Silent & Fan-Less Mini-PC using Case for Passive Cooling

Jasmohan Singh Narula, Siddhivinayak Zaveri, Rohan Chaubey and Dhruv Nagpal
Shree L. R. Tiwari College of Engineering, Computer Department
Kanakia Road, Kanakia Park, Mira Road East, Mira Bhayandar, Maharashtra 401107, India
jasmohan.92@gmail.com, siddhivinayak459@gmail.com, rohanchaubey4321@gmail.com

Abstract- Small form factors personal computers are on the rise as there is a demand for them from users. This document explores the different form factors of personal computers and ways in which Mini-PCs can be improved to provide a better alternative for their bigger counterpart Desktop PCs. The main aim of this document is to explore ideas and try to innovate with the existing as well as new methods, using newer designs and manufacturing techniques for creating better Mini-PCs which can achieve a balance between performance, size, and noise. Originally the concept of Passive Cooling was only used for heat producing components other than CPU, but through our findings it can be a better option for such small factor computers like Mini-PC and their case can be given a secondary purpose other than for aesthetics.

Keywords–*PC, Desktop, Mini-PC, Heatsink, Benchmarks, Thermal Management & Throttling, Thermal Design Power, Dynamic Frequency Scaling*

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I. INTRODUCTION

With rapid advancement in computer design and engineering, PC's are becoming smaller. Computers which were once the size of a room have been condensed to fit in the palm of our hands. It is said that the Desktop market is declining; this can be due to alternatives like Laptops, Tablets and Mini-PCs being available as an alternative for the user. Desktops are not the only computers available to users. The decades of development means that most people already own desktop computers that meet their needs and have no need of buying a new one merely to keep pace with advancing technology.[1]

Mini-PCs are still a new and emerging small form factor computer which has not yet been developed to its full potential. The current generations of Mini-PCs are being manufactured using traditional designs and techniques which were made for making Desktops and Laptops. The current Mini-PCs use fans for cooling or do not use any cooling method, relying on thermal throttling technology to regulate the temperatures. This results in either noise being generated due to fans or degradation in performance due to thermal throttling. The body of the Mini-PC currently is only used for housing the components and has no secondary purpose.

Desktop PCs are considered large, heavy, noisy & heat generating boxes surrounded by cables that many of us have to put up with if high performance is needed while sacrificing portability. Desktops give the flexibility of using many peripherals by attaching to them but cannot be easily moved. Laptops are portable computers which contain all the peripheral like Screen, keyboard, etc. that are needed to use the computer. Laptops typically have low to medium performance and have become an appropriate solution where portability is required. Laptops don't offer much flexibility concerning peripherals as the desktop can, and due to the peripherals being integrated into its body, its size is still bigger than what its necessary parts like motherboard, storage, memory, etc. require.

Mini-PCs have come into the picture today by the combination of flexibility of Desktops and portability of Laptop. Based on small, low-power components, they take up a fraction of the space of a traditional desktop PC and don't require parts such as an expensive built-in screen, battery, and keyboard which can be attached separately as per the user's requirements.

Many have such a small size and less weight that you can mount them to the back of a monitor and create your all-in-one PC. This has the advantage that you can upgrade your display without needing to replace the entire system.

For basic tasks like web browsing, word processing and media consumption like watching a video, a high-performance desktop is not required. A lower power computer like Mini-PC can become an ideal solution in these scenarios.

II. FORM FACTORS OF PC'S

Computer form factors comprise a number of specific industry standards for motherboards, specifying dimensions or size, configuration, power supplies, placement of mounting holes and ports, and physical arrangement of other parameters.[2]

In 2017, computers are made in 5 broad categories, and they are Desktops, Laptops, Tablets, All-In-One and Mini-PC.

A. Desktop

A desktop computer is a personal computer designed for regular use at a single location on or near a desk or table due to its size and power requirements. The most common configuration has a case that houses the power supply, motherboard (a printed circuit board with a microprocessor as the central processing unit (CPU), memory, bus, and other electronic components), disk storage (usually one or more hard disk drives, optical disc drives, and in early models a floppy disk drive); a keyboard and mouse for input; and a computer monitor, and, often, a printer for

output. The case may be oriented horizontally or vertically and placed either underneath, beside, or on top of a desk.[3]

Fig. 2(a) – Desktop Example[4]

B. Laptop

A laptop, often called a notebook or "notebook computer", is a small, portable personal computer with a "clamshell" form factor, an alphanumeric keyboard on the lower part of the "clamshell" and a thin LCD or LED computer screen on the upper portion, which is opened up to use the computer. Laptops are folded shut for transportation, and thus are suitable for mobile use.[5]

Fig. 2(b) – Laptop Example[6]

C. Tablet

A tablet is a wireless, portable personal computer with a touchscreen interface. The tablet form factor is typically smaller than a notebook computer, but larger than a smartphone.[7] The tablet differs from a laptop as it does not include a keyboard in its casing and the touchscreen is the main input for it.

Fig. 2(c) - Tablet Examples:iPad[8], Microsft Surface[9]

D. All-in-One

All-in-One PC is a desktop computer with the monitor and CPU in the same case. The main difference between a Tablet and All-in-One are that tablets are more portable, and have a battery inside their casing. The All-in-One PC use an external power supply, are more bulkyand have more ports for external devices.

Fig. 2(d) – All-in-One Example [10]

E. Mini-PC

The Mini-PC is like a Desktop PC but it is much smaller, portable and consumes less power. Some Mini-PCs can fit inside the palm of your hand. Desktop are usually more powerful and have more options for components.

Fig. 2(e) – Mini-PC examples: Intel NUC[11], Raspberry Pi 3[12]

III. E-BALL PC CONCEPT

The E-Ball is a sphere shaped computer concept which is the smallest design among all the laptops and desktops have ever made. This PC concept features all the traditional elements like a mouse, keyboard, large screen display, DVD recorder, etc. all in an innovative manner. E-Ball is designed to be placed on two stands, opens by simultaneously pressing and holding the two buttons located on each side. After opening the stand and turning ON the PC, pressing the detaching mouse button will allow you to detach the optical mouse from the PC body. This concept features a laser keyboard that can be activated by pressing the particular button.

Fig. 3 – E-ball PC Concept by ApostolTnokovski

There's no external display unit; a projector will pop up by pressing and holding the button and focus the computer screen on the wall which can be adjusted with navigation buttons. If there is no wall around, the paper sheet holder divides into three pieces like an umbrella just after popping up, will help to focus the desktop on a piece of paper.

The software interface of E-Ball is highly stylized with icons that can be remembered easily and is user-friendly. This small PC will be ideal for use when working in an office, making video presentations, watching large screen movies, listening music and chatting on the net.[13]

IV. Traditional and Widely Used Cooling Methods for CPU

The computer has electricity moving through its components during operation and generates heat due to the nature of the components selected. Computer cooling is required to remove the waste heat produced by computer components, to keep components within permissible operating temperature limits. The computer's components are very sensitive to temperature and if these components get too hot in the computer case/body, it will start to overheat and shut down. This can be annoying, but it's preferable to having the components melt.

Components that are susceptible to temporary malfunction or permanent failure if overheated include integrated circuits such as CPU (Central Processing Unit), GPU (Graphics Processing Unit), chipset, hard disk drives, etc.

In Mini-PCs, the CPUs usually selected have GPU build inside the CPU die. Instead of HDD, SSD or EMMC flash storage is used. So, the main component left which requires cooling is the CPU.[15]

One of the most commonly used tools to cool the CPU is a Heatsink. Heatsink is a passive device with large thermal capacity and with a large surface area relative to its volume. Heatsinks are usually made of a metal with high thermal conductivity such as aluminium or copper, and incorporate fins to increase surface area. Heat from a relatively small component is transferred to the larger heatsink; the equilibrium temperature of the component plus heatsink is much lower than the component's alone would be.

The so combination of heatsink and methods that are used to cool the CPU are:-

A. Passive Heatsink (Passive Cooling with Heatsink)

Passive heatsinks are designed to move heat away from a computer's central processing unit without using a fan.A passive heatsink does not include a fan in the design, and is typically larger than a standard model, using the extra surface area of the device to improve thermal cooling in compensation for lack of a fan.

Passive heat-sink cooling involves attaching a block of machined or extruded metal to the part that needs cooling. A thermal adhesive may be used. More commonly for a personal-computer CPU, a clamp holds the heat sink directly over the chip, with a thermal grease or thermal pad spread between. This block has fins and ridges to increase its surface area. The heat conductivity of metal is much better than that of air, and it radiates heat better than the component that it is protecting (usually an integrated circuit or CPU).[14][15]

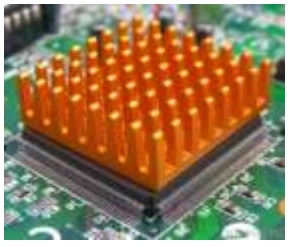

Fig. 4(a) – Passive Heatsink with copper block[16]

B. Active Heatsink Cooled by Fan

Fans attached to components are usually used in combination with a heatsink to increase the area of the heated surface in contact with the air, thereby improving the efficiency of cooling. Fan cooling is often used to cool processors and graphics cards that consume significant amounts of electrical energy. Fans are used when natural convection is insufficient to remove heat.

In a computer, a typical heat-generating component may be manufactured with a flat surface. A block of metal with a corresponding flat surface and finned construction, sometimes with an attached fan, is clamped to the component. To fill poorly conducting air gaps due to imperfectly flat and smooth surfaces, a thin layer of thermal grease, a thermal pad, or thermal adhesive may be placed between the component and heatsink.[15]

Main difference between active and passive is that a fan is used along with a heatsink for cooling for active.

Fig. 4(b) – Active Heatsink cooled by fan[17]

C. Liquid Cooling

Liquid cooling is a highly effective method of removing excess heat, with the most common heat transfer fluid in desktop PCs being (distilled) water. The advantages of water cooling over air cooling include water's higher specific heat capacity and thermal conductivity.

The principle used in a typical (active) liquid cooling system for computers is identical to that used in an automobile's internal combustion engine, with the water being circulated by a water pump through a waterblock mounted on the CPU (and sometimes additional components as GPU and northbridge) and out to a heat exchanger, typically a radiator. The radiator is itself sometimes cooled additionally by means of a fan.Also, a coolant reservoir is often also connected to the system.

Disadvantages of liquid cooling include complexity and the potential for a coolant leak. Leaked water can damage any electronic components with which it comes into contact and the need to test for and repair leaks makes for more complex and less reliable installations. [15]

Fig. 4(c) – Example of Liquid Cooling setup

D. No Cooling

The outer surface area of the CPU is not covered by any heatsink. It is exposed directly to the air and temperatures are mostly controlled by the motherboard by changing the frequencies and voltages supplied to CPU to keep heat generation in check. The technology used is for this is called Thermal Throttling.

Fig. 4(d) – CPU of Raspberry Pi 3 exposed[19]

V. Passive Cooling with Desktop Case

DB4 Fanless Chassis by Streacom is a Desktop form factor computer case.[20] Instead of just using a comparatively small Passive Heatsink for the CPU, they have made the Case with 4mm thick Aluminium and connected the CPU with the case via Heatsink block and Thermal heat pipes made out of Copper.

Fig. 5(a) & 5(b) - DB4 Fanless Chassis by Streacom

Tests and Benchmarks conducted by HardwareCanucks YouTube channel indicate that with proper thermal compound adhesive the case was efficiently able to cool a Desktop grade processors with higher TDP(Thermal Design Power) was within the acceptable temperature limit of 80 degrees Celsius and giving good performance.[21] The results are comparable to the temperatures that are achieved by using the stock coolers(active heatsink with fan).

VI. Passive Cooling with Case for Raspberry Pi 3

Raspberry Pi 3 is a Mini-PC made by the 'RASPBERRY PI FOUNDATION UK' which runs Linux and can be used to make small projects.[22]

There is a Passive Cooling Case solution available for the Raspberry Pi 3 by a third party'Flirc.tv' which is known as the FLIRC case.[23]

Fig. 6(a) – FLIRC case for Raspberry Pi 3

Tests and benchmarks conducted by YouTube Channels ETA Prime[24] and ExplainingComputers[25] show that with no cooling (No Heatsink) and a passive heatsink (EBAY Heatsink), thermal throttling occurred and affected the performance by reducing the highest clock frequency. Thermal Throttling did not occur with the FLIRC Case and the highest clock frequency was maintained throughout the benchmark. The figure below shows a table containing the temperatures recorded at different time intervals with all the 3 cooling methods.

NO HEATSINK		EBAY HEATSINK		FLIRC CASE	
45.1'C	113'F	44.0'C	111'F	39.2'C	102'F
76.8'C	170'F	69.3'C	156'F	56.4'C	133'F
80.6'C	177'F	77.4'C	171'F	58.5'C	137'F
80.6'C	177'F	80.1'C	176'F	60.1'C	140'F
81.1'C	178'F	81.1'C	178'F	61.2'C	142'F
80.6'C	177'F	81.7'C	179'F	62.3'C	144'F
81.7'C	179'F	81.7'C	179'F	63.9'C	147'F
82.7'C	180'F	81.7'C	179'F	64.5'C	148'F
81.7'C	179'F	81.7'C	179'F	65.0'C	149'F

Ambient Room Temperature = 24.4'c 76'F

Fig. 6(b) – Temperatures after Benchmarks by ETA Prime

From the table and tests we can conclude that the Raspberry Pi 3 Mini-PC ran at a lower temperature with the Passively Cooled FLIRC Case than the no cooling and passive heatsink methods. The maximum temperature reached by the CPU is also far lower. Hence, we can conclude that the Passive Cooling with Case for the Mini-PC is a better alternative than the other 2 methods used.

VII. Limitations of current Mini-PC

The designs for current Mini-PCs suffer from some problems and have limitations due to them using traditional methods that are used for making Desktop. Some of them are:-

A. Thermal Throttling Due To Inadequate Cooling

Thermal Throttling is a great technology, but if you are experiencing it; in most cases there is something wrong with your computer, its design or the conditions in which the computer is being used.[35]

The earlier CPUs used to run at 1 frequency only and the heat that they produced at idle or full use was the same. If proper cooling like a heatsink was not used, it would cause the CPU to overheat and melt or damage itself. To overcome this, Intel introduced a technology which they named SpeedStep with their later Pentium processors. It allowed the clock speed of the processor to be dynamically changed which in turn reduced heat generated.[38]

The evolution of that technology is Dynamic Frequency Scaling which is now used by modern CPUs. Dynamic frequency scaling (also known as CPU throttling and Thermal Throttling) is a technique in computer architecture whereby the frequency of a microprocessor can be automatically adjusted "on the fly", either to conserve power or to reduce the amount of heat generated by the chip. Dynamic frequency scaling is commonly used in laptops and other mobile devices, where energy comes from a battery and thus is limited. It is also used in quiet computing settings and to decrease energy and cooling costs for lightly

loaded machines. Less heat output, in turn, allows the system cooling fans to be throttled down or turned off, reducing noise levels and further decreasing power consumption. It is also used for reducing heat in insufficiently cooled systems when the temperature reaches a certain threshold, such as in poorly cooled overclocked systems.[34]

Due to their size, Mini-PC often uses small fans and heatsink or no cooling at all. This results in thermal throttling to occur which affects the performance and responsive of the computer.

B. Increased Noise Due To Small Fan in Tight Space

Small fans are used in Mini-PC to cool the components like CPU. As the temperature rises inside the case due to components like CPU generating heat, too dissipate heat in such a small space over a small surface area, the fans have to work harder and faster to effectively cool down the components. This results in noise to be generated as the fans displacing hot air and the fan's mechanical nature.[26]

C. Dust built-up due to openings for fans

To provide cool air inflow and to expel hot air out of the Mini-PC, openings must be created in the case.

Dust is a natural phenomenon and it tends to get sucked inside the Mini-PC due to fan. The dust slowly gets built-up over a course of time and blocks the openings for air. This problem is faced by Desktops and Laptops too.

Fig. 7(c) – Dust built-up rendering cooling work offan useless[39]

D. Case have no secondary purpose

Case of Mini-PC, if any, are made to just hold the components and for aesthetics. They have no other purpose. They only provide minimal protection to the components inside.

VIII. New Designs for Mini-PCs: Our Concept

Through our research and the findings shown in this paper, we think that a better design for Mini-PC can be made. We think that due to lower performance requirement and the tasks that can be done with the Mini-PC we must use components and designs but suited to maximize their potential. Our design concept is based on the combination of various ideas, methods and designs like the E-Ball PC Concept [13], Intel NUC (Next Unit of Computing)[30], etc.

The case of the Mini-PC should be made out of the material aluminium. The material for the case should be aluminium as it is one of the best metals due to its high heat conductivity and lower weight next to copper. The body/case will be acting as the main Passive Heatsinkfr the Mini-PC. Aluminium is also easier to manufacture, factories are using it currently to make cases, and it is one of the abundant materials availablewhich does not corrode. If plastic is used for the case, then the Mini-PC will be lighter than one made of Aluminium, but the heat conductivity and strength will be compromised.

For cooling, the higher the surface, the more effective is the heat dissipation; which is one of our main objectives of this concept. The shape of Mini-PC should be spherical. Out of all the shapes, the sphere has the largest surface area for the least amount of material used. There are a few problems with using a sphere for the shape. Most of the components used for making the Mini-PC like the motherboard are rectangular in shape. This will result some waste space being left. Another problem is the manufacture of spherical body. The spherical body can be made out of two separate hollow semi-spheres. The semi-spheres can be either made by CNC with all the mounting points for components or using techniques used during the manufacture of aluminium cans.[36] The hollow semi-sphere can be started from a sheet of thicker aluminium metal. Then the Doming Tool can be used to make the shape.

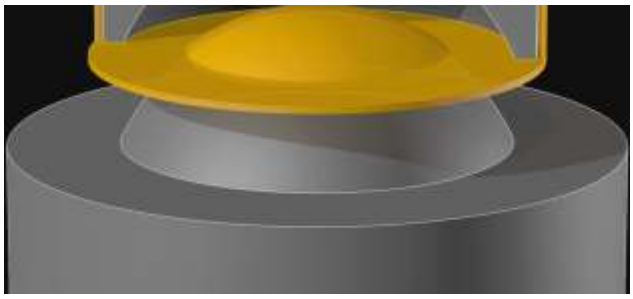

Fig. 9(a) – Doming Tool used to give semi-spherical shape to metal sheet

Then the mounting points for the components can be soldered inside the semi-sphere. After the completion of both the halves, they can be joined with rivets or screws in place.

The Motherboard of the Mini-PC should be square in size, with all its ports like HDMI, Thunderbolt 3.0, USB 3.0, Audio jack, Ethernet Jack, etc. on one side(back) of the motherboard. External peripherals like displays, keyboard, speakers, mouse, etc. can be connected via the port provided by the motherboard.

CPU will be soldered in the centre of the motherboard. The CPU must be a low TDP laptop grade processor like Intel Celeron, Intel Pentium, Intel Atom, ARM processor, or others since our main goal for creating this Mini-PC is to achieve a balance between heat generated, performance and size of the computer. Lower TDP processors will create less heat as compared to their Higher TDP counterparts while giving lower performance. This much performance is enough for the use cases that the Mini-PCs are being used for. To maintain the performance we are using passive cooling.

The CPU on the motherboard will be connected with Thermal Heat pipes & heatsink with a layer of thermal paste to make proper connection. The contact part of the heatsink & Thermal Heat Pipes with the case will also be using Thermal Paste but will a curved surface with an arc measuring the curvature of the spherical body of the case.

Instead of HDD, SSD or EMMC drive can be use as storage as they are silent, don't use mechanical parts and generate less heat.

RAM can be soldered or laptop low profile SODIMM rams can be used on the motherboard.

The power button can be mounted on the case and connected to the motherboard via wires and connectors.

Metal stand be made to hold the sphere or legs can be soldered on the case itself.

These are the major designs and components that are required to make Mini-PC. The next design choices are an attempt to make a Mini-PC and All-in-One hybrid.

Small speakers can be installed on either curve of the sphere with cut-outs or holes provided for them. This will be useful to utilize the waste space inside between the motherboard and case. This will provide one more functionality that current Mini-PC don't offer.A projector can be mounted from inside the case above the ports of the motherboard which will integrate act as the screen of the Mini-PC.Webcam, Laser keyboard and touchpad can also be integrated on one face/side of the sphere. Allthis functionality will have all the components that the user needs to interact with the computer.

The size of the whole Mini-PC will be a little larger than the Intel NUC but it will still be portable.

Since there are no moving or mechanical parts, this Mini-PC will be completely silent and fan-less.

IX. Conclusion

In this paper passive cooling and new features for Mini-PCs were discussed. Our findings suggest that Passive Cooling using the case of the Mini-PC is a better alternative to using heatsink and fans for its cooling as it offers comparable or even better performance while eliminating some the limitations like noise.Having some type cooling instead of no cooling gives better performance; so passive cooling gives an alternative with acceptable performance and completely silent operation in small form factor computer like Mini-PC when compared with Liquid Cooling and Active Heatsink with Fan. Limitations discussed can beovercome with our findings and new design for Mini-PCs. Other components and devices like Speakers, keyboard, projector, etc. can be integrated into the case of the Mini-PC if required to make a Mini-PC & All-in-One hybrid personal computer.

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