

## **Inter-disciplinary Project Based Freshman Engineering Curriculum at NJIT**

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### **Abstract**

The new inter-disciplinary project based freshman engineering curriculum at NJIT is described in this paper. The course is called Fundamentals of Engineering (FE) 101. In this course, the freshman engineering students are introduced to two disciplines of engineering – Mechanical, and Electrical and Computer Engineering working together as an unit on the project. The students are also introduced the concept of teamwork in engineering design project.

The selected project is Heat-sink and Fan for Intel's Pentium® Microprocessor. Heat-sinks and fans are devices used to dissipate heat generated by microelectronic devices - in this case, microprocessor or CPU. Heat-sink and fan assembly is mounted on the top of microprocessor. This allows more heat to be dissipated through conduction and forced convection heat transfer, and consequently lowers the device operating temperature. The primary purpose of a heat-sink and fan is to maintain the microprocessor temperature below the maximum allowable temperature specified by the device manufacturer.

Furthermore, the course is paired and running concurrently with Humanities and Social Science (HSS) 101 and Computer and Information Science (CIS) 101. HSS faculty advises the students on the preparation of the project reports and oral presentations. Applications software required for the project is taught by CIS faculty.

### **Introduction**

Today, millions of transistors can be etched on wafers of silicon. Pentium® processor that was introduced in late 1993 has 3.3 millions of transistors, Pentium® Pro (late 1995) as Pentium's successor has 5.5 millions of transistors, Pentium® with MMX (MultiMedia eXtension) technology (January 1997) has 4.5 millions of transistors, and Pentium® II (April 1997) which is Pentium® Pro with MMX instruction added to it has 7.5 millions of transistors. Note that Pentium II processor is

much more powerful than Pentium processor. Thus, more and more transistors are packaged inside the CPU. In addition to that, the continued push technology demands for more performance levels – translated to be higher operating speeds or MHz. For the same family of microprocessors, the processor with higher frequency obviously generates more heat. If the microprocessor operates outside the functional temperature limit, the system performance can be degraded, causing logic errors or component damage. The most common solution to the problem in today's Personal Computer (PC) is by installing integrated fan/heat-sink on the microprocessor. The students in this course are looking into this matter.

Heat-sinks are generally extruded from blocks of aluminum. Aluminum is chosen material due to its low price/performance ratio. The heat-sink fins provides extended surface area to dissipate the heat. To maximize the heat transfer, a fan is integrated with heat-sink or a dedicated fan is installed on the system so that the airflow through the heat-sink fins is maximized. Microprocessor is an electrical computer engineering component, the other important electrical part is a small DC motor that is used to drive the fan. So, it is obvious that fan/heat-sink assembly is mechanical and electrical and computer engineering unit.

In this course, the students are introduced with the design process related to the project. The procedure encompasses the following activities: problem identification; gathering information; generate multiple design solutions; select and analyze one “best” solution, is used in completing the assigned project.

Calculation is done using Mathcad, MS Excel is used for plotting, MS Word for words processing, and PowerPoint for presentation.

In this paper, the Mechanical Engineering contents related to heat transfer methods in the project will be described in detail. Intel's Microprocessors design guidelines, thermal parameters, and formulas are used by the students in completing their project.

### **Project Assignments**

Students normally work in teams of four, and each team is assigned with different type of microprocessor. For example, there are five teams in one section, and each team is required to do analytical design of heat-sink and fan for:

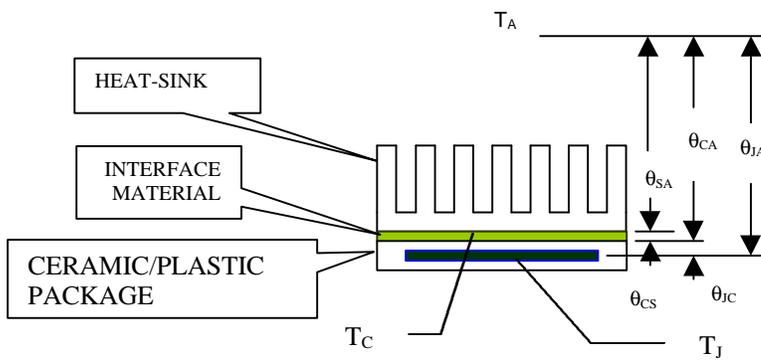
- Team 1: Intel Pentium® MMX 233 MHz
- Team 2: Intel Pentium® MMX 200 MHz
- Team 3: Intel Pentium® MMX 166 MHz
- Team 4: Intel Pentium® Pro 180 MHz
- Team 5: Intel Pentium® Pro 166 MHz

The design solution is presented, and a comprehensive report is submitted in the end of the semester. In addition to that, individual assignments and quizzes are also given to ensure a fair evaluation of the performance of each student. Thus, students in one design team will not have the same final grade.

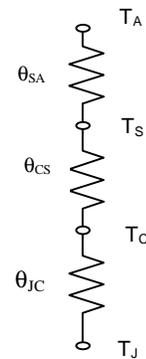
## Design Thermal Parameters

In order to accomplish the tasks, the students were introduced with systems of units; the concepts of work, energy, power and heat; three modes of heat transfer – conduction, convection and radiation; thermal conductivity of various materials; the concept of thermal resistance for both conduction and convection; two modes of convection – natural and forced convection; combined conduction and convection heat transfer; heat transfer from fins; electrical resistance analogy for thermal circuit; examples problems and design calculations using formulas. Introductory experiments – resistors, capacitors, power supplies, and DC motor using test kit familiarize the students with electrical components of this project.

The following describes the thermal design guidelines and formulas used by the students.



**Figure 1. Design thermal parameters for heat-sink.**



**Figure 2. Thermal circuit for heat-sink.**

The parameters are defined by the following relationships – see Figures 1 and 2:

$$q_{CA} = \frac{T_C - T_A}{P_D} \quad (1)$$

$$q_{CA} = q_{CS} + q_{SA} \quad (2)$$

$$q_{JA} = q_{JC} + q_{CA} \quad (3)$$

where:  $\theta_{CA}$  = Case-to-ambient thermal resistance ( $^{\circ}\text{C}/\text{W}$ ). It is used to measure cooling solution's thermal performance;  $\theta_{CS}$  = Case-to-sink thermal resistance ( $^{\circ}\text{C}/\text{W}$ );  $\theta_{CS}$  is a measure of the thermal resistance along the heat flow path from the top of the IC package to the bottom of the thermal cooling solution (heat-sink). This value is strongly dependent on the material, conductivity, and thickness of the thermal interface used;  $\theta_{SA}$  = Sink-to-ambient thermal resistance ( $^{\circ}\text{C}/\text{W}$ ),  $\theta_{SA}$  values depend on the material, thermal conductivity, and geometry of the heat-sink as well as on the airflow rates;  $\theta_{JA}$  = Junction-to-ambient thermal resistance ( $^{\circ}\text{C}/\text{W}$ );  $T_C$  = Case temperature of the device ( $^{\circ}\text{C}$ ). To ensure functionality and reliability, the case temperature should be maintained between  $0^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ ;  $T_A$  = Ambient temperature ( $^{\circ}\text{C}$ ), usually between  $35^{\circ}\text{C}$  to  $45^{\circ}\text{C}$ ; Junction temperature  $T_J$  is the average

temperature of the die within the package. Maximum junction temperature must remain below 100 °C;  $P_D$  = Total power dissipated by dies – microprocessor (W).

The information on maximum power dissipated  $P_D$  for microprocessor is provided by manufacturer – in this case, Intel Corporation. For example,  $P_D$  for Intel Pentium® Pro 180 MHz is 31.7 Watts. With  $T_A = 45$  °C and  $T_C = 85$  °C, Case-to-ambient thermal resistance  $\theta_{CA}$  can be found to be 1.26 (°C/W). The calculated value of  $\theta_{CA}$  can then be used further to obtain proper height and rectangular dimensions of heat-sink and linear feet per minute of airflow produced by fan. These data are available from Intel Corp., and fan/heat-sink manufacturers. They can be easily access via internet.

It is important to note here that above notations, terminology, design parameters and formulas conform the ones used in industry.

## Conclusions

We do not expect freshman students who have no prior engineering experiences to be professional engineer in fourteen weeks (1.5 hours per week). However, we give them a firm theoretical foundation and insight on how to apply theoretical knowledge to the solution of design problem in their first semester. We hope this course will increase students' motivation to study engineering.

We observe the students' creativity, motivation, confidence in their abilities and satisfaction increasing as they go through the preparation for oral presentation and final report. This course is an excellent training for researching information – via internet, project time-management and communication skills - technical writing and presentation.

Overall, this course has done remarkably well at achieving its goal – to introduce to the students what will engineers do in the real-world.

## Acknowledgments

We are indebted to Professor Geraldine Milano for her repeated encouragement and invaluable advice. Thanks to Professors Rob Friedman (HSS Department), Michael Kerley (HSS Department) and Jim Calvin (CIS Department) for helping to make this work possible.

## References

1. Holman, J.P: “Thermodynamic,” 4<sup>th</sup> ed., McGraw-Hill Company, New York 1988.
2. Intel Corp. AP-480 Application Note: “ Pentium® Processor Thermal Design Guidelines Rev. 2.0,” Intel Corporation, IL, November 1995.
3. Intel Corp. AP-525 Application Note: “ Pentium® Pro Processor Thermal Design Guidelines,” Intel Corporation, IL, September 1995.
4. Web sites visited: “[www.thermalloy.com](http://www.thermalloy.com), [www.intel.com](http://www.intel.com), [www.aavid.com](http://www.aavid.com), [www.iercdya.com](http://www.iercdya.com), “