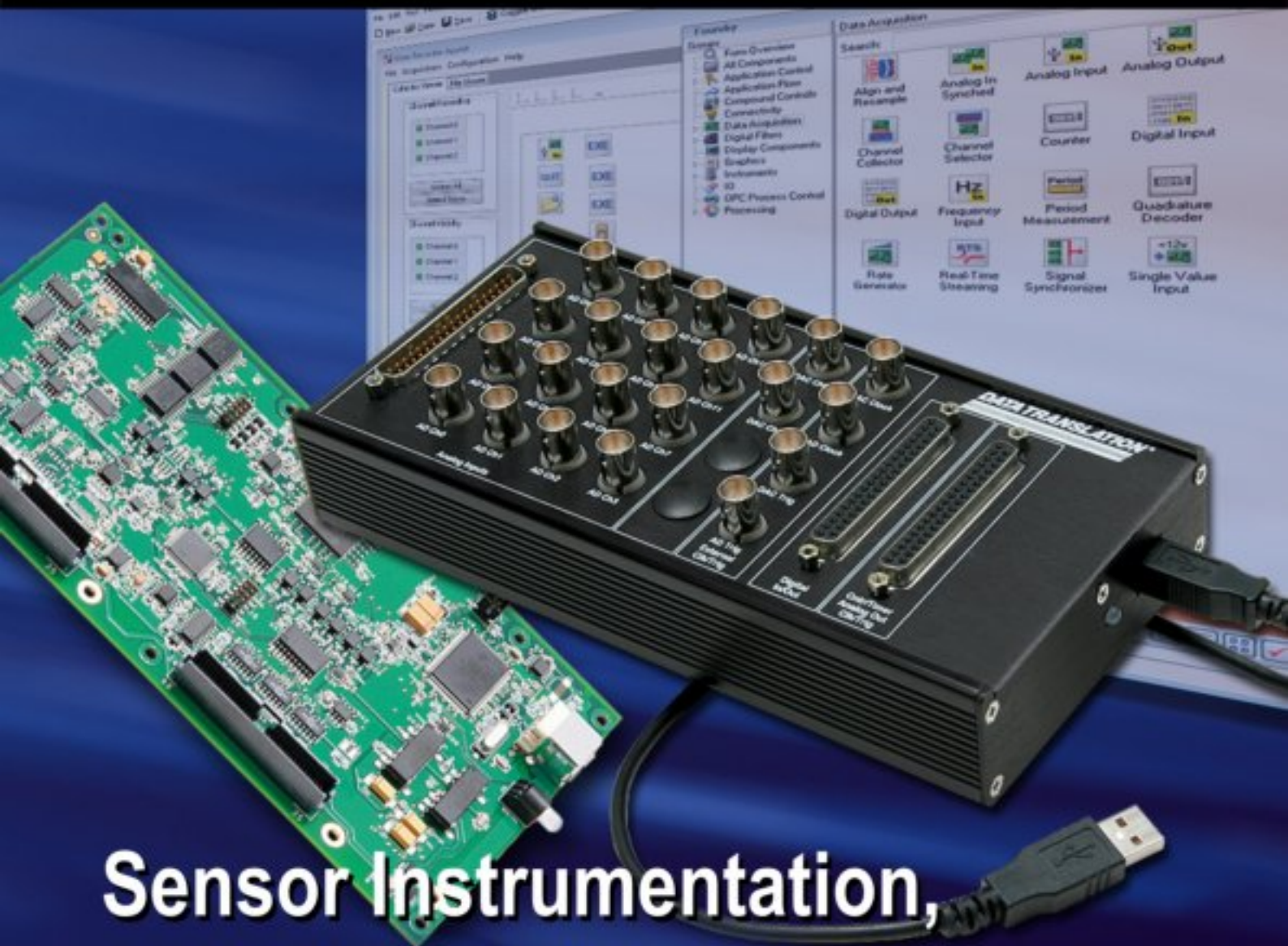


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SENSORDEVICES 2010:

The First International Conference
on Sensor Device Technologies and Applications

July 18 - 25, 2010 - Venice, Italy



The inaugural event SENSORDEVICES 2010, The First International Conference on Sensor Device Technologies and Applications, initiates a series of events focusing on sensor devices themselves, the technology-capturing style of sensors, special technologies, signal control and interfaces, and particularly sensors-oriented applications. The evolution of the nano- and microtechnologies, nanomaterials, and the new business services make the sensor device industry and research on sensor-themselves very challenging.

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SENSORCOMM 2010:

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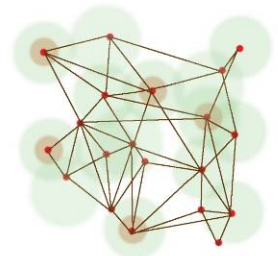
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APASN Architectures, protocols and algorithms of sensor networks
MECSN Energy, management and control of sensor networks
RASQOFT Resource allocation, services, QoS and fault tolerance in sensor networks
PESMOSN Performance, simulation and modelling of sensor networks
SEMOSN Security and monitoring of sensor networks
SECSN Sensor circuits and sensor devices
RIWISN Radio issues in wireless sensor networks
SAPSN Software, applications and programming of sensor networks
DAIPSN Data allocation and information in sensor networks
DISN Deployments and implementations of sensor networks
UNWAT Under water sensors and systems
ENOPT Energy optimization in wireless sensor networks

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Modeling and Verification of Heat Fields by Virtual Instrumentation

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Abstract: This paper introduces about simulation and verification of heat relations in DC/DC converter as a part of various mechatronics systems. Heat transfer is the transition of thermal energy from a heated item to a cooler item. Results of simulation were compared with values obtained by measurement with virtual instruments. Measurements were made at various operating conditions of DC/DC converter. This measurement gives idea about the heat transfer at time dependences. *Copyright © 2010 IFSA.*

Keywords: Thermal analysis, Heat transfer, LabVIEW

1. DC/DC Converters

DC to DC converters are important in portable electronic devices such as cellular phones, laptop computers or engines, which are supplied with power from batteries primarily. Such mechatronics devices often contain several sub-electrical circuits, each with its own voltage level requirement different than that supplied by the battery or an external supply (sometimes higher or lower than the supply voltage, and possibly even negative voltage - Fig. 1). Additionally, the battery voltage declines as its stored power is drained. Switched DC to DC converters offer a method to increase voltage from a partially lowered battery voltage thereby saving space instead of using multiple batteries to accomplish the same thing [1].

The main function of DC/DC converter is conversion of input direct voltage to another direct voltage. DC/DC converter can work in some modes: boost or step-up converter, buck or step-down converter and inverting mode. The principle scheme of measured boost converter is at Fig. 2.

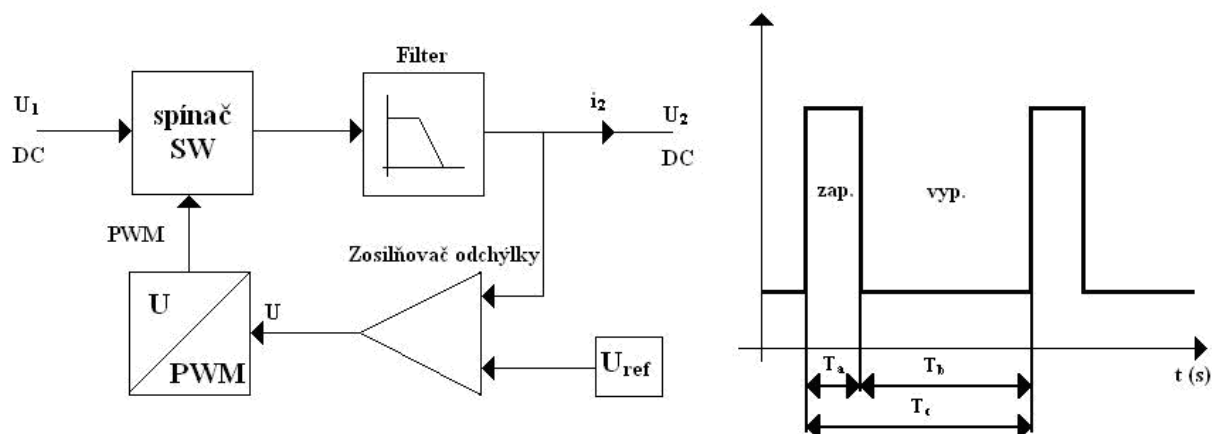


Fig. 1. DC/DC converter block scheme and control impulse.

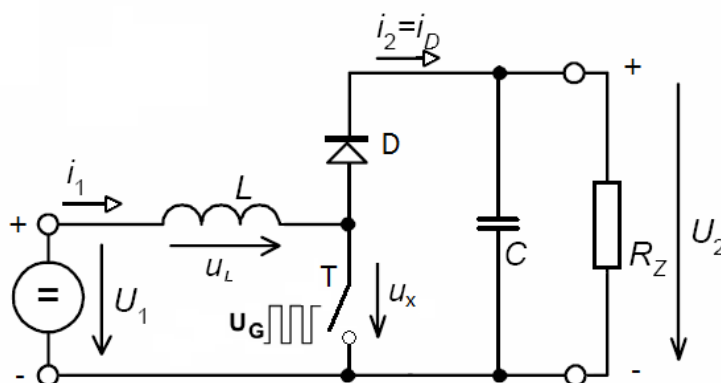


Fig. 2. Principle scheme of boost DC/DC converter.

Electronic switch-mode DC/DC converters convert one DC voltage level to another, by storing the input energy temporarily and then releasing that energy to the output at a different voltage. The storage may be in either magnetic field storage components (inductors, transformers) or electric field storage components (capacitors). This conversion method is more power efficient (often 75 % to 98 %) than linear voltage regulation (which dissipates unwanted power as heat). This efficiency is beneficial to increasing the running time of battery operated devices. The efficiency has increased due to the use of power FETs, which are able to switch at high frequency more efficiently than power bipolar transistors, which have more switching losses and require a more complex drive circuit. Another important innovation in DC/DC converters is the use of synchronous rectification which replaces the flywheel diode with a power FET with low "On" resistance, thereby reducing switching losses.

Most DC/DC converters are designed to move power in only one direction, from the input to the output. However, all switching regulator topologies can be made bi-directional by replacing all diodes with independently controlled active rectification. A bi-directional converter can move power in either direction, which is useful in applications requiring regenerative braking.

Drawbacks of switching converters include complexity, electronic noise (EMI / RFI) and to some extent cost, although this has come down with advances in chip design.

DC to DC converters are now available as integrated circuits needing minimal additional components. DC to DC converters are also available as a complete hybrid circuit component, ready for use within an electronic assembly.

On the base of principle scheme we must respect circuit parameters such as maximal power dissipation of devices, efficiency and place of cooling system. In this measurement we use boost converter from 12V to 24V/5A. Because the current and power is high, we must use cooling system. The cooling system is passive with aluminum cooler (Fig. 3).

2. Heat Transfer Principles

Heat transfers in a subject are defined as the movement of energy due to a difference in temperature. When an object or fluid is at a different temperature than its surroundings or another object, transfer of thermal energy, also known as heat transfer, or heat exchange, occurs in such a way that the body and the surroundings reach thermal equilibrium [2]. It is known the following three physical mechanisms, all of which the heat transfer executes:

Conduction - Heat conduction takes place through different mechanisms in different media. Theoretically it takes place in a gas, in a fluid and in metals. A typical property for heat conduction is that the heat flux is proportional to the temperature gradient.

Convection - Heat convection takes place through the net displacement of a fluid, which transports the heat content in a fluid through the fluid's own velocity. The term convection is also used for the heat dissipation from a solid surface to a fluid, where the heat transfer coefficient and the temperature difference across a fictive film describe the flux.

Radiation - Heat transfer by radiation takes place through the transport of photons, which solid surfaces can absorb or reflect. There is surface-to-surface radiation, which accounts for shadowing and diffuse reflections between radiating surfaces. There is also surface-to-ambient radiation where the ambient surroundings are treated as a black body with known temperature.

Heat Equation - The fundamental law describing all heat transfer is the first law of thermodynamics. This is the basic principle of conservation of energy. However, internal energy is a rather inconvenient quantity to measure.

Therefore, the basic law is usually rewritten in terms of temperature, T:

$$\rho C_p \left(\frac{\partial T}{\partial t} + (\mathbf{u} \cdot \nabla) T \right) = -(\nabla \cdot \mathbf{q}) + \tau : \mathbf{S} - \frac{T}{r} \frac{\partial r}{\partial t} \left(\frac{\partial p}{\partial t} + (\mathbf{u} \cdot \nabla) p \right) + Q \quad (1)$$

where ρ is the density (kg/m^3), C_p is the specific heat capacity at constant pressure ($\text{J}/(\text{kg}\cdot\text{K})$), T is the absolute temperature (K), \mathbf{u} is the velocity vector (m/s), \mathbf{q} is the heat flux by conduction (W/m^2), p is the pressure (Pa), τ is the viscous stress tensor (Pa), Q is the contains heat sources other than viscous heating (W/m^3), \mathbf{S} is the strain rate tensor (1/s):

$$\mathbf{S} = \frac{1}{2} (\nabla \mathbf{u} + (\nabla \mathbf{u})^T) \quad (2)$$

The fundamental law uses Fourier's law of conduction:

$$q_i = -k \frac{\partial T}{\partial x_i}, \quad (3)$$

which states that the conductive heat flux, q , is proportional to the temperature gradient; k is the thermal conductivity ($W/(m \cdot K)$).

The heat equation accepts two basic types of boundary conditions:

- specified temperature,
- specified heat flux.

The former conditions are of Dirichlet types and prescribe the temperature at a boundary:

$$T = T_0, \quad (4)$$

where T_0 is the boundary Temperature, or specifies the inward heat flux: $-n \cdot q = q_0$, q is the total heat flux vector (W/m^2), n is the normal vector of the boundary, q_0 is the inward heat flux (W/m^2), normal to the boundary.

3. Heat Transfer Simulation

Problems involving any combination of conduction, convection and radiation are solved with COMSOL in the Heat Transfer Module. It finds extensive use in systems that involve the generation and flow of heat in any form.

A variety of specialized modeling interfaces are available for different formulations and applications such as surface-to-surface radiation, non-isothermal flow, heat transfer in structures made of thin layers and shells, and heat transfer in biological tissue.

The Heat Transfer Module allows for arbitrary couplings to other application modes in COMSOL Multiphysics as well as other add on modules. This is particularly relevant to applications such as thermal management in the electronics industry, thermal processing and manufacturing, and medical technology and bioengineering.

Heat transfer encompasses many different industries, but is based upon the same laws of physics, such as those describing conduction, convection and radiation. This module provides modeling interfaces to intuitively manipulate these laws. This gets to customers familiar with the physics of heat transfer while a large number of examples introduce them to applications of heat transfer in a range of different industries. The module includes:

Easy-to-use modeling interfaces - The software supplies convenient physics formulations for applications involving heat transfer through convection, conduction, and radiation. Other focused application modes address heat transfer in thin layers and shells, surface-to-surface radiation, and the bioheat equation.

Fluid flow - Additional predefined modeling interfaces allow you to model laminar and turbulent flow, including the k - ϵ and k - ω turbulence models, in conjunction with heat transfer.

Model Library - This set contains some tutorial models to get customers up and running as well as example models from the processing and manufacturing, electronics and power systems, and medical technology industries.

Predefined multiphysics couplings - Special multiphysics interfaces for modeling Joule heating, as well as the interaction of heat transfer with both turbulent and nonisothermal fluid flow, allow students to study many varied industrial applications.

If we want to simulate in COMSOL heat transfer on DC/DC converter cooler, we must create geometrical structure of this cooler. These structures can be drawing in 2D or 3D dimensions. When the structure is done, then we must define initial condition (Fig. 4).

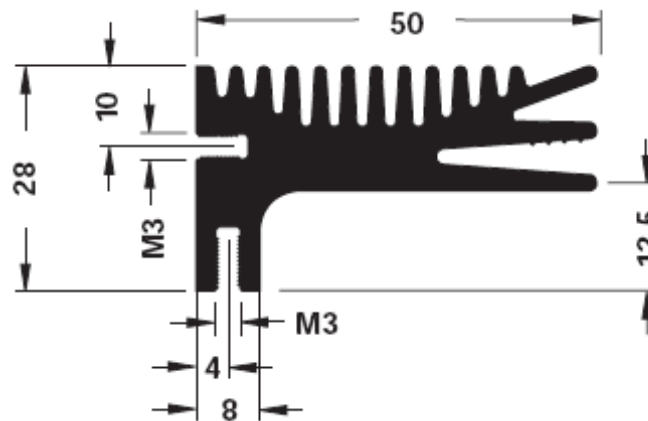


Fig. 3. Aluminum cooler with geometrical dimensions.

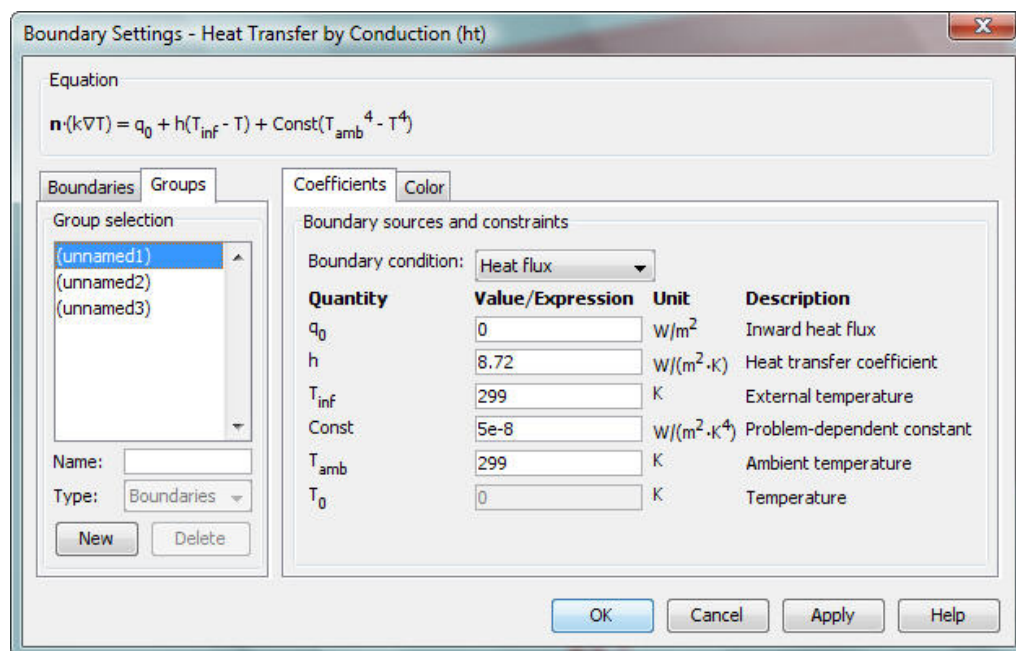


Fig. 4. Cooler boundary settings.

Coefficients can be defined as constant or time or temperature functions. After coefficients are defined, we must create computing mesh as initialize mesh. This mesh is created automatically. Mesh can be manually refine or concentrate (Fig. 5). The mesh density influences simulation (computer memory and time of simulation) [3-7].

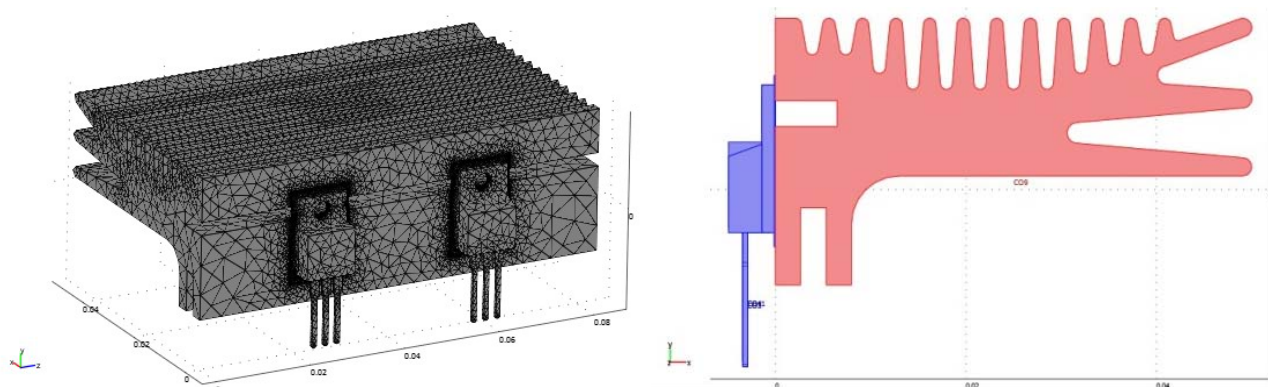


Fig. 5. Cooler computing mesh and cooler profile.

The simulation result for idealized model is shown at Fig. 6. The transistor temperature is approximate 45.5 °C. The diode is colder because it has lower power dissipation.

The simulation result for real model is shown at Fig. 7. The transistor temperature is approximate 69 °C. The cooler temperature is about 60 °C.

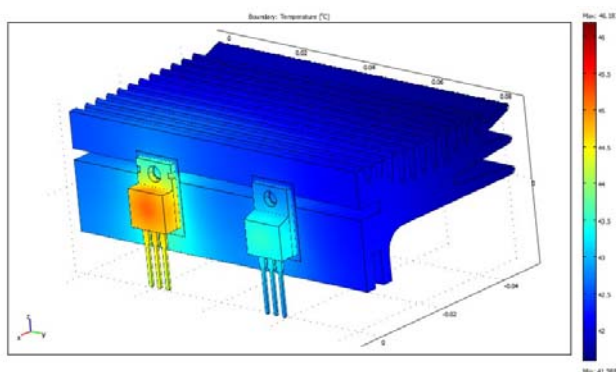


Fig. 6. Simulation result of idealized model.

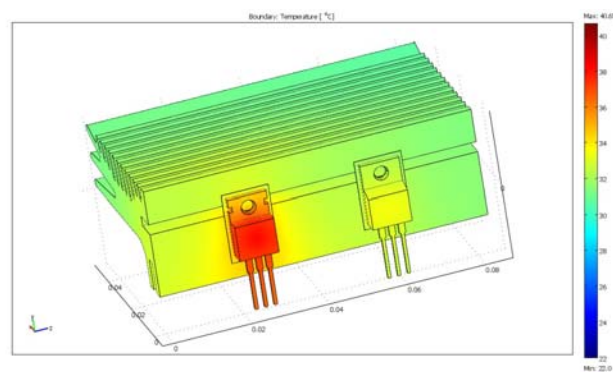


Fig. 7. Simulation result of real model.

4. Verification Using Virtual Instrumentation - LabVIEW

The LabVIEW is a graphical programming environment, which can be used to built data acquisition and instrument control application. The LabVIEW graphical dataflow language and block diagram approach naturally represent the flow of our data and intuitively map user interface controls to his data, so we can easily view and modify our data or control inputs. The LabVIEW programs are called virtual instruments, or VIs, because their appearance and operation imitate physical instruments, such as oscilloscopes and multimeters.

In LabVIEW, we built a user interface, or front panel (Fig. 8), with controls and indicators. Controls are knobs, push buttons, dials, and other input devices. Indicator are graphs, LEDs, ant other displays. After we built user interface, we add code using VIs and structures to control the front panel objects. The block diagram contains this code (Fig. 9).

DC/DC converter verification of simulation was done by current, voltage and temperature measurement. Measurement was realized for various states (the load was not connecting to DC/DC

converter and then the load value was increased). When the load had maximum value, then the measurement was realized. We measured transistor and cooler heating by thermo sensor (Fig. 10) at three points (on transistor and 2 points on cooler). This is shown at Fig. 11.

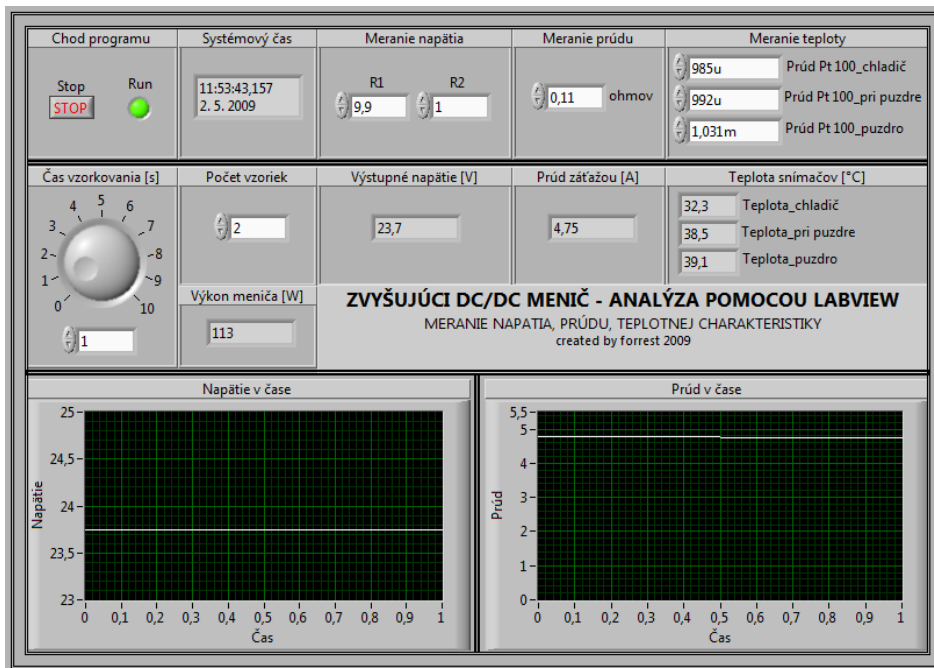


Fig. 8. Application Front panel.

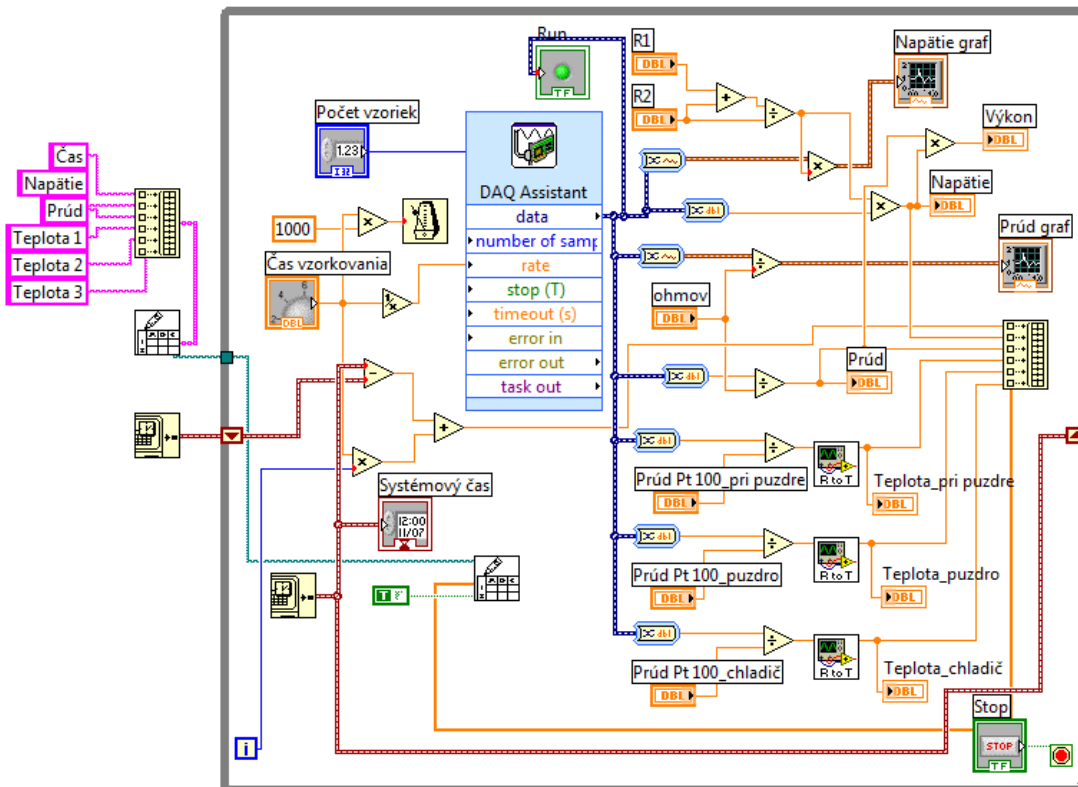


Fig. 9. Application Block diagram.

The DC/DC converter has power off at start. Then the power was on and the output voltage increased to 25 V. When we loaded DC/DC converter the output voltage decreased about 1.7 V. The temperature was increased when we increased load.



Fig. 10. Transistor, cooler and thermo sensors.

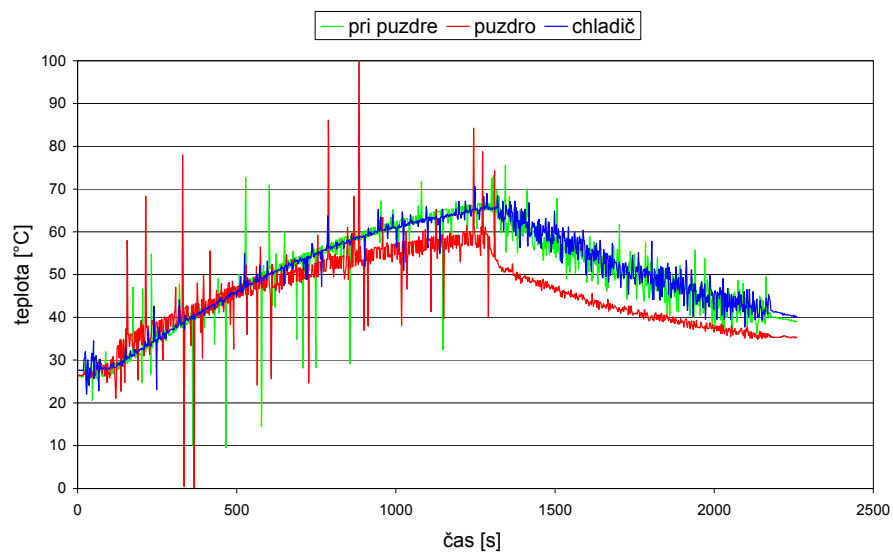


Fig. 11. Graph of transistor and cooler temperature.

5. Conclusions

The paper analyses the simulation and verification of heat relations in DC/DC converter as a part of various mechatronics systems. Results of simulation were compared with values obtained by measurement with virtual instruments. These results are approximately same. The peak in graph was done by electro magnetic interference. In future work we must design filter to decrease interference. The simulation helps us to obtain relevant values for design of electrical circuits as a part of mechatronics systems.

Acknowledgements

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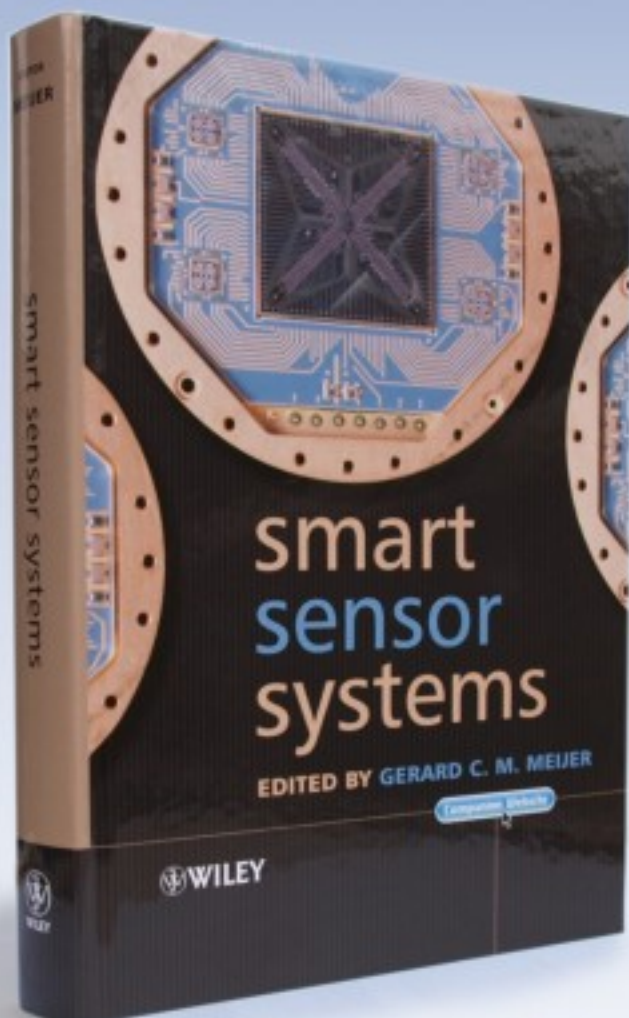
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