"Talent is floating in the air..."

CEI UPM newsletter

CENTRO DE ELECTRÓNICA INDUSTRIAL

January-December 2015 nr. 10

"**Industrial Council at CEI**", a new instrument to connect students and industry, gets started. Industry needs talent. Every year over 400 extremely talented fresh students join the ETSII: the minimum entry score is 11.8/14, being the average of the top 100 higher than 13/14. If you multiply quantity by quality, you get a unique number. When you walk around the school, you are meeting face to face ultra-talented students. The atmosphere is unique if you sum the high number of national and international students who join Master and Doctoral Programs.

CEI invites these students to join the team, on research activities around industrial electronics, as a springboard to their own future. And this is the point where the "**Academic & Research Year round agreement**" comes into play. It is an open-ended agreement "**CEI-Industry partner**", in which education & research activities are defined in a yearly based format, coincident with the academic course (September-July). This implies that every year, on a continuous basis to implement a long term strategy, the industry partner and CEI researchers agree the "Year-round technical annex" for the next academic course. The menu is composed by 4 main dishes: a) scholarships for students at undergraduate, Master and Doctoral levels, co-adviced between industry engineers and CEI faculty; b) Seminars given by industry engineers, as a seed for future subjects at Master level; c) Seminars given by CEI researchers at the Industry site, and d) Pre-competitive research, either specific for a company or shared by a cluster of companies interested to develop knowledge around a topic of joint interest.

Benefit is clear: direct contact between students and industry engineers, through joint research activities, scholarships and seminars. Most important, implemented with a long term strategy (open-ended agreement) with yearly update of the specific research tasks and seminars. We foresee a fruitful way ahead.

We hope to discuss this personally, during **the ninth edition of our Annual Meeting to be held April 7th & 8th**. Do not forget to reserve the dates!!

Help me welcome **Javier Uceda** as new CEI Director for the period 2016-2019. It seems yesterday when we launched formally the Center in 2006, which has experienced a continuous growth and developed a strong Industrial Program. CEI is today an International reference in Industrial Electronics, with more than 80 members (52 active scholarships for students) and over 30 active R&D projects. His initiative and ideas will give CEI a brand new impulse to reach even further.

Numbers and indicators are just reflections of the real value at CEI, which is the lively lab. We invite you to join us, and breathe and feel the talent floating in the air...

The editorial board

Events at CEI

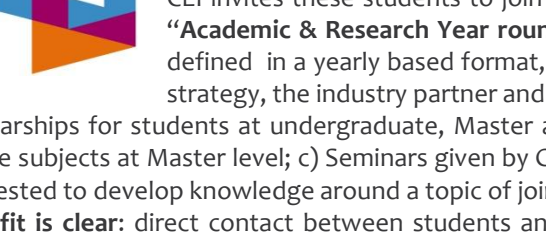
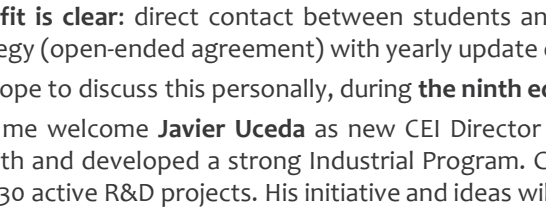
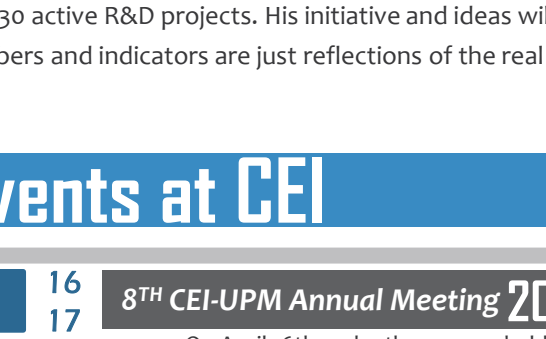
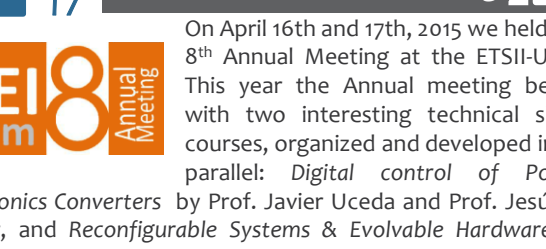
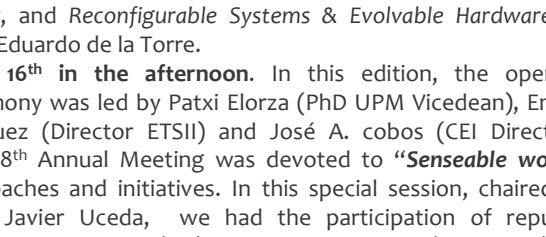
APRIL 16 17 — 8TH CEI-UPM Annual Meeting 2015

On April 16th and 17th, 2015 we held our 8th Annual Meeting at the ETSII-UPM. This year the Annual meeting began with two interesting technical short courses, organized and developed in parallel: *Digital control of Power Electronics Converters* by Prof. Javier Uceda and Prof. Jesús A. Oliver, and *Reconfigurable Systems & Evolvable Hardware* by Prof. Eduardo de la Torre.

April 16th in the afternoon. In this edition, the opening ceremony was led by Patxi Elorza (PhD UPM Vicedean), Emilio Mínguez (Director ETSII) and José A. cobos (CEI Director). The 8th Annual Meeting was devoted to "***Senseable world***" approaches and initiatives. In this special session, chaired by Prof. Javier Uceda, we had the participation of reputed panelist Pablo García (BQ) and Francisco jariego (Telefónica).

April 17th en the morning. Friday technical sessions were structured in two parts where CEI researchers, other University groups and industry representatives, presented their current relevant works.

Social event. Finally, the closing event of the 8th Annual Meeting was a relaxing cocktail. It was a very nice opportunity to share opinions and points of view with others while enjoying some snacks and appetizers. A very warm "see you next year" for all of us was the most wish heard!

PwrSoc — October 2016

International Workshop on Power Supply On Chip

The 5th edition of the International Workshop on Power Supply On Chip will be held at the Universidad Politécnica de Madrid, Spain, scheduled for **October 3-5, 2016.**

This conference is organized by the Centro de Electrónica Industrial (CEI-UPM).

PwrSoC 2016 is the leading international technical workshop dedicated to advancing important power conversion technologies. The workshop focuses on the integration of both modular and granular electronic power converters for multiple applications, by accessing a broad range of leading-edge technologies. Complete on-die integration and integration within package are of prime interest. System performance requirements presented by present day and emerging applications demand ever-greater current density, voltage regulation and optimized control, form factor reduction, high efficiency, and cost reduction.

More information at http://pwrsocevents.com/

Annual Meeting 2016

April 7th & 8th

Take note in your agenda!!

The 9th Annual Meeting of the CEI-UPM will take place in the ETSII-UPM on **April 7th and 8th, 2016.**

As in previous editions, the main objective is to present the activities at CEI and its partners. The Annual Meeting is an interesting networking space, a place to learn and to meet your colleagues and partners.

THURSDAY MORNING (April 7th)

We include in the program 2 short-courses

THURSDAY AFTERNOON (April 8th)

Opening session
Overview of CEI R&D activities
Strategic Research

Keynote

CEI Lab tour and POSTER SESSION

FRIDAY MORNING (April 8th)

Technical Sessions
CEI, University and Industry Sessions

Wrap-up Cocktail

More information at www.cei.upm.es

PhD Theses 2015

19/06/2015

A methodology to analyze, design and implement very fast and robust controls of Buck-type converters

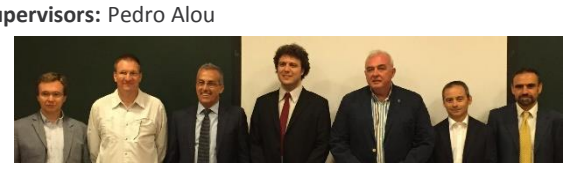
by **Jorge Cortés** **Supervisors:** Pedro Alou & Jesús A. Oliver

28/07/2015

Output Impedance Correction Circuit (OICC): A New Concept to Improve the Dynamic Response of DC/DC

by **Vladimir Šviković**

Supervisors: Pedro Alou



3/12/2015

Parametric and structural self-adaptation of embedded systems using evolvable hardware by **Rubén Salvador**

Supervisor: Eduardo de la Torre & Lukas Sekanina

16/12/2015

Run-Time dynamically adaptable fpga-based architecture for high-performance autonomous distributed systems

by **Juan Valverde** **Supervisors:** Jorge Portilla & Eduardo de la Torre

Master Theses 2015

Análisis, Diseño e implementación de un convertidor triple active bridge con conmutación suave en todo el rango de funcionamiento
Author: **Carlos A. Calderón**
Supervisor: P. Alou & A. Barrado

Developing point of care devices for in-vitro diagnosis
Author: **Mª Victoria Maigler**
Supervisors: T. Riesgo & M. Holgado

Diseño y Control de Convertidor de 2 y 3 niveles (ANPC DNPC) conectado a red mediate filtro LCL para aplicación eólica
Author: **Santiago Monteso**
Supervisor: P. Alou

Graduation ceremony of ETSII-UPM held on December 2015 where the graduates of the Master in Industrial Electronics received their diplomas: Uroš Borović, Julio Camarero, Javier Mora, David P. Daza, Antonio C. Rodríguez and Mónica Villaverde (left to right)

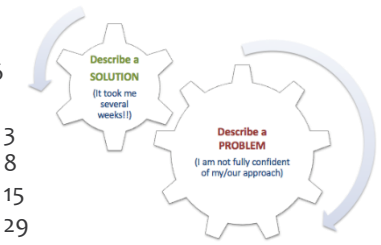
Friday Seminars 2015

JAN	12	*"Design and Development of a HW/SW-based Commissioning Toolset for Deploying, Debugging & Optimizing Wireless Sensor Networks"* by **G. Mujica**
	26	*"FPGA-based Architecture for High Performance Autonomous Systems with Limited Resources"* by **J. Valverde**
FEB	2	*"Hardware implementation of Artificial Neural Networks for WSN"* by **D. Aledo**
	16	*"Physical Model of a GaN HEMT with a Field Plate structure and general directions for design optimization in a High Frequency DC-DC converter"* by **D. Čučak**
	23	*"More CARE II: Three-Phase Buck Rectifier for More Electric Aircraft"* by **R. Ramos**
MARCH	2	*"Current progress on reconfigurable & evolvable hardware systems"* by **J. Mora**
APRIL	27	*"Superconducting Magnets Power Supplies for the European XFEL"* by **J.M. Fernández**
NOV	6	*"ARTICo3: Past, Present & Future"* by **A. Rodriguez**
	13	*"The 2D winding loss calculation method applied to coupled inductors"* by **F. Holguín**
	20	*"Analysis & Design of an Isolated Single-Stage Three-Phase Full-Bridge with Current Injection Path PFC Rectifier for Aircraft Application"* by **S. Zhao**
	27	*"Physical Model & Design Optimization of a GaN HEMT with a field-plate structure for a High Frequency Switching Application"* by **D. Čučak**
DEC	4	*"WSNs & IoT Technologies in the context of Smart Cities: PhD Research Stay"* by **G. Mujica**
	11	*"Automatic Surveillance and Monitoring System Using Lwir Cameras"* by **K. Bellazi**
	18	*"Hardware implementation of Artificial Neural Networks for WSN"* by **D. Aledo**

IDEAS Meetings 2016

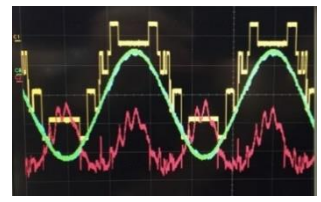
IDEAS: "Innovative Discussions on Experiences, Analysis and Solutions"

Sisi Zhao	Jan. 26
Marcelo Silva	Feb. 2
Dejana Cucak	Feb 9
Uros Borović	Feb. 16
Fermín Holguín	Feb 23
Regina Ramos	March 3
Yann Bouvier	March 8
Galo Guarderas	March 15
Airán Francés	March 29
Diego Serrano	April 4
José Mª Fernández	April 19
Branislav Stevanović	April 26
Vladan Lazaravić	May 3
Alejandro García	May 10
Guillermo Salinas	May 17
Antreas Naziris	May 24
Jesús Maañón	May 31



Little Box Challenge: what we learned at CEI, UPM

Our team "CEI at UPM", led by Prof. José A. Cobos, did not qualify as finalist for the testing phase at NREL, but we tried very challenging new concepts for the power stage and inductors, we found some technical problems (driving of paralleled GaN devices not reliable yet) and we measured very promising experimental results.

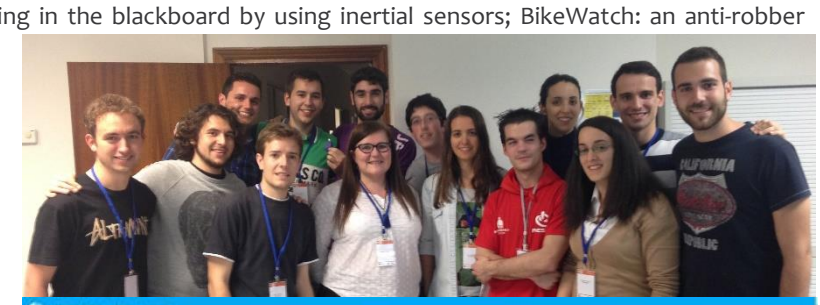


Our participation in the Google Little Box Challenge has been extremely exciting and productive, projecting a 2kVA inverter of **12.9 in3 (211 cm3)**, which is **less than 1/3** of the required volume to participate (40 in3). This means a power density of 156 W/in3 (9.5 kW/liter).
The inverter is not fully functional yet, but we hope to show soon the potential of **our inventions.** Find http://www.cei.upm.es/blog/2015/09/25/google/ its progress, including the **problems we faced** and **how we developed it.**
We made **two novel key contributions**, to be published soon**:**

- **Energy buffered converter**. A novel family of inverters has been proposed and validated. They use the same current to perform two functions simultaneously: energy transfer and energy storage. The internal power handled by the inverter is dramatically reduced. Smaller magnetic components and lower losses means smaller size of the inverter.
- **Thermally distributed inductor**. Magnetic components make most of the volume of converters, and/or are hot spots. By designing custom magnetics, we solved both issues. We achieved a better form factor and allowed an homogeneous thermal distribution, guaranteeing less than 60°C on the outer accessible surfaces of the box.

INGENIA at CEI-UPM

During the last years there have been a transformation on the way of teaching engineering subjects from a theoretical to a practical vision with aspects related with "learning by doing", "hands-on labs" and more recently CDIO (Conceive, Design, Implement, Operate). ETSII-UPM decided to include a key subject in the curriculum of the Master of Industrial Engineering based on this concept, and this is called INGENIA (it is a 12 ECTS subject that runs during the whole year, compulsory for all the students). Groups of professors propose their subjects and there are a collection of eight of them (course 2014/15) in a variety of topics, from Systems Engineering to Bioengineering, from factory design for beer brewers to electrical systems based on renewable energies.
Some professors of CEI-UPM proposed a subject whose main aim was that students conceived, designed, implemented and operated a system to improve our live in the School. We started with brinstorming sessions that were so funny and creative that we could have started fifty projects instead of five, that we finally decided to be done by the 16 students registered in the course. MapPi: A system to find your way in ETSII building, using your smart phone and a set of low-cost beacons distributed in the building; Spin: a bicycle to recharge to electronic devices in a sustainable and healthy way; ETSII-Pocket: a sensor-based system to book a place in the University library; SmartChalk: a system to record the professor writing in the blackboard by using inertial sensors; BikeWatch: an anti-robber system for your bicycle.
In this case, as in many things in life, we enjoyed very much the path to have the prototypes (design decisions, team work, nothing works, everything works fine...) as well as testing and showing the results. The students presented their work at the CEI-UPM Annual Meeting, they learnt how to do an "elevator pitch" to sell their products, they showed them at the Ingenia day at ETSII... And all the prototypes worked!
Many lessons learnt, many hours spent, many discussions in the teams for achieving a common goal.
If you want to see more, there is a summary video in YouTube at
https://www.youtube.com/watch?v=achuMLfruzc

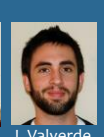


NEWS BRIEFS

OUTGOING VISITING researchers

- **Sisi Zhao,** doctoral student, stayed at Power Electronic Systems Laboratory in Swiss Federal Institute of Technology Zurich (ETH Zurich) since 16/05/2015 until 15/08/2015
- **Juan Valverde,** doctoral student, stayed at UTRC (Cork, Ireland), since 1/6/2015 until 30/11/2015
- **Gabriel Mujica,** doctoral student, stayed at Distributed Systems Group - Future Cities: Trinity Centre for Smart and Sustainable Cities, Trinity College Dublin (Ireland since 30/7/2015 until 30/10/2015.
- Filip Velković, doctoral student, stayed at European Space Agency (ESA)


S. Zhao


J. Valverde


G. Mujica


F. Veljković

INCOMING VISITING researchers

- **José Luiz de Freitas Vieira** professor at Universidade Federal do Espírito Santo (Vitória, Espírito Santo, Brasil) since 5/3/2014 until 25/2/2015.


J.L. Vieira

AWARDS


Jesús A. Oliver, Óscar García, Miroslav Vasić, Dejana Cucak, José A. Cobos & pedro Alou(left to right)

- **IETE-S K Mitra Memorial Award** for the Best Research Oriented Paper. November, 2015.D. Cucak, M. Vasic, O. Garcia, J. Oliver, P. Alou, J. A. Cobos, "*Filter Design methodology and Application of GaN HEMTs in High Frequency DC/DC Converter*" published in IETE Journal of Research


Miroslav Vasić (left)

- **Spanish Royal Academy of Engineering** award to **Miroslav Vasić**, November 2015. Every year the Royal Academy of Engineering awards the engineers younger than 40 years of age for their exceptional trajectory as researchers. One of this year's medals was awarded to the researcher from our research center.

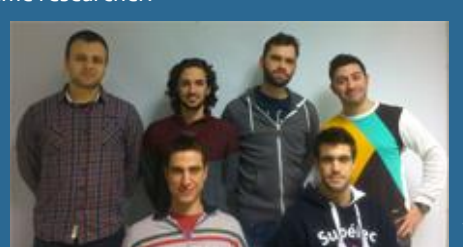

D. Díaz

- UPM PhD Award to thesis *High Efficiency Evelope Amplifier based on a Ripple Cancellation Buck Converter. Design, Optimization and Integration in an EER RFPA* by **Daniel Díaz,** December 2015

WELCOME...

- to new members who have joined CEI-UPM as full-time researcher and Master student during this period:
  - **Jesús Maañón, Irene Potti, Bruno Lansac, Alejandro García, Guillermo Salinas, Ramón Conejo,** from UPM (Spain) and **Gabriela Cabrera** from Universidad de La Laguna (Sta. Cruz de Tenerife, Spain)
  - **Antreas Naziris** from KU Leuven (Belgium) **, Leonardo Suriano** from Ecole Polytechnique de Paris (France), **Vladan Lazarević and Branislav Stevanović** from University of Belgrado (Serbia)
- And **César Castañares** as part-time researcher.

Gabriela Cabrera, Bruno Lansac & Irene Potti (left to right)


Vladan Lazarević, Guillermo Salinas, Antreas Naziris & Leonardo Suriano (row up. left to right) Branislav Stevanović & Jesús Maañón (row bottom, left to right)

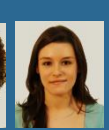
FAREWELL...

- to **David P. Daza, Fátima Hernández** and **Jorge Cortés** who joined at CRISA Airbus Defence & Space (Spain), **José Mª Molina** at SP Technologies (Spain), **Vladimir Šviković at Thales Alenia Space (Spain)**, **Juan Valverde** at UTRC (Cork, Irlanda).


J.M. Molina


D.P. Daza


V. Šviković


F. Hdez.


J. Cortés

- Big hugs and words of huge appreciation to our colleague and good friend **Alfonso Martín.** He has devoted 48 years of his life working in the lab. He helped in all possible ways, in teaching and research activities, and contributed significantly to students education and industry research. We wish him the best in his retirement, and look forward meeting him often and in every year traditional Christmas dinner .


A. Martín

current research projects

Integrated DC/DC Converters

- *PowerSwipe: POWER SoC With Integrated PassivEs* funded by ***European Comission Frame Program 7,*** 01/10/2012 to 30/9/2015

Industrial Applications

- *CAVE: Convertidores de Alta VElocidad de conmutación multinivel y multifase para aplicaciones espaciales* funded by **M° de Economía y Competitividad,** 1/1/2013 to 31/12/2016.
- ETHER: Transferencia de Energía Inalámbrica - Sistema Completo e Impacto en la Salud funded by **M° Economía y Competitividad,** 1/1/2014 to 31/12/2016
- PEM: Sistema de pila de combustible PEM de baja potencia en configuración híbrida con baterías para aplicación a un vehículo: sistema de control electrónico funded by **Española de pilas de hidrógeno,** 01/12/2014 to 30/11/2015
- *Little Box Challenge* funded by **Google,** 1/10/2014 to 31/7/2015

Modeling & Simulation of power architectures, circuits and components

- *PExprt-SMPS: PExprt and SMPS Library funded by* ***ANSYS,*** *1/5/2007 to 1/5/2017*
- Design of experiments based on Electromagnetic Simulation for the validation of magnetic omponent designs on given applications funded by **PREMO,** 1/11/2014 to 31/1/2015
- EVA-ANRI: Evaluación y modelado de arquitecturas de nano-redes inteligentes en corriente continua funded by **M° Economía y Competitividad,** 01/01/2014 to 31/12/2016

More Electric Aircraft

- *AIR: Active and Isolated Rectifier unit for more electric aircraft: Design and Manufacturing of a 10kW AC-DC Converter Unit* funded by ***European Comission (Program CleanSky),*** 1/10/2013 to 30/9/2015

Optimization of Power Architectures

- XFEL: *Fuentes de alimentación para los imanes superconductores del XFEL europeo* funded by **M° Ciencia e Innovación,** 1/12/2010 to 31/12/2015
- *MORE-CARE: Modelado y optimización del rectificador para la cadena de alimentación del radar electrónico* funded by **INDRA,** 1/1/2013 to 28/2/2015

Reconfigurable Embedded Systems

- *DREAMS: Dynamically Reconfigurable Embedded Platforms for Networked Context-Aware Multimedia Systems* funded by ***M° Ciencia e Innovación,*** *1/1/2012 to 30/6/2015*

Sensor Networks

- TECALUM: *Sistema de Iluminación Inteligente LUIX* funded by **INNPACTO. M° Ciencia e Innovación,** 1/11/2011 to 31/3/2015
- WSN DPCM: *WSN Development, Planning and Commissioning & Maintenance ToolSet* funded by **Artemis/MICyT,** 1/10/2011 to 31/3/2015

Telecommunications consulting

- *ECOLOG. Nueva solución de pesca integral, responsable y sostenible para la mejora de la productividad y el aprovechamiento en el sector pesquero* funded by **Satlink** and **M° de Economía y Competitividad**
- Investigación y desarrollo en tecnologías para la discriminación pesquera y el aprovechamiento sostenible del medio marino funded by **SATLINK,** 02/01/2014 to 31/12/2015
- Investigación y desarrollo en tecnologías para la observación de actividades de buques en tiempo real funded by **SATLINK,** 02/01/2014 to 31/12/2015

Wide Band-gap devices

- UE: *Advanced Wide band gap semiconductor devices for rational use of energy* funded by ia e Innovación, 1/11/2009 to 16/12/2015

Medical applications

- NANOHYPERTHERMIA: Development of new nanoparticles and protocols for enhanced hyperthermia. This project is scheduled for 2014-2015.

new research projects

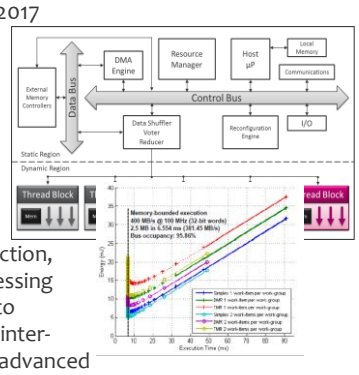
Development of a biosensor technology for environmental monitoring and disease prevention in aquaculture ensuring food safety (ENVIGUARD) funded by European Commission 7PM, 01/12/2013 to 30/11/2018

The objective of EnviGuard is to develop a highly specific and precise in-situ measurement device for man-made chemical contaminants and biohazards (i.e. microorganisms and toxins from biological sources) which are currently hard to measure. The device to be developed under the project would be used as an early warning system for the European aquaculture sector and as an environmental monitoring tool to assess the Good Environmental Status (GES) of the sea. CEI-UPM is in charge of developing the EnviGuard Port as an interface between sensors and web tool

Resilient EmBedded Electronic systems for Controlling Cities under Atypical situations (REBECCA), funded by Ministerio de Ciencia y Tecnología 1/1/2015 to 31/12/2017

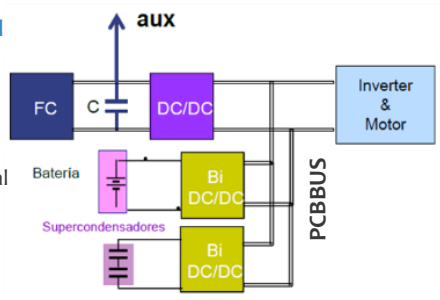
The REBECCA project is mainly devoted to meet the needs arisen by the "Economy and Digital Society" challenge. This project therefore provides alternative solutions to the problems underlying systems supporting multimedia-based (image) services for citizen security in the aforementioned scenarios. REBECCA proposes the design of a platform for sensing and distributed computing for visible and multi/hyper-spectral image processing.

This platform will provide adaptive tools and mechanisms for detection, recognition, and tracking tasks. To this end, nodes with local processing capabilities are deployed, able to adapt (reconfigure) themselves to different circumstances. These nodes are network-connected and inter-operate with each other in a transparent manner in order to offer advanced services for the Smart City.



Simulation and control of energy management of a fuel cell/supercapacitor/battery power source for electric bus (PCBUS) funded by Ministerio de Economía y Competitividad, 1/1/2015 to 31/12/2017

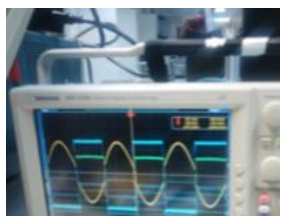
This project presents an energy management method in an electrical hybrid power source for electric bus. This electrical hybrid power source is composed of a fuel cell system as the main source and two energy storage sources, a bank of supercapacitors and a bank of batteries, as the auxiliary source.



Resonant Switched Capacitor converter funded by Huawei, 1/5/2015 to 30/4/2016

A DC-DC converter is developed for PV panels. Ultra-high power density and ultra-low losses are the key challenges of this high power (kW) converter.

The power architecture is a "Switched capacitor", including a resonant inductor to achieve soft transitions in the power switches and hence improve efficiency



Power supply design for the detection support electronics (DSE) de SENTINEL 5 / UVNS instrument , funded by THALES, 1/7/2015 to 31/12/2016

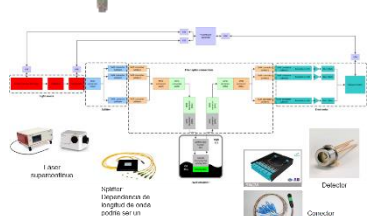
Objective: Design and prototyping of the power distribution system for the SENTINEL 5 / UVNS INSTRUMENT DETECTION SUPPORT ELECTRONICS Challenges: Design of high power density power supplies complying with space requirements.

Bootloader para núcleo ARM de Zynq (BootZ), funded by SP Control Technologies 01/09/2015 to 31/10/2015

In this Project, a bootloader for the ARM cores of the Xilinx Zynq device has been developed, to be able to load custom SW to the SP CARD allowing the addition of DSP functionalities, apart from the standard SP Control HW blocks for control of power converters.

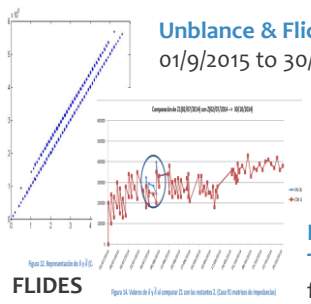
Real time monitoring of fluids properties with photonic and electromagnetic transducers (REMO), funded by REPSOL & INDRA (Inspire program), 1/9/2015 to 30/8/2018

Development of a system to measure physical and chemical properties of fluids at extreme conditions (temperature and pressure). In cooperation with CTB-UPM, ICMSE-CSIC and UC3M.



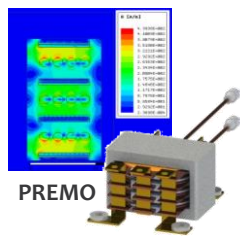
Unblance & Flicker in Transport network (FLIDES) funded by Red Eléctrica, 01/9/2015 to 30/4/2017

The project will allow to estimate power quality parameters (harmonics, unbalances) in the transmission network with a limited number of measurements. Also, detailed models of different loads will be developed, to improve the accuracy of the estimations.



Design of Experiments for Modeling of Transformers for Power Electronic Converters) funded by PREMO, 1/11/2014 to 31/1/2015

Objetive: Analyze the Electrical and thermal behaviour of a high frequency transformer to be applied in a 2,5kW DC-DC converter from 400V to 14V for Electric Vehicle and Plug-In Hybrid Electric Vehicles.

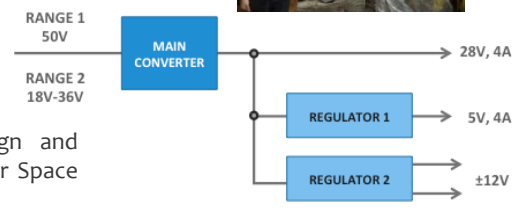


Digital control circuit design for high speed brushless de-excitation system (HSBDS), funded ALSTOM , 1/10/2015 to 30/6/2015

Based on the previous analog project, a new digital control alternative based on a micro controller is implemented to increase the performance and flexibility of the whole system. In addition, a low-power Bluetooth module is mounted in order to analyze the behavior of the system and have real-time information.

Some tests have been successfully done to validate the ew functionality and develop new control algorithms to improve he dynamic response.

Design, development test of a power distributed module for "Data Handling" , funded by THALES, 4/12/2015 to 03/05/2016

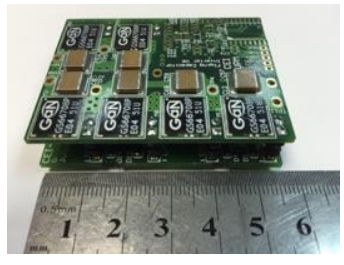


The main goal of this project is the design and development of a power distribution system for Space applications.

The system has several voltage and power levels. Different architectures are analyzed and compared and the converters are designed to meet the space regulations.

Little Box Challenge 2 funded by own resources

In this second stage of the project, we are solving the problems we encountered in our prototype for the "Little Box Challenge" competition, co-sponsored by Google and IEEE-PELS: Drivers of the advanced (High dv/dt) GaN transistors and Implementation of the sophisticated control strategy. Both problems have been solved, and we are now in the integration stage, where a very high power density is expected: 9.5kW/l in a 12.9 in3 box. Two innovations have been implemented Energy buffered converter and Thermally distributed inductor:



Boosting the Energy Efficiency in RF Power Amplifiers

by M. VASIĆ

Energy efficiency is the most important driver in the today's wireless industry. Due to complex signal modulations that are used, the transmitter signals have a varying envelope and the classical linear PA solutions suffer from very low efficiency (as low as only 30%). In the last decade techniques such as Envelope Tracking (ET) and Envelope Elimination and Restoration (EER) have emerged as the most interesting ones. These techniques have been known for decades, since the 60's, however, due to their complexity they could not gain on the importance until the fast development of high frequency semiconductor devices and digital control widely opened the gate for their implementation. Using these techniques it is possible to obtain a highly efficient and linear Radio Frequency Power Amplifiers (RFPA) cutting the system power losses for 30%-50% and reducing the temperature of the power amplifier by 20°C. In today's market there are 14 handsets with envelope tracking technology and some predictions assert that 8 billion ET solutions will ship over the next five years.

All these advances are possible thanks to a DC-DC converter called Envelope Amplifier that has to supply RF PAs with a voltage proportional to the signal's envelope. A good Envelope Amplifier presents a very complex engineering challenge because it has to simultaneously achieve extremely high bandwidth (>20 MHz), high efficiency (>80%), very low noise, and high peak output currents (>1A). Nevertheless, a good Envelope Amplifier is only the first step towards the complete RF transmitter because the problem of the RF signal predistortion and is the second big challenge for ET and EER. Digital predistortion is one of the most cost-effective and powerful linearization schemes available in the modern wire-less communications. Nowadays, the most popular approaches for digital predistortion are using look-up tables (1D and 2D) and using feedback path.

CEI has been working on the ideas related to ET and EER for the last ten years. We have implemented several solutions for the Envelope Amplifier and have implemented several complete RF transmitters and one of them even for a space application. Additionally, new technologies such as GaN HEMTs have been tested (in Envelope Amplifiers and RF PAs) and modeled in order to investigate the theoretical limits of ET and EER. Furthermore, we have shown clear benefits of Envelope Tracking even in the industrial applications such as ink-jet printing where it is possible to decrease the power losses up to 50%. All this gained experience enables CEI to be one of the important references on this topic.

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- J.G. Mayordomo, L.F. Beites, A. Carbonero, X. Yang, W. Xu, *An Analytical Procedure for Calculating Harmonics of Three-Phase Uncontrolled Rectifiers Under Nonideal Conditions,* ***IEEE Transactions on Power Delivery,*** January
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- A. Berger, M. Agostinelli, S. Vesti, J.A. Oliver, J.A.. Cobos, M.Huemer, *A Wireless Charging System Applying Phase-Shift and Amplitude Control to Maximize Efficiency and Extractable Power,* ***IEEE Transactions on Power Electronics,*** pp. 6338 - 6348, November
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- J. Cortés, V. Šviković, P. Alou, J.A. Oliver, J.A. Cobos, *v^1 concept: designing a voltage mode control as current mode with near time-optimal response for Buck-type converters,* ***IEEE Transactions on Power Electronics,*** pp. 5829 - 5841, October
- M. Villaverde, D. Pérez, F. Moreno, Self-Learning Embedded System for Object Identification in Intelligent Infrastructure Sensors, ***Sensors***, vol. 15, issue 11, pp. 27393-29764, November, 2015
- S. Zhao; J. M. Molina; M. Silva; J. A. Oliver; P. Alou; J. Torres; F. Arevalo; O. Garcia; J. A. Cobos, Design of Energy Control Method for Three-Phase Buck-Type Rectifier with Very Demanding Load Steps to Achieve Smooth Input Currents, **IEEE Transactions on Power Electronics**
- G. Mujica, J. Portilla, T. Riesgo, Performance evaluation of an AODV-based routing protocol implementation by using a novel in-field WSN diagnosis tool, **Microprocessors and Microsystems**
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- E. de la Torre, J. Portilla, T. Riesgo, *Letter from the guest editors of the special issue on DCIS 2014,* ***Journal on Microprocessors and Microsystems***, Volume 39, Issue 8, November 2015, Pages 919
- R. Cumplido, E. de la Torre, C. Peregrino-Uribe, M. Wirthlin, *Introduction to Special issue on Reconfigurable computing and FPGAs,* ***Journal Microprocessors & Microsystems,*** Volume 39 Issue 7, October 2015, Pages 541-542

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IEEE Applied Power Electronics Conference and Exposition

- F. Holguin, R. Asensi, R. Prieto, J.A. Cobos, *A simplified capacitive model for center-tapped multi-windings transformers*
- J. Cortés, V. Šviković, P. Alou, J.A. Oliver, J.A. Cobos, *Overview, equivalences and design guidelines of v1 concept: A voltage mode control that behaves as a current-mode with near time-optimal response*
- A. Berfer, M. Agostinelli, S. Vesti, J.A. Oliver, J.A. Cobos, M. Huemer, *Phase-shift and amplitude control for an active rectifier to maximize the efficiency and extracted power of a Wireless Power Transfer system*
- F. Holguin, R. Asensi, R. Prieto, J.A. Cobos, *Power losses calculations in windings of gapped magnetic components: The extended 2-D method*
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IEEE International Symposium on Circuits and Systems

- A. Rodríguez; Juan Valverde; César Castañares; Jorge Portilla; Eduardo de la Torre; Teresa Riesgo, *Live Demonstration: A Dynamically Adaptable Image Processing Application Running in an FPGA-Based WSN Platform*
- G. Mujica, A. Garcia, J. Gordillo, J. Portilla, T. Riesgo, "A novel on-site deployment, commissioning and debugging technique to assess and validate WSN based smart systems,

ReCoSoC — Bremen (Germany), June 2015

International Symposium on Reconfigurable Communication-centric Systems-on-Chip

- A. Rodríguez, J. Valverde, C. Castañares, J. Portilla, E. de la Torre, T. Riesgo, *Execution Modeling in Self-Aware FPGA-Based Architectures for Efficient Resource Management*
- J. Mora, A. Otero, E. de la Torre, T. Riesgo, *Fast and compact evolvable systolic arrays on dynamically reconfigurable FPGAs*
- *A. Rodríguez, J. Valverd, E. de la Torre, Design of OpenCL-Compatible Multithreaded Hardware Accelerators with Dynamic Support for Embedded FPGAs*

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- O. García, A. Bravo, N. Moreno-Arrones, A. Gutiérrez, P. Alou, J.A. Oliver, J.A. Cobos, J. Uceda, E. Aznar, R. Martínez-Máñez, C. Sánchez, O. Casanovas, J. Serrano, F. del Pozo, *Configurable power inverter for magnetic hyperthermia for cancer treatment purpose*

EUROMICRO — Funchal (Madeira, Portugal), July 2015

Euromicro Conference on Digital Systems Design

- M. Villaverde, D. Pérez, F. Moreno, *Adaptive-Reactive Cooperative System for Object Identification*
- D. Pérez, M. Villaverde, F. Moreno, *Towards an Adaptive Hardware Parallel Particle Filter*

ECCE — Montreal (Canada), November 2015

IEEE Energy Conversion Congress and Exposition

- S. Zhao, M. Silva, J. A. Oliver, P. Alou, O. García and J. A. Cobos, *Analysis and Design of an Isolated Single-Stage Three-Phase Full-Bridge with Current Injection Path PFC Rectifier for Aircraft Application*
- F. Holguín, R. Prieto, R. Asensi, J.A. Cobos, *Power losses calculations in windings of gapped magnetic components: The i2D method applied to flyback transformers*

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Conference on Design of Circuits and Integrated Systems

- G. Mujica, J. Portilla, T. Riesgo, *Testbed Architecture and Framework for Debugging Wireless Sensor Networks*
- W. He, M. Stottinger, V. Diaz, E. de la Torre, *A Self-Tuned Thermal Compensation System for Reducing Process Variation Influence in Side-Channel Attack Resistant Dual-Rail Logic*

Other

- J. Dragon, J. Hanson, L.F. Beites, M. Callavik, D. Eichhoff, A.K. Marten, D. Westermann, A. Morales, S. Sanz, F. Schettler, S. Wietzel, M. Zeller, R. Whitehouse, *Development of functional specifications for HVDC grid systems ,* ***The Institution of Engineering and Technology. AC and DC Power Transmission 2015,*** Birmingham (United Kingdom), February 2015
- F. Veljkovic, T. Riesgo, E. de la Torre, *Adaptive reconfigurable voting for enhanced reliability in medium-grained fault tolerant architectures,* ***NASA/ESA Conference on Adaptive Hardware and Systems (AHS),*** Montreal (Canada), June 2015
- J. Gordillo, G. Mujica, J. Portilla, T. Riesgo, *Novel Cluster-based Routing Protocol Optimization Approach for Wireless Sensor Mesh Networking,* ***Jornadas de computación empotrada,*** Córdoba (Spain), September 2015
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