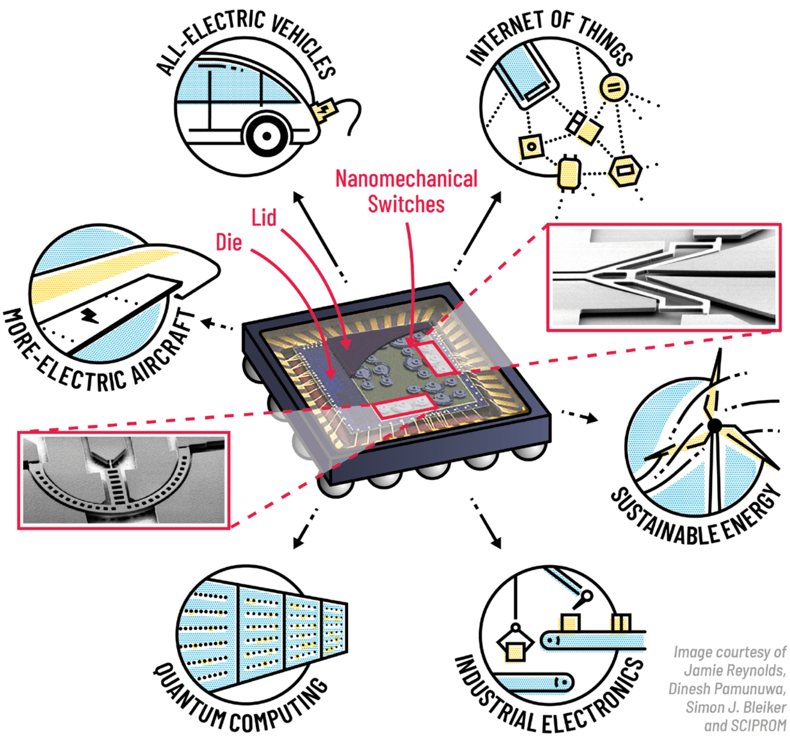
PUBLISHABLE SUMMARY II

July 2021 – December 2022

1. Summary of the context and overall objectives of the project

The ZeroAMP project aims to go “where no computing has been before”. Our NEM Switch technology also aims to do so at half the power consumption of conventional CMOS electronics, allowing it to function with a wide range of power sources. In the future, our technology may enable better baked cakes or allow satellites to get closer to the sun. We aim for it to benefit our European businesses and society by deriving lower energy usage, improving process outcomes whilst lowering their costs.

NEM Switch logic and memory is based on conventional MEMS wafer manufacturing processes used, for example, to produce motion sensors found in our mobile phones. Nano-Electro-Mechanical (NEM) Switches are tiny electrostatically operated relays, their contacts separated by a gap of around 1000th the size of a hair, less than a tenth of a micron. Relays can work at much higher temperatures and radiation levels than conventional transistors. They also work at lower power because their switch contacts snap shut abruptly and, as a results of their microscopic size, can be held shut by subatomic forces. They neither need power to stay shut or leak energy when open. Thus, NEM Switch technology has the potential to enable a new class of digital processors that meet the requirements of applications with very demanding constraints.



Markets targeted by ZeroAMP

NEM Switch technology is expected to allow data collection from, and control of, very harsh environments: temperatures to 325°C and high radiation levels of over 1 MRad absorbed dose. This capability should allow IoT and other devices to harvest information for the cloud from previously inaccessible areas or push the boundaries of existing technologies. It is expected to have applications in space, domestic and industrial ovens, nuclear power, radiation therapy and many further areas.

The main challenges in using NEM switches are related to reliability and large-scale integration of the switches. Innovative solutions in materials, fabrication processes and designs are being investigated in the ZeroAMP project to address these challenges. The overall objectives of the project are to develop a complete nanomechanical fabrication and integration platform with the flexibility to produce reliable and densely integrated reprogrammable processors and electronic memories for diverse applications. We will test the harsh-environment capability of the technology to operate at extreme temperatures and radiation levels and produce demonstrators to showcase its potential.

2. Work performed and main results achieved so far

In the first 36 months of the project, we have made significant technical progress on our switch hardware platform, including:

1. Developing three types of nanomechanical relays (switches) to serve as the building blocks for our circuits, comprising 3-terminal and 4-terminal relays for logic circuits and a 7-terminal relay for integrated non-volatile memory.
2. Demonstrating the important concept of body biasing in four-terminal relays where the voltage swing can be reduced to achieve improvements in energy efficiency.
3. Demonstrating key circuit concepts including multiple devices working in tandem where the output of one relay drives the input of another in a digital operation, efficient logic design using 4-terminal relays and a non-volatile memory cell with zero standby power made entirely of relays.
4. Successful bonding and post processing of wafers fabricated by X-FAB within their standard process, an important stepping stone to fabricating densely integrated nanomechanical circuits.
5. Demonstration of a packaged switch being actuated.

Further, we have made very good progress on developing design and simulation tools and a top-down design methodology, including:

1. A set of scripts to automatically generate the layout design for our three types of devices.
2. A method to carry out simulations and design verification for circuits made up of multiple devices.
3. A method to investigate suitable processor architectures and map a given software programme to it.

Finally, using these tools, we have developed the full designs for target prototypes identified through discussions with our Exploitation Council including a temperature logging token with on board memory and processing, a non-volatile memory chips and a field-programmable gate array (FPGA) type processor.

For additional information please visit our website at www.zeroamp.eu. In the “outcomes” tab, at https://www.zeroamp.eu/outcomes/, you will find details of a workshop we held to (i) disseminate our work to date, and (ii) interact further with our Exploitation Council and other relevant industrial stakeholders in order to discuss the project́s target markets, potential applications of the ZeroAMP technology in those markets as well as technological and commercial roadmap for this technology to enter those market areas. The list of our latest papers and presentations is also available on the “outcomes” webpage.

3. Progress beyond the state of the art, expected results and potential impacts

By the end of the project, we plan to produce electronic memory and processor chips built using nanomechanical technology. In achieving this goal, we expect to produce the first ever nanomechanical processor and memory prototypes as well as significant improvements over the current state-of-the-art in different aspects of the technology. These include a contact coating that can be used as an anti-stiction material in the wider field of micro and nanoelectromechanical systems (MEMS / NEMS), a heterogeneous integration approach that allows disparate technologies to be integrated in the same chip instead of multiple chips placed on a circuit board, efficient computing architectures that leverage the presence of logic, memory and sensors on the same chip, and sealing and packaging technologies to withstand very high temperatures.

We anticipate that the biggest impact of the ZeroAMP project will be in achieving a step change in the harsh-environment capability of electronics, and improvements in energy efficiency that transform the capability of processors for edge computing. Edge computing, where processing takes place at the edge of the network, often includes applications that exhibit long idle times, with low-throughput bursts of activity triggered by sensing events. Energy conservation is at a premium, as power sources are often batteries, or scavenged energy. This type of characteristic performance is ideal for nanomechanical processors as they have zero standby power, and memory can be placed next to logic on the same chip. This innovation significantly reduces the energy consumption while simultaneously improving performance in computing by drastically reducing off-chip memory accesses. Such “in-memory computing” has long been seen as a way of eliminating the memory communication bottleneck, a fundamental issue in computer architecture, but is technologically infeasible in traditional solid-state transistor manufacturing processes.

We have now received funding from the European Union, the Swiss State Secretariat for Education, Research and Innovation (SERI) and UK Research and Innovation (UKRI) to investigate edge computing applications in a new project called i-EDGE. In this project, we will build processors with integrated memory and sensing using the nanomechanical switch integration and design platform developed in ZeroAMP. Thus, the ZeroAMP project has potential to provide important societal benefits, such as advancing initiatives to reduce dependency on fossil fuels and unlocking the full power of the IoT.

Partners involved in ZeroAMP

Microchip Technology	Monmouthshire, UK
X-FAB MEMS Foundry GmbH	Erfurt, Germany
Gesellschaft für Angewandte Mikro- und Optoelektronik mbH	Aachen, Germany
University of Bristol	Bristol, UK
KTH Royal Institute of Technology	Stockholm, Sweden
Swiss Centre for Electronics and Microtechnology SA	Neuchâtel, Switzerland
SCIPROM Sàrl	Saint-Sulpice, Switzerland

www.zeroamp.eu

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