Personal Computers

Frank J. Vilimek

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Contents

Chapter 1

Cases

CHAPTER MOTIVATION

Usually the part of a computer that people will see first, the case is not only important in providing a certain look to the build, but also in allowing the internals to be properly cooled. Cases can come in lots of different shapes and sizes, and knowing how to choose one for your specific build can impact aesthetics and possibly even performance. Cases nowadays support air-cooled and water-cooled configurations, and this chapter will cover most of the basics.

1.1 The Purpose of A Case

A computer case is a pretty simple part of a computer build in that there really isn't too much going on with it, however its design and use can impact how one goes about their build. Of course, the main function of a case is to hold all the internal components so that they are not out in the open, where things can bump into them and/or dust can accumulate on them. Another function of a case is to supply the proper air flow to the build – whether you plan to make your build totally air-cooled or totally water-cooled, there needs to be air flow somewhere to dissipate heat that is generated from the components. The last function of a case is to be aesthetically pleasing – whether you want a super gamer-y, RGB-riddled behemoth or an off-white, retro sleeper build, the case can play a part in what internal parts you choose.

There are a few important aspects about cases that we need to know, such as its dimensions, what types of components fit in it, if it support only a certain type of cooling configuration, etc. These will be covered in the sections ahead.

(a) Alienware Aurora R13[?] (b) AOpen H600A[?]

Figure 1.1: Two examples of PC cases. Do you want a flashy RGB build with the Alienware Aurora R13, or an unassuming sleeper build with the AOpen H600A?

1.2 Case Form Factor and Size

Computer cases can come in a lot of shapes and sizes, however they must still adhere to specific industry-standard form factors. The form factor of a case refers to what kind of motherboard it can fit; there are three main form factors that case manufacturers account for: Advanced Technology Extended (ATX), Micro-ATX (mATX), and Mini Information Technology Extended (ITX)[?]. There are some form factors, such as DTX (not sure what the “D” stands for), that are similar to ATX except shorter (a DTX motherboard is slightly shorter than an mATX motherboard, losing a couple PCIe slots). Figure (1.2) shows a more detailed list of cases and their form factors. Though each form factor is either larger or smaller than the others, they can all generally be used in a case that accepts the larger sizes. For example, if you had an ATX case and you have an mATX motherboard, it will still fit with some extra room at the bottom. Motherboards will be talked about in greater detail in chapter 3.

Though case manufacturers must adhere to these form factors, beyond that they can make the case as big or as small as they want. Some cases are very bare-bones and come with hardly any room to add SSDs or HDDs, fans, water cooling, etc., while other cases are massive and can be fitted with a plethora of fans, water reservoirs, disk drives, radiators, and more. When you want everything in a build to be perfect, both the case form factor and size need to be accounted for.

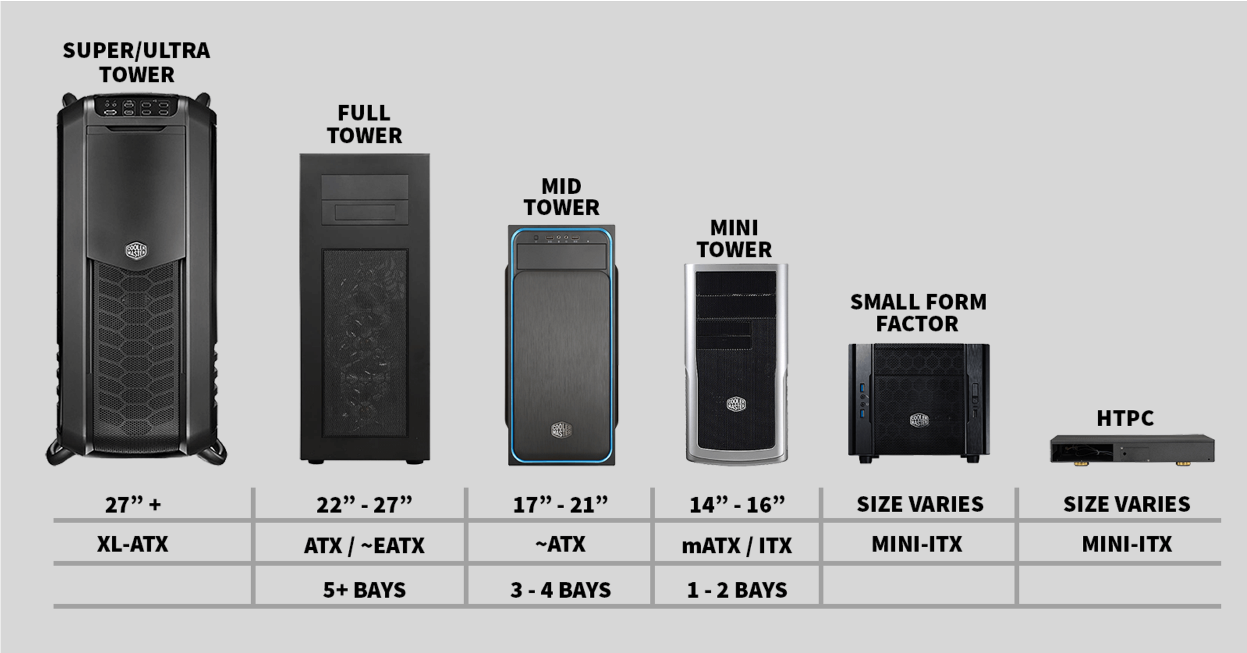


Figure 1.2: Case sizes with the motherboard form factors that they support. Case manufacturers can make a case as big or as small as they want, as long as they meet the form factor requirement.

1.3 Case Fans and Cooling

No matter how fast and expensive your CPU and GPU are, if they are too hot they will thermal throttle and reduce your performance. One way to prevent this from happening is making sure that your case has proper fans that can dissipate any heat generated from the internal components. Being totally honest, if you have four or five fans in your build with some pointing inwards and some pointing outwards, you will not really have any drawbacks unless you need the absolute most performance out of your system. Most people will not need to push their computer to its limits like this, however understanding temperature control in a computer is still cool.

The main thing to account for in fan placement is how it will affect the pressure differential between the environment and the inside of the case. A computer case has a few main ports where air can enter and exit, and these can be fitted with a fan or have nothing. Let us model a computer case as a system with one main inlet and one main outlet, both are fitted with fans; there are also holes on the top and bottom that are not fitted with fans, and allow air to enter or exit naturally. We will be modeling this system on the basis of mass balance, however it should be noted that modeling this system on the basis of fluid mechanics may yield different results.

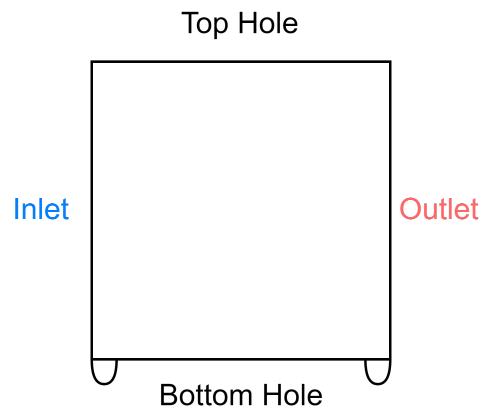


Figure 1.3: A simple model for a computer case. The inlet and outlet are fitted with fans, and the top and bottom holes are not.

The inlet and outlet can (usually) accept up to three fans, each capable of transferring 1 fan-flow per second (ff/s) of air (just made this unit up). The number of fans connected to the inlet and outlet will determine if the case has positive pressure, negative pressure, or equal pressure relative to the environment, and any difference in the amount of air in the case needs to be taken in/pushed out the top and bottom holes. Let us go over some example situations.

1.3.1 Positive Case Pressure

To make a case have positive pressure, there needs to be more inlet fans than outlet fans.

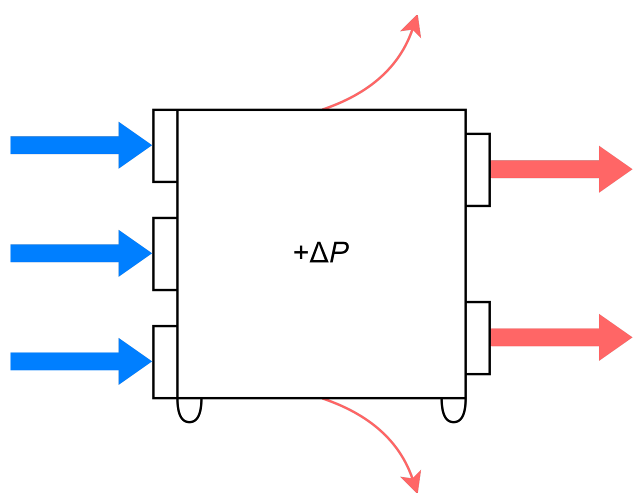


Figure 1.4: A case with positive pressure.

In this example, the inlet has three fans and the outlet has two fans, for a net fan flow of

$$\text{Fan Flow} = \Delta F = 2 \text{ ff/s} - 3 \text{ ff/s} = -1 \text{ ff/s}$$

This means that the case is taking in more air than it expels through fans, forcing the rest out of the top and bottom holes. This is positive pressure: the case naturally needs air to leave rather than to enter. There are (pretty insignificant) pros and cons to designing a case to have positive pressure:

- √ The air flow out of the case does a good job of preventing dust from settling on the internals,
- × After cold air enters it stays near the middle of the case and heats up, becoming slightly less efficient at cooling the internals.

1.3.2 Negative Case Pressure

To make a case have negative pressure, there needs to be more outlet fans than inlet fans.

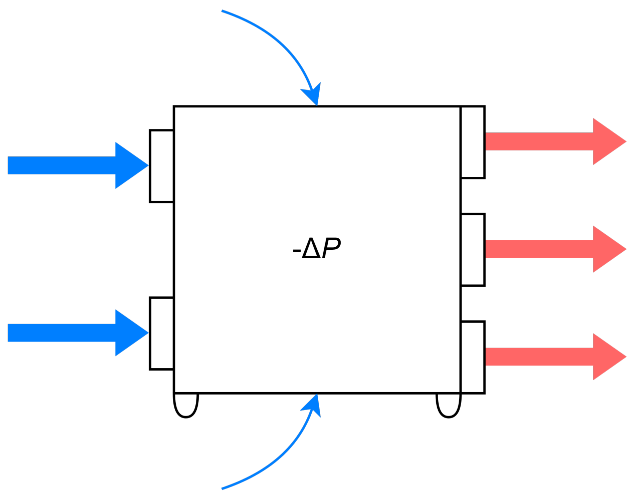


Figure 1.5: A case with negative pressure.

In this example, the inlet has two fans and the outlet has three fans, for a net fan flow of

$$\text{Fan Flow} = \Delta F = 3 \text{ ff/s} - 2 \text{ ff/s} = 1 \text{ ff/s}$$

This means that the case is expelling more air than it takes in, forcing air from the environment to enter through the top and bottom holes. This is negative pressure: the case naturally needs air to enter rather than leave. Again, there are pros and cons to designing a case to have negative pressure:

- ✓ Hot air generated from the internals leaves almost immediately for more efficient cooling,

- × The inward air flow causes more dust to settle on the internals.

1.3.3 Equal Case Pressure

To make a case have equal/neutral pressure, the inlet and outlet need to have the same number of fans.

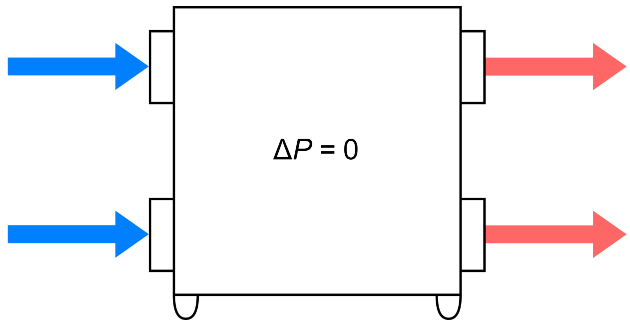


Figure 1.6: A case with equal pressure.

In this example, the inlet and outlet have two fans, for a net fan flow of

$$\text{Fan Flow} = \Delta F = 2\ \text{ff/s} - 2\ \text{ff/s} = 0\ \text{ff/s}$$

This means that the case is not taking in more or less air than it can expel. This is neutral/equal pressure: the case does not need extra air to enter or exit through the top and bottom holes. There are pros and cons to designing a case to have neutral/equal pressure:

- ✓ The air can be redirected easily so that hot spots around the case do not build up,

- × The temperature of the air in the case evolves fairly steadily, making the cooling for the components on one side of the case less effective.

1.3.4 Case Temperature Profiles

Each fan configuration for different pressure differentials will result in a different temperature profile within the case. Though these differences may be small, it is good to know where the hot spots are within the case if thermals become an issue. Depending on where the cold air enters and hot air exits the case, some approximate temperature profiles you might expect are shown in fig. (1.7) below. Note that these are entirely speculative, and there was virtually no math done to confirm these graphs.

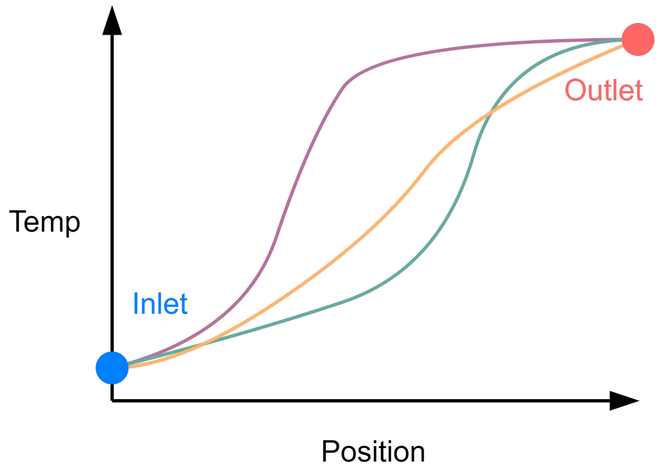


Figure 1.7: Temperature profiles for positive pressure (purple), negative pressure (green), and equal pressure (yellow) configurations.

1.3.5 Fan Placement for Air-Cooled Systems

Once the case pressure has been chosen, the placement of the fans must then be considered. The placement of the fans largely depends on which component needs colder air more than the others. These components are usually the CPU and GPU, and knowing if one runs hotter or colder decides the fan placement. Most motherboards have the CPU located in its upper half, and the GPU is located in the bottom half.

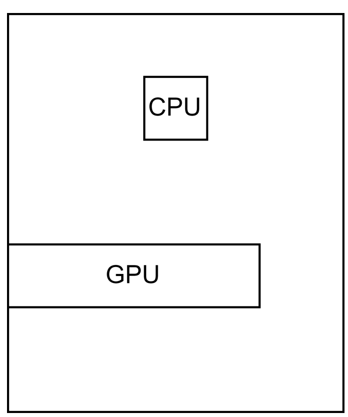


Figure 1.8: Simplified ATX motherboard showing the CPU and GPU locations.

This placement is important to consider: when cold inlet air reaches the first component in its path, it heats up before going to the next component and becomes less effective at transferring heat. If the fans were placed such that air passed over the component that runs colder, then the air would heat up before going to the hotter component and may cause it to thermal throttle faster than if the fans were placed in another configuration.

Another thing to consider is that cases usually only allow fans to be placed in specific spots, limiting the possible fan configurations. Figure (1.9) shows the general locations that fans can be placed on modern cases.

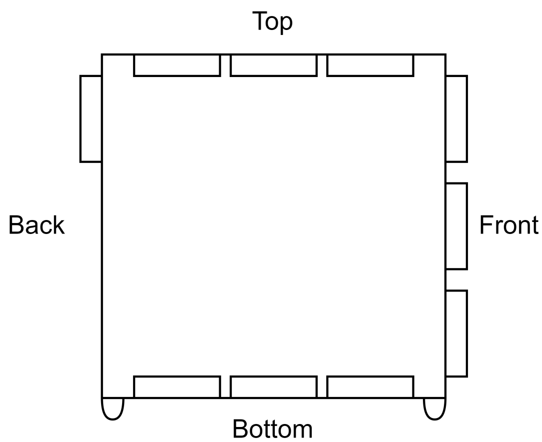
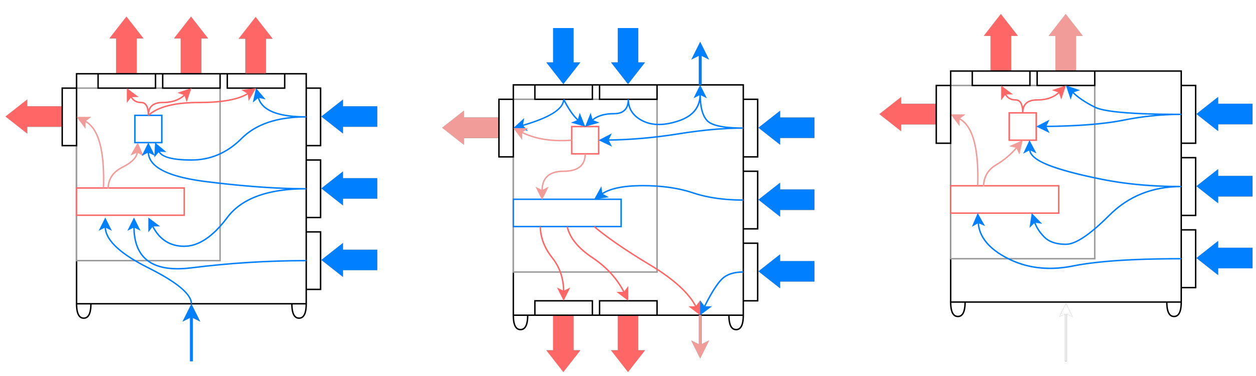


Figure 1.9: General locations for fan placement on most cases. Some cases can have more or less locations, depending on the other case features.

Taking the case pressure, component locations, and fan locations into account, some example designs are shown below. These do not form an exhaustive list, and each fan configuration should be tailored for each build.



(a) Negative pressure, cold CPU & hot GPU

(b) Positive pressure, hot CPU & cold GPU

(c) Equal pressure, hot CPU & hot GPU

Figure 1.10: Some example fan configurations for components that run hot and cold. This is, of course, not an exhaustive list – more or less fans can also be used.

1.3.6 Fan Placement for Liquid-Cooled Systems

These examples assumed that the case only used fans and open air intakes; in modern builds, however, it is common to find liquid (usually water) cooling with radiators placed in the case. The radiators are heat exchangers that depend on convective cooling between the radiator and the outside air to cool the water inside the loop. A liquid-cooling loop can be an All-In-One (AIO) assembly usually designed for CPUs, or it can be the entire system and each component has its own liquid inlet and outlet.

(a) NZXT Kraken CPU cooler[?]

(b) Water-cooled computer[?]

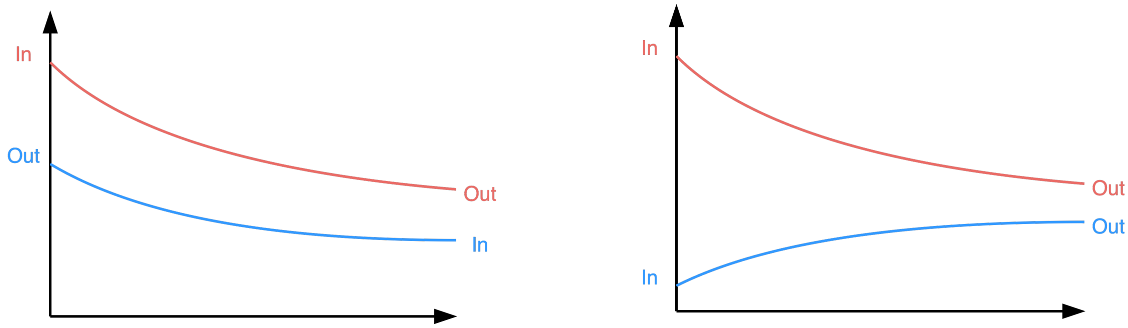
Figure 1.11: An AIO and an entire liquid-cooled computer both need to consider fan and radiator placement for optimal cooling.

Fan placement for builds involving radiators need to consider the efficiency of heat transfer between hot and cold fluids, especially entirely liquid-cooled builds or builds with multiple AIOs. To help, we must consider how shell-and-tube heat exchangers are designed. The heat transfer rate between a hot and cold fluid takes the form

$$Q = UA\Delta T_{LM} \tag{1.1}$$

where Q is the heat transfer rate, U is the overall heat transfer coefficient, A is the surface area of the radiator, and ΔT_{LM} is the log-mean temperature difference (which accounts for the non-linear temperature profiles within the heat exchanger). The efficiency of heat transfer between the air and the radiator(s) depends on how the air blows over it: should cold air come into contact with the inlet of the radiator, or the outlet? If there are multiple radiators, which one should receive the coldest air and which can receive the warm exhaust?

ΔT_{LM} for the counter-current configuration is larger than that for co-current, meaning that for the same U you can get away with a smaller radiator. Therefore, in a build with



(a) Counter-current flow, more efficient (b) Co-current flow, less efficient

Figure 1.12: The different types of flow for heat exchangers. Mathematically, counter-current flow is more efficient than co-current flow[?].

two radiators, the cold air going into the case needs to come into contact with the radiator of cooled water, and the hot air coming out of the case needs to come into contact with the radiator of hot water for the most efficient cooling configuration.

1.3.7 High Airflow vs. Static Pressure Fans

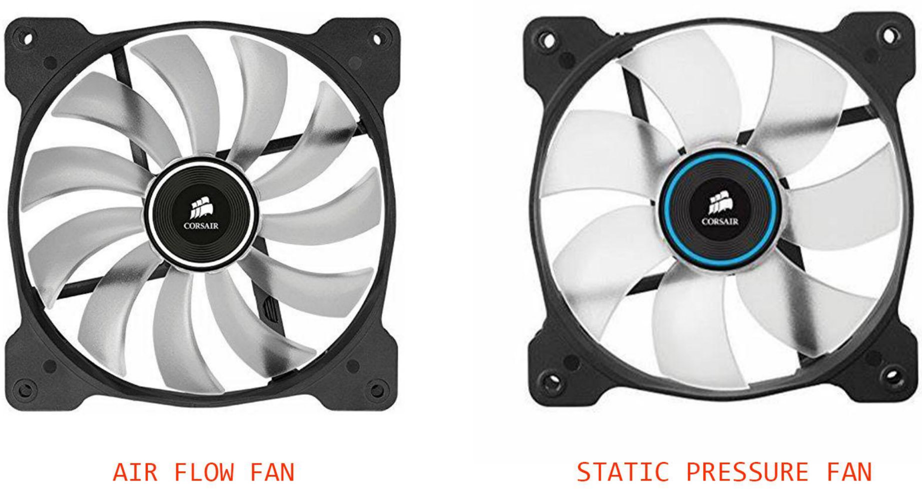


Figure 1.13: High airflow and static pressure fans from Corsair[?].

When choosing the fans for a build, one must consider what type of fans to place where. There are two main flavors: high airflow and static pressure fans. A high airflow fan is typically one that has many thin blades that are at a relatively sharp angle. They spin with a high RPM in order to maximize the amount of air that passes through an area. A static pressure fan is typically one that has fewer but thicker blades that are at a relatively shallow angle. They spin with a lower RPM, but due to their shape they can maintain a certain air pressure in the case.

From Bernoulli's principle, the higher airflow fan cannot maintain as high a pressure, and is best used for air inlets and outlets, such as the front, top, or back of the case. This can supply the case with enough air movement for optimal heat transfer.

Once the air is inside the case, static pressure fans can be used to push the air across a CPU heatsink or liquid-cooled radiator. They are better used when there is some obstruction in the direction of airflow.

The interesting situation comes from choosing what fans to use if you have radiators covering the case inlets and outlets – should you prioritize airflow or pressure? The decision depends heavily on the specific situation, however I would argue that maintaining the pressure drop across a radiator is more important than pure airflow. If the fans cannot maintain pressure across the radiators, then the hot air will stagnate within the case and cause temperatures to rise. Thus, static pressure fans should be chosen.

1.4 Features and Popular Manufacturers of Cases

1.5 Summary

Chapter 2

Power Supply (PSU)

Chapter 3

Motherboard

Chapter 4

Central Processing Unit (CPU)

4.1 Purpose of a CPU

4.2 Parts of a CPU

4.2.1 Cores and Threads

Chapter 5

Graphics Processing Unit (GPU)

Chapter 6

Random Access Memory (RAM)

CHAPTER MOTIVATION

Accessing data directly from your storage device can be time-consuming, especially if the device has slow read/write speeds. Random Access Memory, or *RAM*, solves this problem by allowing the data to be temporarily stored in smaller cache with significantly faster read/write speeds. With the right RAM size, speed/frequency, and timings, your PC can dramatically improve responsiveness.

6.1 The Basics of RAM

RAM, an acronym for "Random Access Memory," is a way of storing the most frequently-used data and files in an easily-accessed place so that the CPU can grab it and go without waiting for the comparatively slower HDD or SSD. DDR4 RAM, the most popular type of RAM at the time of writing, can be over 100 times faster at reading/writing than an SSD, the fastest form of data storage. But what is "DDR," and why are there 4 of them? What about "DDR3" or "DDR5?"

6.1.1 SDR, DDR, and QDR

When talking about RAM, there are three branches: Single Data Rate (SDR), Double Data Rate (DDR), and Quad Data Rate (QDR). These branches are communication signalling techniques, which describes how the RAM sends data. All RAM has a *clock cycle*, which is a consequence of computers operating on 1's and 0's – a 1 is on and a 0 is off. SDR, DDR, and QDR all take advantage of each clock cycle differently.

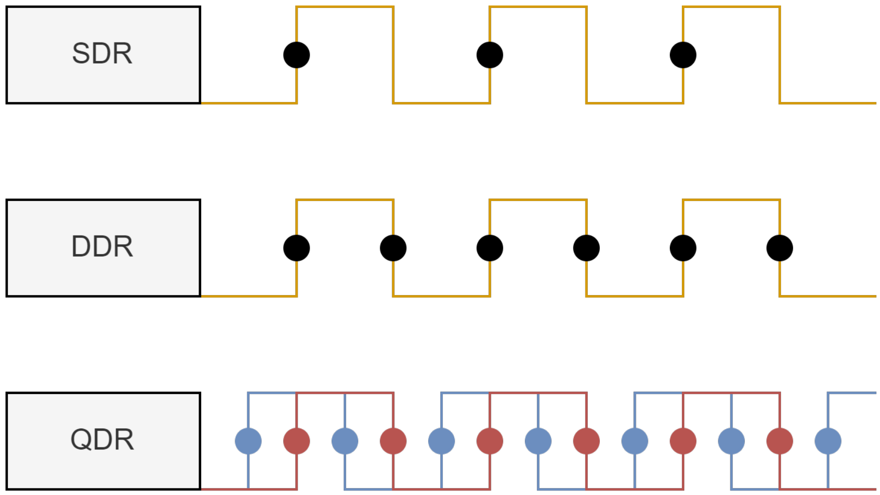


Figure 6.1: Communication signalling with SDR, DDR, and QDR.

SDR is a technique that transfers data only on the rising edge of a clock cycle (when it turns on). This limits the data to the speed of the clock cycle. SDR is an old technique, and computers before the early 2000's use SDR. It is relatively inefficient in the way it transfers data in a single clock cycle.

DDR is a technique that transfers data on the rising and falling edges of a clock cycle (sometimes called a *clock beat*). This doubles the amount of data transferred compared to SDR with the same clock speed. Because DDR uses the rising and falling edges of a clock cycle, it maximizes the amount of data that can be transferred. The DDR format has become extremely popular for PCs because of its high speed and efficiency and low latency times, which we will discuss later.

QDR is a technique that transfers data on the rising and falling edges, and two midpoints in between in a clock cycle. This means that for each clock cycle, QDR can transfer four times as much data as SDR and twice as much as DDR. QDR is useful for systems where many components need to use some bit of RAM, such as systems with multiple CPUs. However, because QDR transfers data at twice the rate of the clock speed, it is usually delayed using CAS latency to improve stability and usability in typical PCs. Because of this, QDR has mainly seen use in networking hardware where many systems connect to a central unit.

6.1.2 Clock Speed and CAS Latency

There is a balance between how fast the RAM can transfer data and how often the RAM allows the CPU to process the data it sent. The clock speed of the RAM, often measured in megahertz (MHz), is directly proportional to the speed of data transfer. Unit that are increasing in popularity are megatransfers-per-second (MT/s) and megabits-per-second (Mbps). MT/s is equivalent to Mbps, which are the number of bit transfers per clock cycle – so for SDR, 1 MHz = 1 MT/s = 1 Mbps; for DDR, 1 MHz = 2 MT/s = 2 Mbps; and for QDR, 1 MHz = 4 MT/s = 4 Mbps. Keep in mind, however, that manufacturers will use these units interchangeably, so be weary of advertised speeds.

Of course, a higher speed is better than a lower speed; however, if the data is transferred too quickly, then it can become corrupted as the CPU is overwhelmed with data. One solution to this is to manually decrease the clock speed in BIOS if possible. This will help stability, but of course you lose performance – you should only pair RAM that has a clock speed that is supported by your motherboard and CPU to prevent this in the first place.

Another way to prevent your CPU from being overwhelmed is to implement *memory timings*. Memory timings essentially force the RAM to stop transferring data for a certain amount of time or a certain number of cycles to allow the CPU to process the data sent to it. The standard for memory timings is Column Address Strobe Latency (CAS Latency, or CL). For most RAM used in PCs, *Synchronous Dynamic* RAM (SDRAM), the CL is measured in clock cycles.

You can calculate the CL time delay if you know the clock speed of the RAM and the CL. For example, let's say we have a stick of DDR4 1600 MHz CL16 SDRAM. The time per clock cycle is

$$\text{Time per cycle} = \frac{1}{1600\text{ MHz}} = 0.625\text{ nanoseconds}$$

Since it is DDR, the number of data transfers is

$$\text{Time per transfer} = 2 \times 0.625\text{ nanoseconds} = 1.25\text{ nanoseconds}$$

Finally, since the latency is CL16 (a delay of 16 cycles), the total delay is

$$\text{Latency Time Delay} = 16 \times 1.25\text{ nanoseconds} = 20\text{ nanoseconds}$$

The general equation is

$$\text{Latency Time Delay} = \frac{(\text{Transfers per Cycle})(\text{CL})}{\text{Clock Speed in MHz}} \times 1000\text{ MHz/kHz} \tag{6.1}$$

where "Transfers per Cycle" depends on if the RAM is SDR, DDR, or QDR.

Chapter 7

Storage

Chapter 8

PC Peripherals

8.1 Monitors

8.2 Audio

8.3 Mouse

8.4 Keyboard

8.4.1 Case

8.4.2 Printed Circuit Board (PCB)

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8.4.6 Lubrication