1802CF_tentative - ICFYKAF1

APPLICATION DETAILS

Project Title	Long-term implantable ambulatory EEG monitoring SOC	**Size X (mm)**	3
Design Name	ICFYKAF1	**Size Y (mm)**	3
Applicant	Al Freeman (afreema@yorku.ca)	**Grant X (mm)**	0
Supervisor	Hossein Kassiri (hossein@eecs.yorku.ca)	**Grant Y (mm)**	0
Co-supervisor		**Exact X (mm)**	0
Principal Designer	Al Freeman (afreema@yorku.ca)	**Exact Y (mm)**	0
Design Description	The Objective of this design is to enable long-term ambulatory EEG monitoring using an implantable SOC for neurological diagnosis and real time monitoring of EEG signals over an ultra-Low power wireless link. Conventional EEG monitoring systems have significant limitations for long-term monitoring application including unreliable electrode to skin connection (for extended period of time), being prone to motion artifacts and creating obstacles for patients in their daily activities/routines due to the size and wire connections. Long-term EEG monitoring enables diagnoses of infrequently occurring neurological symptoms as well as providing real-time and potentially lifesaving alerts to patients with disorders such as epilepsy. The proposed low-power, battery operated EEG monitoring SOC will be fully implantable and relies on wireless technologies for both data communication and power transfer, as the result any effect of motion artifacts or electrode connection unreliability is virtually eliminated, it also won't cause any limitations to patient's daily activities due to its compact size and elimination of all external parts. Fabricated prototypes will be validated in vivo in collaboration with neurosurgeons and neurologists at Toronto Western Hospital. This project involves the design, simulation and experimental characterization of a long-term implantable EEG monitoring SOC solution and subcomponents such as ultra-low power wireless comminutions and inductive power reception.	**Additional X (mm)**	0
Test Report Plan	The testing will complete in three stages: Front-end monitoring, complete system with wireless links and neurophysiological level. Front-end monitoring: Analog recording front end will be interfaced with a microcontroller to validate the quality of data, in addition to testing for Power dissipation, noise, SNR, THD, dynamic range, CMRR, PSRR, ENOB, INL and DNL, power dissipation to be measured. Tools: Tektronix mixed-signal oscilloscopes, SR785 spectrum analyzer, Keysight PNA-X, Keysight wideband real-time oscilloscope, Low-distortion waveform generator DS360. Complete system with wireless links: Front-end monitoring SOC will be assembled with wireless transceiver module and battery and will be tested for wireless data communication and power reception over inductive link. Neurophysiological: in-vitro and in-vivo test the EEG monitoring SOC.	**Additional Y (mm)**	0
Special Requirements			
Application Status	Saved	**Estimated University Cost based on area applied for**	$2700
Create Date			
Last Updated			
Submit Date	2018-06-11		

Section 1 - CONTRIBUTION TO MICROSYSTEMS RESEARCH

CONTRIBUTION TO MICROSYSTEMS RESEARCH

1a. Provide an overall goal of this research, a brief description of the project and the prototype for which the product/services are required. State clearly the novelty of the design and/or application.

The goal of this research is to design a long-term implantable EEG monitoring SOC that enables recording of infrequently occurring neurological symptoms which is essential for diagnosis of some neurological disorder as well as providing real-time feedback to patients with disorders such as epilepsy to alarm them ahead of their neurological system's disruption. Project description : this research involves design of a high quality, ultra-low power and low noise front-end analog recording circuitry and programmable digitization of the acquired signal to be send over a wireless communication link for further processing, this system will also include circuitry to charge and regulate the battery over an inductive wireless link as well as digital logic to control various modes of front-end signal acquisition, digitization and wireless data rate and power consumption. Prototype: This SOC is planned to include 4 to 8 programmable actively shielded channels to record EEG data from implanted electrodes. Front-end analog recording will include a chopper stabilized amplifier to minimize the infrared noise and maximize SNR, also 8 programmable 8bit analog-to-digital converter then convert the acquired signal into digital domain which is then fed to a serializer before transmission over UART port of the transceiver. A CMOS full-wave rectifier followed by a low pass filter recovers a DC voltage from the AC voltage on the receiving coil and a buit-in volatage regulator, regulates this voltage and holds it constant regardless of the load current. The voltage regulator produces a steady 3.7 V output and can supply upto 20 mA current to charge the 3.7 V rechargeable lithium-ion battery. Two additional regulators are required for the front-end recording and RF transceiver to provide noise isolation. Additional ASK receiver will be implemented to receive initiation/setup commands using the wireless power reception link. Area Justification: few factors contribute to the overall size requested, Due to implantable nature of this design it's essential to have it inductively powered since the SoC won't be accessible without invasive surgery, based on our calculations the coil to satisfy the power requirements will occupy 3x3 sq-mm. the coil will be implemented using the top metal layers to achieve highest possible quality factor and inductance, hence yielding highest possible power transfer efficiency. Additionally this chip will include 8 chopper stabilized differential amplifier, 8 programmable 8-bit Analog-to-Digital converters, a Parallel to Serial converter, ASK receiver, Voltage rectifier, 3 dedicated low-dropout voltage regulators along with logic control for modes of operation.

1b. Provide reference for papers (conference or journal), produced by members of your research team within the last three years, that are most relevant to this project (maximum 5 papers in total).

1. H. Kassiri, M. T. Salam, M. R. Pazhouhandeh, N. Soltani, J. L. Perez Velazquez, P. L. Carlen, R. Genov, "Rail-to-Rail-Input Dual-Radio 64-channel Closed-Loop Neurostimulator," IEEE Journal of Solid-State Circuits, Oct. 2017. (Invited, special issue on best biomedical papers of IEEE ISSCC'17 Conference)
2. H. Kassiri, S. Tonekaboni, M. T. Salam, N. Soltani, K. Abdelhalim, J. L. Perez Velazquez, R. Genov, "Closed-Loop Neurostimulators: A Survey and a Seizure-Predicting Design Example for Intractable Epilepsy Treatment," IEEE Transactions on Biomedical Circuits and Systems, Vol. 11, No. 5, pp. 1026-1040, Oct. 2017.
3. H. Kassiri, A. Bagheri, N. Soltani, K. Abdelhalim, H. Jafari, M. T. Salam, J. L. Perez Velazquez and R. Genov, "Battery-Less Tri-Band-Radio Neuro-Monitor and Responsive Neuro-Stimulator for Diagnostics and Treatment of Neurological Disorders," IEEE Journal of Solid-State Circuits, Vol. 51, No. 5, pp. 1274-1289, May 2016.
4. H. Kassiri, N. Soltani, M. T. Salam, J. L. P. Velazquez, R. Genov, "Battery-Less Modular Responsive Neurostimulator for Prediction and Abortion of Epileptic Seizures," IEEE Int. Symp. on Circuits and Systems (ISCAS'2016), Montreal, May 2016.
5. N. Soltani, H. Kassiri, H. Jafari, K. Abdelhalim, R. Genov, "130nm CMOS 230Mbps 21pJ/b UWB-IR Transmitter with 21.3% Efficiency," IEEE European Solid-State Circuits Conference (ESSCIRC'2015), 2015.

1c. Does this project involve Microsystems Research (ie. more than one technology component)?

Section 2 - CONTRIBUTION TO HIGHLY-QUALIFIED PERSONNEL

CONTRIBUTION TO HIGHLY-QUALIFIED PERSONNEL

Team Member	Position	Percentage Of Time	Organization	Email
Al Freeman	MSc Student	100	York University	afreema@yorku.ca
Hossein Kassiri	Assistant Professor	20	York University	hossein@eecs.yorku.ca
Mansour Taghadosi	PhD Student	50	York University	mtaghadosi@cse.yorku.ca

Section 3 - INDUSTRIAL RELEVANCE

INDUSTRIAL RELEVANCE

3a. Is this project part of a collaboration with industry or other external agencies? Yes

Organization	Contact	Industry Support Type	Description	% Total Project Budget
panaxium inc.	Aaron WEINROTH	Other	Panaxium is a medical equipment manufacturer with expertise and capabilities in manufacturing of long-term implantable electrodes for EEG signal recording.	0

Please provide details about your industrial collaboration experience :

Describe any other support (e.g. funding, facilities) available for this project:

Section 4 - ECONOMIC AND SOCIAL BENEFITS TO CANADA

ECONOMIC AND SOCIAL BENEFITS TO CANADA

4a. Indicate existing or potential commercial outcomes or other economic / social benefits to Canada (e.g. technology licenses, disclosures, patents or start-ups)

Fully implantable long-term EEG recording solution is ground breaking and it's not currently available in the market. The unique advantage of this SOC is enabling diagnosis of neurological disorders which are difficult to identify in short period of time and in Lab settings, it also enables real-time neurological feedback. The result of this research may improve quality of life for Canadians with neurological disorder and it has a significant potential for commercialization.

4b. List any contributions your team has made to the CMC-Supported University Microsystems Environment (National Design Network) and/or the organization of CMC

Prof. Kassiri and other members of our team have presented their work in CMC TEXPO and won Brian L. Barge Award for excellence in microsystem integration in

Microsystems in the last three years (e.g., designs, tools, services, tutuorials and application notes, participation on the CMC Technical Advisory Committee (TAC), etc.)

2012.

Section 5 - COLLABORATION

COLLABORATION

5a. Is this research part of an existing or potential collaboration with another department within your university? If yes, indicate department and Principal Designers involved.

5b. Is this research part of an existing or potential collaboration with a different university? If yes, indicate the university, department and Principal Designers involved

5c. Application End Use

End Application	Other
Health/Biomedical	

Section 6 - DEMONSTRATED NEED FOR RESOURCES

DEMONSTRATED NEED FOR RESOURCES

6a. Explain why fabrication in this chosen technology (e.g. explain why simulation or FPGA's, or fabrication in a less expensive technology, etc. is not sufficient)

Since this fully implantable wireless EEG monitoring system is planned to be implanted in an animal for in-vivo testing, it requires ultra-low power and is very sensitive to noise, it's also essential for this system to be very small and biocompatible. Furthermore it's not possible to implement the Analog front-end, RF receiver and power management blocks with a FPGAs
(since FPGAs are for generic applications) or discrete components (since they introduce parasitic and compromise integrity of data) so custom IC implementation is required to meet the performance and power requirements of this design. Finally 180 nm CMOS technology is the lowest cost technology supported by CMC that satisfies this design's power and speed and leakage requirements as well as desired specifications of RF block and minimum metal stack required to implement the Coil and inter-block connections.

6b. Does this project contribute to the postgraduate degree work of student(s)?

✔

6c. If yes, and if so how?

Al Freeman, a Master of applied science student will lead the circuit and layout design of this SOC and will be responsible for testing the fabricated chip as a part of his program.

Mansour Taghadosi , a PHD student will contribute to the design of inductive wireless charging circuitry.

6d. If this is required for Journal/Publication or Conference Paper, please indicate Publication & Target Submission Date.