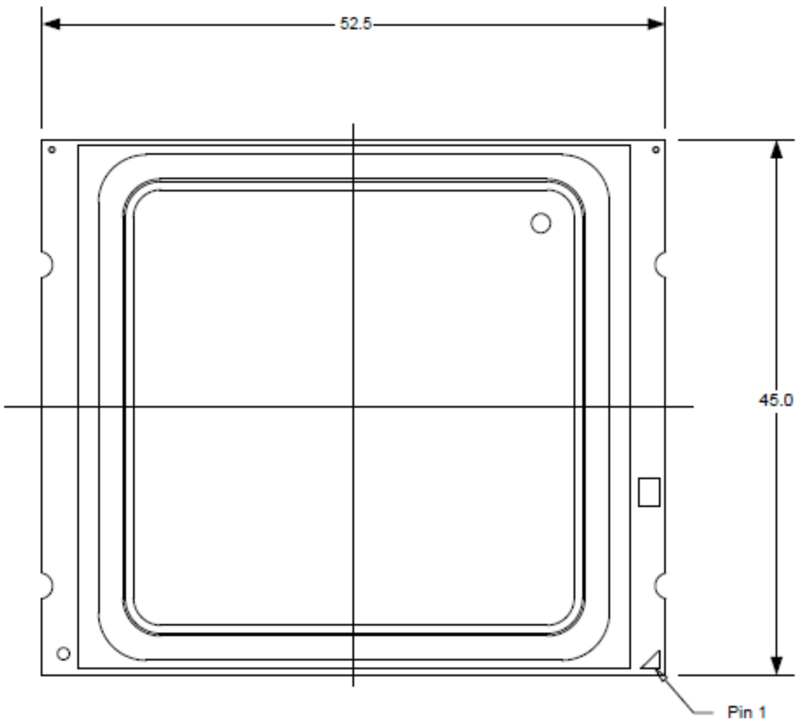
Sample: SolidWorks CosmoWorks Ansys - Cfd Simulation Analysis

As an example I would like to perform design and calculation of temperature on CPU Heat Sink Core Duo i7. This case very impotent in a real life because a modern processor consumes about 130 W. The work of the whole system of PC depends on proper cooling of processor (CPU).

In this example I calculate passive cooling (free convection) and forced convection (with fans). The calculation will be made for a few models of heat sinks.



The restriction of the programs. The program that uses the method of Finite Elements have the following limitations:

1. The accuracy of the result depends very much on a grid.
2. RAM of PC imposes restriction of the scale of the grid.
3. The opportunities of the PC (in my case CPU speed) strongly influence the Processor calculation speed.

Design of a Heat Sink for a Modern Microprocessor

Abstract.

Research of model of a radiator for processor cooling is conducted. It was considered that the monolithic model will be more effective than compound. At compound model there will be transitive resistance. At sampling of a material of a radiator physical characteristics (heat conductivity and a specific heat) were considered. The regime of a free convection for a radiator leads to increase in the square of heat dissipation (in our case to increase to quantity and a size of plates on a radiator). The forced convection regime is optimum if the chosen ventilating fans have low noise level.

Introduction:

The basic components of the air cooling system

The radiator serves for the distribution of heat of cooled object (in our case - processor kernels) into environment. It should be in direct physical contact to cooled object. So far as the heat transports from one body to another through a surface the area of contact of a radiator and the processor should be as much as it possible. The side which the radiator adjoins to the processor is called as a base or a sole. A warm from a kernel passes to the base, and then distributes on all surface of a radiator (and allocation is non-uniform) and it is shunted in environment. A radiator without a fan is cooling by natural convection and radiation. To increase efficacy of radiance it is possible if to raise area of surface of a radiator. For this purpose they are made ribbed: on the base mounts ribs from which a heat removes to the environment. Ribs should be thin as more as possible and they should have the best contact to the base as more as possible (in an ideal the radiator should be monolithic). Flat radiators (without ribs) have received the name "heat distributors". For the effective radiators disperse, it should possess high thermal conductivity and heat capacity. The physical quantity thermal conductivity has dimension of W/M*K, for stuff unit, so-called thermal conductivity. It defines the speed of heat distribution on volume. In a case if thermal conductivity of a radiator will be low, we receive a situation when its base will heat up more strongly, than its ribs. Refrigerating in this case will be inefficient. Radiators with high thermal conductivity have the slightly difference of the temperature of the base and a tip of ribs and heat effectively leads from all surface. Heat capacity, as it is known from a physics course, defines quantity of heat which is necessary to transport to a body for increasing of its temperature at 1 degree. Specific heat has dimension of J/Kg*K. The radiator with low heat capacity will have the temperature close to temperature of the most processor kernel and here it is not necessary to speak about any refrigerating. It should have high heat capacity because at body cooling on one degree it gives the same quantity of heat which has received at heating on one degree. For this reason the radiator with high heat capacity will always have considerably smaller temperature, than a processor kernel. These two physical quantities are defined by a stuff used for manufacturing of a radiator. Specific thermal conductivity and heat capacity of metals. The ideal stuff for radiator building does not exist. Silver has the highest thermal conductivity, but it is very expensive metal and heat capacity at it low. Copper has hardly smaller thermal conductivity and almost in one and a half time the big heat capacity. This stuff is better approaches for manufacturing of the establishment of radiators. Aluminum has in 1.6 times smaller thermal conductivity, than at copper, but at 2.29 time the big heat capacity. Yielded threw better to apply to ribs of radiators. Gold has high thermal conductivity, big, than at aluminum, but smaller, than at copper. Some generators of coolers, such as Zalman and Glacialtech report that top models of coolers have the radiators covered with a thin film of gold. In it there is no sense from the point of view of thermal conductivity. Nevertheless a thickness of this film is too small for influence on physical properties of a radiator. The same concerns nickel. The nickeled radiators from the aesthetic point of view, of course, are more attractive, but not from the point of view of thermal properties. As ideal contact between two metals to achieve very frequently radiators from one stuff - purely copper or purely aluminum have the big efficacy, but it already depends on the concrete generator of radiators. Because, as a rule, radiators with the copper establishment and aluminum ribs cool better, than purely aluminum, and copper cool even better. Besides a stuff of a radiator its design has great value. A configuration of ribs: their height, length, a locating on the establishment pay off individually for each model of a cooler. But the sense of calculations is always reduced to one: air should pass unconstrained and in regular intervals on all surface of a radiator. Turbulence (an air current turbulence) in a radiator, as a rule, improves heat removal from ribs and the establishment to an air current, but reduces speed of this stream. So definitely to tell, whether turbulence positively influences refrigerating or not is applicable to all coolers it is impossible. But as now many generators of coolers try to make a stream of air in a cooler more linear (some generators, for example Thermaltake, even let out adapters for fans which level air stream through a radiator), it is possible to draw a conclusion that for processor coolers the direct stream is better turbulent though even in this stream small turbulences will be conserved.

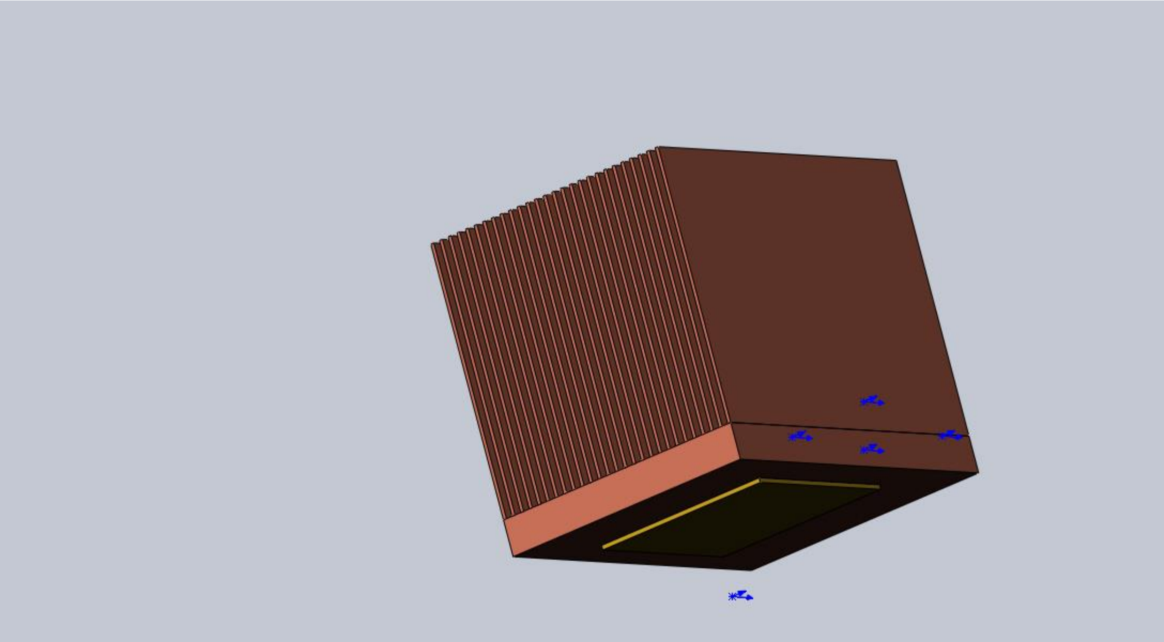
Method

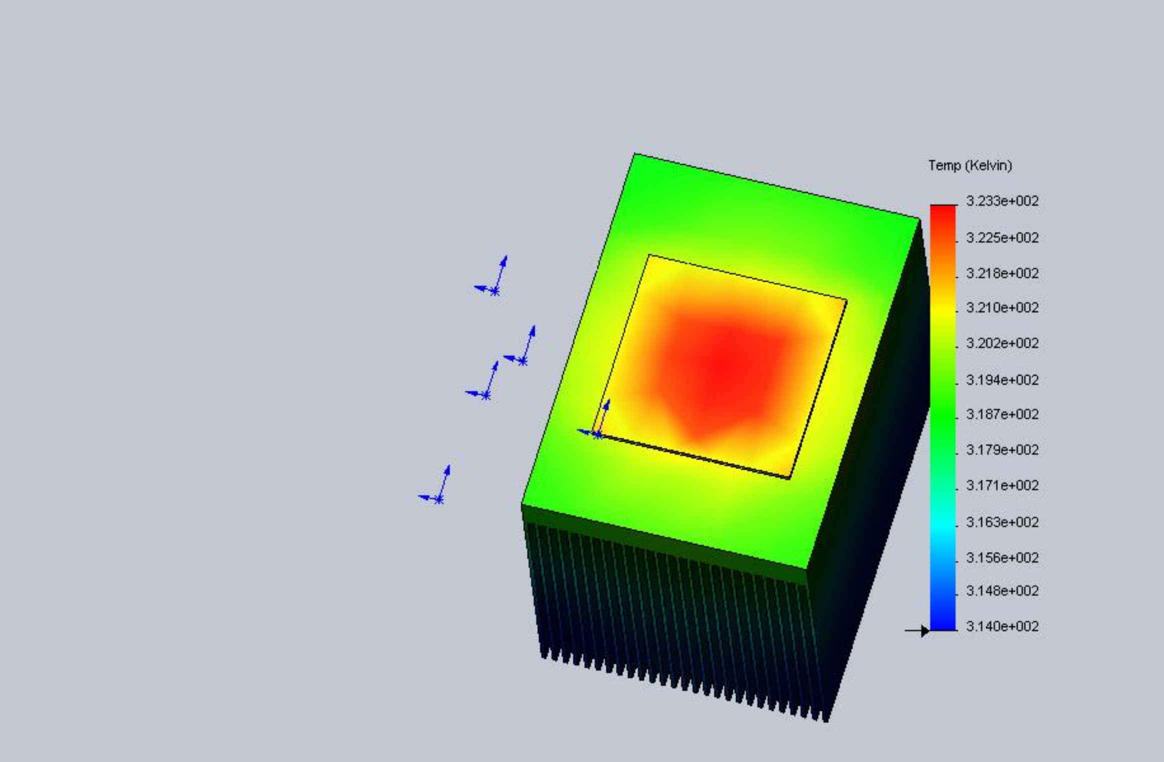
If the processor of the computer heart of system that a radiator its lungs. Simultaneously effective, hi-tech, compact and low-cost systems does not happen. If we get advantage in what that one means we worsen something another. Radiators with a free convection demand a lot of place in the case and consequently do not approach for portable solutions. Radiators with the forced convection can have smaller sizes but they essentially increase noise level. Noise level from the ventilating fan, crucial for many trades. In the application the chosen model with the forced convection has been counted. For control was this model in package CosmoWorks (SolidWorks) And though a difference not too big model of a free convection was not tested is counted.

Result and discussion.

Radiator Base (61 mmX 83 mm) Height 60 mm Z=27 Ribs Version **Copper**

Version: Forsed convection 2m/s. Mass of radiator 1.33 kg The surface square= 0.29 m2





The integral copper radiator is unconditionally good for the heat abstraction. Characteristics of heat conductivity of copper do by its leader. But high weight of a radiator, complexity of manufacturing of an integral radiator and high cost too it is necessary to consider. Optimum to do contact baseline of copper and other details from aluminum if predesign shows possibility of such solution.

The conclusion

For today there is no refrigerating problem as that, and exists a problem conduction of heat from a processor surface in environment. To cooling systems mutually exclusive requirements are shown high and at times: they should be effective, silent, and inexpensive. Today there are some kinds of cooling systems: classical air cooling, systems of water cooling, system for extreme refrigerating at dispersal on liquid nitrogen, cooling systems on thermal tubes and elements of Peltier. Efficacy, availability and the low price of systems of air cooling is their basic advantages, rather low reliability and a noise high level concern lacks in comparison with other systems. Water cooling systems - more expensive and effective variant which is applied in systems with the big development of heat or higher requirements to system noise level. Cooling systems on liquid nitrogen do not find wide application in connection with their complexity of operation. Basically they are applied at finding-out of frequency potential of processors "overclocker" which aspire to open frequency potential of the processor, despite low stability of work.

Appendix.

Calculation of a finned radiator, as element a heat interchanger with a forced convection.

The initial datas:

P = 130 W, power on CPU;

$\mathbf{\Theta_{amb}}$ = 293 °K, temperature of the environment (air) in Calvin's degrees;

$\mathbf{\Theta_{max}}$ = 348 °K, the maximum temperature of a crystal;

$\mathbf{\Theta_{avg}}$ = nn °K, average temperature of the basis of a radiator (it is calculated in process);

H = $6\cdot 10^{-2}$ m, height of the rib of a radiator in meters;

δ = $0{,}8\cdot 10^{-3}$ m, a thickness of the rib in meters;

b = $1{,}5\cdot 10^{-3}$ m, distance between ribs;

λ_M = 380 W / (m °K), heat conductivity of a copper radiator()r;

L =8,3 10^{-2} m, the size of a radiator along the rib in meters;

B = 6,1· 10^{-2} m, the size of a radiator across ribs;

A = 8 10^{-3} m, a thickness of the basis of a radiator;

V ³ 2 m/s, air speed in radiator channels;

Z = 27, radiators number of ribs ;

υ_p = nn K, an overheat temperature of the basis of a radiator, is calculated in process;

ε_p = 0,7, degree of radiation.

It is supposed that heat source is located on the radiator center.

All linear sizes are measured in meters, temperature in Calvin's degrees, capacity in watts, and time in seconds.

The design of a radiator and parameters necessary for calculations is shown in a Fig. 1.

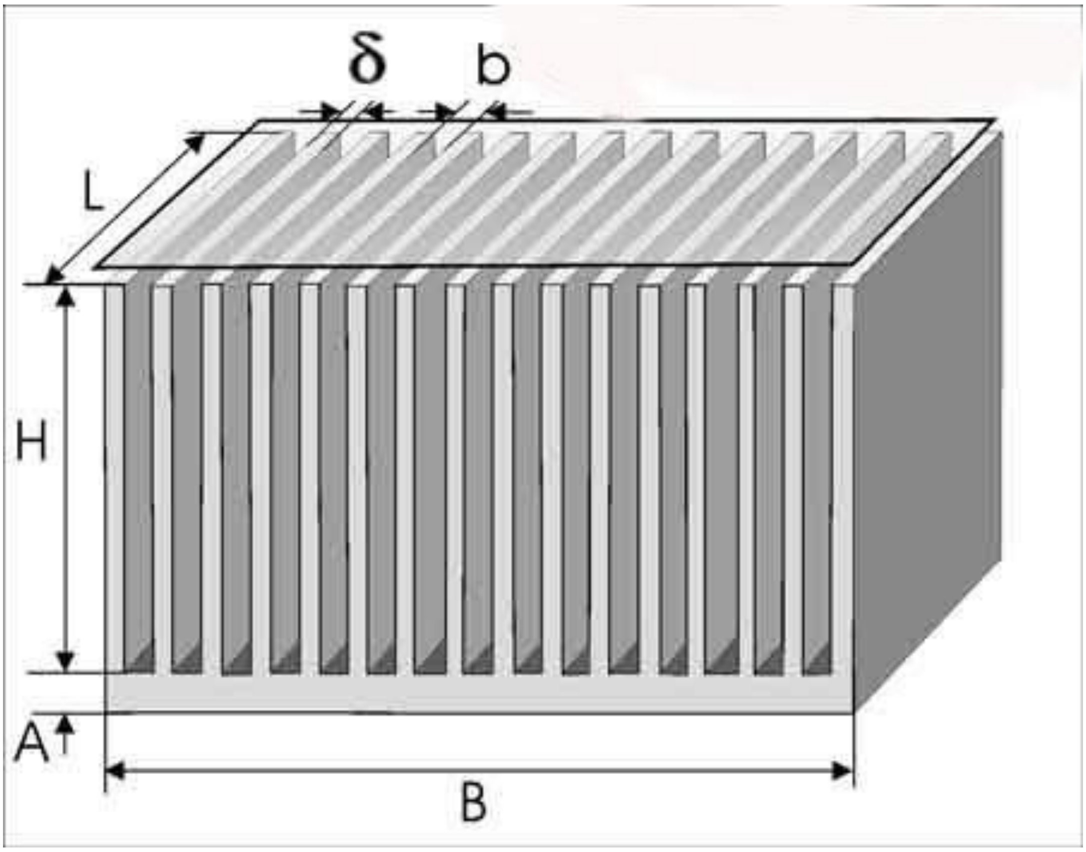


Fig 1.

Solving.

1. We define the total area of section of channels between edges under the formula:

$$S_к = (Z - 1) \cdot b \cdot H \quad [1]$$

For the accepted initial data - $S_к = (Z - 1) \cdot b \cdot H = (27-1)*1.5*10^{-3}*6*10^{-2} = 2{,}34 \cdot 10^{-3}$ м^2

2. We are set by two values of temperature of the basis of a radiator and calculate for each value:

Θ_{avg} = {353 K (+80°C) and 313 K (+40°C)}

From here the temperature of an overheat of the basis of a radiator u_p concerning environment is defined.

$$\upsilon_p = \Theta_{avg} - \Theta_{amb} \quad [2]$$

For the first point υ_p = 60°K, for the second υ_p = 20°K.

3. We define temperature **Θ**, necessary for calculation of criteria of Nusselt (Nu) and Reynolds (Re):

$$\Theta = \Theta_{amb} + P / (2 \cdot V \cdot S_к \cdot r \cdot C_p) \ [3]$$

Where: Θ_{amb} **-** temperature of air, environment,

V - speed of air in channels between edges, in m/s;

$S_к$ - the total area of cross-section section of channels between edges, in m^2;

ρ - air density at temperature Θ_{amb}, in kg/m^3,

C_p - air specific heat at temperature Θ_{amb}, in J / (kg x °K);

P - capacity taken away by a radiator.

For the accepted initial data **-** $\mathbf{\Theta = \Theta_{amb} + P / (2 \cdot V \cdot S_{к} \cdot \rho \cdot C_p)}$ =

296 K + 130 / (2·2m/s ·2,34* 10^{-3}м^2·1,21·1005) = 302,3°K (29,3°C)

4. We define sizes of criteria of Reynolds and Nusselt necessary for calculation of factor convective heat transfer of edges of a radiator:

$$\mathbf{Re = V \cdot L / \nu} \ [4]$$

Where: ν =15,8 10^{-6} - factor of kinematic viscosity of air at $\mathbf{q_c}$, **m2/with** from Appenix, table 1.

For the accepted initial data - $\mathbf{Re = VL/ \nu}$ = 2·8,3 10^{-2} / 15,8 10^{-6} = 1,05 10^4

$$\mathbf{Nu = 0{,}032\ Re^{0{,}8}} \ [5]$$

For the accepted initial data - Nu = 0,032 Re ^{0,8} = 0.032 (2.62*10^4) ^{0,8} = 52,8

5. We define factor of convective heat exchange of edges of a radiator:

$$\mathbf{\alpha_c = Nu \cdot \lambda_м / L \quad W / (м^2\ K)} \ [6]$$

Where $\lambda_м$ =2,72 10^{-2} - heat conductivity of air (W / (m C)), at $\mathbf{\Theta_{amb}}$.

For the accepted initial data - $\mathbf{\alpha_c = Nu \cdot \lambda_м / L}$ = 52,8 · 2,72 10^{-2} / 8,3 10^{-2} = 17,3

6. We define auxiliary coeffitients:

$$\mathbf{m = (2 \cdot \alpha_c / \lambda_м \cdot \delta)^{1/2}} \ [7]$$

We define value mh and a tangent hyperbolic th (mh).

For the accepted initial data - $\mathbf{m = (2 \cdot \alpha_c / \lambda_м \cdot \delta)^{1/2}}$ = (2 · 17,3 / (380 · 0,8 10^{-3})) $^{1/2}$ = 10,6

For the accepted initial data - $\mathbf{m \cdot H}$ = 10,6 · 6 10^{-2} = 0,64; th (m·H) = 0,54

7. We define the quantity of heat given by convection from edges of a radiator:

$$\mathbf{Pc = Z \cdot \lambda_м \cdot m \cdot S_p \cdot \upsilon_p \cdot th\ (m \cdot H)}\ [8]$$

Where: **Z** - number of edges;

$\lambda_м$ = factor of heat conductivity of metal of a radiator, W / (m · °K);

m - see the formula 7;

S_p - the area of cross-section section of an edge of a radiator, м^2,

$$\mathbf{S_p = L \cdot \delta}\ [9]$$

υ_p - temperature of an overheat of the basis of a radiator.

$S_p = L \cdot \delta = 8{,}3\ 10^{-2} \cdot 0{,}8\ 10^{-3} = 6{,}6\ 10^{-5}$ м^2

$\mathbf{P_c = Z \cdot \lambda_м \cdot m \cdot S_p \cdot \upsilon_p \cdot th\ (m \cdot H) = 27 \cdot 380 \cdot 10{,}6 \cdot 6{,}6\ 10^{-5} \cdot 60 \cdot 0{,}56 = 246\ W.}$

8. We define average temperature of an edge of a radiator:

$$\mathbf{\Theta_{avgrad} = (\Theta_{avg}/2)\ [1 + 1 / ch\ (m \cdot H)]}\quad [10]$$

Where: **ch (mH)** - hyperbolic cosine.

For the accepted initial data - $\Theta_{avgrad} = (\Theta_{avg}/2)\ [1 + 1 / ch\ (m \cdot H)] = (353/2\ [1+1/1{,}21]) = 322$°K (49°C)

9. We define radiant factor of heat exchange:

$$\phi = b / (b + 2h)$$

$\phi = b / (b + 2H) = 1{,}5\ 10^{-3}/(1{,}5\ 10^{-3} + 2*6\ 10^{-2}) = 0{,}024$

$$\mathbf{Sr = 2\ L\ [(Z\text{-}1) \cdot (b + \delta) + \delta] + 2\ H \cdot L \cdot Z\ (m^2)}\ [11]$$

For the accepted initial data - $\mathbf{Sr = 2\ L\ [(Z\text{-}1) \cdot (b + \delta) + \delta] + 2\ H \cdot L \cdot Z} = 0{,}279$ м^2

11. We define quantity of heat given through radiation:

$$P_r = \varepsilon_p \cdot \phi \cdot S_л \; \sigma \cdot (\Theta_{avgrad}^4 - \Theta_{avg}^4) \; [12]$$

σ - the Stefan-Boltzmann constant

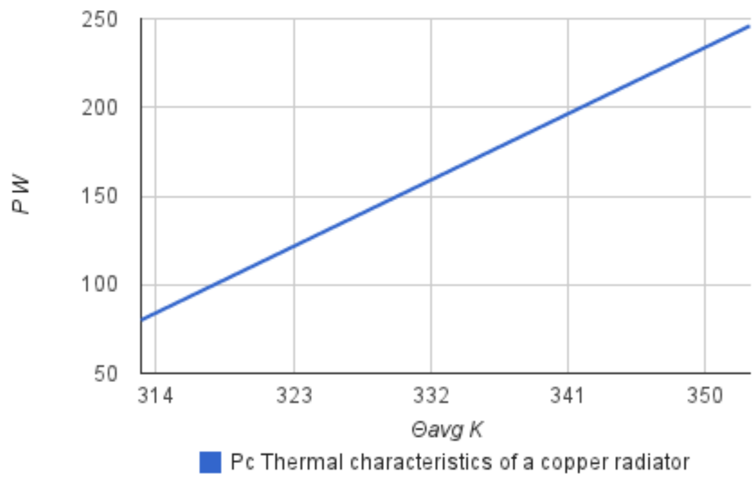
For the accepted initial data - $P_r = 0.464$ W

12. Heat total given by a radiator at the set temperature of a radiator $\Theta_{avg} = 353K$:

$$P = Pc + P_r \; [13]$$

For accepted initial given - $P = Pc + P_r = 246 + 0.464 = 246{,}46$ W.

13. We repeat calculations for radiator temperature $\Theta_{avg} = 313K$, and we build on two points the thermal characteristic of the calculated radiator. For this point Pr=80 W. Here on a vertical axis the quantity of heat given by radiator P_r, and on horizontal radiator temperature Θ_{avg}.



From the received schedule it is defined for the set capacity 130W, $\mathbf{\Theta_{avg}}$ = 323 °K or 50°C.

14. Under the thermal characteristic of a radiator it is defined that at set capacity P_p=80W, radiator temperature $\mathbf{q_p}$=328,5°C. Temperature of an overheat of a radiator $\mathbf{u_p}$ it is possible it is defined under the formula 2.

It is equal $\mathbf{\upsilon_p} = \mathbf{\Theta_{avg}} - \mathbf{\Theta_{amb}} =$ 323 - 293 = 30°K.

15. We define temperature of a crystal and it is compared it to limiting value the established manufacturer

$$\mathbf{\Theta chip = \Theta_{avg} + P\ (r_{gr} + r_{ch\text{-}rad}) = 323 + 130 \cdot (0{,}0004+0.1) = 336\ (63°C),\ [14]}$$

Where:

$\mathbf{r_{gr}}$ - thermal resistance of the thermal grease equal 0,0004 K/W

$\mathbf{r_{ch\text{-}rad}}$ - - thermal resistance chip-radiator – 0.1 K/W

In a general view, thermal resistance between two flat surfaces at application of thermal grease

$$\mathbf{r_{gr} = \delta\kappa} \cdot \lambda gr^{-1} \cdot S_{cont}^{\mathbf{-1}}\ [16] =$$

$$=(2{,}54\cdot10^{-6}\cdot3.3^{-1}\cdot(42\cdot42\cdot10^{-6})^{-1}=0.0004\ K/W$$

Where: δк - a thickness of a backlash between a radiator and the case of the cooled knot filled with a heat-conducting material in m,

λgr - factor of heat conductivity of a heat-conducting material in a backlash of W / (m K),

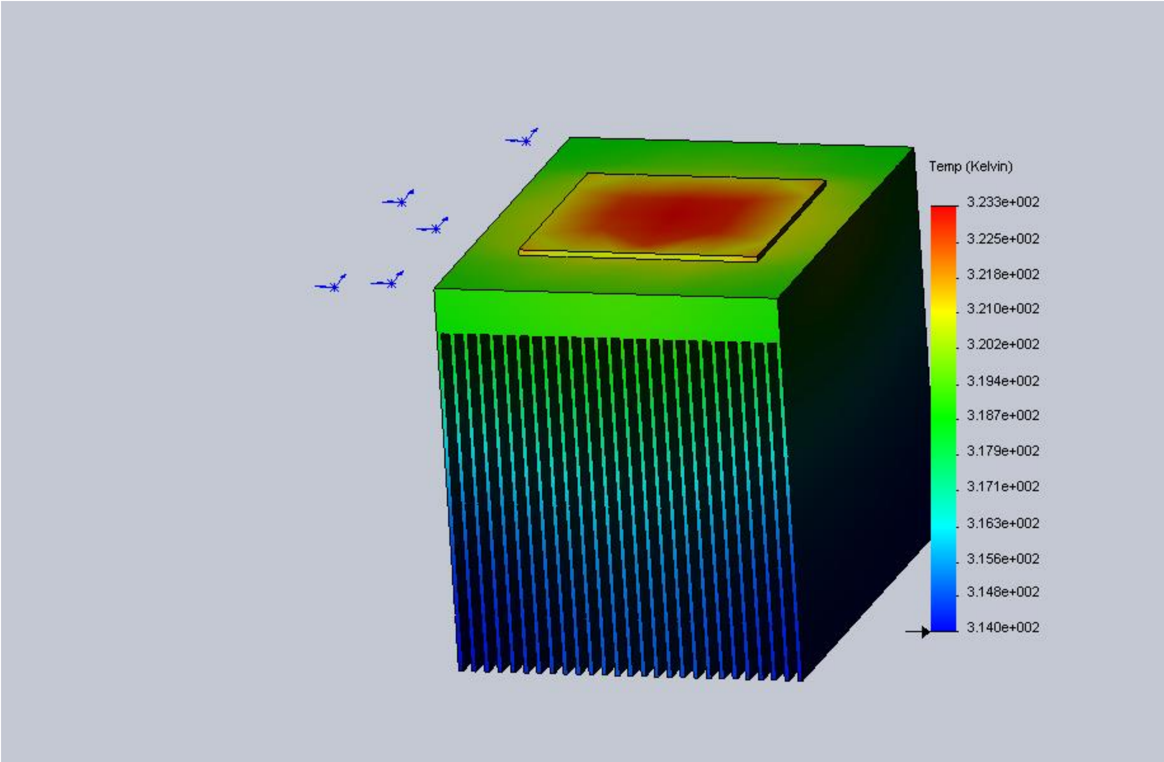
S_{cont} - the area of a contact surface in m^2.

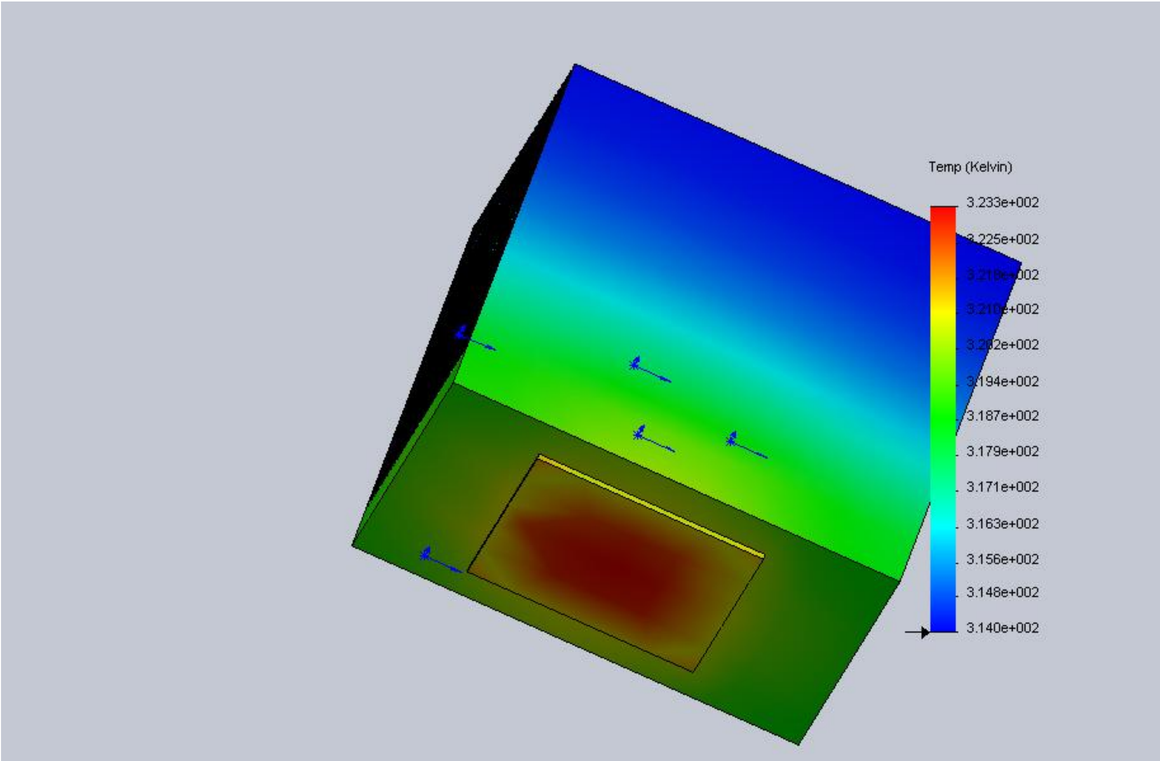
Conclusion: the Radiator with the specified characteristics will allow to cool the processor to temperature less than the critical.

Some results (Modelling in SolidWork(CosmoWorks))

Radiator Base (61 mmX 83 mm) Height 60 mm Z=27 Version **Copper**

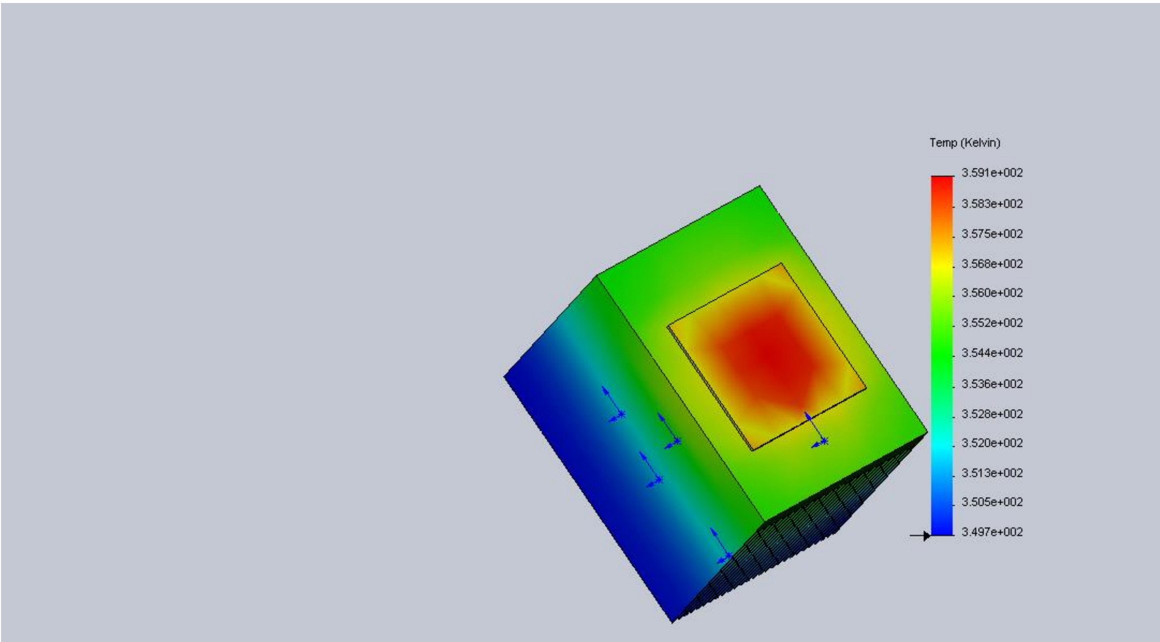
Version: Forsed convection. Mass of radiator 1.33 kg The surface square= 0.29 m2

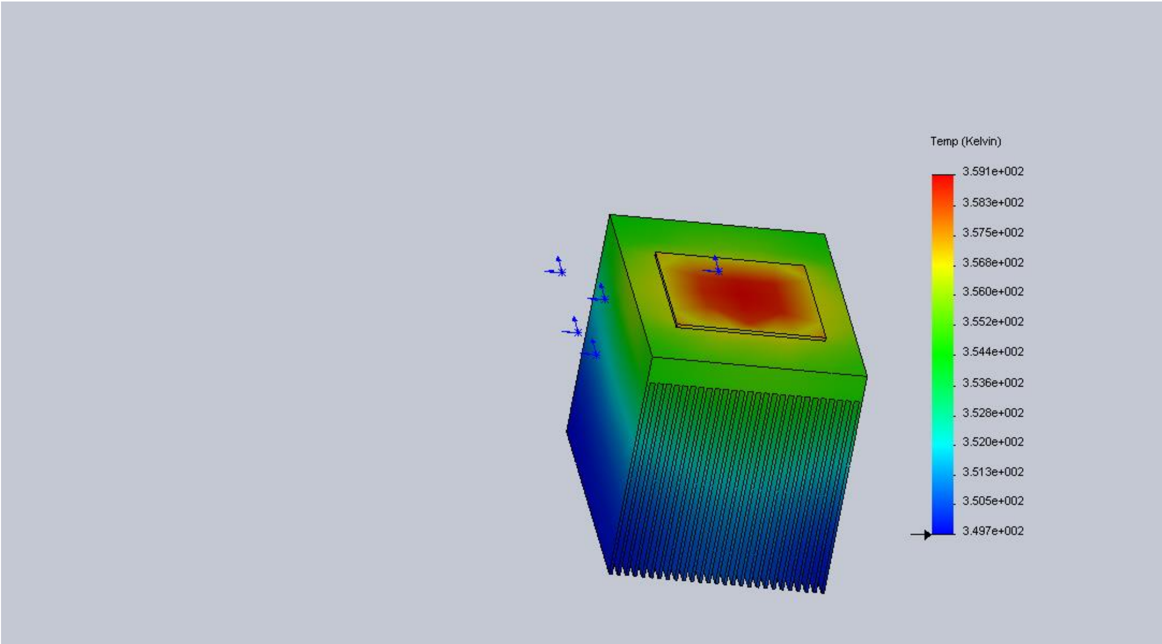




Radiator Base (61 mmX 83 mm) Height 60 mm Z=27 Version **Copper**

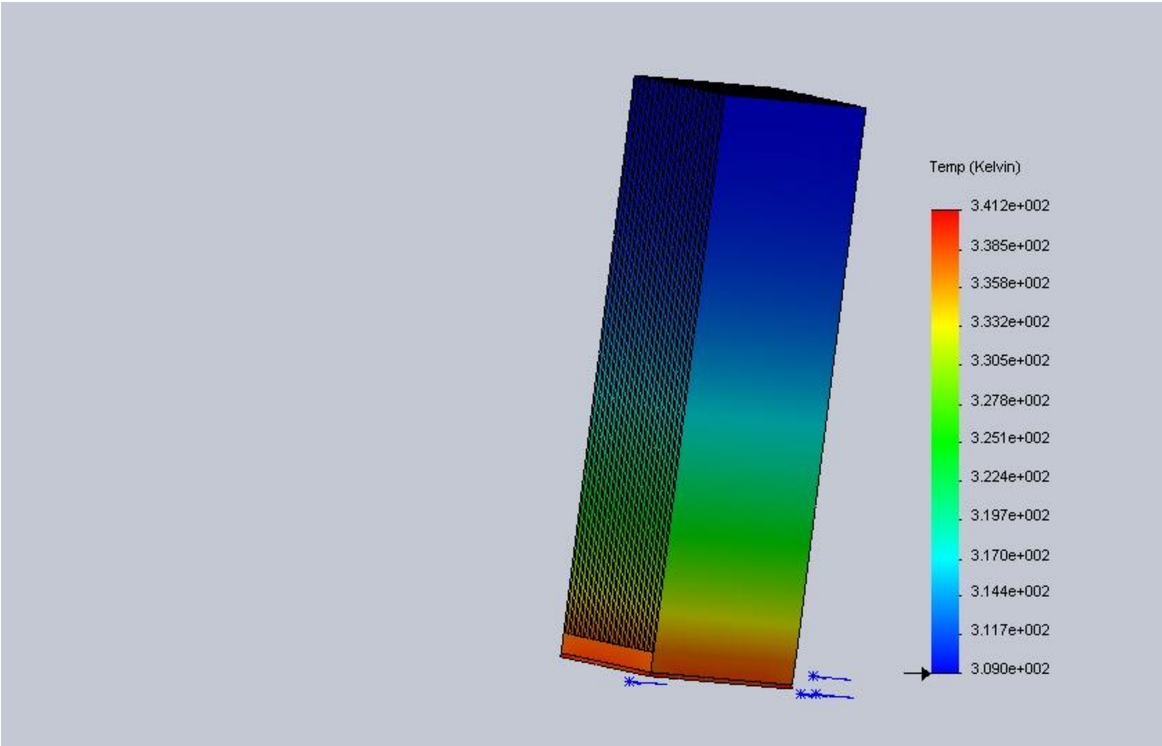
Version: Free convection. In a regime of a free convection of temperature appeared too high

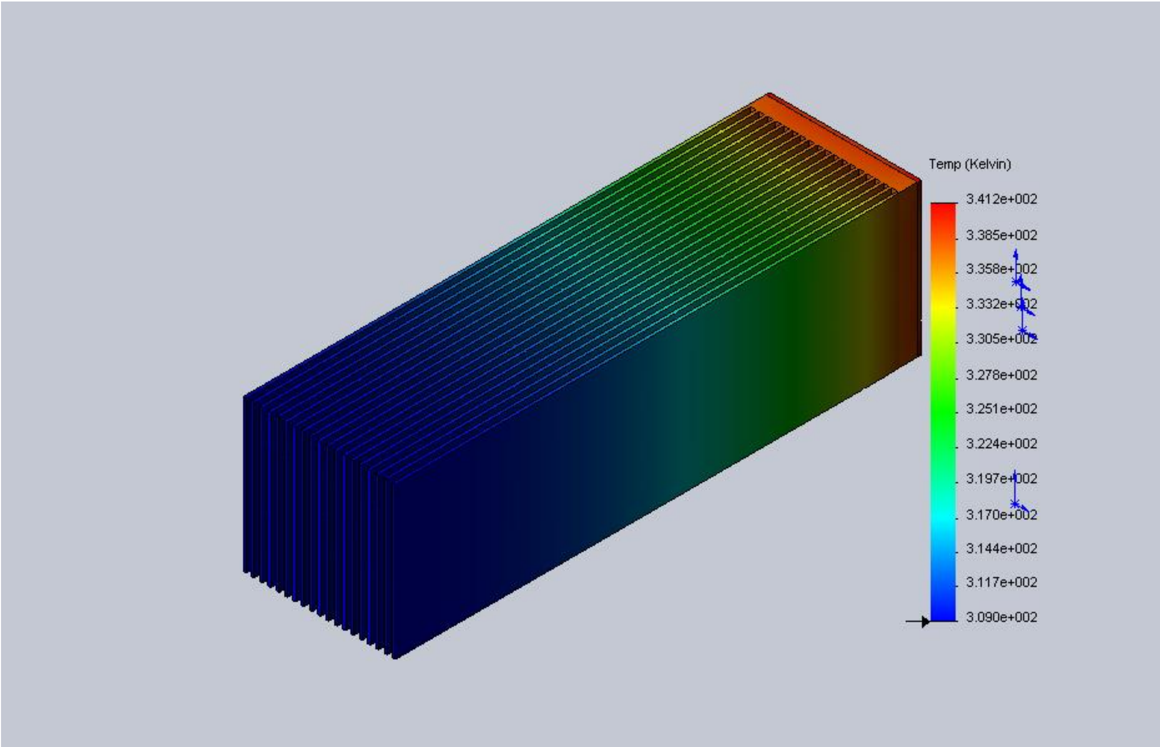




Radiator Height =120mm (it is not good for usability) Radiator Base (42mmX 42 mm) Z=19

Version Free Convection





For an instance the radiator has been calculated

http://www.thermalright.com/products/index.php?act=data&id=95