# 1801CX-tentative - ICXYKAD1

## APPLICATION DETAILS

| | | | |
|---|---|---|---|
| **Project Title** | A 16-channel self-contained multi-modal implantable brain neural interface | **Size X (mm)** | 3.5 |
| **Design Name** | ICXYKAD1 | **Size Y (mm)** | 3.5 |
| **Applicant** | Alireza Dabbaghian (dalireza@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** | Alireza Dabbaghian (dalireza@yorku.ca) | **Exact Y (mm)** | 0 |
| **Design Description** | This project's main objective is design, simulation, and experimental characterization of a 16-channel wireless and battery-less implantable microsystem for multi-modal neural interfacing. The SoC will be used for simultaneous measurement and real-time analysis of neuro-chemical and neuro-electrical brain activity, as well as for responsive electrical stimulation of the brain. It will be used to study the root cause of brain functions and dysfunctions in a multi-modal fashion. This can be helpful for research studies on neurological disorders such as Alzheimer's disease and seizure detection and control for epilepsy. To analyze and predict/detect the onset of a neurological event, chemical and electrical data will be fed to an on-chip processing unit or sent to a computer using on-chip wireless transmitters. The system will be powered up using an on-chip receiver coil, which removes the need for a battery or an on-board receiver coil. The same on-chip coil will be used for data communication. | **Additional X (mm)** | 0 |
| **Test Report Plan** | Three levels of testing: circuit, system and neurophysiological level.<br>Circuit: A PCB in conj. with an FPGA to interface the DUT is used. Power dissipation, noise, SNR, THD, dynamic range, CMRR, PSRR, ENOB, INL and DNL, power dissipation to be measured.<br>Tools: Tektronix mixed signal oscilloscopes, SR785 spectrum analyzer, Keysight PNA-X, Keysight wideband real-time oscilloscope, Low-distortion waveform generator DS360.<br>System level: Test signal processing blocks responsible for determining the concentration of chemical analyte and detecting the seizure.<br>Neurophysiological: In vivo and in vitro test of electrical and chemical recording | **Additional Y (mm)** | 0 |
| **Special Requirements** | | | |
| **Application Status** | Saved | **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 an all-wireless and battery-less multi-modal implantable microsystem that will be used for real-time monitoring and analysis of brain electrical and chemical activities and their role in forming neurological event. This, along with subsequent neuro-stimulation that will be embedded in the SoC, will offer a viable alternative diagnostic and treatment solution to the patients with various brain disorders. PROJECT DISCRIPTION: This project involves design, development and experimental characterization of a 16-channel ultra-low-power small area/channel, low-noise CMOS neural recording and stimulation SoC with digital signal processing, on-chip wireless transceiver and inductively-coupled power transfer. The device will be used as a therapeutic tool for diagnosis and treatment of neurological disorders, as well as a research tool for comprehensive understanding of the process that underlies the brain functions and dysfunctions. Previously, team members of our group have successfully designed and characterized 2 generations of 64-channel wireless closed-loop neural recording/stimulation systems (ICGTRHK2 and ICGTRHK3) as well as a 12-channel neuro-chemical potassium-sensing microchip (ICGTRHK1) with the help of CMC. This project aims not only to integrate the capabilities of both systems onto a single chip, but also to further advance the chemical sensing feature by enabling sensitivity to a number of chemicals in addition to potassium ions. PROTOTYPE: The system-on-chip will include 8 neuro-electrical recording/stimulation channels, 6 neurochemical recording channels, and 2 channels for temperature and PH sensing. An on-chip coil will be designed and utilized for both wireless data communication and power telemetry. The coil will be employed 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 16-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, 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. (Invited, special issue on best papers of IEEE ISCAS’16 Conference)
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. M. ElAnsary, N. Soltani, H. Kassiri, R. Machadoa, S. Dufour, P. Carlen, M. Thompson, R. Genov, “50nW 5kHz-BW Opamp-less ?S Impedance Analyzer for Brain Neurochemistry Monitoring,” IEEE International Solid-State Circuits Conference (ISSCC’2018), Feb. 2018.
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 |
|---|---|---|---|---|
| Alireza Dabbaghian | MSc Student | 100 | York University | dalireza@yorku.ca |
| Mansour Taghadosi | PhD Student | 50 | York University | mansour_t68@yahoo.com |
| Hossein Kassiri | Assistant Professor | 20 | York University | hossein@eecs.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 |
|---|---|---|---|---|
| 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)**

This project’s main objective is design, simulation and experimental characterization of a low power wireless implantable microsystem to be used for neural recording. This can be helpful for research studies on neurological disorders such as Alzheimer's disease and seizure detection and control for epilepsy. Chemical and electrical data will be send to signal processing unit or to the computer by using on-chip wireless transmitters to analyze and reveal the relation between chemical and electrical reaction.

**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 |

**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 and battery less 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. FPGAs cannot satisfy these requirements due to the fact that they are designed for general purpose applications. Furthermore, it is not possible to implement the analog and RF blocks of this design with an FPGA and IC implementation is necessary for this part of our design. 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, Alireza Dabbaghian, 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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