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Central Processing Unit Binary Cooling System using Tetrafluoroethane as Refrigerant

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Abstract: ***Electronic devices and instruments generate heat that can cause serious damage and low efficiency towards its components. The heat that the different electronic elements and components emit can decrease both efficiency and life capacity of the device. And with the increase of use of electronic devices in industries and processes, heat dissipation in electronic devices should be taken into strict consideration. This study aims to develop a cooling system under vapor compression refrigeration system. The prototype fabricated was designed for the cooling system of two Central Processing Units of desktop computer which can be as good equivalent for the electronic devices in industries. Though ventilation was present in the processing units, certain condition such as condition in surroundings can be of great help to improve the device efficiency. This study also aims to analyze the CPU's efficiency in relation to lowering ventilation temperatures. The vapor compression refrigeration system will be the main device used for lowering and maintaining a suitable temperature inside the CPU casing. The system works like a centralized air-conditioning system wherein the air from the surroundings will be cooled down by the evaporator in the vapor compression refrigeration system. The cooled air will then be delivered to the CPU through the installed air ducting connections. The recording of CPU's efficiency is provided by the installed software. It also measures the air conditioned parameters and computation of the CPU power consumption. The results from the test and the analysis of the gathered data showed that 165 watts of heat dissipated was removed by the cooling system and the CPU performance index rose up from 424 to 446 with a discharge air temperature of 29.67 °C. Based from the result, the fabricated binary cooling system is efficient enough to increase the performance index of the CPU and absorbing heat dissipated by the device.***

Keywords: ***Binary Cooling System, Central Processing Unit, Tetraflouroethane, Vapor Compression Refrigeration System***

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I. INTRODUCTION

The electronic devices and instruments generate heat that can cause serious damage and low efficiency towards its components. The heat that the different electronic elements and components emit can decrease both efficiency and life capacity of the device or the instruments. The second law of thermodynamics states that the efficiency of a device can be increased by reducing the energy wastage[1]. And with the increase of use of electronic devices in industries and processes, heat generated in electronic system should be taken strict consideration. Take for example a Central Processing Unit (CPU), it acts as the brain of the computer and contains these devices that generate heat. Air circulation inside the CPU allows the heat to get carried away and reject it to the surroundings by the use of the fan. We can also observe that fins are attached in order to improve heat transfer through the system. This basic system of air circulation and fins can lessen the heat that is generated by the devices. However, the simple air circulation is not be enough for the operating CPU and thus slowly damaging the devices inside the CPU. Applying the basic knowledge for the theory and application of the subject in Refrigeration and Air Conditioning to the CPU as its medium of cooling, can be of great help for removing the amount of heat generated all over the CPU. A one (1) degree Celsius temperature drop can give a large effect for the CPU's performance index. Thus a low temperature supply air is necessary for the CPU's cooling system and to improve system performance.

The CPU generates heat according to its surroundings and usage. As the main component of the computer, it operates with more heat and houses most of the devices that generates heat energy. These are just some of the common devices that generate heat inside the CPU: video card, microchips, soundcard, power supply, hard disk and etc. Too much use of CPU might cause the following problems: overheating, hindrance of performance and damage to devices. CPU has its own normal operating conditions which must be observed when in operation. Some of these operating conditions are: temperature, humidity, and air flow. In order to maintain the desired normal operating conditions, research on its cooling system and experiment for applying a vapor compression cycle must be conducted.

This study aims to design and fabricate a cooling system for the CPU under the principle of vapor compression refrigeration system by utilizing a commercial water dispenser and study its impact in cooling the CPU.

These are the objectives of this study:

• 1.To fabricate a binary system with heat exchanger using cold water and a primary system with tetraflouroethane as refrigerant.

• 2.To study the effects of lowering the CPU's supply air temperature.

• 3.To measure the change in temperature between the supply air temperature and discharge air temperature of the CPU.

• 4.To determine the power consumption of the fabricated cooling system.

A. Conceptual Framework

This study involves the principles related to the subjects in Heat Transfer, Fluid Mechanics, Refrigeration and Air Conditioning Theory and Application. An experimental rig is fabricated and assembled with the binary system from a commercial water dispenser. This modified system is still under the principle of vapor compression refrigeration system wherein a compressor, condenser, expansion device, and evaporator are the main component of the system.

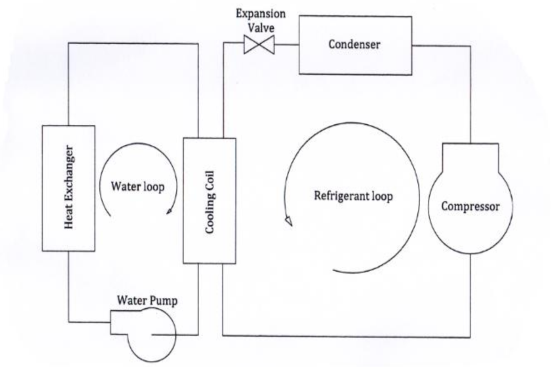

Fig. 1. CPU binary cooling system

Fig. 1 shows the binary system utilizes tetraflouroethane refrigerant on the first loop and tap water on the second loop. A built-in fan inside the heat exchanger on the second loop is used to circulate the air and thereby rejects heat in the evaporator. The cold air from the heat exchanger is being delivered directly to the CPU casing with air ducting connections installed. At least two (2) CPU with a gradual enlargement at one side were considered. These design will be evaluated and compare to the standards for a better cooling system.

B. Significant of the study

1. The binary cooling system for CPU is not only limited for small scales like internet cafes but can also be applied to large industries where computers and electronic devices generates more heat.

2. It can supply data and results such as temperature, pressure, flow rates and heat dissipated from the experiment that can be used as a useful study.

C. Scope and Limitations

The main purpose of the study is to remove the heat that is generated by the two (2) units of CPU using Vapor Compression Cycle. The data and results are used to tabulate graphs and tables. The strength and durability of the system are not considered in this study since it only focuses for the cooling system of computers. The study is limited only for the computer cooling system engineering study using vapor compression cycle and computer software Sandra as a tool used to evaluate the performance index of the CPU.

II. METHODOLOGY

The study conducted includes fabrication of two cooling systems: a primary system that allows the liquid refrigerant to flow directly to the air handling unit and a secondary system that allows only water to flow into the air handling unit. These two systems are mostly similar in nature, since both systems has heat exchangers. Their difference is that in the primary system, tetraflouroethane refrigerant is used to flow directly to the evaporator coils of the air handling unit. The binary system on the other hand includes the use of two separate evaporator tubes; one where refrigerant flows and the other where water flows. The evaporator coil where refrigerant flows is submerged in liquid and is placed inside a water storage drum to induced a high coefficient of heat transfer[2].

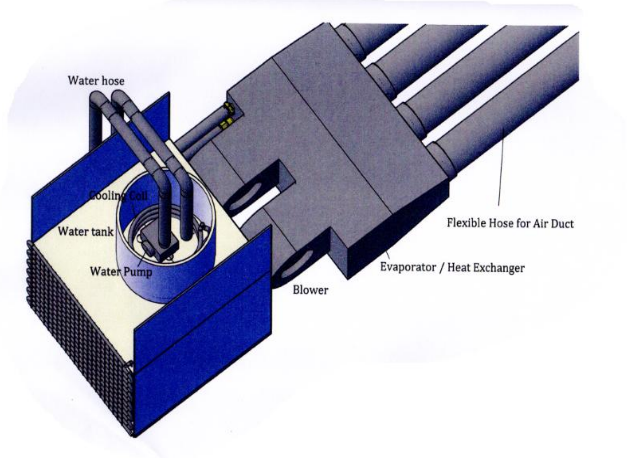

Fig. 2. Binary cycle detailed view

The water floods the evaporator coil containing the low temperature refrigerant and pumped to the air handling unit on the secondary loop. The purpose of which is to cool down water to a lower temperature. Water from this drum is then pumped to the evaporator coil of the air handling unit containing the fan through a tube connector. Air that passes through the air handling unit decreases its temperature and cooled air circulates inside the CPU and back to the air handling unit as shown in Fig.2.

Materials used in the fabrication of the system includes the copper tubes (¼ inches in diameter), capillary tube (smallest tube available), flare knots, and rubber tubing and water pump which are both used in the binary system[3]. Connections of the copper tubes are made possible through the use of acetylene welding. Proper handling of the welding tool and balance mixing of fuel and oxygen in the welding process contributed to the success of the experimental rig

Since the study conducted by the authors is to create a system out from a modified water dispenser, the authors started the fabrication through the selection of a water dispenser to be used.

The system where the commercial water dispenser had been used was for the binary system mention above, wherein the water cooled by the evaporator coil is pumped to the air handling unit by means of a water pump. Due to elevation and pressure losses, additional head is required to complete the cooled water circulation throughout the system[4].

The two systems; binary and primary, were operated by a single compressor. Refrigerant flows of the two systems are controlled by valves. When primary system was running, the valve which controls the flow of refrigerant in the binary system was kept closed. When the binary system was running, the valve which controls the flow of refrigerant in the primary system was kept closed as shown in Fig.3.

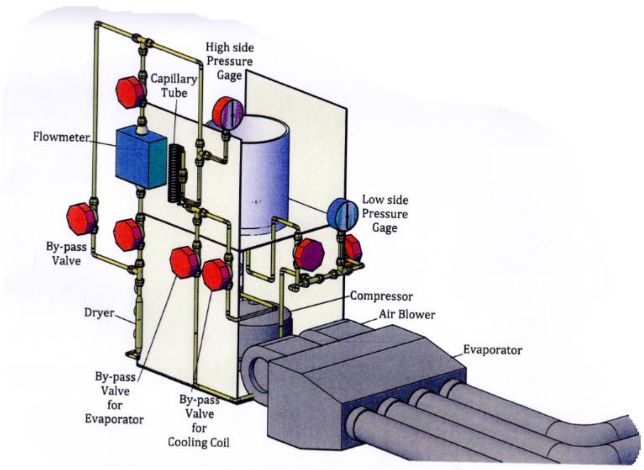

Fig.3. Binary system copper tube connection

The cooling load capacity of the system is 150 W. Since the components comprising the refrigeration system of the dispenser was almost complete, the need for a handling unit arises. The proponent then decided to buy an air handling unit that will be responsible for the transmission of cool air to the CPU though plastic tube connectors. Number of CPU's used were limited only to two and number of plastic tubes connector used per CPU was two also. CPU under study had within it a certain program that measures temperature during its usage. This program was used by the researcher to analyze and to compare the performance of CPU with or without the installation of the cooling system.

Vapor-compression refrigeration is one of the many refrigeration cycles commonly used nowadays in industries. It is the most widely used method in the air conditioning systems of large buildings, offices and even refrigerators at home. Oil refineries and chemical processing plants include those industrial plants that utilize the use of vapor compression cycle.

A liquid refrigerant is the main medium used in a vapor compression cycle. Vapor compression refrigeration system comprises four basic components: a compressor, a condenser, a thermal expansion valve and an evaporator[6]. Refrigerant enters the compressor as a saturated vapor and is compressed to a higher pressure which results to a higher temperature. Superheated vapor then results after the vapor is compress in the compressor. That hot vapor then flows through the condenser where it is cooled and condensed into liquid form by flowing through a coil or tube. The flow of refrigerant in the condenser tube is where heat rejection takes place.

The condensed liquid refrigerant, which is a saturated liquid, flows through an expansion valve where it undergoes a decrease in pressure. This decrease of pressure results in a decrease of temperature in refrigerant. Decrease of temperature and pressure of refrigerant is indicated by the formation of ice along the evaporator coil or after the capillary tube[5].

The refrigerant after being throttled in the expansion valve flows to the evaporator tubes. The evaporator is where the circulating refrigerant absorbs and removes heat. In air conditioning systems, a fan is usually used to blow air to the evaporator coils containing the low temperature refrigerant. The blowing of air unto the evaporator coil results in the evaporation on the part of the refrigerant. Air that passes through the evaporator coils decreases its temperature. This then results to a low temperature inside the enclosed space on which the cooled air is intended to circulate.

To complete the refrigeration cycle, the saturated vapor in the evaporator is routed back to the compressor of which it is to undergo compression once more.

III. EXPERIMENTAL

Data gathering from the experimental rig are measured from the instruments available from the M. E. Laboratory.

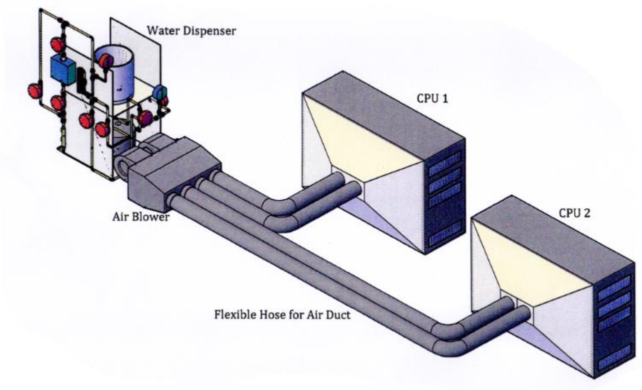

Fig. 4. CPU binary cooling system experimental rig

The complete system of the vapor compression refrigeration system which includes the evaporator, condenser, expansion device, drier, and compressor are all assembled in according to their functions[7]. The ducting system of the CPU should also be assembled. Also, the pressure gages are calibrated to ensure accurate readings. Before making test, the vapor compression refrigerating system from the commercial water dispenser should be flushed out in order to remove impurities and moisture contents of ambient air. The flushed refrigeration system is then charged with the tetraflouroethane refrigerant with a compressor running between 150 psi to 250 psi as shown in Fig. 4.

Available instruments in the M.E. Laboratory to be used in data gathering were two(2) units of velometer, three(3) units of thermocouples and one(1) unit of flowmeter. Velometer is used to measure the ambient temperatures and relative humidity of ambient air.

The second velometer is used to measure the temperature of air discharge from the CPU, either dry or wet bulb of air temperature, relative humidity of air and volume flow rate of air[8]. The thermocouples are used to measure the temperature of tetraflouroethane refrigerant at the evaporator's inlet and outlet, as well as the temperature of circulating water in the second loop. Flowmeter is used to measure the volume flow rate of the tetraflouroethane refrigerant in gallons per minute.

Fig.5. The fabricated experimental rig

Each test was given a time of one minute and 15 number of trials or until the system stabilizes. The velometer is placed at the discharge side of the second evaporator to measure the air temperature.

Another test was conducted at the CPU discharge air to measure its output parameters. Together with this test, a program has been ran for CPU in order to measure the temperature and fan speed of the mother board. All these data were tabulated in tables to generate graphs. With the velometer test, a temperature test was also conducted for measuring the evaporator temperature inlet and outlet by the thermocouples. The pressure of the tetraflouroethane refrigerant was also recorded for every 30 seconds intervals throughout the whole data gathering[9].

IV. RESULT AND DISCUSSION

To achieve the specific objective of this study, prototype testing and experiment were performed in order to determine the temperature and the performance index of the CPU (Central Processing Unit) with a cooling system installed and without the cooling system.

Specific Objective 1: To fabricate a binary system with heat exchanger using cold water and a primary system with tetraflouroethane as refrigerant.

The system fabricated, as shown in Fig. 5, was designed to pump cold water from a water tank installed in the water dispenser with a temperature of 4.5°C. This temperature was achieved after 50 minutes of cooling the water. The water dispenser system has a cooling capacity of 150 W and a thermostat which was fully adjusted to reach the lowest temperature possible. This cold water was then pumped into a heat exchange unit with an air blower installed. The heat exchange unit can release air of up to 25 cubic feet per minute. Yet, the study only limited its volume flow capacity up to 17 cfm as to allow proper heat load capacity. The outlet air temperature in this system yielded for a temperature as low as 21°C. But after 17 minutes later, the air temperature of the heat exchanger outlet rose until its 0.5°C lower than the ambient temperature. With this observed parameters, the study proceeded to the modification of the system by utilizing a primary vapor compression refrigeration system and using the water dispenser available in the market.

# of	Time	Pressure (psi		Flowmeter (gpm)	Thermocouple (Celcius)		
Trial	mins	High Side	Low Side	Refrigerant Flow	Evap. Inlet temp.	Evap. Outlet temp.	Ambient
1	1	215	15	0.9	1.0	12.8	30.4
2	1	215	15	0.74	0.4	12.3	29.9
3	1	215	15	1.11	0.1	12.3	29.8
4	1	215	15	0.73	0.7	11.9	29.8
5	1	215	15	0.93	0.2	11.8	29.6
6	1	215	15	1.01	-0.1	11.7	29.5
7	1	215	15	0.9	0.3	11.9	29.5
8	1	215	15	1.03	0.2	11.9	29.5
9	1	215	15	0.81	0.1	11.9	29.6
10	1	215	15	0.86	0.0	11.7	29.5
11	1	215	15	0.85	0.3	11.8	29.8
12	1	215	15	0.96	-0.5	11.4	29.7
13	1	215	15	1.06	0.7	11.6	29.6
14	1	215	15	1.14	-0.5	10.9	29.5
15	1	215	15	0.89	-0.4	11.1	29.5

Fig. 6. Temperature reading for the water dispenser

Figure 6 shows the evaporator temperature of the water dispenser used as the driving mechanism in the fabricated experimental rig.

The second system fabricated used tetraflouroethane refrigerant as the primary cooling medium. Since the study allows the modification of the commercial water dispenser, the fabricated design provided a bypass and isolation valves to direct the refrigerant to the evaporator coils. The evaporator is bypassed after the installed capillary tube and returned to the main system before the refrigerant can enter the compressor. Pressure gauges were mounted before and after the bypass lines were it is accessible in monitoring the pressure of both the high and the low side pressure of the experimental rig

The main line is mounted along with a liquid flowmeter that provides a real time measurement of the mass flow rate of the tetraflouroethane refrigerant. This system is designed to allow the flow of tetraflouroethane refrigerant to the evaporator and eventually, cool down the air supplied by the blower. Pressure in the system is determine through the real time measurement since the name plate of the compressor didn't have the pressure data for the system. The highest pressure readings before the compressor tripped was around 275psig and 28psig, respectively.

The system yielded the temperature of air for as low as 26.4°C. The results were satisfactory since the temperature of air dropped to 4.6°C and the relative humidity of air dropped as the air evaporator continue to extract heat from the circulated water. This is due to the dew point temperature being reached by the evaporator coils and therefore extracting the moisture before it was blown away towards the outlet of the evaporator. This can be a good indication that the study minimizes moisture content in air which can be a helpful parameter for cooling systems in electronic devices where moisture is a problem of corrosion.

Specific Objective 2: To study the effects of lowering the CPU's supply air temperature.

The test results showed temperature and performance index with regards to a low temperature supply to the CPU. The temperature of the motherboard in the CPU, with a cooling system lowered from 45°C to 41°C is an indication that the devices reacted to the change in temperature. The motherboard was an important heat emitter inside the CPU since all of the main electronic devices were installed and correlated in the mother board. The mother board is allowed to process heavy programs such as gaming and video playback during the test thereby generating a lot of heat. It was noticed that as the software programs started, the board as well as the processors, there is an immediate increase in temperature. There are also effects on the speed in the variable fan installed inside the CPU's mother board. Due to the installed Digital Thermal Sensors(DTS) for Pentium 4 and higher, the fan varied in proportion to the temperature of the mother board. From 2,872 rpm and a board temperature of 42°C, it increased to 4,167 rpm and at a temperature of 45 °C without the cooling system.

With the installed cooling system, the board temperature dropped from 45°C to 41°C with fan speed drop from 3,649 rpm to 3,392 rpm and rose again up to 3497 rpm. With the CPU's performance index, the over-all score of CPU performance index increased from 424 without the cooling system to 446 with the cooling system as shown in Fig.7 and represented by the equation of $y = 0.0843x^2 - 7.7648x + 602.07$ with a value of $R^2 = 0.999$.

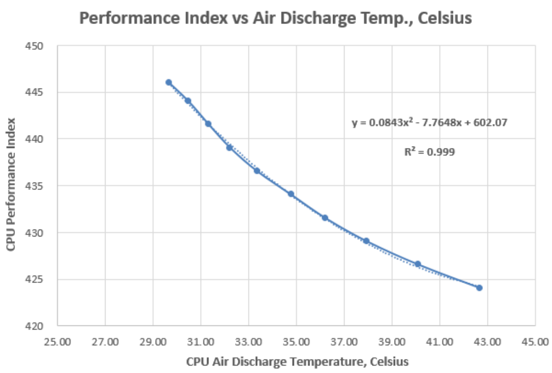

Fig. 7. Performance Index vs. Air Discharge Temperature

With the handling of the user in the CPU, there were no major changes being noticed by the user in the operation of the CPU. This is probably caused by the changes in CPU's performance index and can be noticed with human's perspective that the fan speed is drastically reduced with the presence of air cooling system. The result is satisfactory with the basis of the Sisoftware Sandra Home 2011 being used in this study. The CPU performance index increases as the air discharge temperature reduces as shown in Fig. 7.

Specific Objective 3: To measure the temperature change between the supply air temperature and discharge air temperature of the CPU.

The cooling system being installed yield a lower temperature and as low as 26.4°C and the discharge air temperature is 42.7°C. This entails that there was heat absorbed from the CPU as the cooling system is running with the maximum air temperature change of 16.3 °C. Calculations were used in obtaining the heat removed inside the CPU and it yielded up to 165.14 Watt with the specific heat of air and the air density used, with the average temperature and at an atmospheric condition. The researched energy that can be emitted from the CPU was approximately 145 Watt[2]. Figure 8 shows the reduction of CPU discharge temperature in degrees centigrade represented by the equation as $y= 0.1066x^2 - 2.5738x + 44.943$ with a value of $R^2 = 0.9988$.

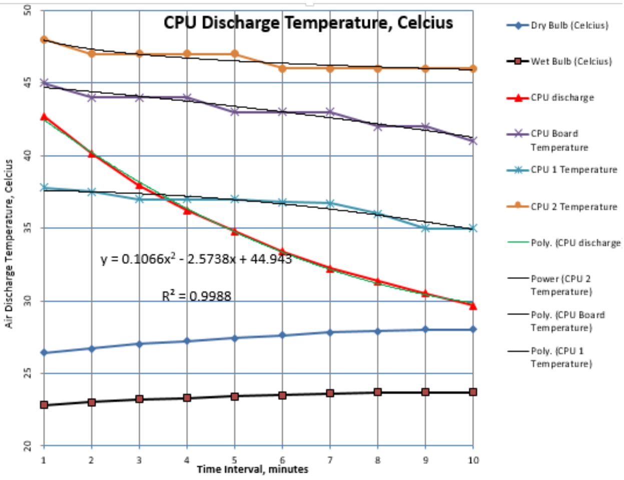

Fig.8. CPU Air discharge temperature

Specific Objective 4: To estimate the power consumption of the fabricated cooling system.

The power consuming devices in the system includes the compressor from the water dispenser and the air blower. The compressor is consuming 150W of electrical energy based on its name plate. The blower runs in a 12V battery with approximately 7.5A of current. Since the air-evaporator run for a battery used in automobiles, the blower worked with a battery of 7.5A of current for a short period of time. With a power-supply directly from the electric source, 240 Watts is the power consumption.

V. CONCLUSION

Heat energy is a very expensive commodity and waste heat recovery system is very important component in a successful industrial operation for the modern world[10]. This waste heat dissipated by the device is also essential for the generation and energy conversion for the use in other devices.

The main objectives of the study were to design and fabricate a cooling system for the CPU under the principle of vapor compression cycle. Using a modified commercial water dispenser, the effects of the binary cooling system is analyzed through the gathered data from the fabricated experimental rig. An experimental rig and the prototype model of the cooling system were developed in order to maintain the required temperature in the electronic devices and for the improvement of the efficiency of the device.

The CPU performance index increases from 424 to 446 as shown in Fig. 7.

This data shows that at higher temperature environment, the electronic devices, such as the desk top, would not deliver the ultimate performance or efficiency of the whole system. The data also shows that a better performance index would still be possible if the binary cooling system temperature would be brought down to a temperature lower than 29.67 ^{o}C.

The study conducted showed that a cooling system directly installed in the CPU's main body can give satisfactory performance results. Integration of the principle of the vapor compression refrigeration system can be of a good system in cooling down the heat generated by electronic components. For better performance index and better temperature control of the CPU, the designed cooling system only consumed 240 Watts for power consumption. The binary cooling system will also increase the life span of the device which is very essential parameter in industrial operation.

Microchips are made up of elements that emit heat when passed by electric current. This heat is very disastrous when it reaches its critical temperature. Protecting these heat emitting components through a binary cooling system is an excellent practice of protecting the electronic system in desk top computer and other similar devices.

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