Windows 10 would be the “last” version of its operating system, shifting to a model called "Windows as a Service" (WaaS). This approach moved away from traditional, distinct version releases and instead delivered regular updates that introduced new features, enhancements, and fixes. In April 2017, Microsoft stated that these updates would be released twice a year, in March and September. With the introduction of Windows 11, Microsoft continued this update model, labeling mainstream builds as "YYH1" or "YYH2," where "YY" represents the release year, and "H1" or "H2" indicates whether the update was issued in the first or second half of the year. For instance, version 23H2 was released in the second half of 2023.

However, this changed with the release of Windows 11 in October 2021. Windows 11 introduced a new interface, enhanced performance, and other improvements, indicating that despite the original plan for Windows 10 to be the "last" version, evolving technology and user expectations led to the development of Windows 11.

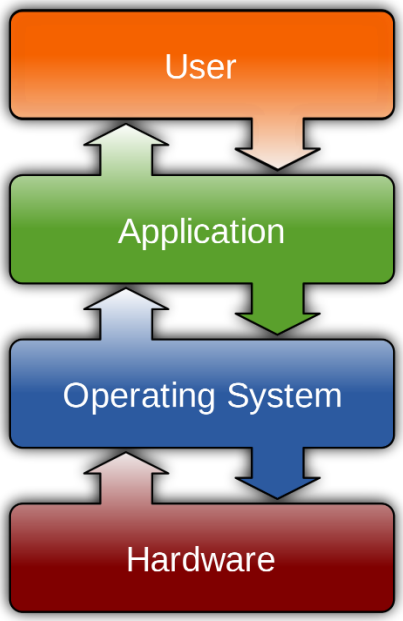


Figure 3.1. OS common features

Other operating systems for desktop devices include “macOS” by Apple and various distributions of the “Linux” operating system.

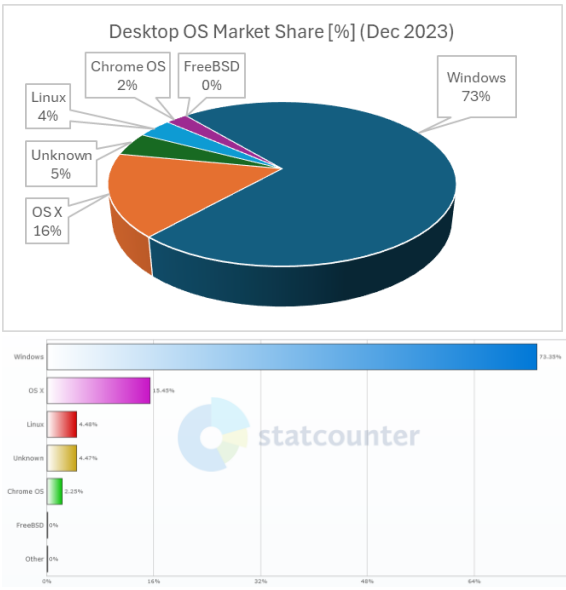


Figure 3.23. Desktop OS market shares as of September 2024

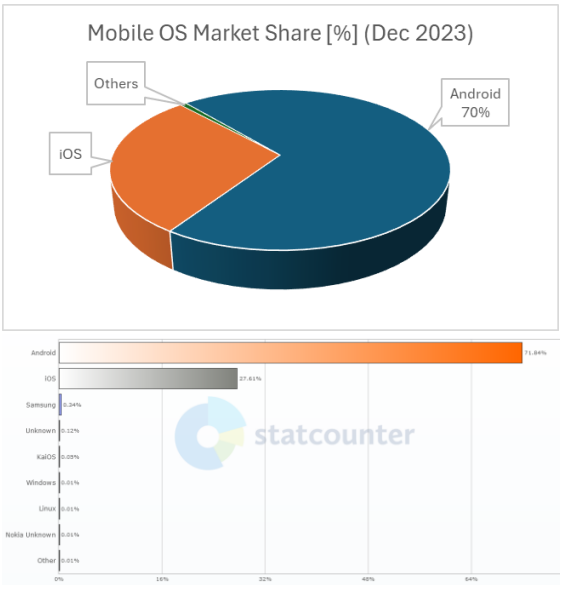


Figure 3.3. Mobile OS market shares as of December 2023

For mobile devices the most common operating systems used worldwide are Google's "Android" and Apple's "iOS".

Operating system types

Operating systems are generally divided into three major categories:

1. Single-tasking operating systems
2. Multi-tasking operating systems
3. Real-time operating systems

The difference between the first two classes of operating systems is that while a single-tasking OS can run one program at a time, a multi-tasking operating system will allow more programs (or processes) to be run concurrently. This is achieved by employing a technique called time-sharing, where available processor time is divided between multiple processes. These processes are each interrupted repeatedly in time slices by a task-scheduling subsystem of the operating system. Multi-tasking may be characterized in preemptive and co-operative types. In preemptive multitasking, the operating system slices the CPU time and dedicates a slot to each of the programs. Unix-like operating systems, such as Solaris and Linux—as well as non-Unix-like, such as AmigaOS—support preemptive multitasking. Cooperative multitasking is achieved by relying on each process to provide time to the other processes in a defined manner. 16-bit versions of Microsoft Windows used cooperative multi-tasking. 32-bit versions of both Windows NT and Win9x used preemptive multi-tasking.

Of course, as we have seen in the previous chapter, modern processors have a multicore, multithread hardware configuration and therefore provide major advantages to multitasking. While a single core processor can run only one process at a time, a quad-core processor will be able to run four parallel processes at any given moment, without those processes interrupting one another. Moreover, a processor that is able to run multiple threads in parallel on a single core, will also provide additional performance boosts to applications which are able to run on multiple threads. Therefore, and Intel i9-9820X Skylake processor, which is a 10-core processor with capabilities of running two threads per core, will be able to run 20 threads in parallel, without having to rely on time-sharing between these threads.

Real-time operating systems, on the other hand, are operating systems that guarantee to process events or data by a specific moment in time. A real-time operating system may be single- or multi-tasking, but when multitasking, it uses specialized scheduling algorithms so that a deterministic nature of behavior is achieved. An event-driven system switches between tasks based on their priorities or external events while time-sharing operating systems switch tasks based on clock interrupts. These types of operating systems are used in specialized applications, such as the automotive or aeronautical industry, where response time to a given event is time critical. For instance, in the case of an operating system running on the control unit (ECU) of a car, if the antiskid sensor senses that the wheels of the car have locked up during braking, it must employ ABS (antilock braking system) techniques to control the skid in a given amount of time. This means that the OS, in this case, has to act in a limited and well-defined amount of time (for example 50 milliseconds) to the data it is receiving.

Functions and components of the operating system

Any operating system has the following main functions:

- Provide communication between the user and hardware.
  The OS must facilitate that the intentions of the user, expressed via the input devices, are registered, processed and responded to adequately by the hardware.
- Control program execution.
  The OS must make sure that the programs running on the users' device are performing as expected, and if they stop responding, crash, or otherwise misbehave, it is the operating systems job to gracefully handle the unexpected event (force-close the program and inform the user of the problem).
- Ensure optimal resource allocation.
  The OS is responsible for allocating CPU time, cores, threads as well as RAM memory to any running process, based on the needs of the given process and the available hardware resources. The OS should prioritize resource allocation for applications with which the user is currently interacting and set background applications to have low priority resource access if these are scarce.
- Facilitate efficient data processing.
  The OS should ensure all the users' data is processed as expected.

- Ensure system security.

  The OS should also protect the system of unauthorized access and ensure that the users' sensitive information is only available to the user logged in with the proper credentials. Within this category also falls the protection from computer viruses, which is primarily the operating system's responsibility.
- Enable application development.

  The vendor of the OS should enable programmers to develop applications to run under the given operating system. The easier it is for developers to create applications for a given OS, the more applications will be available and therefore the more popular the OS in question will be.

The two main components of an operating system are the core, also known as the kernel, and the user interface, commonly referred to as the shell. The kernel contains the necessary programs for optimal resource management and for controlling the activity of programs and applications and is generally not visible to the user. The shell, on the other hand, is the software interface that provides the user access to the services of the kernel and is generally an interface with which the user interacts. The shell can be presented either in a text-like form (such as a command prompt, where the user inputs commands) for simple operating systems or in the form of a GUI (graphical user interface) with which the user can interact either by using a keyboard, a mouse or by touches or gestures.

Installing an operating system

In order to install (or re-install) an operating system on your computer, you should adhere to the following checklist:

1. Determine the bitness of your CPU.
2. Download the appropriate OS.
3. Create the installation (bootable) media for your device.
4. Boot your device from the media created in step 3
5. Select the necessary options for your installation.
6. Optionally, create hard drive partitions (if installing on a brand-new system) and install the OS on the appropriate partition.
7. Configure the OS at first launch.
8. Check and install any important updates, before installing any other applications

Determining the bitness of your CPU should be quite straightforward, as most modern CPUs are 64-bit versions, so it is very unlikely that you would encounter a 32-bit processor, unless you are working with a specialized embedded system or a very antiquated one. However, based on your CPU make and model, a quick internet search should tell you whether you are using a 32- or 64-bit processor.

A more important part is downloading the OS with the correct bitness from your vendor. 32-bit versions will usually be marked as "x86" and the 64-bit distributions will be marked as

"x64". This step is especially important to get right, because a 32-bit OS **can be** installed on a 64-bit machine, however, it will not take advantage of the full power of the processor. For instance, a 32-bit OS can only address about 4 GB of RAM, so no matter how much RAM your system has (16 GB, 32 GB), if you install a 32-bit OS, only about 4 GB will be usable.

Figure 3.4. Windows USB/DVD Download Tool

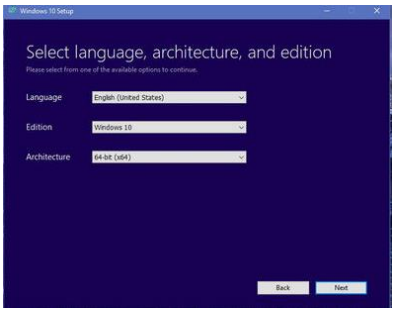


Figure 3.5. Windows 10 Media Creation Tool

Most vendors provide clean ISO images of their operating systems on their websites/webstores. All you need to do is download the appropriate image and make sure you have a valid license key, to be used later in the installation process.

Once you have your ISO image, you need to create an installation media. For this you can either burn a DVD or create a bootable USB flash drive. In order to create installation media for Microsoft Windows installation, you can use either the "Windows USB/DVD Download Tool" or the "Windows 10 Media Creation Tool". These tools are straightforward to use: all you need to do is download them, install them on an already working PC and then follow the step-by-step instructions on the screens of the tools.

Now that you have your media, all you need to do is insert it on the device you want to install your OS on, and then make sure the device uses the given media as its primary boot device. This can be configured from the BIOS/UEFI of your device. However, most devices also offer a "Quick boot" menu, which can usually be accessed by hitting the F12 key, while the device is starting. This will display a menu with all available boot devices, from which you can select the media you have inserted in order to boot from that.

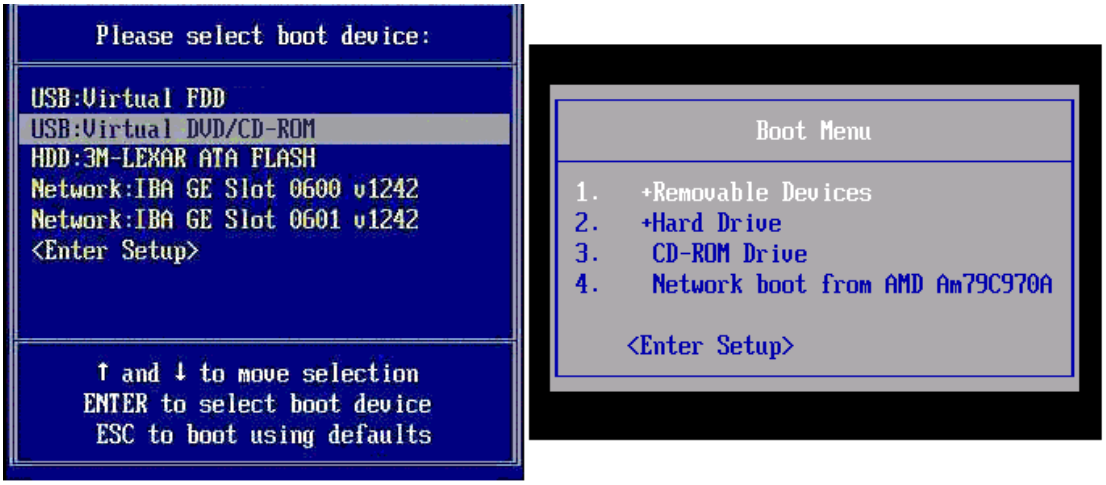


Figure 3.6. Examples of Quick Boot menus

After the installer has loaded, you will be greeted by a welcome screen and then you can choose a number of options, such as the language, keyboard layout, time zone, etc. You will be also asked to provide a valid serial number for your OS license.

Finally, you will be asked to select on which disk/partition to install the operating system. At this stage, if you have a brand-new device, there will be no partitions created, so you will need to create at least one. However, you do have the option to create more than one partition. Disk partitioning itself is the act of dividing a hard disk drive into multiple logical storage units referred to as partitions, to treat one physical disk drive as if it were multiple disks, so that different file systems can be used on each partition. It is recommended to create at least two partitions: one called a “system partition”, where the OS and all your programs will be installed, and a “data/storage partition”, where you will store your other data such as documents, photos and everything else. Note that the installer will probably create additions “System Reserved” partitions. Do not delete or modify these, as these contain important information for the OS on how your drive is structured and how files are stored on it. Deleting these partitions will surely result in data loss!

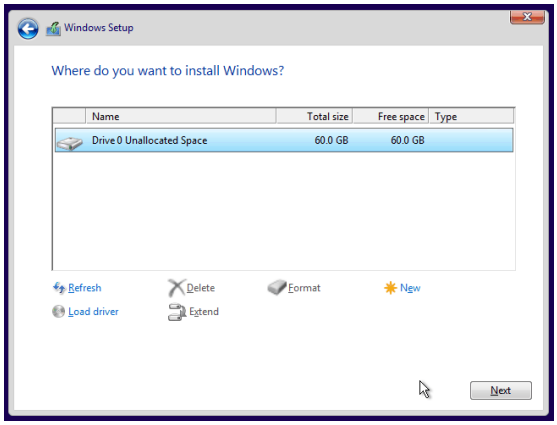


Figure 3.7. Unallocated disk space (no partitions created)

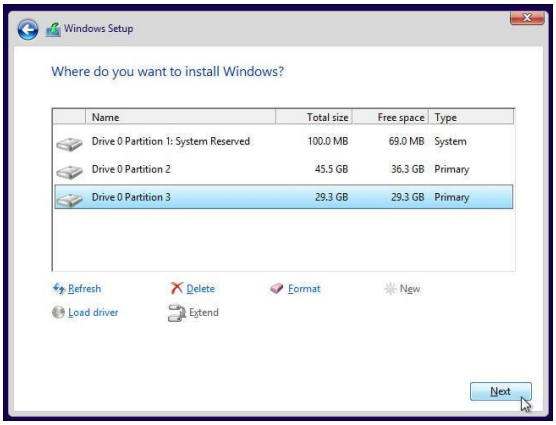


Figure 3.8. Two usable partitions and one "system reserved" partition

Note that after creating the partitions, the partition selected (marked with blue), will be the partition on which the OS will be installed when you click "Next". In the case of Figure 3.8 for example, this will be "Drive 0 Partition 3". So, make sure you have the appropriate partition selected on which you want to install the OS, before proceeding to the next step.

Finally, the operating system should be installed, restarting the device in the process a couple of times. After this, you will be greeted by a welcome screen, where you will be required to setup your username (or online account), Wi-Fi and other settings, amongst which, most annoyingly how Microsoft processes your personal data and delivers advertisements to your device.

Troubleshooting

The most common problems after installing a new operating system are missing device drivers for some of your hardware components. However, these can be easily identified by inspecting the "Device Manager". The "Device Manager" will highlight any problematic devices by placing a yellow exclamation mark next to them (as in Figure 3.9). In order to fix such problems with devices showing errors, you can try the following steps:

- Right-click on the device and select "Update driver" and then select "Search automatically for updated driver software".
- If a driver CD/DVD was shipped with your system, use that specific media to install the appropriate device drivers.
- Identify your device make and model, or better yet, its service tag, and search on the manufacturer's website for up-to-date device drivers.

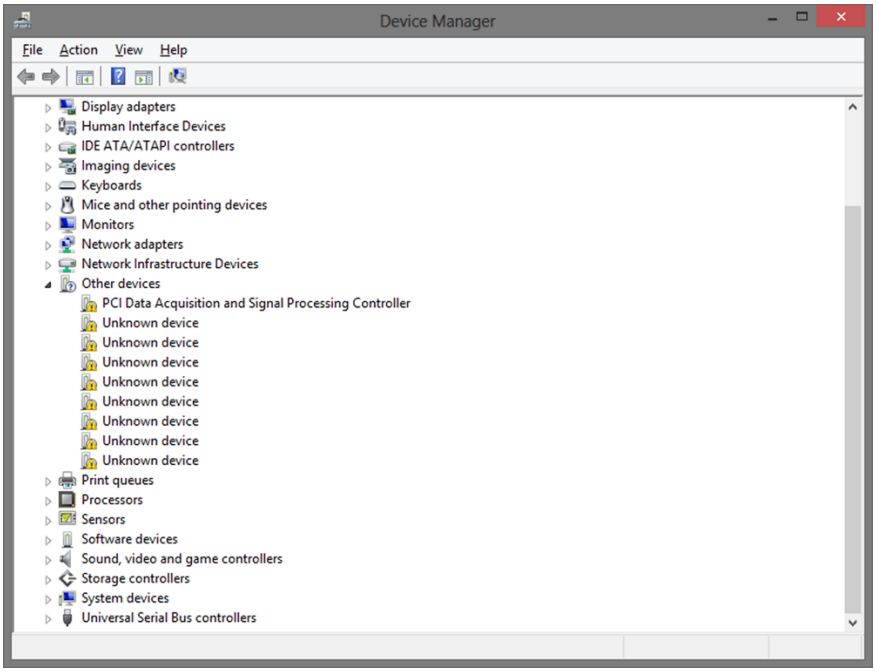


Figure 3.9. Device Manager showing unknown devices

If neither of the troubleshooting steps managed to solve the problem with your inoperable device, then it may be that there is a hardware problem with the device in question. Try replacing it with the same or compatible device and see if that solved the issue. When all devices are installed and working correctly, the “Device Manager”, by default, should not have any expanded nodes and none of the devices should have the yellow exclamation mark next to them.

Chapter 4

Microsoft Word

In this chapter

- Microsoft Word and Office 365
- Word user interface
- Configuring and setting up Word
- Formatting and styles
- Working with pictures and images
- Cross-referencing and citing references
- Inserting equations
- Reviewing work

Microsoft Word is a word processor developed by Microsoft. It is the most popular word processor and is part of either Microsoft's Office line or its subscription-based services, known as Office 365.

In this chapter, you will learn how to work with the Word interface, format text, tables and pictures, create styles, templates and many more.

Word user interface

The Word user interface, as seen in Figure 4.1, is divided in the following areas:

- The title bar
- The Ribbon Interface
- The editing area
- The status bar

- The reading pane

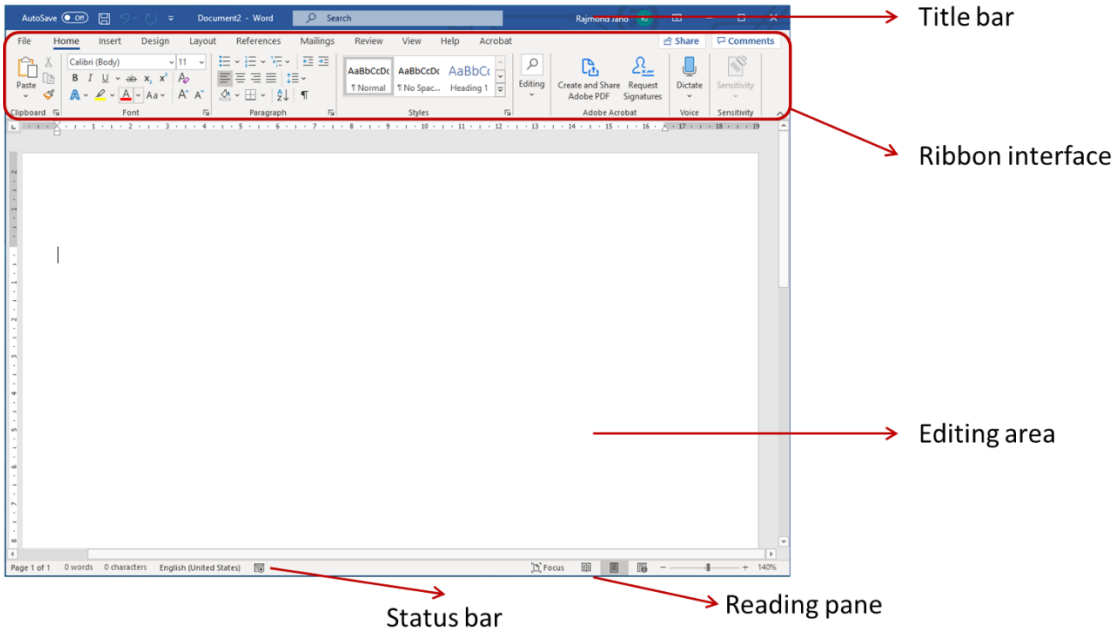


Figure 4.1. Microsoft Word user interface (UI)

The title bar

The title bar (Figure 4.2) itself is also divided in the following blocks:

- Autosave status – allows the user to enable/disable the autosaving of the document. When this feature is enabled, there is no need to manually save the document, all changes will be automatically saved as the document is edited (on the fly). To be noted, however, that this feature can only be enabled if the document is saved in a cloud environment, such as Microsoft OneDrive.
- Quick access toolbar (QAT) – allows quick access to the most frequently used commands. The QAT is customizable, the user can add/remove buttons to it by clicking the downward pointing arrow right at the end of the toolbar.
- Current document title – shows the title of the current document.
- Search bar – allows searching for information within the document, recently opened document or within the user's organization (if logged on with an account belonging to an organization).
- User information – displays the currently logged on user (if any).

- Ribbon display options – allows the user to hide/show the Ribbon Interface, or to set it to automatically be displayed only when it is hovered over with the mouse. This is especially useful on smaller devices, since hiding the Ribbon Interface will grow the editing area.

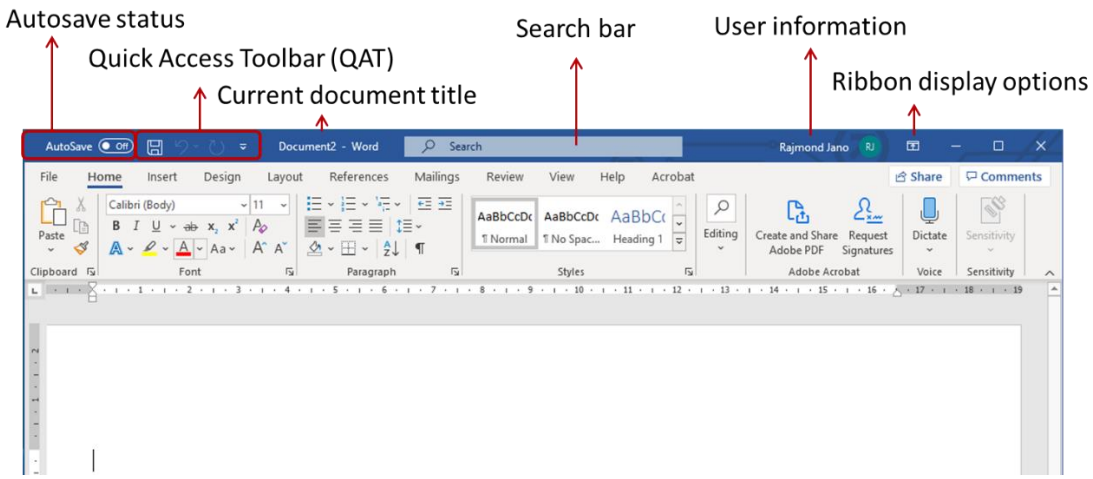


Figure 4.2. The components of the title bar

Try customizing the Quick access toolbar by adding the following commands: Spelling and Grammar, Quick Print.
By using the ribbon display options button, try the different display options for the Ribbon Interface and see which one best suits your liking. The same effect can also be achieved by using the shortcut keys Ctrl+F1 to cycle through the display modes.

The Ribbon Interface

The Ribbon Interface consists of the tab row, which contains all the available editing options through which you can cycle, such as “Home”, “Insert”, “Layout”, etc. The tab row is also contextual, meaning that not all commands are available all the time. For instance, the picture formatting commands only show up in the tab row if you have actually selected a picture that can be formatted in your document.

On the Ribbon Interface commands are also grouped into so called groups or chunks. These are usually grouped by function, so font formatting command will make up one chunk, then paragraph formatting commands another one, and so on.

To be noted however, that the Ribbon Interface only displays the most widely used commands and therefore many of the more advanced commands are hidden from plain sight. In order to get to these commands, the user can press on the small dialog box launcher command, present in the bottom right corner of most groups. As the name suggests, this will launch a dialog box, where all of the available formatting commands for the given topic can be found. For example, the paragraph formatting dialog

box, which is displayed by clicking the dialog box launcher marked in Figure 4.3, can be seen in Figure 4.4.

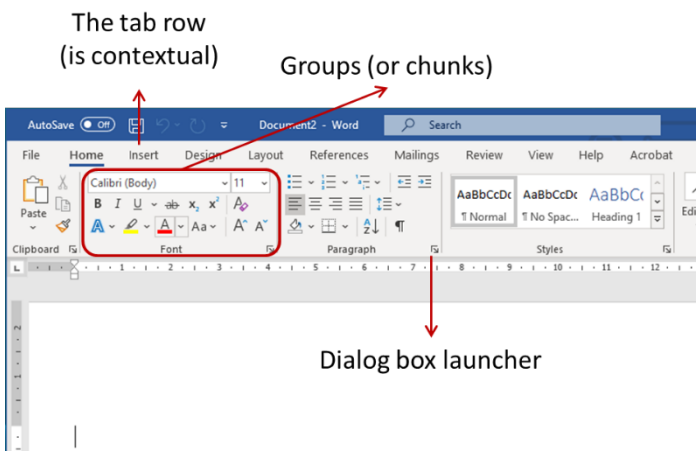


Figure 4.3. The Ribbon Interface

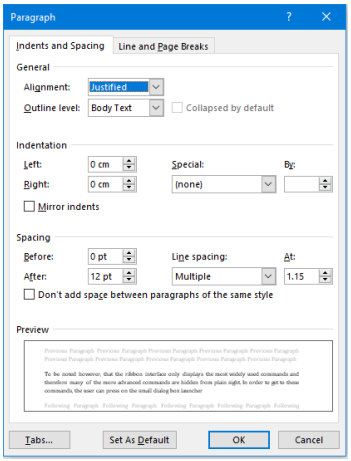


Figure 4.4. Paragraph formatting dialog box

The status bar and reading pane

The status bar and reading pane can be found on the bottom margin of the Word window. The status bar offers more than 20 optional pieces of information that can be displayed. It can be customized by right clicking and then selecting the desired information to be displayed (Figure 4.5).

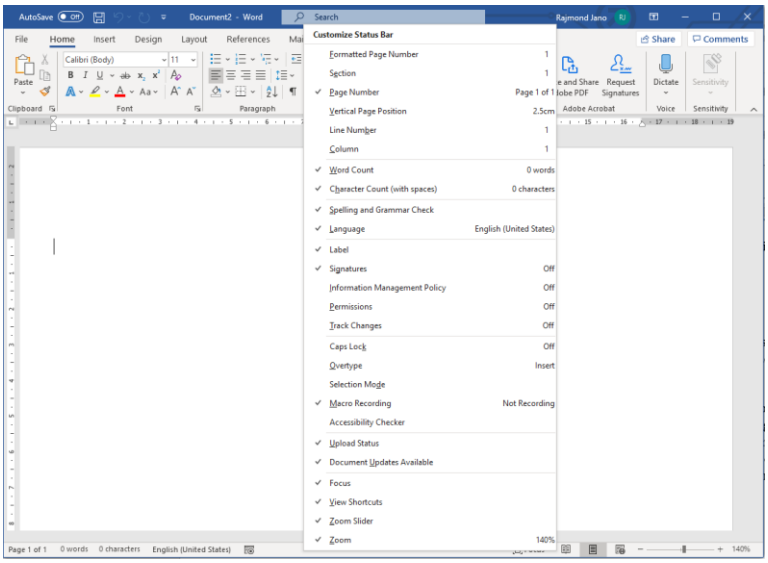


Figure 4.5. Status bar customization options

The reading pane offers a "Focus" button, which, when activated, Word will hide all formatting toolbars and ribbons, displaying only a white document. This feature can be used, as the name suggests, to focus only on writing the document you are creating, rather than formatting it. Other reading modes available are "Read Mode", "Print Layout" – which is the default view, and "Web Layout". Also here is where you will find a zoom controller, which helps you zoom in/out of your document. However, it is worth remembering that zooming in/out can also be achieved by holding the Ctrl key on your keyboard and then scrolling the mouse wheel up or down.

The MiniBar

The MiniBar (Figure 4.6) is displayed automatically whenever the user selects text (alone) or together with the context menu on right clicking anywhere within the editing area.

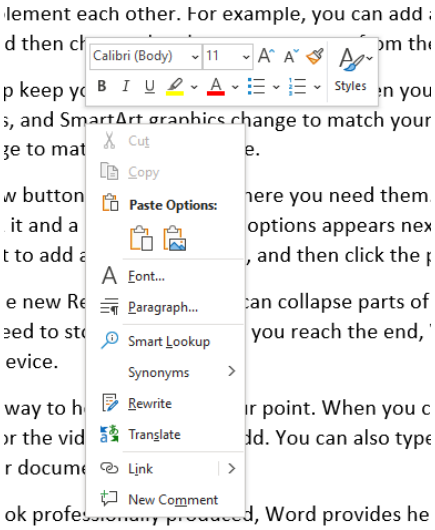


Figure 4.6. The MiniBar (top) and context menu (bottom)

The purpose of the MiniBar and the context menu is to display the most frequently used formatting and edition commands as close to the cursor as possible. This way, mouse travel across the screen is minimized and efficiency increases.

Configuring Word

Before actually starting editing documents in Word, there are a few settings you should inspect and maybe change to your liking. In order to do this, you should open the "Word Options" panel by accessing "File > Options". Here, you will find the following pages and settings:

- General – for configuring UI, user and startup options.

- Display – for configuring the display of non-printable characters and a few printer options.
- Proofing – for controlling Autocorrect and Spelling and Grammar settings.
- Save – for setting up where backup copies of documents are automatically saved and how often Word autosaves the document.
- Language – for controlling Word display language.
- Ease of Access – for configuring options for users with disabilities
- Advanced – the vastest page on the Options page, for configuring advanced editing options, how cut, copy and paste operations behave, the size and quality of images stored in your documents, display and measurement units' options and layout settings.
- Customize Ribbon – for customizing the commands that can be seen on the Ribbon Interface.
- Quick Access Toolbar – for customizing the commands on the Quick Access Toolbar.
- Add-Ins – for viewing and managing Microsoft Office add-ins.
- Trust Center – helps keep your document safe and secure.

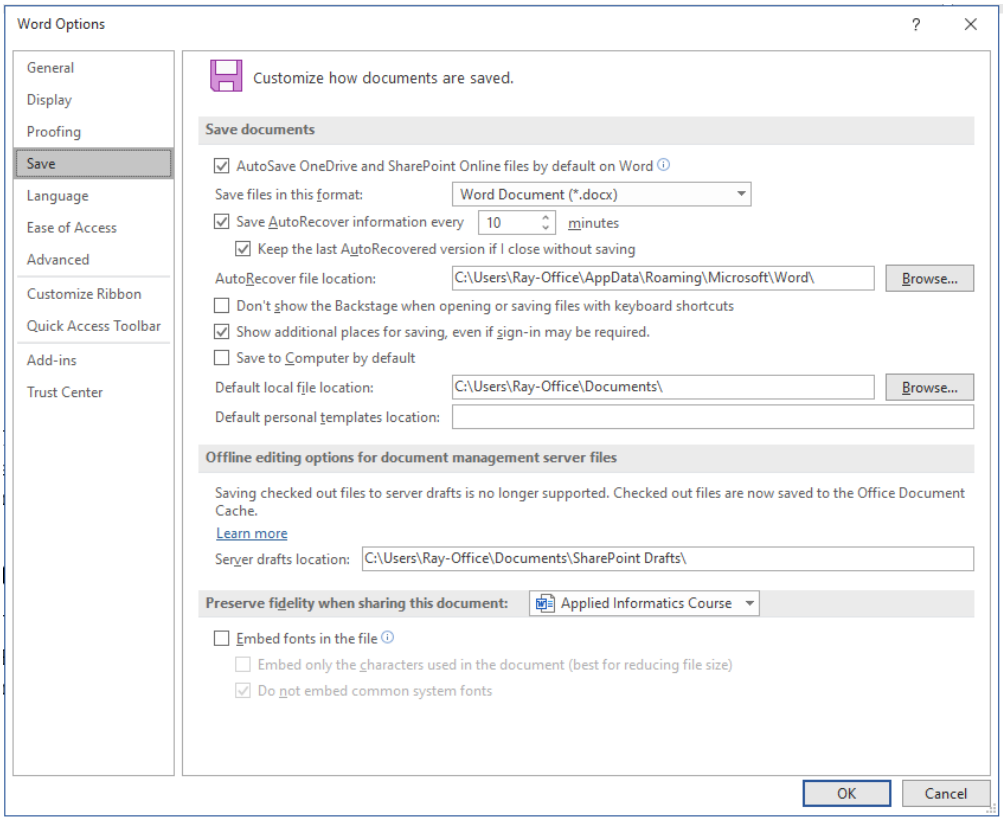


Figure 4.7. The "Save" page in Word Options

Before you get started with Word, check and possibly change the following options:

- Set the "Save AutoRecover information every: *x* minutes" to a value that is satisfactory for your typing speed, so that in the case Word crashes or there is a

power outage, you do not lose more than 2-4 paragraphs of text. Take care, however, because setting this interval to a too frequent value (such as 1 minute) will cause Word to save the document way too often, which in case of large documents can be annoying (since depending on the speed of your computer, Word will very likely stop responding to your inputs for a few seconds, every time it saves the document)

- Under the "Advanced" page's "Display" section, check the units of measurement used by Word. Change it to whatever suits your needs (inches, centimeters, millimeters).
- Also, on the Ribbon interface, navigate to the "View" page and in the "Show" group, check to enable the "Ruler", which will show the horizontal and vertical rules in the editing area (Figure 4.8). This will come in handy later on.

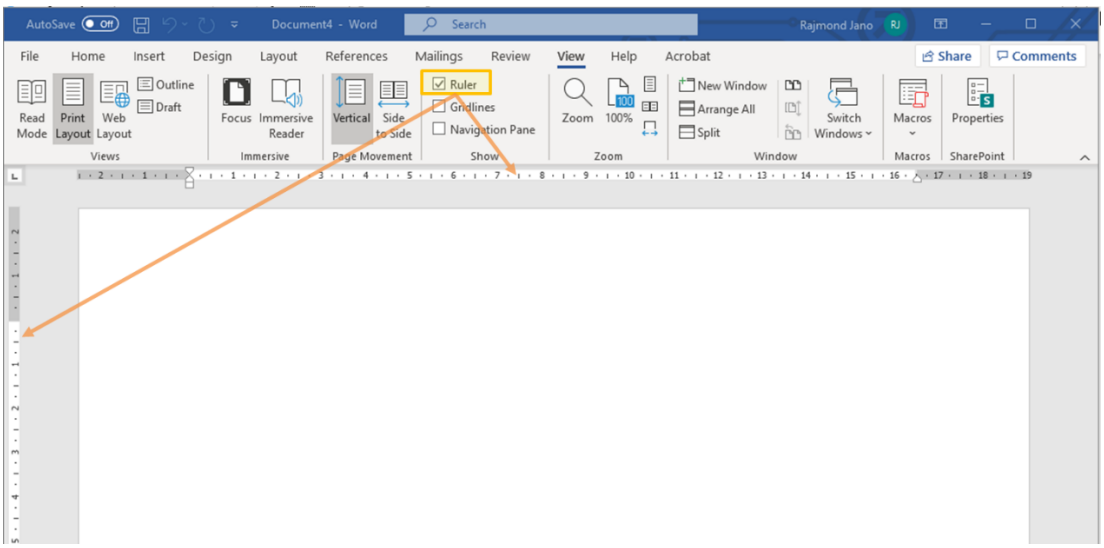


Figure 4.8. Horizontal and vertical rules enabled

Character formatting

Word has four levels at which formatting can be applied: character formatting, paragraph formatting, section formatting and document formatting. As the name suggests, character formatting will apply the formatting settings only to a single character.

There are at least six ways of applying various kinds of character formatting:

- Using the Font group on the Home tab of the Ribbon (Figure 4.9)
- Using the Font dialog box (Figure 4.10, accessed by pressing Ctrl+D or Ctrl+Shift+F, or clicking the Font Dialog Box Launcher)

- Using the Mini toolbar (hover the mouse over selected text)
- Using shortcut keys (Ctrl+B for bold, Ctrl+I for italics, etc.)
- Using the Font group or components placed on the Quick Access Toolbar (QAT)
- Using the Language tool on the status bar (Figure 4.11)

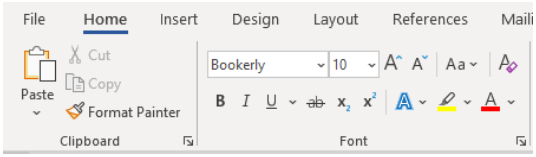


Figure 4.9. The Font group on the Home tab of the Ribbon interface

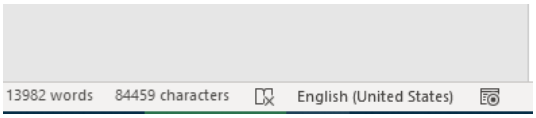


Figure 4.11. The Language tool on the status bar

Note: Language is applied at the character level, rather than on a word or paragraph level in Word!

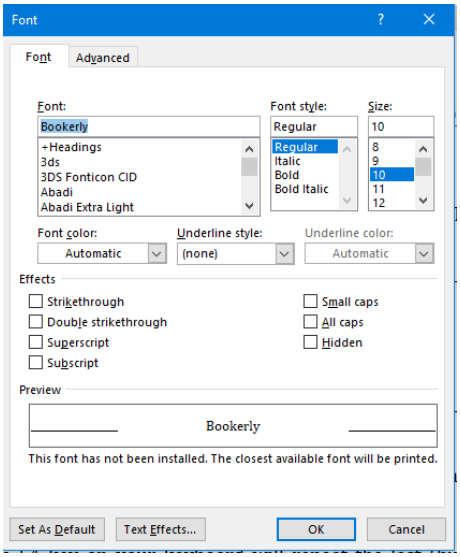


Figure 4.10. The Font dialog box

There are also at least three ways of repeating/copying character formatting from one place to the other:

- Pressing the F4 key on your keyboard will repeat the last (but only the last) formatting command applied. For instance, if you have applied a bold, italics formatting beforehand, selecting another word and hitting F4 will apply the italics formatting to the selected word.
- By using Ctrl+Alt+C you can copy formatting from the area where the cursor is located and then by selecting other text, you can paste **only** the formatting by pressing Ctrl+Alt+V. This will copy and paste all formatting. So, for instance, if the text where the cursor was located when you pressed Ctrl+Alt+C was formatted as bold, italics and red, the text you paste the formatting will have all these properties: it will become bold, italics and red.
- In the "Home" section of the Ribbon interface, in the "Clipboard" group, there is a "Format Painter". This is able to pick up formatting from the current location of the cursor and then "paint" the same formatting to any text it is dragged over. By default, the "Format Painter" will deactivate after one use (one application of the format). To keep it active for several uses, double click the "Format Painter" button. This will keep the tool active until you deactivate it (by clicking the "Format Painter" button again). The "Format Painter" can also be seen in Figure 4.9.

Direct character formatting is recommended only for singular usage! If you are applying the same formatting in more than one place in your document, you should define and use a "Style" (see the appropriate chapter in this book).

Create a document with random text and apply the formatting seen in Figure 4.12. Don't forget to use the formatting replicating tools presented above, when needing to copy formatting in more places.
You can generate a document with random text in Word by opening an empty document and then typing "=rand(*x*)" and hitting "Enter", where you replace x with the number of paragraphs of random text you want to generate. For example, typing "=rand(10)" and hitting "Enter" in an empty document, will generate 10 paragraphs of random text.
Also, you can use =rand(*x*,*y*) to generate a specific number of paragraphs and sentences per paragraph of random text (*x* represents the number of paragraphs and *y* represents the number of sentences per paragraph). For example, typing "=rand(3,5)" and pressing "Enter" will create 3 paragraphs, each containing 5 sentences. This gives you more control over the structure of the generated text.
Similarly, you can use "=lorem(*x*)" or "=lorem(*x*,*y*)" if you'd like the same structure but with "Lorem ipsum" text instead.

Video provides a **powerful way to help you prove** your point. When you click Online Video, you can paste in the embed ***code for the video you want to add***. You can also type a keyword to search online for the video that best fits your document.

To make your document **look professionally produced**, Word provides header, footer, cover page, and text box designs that complement each other. For example, you can add a matching cover page, header, and sidebar. Click Insert and then choose the elements you want from the different galleries.

Themes and styles also ***help keep your document coordinated. When you click Design and choose a new Theme, the pictures, charts***, and SmartArt graphics change to match your new theme. When you apply styles, your headings change to match the new theme.

Save time in Word ***with new buttons that show up where you need them. To change the way a picture fits in your document, click it and a button for layout*** options appears next to it. When you work on a table, click where you want to add a row or a column, and then click the plus sign.

Reading is easier, too, in the **new Reading view**. You can collapse parts of the document and focus on the text you want. If you need to stop reading before you **reach the end**, Word remembers where you left off - **even on another device**.

Figure 4.12. Create a document and apply the formatting presented in this figure

Paragraph formatting

The definition of a paragraph, according to Word at least, is everything that can be found either between two paragraph delimiters (also called pilcrows, shown as ¶) or between the beginning of the

document and the first pilcrow. This includes all text, images, and tables. So, for instance, the document seen in Figure 4.13, will have four paragraphs: one paragraph between the start of the document and the first pilcrow, and then three more paragraphs between each pilcrow pair.

By the way, to see non-printable characters, such as white spaces, tabs and yes, even pilcrows, you can use the "Show/Hide ¶" command from the "Paragraph" group of the "Home" tab (Figure 4.14).

Video·provides·a·powerful·way·to·help·you·prove·your·point.·When·you·click·Online·Video,·you·can·paste·in·the·embed·code·for·the·video·you·want·to·add.·You·can·also·type·a·keyword·to·search·online·for·the·video·that·best·fits·your·document.¶

To·make·your·document·look·professionally·produced,·Word·provides·header,·footer,·cover·page,·and·text·box·designs·that·complement·each·other.·For·example,·you·can·add·a·matching·cover·page,·header,·and·sidebar.·Click·Insert·and·then·choose·the·elements·you·want·from·the·different·galleries.¶

Themes·and·styles·also·help·keep·your·document·coordinated.·When·you·click·Design·and·choose·a·new·Theme,·the·pictures,·charts,·and·SmartArt·graphics·change·to·match·your·new·theme.·When·you·apply·styles,·your·headings·change·to·match·the·new·theme.¶

Save·time·in·Word·with·new·buttons·that·show·up·where·you·need·them.·To·change·the·way·a·picture·fits·in·your·document,·click·it·and·a·button·for·layout·options·appears·next·to·it.·When·you·work·on·a·table,·click·where·you·want·to·add·a·row·or·a·column,·and·then·click·the·plus·sign.¶

Figure 4.13. A document with four paragraphs

Figure 4.14. "Show/Hide ¶" command

Paragraph formatting can be applied from:

- The "Paragraph" group of the "Home" tab (Figure 4.15) and the "Paragraph" group from the "Layout" tab (Figure 4.17) –Microsoft divides paragraph settings into two tabs to enhance organization and usability. The Home tab contains basic, frequently used formatting options like alignment and line spacing, while the Layout tab includes advanced settings such as indentation and spacing.
- By using the "Paragraph" dialog box, by clicking the dialog box launcher on either of the two groups mentioned above (Figure 4.16).

When setting up a paragraph, the most common attributes that you will want to consider setting are the following:

- Alignment – determines how the text of the paragraph is aligned relative to the margins of the page.

- Align left (Ctrl+L) – all text will be aligned to the left side of the page, unoccupied space will be left on the right side of the page.
- Align Right (Ctrl+R) – all text will be aligned to the right side of the page, unoccupied space will be left on the left side of the page.
- Center (Ctrl+E) – all text will be aligned to the middle of the page, unoccupied space will be left both on the right and left sides of the page.
- Justify (Ctrl+J) – all text will be aligned both to the left and right margins of the page, unoccupied space will be evenly distributed between the words of the paragraph (for example paragraphs in this book are justified).

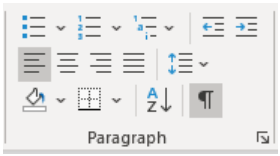


Figure 4.15. "Paragraph" group on the "Home" tab

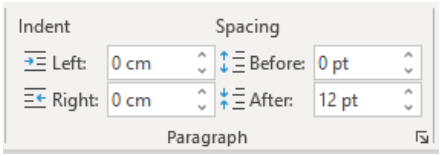


Figure 4.17. "Paragraph" group on the "Layout" tab

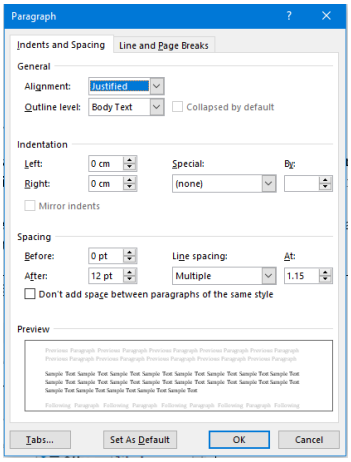


Figure 4.16. "Paragraph" dialog box

- Indentation – determines how much space (usually in inches, millimeters, or centimeters) is left from the margins of the page until the paragraph text.
  - Left and right – sets the indentation for the whole paragraph.
  - Special – sets the indentation for the "First line" of the paragraph, but also a "Hanging" indentation can be set. "Hanging" is a type of indentation where the first line of a paragraph is aligned with the left margin, and all subsequent lines are indented. This creates a visual effect where the first line "hangs" out to the left of the rest of the paragraph. This style is often used in lists of references or citations.

Note that the indentations are reflected and can also be set on the horizontal ruler.

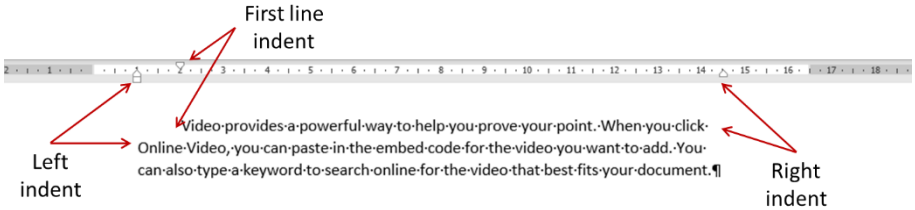


Figure 4.18. Indentation setup reflected on the horizontal ruler

Always indent your paragraphs using the indentation controls available. Never indent your text using the "Tab" key or even worse, by using white spaces, since this can cause unexpected behavior, especially if you later change the font throughout the document.

- Paragraph spacing – determines how much space (usually in points – pt) is left horizontally between each paragraph (1 pt is equal to 1/72 of an inch).
    - Before – sets how much space is left before each paragraph.
    - After – sets how much space is left after each paragraph.

  Note that on adjacent paragraphs, if the spacing set for "before" and "after" do not match, the higher value will be used. For example, if we have a paragraph that has "12 pt" set as spacing "after" followed by a paragraph that has "24 pt" spacing set as "before", the horizontal distance between the two paragraphs will be "24 pt" (the higher value is applied, rather than the sum of the values).

Always use the paragraph spacing controls available to set horizontal distances between paragraphs. Never use empty paragraphs (i.e. adding line breaks by using the "Return/Enter" key) in order to distance paragraphs between one another as this can cause paragraphs to move around unexpectedly when applying/changing formatting, especially if changing fonts later on.

- Line spacing – determines the horizontal spacing between the lines of text within the paragraph. By default, line spacing is set at "1.08 pt", however most professional documents (such as articles, scientific journal papers, etc.) will have a specific requirement for line spacing, ranging from "single" up to "1.5 lines".
- Tabs – determines the exact position a "Tab" character will stop and how the text will be aligned respective to that tab character. Tab stops are predefined positions set along the horizontal ruler in a Word document, which determine where the cursor moves when you press the Tab key. There are different types of tab stops that align text in various ways (Figure 4.19 and Figure 4.20). This can be used in exceptional cases, when there is no better way of setting up a paragraph (Figure 4.21).

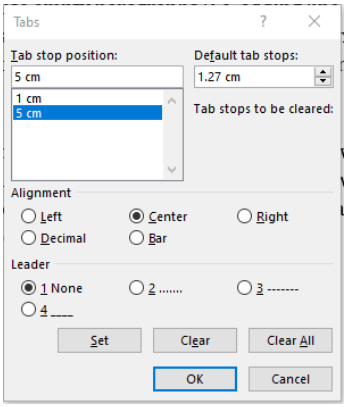


Figure 4.19. Tab stops setup

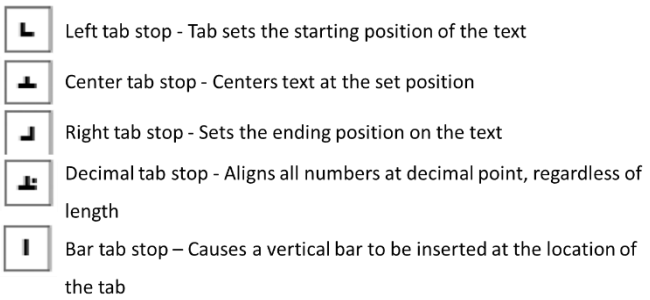


Figure 4.20. Tab stops types

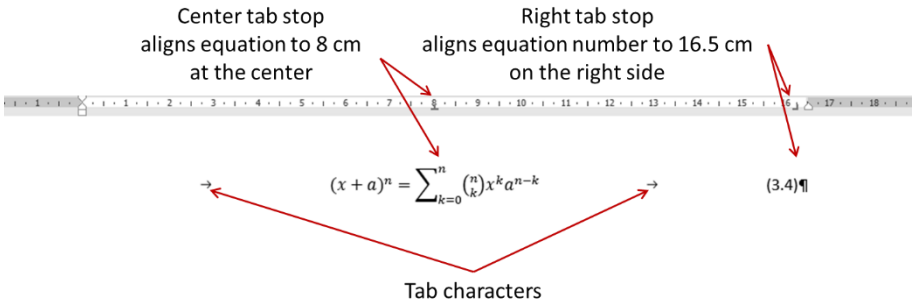


Figure 4.21. Aligning and numbering an equation by using tab stops

Create a document with random text and then format the paragraphs by using the techniques presented in the previous two sections, regarding character and paragraph formatting as presented in Figure 4.22.

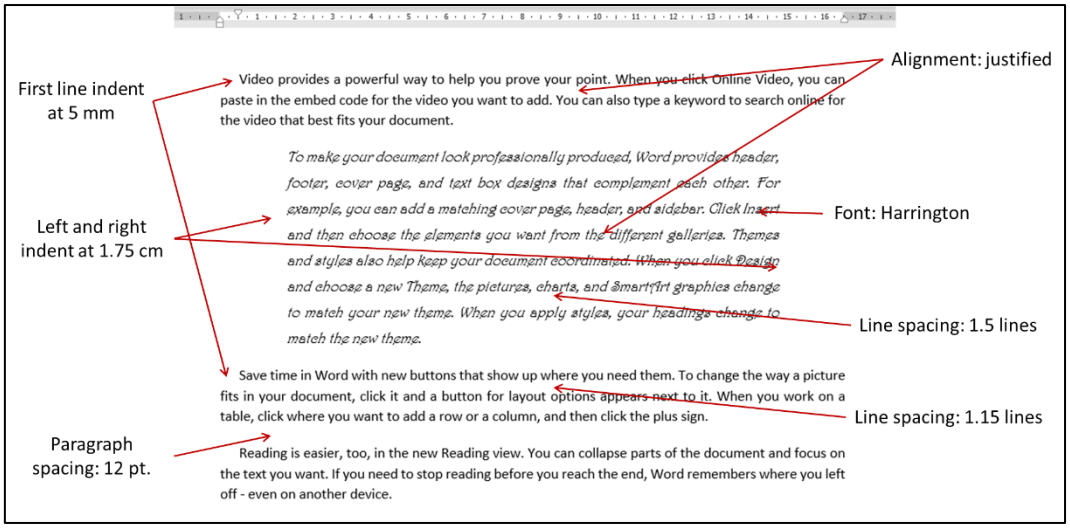


Figure 4.22. Character and paragraph formatting exercise

Section formatting

In order to apply formatting at a section level, first you must define sections within your document. A document can be separated into multiple sections by using “Section breaks” which can be inserted from the “Break” button in the “Page setup” group of the “Layout” tab of the Ribbon interface (Figure 4.23).

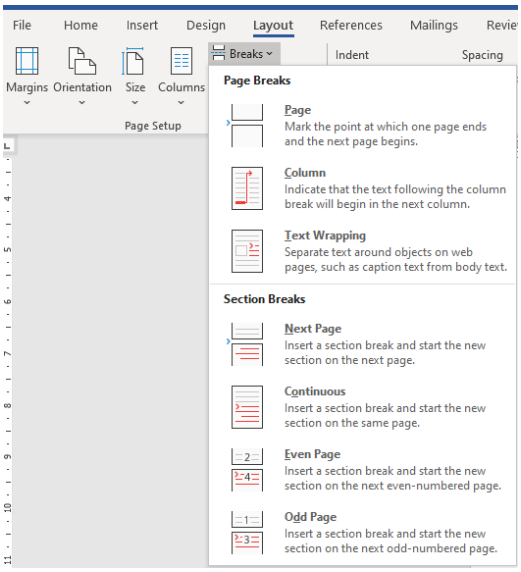


Figure 4.23. Section break types

Inserting a “Section break” will divide the document into two sections. Further sections can be added by inserting additional “Section breaks”. By definition, Word considers a section, everything that is found between two “Section break” symbols or between the beginning of the document and the first “section break” as well as the last “section break” and the end of the document (Figure 4.24). “Section break” symbols can be observed by showing the non-printable characters in the document (Figure 4.14).

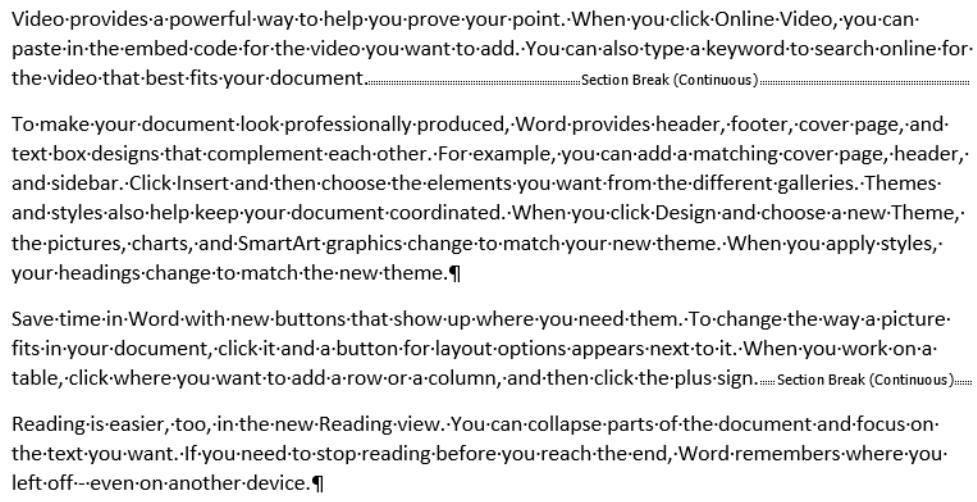


Figure 4.24. A document with three sections

There are four types of section breaks that can be used:

- Continuous – will just divide the document into sections, at the point where it is inserted.
- Next page – will divide the document into sections, but it will also force the text following the point of insertion onto a new page.
- Even page – will have the same effect as the “next page” section break, however, it will force the text following the insertion point to be positioned on the next even page (will skip and leave blank an odd page, if it is the case).
- Odd page – will have the same effect as the “next page” section break, however, it will force the text following the insertion point to be positioned on the next odd page (will skip and leave blank an even page, if it is the case).

Even and odd page section breaks are especially useful for large documents (such as books), in case the user wants a new section (typically a chapter) to begin either on the left- or right-hand side of the book. An important thing to be remembered, however, is that if the insertion of an even or odd page section break results in the need of an empty page, this **will not show up in the Word document** as an empty page, however it will result in an empty page, when printing the document. For example, inserting an even page section break on page 62 of a document will force the text following the section break onto page 64. Page 63 will be a blank page, however, it will not show up at all in the document

in Word. In this case, when scrolling through the document page 62 will be followed directly by page 64. But, when printing the document, page 63 will be printed as a blank page.

Inside a Word document, each section can have separate (and hence different) settings for the following:

- Margins – the space between the margins of the paper and where the text starts/ends. Margins can have different settings on all directions: top, bottom, left and right. They can also be mirrored when editing bound publications such as books (in which case the inside margins should be wider to have enough space for the binding).
- Orientation – defines the orientation of the pages within the section, between portrait and landscape.
- Size – defines the page size for the section.
- Columns – sets across how many columns the text is displayed.
- Line numbering – provides the ability to number the lines within a section. Especially useful when documenting computer code, as lines of code can be numbered and then referenced later by their number.
- Hyphenation – tell Word whether to use hyphenation when breaking sentences across the page.
- Headers and footers – usually used to provide navigation information to the user across a long document, such as page numbers, chapter or subchapter titles and so on. Headers and footers not only be customized for each section separately, but for each section, different headers and footers can be defined for odd and even page or the first page of the section (Figure 4.25).

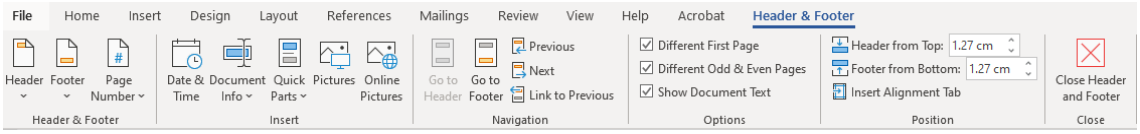


Figure 4.25. Header and footer settings with different headers and footers enabled for the first page of the section and for odd and even pages

When setting up different headers and footers for different sections the "Link to Previous" button in the "Navigation" group will be enabled by default. This links the current headers and footers of the current section to the ones from the previous section. As a result, all changes made in the headers and footers of the current section will be also applied to the headers and footers of the previous section. In cases where this is not the desired behavior (for instance, if each section wants to have its title in the header), the "Link to Previous" button needs to be disabled before making any modifications in the headers and footers.

When working with a document that contains multiple chapters, each chapter should be separated into a separate section, even when all the settings across the chapters are the same. This will make any future modifications to the document much easier, as well as enable

numbering of chapter titles, figures and tables to contain the chapter number (such as the numbering of figures in this book, for example).

Create a long document (20+ pages) with random text and then perform the following operations:

- Divide the document into three chapters/sections.
- Set up all chapters to have the paper size of A4.
- In the second chapter the orientation of the pages is landscape, while in the other chapters the orientation is portrait.
- In the second chapter the text is displayed in two columns across the page, while in the other chapters the text is displayed normally, in one column.
- Insert page numbers in the footer of the document, for each chapter. The numbers are aligned to the middle of the page.
- For each individual chapter, set up the headers as follows:
    - The first page of each chapter does not have any information in the header.
    - The odd pages of the chapters contain the chapter title, i.e. Chapter One, Chapter Two and Chapter Three, aligned to the right side of the page.
    - The even pages of the chapters contain the imaginary title of your work, aligned to the left side of the page.

Styles

By using styles, you can make easy and consistent changes across the whole document with a few (or even just one) click. This ensures a more organized way of editing and formatting your document as well as aids in making changes throughout the document without the need for searching for specific sections/paragraphs within it.
By setting up a style, you can predefine settings to all things related to font and paragraph formatting, tab stops, borders, language, frames, numbering and text effects. You can even add a shortcut key to your style, which makes it easier to apply.
Microsoft Word comes with a set of predefined styles. These can be found in the appropriately named "Styles" group in the "Home" tab of the Ribbon interface (Figure 4.26).

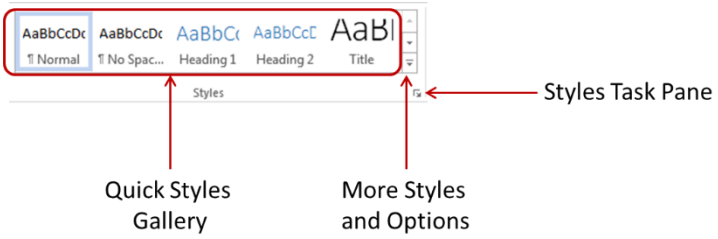


Figure 4.26. The "Styles" group with predefined styles

To be noted however, that these predefined styles might not be to your liking (and honestly, no wonder, since they are truly horrendous). But they are a good starting point and luckily then can be customized and set up to look just the way we want it. But before we do that, we need to know how a few of these styles work.

First of all, we should bear in mind that all paragraph text in a document (such as this text that you are reading), if not modified, by default, uses the "Normal" style defined within the document. This means that if we modify the "Normal" style in a document, the modification that we make will be applied to all of the paragraphs within the document.

There are a few other styles which we should use in a particular fashion, in order to get the most of our document. For example, "Heading 1/2/3…" styles should always be used to define chapter titles – "Heading 1", subchapter titles – "Heading 2", and so on. This will make it easier later on to generate an automatic table of contents for our document.

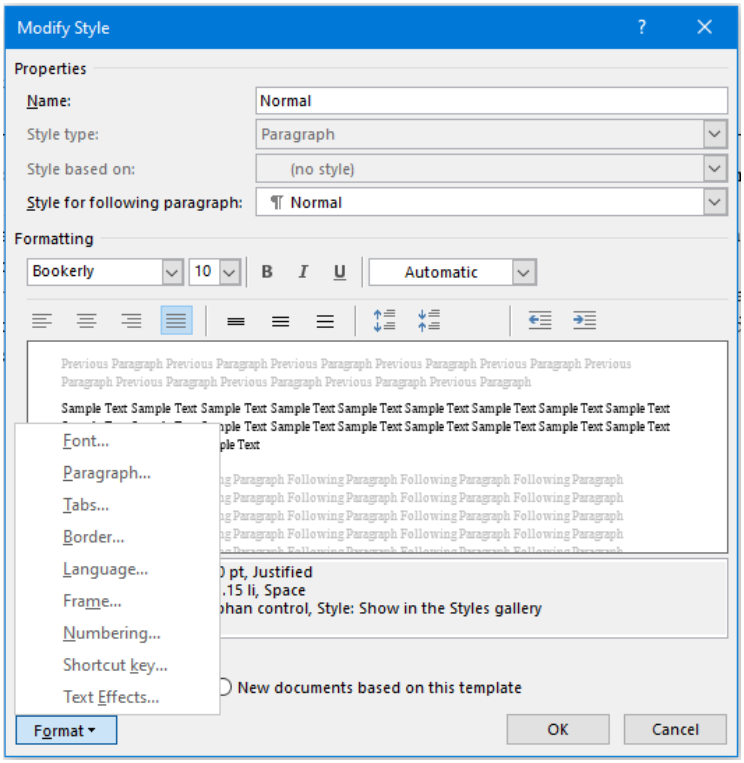


Figure 4.27. The dialog box for modifying a predefined style

Image captions (which we will learn about a little bit later), on the other hand, use the "Caption" predefined style. Again, by default, this style is not the prettiest, but we can later modify it to suit our needs.

All other formatting that you consistently apply to your document should also be defined as a style. For example, if you constantly have quotations within your document and you want them to be formatted in a specific way (let's say you want them to use a font that simulates handwriting and are aligned more to the middle of the page), you should create a new style for that (or use the build-in "Quote" style). If you have text within your document that you want to make it stand out (for instance, you want it to be bold), you should define a style for that too (or use the predefined "Emphasis" style). So, all formatting that you apply more than once across your document, should be defined as a separate style. This way, if you ever change your mind, you can just change the definition of the style, and all formatting is applied across the document, without the need of manually reformatting.

Styles from the "Styles" group can be quickly modified by right clicking on any of them and then selecting "Modify". This will display the "Modify Style" dialog box, where you can directly modify a few settings on the main window, however you have access to all the settings of the style by clicking on the "Format" dropdown button on the bottom left-hand side (Figure 4.27).

You can also access the "Styles" task pane (Figure 4.28) by clicking the dialog box launcher button on the "Styles group" (Figure 4.26). From here, you can create your own style by using the "New Style" button, inspect the style a given element is using by selecting the "Style Inspector" or access additional features by using the "Manage Styles" button.

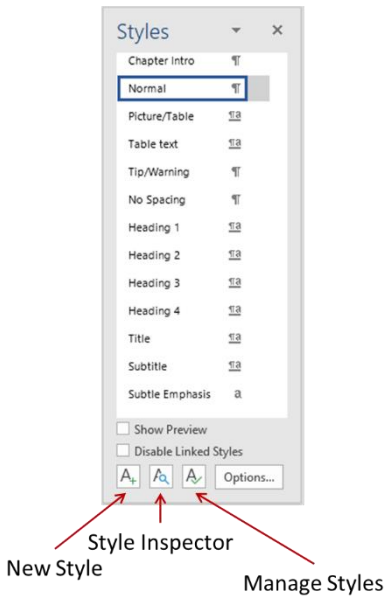


Figure 4.28. "Styles" task pane

Create a document with a chapter title and 3 paragraphs and format the "Styles" to reflect the formatting presented in Figure 4.29.
Format "Heading 1" as follows:

- Font: Arial, 26 pt., bold, red

- Paragraph: justified, aligned to the left by 1 cm, 12 pt. before, 18 pt. after, single line spacing
- Border: 3 pt. red border below the text

Format the "Normal" text as follows:

- Font: Arial, 12 pt.
- Paragraph: justified, first line at 1.5 cm, 0 pt. before, 12 pt. after, line spacing at 1.5 lines

Create a new style named "MyQuote" and format it as follows:

- Font: Brush Script MT, 16 pt., italics, gray
- Paragraph: justified, 1.5 cm indentation both on the left and right sides, no first line indentation, 6 pt. before, 18 pt. after, single line spacing

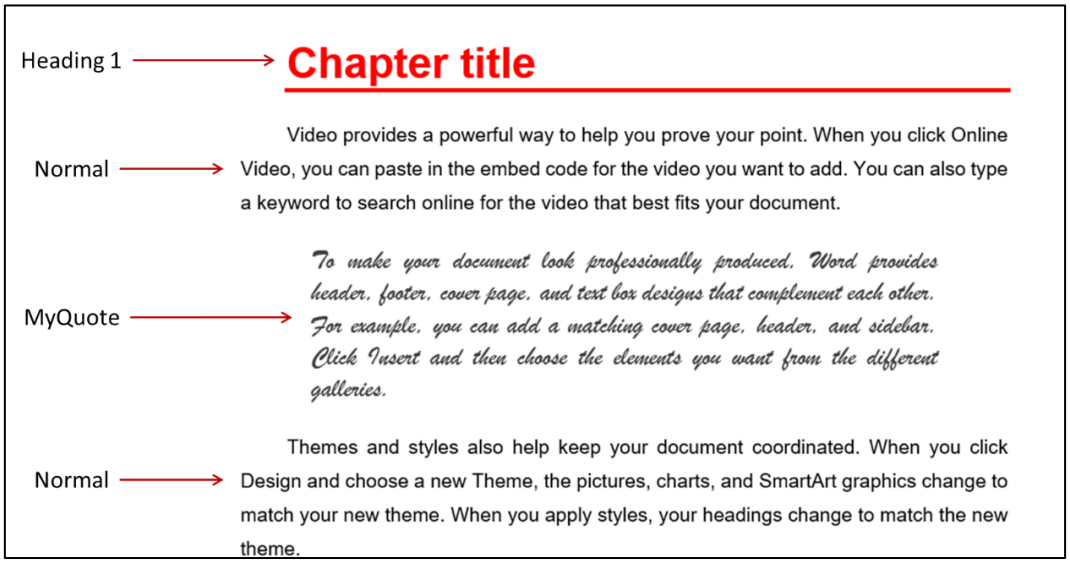


Figure 4.29. Practice exercise

Now, let's imagine a scenario where we wake up one morning, and we come to the realization that the red title is a little bit too "in your face" and that the font used for quotations is really unreadable and that it's outdated to indent the first lines of paragraphs. And now we need to change that throughout the document. If we wouldn't have used styles, this would be a very laborious process, where we would need to change each individual paragraph, find all quotations and change their fonts, etc. Luckily, with styles, we can change the style definition, and all changes are applied automatically, across the whole document. The modified document should now look like Figure 4.30.

Modify the "Heading 1" style to replace the red font color with green and update the border to also be the same shade of green.

Modify the "Normal" style to remove the first line indentation for paragraphs.

Modify the "MyQuote" style to use "Lucida Handwriting" as font with the size of 12 pt.

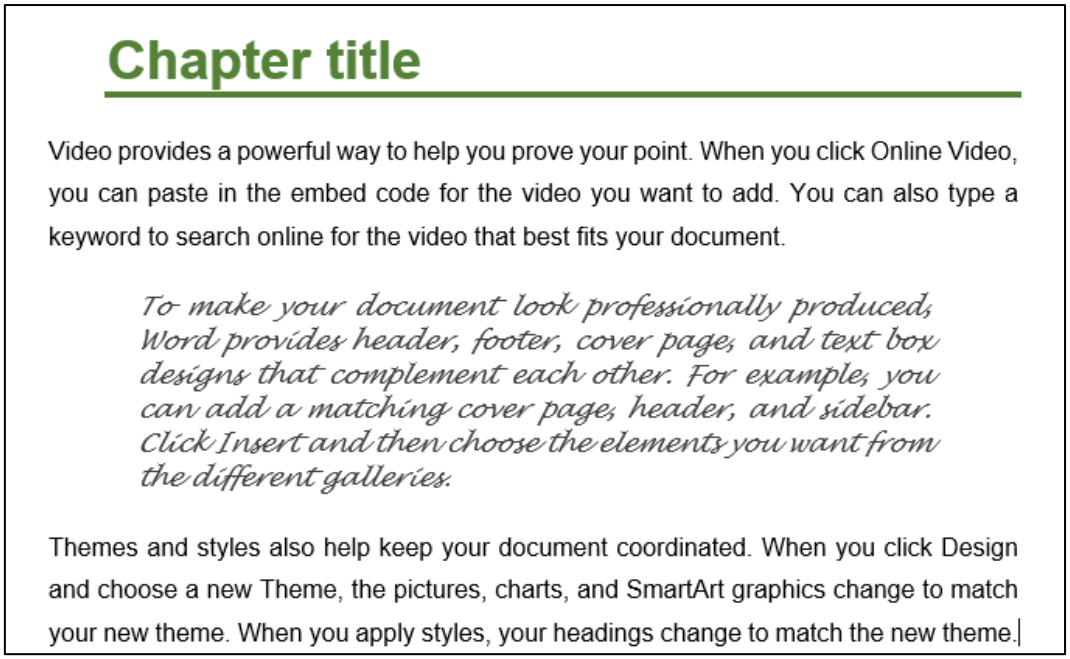


Figure 4.30. Modifying styles

You may encounter difficulties in applying or modifying borders. This is because there is a certain order in which the process should be performed. First off, select the "Style" of the border, the "Color" and the "Width". Then, on the "Preview" pane, click where you want to apply the border defined (i.e. click below the diagram to apply border below a paragraph). See Figure 4.31.

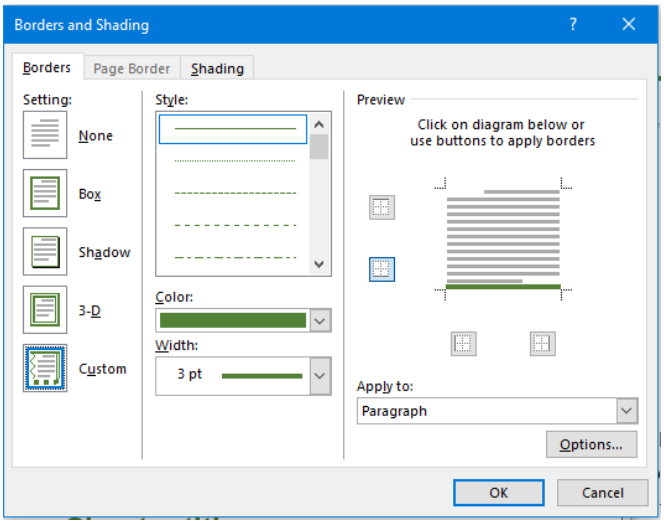


Figure 4.31. Applying borders to paragraphs

Pictures and images

There are several ways of inserting images into a Word document. You can use the “Pictures” option from the “Illustrations” group of the “Insert” tab from the Ribbon interface. Alternatively, you can either drag-and-drop an image into a document, or you can copy-paste it. However, when inserting an image by using the “Pictures” option, you have a little bit more control over how your image is inserted into the document by using the dropdown arrow on the “Insert” button (Figure 4.32):

- Insert – the picture will be embedded (saved inside) the document. This is the default option and it is also used when pasting or drag-and-dropping an image into a document.
- Link to file – only the path of the picture is saved in the document. Whenever the document is opened, the path is searched and if the image is found, it is displayed in the document. This is great, because in this scenario, the image is updated every time the document is opened. So, it is a great way of keeping your images up to date. However, if the image is moved or deleted, and it is not found, no image will be displayed.
- Insert and Link – is both above options combined. Both the path of the image, and the image itself are saved in the document. When opening the document, if the image is found in the stored path, the image in the document is updated and the updated version is saved. If the path is no longer valid, the last saved version of the image is displayed in the document.

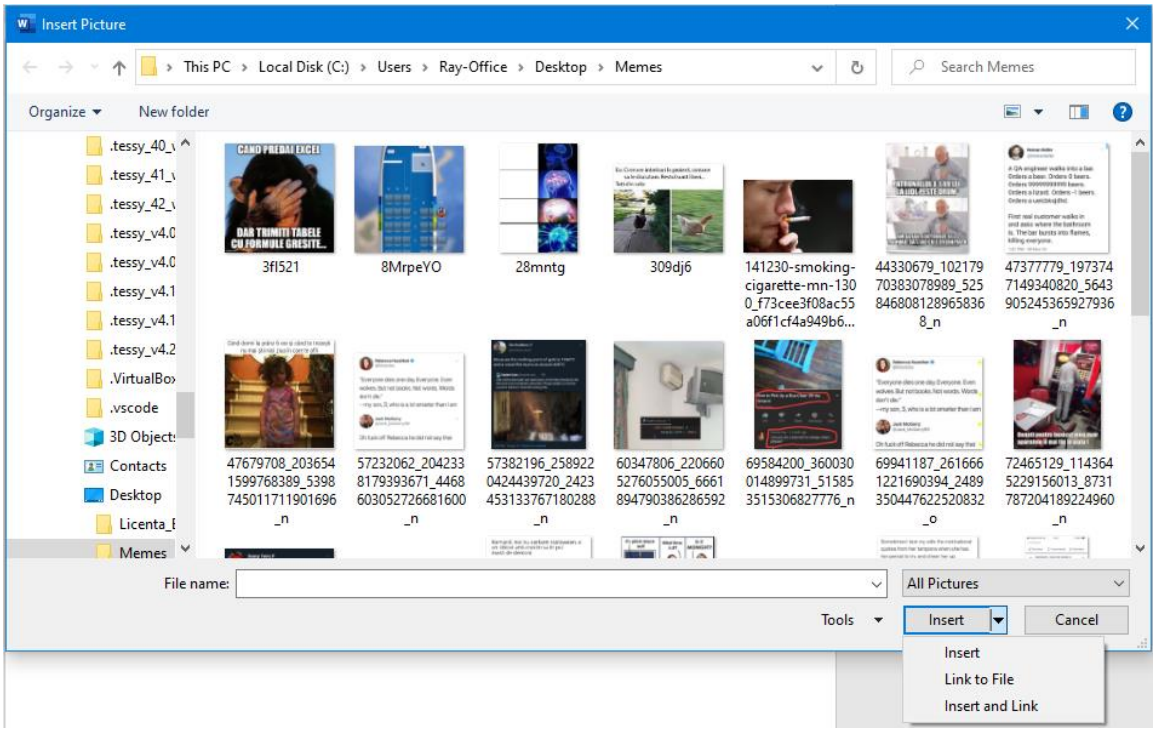


Figure 4.32. Picture insert options

When working with a picture (a picture is selected), the "Picture Format" tab is available in the Ribbon interface (Figure 4.33). This contains the following formatting options and submenus:

- Remove background – a tool for removing the background color from images.
- Adjust – several tools for adjusting the look of the image.
    - Corrections – Sharpness, brightness and contrast adjustments.
    - Color – Saturation, tone and recolor options. Also, here you can find a "Set transparent color" option, with which you can define a color in an image as being transparent. Select this tool and click on any color in the image and that given color will be set to transparent. This is also useful for removing white (or any other) background colors from images.
    - Artistic Effects – different artistic styles. Note that your Word document is not your Instagram account, so you should probably just ignore this feature.
    - Transparency – controls the transparency of the image (duh!).
    - Compress Pictures – will reduce the amount of memory the images take up in your document (but it may also reduce image quality, so use with caution!).
    - Change Picture – replace the selected image.
    - Reset Picture – reset all formatting applied to the image.
- Picture styles – applies borders and other artistic effects to your image. Again, not Instagram, so not recommended.
- Alt Text – alternative text if image is not visible or audio description is used for people with disabilities.
- Position – where the image is placed on the document (usually the default placement is quite alright in newer versions of Word, so not necessarily something to change).
- Wrap Text – how the image and text interact within the document.
    - In Line with Text – the whole image will behave as it were a line of text, it will be aligned with the text, on the same line (the bottom of the image) (Figure 4.34).
    - Square – the text will wrap around the image, so multiple lines of text will be displayed next to the image (if they fit) (Figure 4.35).
    - Through – the same as "Square", however, text will also flow inside the transparent portions of the image (if it fits).
    - Top and Bottom – no text will be placed near the image and all text will flow either above or below the image (Figure 4.36).
    - Behind Text – image will be placed behind the text (the text will cover the image)
    - In Front of Text – image will be placed in front of the text (the image will cover the text).

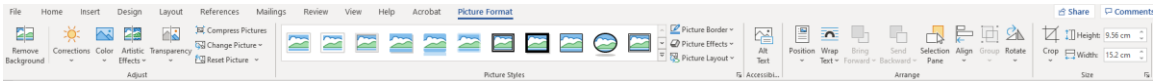


Figure 4.33. Picture format tab

- Bring Forward/Send Backward – controls for overlapping images and which overlaps which.
- Selection Pane – a list of selected images.

- Align – aids with aligning multiple images.
- Group – transforms multiple images into a single group so they can be manipulated together.
- Rotate – apply rotation or vertical/horizontal translations to the image.
- Crop – cut out unwanted pieces from the image sides to make the image smaller or remove elements which you do not want to show. Note that this operation is non-destructive, so you can always have the original image back or lessen the crop, if you wish to do so later on.
- Height/Width – control the height and width of the image.

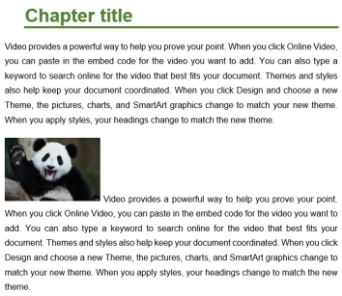


Figure 4.34. Image alignment: In Line with Text

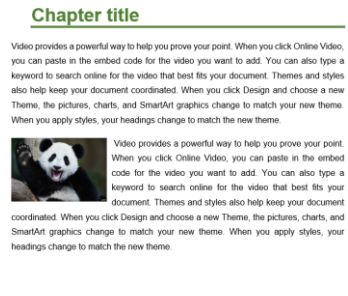


Figure 4.35. Image alignment: Square

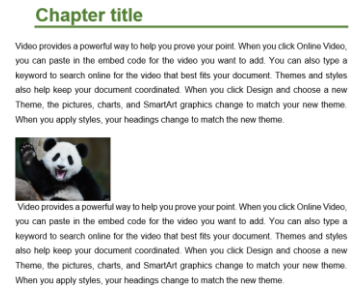


Figure 4.36. Image alignment: Top and Bottom

Note that when resizing images via the "Height" or "Width" controls in "Picture Format" tab on the Ribbon interface the aspect ratio of the image (meaning the relative height and width) is kept constant. This is not the case however, if you decide to resize the image by using the mouse and dragging one of its sides/corners. In this case, since you cannot manually drag the same amount both horizontally and vertically (unless you are some sort of mouse dragging champion), your image will end up distorted. In order to prevent this from happening, and to keep a constant aspect ratio, hold the **Shift** key on your keyboard, while dragging one of the **corners** of the image. Alternatively, you can right-click the image, choose **Size and Position**, and check the **Lock aspect ratio** box under the **Size** tab.

In most cases, when you insert an image in your document, you will want to explain it or talk about it in your text. As a matter of fact, you should never insert an image in your document unless you want to talk about it (do not use images as filler items, just to make your document longer and meet the required length). When you want to reference an image in your document, you should do it by using its caption. Which means actually adding a caption to the image, in the first place.

Captioning an image can be done by right clicking on the image and selecting "Insert Caption…" from the dropdown menu. This will display the "Caption" dialog box (Figure 4.37). Here, you can choose the label for your image. You can either selected from a predefined list of labels or define your own label by pressing the "New Label…" button. For example, in this document, all images are labeled as "Figure". You can also select the position of the caption to be either above or below the image.

Finally, by using the "Numbering" button you can define the numbering style you want to use, by setting the options available in the "Caption Numbering" dialog box (Figure 4.38). Here you can define

the numbering style (e.g.: roman numerals, Arabic numerals, etc.) or whether to include or not the chapter number. Please bear in mind that to include chapter and subchapter numbers, your chapters and subchapters need to be defined using the appropriate heading levels, as discussed in the "Styles" section, earlier on. For example, in this document all images include the chapter number when captioning images.

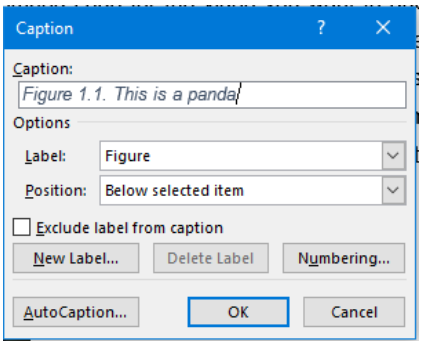


Figure 4.37. Caption dialog box

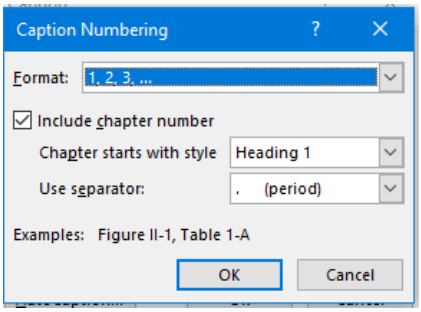


Figure 4.38. Caption numbering dialog box

Image captions use the predefined "Caption" style by default. This means that modifying the styling of image captions is as easy as updating the "Caption" style available in the "Styles" gallery.

Create a document with random text and several chapters. Remember to delimit chapters into separate sections and style chapter titles using the appropriate heading styles. Now, insert a few random images across the document. Practice different image positioning options. Finally, caption the images. Modify the caption style, so the captions are aligned to the middle of the image, they use a black straight font and they include the chapter number as well. If set up correctly, your image captions should resemble the ones used in this document.

Cross-referencing

Cross-referencing helps you to refer to any structural part of a document in your text without the need of remembering numbering or where given items are located. Moreover, you can insert references without the need to type them out and you can update them with a single step, without the need of parsing through the whole document. This way, you can keep your document clean, organized, and up to date.

Take the following scenario. Let's say you have a very large document, with several tens or hundreds of images, all captioned and numbered. Obviously, you refer to those images in your text, by their label (e.g.: "Figure 4.37", "Figure 4.38"). Now imagine that you insert one additional image in the middle of your document. Obviously, this will renumber all images in your document, and now, if you typed out

the references to the images manually, in your text, all references that follow the newly inserted image are wrong. Cross-referencing fixes exactly this problem.

In order to insert a reference, you need to access the “Insert” tab and then find the “Cross-reference” button in the “Links” group of the Ribbon interface (Figure 4.39). This will show the “Cross-reference” dialog box.

Figure 4.39. The "Insert" tab of the Ribbon interface

In the “Cross-reference” dialog box (Figure 4.39) you can choose:

- Reference type: what type of item are you referencing (headings, figures, tables, etc.).
- Insert reference to: whether you want to insert the whole caption of the item, only the label and number (like in this document, for example), only the caption text, the page number the reference is on, or a navigational aid, such as “above” or “below”.
- Insert as hyperlink: will make the reference clickable, if the user opens the document on a computer, they can use “Ctrl+Click” in the reference to navigate directly to it.
- For which caption: finally, choose the item you want to reference.

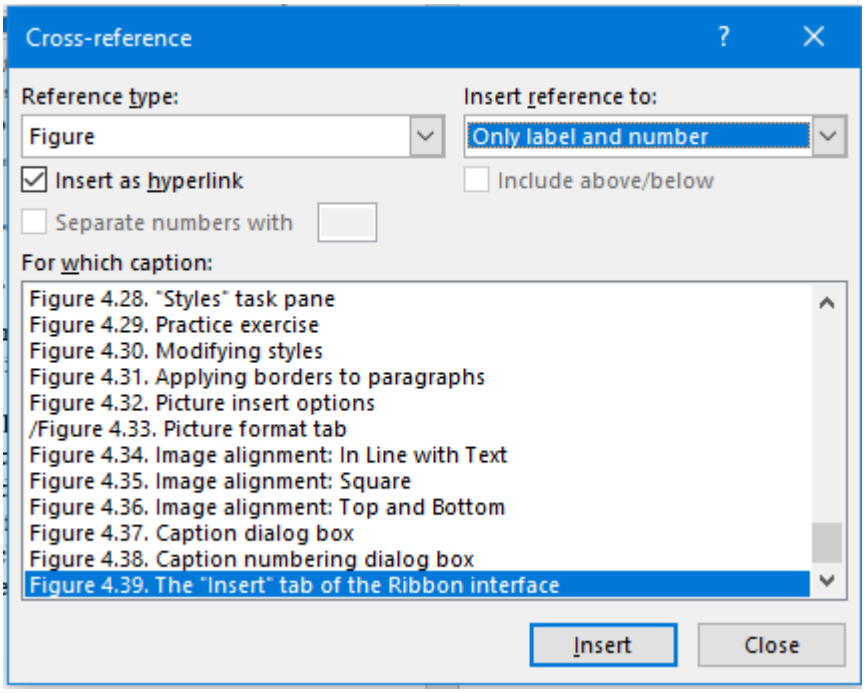
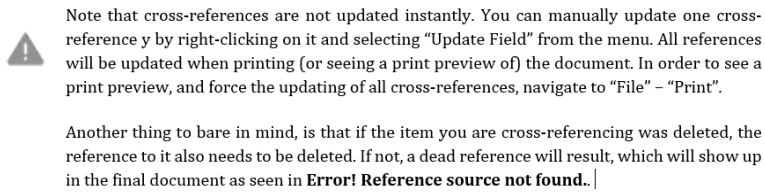


Figure 4.40. "Cross-reference" dialog box

By using this technique to insert references, instead of directly typing them out, whenever you change the numbering of an item or insert additional items, the references will be automatically updated.

Note that cross-references are not updated instantly. You can manually update one cross-reference by right-clicking on it and selecting “Update Field” from the menu. All references will be updated when printing (or seeing a print preview of) the document. In order to see a print preview, and force the updating of all cross-references, navigate to “File” – “Print”.

Another thing to bare in mind, is that if the item you are cross-referencing was deleted, the reference to it also needs to be deleted. If not, a dead reference will result, which will show up in the final document as an unfound reference (as seen in the last sentence of Figure 4.41).


Note that cross-references are not updated instantly. You can manually update one cross-reference y by right-clicking on it and selecting “Update Field” from the menu. All references will be updated when printing (or seeing a print preview of) the document. In order to see a print preview, and force the updating of all cross-references, navigate to “File” – “Print”.

Another thing to bare in mind, is that if the item you are cross-referencing was deleted, the reference to it also needs to be deleted. If not, a dead reference will result, which will show up in the final document as seen in **Error! Reference source not found.**.

Figure 4.41. Missing reference example

Citing bibliographical references

Plagiarism, also known as theft of intellectual property, is not only frowned upon, but is also illegal and, if detected, will certainly get your work rejected. Therefore, whenever you make a factual statement or take results from other sources, you should always cite where that information is from. In order to do this, we can use the “References” tab from the Ribbon interface. Here, you will find the “Insert Citation” button, which can be used to insert a new bibliographical reference (Figure 4.42).

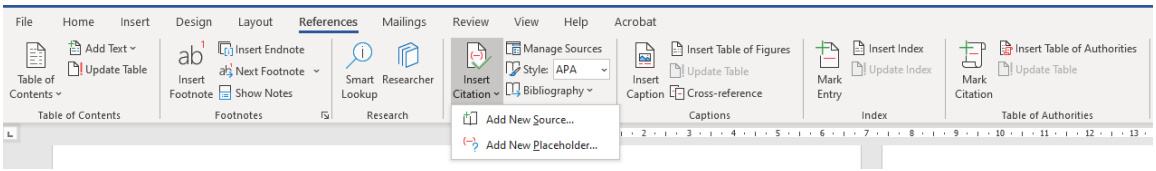


Figure 4.42. The "References" tab on the Ribbon interface

Here, you can either choose to insert an already existing source or add a new source by selecting the “Add New Source…” option. This will launch the “Create Source” dialog box (Figure 4.43). From this dialog box you can select the type of source you are citing (books or journal articles are preferred for scientific papers) and then complete the appropriate fields (the more, the better) about your cited source. After completing this dialog box and hitting “OK”, the bibliographical reference will be inserted. The default style is “APA”, however, in engineering works the “IEEE” style defined by the Institute of Electrical and Electronics Engineers should be used.

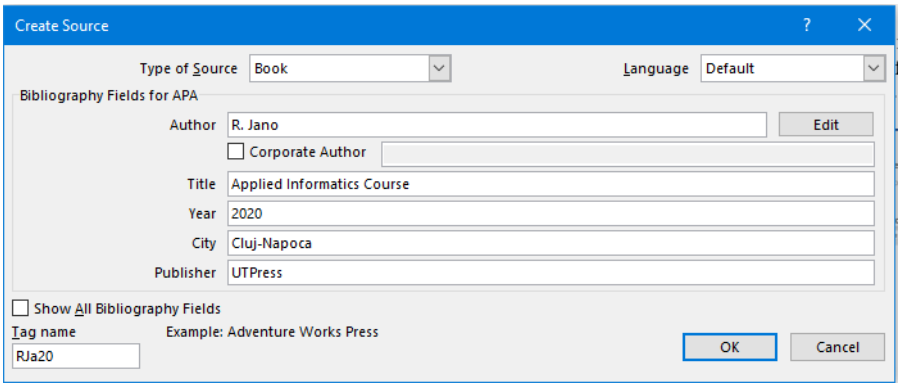


Figure 4.43. "Create Source" dialog box

Finally, at the end of your document, you should generate the full list of Bibliographical references, of Bibliography, as it is commonly called. To do this, you can use the "Bibliography" button from the "Citations & Bibliography" group found on the "References" tab (Figure 4.42). This will generate the list of Bibliographical references, as seen in Figure 4.44.

Bibliography

[1] D. Pitica and M. E. Radu, Elemente de testare pentru sisteme electronice, Cluj-Napoca: Editura Albastra, 2001.

[2] D. Pitica and C. Sortoc, Testarea echipamentelor electronice, Cluj-Napoca: Casa Cartii de Stiinta, 2001.

[3] S. Mourad and Y. Zorian, Principles of Testing Electronic Systems, USA: John Wiley & Sons, 2000.

[4] E. Larsson, Introduction to Advanced System-on-Chip Test Design and Optimization, Netherlands: Springer, 2005.

[5] D. Gizopoulos, Advanced in Electronic Testing, Netherlands: Springer, 2006.

[6] M. Nicolaidis, Y. Zorian and D. K. Pradhan, On-line Tesing for VLSI, UK: Kluwer Academic Publishing, 1998.

[7] M. Abramovici, M. A. Breuer and A. D. Friedman, Digital Systems Testing and Testable Design, USA: IEEE Press, 1990.

Figure 4.44. Example of an automatically generated list of Bibliographical references

Office clipboard

The “clipboard” is the name of the memory space where applications store the information that has been “copied” or “cut” and can later be inserted via a “paste” operation into a document. This memory space usually has a “size” of one item, which, let’s face it, can be very small, when working in a large document.

The Office clipboard extends this to a 24-item memory space and allows you to handle multiple items at a time. To activate the Office clipboard, you need to press the dialog box launcher button of the “Clipboard” group from the “Home” tab of the Ribbon interface (Figure 4.45).

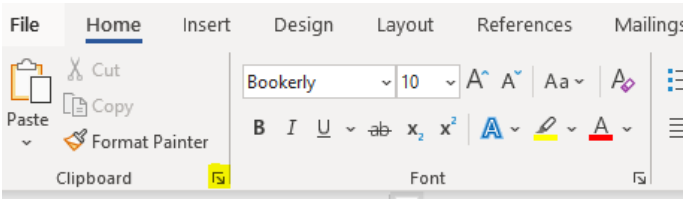


Figure 4.45. Activate the Office clipboard by pressing the marked dialog box launcher

Once activated, the Clipboard side panel is displayed, from which you can paste the items from the Office clipboard by clicking or manipulate them by clicking on the dropdown arrow found near them.

Also, whenever pasting something in a document, the “Paste Options” button is shown (Figure 4.46), which allows you to select from between a number of ways you want to paste your content (e.g.: paste only text, but not the formatting, match formatting when pasting, paste as a picture, etc.).

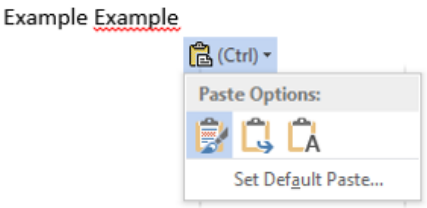


Figure 4.46. Paste Options button

Inserting equations

When inserting equations, they should never be edited using plain text, as this not only is unprofessional, but most likely will make the equation much more difficult to read and understand. Also, if you refer to the equation within your text, then the equations should also be numbered on the right-hand side.

To insert equations, the “Equation Editor” should be used. This can be found in the “Symbols” group of the “Insert” tab of the Ribbon interface (Figure 4.47).

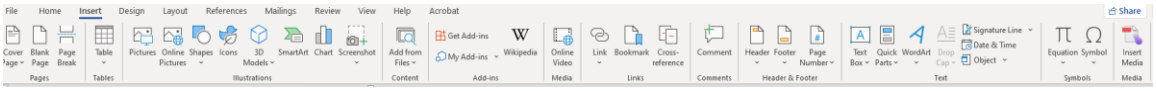


Figure 4.47. The “Insert” tab of the Ribbon interface

After inserting an equation, the “Equation” tab is available in the Ribbon interface (Figure 4.48). Here, you have multiple options to insert and format your equation. The “Symbols” group offers the most commonly used mathematical symbols. It also has a dropdown with the help of which you can switch to other useful sets, such as Greek letters, operators, arrows and many more. The “Structures” group offers ways of adding fractions, scripts and other functions and operators to your equations.

Figure 4.48. Equation editing tools

Create a Word document and insert the equations presented in Table 4.1.

Table 4.1. Equations to be inserted

Equation name	Integral form	Differential form
Gauss’s law	$\oiint_{\partial\Omega} E \cdot \mathrm{dS} = \frac{1}{\varepsilon_0} \iiint_{\Omega} \rho \mathrm{dV}$	$\nabla \cdot E = \frac{\rho}{\varepsilon_0}$
Gauss’s law for magnetism	$\oiint_{\partial\Omega} B \cdot \mathrm{dS} = 0$	$\nabla \cdot B = 0$
Maxwell-Faraday equation	$\oint_{\partial\Sigma} E \cdot dl = -\frac{d}{dt} \iint_{\Sigma} B \cdot \mathrm{dS}$	$\nabla \times \mathrm{E} = -\frac{\partial B}{\partial t}$
Ampere’s law	$\oint_{\partial\Sigma} B \cdot dl = \mu_0 \iint_{\Sigma} J \cdot \mathrm{dS} + \mu_0 \varepsilon_0 \frac{d}{dt} \iint_{\Sigma} E \cdot \mathrm{dS}$	$\nabla \times \mathrm{B} = \mu_0 (\mathrm{J} + \varepsilon_0 \frac{\partial E}{\partial t})$

Generating automatic table of contents

Larger documents, those spanning multiple pages or chapters, should have navigation aids to help the reader easier find information in the document. In order to do this, you can use headers to include chapter and subchapter titles across the document. In addition to this, pages should be numbered. This can be done by accessing the “Header & Footer” group from the “Insert” tab of the Ribbon interface (Figure 4.49).

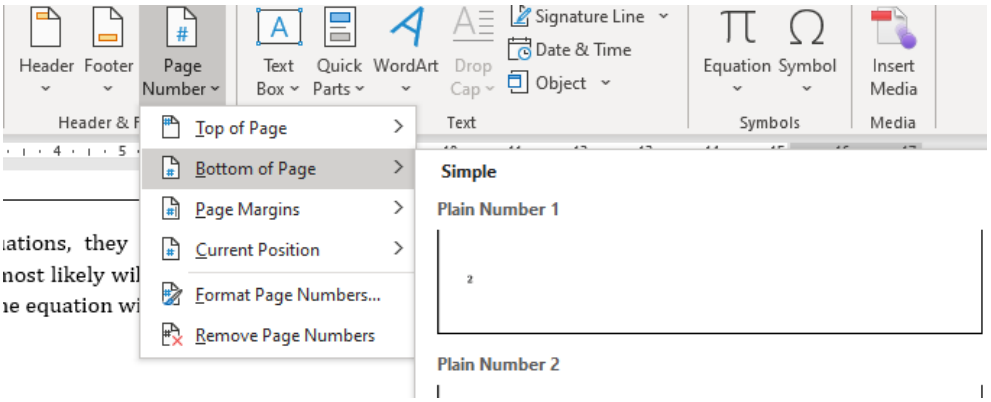


Figure 4.49. Inserting page numbering

Finally, a table of contents should be included either at the beginning or the end of the document. If everything was set up according to the expectations of Word (and as presented in the document: chapter titles formatted as Heading 1, subchapters as Heading 2, etc.) generating the table of contents, can be done with a few simple clicks. You just need to access the “Table of Contents” option from the “Table of Contents” group of the “References” tab from the Ribbon interface (Figure 4.50).

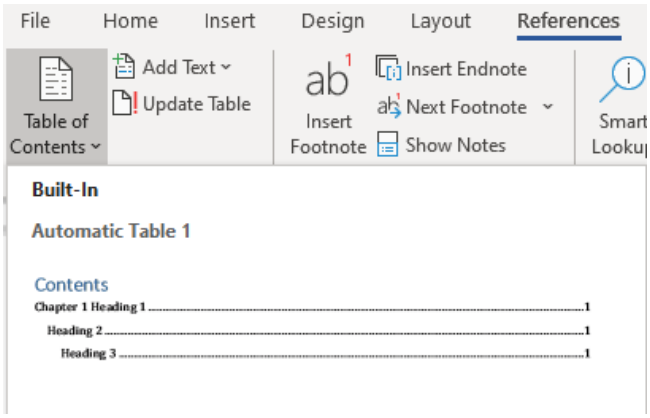


Figure 4.50. Generating automatic table of contents

If you haven't set up everything in accordance with the default expectations of Word, you can still generate a custom table of contents, by selecting the "Custom Table of Contents…" options from the same "Table of Contents" button mentioned above.

Reviewing documents

Reviewing your own document

Before submitting your work, you should always adhere to the following checklist:

1. Reread your document: although this may seem tiresome, always fully reread your document. Very often, our thought process is much faster than we are able to type. This may result in forgetting to type whole or half sentences, which makes the idea we are trying to convey, unclear. Rereading the document assures us that our ideas are understandable. This also helps us proofread our document for spelling and grammar mistakes.
2. Run the automatic "Check Document" option from the "Proofing" group of the "Review" tab from the Ribbon interface. This will check and highlight any spelling and grammar errors in your document and generate a report, from which you can then fix these issues.

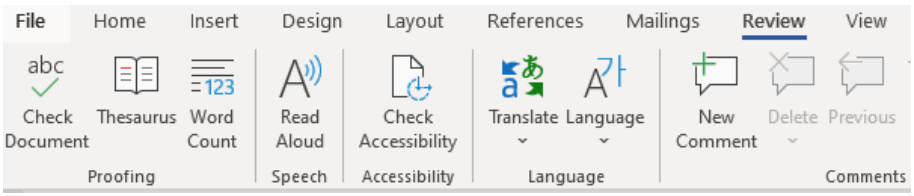


Figure 4.51. The Check Document button

3. If you are planning to print your document, save it to PDF beforehand, review the PDF document and print from PDF, especially if you print your document from another computer, than the original on which you edited your document. PDF ensures that "what you see is what you get", when printing, while printing directly from Word may move around items in your document, depending on the settings of the computer you are printing from. To save a document to PDF, navigate to the "File" tab, and then select "Save a copy" and from the dropdown menu below the document name, select PDF (*.pdf).
4. Optionally, you can mark the document as "Final" or restrict editing by adding a password. These options are available from the "Protect Document" button of the "Info" section of "File" tab from the Ribbon interface.

Reviewing other documents

When reviewing other people's documents, you have two options. The more basic one is just to make a copy of the original document and then make changes/recommendations in the copy. Then, the

original author can use the “Compare” option from the “Review” tab of the Ribbon interface, to see the differences between the original and the reviewed document and decide on the final form of their work.

A more advanced way of doing a review, however, is to use the “Tracking” features found in the “Review” tab of the Ribbon interface (Figure 4.52).

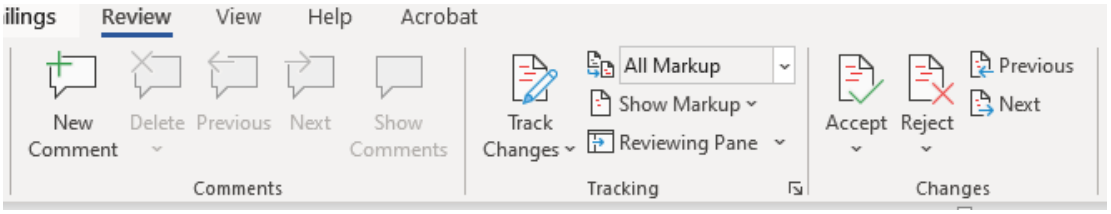


Figure 4.52. Reviewing tools in Word

After activating the “Track Changes” button, all changes made to the document are done in a non-destructive manner and are marked clearly in the document. How much details of the changes made in the document are shown, is controlled by the “Display for Review” dropdown option. Showing “All Markup” will display all the changes made to the document (Figure 4.53). This way, Word will track all deleted, added and modified text and all style and formatting changes and mark them accordingly. If you do not wish to make changes to the document, but have some observations, you can add comments by using the “New Comment” button.

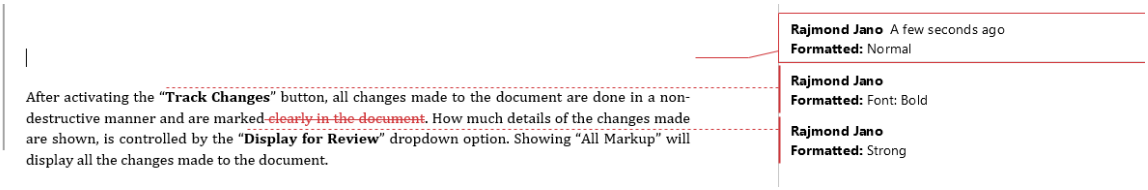


Figure 4.53. Tracking changes to the document

Once you finished your review, you can deactivate the tracking of changes, save the document and send it back to the original author. Now, all they need to do is to navigate through your changes by using the “Previous” and “Next” buttons in the “Changes” group of the “Review” tab and “Accept” or “Reject” these by using the appropriate buttons (Figure 4.52).

Chapter 5

Microsoft Excel

In this chapter

- Excel user interface
- Autofill and entering data
- Formatting cells and creating tables
- Working with formulas
- Data validation and conditional formatting
- Inserting charts and graphs
- Using macros

Microsoft Excel is a spreadsheet developed by Microsoft. It features calculation, graphing tools, pivot tables, and a macro programming language called Visual Basic for Applications. It has been a very widely applied spreadsheet for these platforms, especially since version 5 in 1993, and it has replaced Lotus 1-2-3 as the industry standard for spreadsheets. Excel forms part of the Microsoft Office suite of software.

In this chapter, you will learn how to work with the Excel interface, create tables, automate calculations and formatting, and graphically represent your datasets.

Excel user interface

The Excel user interface is very similar to its Word counterpart, however there are some key differences. First of all, the cursor that indicates the current position within the text in Word, in Excel is replaced by the active cell indicator Figure 5.1). This shows the user which cell is currently active and hence which cell the data will be introduced in. An important thing to note here is that each cell is referenced in Excel by its row number and column letter. So, for example in Figure 5.2 the active cell can be referenced as cell C3. Also note that the cell reference is displayed in the “Name Box”, shown in

Figure 5.2 in the top left-hand side. By typing a custom name in this box, a custom cell reference can be created. For example, by selecting the "Name Box" and typing "myCell", now cell C3 can be referenced later on either by "C3" or by "myCell".

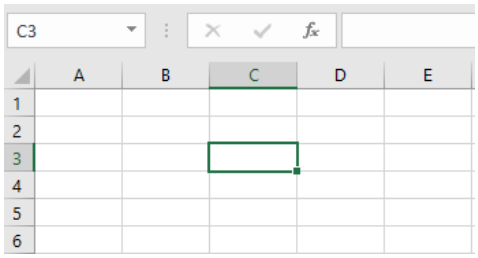


Figure 5.1. Active cell indicator in Excel

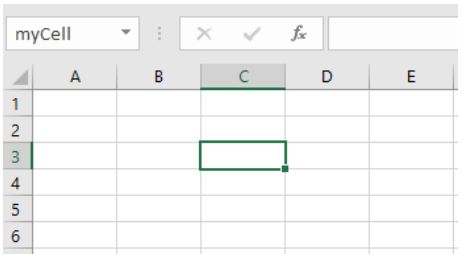


Figure 5.2. Creating custom cell references

Finally, several text editing specific tabs in the Ribbon Interface have been replaced by tabs specific to data entry, processing, representing, and editing. We will gradually go over the most important of these.

Autofill

Excel facilitates manual data entry by providing a feature called Autofill. Using this feature the user can enter the first few pieces of data from their dataset and then either by dragging or by using the Fill command, Excel can "guess" the next pieces of data.

For using the drag feature for Autofill proceed as follows:

- Enter the first two or three pieces of data (Figure 5.3). A single piece of data is enough for dates, days, or single just to copy data. However, if you want your data to follow a mathematical formula, e.g. increment the number 3-by-3, you need to provide the first two pieces of data.
- Select all the cells you have entered data into and then drag the right lower corner of the last cell in the direction you want to fill the data (Figure 5.4).
- Optionally, use the "Auto Fill Options" button to control how the data is filled (Figure 5.6):
    - Copy Cells: Excel will repeat the data in the selected cells, it will not follow a formula to try to guess the next pieces of data.
    - Fill Series: Excel will try to guess the next pieces of data and fill them according to the formula it estimated.
    - Fill Formatting Only: Excel will only replicate the formatting of the selected cells, however data in the cells you dragged over will not be affected.
    - Fill Without Formatting: Excel will only fill the data based on the formula it guessed, but will not replicate the formatting of the source cells.

- Flash Fill: automatically fills your data when it senses a pattern. For example, you can use Flash Fill to separate first and last names from a single column or combine first and last names from two different columns.

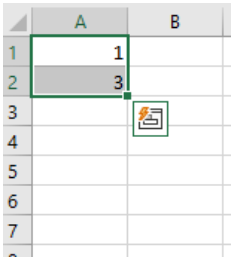


Figure 5.3. Entering data for Autofill

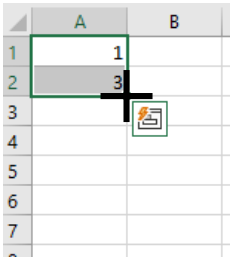


Figure 5.4. Dragging data for Autofill

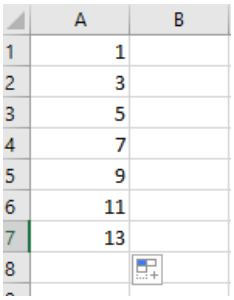


Figure 5.5. Autofill results

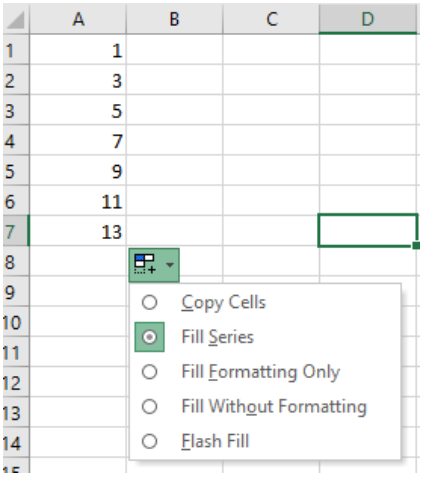


Figure 5.6. The "Auto Fill Options" button

Obviously, dragging is not a solution for large sets of data. In this case, you can use the "Fill" option from the "Editing" group of the "Home" tab from the Ribbon Interface (Figure 5.7). For using the "Fill Series" command (Figure 5.8) you need to:

- Specify the series starting value in your starting cell and select the cell before calling the command.
- In the command dialog bow specify whether to fill the series in Rows or Columns, the type of series you want to use (Linear, Growth, Date or AutoFill) and if needed the Date Unit used.
- Then specify the Step value and the Stop value (up to which value the data is generated).

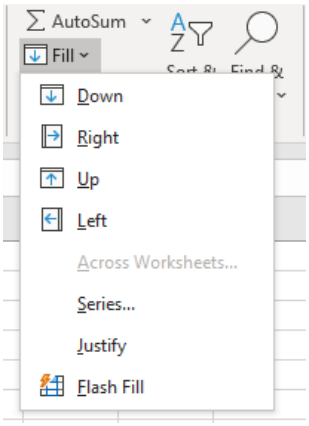


Figure 5.7. the "Fill" option from the "Editing" group of the "Home" tab from the Ribbon Interface

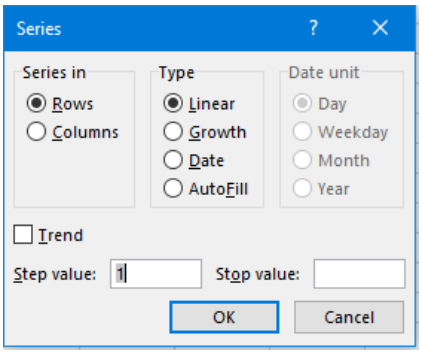


Figure 5.8. Fill Series command

Create the following data series:

- [-10; 10] with a step of 0.5
- [-3.14; 3.14] with a step of 0.1 and alternating red and green text
- [0; 100] with a step of 0.005

The datasets should look like in Figure 5.9.

	A	B	C
1	-10	-3.14	0
2	-9.5	-3.04	0.005
3	-9	-2.94	0.01
4	-8.5	-2.84	0.015
5	-8	-2.74	0.02
6	-7.5	-2.64	0.025
7	-7	-2.54	0.03
8	-6.5	-2.44	0.035
9	-6	-2.34	0.04
10	-5.5	-2.24	0.045
11	-5	-2.14	0.05
12	-4.5	-2.04	0.055
13	-4	-1.94	0.06
14	-3.5	-1.84	0.065
15	-3	-1.74	0.07
16	-2.5	-1.64	0.075
17	-2	-1.54	0.08

Figure 5.9. Sample data for the proposed exercise

Formatting cells

Given the wide range of data Excel is able to process, cells can be formatted to represent data differently. Typically, the data type of each cell is set to "General", meaning that in this case Excel tries to guess the type of data presented in the cell and format it accordingly. Most of the times it does a decent job, and no intervention is necessary, but there are times where Excel either gets the guess wrong, or you want to have a different data representation than the built-in one.

Formatting cells can be done by selecting the cells needed to be formatted and the right-clicking and accessing the “Format Cells…” option. This will display the “Formal Cells” dialog box (Figure 5.10).

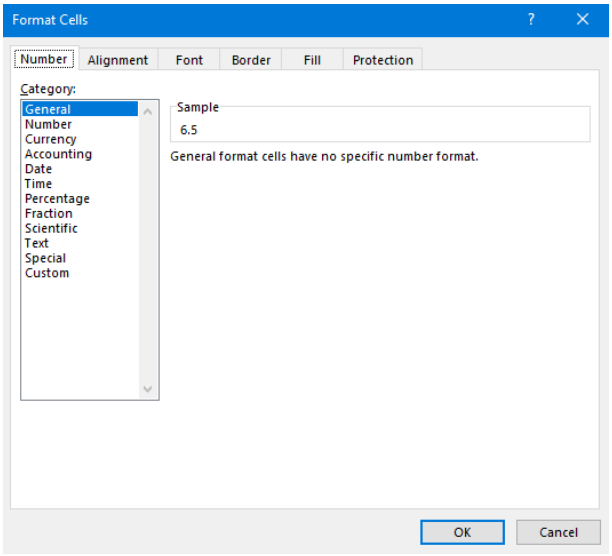


Figure 5.10. Format Cells dialog box

The “Number” tab will allow you to control how data is displayed in your cell. In Figure 5.11 the number 3.14 was introduced in a cell and then each “Category” option was applied manually. Check how the displayed result varies based on this selection.

General	3.14
Number	3.14
Currency	$3.14
Accounting	$ 3.14
Date	03-01-00
Time	03:21:36
Percentage	314.00%
Fraction	3 1/7
Scientific	3.14E+00
Text	3.14
Special (SSN)	000-00-0003
Custom	3.14

Figure 5.11. Different cell formatting options applied to the same (3.14) value

Note that by default, Excel will align all numbers to the right side of a cell and all text to the left side of the cell. This can be particularly useful when a formula does not function according to expectations and you need to check which cells have been parsed as numerical values and which are interpreted as text.

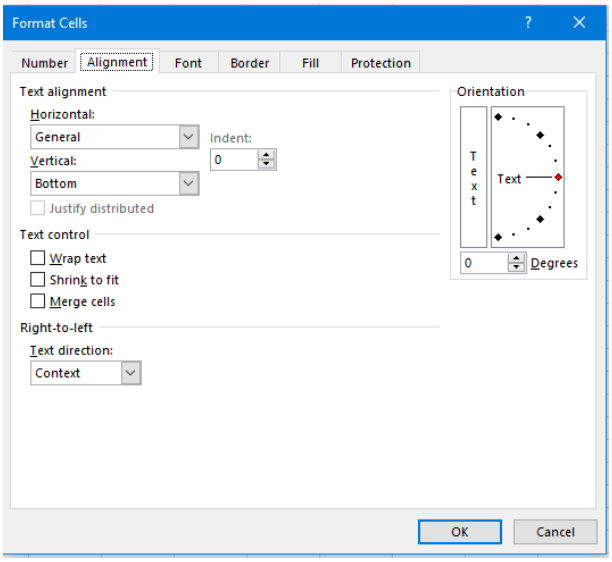


Figure 5.12. "Alignment" tab from the "Format Cells" dialog box

Furthermore, you can control the text alignment within your cell by accessing the “Alignment” tab (Figure 5.12). Check the “Wrap text” option under “Text control” if you want your text to overflow across multiple lines if it does not fit within the width of the cell. All the other options are rather self-explanatory and will control the horizontal and vertical alignment, or even the angle at which the content of the cell is aligned.

Using the other tabs, you can format the “Font” options, such as the font face, style, size, color, the “Border” options, such as style, width and color and of course the “Fill” options for the cell, meaning the background color and style. In the “Protection” tab you can protect your cell, which will disable any future attempt to modify its contents or hide the cell.

Tables

Tables represent the essence of Microsoft Excel. They allow representing data in a compact form, filtering, and sorting of data, as well as help increase legibility. To be noted that solitary cells, even when formatted to look like a table, do not actually make up a table. In order to have a legitimate table, one must be defined.

To define a table, enter all preliminary data in your rows and columns (Figure 5.14). While it is optional, it is always a good idea to also name your columns appropriately: these will be called table headers and should state what each column of data represents. Then, navigate to the “Insert” tab of the Ribbon Interface and from the “Tables” group, select “Table”. This will launch the “Create Table” dialog box (Figure 5.13). Here, the location of the table should already be correct. If your table has a header, you should check the appropriate option.

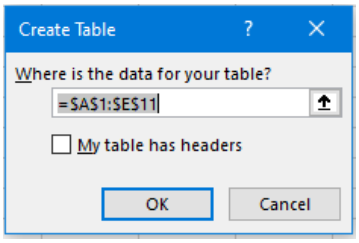


Figure 5.13. Create Table dialog box

	A	B	C
1	First Name	Last Name	GPA
2	John	Snow	4.5
3	Snow	White	6.5
4	Lion	King	5.6

Figure 5.14. Raw data

	A	B	C
1	First Name	Last Name	GPA
2	John	Snow	4.5
3	Snow	White	6.5
4	Lion	King	5.6

Figure 5.15. Data formatted within a table

After creating a table, the "Table Design" tab will be available in the Ribbon Interface. The two most important groups here are the "Table Style Options" and "Table Styles" chunks (Figure 5.16). From within the "Table Styles" group you can change the colors and look of the table, while from the "Table Style Options" you can control the following:

- Header Row: Show/Hide the header row.
- Total Row: Enable/Disable the automatic total row of the table.
- Banded Rows: alternate the shade of even and odd rows for better legibility.
- Banded Columns: alternate the shade of even and odd columns for better legibility.
  Do not use both banded rows and columns as this will create a chessboard look and will make the table very hard to read!
- First Column: Highlight (bold) the first column.
- Last Column: Highlight (bold) the last column.
- Filter button: Show/Hide the "Filter button" on the Header row.

Figure 5.16. Table formatting options

Besides increasing eligibility, tables offer two major advantages: they can be easily sorted, and data can be easily filtered.

Sorting data in a table can be done from one of two places. A simple sorting by a single column can be done by using the “Filter Button” (if displayed) on each column header (Figure 5.17). By clicking the corresponding “Filter Button” on the column header you want to sort by, you have the option of sorting in an ascending or descending order the data in the table by the given column.

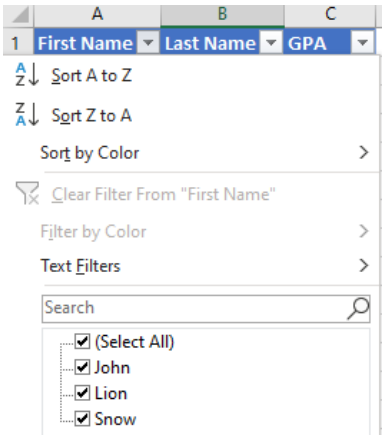


Figure 5.17. Using the "Filter Button" to sort or filter table data

A more complex sorting can be done, by several criteria, using the “Custom Sort…” option from the “Sort & Filter” button available in the “Editing” group of the “Home” tab in the Ribbon Interface. By using this option, a multi-level sorting mechanism can be defined for your table, as seen in Figure 5.18.

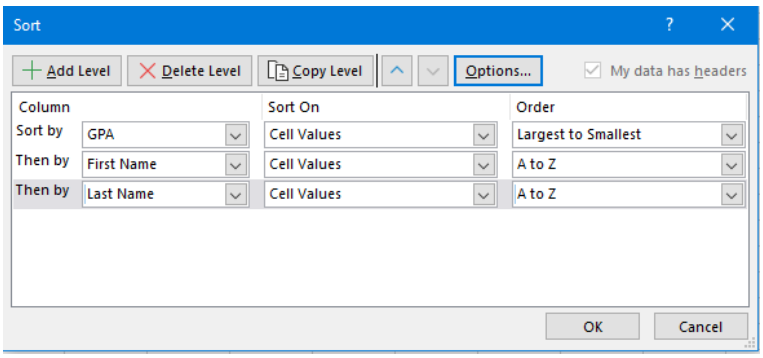


Figure 5.18. Custom multi-level sort by several criteria

By filtering data, you have the ability to only display a subset of the data from the table, based on one or more selection criteria. Filtering can also be accessed by using the “Filter Button” presented in Figure 5.17. By using the available checkboxes, you can select the pieces of data you want to include in your table. Cells that contain numerical values can be filtered by several criteria using the “Number Filters” option (Figure 5.19).

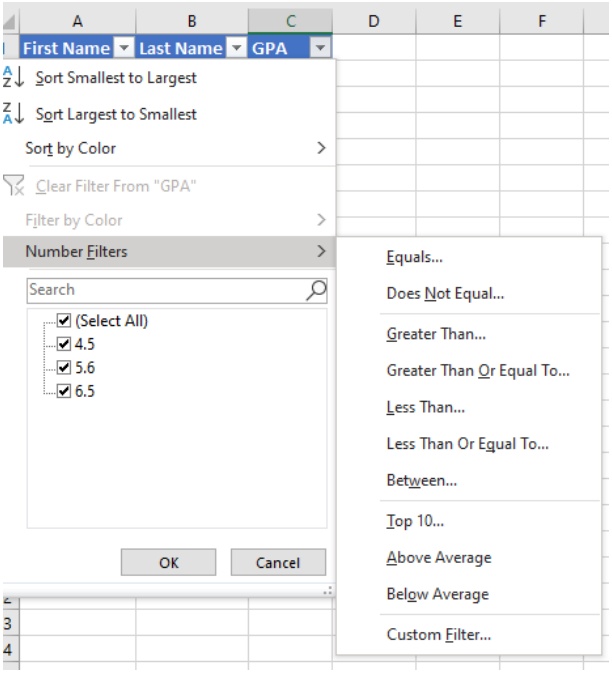


Figure 5.19. Filtering cells with numerical values

Formulas

Formulas constitute an essential part of Microsoft Excel since they can be used to automate calculations in your spreadsheet. Obviously, Excel has several hundreds of built-in formulas and going over all of these would be not only very painstaking, but also quite boring, so we are not going to do that. What we are going to do, nonetheless, is understand how formulas work, and from then on you can either search for a formula that is the most appropriate for your task either in the Help of Excel or on Google.

Formulas are so important that they even get their own separate tab on the Ribbon Interface (Figure 5.20). Here you can find the “Function Library”, which groups the available formulas by their purpose, the “Defined Names” group, which helps you define and track custom cell designators, the “Formula Auditing” section, which helps you debug your formula, and finally, the “Calculation” section, which gives you control over how and when formulas are evaluated.

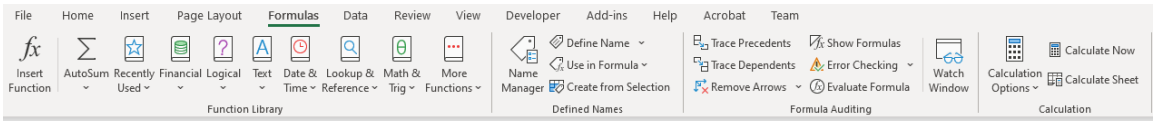


Figure 5.20. The "Formulas" tab on the Ribbon Interface

Formulas can be inserted in one of two ways. The simpler, however, more advanced way is selecting the cell you want to insert your formula into, and then starting by typing an equal sign ("="), followed by the formula. For example, typing "=A2+B2" (without the quotation marks) would insert a formula that would calculate the sum of the values of cells A2 and B2 and place the result in the current cell.

Another way of inserting a formula is by selecting the cell you want to insert the formula into and then using the "Insert function" button from the "Formulas" tab on the Ribbon Interface. This will launch the "Insert Function" dialog box (Figure 5.21), which can guide you through the usage of the function and help you achieve your goals faster.

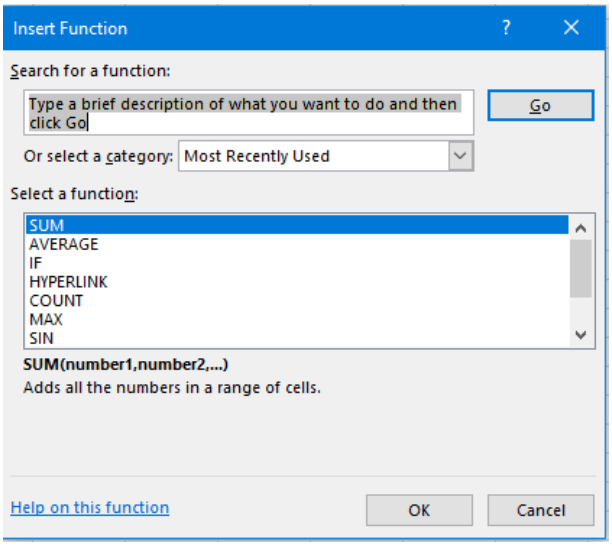


Figure 5.21. The "Insert Function" dialog box

Autofill and formulas

The main advantage of formulas is that once defined for a set of values, they can be repetitively applied over all our data. This can be done, by first defining the formula, and then by dragging the cell either sideways or downwards (depending on how your data is organized) just like you would drag to use the Autofill function on your data (see section Autofill earlier in this chapter).

For better explain this, let us take the data given in Figure 5.22. In column C we want to have the sums of columns A and B, and in column D we want to have the product of columns A and B. For this we define the first row of cells as presented in Figure 5.23. Finally, you drag the formulas using Autofill downwards, for each column. As you can see in Figure 5.24, Excel will automatically increase the row designator (A2, A3, A4, … and B2, B3, B4, …) when applying the formula in each row. This is because we dragged our formula downwards. In case we would have dragged our formula sideways, Excel would have increased the column designator instead (A2, B2, C2, …).

	A	B	C	D
1	a	b	a+b	a*b
2	1	3		
3	2	6		
4	3	9		
5	4	12		
6	5	15		

Figure 5.22. Raw data

	A	B	C	D
1	a	b	a+b	a*b
2	1	3	=A2+B2	=A2*B2
3	2	6		
4	3	9		
5	4	12		
6	5	15		

Figure 5.23. Define the formulas in the first rows

	A	B	C	D
1	a	b	a+b	a*b
2	1	3	=A2+B2	=A2*B2
3	2	6	=A3+B3	=A3*B3
4	3	9	=A4+B4	=A4*B4
5	4	12	=A5+B5	=A5*B5
6	5	15	=A6+B6	=A6*B6

Figure 5.24. Drag the formulas downwards in each column

The result of the calculation can be seen in Figure 5.25. As you can observe, the results are correct for our defined formulas.

	A	B	C	D
1	a	b	a+b	a*b
2	1	3	4	3
3	2	6	8	12
4	3	9	12	27
5	4	12	16	48
6	5	15	20	75

Figure 5.25. Final results of the calculation

There are cases, however, when we specifically want to tell Excel not to automatically increment either the row or column designator (or both) when calculation formulas. This can be done by placing a "$" symbol in front of the row or column designator. For example, "$C4" will tell Excel to lock the column designator to column C. So, dragging this value downwards will increase the row designator (C5, C6, C7, …), however, dragging it sideways will always result in C4.

Similarly, when locking the row designator: C$4 will tell Excel not to increment the rows. So, dragging this value downwards will always results in C4, however, dragging it sideways will increment the column designator to D4, E4, F4, …, etc.

Locking both designators, such as in C4, will result in C4, both when dragging horizontally and vertically.

Let us take the data in Figure 5.26. We want to convert the price of some goods from EUR to RON. The exchange rate is stored in a static cell, found at C1. So, when doing the calculations, C1 will always be the cell we want to multiply the values for the EUR price of the products, found in cells B4, B4, B6, B7. Therefore, when we define our formula, we tell Excel that the C1 cell needs to be static, and we lock both the column and row designators, by using the "$" sign: C1. The formula used is defined in cell C4 and then it is dragged downwards for the other cells. Excel will automatically increment the designators for the price of the product but leave the conversion rate always in the static C1 cell (Figure 5.27.).

	A	B	C
1	Exchange rate		4.82
2			
3	Product	Price (EUR)	Price (RON)
4	Prod A	€ 3.54	RON 17.06
5	Prod B	€ 6.54	RON 31.52
6	Prod C	€ 8.21	RON 39.57
7	Prod D	€ 9.65	RON 46.51

Figure 5.26. Calculation results

	A	B	C
1	Exchange rate		4.82
2			
3	Product	Price (EUR)	Price (RON)
4	Prod A	3.54	=B4*C1
5	Prod B	6.54	=B5*C1
6	Prod C	8.21	=B6*C1
7	Prod D	9.65	=B7*C1

Figure 5.27. Applied formula

There is, however, a simpler way of doing what we just did above. Since we have already seen previously that you can assign custom cell designators to any cell, we can use that functionality to make our formula clearer and our work easier. We take cell C1 and assign a custom name, let's say "conv_rate" to it, and then use that name in our formula (Figure 5.28). The result will be exactly the same as in Figure 5.26.

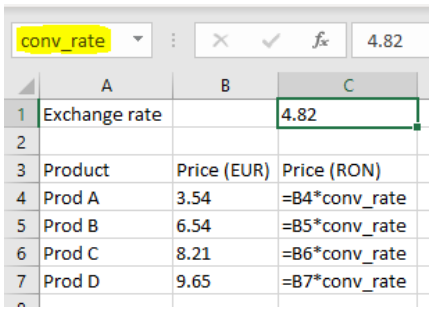


Figure 5.28. Using a custom cell designator in a formula

Tables and formulas

Using formulas in tables is even more straightforward than using them in raw cells. When tables are defined, the cell designators are actually replaced by a reference to the column headers of the table, so the formula is more legible but also easier to follow and understand. Moreover, when defining a formula in a table row, this does not need to be dragged to fill the rest of the rows, this will be done automatically across all rows once the formula is inserted.

Let us take the data in the table presented in Figure 5.29. We want to calculate the total price for each item by multiplying the item price with the purchased quantity. For this we can just start by typing "=" and then clicking on the cell that contains a value of the price, then typing "*" and then clicking on the cell than contains the quantity of the product and exiting the cell. As it can be seen in Figure 5.30, clicking on the cells cause Excel to automatically insert the reference to the column that was clicked (i.e. either [@Price] or [@Qty]). The references can also be typed out manually, however it is always safer to click on the cells, as this will eliminate the possibility of potential spelling mistakes and therefore erroneous formulas.

	A	B	C	D
1	Product	Price	Qty	Total
2	Prod A	$0.85	10	$8.50
3	Prod B	$1.20	5	$6.00
4	Prod C	$6.32	4	$25.28
5	Prod D	$1.02	15	$15.30
6	Prod E	$0.55	200	$110.00
7	**Total**			**$165.08**

Figure 5.29. Total price calculation

	A	B	C	D
1	Product	Price	Qty	Total
2	Prod A	0.85	10	=[@Price]*[@Qty]
3	Prod B	1.2	5	=[@Price]*[@Qty]
4	Prod C	6.32	4	=[@Price]*[@Qty]
5	Prod D	1.02	15	=[@Price]*[@Qty]
6	Prod E	0.55	200	=[@Price]*[@Qty]
7	**Total**			**=SUBTOTAL(109,[Total])**

Figure 5.30. Formula used

Create the table presented in Figure 5.31. The product names, prices per piece and quantities are inserted manually. All other cells are calculated automatically. Apply the following formatting options:

- Table headers can overflow when the text does not fit within the width of the column.
- Columns B, D, E and F contain EUR currency values, while column G is also currency, but RON.
- Column C, representing quantity is a number with no decimal places (integer)

Apply the following calculations:

- Column D, the total cost in EUR excluding VAT is calculated as the price per piece (column B) multiplied by the purchased quantity (column C).
- Column E, the value of VAT in EUR, is calculated as 19% of the total cost without VAT (column D).
- Column F, the grand total in EUR, is calculated as the sum of the total without VAT and the VAT value (the sum of columns D and E).
- Column G, the grand total in RON, is calculated as the grand total in EUR multiplied by the RON/EUR exchange rate (stored in cell B12).
- Grand totals are automatically calculated by the table at the final row for columns D, E, F and G.

	A	B	C	D	E	F	G
1	Product name	Price (EUR/pc)	Qty	Total cost (EUR, excl. VAT)	VAT (EUR)	Grand total (EUR)	Grand total (RON)
2	Prod 01	€ 5.65	20	€ 113.00	€ 21.47	€ 134.47	RON 648.15
3	Prod 02	€ 2.54	25	€ 63.50	€ 12.07	€ 75.57	RON 364.22
4	Prod 03	€ 2.36	10	€ 23.60	€ 4.48	€ 28.08	RON 135.36
5	Prod 04	€ 10.50	15	€ 157.50	€ 29.93	€ 187.43	RON 903.39
6	Prod 05	€ 63.50	20	€ 1,270.00	€ 241.30	€ 1,511.30	RON 7,284.47
7	Prod 06	€ 4.25	3	€ 12.75	€ 2.42	€ 15.17	RON 73.13
8	Prod 07	€ 96.20	10	€ 962.00	€ 182.78	€ 1,144.78	RON 5,517.84
9	**Total**			**€ 2,602.35**	**€ 494.45**	**€ 3,096.80**	**RON 14,926.56**
10							
11							
12	Exchange rate	4.82					

Figure 5.31. Table to be created

Data validation

Especially when using formulas, you often rely on the user to input the data type that you are actually expecting in a given cell. So, if you do calculations with a cell, you expect the user to input a number. However, if the user inputs text instead, your formula will not work. Moreover, there are times when you want to limit data to a minimum or maximum value, to be a whole number and not allow decimals and many more examples. This is where data validation comes in.

With data validation, you can apply the following restrictions to a given cell or range of cells:

- Any value – the default, cell accepts all inputs.
- Whole number – a whole number (without decimals), which can be limited to a range, to a minimum or maximum and other constraints.
- Decimal – a decimal number which can also be constrained as the whole number above.
- List – a list of specified items to which the user is limited to. An in-cell dropdown menu with these values can be created if the appropriate checkbox is checked (see Figure 5.32).
- Date – a date value, with optional limits.
- Time – a time value, with optional limits.
- Text length – text with constrained length.
- Custom – specify a formula which validates the data.

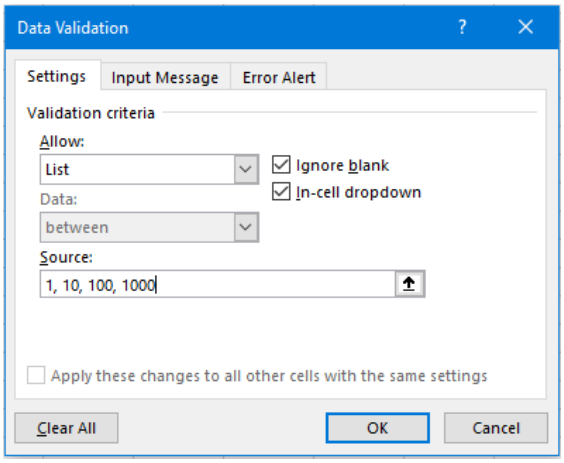


Figure 5.32. “Data Validation” dialog box

To activate data validation, first select the cell or range of cells to which you want to apply the same formula. Then, in the Ribbon Interface, navigate to the “Data” tab and there from the “Data Tools” group select the “Data Validation” drop-down and select “Data Validation…”. This will launch the “Data Validation” dialog box (Figure 5.32). Here, in the “Settings” tab specify the Validation criteria. In the “Input Message” tab you can create a custom input message, which will be displayed to the user when they select the cell which contains the data validation rule, to tell them what values are expected. This

should be used with caution, as it can be very annoying to the user if multiple data validation rules are active. Finally, in the "Error Alert" tab you can specify a custom error message. This will only be displayed if the user enters data that is not valid, and therefore is a better way of informing the user of their mistake, rather than using input messages. If a custom error message is not defined, a standard error will be shown.

Take the table you created in the previous exercise (Figure 5.31). Apply the following data validation rules:

- The "Product name" is text, which cannot be longer than 50 characters and shorter than 3 characters.
- The "Qty" (quantity) values cannot be negative or zero and will always be a whole number.
- All prices must be positive decimal numbers.

Please note that to avoid data loss, data validation is not applied retroactively. This means that if data validation rules are applied to cells that already have data in them, the data will not be removed, and the erroneous value will still be kept.

Conditional formatting

Conditional formatting refers to the ability to automatically format cells, rows, column and/or tables based on their contents. If the contents are updated, so is the formatting, automatically, without the need to manually make any formatting changes. This is a great way to highlight important data in your tables, helps you quickly identify patterns, trends, identify special or erroneous data and overall increase the legibility of your document.

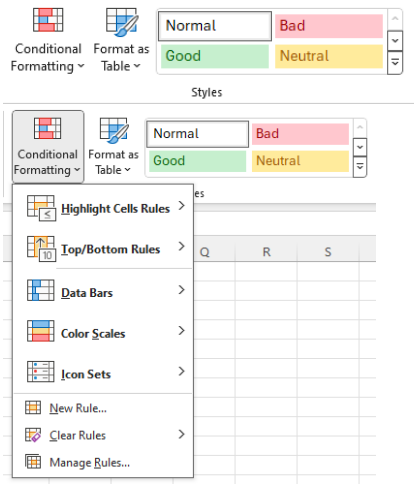


Figure 5.33. The "Conditional Formatting" option on the Ribbon Interface

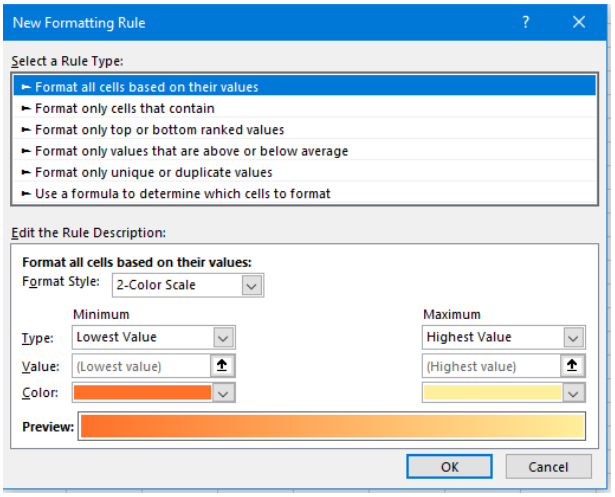


Figure 5.34. The "New Formatting Rule" dialog box

Conditional formatting works by setting rules that cause specific formatting when certain criteria are met. For example, you can highlight cells with values above a certain number, use color scales to show relative differences between values, or apply icons to categorize data into different groups. These visual enhancements make it easier to spot important data points. Conditional formatting is widely used in various business and academic settings. For instance, in project management, it can help track deadlines by automatically coloring cells based on how close a task is to its due date or teachers might use conditional formatting to visually differentiate between student grades, making it easier to see who is excelling or who might need extra help.

To apply conditional formatting, first select all the cells you want the formatting rule to apply to and then select the "Conditional Formatting" button from the "Styles" group of the "Home" tab from the Ribbon Interface (Figure 5.33). Under this button you will find a set of prebuilt rules, such as highlighting certain cells, data bars, and color and icon scales. Some of these may be useful to you, but quite honestly, I have rarely seen them used in a professional document.

A more useful feature is defining your own formatting rules by selecting "New Rule…" from the "Conditional Formatting" button. This will display the "New Formatting Rule" dialog box (Figure 5.34). Here you can select from the multitude of sets of criteria available and define which cells to format and how those cells should be formatted. You can even use a custom formula to define a rule.

To be noted that if a cell fulfills multiple criteria, the earliest defined one will have priority over the other ones. The order in which formatting criteria are applied can be controlled from the "Manage Rules…" dialog box also selectable from the "Conditional Formatting" button mentioned above.

Take the table you created in the previous exercise (Figure 5.31). Apply a conditional formatting rule, where if the "Grand total (RON)" column exceeds 5,000 RON, the cell is highlighted with a red background. The table should automatically apply or remove the red background when needed and should look like in Figure 5.35.

	A	B	C	D	E	F	G
1	Product name	Price (EUR/pc)	Qty	Total cost (EUR, excl. VAT)	VAT (EUR)	Grand total (EUR)	Grand total (RON)
2	Prod 01	€ 5.65	20	€ 113.00	€ 21.47	€ 134.47	RON 648.15
3	Prod 02	€ 2.54	25	€ 63.50	€ 12.07	€ 75.57	RON 364.22
4	Prod 03	€ 2.36	10	€ 23.60	€ 4.48	€ 28.08	RON 135.36
5	Prod 04	€ 10.50	15	€ 157.50	€ 29.93	€ 187.43	RON 903.39
6	Prod 05	€ 63.50	20	€ 1,270.00	€ 241.30	€ 1,511.30	RON 7,284.47
7	Prod 06	€ 4.25	3	€ 12.75	€ 2.42	€ 15.17	RON 73.13
8	Prod 07	€ 96.20	10	€ 962.00	€ 182.78	€ 1,144.78	RON 5,517.84
9	**Total**			**€ 2,602.35**	**€ 494.45**	**€ 3,096.80**	**RON 14,926.56**
10							
11							
12	Exchange rate	4.82					

Figure 5.35. Conditional formatting applied to the table

Charts and graphs

As the old saying goes: “A picture is worth a thousand words”. This is truer when representing data than ever. Whenever it is possible, you should present your data via a chart or a graph, rather than raw values in a table. This will make your data more appealing to the reader and easily understandable.

There are several types of charts and graphs available in Excel and choosing the right one might be challenging sometimes. However, Excel can often help you. In order to insert a chart or graph select all the data you want to represent (including the table headers, as these will be used not only as legends or labels but will also help Excel interpret your data). Then, in the Ribbon Interface, navigate to the “Insert” option and from the “Charts” group, select the appropriate chart. If you are unsure what type of chart to use, you can select the “Recommended Charts” option.

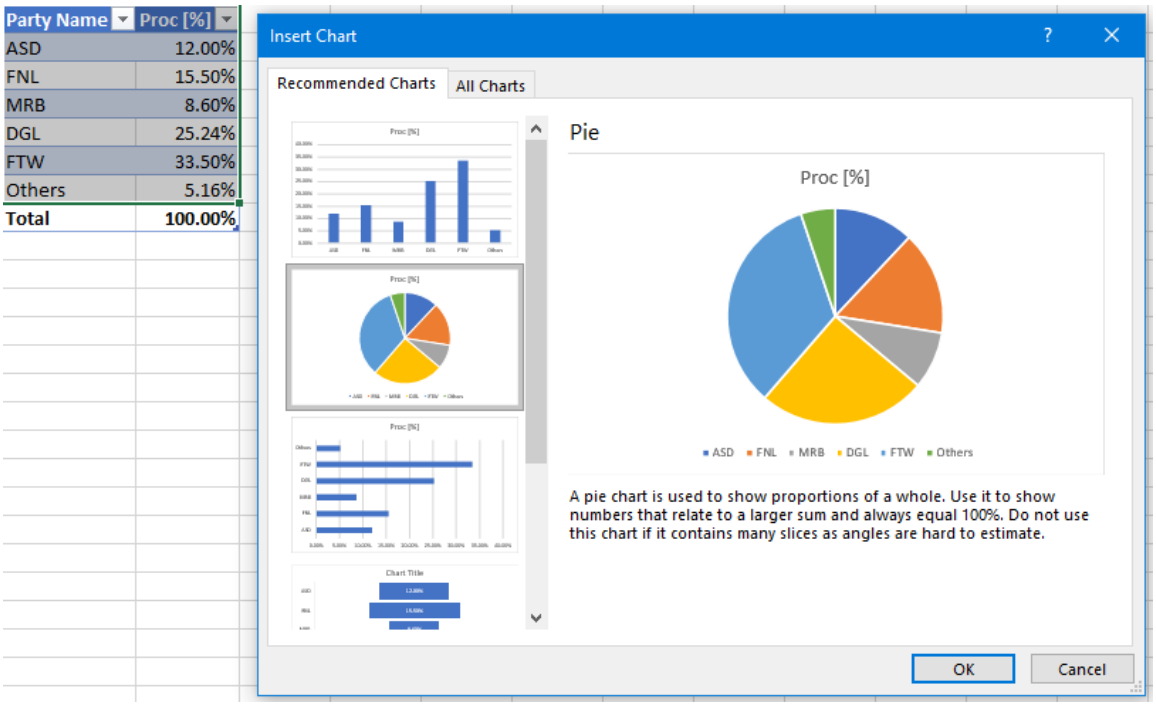


Figure 5.36 Recommended charts for a simulated election result table

Excel offers a variety of chart types to represent data in the most meaningful way. Some of the most commonly used chart types include:

- Column and Bar Charts: Ideal for comparing data across categories, these charts display data using vertical or horizontal bars.
- Line Charts: Perfect for showing trends over time, line charts connect data points with a continuous line.

- Pie Charts: Useful for illustrating proportions, pie charts show how different parts contribute to a whole.
- Scatter Plots: These charts are great for identifying relationships between two variables, plotting data points on an X and Y axis.
- Area Charts: Similar to line charts, but with the area below the line filled in, making it useful for showing volume or cumulative data over time.

There are a few recommendations you should follow when selecting and formatting your chart:

- Keep in mind that more often than not "Less is more": do not over-format and over-color your chart. Just because you can change the color, width or font size of something, does not mean you should. Keep your graphs and charts as clean as possible.
- Name your axis and always provide a unit of measurement for the displayed values. Axis labels can be inserted by clicking on your chart and then using the big "Chart Elements" button on the upper right side (looks like a + sign) and selecting "Axis titles".
- Only use labels and legends when it is necessary and eliminate them when they are redundant (e.g.: a legend is not necessary of series labels also appear as callouts or under the data bars)
- Do not use 3D charts to represent 2D data. If your data has only X and Y dimensions, do not use a 3D chart to represent it, although it may look "cool".

Although it should not be overdone, there are cases where you need to format certain elements of your chart. In order to do this, you can quickly double click on the element you want to format to bring up the "Formatting Options" sidebar (Figure 5.37). You can double click on almost any element of a chart, such as axis, gridlines, series and almost all visible elements.

Users can also take advantage of features like combination charts, which allow multiple chart types to be displayed in a single chart, offering a more complex and informative visual representation. For instance, you might combine a column chart with a line chart to show both individual data points and overall trends simultaneously. For example, in a financial report, a combination chart could use columns to represent monthly sales figures while overlaying a line to show cumulative growth over the same period. This blend of visual elements provides a richer, more detailed analysis, making it easier to identify correlations, patterns, and outliers that might not be as apparent with a single chart type.

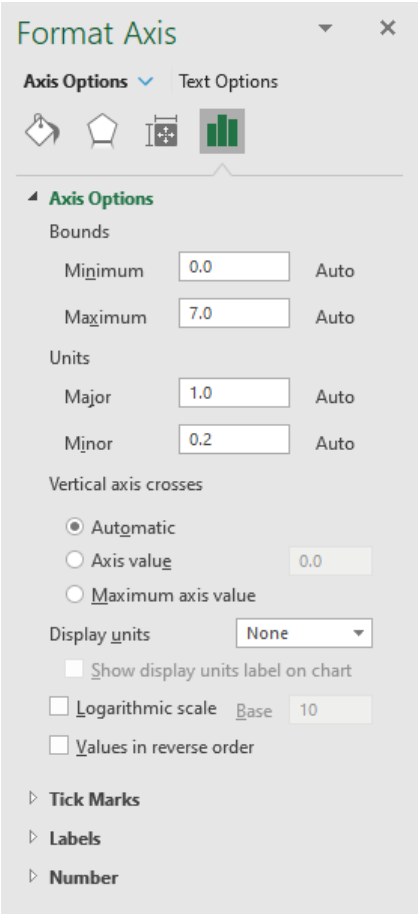
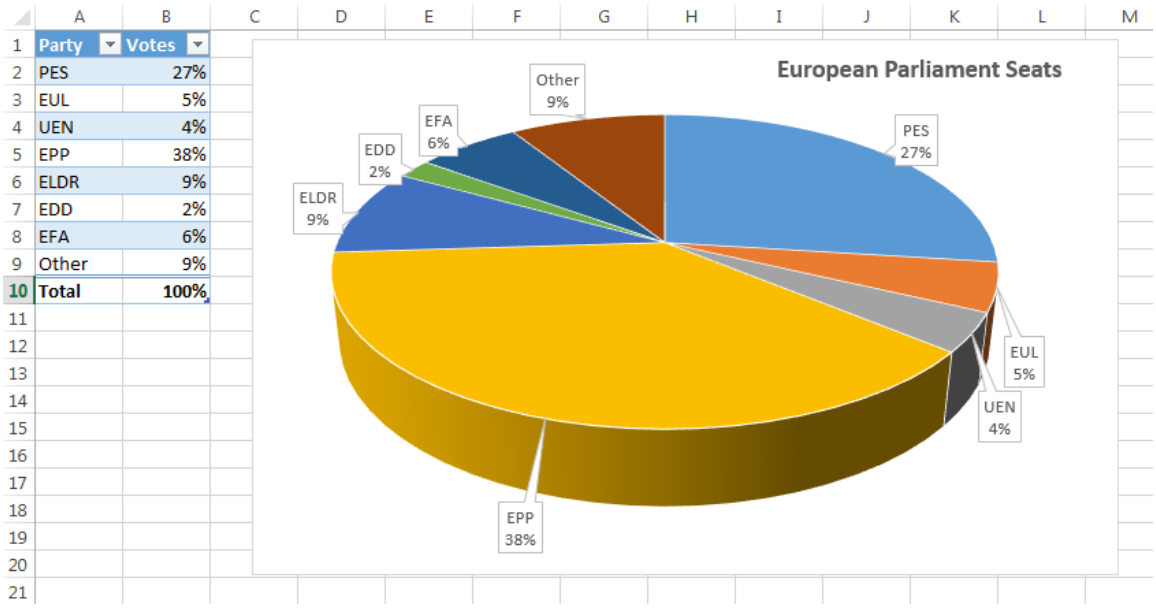


Figure 5.37. Chart "Formatting Options" sidebar

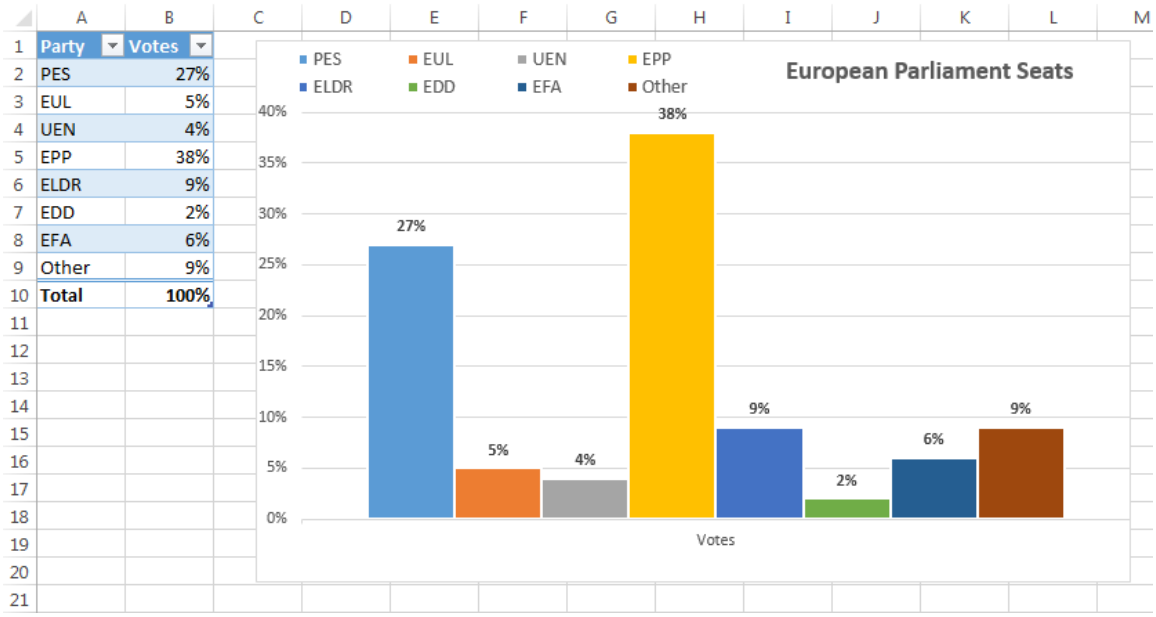
The “Formatting Options” sidebar will automatically just to the appropriate section to format the selected element. Otherwise, you can manually select from a range of options available, depicted by the icons on the top and then by the categories below them.

Create the pie chart presented in Figure 5.38 based on the values shown in the attached table. Use the appropriate formatting options to replicate the appearance of the chart as closely as possible.
Without deleting the chart, use the available options to convert the above pie chart into the bar graph shown in Figure 5.39.



Party	Votes
PES	27%
EUL	5%
UEN	4%
EPP	38%
ELDR	9%
EDD	2%
EFA	6%
Other	9%
Total	**100%**

Figure 5.38. Pie chart to be created



Party	Votes
PES	27%
EUL	5%
UEN	4%
EPP	38%
ELDR	9%
EDD	2%
EFA	6%
Other	9%
Total	**100%**

Figure 5.39. Convert the above pie chart to a bar graph

Macros

Macros can be used to automate a repetitive task, which needs to be done over and over again. They offer the ability to record a set of steps and then play back the recorded steps, even at a faster pace than the recorded one and therefore reducing workload and worktime significantly. A macro is essentially a sequence of instructions or actions that you can record and save to be executed later with a single click.

In order to record a macro, you must enable the “Developer” tab in the Ribbon Interface. To do this in Excel, navigate to the “File” tab in the Ribbon Interface, then select “Options” in the bottom left-hand side. The select “Customize Ribbon” and on the right side of the dialog box check the “Developer” option (Figure 5.40).

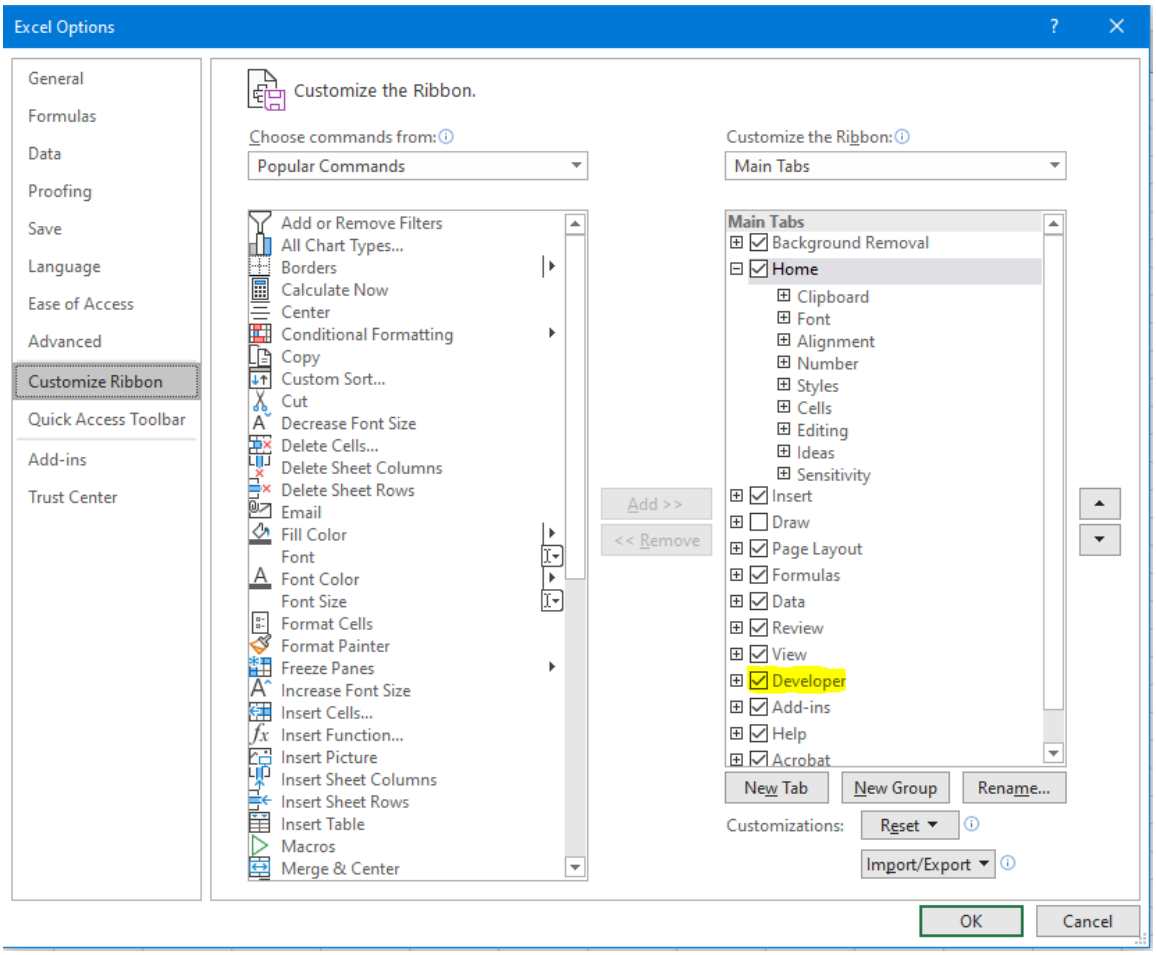


Figure 5.40. Enabling the "Developer" tab in the Ribbon Interface

Then, to record a macro, access the “Developer” tab and select “Record Marco” from the “Code” group (Figure 5.41). This will display the “Record Macro” dialog box, where you need to give a name to your macro, optionally assign a shortcut key and tell Excel where to store the macro. Macros stored in “This workbook” will only be available locally in the workbook they were recorded in, while macros stored in the “Personal Macro Workbook” will be available globally.

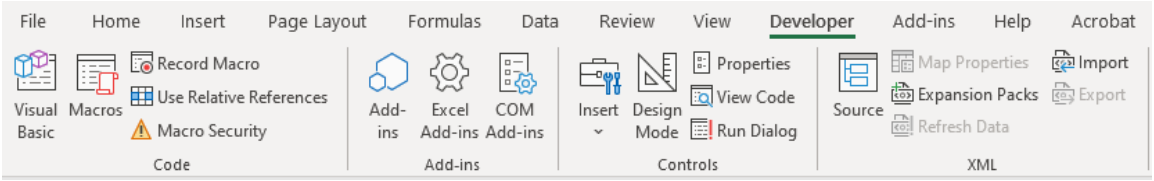


Figure 5.41. The "Developer" tab in the Ribbon Interface

After validating the “Record Macro” dialog box, the macro will start to record and all the steps you execute in Excel will be recorded. You can stop the recording of the macro by using the “Stop Recording” button in the same “Code” group mentioned above (the “Record Macro” button will turn into “Stop Recording” while a macro is being recorded).

All recorded macros are available in the “Macros” menu, from the “Code” group. Also, recorded macros can be added to the Ribbon Interface or the Quick Access Toolbar by customizing these.

Record a macro that executes the following steps:

- Completes your name in cell A1.
- Completes your address in cell A2.
- Formats your name as bold.
- Formats address as red text.
- Generates numbers from 1 to 1000 in cells A4:A1004.

Save the macro and pin in to the Quick Access Toolbar.

For those comfortable with coding, Visual Basic for Applications (VBA) provides the flexibility to edit recorded macros or write new ones from scratch. VBA allows you to add conditional logic, loops, and error handling to your macros, enabling them to perform complex tasks and make decisions based on the data they process. For example, you can create a macro that checks the value in a specific cell and then performs different actions depending on whether the value meets certain criteria. Additionally, VBA can interact with other Excel features, such as tables, charts, and external data sources, giving you the ability to automate nearly any task within Excel. To make your macros easily accessible, Excel allows you to assign them to buttons or keyboard shortcuts. You can add a button to the ribbon or Quick Access Toolbar, or insert a button directly into a worksheet, allowing you to run the macro with a single click. Alternatively, you can assign a macro to a specific keyboard shortcut, enabling quick execution without leaving the keyboard.

To insert a button directly in the worksheet, you have two options. First, in the "Controls" group, select the "Insert" button and then under "Form Controls" select "Button" (Figure 5.42). Next, click the worksheet location where you want the upper-left corner of the button to appear. This will cause the "Assign Macro" popup window to appear and allows you to assign a macro to the button. Form controls are best suited for simpler tasks where you need basic interactivity without extensive customization.

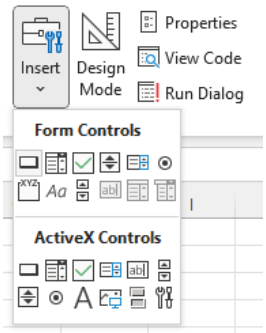


Figure 5.42. "Controls" group in the Developer Tab

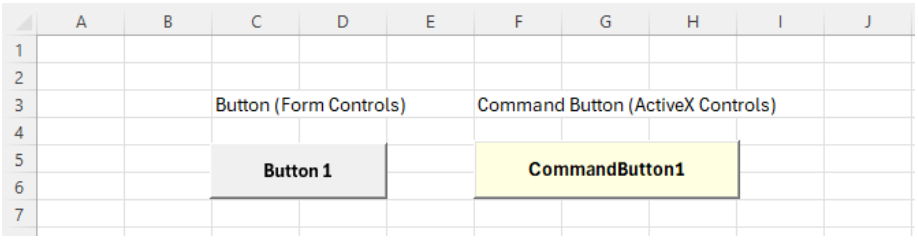


Figure 5.43. Buttons in Excel Worksheet

Another option is using the "ActiveX Controls" instead of "Form Controls". ActiveX Controls are ideal when you need advanced functionality and greater control over the appearance and behavior of your controls. In this case, under "ActiveX Controls" select "Command Button" and select the location where

you want the upper-left corner of the command button to appear. In the “Controls” group, select “View Code” which will automatically launch the Visual Basic Editor and activate the “Design Mode” button.

In Figure 5.44, the sub procedure CommandButton1_Click runs the MyMacro macro when the button is clicked. MyMacro was recorded before and saved in the “Personal Macro Workbook”. If the macro had been created and saved in “This Workbook”, in the sub procedure you should only write the name of it. In the sub procedure of the command button, you can run multiple macros by entering the macro names on separate lines. As needed, feel free to add your own VBA code into the sub procedure to customize and enhance the functionality further.

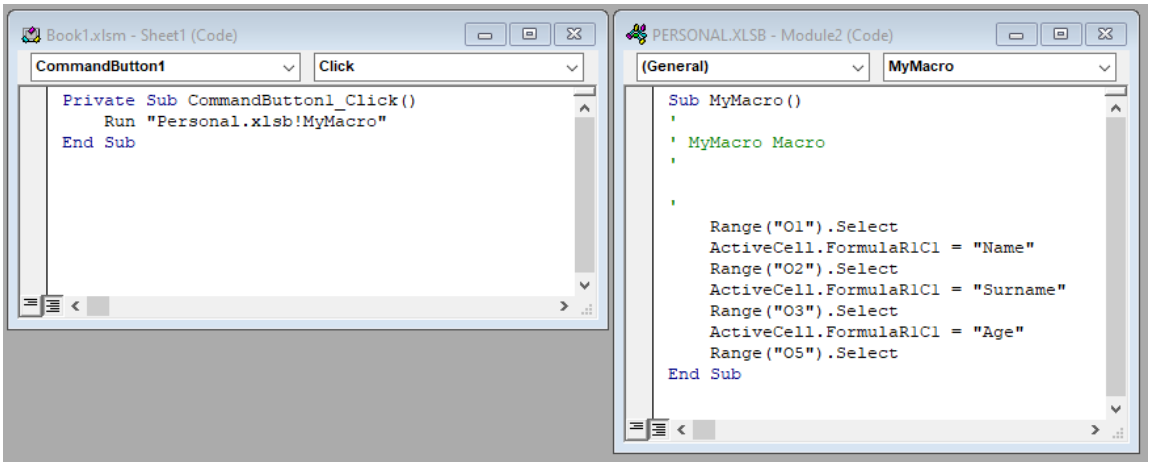


Figure 5.44. The sub procedure for the command button and MyMacro code

To execute the VBA code linked to the button, first ensure that the Design Mode is off, then simply click the ActiveX command button you just created. To edit the ActiveX control, ensure you are in design mode.

Form Controls and ActiveX Controls are both useful for adding buttons, checkboxes, dropdowns, and other user interface elements to your Excel sheets, but they differ in terms of functionality, customization options, and underlying technology. While Form Controls are the simpler type of the two, designed for straightforward tasks, ActiveX Controls offer a more advanced and flexible alternative, but they are specific to Excel in Windows and will not work on Mac versions of Excel.

Chapter 6

Microsoft PowerPoint

In this chapter

- DOs and DON'Ts for an oral presentation
- Designs, themes, and layout options
- Configuring the Slide Master
- Using animations
- SmartArt diagrams

Microsoft PowerPoint is a presentation program, designed to facilitate oral presentation by an accompanying slideshow, which displays visual aids to further engage the audience. PowerPoint relies on slides through which the presenter moves through during their presentation. These can include text as well as several types of graphical elements, such as pictures, graphs/charts, tables and so on. Several of these can be animated in order to aid the flow of the presentation.

To be remembered that PowerPoint is a tool just to **aid** your oral presentation, however, the focus should always be on the story you tell, the presentation you give, it is not a means to replace you as a presenter. It is just a utility to help you display elements that would be hard to describe in words, such as data charts, numerical information or to help you remember and your audience to follow along with your main ideas.

In the column below, you will find several hints which you should do and not do during your PowerPoint presentation. Following these, will help you deliver a professional speech without being boring.

DO…	DO NOT…
• Start by writing the content of your presentation first. • Display only main ideas on each slide. • Use a legible and professional looking font. • Use a non-obstructive and clean theme. • Use charts, graphs, or pictures to convey data ("A picture is worth a thousand words"). • Make your presentation easy to follow (give titles to slides, number slides, caption images, etc.). • Maintain consistency in fonts, colors, and slide layouts. • Proofread your presentation.	• Start creating a PowerPoint presentation by opening the app and choosing a theme and colors for your slides. • Put everything you are about to say on the slide. • Read information off slides. • Use animation unless it is completely necessary. • Put irrelevant information on slides. • Choose dark colors (Figure 6.1). • Be boring. • Ignore slide timing.

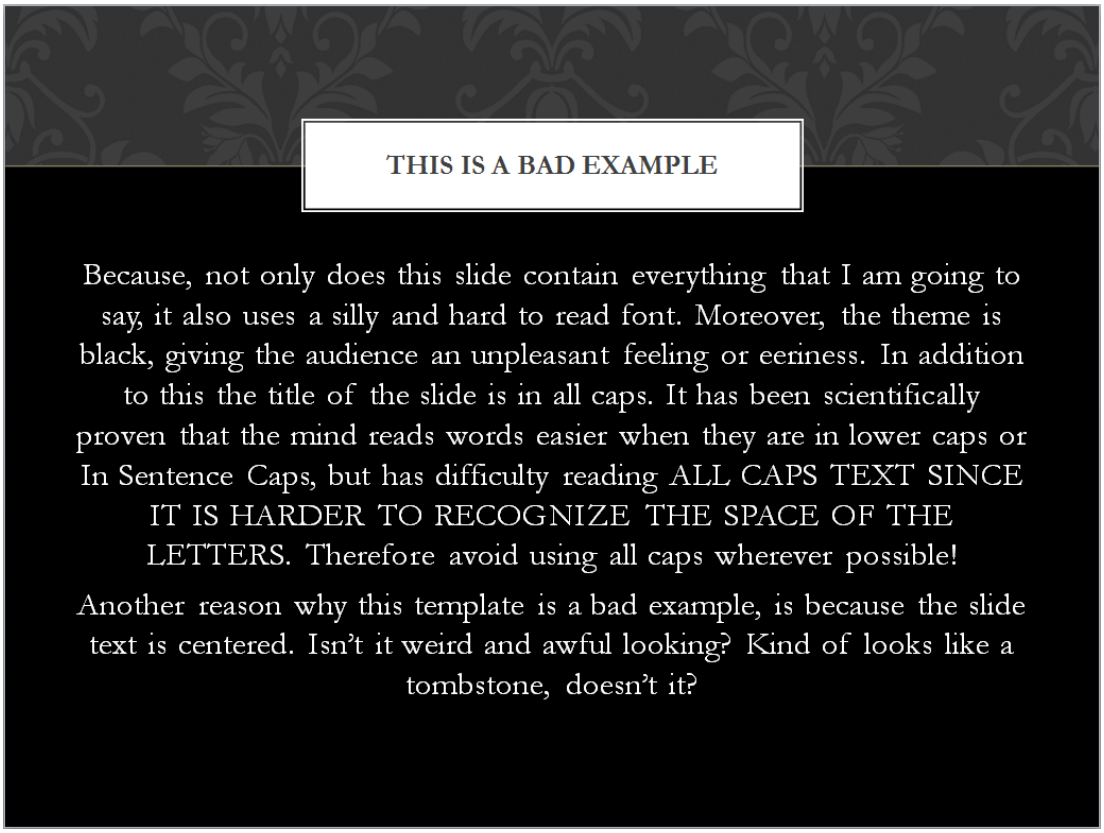


Figure 6.1. This slide is bad and you should feel bad

Designs, themes, and layout

The first step in creating your slideshow is gathering information about the setup you will be provided with for your presentation. Find out if you will be using a projector or a screen to display your PowerPoint presentation. This is important because most projectors still use a 4:3 aspect ratio, while screens (or large monitors) will usually have an aspect ratio of 16:9. This is important, because having slides with improper aspect ratios relative to the screen will cause black banding, as seen in Figure 6.2, to fill the unused area.

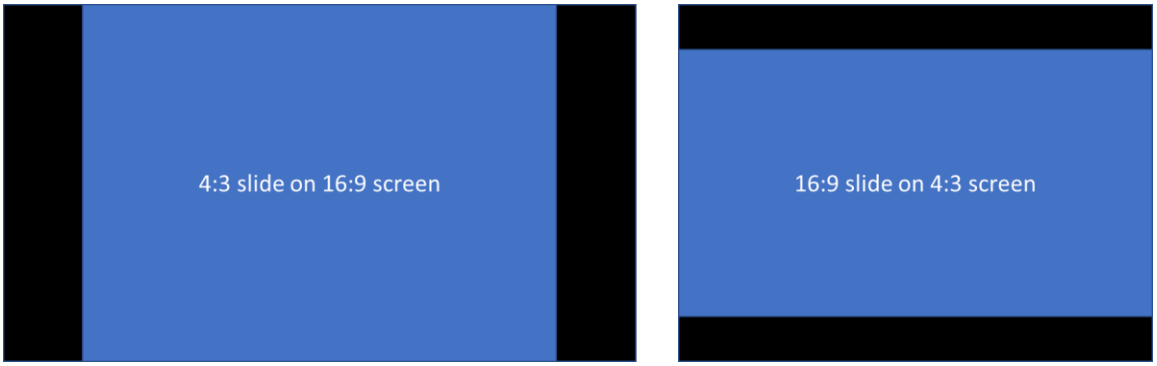


Figure 6.2. Improperly set slide aspect ratios relative to presenter screen

To set the correct slide aspect ratio, use the “Slide Size” button from the “Customize” group from the “Design” tab of the Ribbon Interface. Try not to change the aspect ratio after you have created your slideshow as this will most certainly cause elements to move around on your slides and will likely have unexpected consequences.

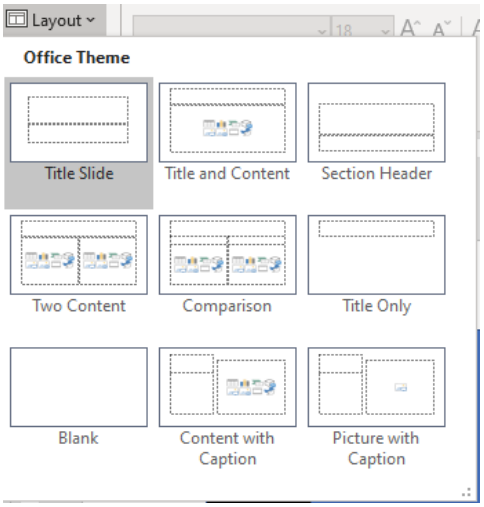


Figure 6.3. Built-in slide layouts

Next, you can choose a theme for your slides. You can do this from the “Themes” section of the “Design” tab. However, make sure you choose an elegant, not very crowded, and non-obtrusive theme.

Slide layouts can be defined individually for each slide. Slide layouts control how the content is displayed on your slide. These practically have placeholders, where you can place your slide elements. There are several slide layouts you can choose from, as seen in Figure 6.3. These can be found by selecting the “Layout” button from the “Slides” group on the “Home” tab of the Ribbon Interface.

The Slide Master

The Slide Master defines the layout of the customizable elements of each theme or allows you to define your own. It determines where placeholders are placed, where background graphics are located, what colors and fonts are used. It can also add static graphic content which cannot be accidentally moved.

The Slide Master is available from the “View” tab, by accessing the “Slide Master” button from the “Master Views” group (Figure 6.4). The “Slide Master” will contain a master slide, which applies to all slides and layouts and then a master slide for each layout available. This way you can customize all the slides or just the layout you want to change.

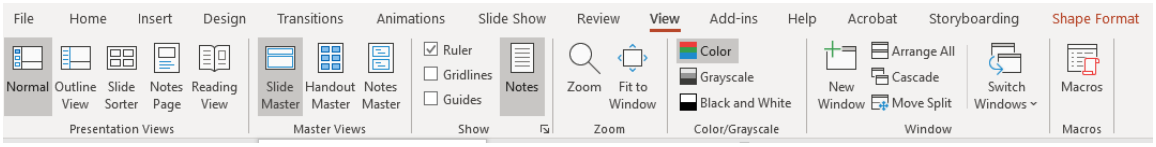


Figure 6.4. Accessing the "Slide Master"

Animations

The first thing you need to remember is that your PowerPoint presentation is not a Pixar movie. Not every element should be animated. Not only can this be very distracting, but it can also ruin the pace of your presentation when animations do not work according to your plan or unexpected ones which you do not remember adding, appear. Therefore, you should only use animations when you want, for example, to hold off displaying something on your slide until you have finished your previous idea or when you want to emphasize something in the information you are presenting. Using sequential animations to control the flow of information, revealing one point, step, or layer at a time, allows the audience to absorb each piece of information before moving on to the next, improving comprehension.

As an engineer, your presentations often deal with complex data, processes, and technical information. Use animations to clarify and emphasize critical points rather than to simply add visual flair. For example, you can use animations to sequentially highlight different parts of a diagram or process flow, guiding the audience through each step with precision.

Animations can be added by using the “Animations” tab from the “Ribbon Interface”. From here you can add animations to your elements and control their trigger. Animations can be triggered automatically together with the previous animation, after the previous one, or on click (presenter or mouse). You can also define the duration of your animations. Try to keep them as short as possible.

Do not ever animate transitions between your slides. There is an option, however, I am not even going to tell you where it is. Just do not!

SmartArt diagrams

There will be occasions where you will want to create an illustration to represent a process, an interdependence between items or a concept which needs to be visually illustrated. For this purpose, you can use SmartArt diagrams built into PowerPoint (Figure 6.5).

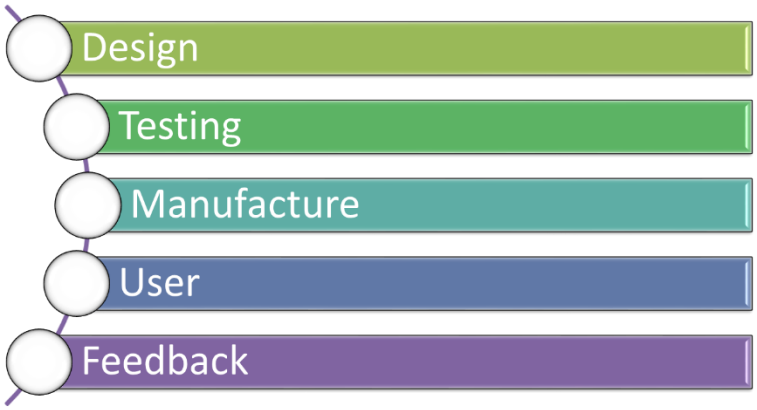


Figure 6.5. Sample SmartArt diagram

To create a new SmartArt diagram, use the “SmartArt” button from the “Illustrations” group of the “Insert” tab from the Ribbon Interface. This will launch the “SmartArt chooser” dialog box, where you can choose the SmartArt type most useful for your needs. After that it is just a matter of adding elements and formatting the SmartArt diagram to your liking by using the “SmartArt Design” tab which will automatically appear on the Ribbon Interface when working with SmartArt diagrams.

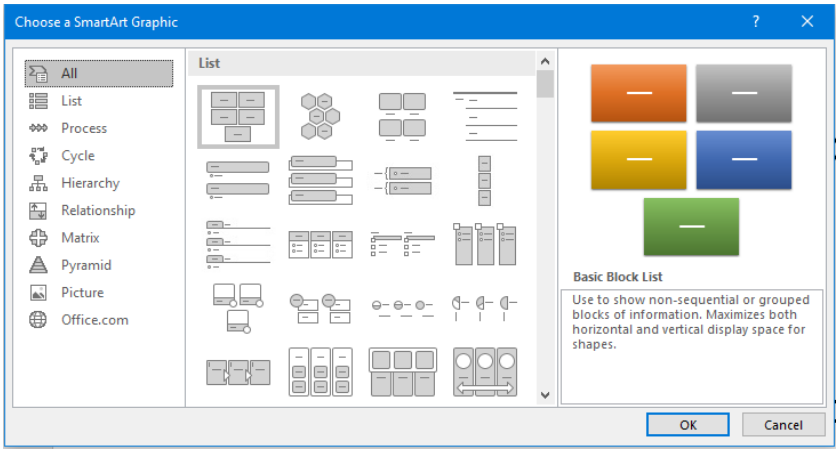


Figure 6.6. SmartArt chooser dialog box

Selecting the right SmartArt diagram type depends on the nature of the information you're presenting and the message you want to convey. By considering the purpose of your content, the flow of information, and your audience's needs, you can choose the SmartArt diagram that best enhances your presentation and makes your data more understandable and engaging. Before choosing a diagram type, consider the amount of text or content you need to include. Some diagrams work better with limited text, while others can accommodate more detailed information.

If you need to present a series of ideas, concepts, or items that don't follow a specific order, a List diagram is ideal. When illustrating a sequence of steps or a workflow, Process diagrams are the best choice. They help visually communicate how one step leads to the next, making them perfect for tutorials, procedures, or project timelines. For processes that loop or repeat, such as life cycles, feedback loops, or ongoing processes, Cycle diagrams are effective. They emphasize the continuity and repetitive nature of the information. If you need to depict levels of authority, organizational charts, or any kind of hierarchy, Hierarchy diagrams are ideal. They clearly show relationships between different levels or groups, making them useful for organizational charts, family trees, or classification structures.

Avoid overcrowding your SmartArt with too much text or too many elements. Aim for simplicity to ensure that your diagram is easy to read and understand. Use PowerPoint's customization options to adjust the colors, shapes, and layout of your SmartArt diagram to fit your presentation's theme and enhance readability.

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