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A Novel Detection Method for mTBI
Always-On Context-Aware Processors

Background:

In order to implement a low power mode context-aware EEG device for mTBI detection, some sort of supervisor must be present in order to acquire and process the brain activity signal. Of course, a large-scale applications processor, or even some IoT wireless processor (for cloud computing) – will not suffice. They are designed for much more intensive processes, and as such, do not feature the low power needs of a battery-operated system. What, then, has the low power performance coupled with the processing power to conduct such a task? The answer is system-on-chip devices. These devices not only offer robust digital cores that can perform complex digital DSP, memory management, and more – but also commonly feature the analog peripherals needed to interface with raw sensors.

The Most Common SoC Devices

The most commonly available SoC devices are microcontrollers. Commonly, these devices are developed by a semiconductor company that licenses their digital core IP from ARM. Peripherals are developed in house by the semiconductor company. These devices typically feature common digital peripherals such as a multiple serial communication subsystems (configurable to handle SPI, I2C, UART, etc – in firmware), PWM, and more. It is becoming more common in modern controllers to include an ADC and DAC. It is important to note that microcontrollers in this context refer to those that feature real-time cores. In most cases, this means ARM Cortex-M series. Application processors, which are not as predictable, belong in another class – not applicable to this project. In the state-of-the-art, real-time microcontrollers are focused on becoming much faster. So fast, in fact, that they are beginning to rival lower-end application processors in speed. At the forefront of this market development, ST Microelectronics and NXP introduce application capable real-time microcontrollers. [1][2]. For this project, since we are seeking a high level of system integration, standard microcontrollers do not answer the design requirements. They lack integrated analog capability.

Field Programmable Analog Arrays (FPAA)

Field Programmable Analog Arrays answer the need of integrated analog capability, but often do not feature the digital DSP capability required by the project. FPAAs are a new technology, in terms of market share and availability. Developed to streamline board-level analog design, they offer a compelling delineation between board design and analog development. They create a market that mitigates the cost board re-spins. What if you could fix an analog mistake by just 'hitting compile'? FPAAs are the answer. While FPGAs exist to produce highly integrated digital systems (with specific timing requirements, streamlined algorithm processing, etc), FPAAs similarly lower the bar (in terms of cost) to

test and prototype analog systems.[3] While the opportunity becomes viable for rapid prototyping in the analog domain, if digital processing is desired, these devices must interfaced with a digital core to deal with a mixed-domain problem. In the case of this project, they provide a fruitful but perhaps limited solution the 'analog problem'. Tooling is in its infant stages, and the need for a separate digital core introduces power concerns (particularly when the state-of-the-art is implemented in the 100s of nm process, compares to <100nm for mass produced digital).[4]

Mixed-domain SoCs

Mixed-domain SoCs offer an excited solution to the low-power problem. In comparison to the above, they feature a digital core (like microcontrollers), but ALSO feature configurable FPAA-like peripherals. In market, commercial devices in this area are spearheaded by Cypress Semiconductor.[5] The state-of-the-art (in terms of market availability) exists in the Cypress PSoC product line. The PSoC series features a typical microcontroller ARM core with Cypress-designed configurable analog and digital blocks. The digital block includes typical serial interfaces while the analog block features op-amps, high resolution ADCs, MUXes, and more. Even more intriguing is the associated development tool associated. Cypress's 'PSoC Creator' allows the user to develop analog systems in schematic form. This abstraction carries across into the digital block, and even permits custom system 'blocks' defines in software that are coded in the ARM core.

This abstracted block diagram method to development streamlines the process and substantiates an easily understandable design process. For a team-oriented perspective, this method dominates over the raw code design presentation of classical microcontroller and the raw tooling of FPAAs.[6]

Conclusion: Pros and Cons of the current SoC State-of-the-Art

This project requires a highly integrated device in order to meet the performance needs of the sensor along with the low power needs of the system's use case. Classical microcontrollers tend to focus on performance over low power in the current market, and further do not contain in-package analog peripherals. FPAAs provide low power and a highly configurable analog development environment, but suffer from raw tooling and the need for an external digital processor. Mixed-domain SoCs tie in the best of both worlds. A robust, familiar digital core, with an integrated and highly configurable analog peripheral. With the high level of integration, the entire system can be designed in robust tooling, and sent into deep sleep mode where it will consume only nanoamps.

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Sources:

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[2] 2020. *I.MX RT1060 Processor Reference Manual*. [ebook] Eindhoven: NXP. Available at:

<https://www.nxp.com/webapp/Download?colCode=IMXRT1060RM> [Accessed 10 October 2020].

[3] J. Hasler, "Large-Scale Field-Programmable Analog Arrays," *Proceedings of the IEEE*, vol. 108, no.
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[4] S. George, S. Kim, S. Shah, J. Hasler, M. Collins, F. Adil, R. Wunderlich, S. Nease, and S.
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[5] E. H. Currie and D. Van Ess, *PSoC3/5 Reference Book*. San Jose, California: Cypress Semiconductor
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[6] "PSoC® Creator™ User Guide." Cypress Semiconductor, San Jose, 2020.

Note: The PSoC Reference Book was published in 2010, which is considered 'not current' by this paper's
guidelines. It is important to note, though, that this book provides very insightful background to
the market, and that Cypress Semiconductor is still the market lead. They released the PSoC 6
within the past year or so. This book is included as a 'current' source because it is still relevant
today, and that claim is confirmed in the more recent 2020 citation of the Cypress PSoC creator
user guide.