European Activity for Smart Power Electronics and Power Discretes - The R3-PowerUP EU Project

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ABSTRACT

Smart power ICs are key enabling components for various applications from mid-power automotive, to industrial power applications, battery management systems electric vehicles and domotics in general like building automation for a home (smart home) involving the control and automation of lighting, heating, ventilation, air conditioning (HVAC), security. Home appliances such as washer/dryers, ovens or refrigerators/freezers remotely monitored and controlled via the Internet are an important constituent of the Internet of Things (IoT). This paper presents and research activity in the field of specialized power electronics IC development and technology availability. It also discusses technical availability of the design support and research needs on a sample development of one of the R3-PowerUp project demonstrators – the ESC controller for UAV. The R3-PowerUp (300mm Pilot Line for Smart Power and Power Discretes) ECSEL JU is a European project, which involve 35 Partners from 14 European countries. Project budget is 180MEuro and coordination belongs to STMicroelectronics [1], [2].

Keywords: *R3-PowerUp, Smart Power Electronics, ESC, UAV, Electronics Speed Controller, BCD.*

1. R3-POWERUP PROJECT

Power electronics serves over 30% of the industrial semiconductors business acting as a stable market with growth estimation up to 134Billion US$ as the global demand for system power electronics is expected to reach 2% of the compound annual growth rate (CAGR) until the year 2020. The 300mm FABs for Smart Power devices are located or announced only in Asia and in the USA at the moment. The R3-PowerUp project [1][2] aim is to setup the first 12” pilot FAB for 90nm and 110nm nodes in Europe for power electronics. The innovation in power device technology, by integrating in a 300mm line an advanced 90/110nm logic process, requiring advanced 193nm lithography, low voltage devices, embedded non-volatile memory, multiple Copper metal levels, with high power high voltage devices, requiring dedicated isolation structures. There are several goals of the project. One of them is to develop and demonstrate advanced manufacturing facility for 90/110nm nodes @12” wafers. It is dedicated for smart power applications where need for chip cost reduction becomes a must according the rapid increase of production volume predicted in close future. It is to be configured as multi-KET pilot line embarrassing nanoelectronics, nanotechnology, advanced manufacturing etc. The productivity and competitiveness improvement for Smart Power and power discrete IC technologies is expected to support and stimulate growth for a variety of applications, at least in the automotive, industrial, smart society, smart city, telemedicine and IoT domains. It is intended to integrate high-density logic, with non-volatile memories embedded on-chip, assisted by analogue front-end modules and smart power stages for the implementation of discretes and complex Systems-on-Chip devices. Results of the whole investment co-fund by the project along with multithread research activity will be assisted and proved to justify by set of dedicated demonstrators led by project partners. The aim is to validate the BCD9 (110nm process node) and BCD10 (90nm process node) technologies being developed by STMicroelectronics (STM). Several technical aspects like device parameters, mismatch, process stability, quality of EDA tools support, device models, IP blocks and many more will be validated in practice. The Instytut Technologii Elektronowej, Warsaw, Poland (ITE) [3] where the Authors are affiliated, stays as the research partner in cooperation with polish SME - Automatix (ATMX) [4] and other R3-PowerUp project partners. The ITE is responsible for development of a one among total number of seven technology demonstrators. The main activity and responsibility of the ITE is to develop a demonstrator based on the fully integrated electronic speed controller (ESC) applicable for brushless motors control dedicated for unmanned aircraft vehicles (UAV). The ITE is responsible for development (design, forwarding for processing in FAB by STM, setting up the system, firmware and development profiting from integrated ESC module as one of the final project demonstrators.

An innovation of the R3PowerUp in FAB equipment and materials used will be realized by adaption of the existing equipment for power devices to reach new levels of the reliability and control, compatible with 300mm substrates. Development of the new ALD equipment, a dedicated FAB control platform, and specific assembly solutions will be introduced into the practice.

The R3-PowerUP Pilot Line project for Discretes profits from the preceding, but still running under ECSEL call 2014 project R2Power300. The R2Power300 was a success whose scope was to set the reference of a feasibility study for the future 300mm Pilot Line, i.e. preliminary specification of the FAB equipment, EDA support evaluation and screening of the new process, process optimization and characterization steps and so forth to get the full useful development ecosystem

Within the scope of R3-PowerUP project new generation's PCM memory modules and MIM capacitors for some of the Final Application Demonstrators will be developed and made available for design. Further enhancement of BCD10 maximum voltage capability to 40V and 60V with high burst currents is attractive. The 300mm Pilot Line equipment's base will guarantee the future technology roadmap of the Smart Power logic features down to 65nm minimum gate length and beyond still valid

2. THE RESEARCH ON ESC FOR UAV

The polish cluster is formed by ITE and ATMX within the project will profit from cooperation with technology operator (STMicroelectronics) [5] and other project partners [1], [2]. Authors are involved in specification and development of the electronic speed controller (ESC) intended for application as smart power driver for brushless motor.

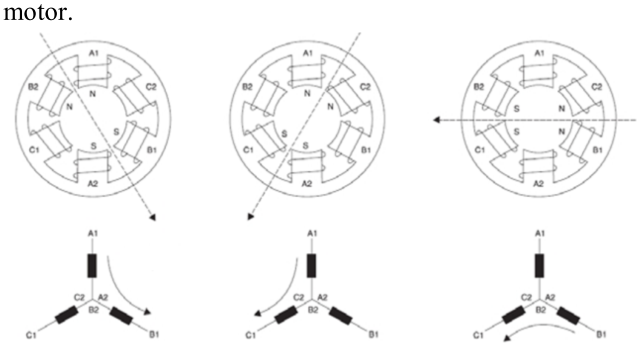

Fig. 1: The current switching sequence for brushless motor driver module.

Development of the dedicated mixed mode ASIC to assure synchronous drive control, external communication and intentionally data processing unit will be realized in frame of the R3-PowerUp project.

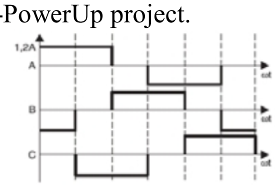

Fig. 2: Three phase driving signal to drive power module (Fig. 3)

Such solutions are useful for various vehicles - here unmanned aircraft (UAV) which becomes very popular with radio control aero-modeling. It is the power efficient solution, light and well controlled for burst vs. flight economy in opposite to traditional brushed motors and motor controllers.

The Principle of operation of the power module for brushless motors in UAV relies on specific current switching sequence imposed to the for brushless motor inductances driver module (Fig. 1). The tri-phase, switched AC power output of limited voltage from an onboard DC power input runs the motor. There is a three-phase analogue driving signal of square-wave/trapezoid or sinusoidal shape used for Brushless Direct Current Motor (BLDC) and Permanent Magnet Synchronous Motor (PMS) controllers respectively. Sample signals of the BLDC controller have been depicted on Fig.2.

The signal phase sequence affects direction of brushless motor rotation whereas the frequency of the signal frequency fixes the rotation speed. The set of the high-current power elements in the motor driver is controlled by 3-phase driving signal to control the BLDC motor. Brushless ESC controller systems basically create a tri-phase switched AC power output of limited voltage from an onboard DC power input, to run brushless motors. The motor rotation speed and direction are controlled by sending a sequence of AC signals generated from the ESC's circuitry, representing very low impedance for rotation. The sample implementation idea applicable for an ECS power module implementation is presented on Fig. 3.

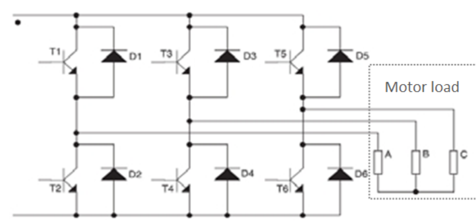

Fig. 3: Principle of operation of the power module for brushless motors in UAV: sample diagram of ECS power driver module.

Correct phase of the signal varies in time with the loaded motor rotation, so it has to be analyzed and controlled in a real time by the ESC data processing unit. The back electromotive force (EMF) from the motor is used to detect rotation and speed. Reversing the motor's direction may also be accomplished by switching any two of the three leads from the ESC to the motor. Reversing the motor's direction may also be accomplished by switching any two of the three leads from the ESC to the motor. ESCs are normally rated according to maximum current. Many modern ESCs support various types of battery with a range of input and cut-off voltages.

Technical specification of the desired BCD9 (110nm process node) technology by STM leads to several configurations of the ESC available. System partitioning is an essential part of the UAV ESC system specification. System partitioning will result from electrical (coupling, crosstalk, ESD) and thermal constrains. Authors experience on system partitioning [6] opens three general options for ECS setup.

The first option presented on Fig 4 consists of full integration of whole the ESC structure: microcontroller supporting some standard communication interface (USB, LIN, CAN, BT, RS485, RS232) is physically fabricated on the same chip as the power module is, using the same fabrication technology (here the BCD9 by STM). Such solution has some advances (size, reliability) but also has several technical drawbacks and is challenging due to signal crosstalk and parasitic noise from power module, thermal feedback, the risk for electrical death of the digital part from power module charge peaks. There are several strategies on how to handle with devastating electric shock: from advanced ESD protection to galvanic separation of power and digital parts. Galvanic separation is not always available as an option in IC fabrication process. Research on thermal challenges has been discussed by authors in [7]. There will be an attempt integrate liquid cooling features inspired by the CarrICool [8] EU project achievements.

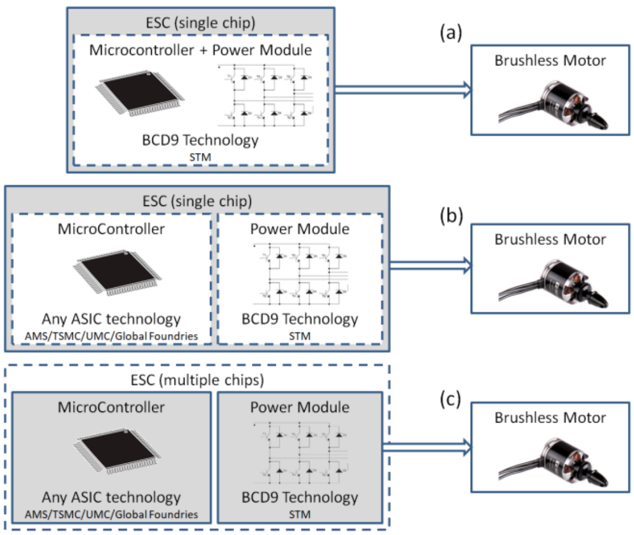

Fig. 4: Available ESC partitioning setups. a) single chip full integration, b) heterogeneous integration partial split, c) total split, two and more chips assembled on PCB.

The second option presented on Fig 4 consists of the single-chip heterogeneous integration where power module is fabricated as a standalone piece of silicon using smart power technology (here BCD9 by STM), microcontroller is fabricated in any other technology, but both modules are assembled into the single chip and bound in some plastics or ceramics. This solution does not solve the problem of electric separation of power module.

The third option presented on Fig 4 is the simplest one and the most popular nowadays. Dedicated power resistant execution module with power electronics is assembled on PDB with power dissipation support fitting operating conditions. Microcontroller module is assembled as standalone chip (IC) within low voltage part of the PCB with optoseparation protecting from power shocks. Eventual failure of the power part must not kill whole the circuitry as galvanic separation should be able to survive and protect the remaining part of the system.

Which option should be selected for particular application is an open question. On one hand, the accessibility of the service, low price of the power module, spare parts availability and applicability lead to the last option presented on Fig. 4. On the other hand, full integration is an attractive solution for all devices with technical requirement of limited weight, volume, high reliability and where price is not the dominating factor. Therefore for the R3-PowerUp project first two options are considered with preference on full integration in the single chip, single technology single device with low number of interconnects.

ESCs support various types of battery with a range of input and cut-off voltages. The UAV ESCs usually can use a faster update rate compared to the standard 50 Hz signal used in most other RC applications. PWM signals up to 400 Hz can be used in some cases, and other control options can increase this rate even higher. Also some software delays, such as low-pass filters, are removed in order to improve control latency.

Brief parameters of ESC under development for new 300mm Pilot Line in Europe for Smart Power and discrete power devices are:

- PWM/PPM driving signal from flight controller,
- PWM @400/600Hz
- 6S/8S battery pack (1S=4.2V)
- 3-Phase Motor
- Burst Current <5A for fully integrated version, and <100A for SiP version.

Modern ESCs contain a microcontroller interpreting the input signal and appropriately controlling the motor using a built-in program, or firmware. Factory built-in firmware update and change for an alternate, open source firmware is optionally implemented to tune the ESC to a particular application.

3. CONCLUSIONS

The R3-PowerUp project started in 2017. Project partners have concluded technical requirements specification for the technology being developed in frame of the project. Technical specification of the demonstrators has been defined. Along with the technology development, there is iterative process of the EDA tools support and development for IC and systems design. The R-3PowerUp project joins efforts of 35 technical partners from all the Europe from research, academia and industry. The ESC controller is the first attempt to achieve full, single technology integration to check and verify real technical capabilities of the BCD9 technology transferred to 300mm substrate wafers. Additional decision factor is the perspective of chip cost lowering, which can change the motivation and risk vs. profits of such ESC development strategy.

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