1801CX-tentative - ICXYKTY1

APPLICATION DETAILS

Project Title	Wireless and batteryless implantable SoC for multi-channel optogenetic stimulation	**Size X (mm)**	3.5
Design Name	ICXYKTY1	**Size Y (mm)**	3.5
Applicant	Tayebeh Yousefi (tyousefi@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	Tayebeh Yousefi (tyousefi@yorku.ca)	**Exact Y (mm)**	0
Design Description	This project's main objective is to design a low-power wireless implantable microsystem to be used for multi-channel closed-loop optogenetic applications. Optogenetic is a relatively new method for brain electro-physiological activity modulation that has the potential to overcome the limitation of conventional electrical stimulation, in terms of spatial resolution and cell-type specificity, by utilizing light to conduct optical stimulation of genetically-modified brain cells. The major benefit of optogenetic stimulation is the unprecedented specificity it provides, allowing spatial, temporal, and cell-type selective modulation of neuronal circuits. Equipped with such tools, it will be possible to begin to address some of the fundamental unanswered questions in neurological disorders such as Alzheimer's and Parkinson's disease and epilepsy and to develop new options for patients that could not be treated using surgery or pharmacological solutions. Fabricated prototypes will be will be validated in vivo in collaboration with neurosurgeons and neurologists at York University. This project involves the design, simulation and experimental characterization of a multi-channel optical stimulation and electrical recording neural SoC that also hosts modules for temperature regulation, wireless data communication and inductive power reception.	**Additional X (mm)**	0
Test Report Plan	Three levels of testing: circuit-, system- and neurophysiological-level. Circuit: A PCB in conj. A FPGA to interface the DUT is used and a LED as the light source. 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. System level: Test the stimulation block generating different optical stimulation patterns with programmable frequency, duty cycle and light intensity. Neurophysiological: in-vitro and in-vivo test the optogenetic stimulator chip.	**Additional Y (mm)**	0
Special Requirements			
Application Status	Submitted	**Estimated University Cost based on area applied for**	$9187.5
Create Date			
Last Updated			
Submit Date	2018-01-10		

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.

GOAL: The main goal of this project is to design a wireless implantable microsystem that will be used for optical stimulation to offer therapy for a wide range of neurological disorders. PROJECT DESCRIPTION: This project involves the design, simulation and experimental characterization of implantable SoC capable of simultaneous optical stimulation and electrical recording. The chip is also equipped with a closed-loop temperature regulation system, as well as circuitry for wireless data transmission and power telemetry. It is envisioned to directly bond micro-scale commercial (e.g. Cree TR2227) or custom-made printable LEDs (in collaboration with Prof Gerd Grau, EECS, York University) to the top-level metal pads on the chip, making the device needless of optical fibers of any kind. This feature, along with full wireless connectivity (i.e. power and data) makes the proposed device a truly-implantable optogenetic stimulator. PROTOTYPE: The SoC is planned to include 9 channels, each capable of digitally-controlled optical stimulation and electro-physiological recording. A programmable current generation unit controls frequency, duty cycle, and light intensity of the optical stimulation in each channel. In addition, since the light source will be in direct contact with the brain tissue, the temperature increase is a major challenge to be addressed. In order to prevent tissue lesion, a

closed-loop real-time temperature regulation unit using a temperature-sensing channel and a digital signal processing unit will be implemented. An on-chip coil will be designed and utilized for both wireless data communication and power telemetry. The coil will be used to receive power through an inductive link operating at >300 MHz frequency, and will be re-used along with an OOK load-modulation backscattering transmitter for wireless data communication. A CMOS full-wave rectifier followed by a low pass filter recovers a DC voltage from the AC voltage on the receiving coil. A voltage regulator module regulates this voltage and holds it constant regardless of the load current. The voltage regulator produces a steady 3.3 V output and can supply up to 20 mA current. AREA JUSTIFICATION: Since the SoC is planned to be powered inductively, the chip area is determined by the minimum required area for the receiver coil. Our calculations, confirmed by reviewing the state of the art, shows that a minimum of 3.5 x 3.5 sq-mm is required to provide the required power for the described 10-channel microchip. The coil will be implemented using top metal layers to achieve highest possible quality factor and inductance, hence yielding highest possible power transfer efficiency. In addition to the coil, the chip area is mainly occupied by the recording/stimulation channels, followed by the on-chip DSP unit, power management circuits, and data transmitter.

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, F. D. Chen, B. Vatankhah, N. Soltani, M. Chang, P. Carlen, T. A. Valiante, R. Genov, “Implantable Arbitrary-Waveform Electro-Optical Stimulator with an Inductively-Powered Load-Adaptive High-Voltage Supply,” IEEE Biomedical Circuits and Systems Conference (BioCAS’2015), Atlanta, Oct. 2015.
2. H. Kassiri, M. T. Salam, M. Chang, F. Chen, B. Vatankhahghadim, N. Soltani, P. Carlen,T. A. Valiante, R. Genov, "Inductively Powered Arbitrary-Waveform Adaptive-SupplyElectro-Optical Neurostimulator," Under Review, IEEE Transactions on Neural Systems and Rehabilitation Engineering, 2016.
3. 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)
4. 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.
5. H. Kassiri, M. R. Pazhouhandeh, J. L. P. Velazquez, R. Genov, “All-Wireless 64-channel 0.013mm2/ch Closed-Loop Neurostimulator with Rail-to-Rail DC Offset Removal,” IEEE International Solid-State Circuits Conference (ISSCC’2017), Feb. 2017.

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
Tayebeh Yousefi	MSc Student	100	York University	tyousefi@yorku.ca
Hossein Kassiri	Assistant Professor	20	York University	hossein@eecs.yorku.ca
Mansour Taghadosi	PhD Student	50	York University	mansour_t68@yahoo.com

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
neuroscience program at St. Michael Hospital	Prof. Georg Zoidl	Other	Canada research chair in Molecular and Cellular Neuroscience at York University and St. Michael Hospital. Will provide the in-vitro and in-vivo testing models of our prototypes. Will ensure that the encapsulated design and specifications are safe for implantation.	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)

Main goal of this project is to design a low power wireless implantable microsystem to be used for optogenetic applications. The major benefit of optogenetic is the unprecedented specificity it provides, allowing spatial, temporal, and cell-type selective modulation of neuronal circuits. Equipped with such tools, it is now

possible to begin to address some of the fundamental unanswered questions in neurological disorders such as Alzheimer's and Parkinson's disease and epilepsy and to develop new options for patients that could not be treated using surgery or any other treatment methods.

4b. List any contributions your team has made to the CMC-Supported University Microsystems Environment (National Design Network) and/or the organization of CMC Microsystems in the last three years (e.g., designs, tools, services, tutuorials and application notes, participation on the CMC Technical Advisory Committee (TAC), etc.)

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 2012. Prof. Kassiri's work was also featured as a success story by CMC in November 2016.

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.

Department	Researcher
Other	Prof. Georg Zoidl
Engineering/ECE/EE	Prof. Gerd Grau

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 the wireless microsystem is planned to be implanted in an animal for in-vivo testing, it requires low power and low noise performance as well as being biocompatible and very small. Furthermore, it is not a good choice to implement the analog and RF blocks of this design with discrete components since it will result in large area and therefore not implantable device. If the device is not implantable in order to deliver the light to the desired area, it is necessary to use waveguides or fiber optics. Therefore, IC implementation is necessary in order to acquire a tetherless optical stimulation device. Finally, 130nm technology is the cheapest supported by CMC that satisfies power and speed requirements as well as desired specifications of the digital signal processing and RF blocks.

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

6c. If yes, and if so how?

A Master's student, Tayebeh Yousefi, a lead designer of the circuit design and layout and is responsible for testing of this chip. Another PhD student, Mansour Taghadosi, will assist in design and characterization of the microsystem. A PhD student of neuroscience will be assisting for in-vitro and in-vivo experiments.

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

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