Report on the project company "Temp"

Problem statement for thermal calculations of a sensor

A sensor, which is presented in the drawing below, must be analyzed in a thermally transient environment by using the subsystem "ASONIKA-T".

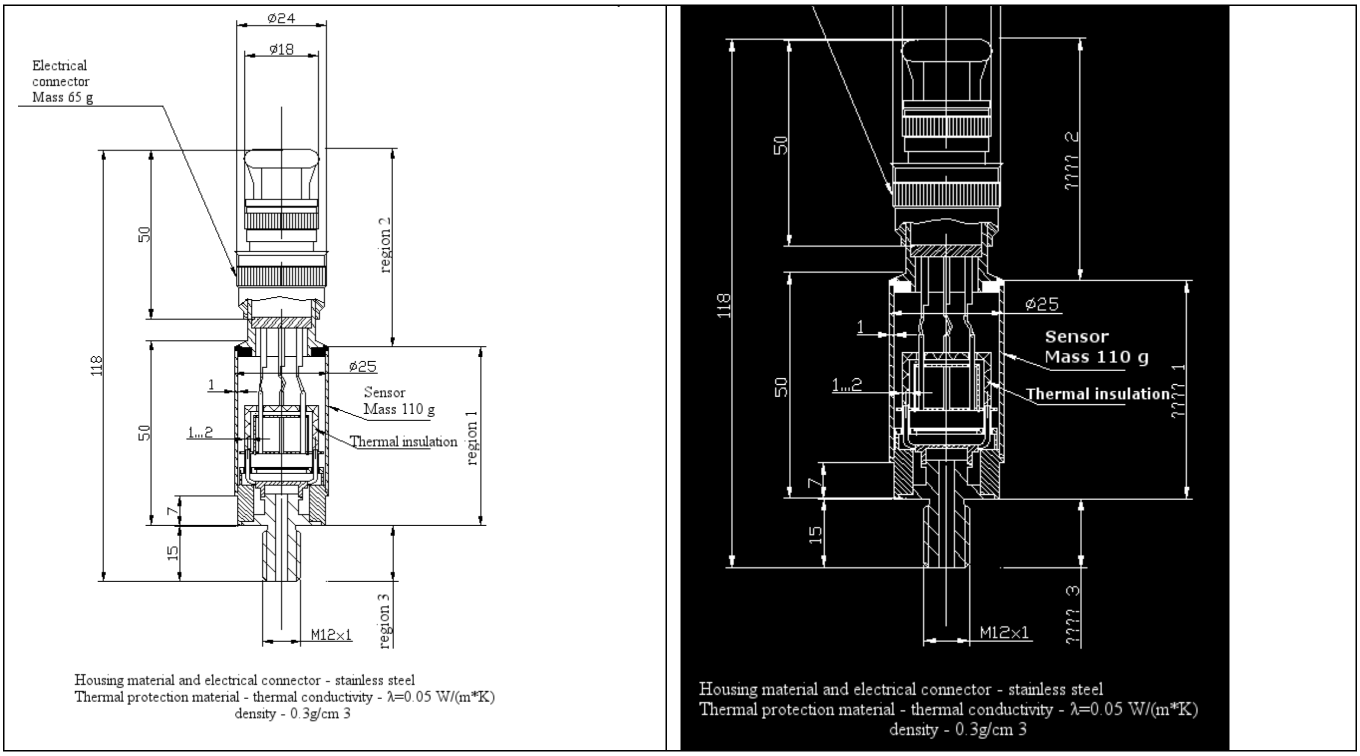


Fig. 1. Sensor drawings in direct and negative color.

The thermal effect on the sensor is given by the table:

Table 1.

Typical conditions of external influences (Option 1)**

№	Ambient temperature	Region 1	Region 2	Region 3
1.	initial setting of elevated temperature (ET), ^{0}C	120	120	120
2.	ultimate elevated temperature (UET), ^{0}C	183	183	183
3.	rate of temperature increase, deg/s	0.25	0.25	0.25
4.	rate of temperature decrease, deg/s	2.3	2.3	2.3
5.	duration of exposure UET, s	300	300	300
6.	duration of exposure ET, s	1346	1346	1346

Exposure is produced in the form of increased ambient temperature, given by the above table or graph below.

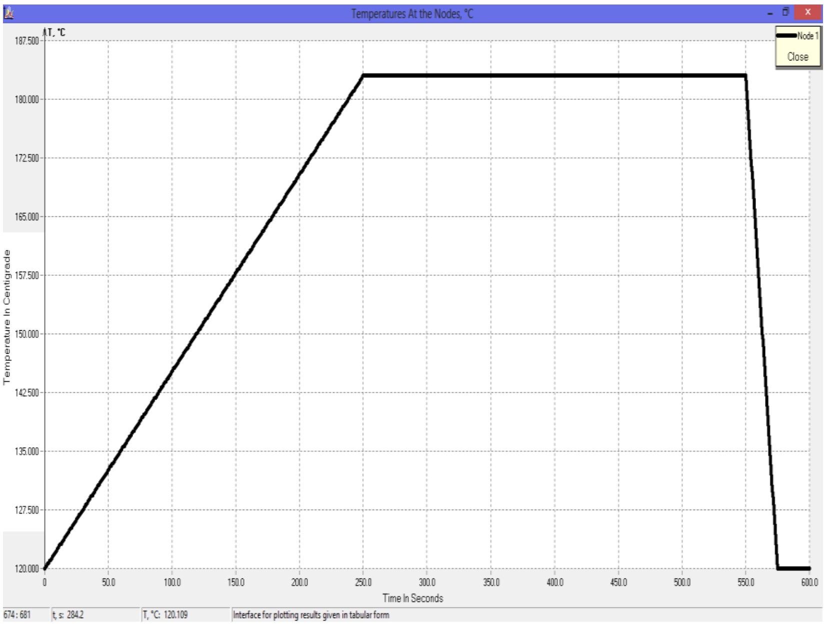


Fig. 2. Graph of typical external thermal influences

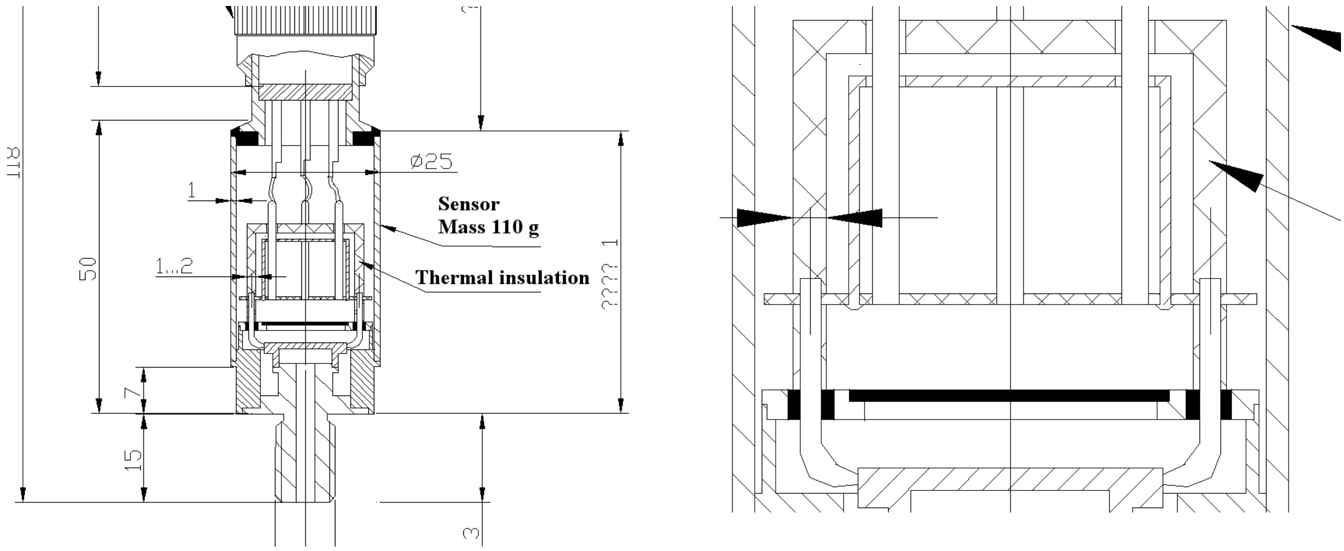


Fig. 3. More detailed drawings of the sensor.

Modelling thermal conditions

Thermal conditions modelling required a construction of a topological model of thermal processes (MTP) during the first phase and preparation of initial data for automated calculations in "ASONIKA-T."

Subsystem "ASONIKA-T" is designed to automate the design process of radio-electronic properties (REP) and allows implementing the following project objectives:

- determination of thermal conditions of all electro-radio instruments (ERI) and design materials and changes in design to achieve specified load factors;
- selecting the best design option from several available options with respect to thermal conditions of operation;

- the rationale for and evaluation of additional protection of REP against thermal effects;
- creating effective hardware testing for thermal effects (selection of tested effects, selection of best installation spots for sensors).

Subsystem "ASONIKA-T" allows analysis of the following design types: microassemblies, radiators and heat sinks, hybrid-integrated modules, stackable blocks and cassette design, cabinets, racks, as well as atypical (arbitrary) design.

The subsystem enables an analysis of hardware operating under steady and transient thermal modes with natural and forced air convection, both in normal as well as under reduced pressure. During the analysis of atypical designs, temperatures of selected isothermal volumes are determined; in the analysis of standard components – temperatures of ERI, as well as discrete temperature field of standard components and their integral temperature.

"ASONIKA-T" includes service support for a database with reference geometrical and thermal ERI parameters and design materials, graphical input data source for design, and graphical output of calculation results.

The resulting temperature calculations are used as boundary conditions for the simulation of thermal conditions of a PCB with subsystem ASONIKA-TM, as a result of which the temperatures can be obtained for all ERI.

Calculation of heating time from thermal impact of the environment

Assumption (idealization) for the refined model - each MTP node represents isothermal (i.e. it is considered that within its own bounds, each node has a constant temperature) component design, etc.:

- the housing of the sensor is divided into two parts -- upper and lower, each of which is modeled by one MTP node;

- printed circuit board (PCB) of the sensor is modeled by an MTP node, and to simulate heat transfer, a constant heat source is included;

- thermal conductivity between the PCB of the sensor and mounting elements is neglected, because PCB material has low thermal conductivity.

-housing insulation is modeled by one MTP node;

-electric screen is modeled by an MTP node;

-the air volume inside the housing is modeled by an MTP node;

-the air volume inside the screen and above the PCB is modeled by an MTP node;

-the environment is modeled with a source temperature defined by the table.

In the simulation we use the following types of heat transfer: heat conduction, natural convection, and radiation.

Subsystem "ASONIKA-T" contains libraries (several dozen) of elementary types of heat transfer with corresponding formulas, criteria equations, etc. The user selects the type of heat transfer from the corresponding menu of items and the system will formulate the appropriate equation and substitute the necessary formulas.

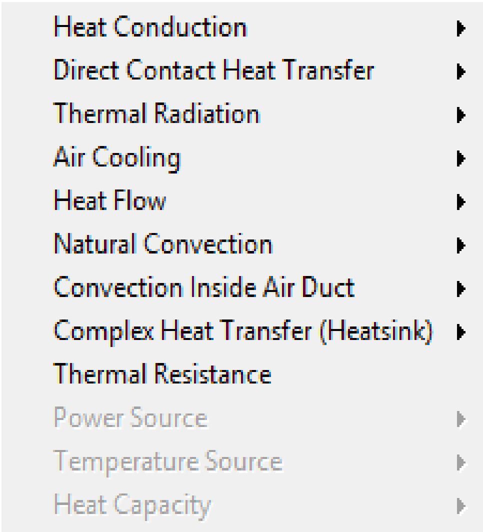
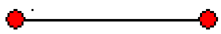
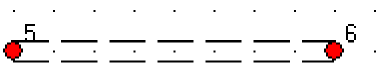
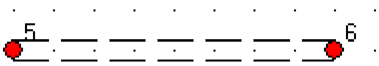
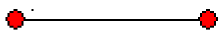
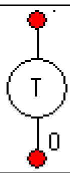
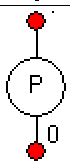


Fig.4. Menu items for heat transfer types in "ASONIKA-T"

The representations of MTP graph branches are given below (they reflect different types of thermal conductivities), which will be used later in modeling of thermal processes.

Table 2.

Branch designation of thermal models

№	Branch type	Branch designation of topological models	Description
1.	2		Conduction (heat transfer)
2.	16		Radiation
3.	11		Direct contact heat transfer
4.	51		Forced convection air cooling
5.	61		Convection inside air duct
6.	71		Heat and mass transfer
7.	111		Temperature source, °C
8.	101		Power source, W

In accordance with the above assumptions, an MTP thermal process of the sensor was built. MTP nodes:

Table 3.

MTP nodes of the sensor

Node number	Node name		Node number	Node name
1	Environment		5	Temperature insulation
2	Sensor housing bottom		6	Air under the housing of the sensor
3	PCB of the sensor		7	Air under the screen
4	Sensor housing top		8	Screen

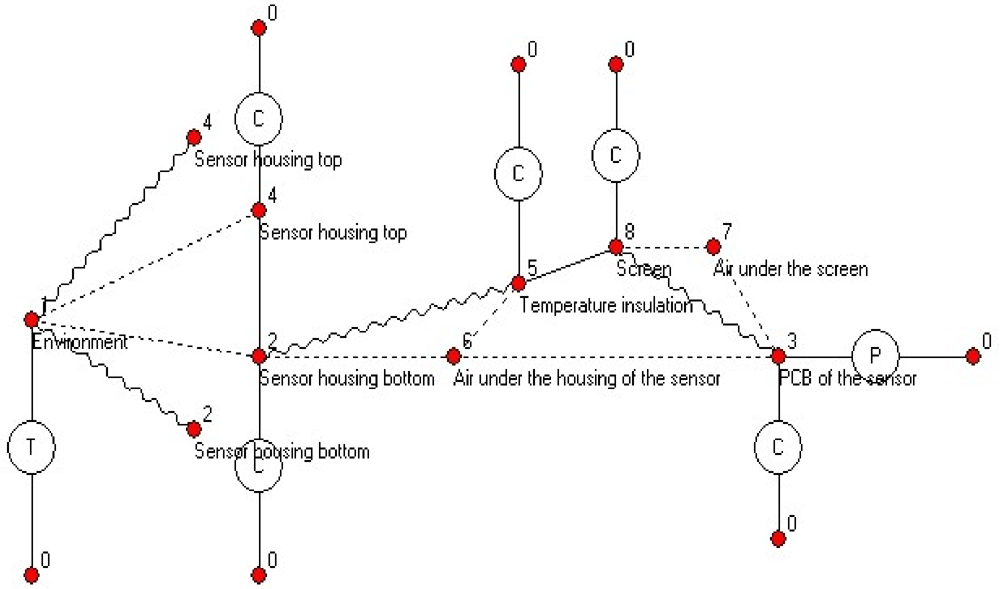


Fig. 5: Sensor's MTP

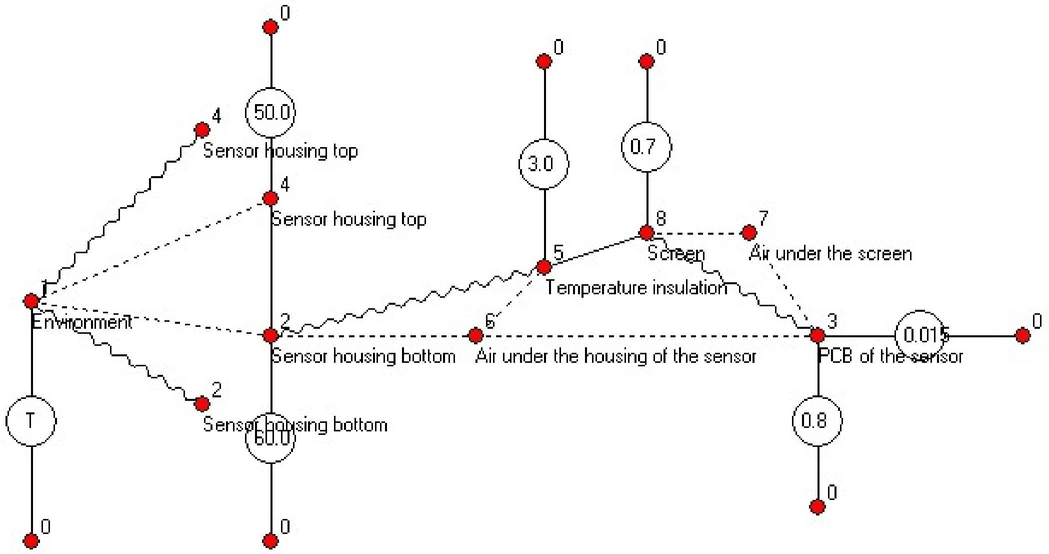


Рис. 6: Sensor's MTP with some input parameters

As a result, we get a graph of MTP node temperatures against time. We calculate the thermal conditions in the interval from 0 to 2000 seconds (though the actual impact is not more than 600 seconds).

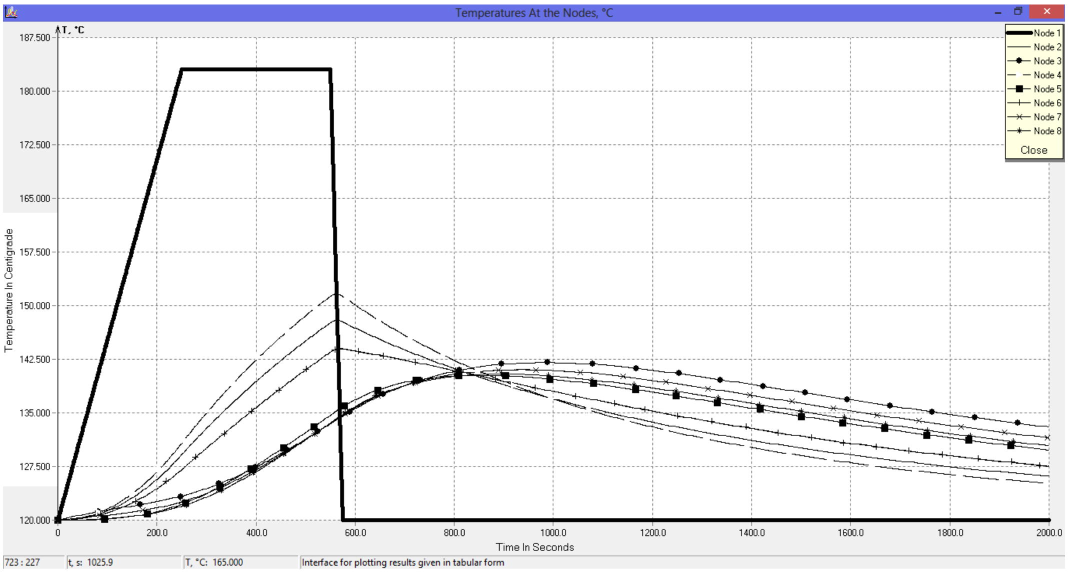


Fig. 7: Results of calculation of the thermal regime of **all** eight MTP nodes of the sensor during thermal exposure

From the graph it is clear that already in 1200 seconds we reach the maximum temperatures. We shall therefore consider results of the first 1200 seconds. For clarity, we will only display results for the most important elements (MTP nodes) of the design. For example, now we select results for the environment (the actual impact), sensor housing bottom, and PCB of the sensor.

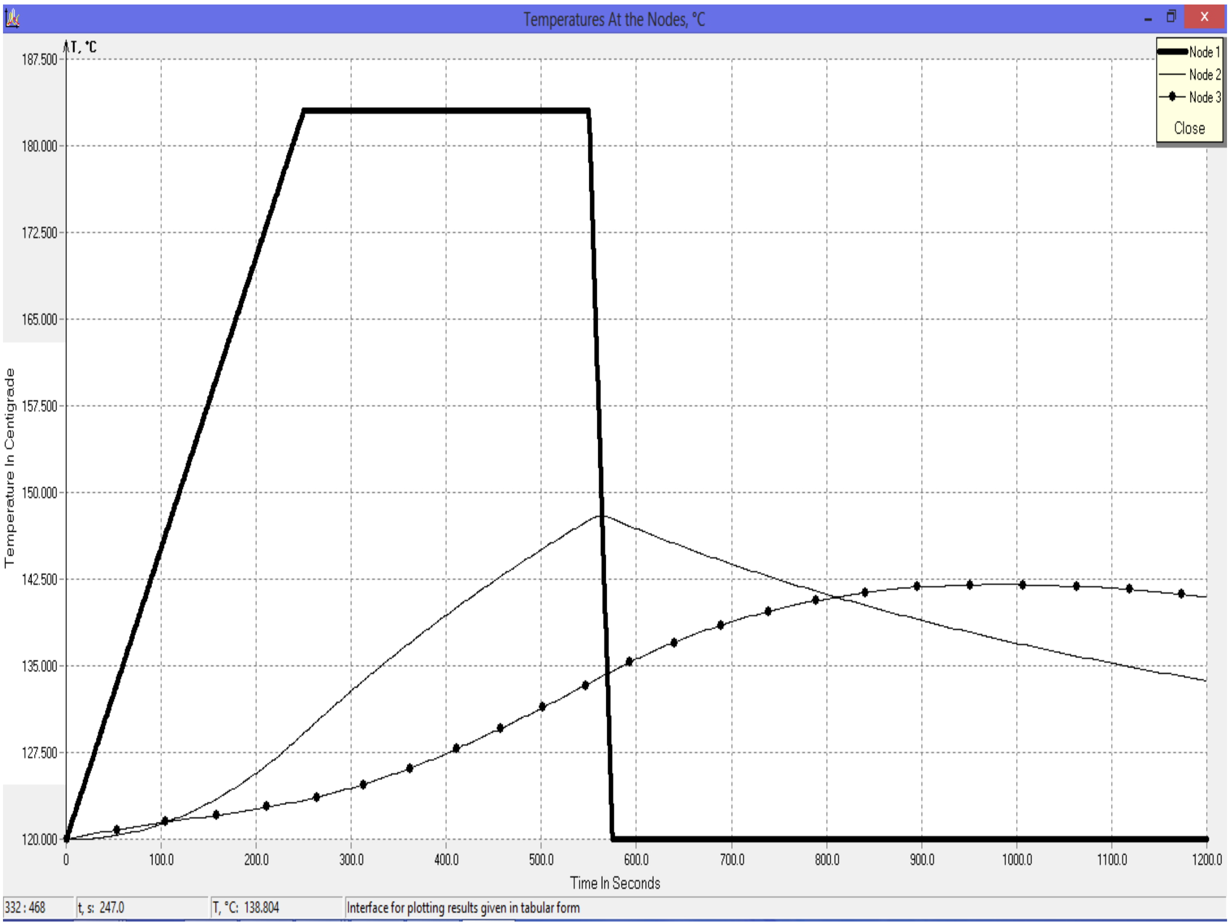


Fig. 8: Thermal calculation results of the sensor’s environment, housing, and PCB

Conclusion:

1. With these parameters, the sensor does not have time to warm up to a temperature of 183 degrees at this level of detail of the heating process.

2. Maximum temperature of sensor’s housing (node 2) (less than 150 degrees) coincides with the time of exposure to heat (node 1), and the maximum temperature of sensor’s PCB (node 3) (142 degrees) is reached later due to inertia and thermal insulation.

To investigate the option with increased heat capacity of thermal insulation from 3 J / K to 5 J / K, we repeat the calculation

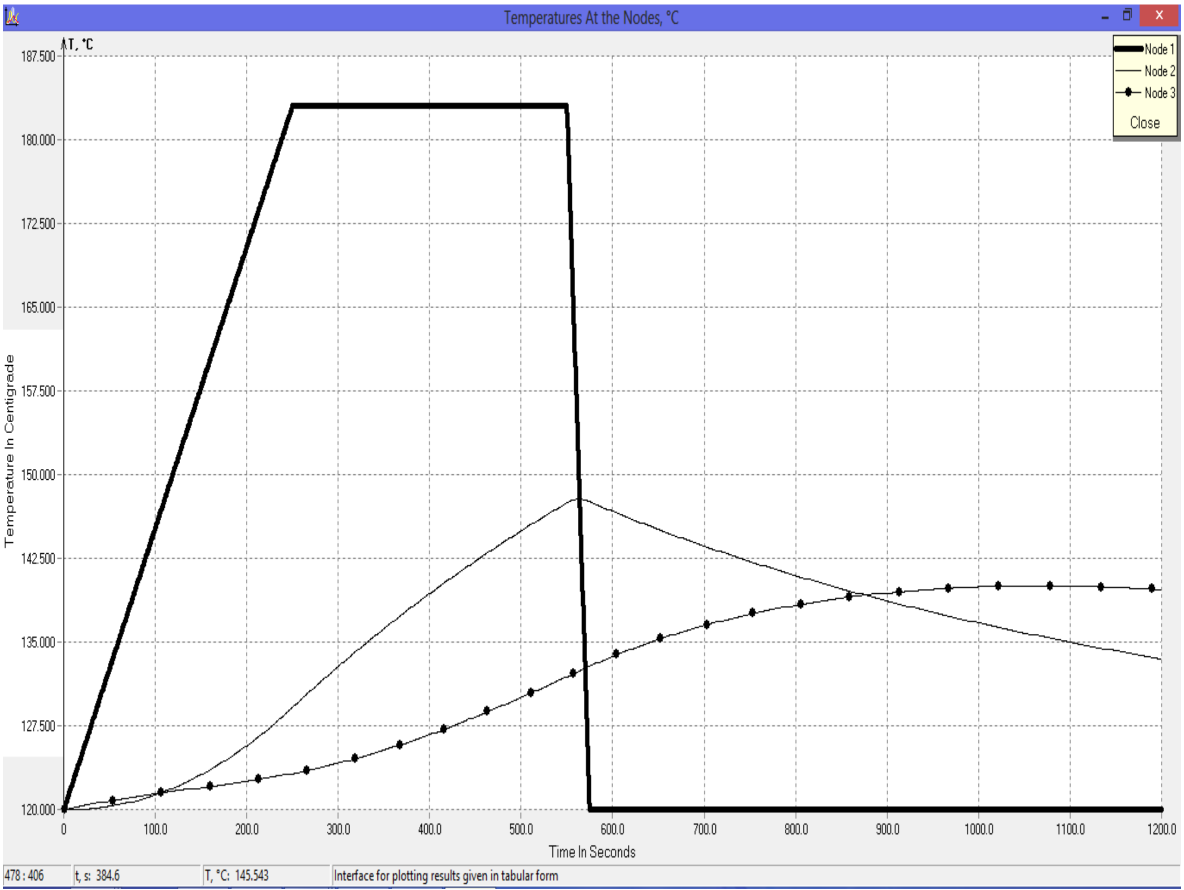


Fig. 9: Thermal calculation results of the sensor’s environment, housing, and PCB with increased heat capacity

Conclusion:

By increasing the heat capacity of thermal insulation from 3 to 5 J / K, the temperature of sensor’s housing has not changed, and the temperature of sensor’s PCB (node 3) reached at 1100 seconds decreased by several degrees.

To investigate an option with a decreased thickness of the insulator from 2 mm to 1 mm, we repeat calculations.

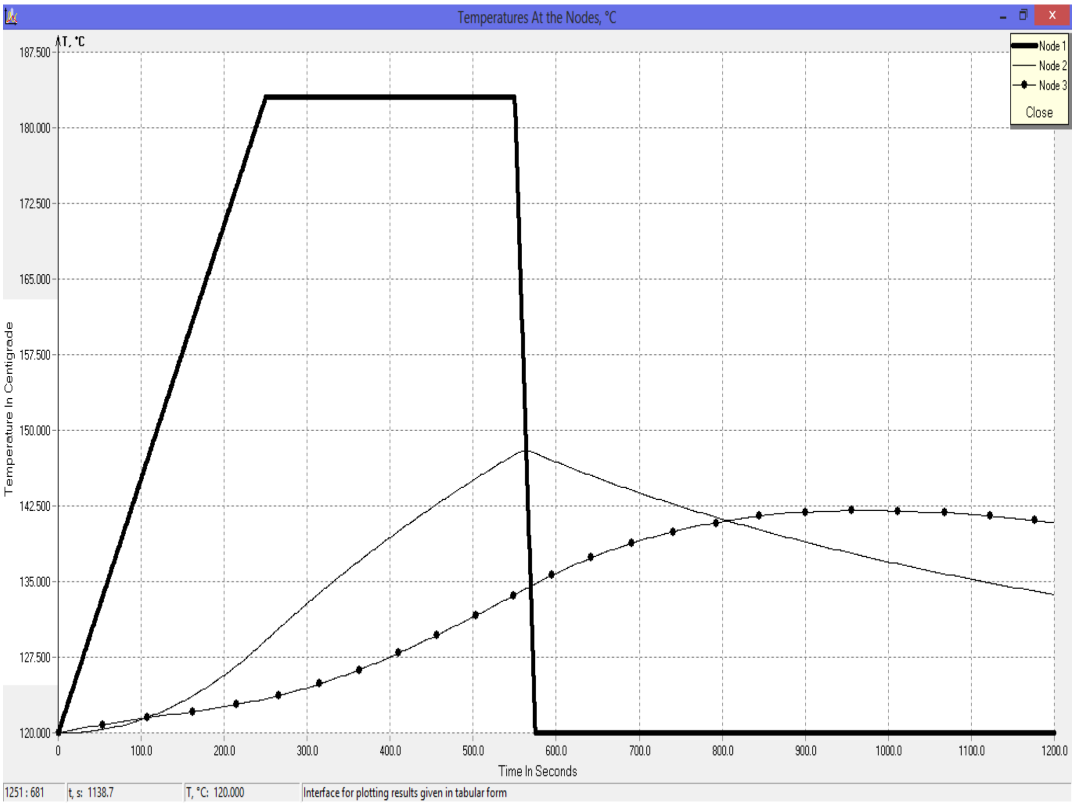


Fig. 10: Thermal calculation results of the senor's environment, housing, and PCB with a thinner thermal insulation

Conclusion:

When the thickness of the thermal insulation is decreased from 2 to 1 mm (with heat capacity of 3 J / K), the maximum temperature of the housing has not changed, while the temperature sensor's PCB (MTP node 3) has not either; however, the duration has slightly decreased - it cools down quicker!

To investigate the option with increased heat capacity of the **sensor's PCB** insulation from 0.8. J / K to 3 J / K, we repeat the calculation

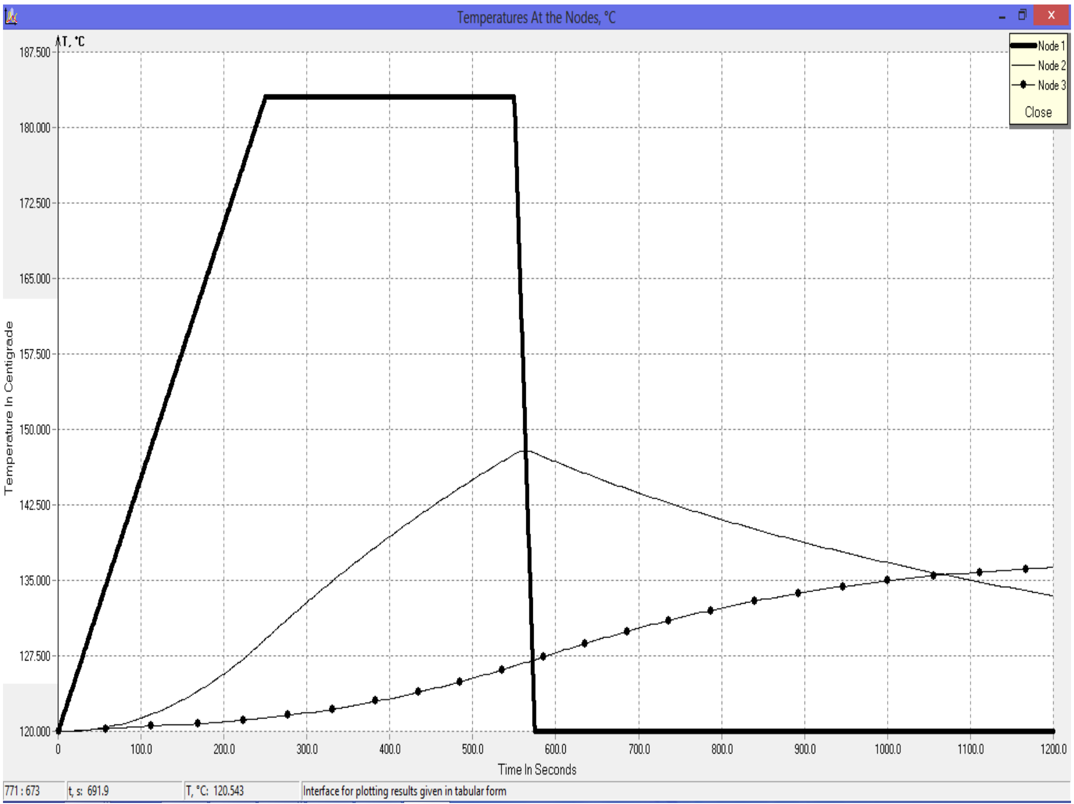


Fig. 11: Thermal calculation results of the sensor's environment, housing, and PCB with increased heat capacity of the PCB

Conclusion:

By increasing the heat capacity of the sensor's PCB from 0.8 to 3 J / K, the temperature of the sensor's housing has not changed, while the temperature of the PCB (node 3) on the 1100 seconds interval was less than 7 degrees, although increasing slightly afterwards, since the maximum occurs after 1200 seconds.

General conclusions.

Increase in heat capacity of a thermal insulator is more effective than increasing its thickness. But we must understand that in this version, we were able to explore these relationships separately. At the same time, in reality they are often interrelated because increasing the thickness of insulation leads to a simultaneous increase in its mass and therefore heat capacity.

From the viewpoint of thermal conditions, it is very effective to increase the heat capacity closer to the PCB of the sensor, since as a consequence it is difficult to gain insulation temperature and therefore it is more effective.

References

1. Automated system ASONIKA for designing highly reliable radio-electronic instruments on principles of CALS-technologies. Volume 1 (+ CD-ROM) Publisher: Energoatomizdat, 2007, pp.368.

2. Kofanov Y.N., Manohin A.I., Uvaisov C.U. Modeling of thermal processes in the design, testing and quality control of radio-electronic instruments: Textbook / MGIEM., Moscow, 1998, pp.140

3. Study of REP thermal characteristics with mathematical modeling methods. Monograph / V.V. Goldin, V.G. Zhuravskii, V.I. Kovalyonok, et al.; Ed. A.V. Sarafanova. M.: Radio and communication, 2003. – pp.456. ISBN 5-256-01697-0

4. Dulnev G.N., Heat and mass transfer in electronic equipment, textbook, M.: University, 1984.

Appendix

MTP sensor parameters are presented in the form of input data file. A detailed explanation is presented in the documentation for the subsystem.

```
MODEL
CTTP=01
CLTP=03
 FPS=00
TEST=10
 8 - MODEL NODES COUNT
"111222333111111122222222233333333444444445555555566666666777777788888888
   4  1 16    25.0   157.0     0.8     1.0
   2  1 16    25.0   157.0     0.8     1.0
   4  1 26    25.0   157.0    25.0     1.0   760.0
   2  1 26    25.0   157.0    25.0     1.0   760.0
   2  5 16    20.0    52.0     0.8     0.8
   6  2 26    25.0   157.0    25.0     1.0   760.0
   8  5  2    20.0    52.0     2.0    0.06
   6  5 26    20.0    52.0    20.0     1.0   760.0
   4  2  4    25.0    24.0    25.0    20.0
   6  3 26    20.0    20.0    20.0     0.8   760.0
   8  3 16    20.0    20.0     0.8     0.8
   8  7 26    14.0    42.0    14.0     1.0   760.0
   7  3 26    20.0    20.0    20.0     1.3   760.0
   1  0112     1.0
   2  0121    60.0
   4  0121    50.0
   5  0121     3.0
   8  0121     0.7
   3  0121     0.8
   3  0101   0.015
*
TAB.01
 +0.000E+00:+1.200E+02
 +2.500E+02:+1.830E+02
 +5.500E+02:+1.830E+02
 +5.750E+02:+1.200E+02
 +2.000E+03:+1.200E+02
E
*
START CALCULATION TIME  0.0
FINISH CALCULATION TIME 1200.0
ACCURACY OF INTEGRATION 0.1
MINIMUM STEP            .5
MAXIMUM STEP            2.0
START TEMPERATURE       120.0
```