Miniature Vapour Compression Refrigeration System for C.P.U. Cooling

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***Abstract*— As the chip power continuous to increase, traditional passive heat dissipation techniques are becoming obsolete and new active cooling techniques are becoming necessary. Among various new active cooling techniques, the Vapor Compression Refrigeration (VCR) system is the leading technology. This project presents a miniature VCR system for CPU cooling. The dimension of the system is 300 × 230 ×70 mm^{3}and its cooling capacity is 300 W. It includes a commercial miniature compressor, a capillary tube, a custom-made condenser and a evaporator. The system is tested systematically by experiments. The results indicate that the temperature of the evaporator can be maintained at about 10℃ for hours as required in CPU cooling. A small refrigeration system for cooling of computer system components is evaluated. A thermodynamic model describing the performance of the cycle along with a computer simulation program is developed to evaluate its performance. The refrigeration system makes use of a miniature reciprocating vapor compression compressor. Due to space limitations in some high performance computer servers, a miniature refrigeration system composed of a compressor, capillary tube, a compact condenser, and a evaporator are used. In addition, a RAS (reliability, availability and serviceability) discussion of the proposed CPU-cooling refrigeration solution is presented. The results of analysis show that the new technology not only overcomes many shortcomings of the traditional fan-cooled systems, but also has the capacity of increasing the cooling system's coefficient of performance.**

***Index Terms*— COP, RAS, VCR System etc**

I. INTRODUCTION

As the number of transistors in integrated circuits has rapidly increased to provide greater functionality and computational power, removing the heat dissipated from electronic chips has become a serious challenge in the design of portable and other space-limited electronics devices. According to the International Technology Roadmap for Semiconductors 2003, the heat dissipation from a single chip package will rise to 170 W in 2005 for high-performance systems. The maximum junction temperature, meanwhile, must continue to be maintained at or below 85C. Conventional air cooling techniques are no longer expected to meet the required heat dissipation needs. The advantages of refrigeration cooling include maintenance of low junction temperatures while dissipating high heat fluxes, potential increases in microprocessor performance at lower operating temperatures, and increased chip reliability. However, these advantages must be balanced against the increased complexity and cost of the cooling system, possible increases in cooling system volume, and uncertainties in the system reliability due, for instance, to moving parts in the compressor. The present work aims to further explore the advantages of refrigeration cooling, and investigate the feasibility of the use of this approach in electronics cooling. Thermal management of semiconductor chips is becoming a major concern in the semiconductor industry. Based on Moore’s prediction the number of transistors in a chip doubles approximately every 18 months. With the increase in the number of transistors, the power consumption and heat dissipation increase. However, it is believed that among all these methods, VCR is the best. It has a number of advantages, including capable of maintaining low temperature for long time, high reliability and most importantly high efficiency. It is widely expected that the VCR technology will lead the market in the future.

II. PURPOSE OF THE PROJECT

The refrigeration system makes use of a miniature reciprocating vapor compression compressor. Due to space limitations in some high and overall efficiency of system are studied. In addition, a RAS (reliability, availability and serviceability) discussion of the proposed CPU-cooling refrigeration solution is presented. Passive cooling methods, such as heat sink, heat pipe and vapor chamber, are widely used nowadays. These methods are aimed at quickly dissipating the heat and hence, their cooling capability is limited. It is estimated that when the chip power reaches 180W, the passive cooling methods would become incompetent. Therefore, new active cooling methods are needed. In a recent study, various active cooling methods, such as vapor compression refrigeration (VCR), thermoelectric refrigeration, Stirling, pulse tube, and absorption refrigeration, are compared.

III. PROJECT OBJECTIVE

This project is used to cool the CPU micro processor unit and to increase the performance and durability.

- Allow cooling to below ambient temperature increasing performance, reliability and allowing operation in higher temperatures.
- High COP
- Ability to remove very large heat loads.
- Ability to transport heat away from its source.

IV. LITERATURE SURVEY

Scott classified refrigerated cooling of electronic equipment into four major categories: refrigerated cooling of air or liquid, refrigerated heat sinks, liquid nitrogen baths, and thermoelectric coolers. The key difference between the first two of these is that a refrigerated heat sink results in a lower temperature at the surface of the chip compared to a refrigerated system using a cooling fluid, since it avoids use of a secondary fluid loop to carry heat from the chip to the refrigeration loop. In addition, the evaporator of the refrigerated heat sink is mounted directly to the chip leading to greater compactness. A liquid nitrogen bath may be used for cryogenic applications; its efficiency decreases significantly in the temperature range typical of electronics cooling. The liquid nitrogen bath is a batch-cooling mode operation and liquid nitrogen needs to be provided from an external cryogenic refrigeration system. The need for insulation of the bath and other implementation difficulties renders this approach impractical for electronics applications. Thermoelectric cooling has the advantage of no moving parts and compact size, but suffers from small cooling capacity, low temperature lift, and low efficiency. The efficiency of the overall thermoelectric system, which requires multiple stacked elements to achieve the desired cooling capacities, is low. A number of refrigeration cooling systems for electronics are commercially available. Schmidt and Notohardjono used a vapor-compression refrigeration system to cool the processor (a multi-chip module) in which was the first IBM system to employ refrigeration cooling: all other components of the server were air-cooled. Two modular refrigeration units (MRUs) were connected to the evaporator, with one of these serving as a backup. The size of the cooling unit was 267×267×711 mm ^{3}, with a weight of 27 kg. The average processor temperature for the G4 server was 4 maintained at 40°C, which was approximately 35°C lower than the temperature that could be achieved with a conventional air cooling design. Peoples incorporated a vapor compression refrigeration system using refrigerant R-134a into an off-the-shelf high-performance computer and developed a KryoTech super GTM computer.

V. EXPERIMENTAL SETUP

A schematic of the miniature-scale refrigeration system (MSRS) for electronics cooling is shown. The system consists of the following components: a commercially available small-scale compressor, a condenser, a capillary tube as the expansion device, a evaporator, one compressor cooling fans, and a heat source which simulates the chip. In addition, a suction line accumulator was installed in the system to guarantee that only refrigerant vapor flows into the compressor. An oil filter and a sight glass were used to provide the required compressor lubrication and to verify refrigerant sub cooling at the condenser outlet.

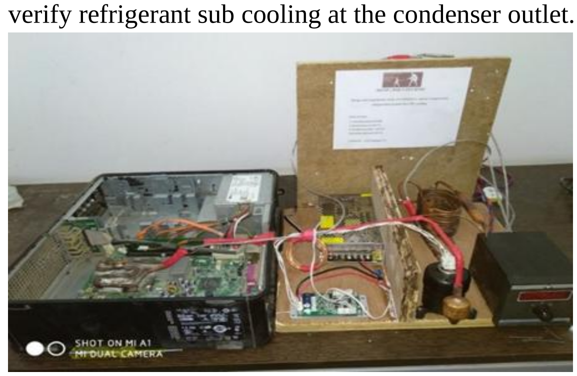

Fig.01.VCR System for CPU Cooling

A commercially available small-scale hermetic R-134a rotary compressor, 8.5 cm in diameter and 5.8cm in height), was used to compress the refrigerant. The compressor is driven by a DC brushless motor and its design operating conditions are an ambient temperature of 55°C, a suction gas temperature of 32°C, and a liquid temperature at the condenser outlet of 32°C. The compressor design cooling capacity varies from 75 to 140 W, the COP varies from 1.13 to 1.35, and the maximum power consumption is approximately 103 W at typical portable refrigerator operating conditions.

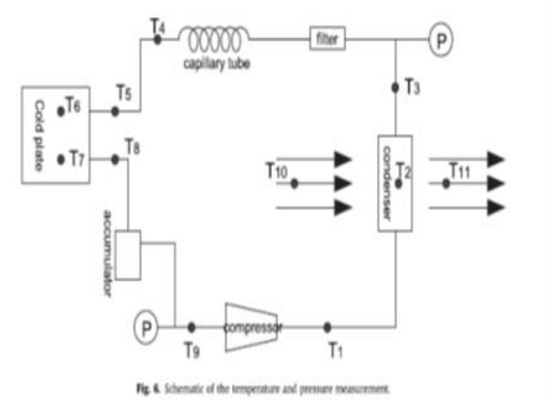

Fig.02.Block Diagram for Pressure and Temperature Measurement

The expansion device is a capillary tube. The condenser has a heat rejection capacity of 300W and dimensions 100 mm × 100 mm × 40 mm, which are consistent with the dimensions. Each fan has dimensions of 100 mm × 100 mm × 25 mm and requires a power input of 24V. The MSRS was charged with 100 g of the refrigerant R-134a. Thermocouples was installed on the refrigerant-side at the inlet and outlet of the compressor, condenser, expansion device, and evaporator to determine the refrigerant state points. Since the compressor needed an inverter to change the power input from DC to 3-phase AC voltage, the power meter was installed after the inverter to measure directly the actual electrical power required by the compressor etc.

VI. VCR COMPONENTS

The refrigeration system makes a cold room work. It is simply a process of transporting heat from one place to another. The vapour-compression system is the most commonly used method of refrigeration. It is frequently used in large cold rooms like industrial chillers. The main components of a

Compressor:

Compressor used in our system is 12V24V48V MAX having capacity of 300W the refrigerant used in this compressor is R134a for portable refrigerator mini air conditioner

- Weight of compressor : 0.72 kg
- Compression rate: Below 8
- Rotary speed : 2000 to 6000 rpm
- Performance : 130 to 400 W
- Evaporation temperature : -18 to 24C
- Maximum discharge temperature : 120C

Evaporator:

An evaporator is used to turn any liquid material into gas. In this process, heat is absorbed. The evaporator transfers heat from the refrigerated space into a heat pump through a liquid refrigerant, which boils in the evaporator at a low-pressure. In achieving heat transfer, the liquid refrigerant should be lower than the goods being cooled. After the transfer, liquid refrigerant is drawn by the compressor from the evaporator through a suction line. Liquid refrigerant will be in vapor form upon leaving the evaporator.

Fig.03 Evaporator

Condenser and Capillary tube:

Condensation changes gas to a liquid form. Its main purpose is to liquefy the refrigerant gas sucked by the compressor from the evaporator. As condensation begins, the heat will flow from the condenser into the air, only if the condensation temperature is higher than that of the atmosphere. The high-pressure vapour in the condenser will be cooled to become a liquid refrigerant again, this time with a little heat. The liquid refrigerant will then flow from the condenser to a liquid line.

Fig 04.Condenser and Capillary tube

The capillary tube is non-adjustable device that means one cannot control the flow of the refrigerant through it as one can do in the automatic throttling valve. Due to this the flow of the refrigerant through the capillary changes as the surrounding conditions changes. For instance as the condenser pressure increases due to high atmospheric pressure and the evaporator pressure reduces due to lesser refrigeration load the flow of the refrigerant through the capillary changes.

Refrigerant

A refrigerant is a substance used in a heat cycle to transfer heat from one area, and remove it to another. Usually in gas state at room temperature, found in pretty much everything that cools, and sometimes in things that heat, most commonly air conditioners, fridges, freezers, and vehicle air conditioners. Traditionally, fluorocarbons, especially chlorofluorocarbons (CFC's), were used as refrigerants, but they are being phased out because of their ozone depleting effects. Other common refrigerants used in various applications are ammonia, sulfur dioxide, and non-halogenated hydrocarbons such as propane. Most refrigerants found in end of life devices are ozone depleting and global warming inducing compounds.

Properties of R-134a

1Boiling Point -14.9°F or -26.1°C
2Auto-Ignition Temperature 1418°F or 770°C
3Ozone Depletion Level 0
4Solubility In Water 0.11% by weight at 77°F or 25°C
5Critical Temperature 252°F or 122°C
6Cylinder Color Code Light Blue
7Global Warming Potential (GWP) 1200

VII. PERFORMANCE RESULT

Temp. Without Heat Sink	Temp. With Heat Sink	Temp. With VCR System
HIGH TEMPARATURE [HEAT SUPPLIED]= 98ºC	HIGH TEMPARATURE [HEAT SUPPLIED]= 98ºC	HIGH TEMPARATURE [HEAT SUPPLIED]= 98ºC
LOWER TEMPERATRE [HEAT REJECTED]= 98ºC	LOWER TEMPERATRE [HEAT REJECTED]= 32ºC	LOWER TEMPERATRE [HEAT REJECTED]= 89ºC [MAINTAINED]= 10ºC

Table No.01 Source and Sink Temperature Reading

VIII. CONCLUSION

A bread board miniature-scale vapor compression refrigeration system (MSRS) using R-134a as the refrigerant was designed, built, and tested. A commercially available small-scale compressor was installed in the MSRS. After an extensive experimental investigation, the main energy losses of the MSRS were highlighted. The most significant losses occurred in the compressor while the condenser and the evaporator performed to specification. A new compressor design for electronics cooling applications is needed to achieve better performance of the systems. The novel compressor has to fit within 45 mm height (1-U rack), has to be reliable, and needs to be inexpensive for mass production. The automatic expansion device is needed to accurately control the expansion process, i.e., the mass flow rate through the expansion valve as a function of the heat load fluctuations of the microprocessor. The system control should prevent condensation at the evaporator by maintaining the refrigerant evaporator temperature slightly above the dew point temperature of the surrounding air.

IX. FUTURE SCOPE

For different application areas, the cycle may be analyzed for different temperatures, pressures and for different refrigerants. Moreover, an optimization 89 study on the components may be performed. Different types of compressors may be designed for the cycle, such as, screw, centrifugal or scroll compressors. In the present study, a steady-state analysis of the refrigeration cycle has been performed. The transient response of the cycle may also be investigated. The effect of radiation in the condenser and the evaporator may be taken into account during the design. The designed cycle would be constructed and tested during the operation to verify the design procedure and the correlations adopted from the literature. Finally, the design procedure may be improved by a variable speed compressor to cope with the variation of the refrigeration load due to different modes of operation.

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