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REVIEW REFRIGERATED SYSTERM FOR TOTAL SYSTERM POWER MINIMIZATION

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ABSTRACT
Power dissipation and thermal problems have become a growing issue for scaled technology. This phenomenon drives the need for advance cooling systems. It is well-known that cooling the operating temperature results in reduced electric power and/or speed gains. Since cooling cost penalizes the total power, a refrigeration system is developed and experimentally tested to demonstrate that cooling the high performance microprocessor can lead to overall system power improvement [1]. A processor that dissipates 175.4W of maximum power with 30% electronic leakage power operating at 97°C is cooled using our refrigeration system. Measurements show that with a minimum refrigeration COP of 2.7, the processor operates with junction temperature <40°C and offers a 25% total system power reduction over the non-refrigerated design. This experiment is the first demonstration of active cooling that lead reduced total wall power. With an improved compressor that maintains the COP across a broad range of cooling capacity, our analysis shows that at least >13% of total power is saved across the entire range of processor utilization.

Keywords:
Refrigerated Systerm, Power in Refrigerated Systerm, microprocessor.

INTRODUCTION
Reducing power consumption and heat loss in high-performance ICs is becoming increasingly important, especially for microelectronics chips for power-limited high-performance server applications which have maximum dissipation without exceeding the junction temperature point. In fact, the power dissipation for single chips in high power systems is predicted to increase to 161W while the maximum junction temperature lines are 85^0C or less. If the temperature and power are not properly regulated, both the processor chip and the power factor will suffer. To satisfy both requirements, the junction temperature must be reduced. It is the reason that refrigeration systems have attracted much interest from researchers as a real choice that provides solutions to both energy and heat problems. Solving the problem of cooling by keeping the junction temperature below the required temperature can reduce power consumption or can increase processor speed. This type of Refrigerated operation can not only lead to significant improvement in energy consumption but also improve overall system performance without increasing the energy of the whole system including for cooling costs [2]. While analyzes indicate feasibility, these achievings require a dedicated refrigeration system with highly efficient to cool the microprocessor ICs.
Some research has been done on a mini-refrigeration system with integrated electrical cooling for microprocessors that can fit in 1-U or 2-U units. For example, a refrigeration system has shown that T_{evap} evaporator temperature ranges from 8 to 22^0C while it has a cooling capacity of 120 to 280 W with an energy efficiency factor COP ranging from 3 to 4.5 [3]. The authors state that the high efficiency but still small to fit a small compressor can help to improve efficiency system.
This paper builds on and extends the problem by developing a miniature refrigeration system capable of operating at a low evaporating temperature with higher efficiency to use the refrigeration system. The paper focuses on developing fully develop the system based on analysis of two characteristics: electrical capacity and cooling efficiency. Instead of using a heat source, the refrigerating system integrated circuit simulation is increased by one

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level. This allows for processing efficiency and energy loss to be found at lower operating temperatures. This refrigeration system is used to experimentally demonstrate improvements to the system.
Parts below describe the experimental setup and describe the performance of the above refrigeration system in detail. Based on characteristics, measurements and a real-world model of refrigeration systems of all levels [2], the paper discusses the total energy savings when using microprocessors.

INTRODUCTION TO REFRIGERATION SYSTEM

The Refrigeration cycle is shown in Figure 1

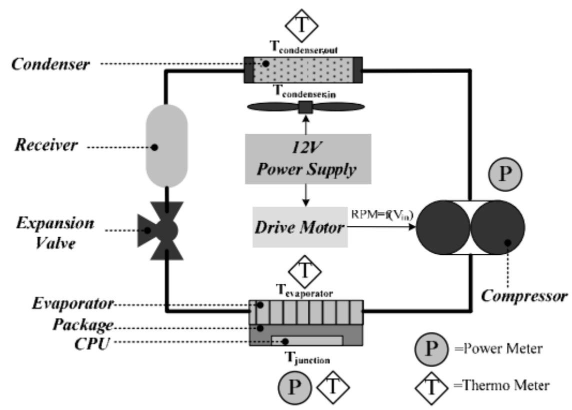

Figure 1: Refrigeration system cycle

Refrigeration system is a closed system and uses volatile liquid such as NH_3, Freon 12 or Freon 22. The capacity evaporation (from liquid to vapor) will collect heat from the cold chamber.

Compressor: The common compressor is a piston pump, which sucks the capacity in the form of vapor from the evaporator, compresses it to create high pressure, and passes it through the condenser to exchange heat with the condenser cooling water and turn it into a supply liquid for the evaporator. When the liquid passes through the throttle valve, it will turn into a vapor. The compressor in the refrigeration system can be single-cylinder or multi-cylinder, compressing one or more stages depending on the cooling capacity and required cooling temperature.

Condenser: The condenser vapor after the compressor has high pressure and temperature, to turn the condensate vapor into a liquid form must take the heat of the compound vapor, that means to cool the compound vapor.

There are two basic ways of cooling:

- First using cooling water. This method is commonly used in refrigeration systems. To supply cooling water, a separate water pump is often used.

- Second fan: Fans blow air through the cooling condenser vapor, commonly used in air conditioning systems (outdoor units).

Throttle valve: The refrigerant through the throttle valve, the pressure is reduced, causing the refrigerant to change from liquid to vapor. When the refrigerant evaporates, the temperature will reduce, collecting heat from the object to be cooled. The throttle valve has the function of reducing the pressure of the refrigerant and is used to adjust the level of liquid supplied to the evaporator.

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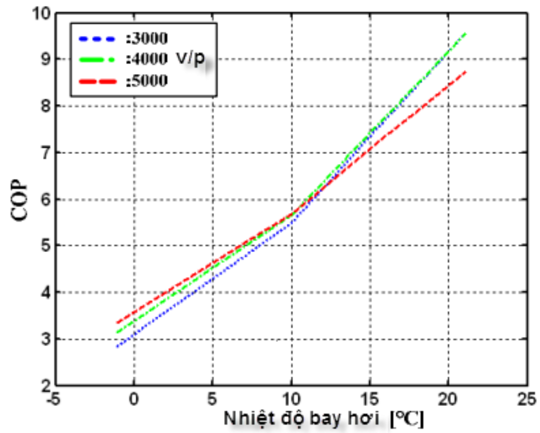

Figure 2: Relationship curve between COP coefficient and evaporation temperature at different compression rates and condensing temperature 27^{0}C

A model of a refrigeration system is simulated to illustrate the factors affecting the efficiency of a refrigeration system [1]

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Electric power 12 voltage is used to supply the system. In addition, an external motor is installed to control the compressor speed and a detector is installed to ensure that only one liquid refrigerant enters the CPEV. The thermo meters T are inserted into the evaporator and into the condenser to measure the temperature. Power meters are used to measure the power consumption of the refrigeration system and measure the heat dissipation flows. The refrigeration system is designed to both cool the microprocessors at different thermal loads and at different temperatures.

Nowaday in the car there are mini refrigeration systems with compressors with a capacity in the range of several hundred watts, suitable for the small spaces of used and used vehicles [4]. Compressor dimensions: 5.58 centimetre in diameter, 7.75 centimetre in height and 590 gram in weight. The compressor is driven by a brushless DC motor that can rotate at 12 voltage DC. The compressor can operate in an evaporator with a temperature range of 18 – 24^{0}C and condensing temperature up to 71^{0}C. Compressor speed around 1800 – 7000 rpm is changed by the auxiliary 20 kΩ resistor. The CPEV automatically regulate the flow of liquid refrigerant into the evaporator at constant pressure for all types of refrigerating system loads, in accordance with the compression capacity. By adjusting the amount of flow (turning the knob of the CPEV unit) the temperature of the evaporator can be adjusted. The test set uses a 50mm x 230mm x 180mm condenser that has a 260W airflow heat rejection at 90CFM. Power 12V DC supplies sufficient air through the entire condenser.

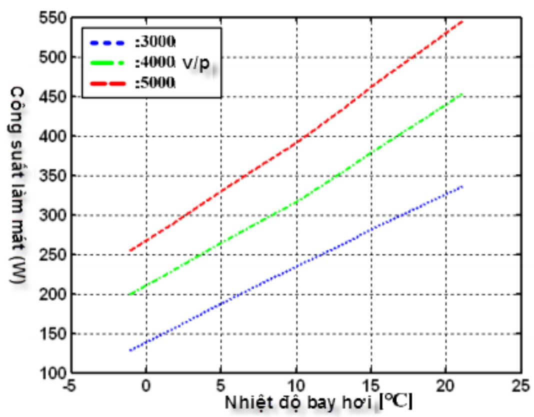

Figure 3: Relationship curve between cooling capacity and evaporator temperature at different compression rates and condensing temperature 27^{0}C

Direct cooling method using refrigerant and using fans (forced air convection). The cooling fans bring hot air to the surrounding. This direct-cooling system is loaded with 120 gram of refrigerant R134.

To ensure insulation from the microprocessor and cooling place, it is necessary to have insulation panels, heat sources and steam pipes that must be sealed and insulated from the surrounding environment. Other layers of insulation are placed between the board frame and the back of the motherboard and on the top surface of the board around the microprocessor.

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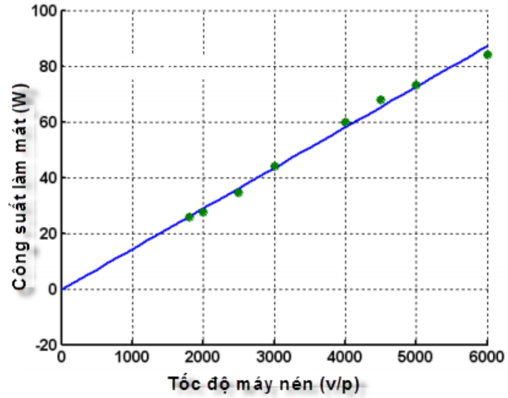

Figure 4: Line showing the relationship between cooling capacity and compressor speed

The designs avoid the removal of any residual gas in the condenser. Additional layers of insulation are attached at the top of the evaporator. The evaporators are also securely fixed via microprocessor mounting TIMs with screws.

CAPACITY OF REFRIGERATION SYSTEM

COP is the energy efficiency factor. While operating a refrigeration system it is desirable that the COP be as big as possible.

The efficiency of the compressor accounts for the majority of the efficiency of the entire refrigeration system. The electrical energy for refrigeration that is calculated according to the Carnot cycle and the energy supplied to the compressor is described by using the coefficient of efficiency COP (Coefficient - Of - Performance). The cooling capacity ($P_{cooling}$) and energy efficiency factor COP of the Carnot cycle appear in the expression to determine the COP coefficient expressed by the expression:

$$\frac{P_{electric}}{P_{cooling}} = COP = \eta.COP_{carnot} = \eta.\frac{T_{evap}}{T_{cond} - T_{evap}} \quad (1)$$

$$P_{cooling} = \frac{P_{electric}}{\eta}.\left(\frac{T_{cond}}{T_{evap}} - 1\right) \quad (2)$$

The detailed operation of the compressor is shown in Figures 2 and 3. The curves are converted from [4] and show COP and cooling capacity as a function of evaporator temperature and compressor speed to give the condensing temperature. [1] has shown that the system is optimally designed to operate when the evaporator temperature is in the range (-1^{0}C – 21^{0}C). At this temperature range the cooling capacity and COP of the compressor (128W - 545W) varies from 2.83 to 9.57, respectively at the condenser outlet temperature of 27^{0}C while the compressor speed is 3000 - 5000v/p. It can be said that the COP increases linearly with Tevap as the compressor speed changes. For example, COP = 3 can be achieved at T_{evap} = 0^{0}C and $P_{cooling}$ > 100W when the compressor speed is from 3000 – 5000 rpm. COP > 4 when T_{evap} > 40C and $P_{cooling}$ = 180W when compressor speed is 3000 rpm. This shows that the requirement of reducing power dissipation has been achieved in a high-performance system and is therefore capable of allowing multiple processors to operate at the same time.

The choice of compressor speed is also important for optimum productivity and depends on the range of the electrical system during operation. Figure 4 shows the data measurement and extrapolation curve of compressor power at different speeds. Compressors with a power range of hundreds of watts are limited to a minimum speed of 1800 rpm while consuming 26W of power (COP = 3; T_{evap} = 0^{0}C), the refrigeration system has a cooling capacity of 78W. The limits below indicate that the refrigeration system is built for below 78W but will have a high cooling efficiency. Assuming the compressor has linear scalability (extrapolation of figure 4 curve), then the optimal operating temperature and total energy loss will be found when the temperature is reduced at other operating conditions. together. Details are shown in part below. Finally, it must be noted that cooling energy costs and inefficiencies of power supplies can reduce refrigeration system productivity.

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RESULT

According to model [1], the power dissipation mechanisms of the digital IC CMOS is thoroughly investigated. Total energy is estimated by the sum of active and dissipated power. At low temperatures it is easier to achieve higher electrical equipment productivity. Lower power and higher speed results are due to the following factors:

- Due to increased system flexibility and saturation acceleration.
- Exponential decrease from a higher threshold to the current minimum threshold (KT/q)
- Improvements in semiconductor materials with lower hysteresis.
- Better threshold voltage controls lower V_{th}.

A general trend in the present limited by the design environment of refrigerating system is to reduce the cost associated with the reduction of dissipated energy by reducing the power supply. This leads to the basic approach of power reduction in this paper.

In summary, the cooling performance of a microprocessor is shown in Table 1. The microprocessor operates at a frequency of 3.64 GHz and dissipates system electrical energy of 175.4 W using a 1.25 V power supply at 97^0C.

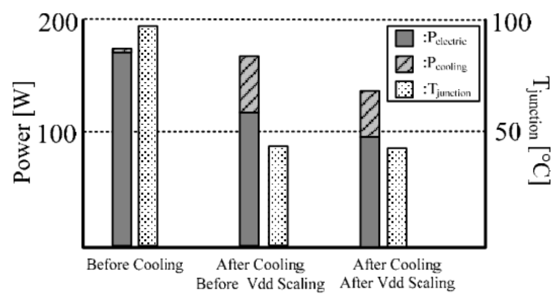

Figure 5: Chart shows the change of refrigeration system capacity before and after changing V_{dd}

Specifications	Value
$T_{junction}$ (^{0}C)	97
V_{dd0}(V)	1.25
Operating frequency (Ghz)	3.64
Power loss	30
$P_{eleectric0}$(W)	175.4
$T_{environment}$ (^{0}C)	22
P_{fan}(W)	1

Table 1: Specifications of the microprocessor using conventional forced air convection

$$T_{junction} = \frac{P_{leakage}}{P_{electric}} = 30\%$$

$T_{junction}$ at the operating time and the environment temperature is 22^0C, the microprocessors are cooled directly by the heatsink fans that send air through the heatsinks. The fans that send air through the heatsink dissipate 1W of the power used by the fan.

The total power is taken while keeping the power constant. Two different options were tested with the refrigeration system. The first is to maintain the supply voltage 1.25V and the second is to reduce the supply voltage to reduce power to increase efficiency. The results are shown in Figure 7. Cooling allows $T_{junction} < 40^0$C. Due to the voltage drop at low temperature points, the total electrical power has been reduced by up to 125W, reflecting the correct ratio:

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$$\frac{P_{leakage}}{P_{electric}} = 30\%$$

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Experimental results show that $T_{evap} = 0^0C – 5^0C$. The compressors operate at 3000 rpm, consuming 125W of electrical power. The cooling cost of the compressor running at this speed is 44W resulting in a total power reduction of 169W.

The second test shows that a drop in supply voltage can lead to further loss of power. By reducing V_{dd} to 1.12V, further reducing the power is 28W, resulting in Peletric = 97W. At this moment the compressor runs at 2500 rpm while consuming $P_{compress}$ = 35W. The total power is 132 W. This efficiency is higher than other model designs. The total power saved from the supply may increase if the compressor efficiency increases.

The most important effect from cooling is the significant reduction in power loss as shown in figure 5. Note that the energy savings are percentages of the amount of energy consumed whose source is referenced in [2]. This measurement implies that the system efficiency will increase if the power is significantly higher than the electrical energy dissipated. The energy saved from extending the supply voltage range offsets the system cooling power.

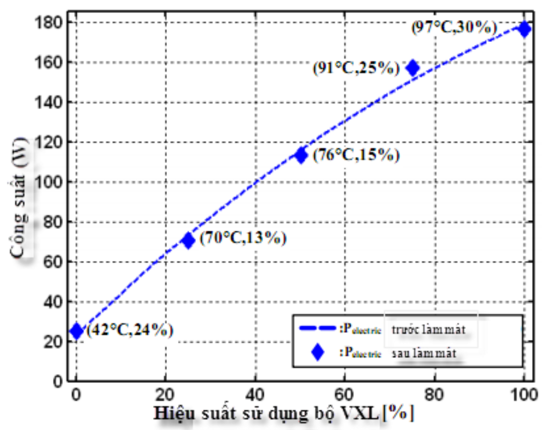

Figure 6: Chart of the relationship between Power and $T_{junction}$ temperature at different microprocessor capabilities

The use of a microprocessor or power factor varies with different applications. The electrical capacity and power loss of the system and other operating components depends on the use of the compressor and the junction temperature at which the compressor junction temperature is determined by the total energy and ambient temperature through a thermistor. For the special microprocessor, $P_{electric}$ and $T_{junction}$ vary from 25W – 175.4W and $42^0C – 97^0C$, respectively shown in figure 6. Figure 6 also shows the variation of power dissipation when using the microprocessor different.

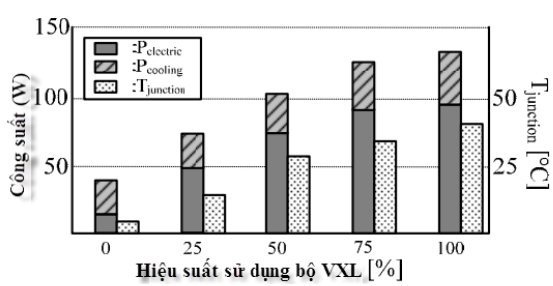

Figure 7: Cooling capacity measurement results when the percentage of processor usage is different

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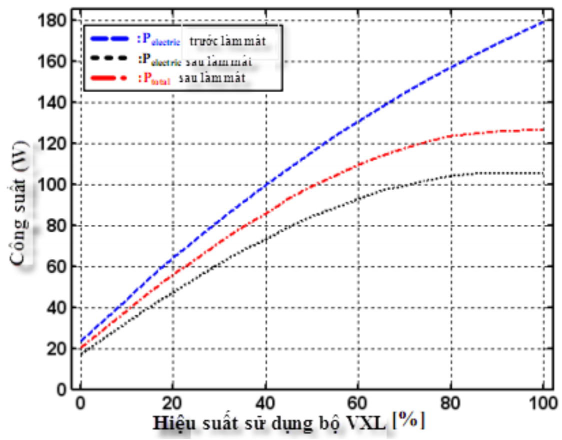

Figure 8: Chart of the relationship between power and percentage of different processor usage[2]

The microprocessor operates on pre-loaded electronic data and is also cooled by the refrigeration system. The results of the used refrigeration system are shown in Figure 7. Notice how the amount of energy saved from cooling increases with the amount of power dissipated. Total power savings of 25% and 20% are obtained when efficiency is 100% and 75%. As described in upper part, compressor capacity significantly reduces refrigerating system efficiency, so that eliminating cooling temperatures below 50% utilization rate results in a loss in the total energy of the refrigerating system. intended for system cooling only. The results show that the total energy of 10 and 60% is achieved when the power factor is 25% and 0% respectively.

Because it is capable of operating the compressor over a wider power range, the total energy saved at the temperature point decreases when using different microprocessors which, assuming that the refrigeration system has a High COP over a wide range of cooling capacity. The results of the analysis are shown in Figure 8. The analysis shows that at least over 13% of the total energy is expended to cool the processor. Total energy savings and $T_{junction}$ temperature from measurement and simulation shown in Table 2 [1].

Utilization [%]	Measurement		Simulation	
	Saving[%]	$T_{junction}$[°C]	Saving[%]	$T_{junction}$[°C]
100	25	40	29	45
75	20	34	20	45
50	5	28	14	40
25	-10	14	13	29
0	-64	3	13	14

Table 2: Measurement results [1]

CONCLUSION

This article gives an overview of a refrigeration system with the aim of showing how to improve the efficiency of the equipment and thereby improving the overall system efficiency. Total energy saving is 25% when the compressor is running at 100% capacity. The total energy saved depends on the total electrical energy and energy loss. The results show that increasing cooling capacity is necessary for refrigeration systems to be used in electronic cooling to reduce power over a wide range of applications and uses of microprocessors that need further study.

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