

Thermal Breath Design of Micro-processor and SOC in DOCSIS Network

Hujiao Wang ^{1, #}, Yong Peng ², Shibo Dong ², Weihua Wen ²

1. Mechanical Engineer/Cisco System/200233, China

2. Hardware Engineer/Cisco System/200233, China

#Email: hujwang@cisco.com

Abstract

To solve the overheat problem and realize the module upgrade in current CATV transmission equipment, power consumptions of micro-processors or SoCs are controlled by monitoring and switching functions. It is like that the product is doing thermal breathing.

Keywords: *Thermal Breath, Power Consumption Control, Thermal Design*

1 BACKGROUND AND PROBLEMS

With the CATV service diversified development in China, signal transmission frequency and bandwidth need to be increased. So more powerful micro-processors and SoCs, which are integrated with multiple functions, are implemented in DOCSIS network. In many projects, especially like the network upgrade in old communities, some equipment cannot be wholly replaced. Modules inside the equipment are always requested to be developed. Even more badly, some modules are not only used for one, but on many platforms. And all platforms have different thermal conditions. With powerful functions, the chips would probably work overheated in worst case.

2 THERMAL BREATH DESIGN

In many scenarios, it rarely happens that all module functions with full-loading are needed at the same time. Closing some temporarily unused functions, or controlling some functions to reduce the power consumptions, will be helpful to lower the unit temperature efficiently. The function blocks only will be opened when they are needed. Thermal sensor can be used to monitor the system temperature, making sure the device temperature will never be overheated.

In Cisco video product family, a monitoring module called transponder is widely used in CATV access products, like node/amplifiers. New DOCSIS2.0 transponder is developed to replace previous HMS/SMC transponder to meet the network monitoring requirement by DOCSIS NMS. The transponder module is a plug-in module to realize status monitoring and status controlling via SNMP protocol over the DOCSIS/Euro-DOCSIS network. It introduces a high level integration CM ASIC which combines an RF receiver, an advanced QAM transmitter, a complete DOCSIS 2.0 MAC, a MCU. Just keeping the necessary functions opened all time and disable those functions which are not used temporarily, reducing the clock frequency to lower the module power consumption, is very helpful to solve the module overheat problem.

2.1 Module Physical Parameter

Since the legacy HMS/SMC transponders are already deployed in many Cisco products, the housing overall dimensions and connectors' locations can not be changed.

1) Module Overall Dimension

$$\text{Length} \times \text{width} \times \text{Height} = 78\text{mm} \times 38\text{mm} \times 12\text{mm}$$

2) Module Structure

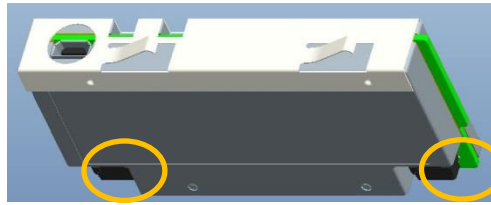


FIG. 1 TRANSPONDER STRUCTURE

Two connectors are at bottom side (In highlighted circles). There are no extra thermal dissipation solutions for this module. Since the module is deployed in different platforms, uniform additional thermal solution is impossible to be developed.

3) Thermal Conditions

DOCSIS transponder consumes about 2.5W with full loading while HMS/SMC transponder consumes less than 1W, which means 2.5 times heat need to be dissipated outside in the same space. By simulating, there will be thermal problems.

2.2 Power Consumption Control

In this case, power consumption control is the most efficient way to lower the temperature. It can be achieved by controlling on/off of each specific function blocks of SoC. Thermal sensor is implemented to monitor the temperature to make sure the module will not running overheated.

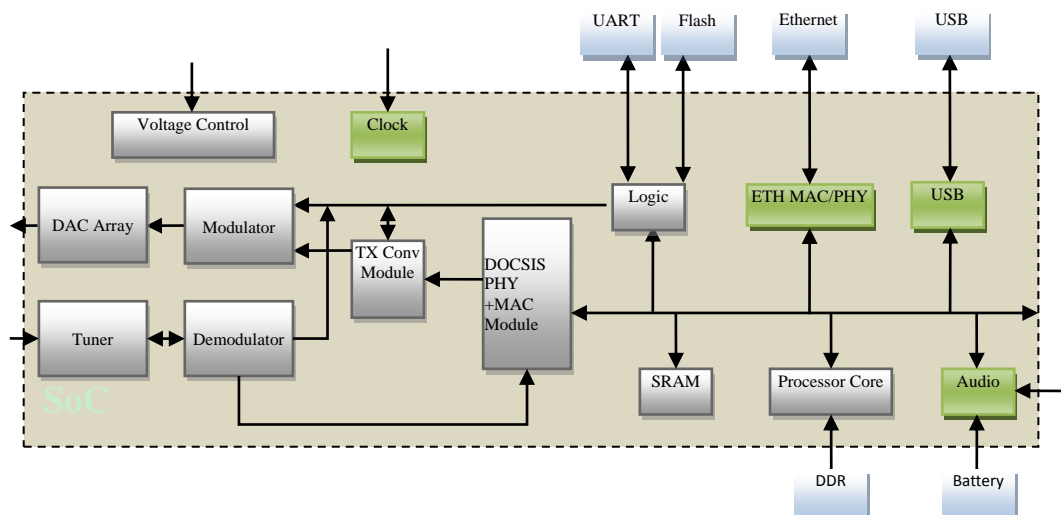


FIG. 2 CABLE MODEM SoC FUNCTION DIAGRAM

Fig. 2 shows the cable modem SoC function diagram. The functions highlighted in grey, like RF transceiver and CPU, should be on any time. Other functions like Audio/Ethernet MAC and PHY, which are highlighted in green, can be temporarily disabled.

The processor clock frequency can be reduced to a lower level which can also meet the system performance requirements.

By above actions, the full load power consumption of CM SoC reduces about from 2.08W to 1.2W.

2.3 Thermal Simulation

Set the maximum working environment temperature 85° C. Fig. 3 and Fig. 4 show the simulation temperature curves of different power consumptions. Two-resistance-module is used for SoC. Pick SDRAM and PCB as another two monitor points to study the feasibility.

SDRAM has the lowest junction limit 110 °C compared to other core chips. When the power consumption of the SoC is 2.08w, the SDRAM junction temp exceeds the limit, which means this chip is running overheated. While the

power consumption of SoC is 1.2w, there are 2 °C margins to the SDRAM junction temp. And the PCB temp also comes down, which means other chips are running in cooler environment.

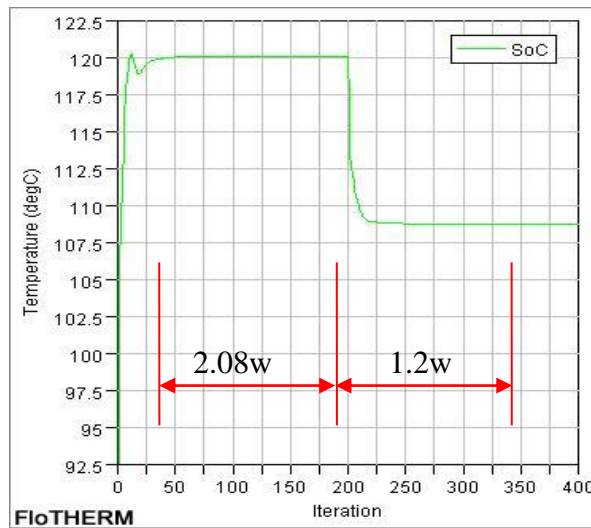


FIG. 3 SoC TEMPERATURE SIMULATION CURVE

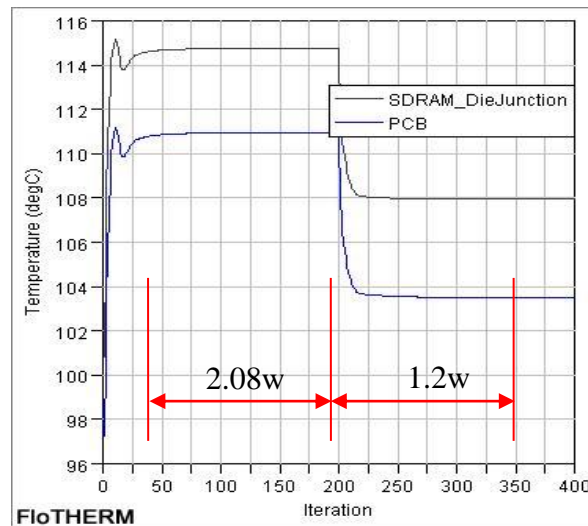


FIG. 4 SDRAM AND PCB TEMPERATURE SIMULATION CURVE

2.4 Feasibility Study

To check the feasibility of this method, the time of SDRAM junction temperature rising to 110 °C with power consumption increasing need to be estimated. If the time is too short for polling, it can't be implemented. For the temperature deviation between the SDRAM junction temperature and PCB temperature, to keep the SDRAM in safe cool, the PCB temp is not suggested to exceed 105 °C.

Use the extreme case, the power consumption of SoC jumps from 1.2w to 2.08w, for calculation. Because the module housing is designed as an integrated heat-sink, simplify the whole module to one integral subject with inside heat source. Temperature of the module is supposed to be the same everywhere and equals the PCB temp. With the power consumption increase, the time of PCB temperature increasing from 103.5 °C to 105 °C can be estimated. Following is the calculation details.

$$B_{iv} = \frac{h(V/A)}{\lambda} = 2.04 * 10^{-4} \quad (1)^{[1]}$$

h Heat transfer coefficient. Here use the maximum natural cooling value 10w/(m2 K)

V Volumn

A External surface area

λ Thermal conductivity. Here use 200w/m K of housing material A413

B_{iv} Biot number

The Biot number is very small and transient heat conduction lumped parameter method is used to estimate the time.

ρ Material density, 2.7g/cm³

c Specific heat capacity, 0.963J/g K

$$\frac{t-t_{\infty}}{t_0-t_{\infty}} = \exp\left(-\frac{hA}{\rho cV} \tau\right) \quad (2)^{[1]}$$

$$\frac{105-110.9}{103.5-110.9} = \exp\left(-\frac{10w/(m^2 \cdot K) \times 35568 \times 10^{-6} m^2}{2700kg/m^3 \times 963J/(kg \cdot K) \times 8712 \times 10^{-9} m^3} \tau\right) \quad (3)$$

$$0.7973 = \exp(-9.42 \times 10^{-4} \tau) \quad (4)$$

$$\tau = 240s \approx 4min \quad (5)$$

Usually, 4 minutes is totally enough for checking all functions and close un-used ones in DOCSIS transponder.

3 CONCLUSIONS

Controlling the power consumption is the most efficient way to lower the temperature. During product upgrade, when multifunctional micro-processors or SoCs are used, disable those functions which are not used temporarily is very helpful to solve the module overheat problem.

REFERENCES

- [1] 杨世铭, 陶文铨. 《传热学》[M]. 北京, 高等教育出版社, 1998 年.R

AUTHORS



¹**Hujiao Wang**, who received Mechanical Engineer Master degree in 2007 Nanjing University of Aeronautics and Astronautics, is working in Cisco System (China) Research and Development Center for mechanical design and thermal design.

²**Yong Peng**, who received Communication and Information System Master Degree in 2007 Wuhan University of Technology, is working in Cisco System (China) Research and Development Center for hardware design.

³**Shibo Dong**, Hardware Engineer of Cisco System (China) Research and Development Center.

⁴**Weihua Wen**, Hardware Engineer of Cisco System (China) Research and Development Center.