Conf.dr.ing. Ioan-Emilian CEUCA

TEZĂ DE ABILITARE

ANALYSIS, MODELING AND DESIGNING OF THE ELECTRONIC CIRCUITS IN AUTOMOTIVE

FACULTATEA DE ELECTRONICĂ, TELECOMUNICAȚII ȘI TEHNOLOGIA INFORMAȚIEI

2017

Abstract

This work presents my scientific, academic and professional activity since 2005, when the Technical University of Cluj-Napoca conferred me the academic title of Doctor (Ph.D.) in the field of Electronics and Telecommunications Engineering. This habilitation thesis presents scientific and professional achievements accumulated between 2005-2017, after completing the thesis. My scientific achievements can be organized under some areas of interests, exposed in the "Scientific achievements" section.

The research conducted in this period was focused on the following areas:

- Analysis, modeling, simulation and design of electronic circuits and ECU (electronic control units) related to automotive industry, in terms of signal integrity, power integrity and functional safety according to the new ISO 26262 (released in 2011 and applicable from 2015 to all ECU);
- Analysis, modeling, simulation and implementation of DC-DC power converters (used in wide electronic applications related on the automotive and e-mobility) and DC-AC power converters;
- Analysis, modeling, simulation and implementation of BLDC motor control circuits;
- Renewable Energy and Smart City Integration.

As result of this research, have been published over 45 articles, of which 1 article in ISI magazine, ISI Proceedings articles 28 and 25 are indexed in international databases. There were also published five books in the recognized national publishing houses. In addition, it should be noted that I have participated in more than 10 research contracts, of which 5 of them are director or project manager. Of these 5 projects, two are international projects with companies well known like leaders in the automotive field (Continental) or in the delivery of equipment for induction heating systems (Miele).

This thesis reviews the contributions for analysis, modeling, simulation and design of electronic circuits of which we selected four directions.

D1. Analysis, modeling, simulation and design of electronic circuits and ECU (electronic control units) related to automotive industry.

This area is related with my doctoral research, where I present some practical solutions for improving the performances of power equipment, and mainly, of power sources from automotive. One can mention here a comprehensive analysis of the battery models (charging and discharging modes). The goal of this analysis was to study the possibilities of using these models for electrical behavior for the correct exploitation and further development, especially to build electric vehicles and hybrid vehicles. The

Research is completed with a comprehensive simulation of charging system including alternator and the battery for confirmation and validation of the theoretical models with experimental measurements. Still, considering the broad spectrum of the problem and the complexity of the domain, the solutions proposed represent just a small part of the multitude of possible approaches of this theme and a starting point for further developments of these solutions because the alternators with diode rectifiers and field control are widely used in the automotive industry.

The appearance of the ISO 26262 standard and application to safety-related systems that include one or more electrical and/or electronic (E/E) systems in series production passenger cars allowed me to join with Continental and starts the new direction in Hardware developing area related to automotive ECU design.

Based on the system design specification, the ECU design is developed from the hardware level perspective. The hardware development process is based on the concept of a V-model with the specification of the hardware requirements and the hardware design and implementation and correlation with software design, testing and integration at System level. I was involved in design of BCM (Body Control Module) for Nissan and Renault platforms where I performed the design of the important functions (ASIL B, ASIL C and ASIL D), up to 50 functions, like Low Beams, Automatic Cruise Control, ESCL (Electronic Steering Control Lock), Cruise Control, Assisted Parking Brake, Flashers, ESP/VDC, Automatic Cruise Control, Dorlock, etc.

The main results are published in 14 papers, 9 of them included in ISI database and 3 contracts with Continental.

D2. Analysis, mathematical modeling, simulation of DC-DC and DC-AC converters implementation

The main results from the investigations direction D2 are related in the DC-DC converters modeling. As modeling and simulation methodology in these converters, it was left to analyze time-converters operating description of the many each interval by differential equations, following the implementation of these equations in a simulation platform designed for each type of converter. The results are then verified and validated by simulating dedicated circuit simulators such as PSpice Orcad and Matlab / Simulink. It starts with analysis of the basic structure of dc-dc converters, following the introduction of these parasitic elements. The method that can be used with success for improving the performances of power equipment's of the automotive industry due the average electrical load in automobiles are continuously increasing for many years and higher power demands are being placed on automotive electric systems. Furthermore, the increasing of power demands motivates the producers to find solution for supply the transient

conditions or to recover the energy during braking periods.

The research is related also to modeling of DC-AC resonant converters, especially those used in induction heating systems. Modeling and simulation for these converters starts with analyze time-converters operating description of the many each interval by differential equations, following the implementation of these equations in a simulation platform designed for each type of converter. The results are then verified and validated by simulating dedicated circuit simulators such as PSpice Orcad and Matlab / Simulink.

The results are valued by publishing a total of 8 scientific papers indexed in Thomson Reuters ISI database.

D3. BLDC motor control

The main results from the investigations in the direction D3 are related to understanding, modeling and design of the the BLDC motor control circuits. The results are then verified and validated by simulating dedicated circuit simulators such as PSpice Orcad and Matlab / Simulink. The studies have allowed to develop a board to drive a sensorless BLDC motor, using the new BLDC control technique, in a basic and simple form, without the use of discrete, low-pass filtering hardware and off-chip comparators. This new control method is base on the single-chip 16-bit device-based solution, which does not require external hardware, only few resistors used to condition the BEMF signals to the operational voltage range of the ADC module. The algorithm described uses nonlinear digital filtering, based on a majority detection function to sense the back-EMF signals generated by a rotating BLDC motor.

In the direction D3 research where oriented also to the implementation of an energy recovery system based on BLDC motor deceleration, in order to be use in e-bike's propulsion systems. The energy, which should be lost during deceleration, is now recovered, stored and after is available in other applications. The energy recovery and reutilization leads to a considerable decrease in total energy consumption necessary for traction mode. At the same time combining with the super capacitors usage is protecting the life expectancy of the battery, which normally supplies the propulsion system of an electric motor.

The results are valued by publishing a number of 15 scientific papers, 8 of which are indexed in the database ISI Thomson Reuters and a Best Paper Award prize at CAS 2015 – International Semiconductor Conference.

The expertise in the field was materialized by a contract with MIELE TEHNICA, *Experimental development of a circuit for energy recovery of the Miele washing machines by using supercapacitors*. The main goal is to identify the parts responsible for efficiency, analyses the contributions and proposals to obtain a modern design in electronic circuits for obtaining the higher efficiency.

D4. Renewable Energy and Smart City Integration

The direction D4, was a topic of interest from the beginning of my academic career. The development of a wind project involves several phases, out of which the most important are: evaluation of the field, energy potential assessment, technical research, implementation of pilot project, financial audit and the implementation of the wind farm project. I was involved in two international contracts of wind measurement (2009 and 2010) based on a real case study, focusing on the use of advanced data acquisition, storage, transmission and processing technology for energy-related data. The main contribution resides in the optimisation of measurement techniques to comply with both the clients' requirements and the existing conditions at the specified location.

With the accumulation of the experience, I was involved in monitoring projects like Ecological Parm of Pianu and analyses of environmental and energy data in Smart City of Alba Iulia. Starting from reducing pollution in cities, energy consumption, as an average for households at a national level, and is considered a „health" indicator for the national economy. The usage of alternative energy solutions in personal homes for increasing the energy efficiency as alternative energy sources, integration with grid and smart management of utilities increase the life quality of inhabitants. My research conclude that these arguments need to be correlate with the raising public awareness on environmentally friendly behavior to reduce pollution in cities.

Some of the results obtained during this research direction arebased on collaboration to complete a doctoral thesis, "Contribuţii la sistemele de management al bateriilor" of Mr.dr.ing. Dorin CADAR and "Contribuţii privind utilizarea energiilor regenerabile în localităţi rurale" of Ms. dr. ing. Georgiana Iacob Corsiuc, both sustained at UT Cluj Napoca.

The results are valued by publishing a number of 8 papers, 6 of which are indexed in the database ISI Thomson Reuters.

In this habilitation thesis, I wanted to present a methodology for modeling and design of the electronic circuits, because the integration of software and electronics, today, like embedded system, for control the electronic power circuits in automotive, change the traditional way of electronic design and requires advanced knowledge about integration and functionality. A reconsideration is necessary in the future thesis because is important to inoculate for the new PhD students a rigorous approach to the problems. As a result, I did a survey of all personal achievements but I tried to point out ways in which, starting from simple to complicated, to analyze and modeling complex electronic circuits, highlighting not only their steady state behavior, but more importantly, the transient's behavior that may occur in such circuits.