NEWS LETTER
on Superconducting Electronics

S-PULSE
Shrink-Path of Ultra-Low Power Superconducting Electronics
www.S-PULSE.eu

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EDITORIAL

Superconducting Electronics is a developing field with currently allows to build quantum limited detectors in a wide range of the electromagnetic spectrum, as well as more and more complex digital circuits that can operate at clock frequencies of several tens of GHz with a very low power consumption for a wide range of applications: telecommunications, super-computing or detectors readout. In this frame, the EUROFLUX 2009 conference, that takes place on 20-23 September 2009, will be an excellent opportunity to gather participants from research centers, universities and industries in the beautiful city of Avignon in France, place of Popes' palace. If you work in the field of superconducting detectors and/or electronics, cryogeny, come to present your last achievements. If you are rather in the field of optics, photonics or semiconductors (high-speed FPGAs, low consumption electronics, SiGe,...), come and see the current state-of-the-art in Superconducting Electronics systems and the associated challenges. There are opportunities to seize to integrate several complementary technologies for developing more complex systems. More information at www.euroflux.org.

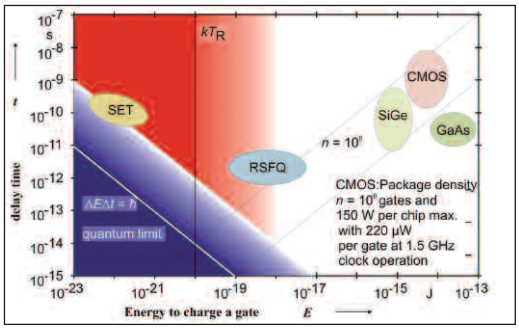
LOW POWER COMPUTING REQUIRES LOW OPERATION TEMPERATURE

by Dr. Thomas Ortlepp

University of Technology Ilmenau, Germany.

The very high integration density in semiconductor technology leads to an ultimate high power density. The power consumption of about 100 Watts on integrated circuits of typically 1 cm^2 causes serious problems leading to the necessity of large cooling fans. Today, this situation is limiting a further increase of the circuit density in CMOS technology [1]. Energy consumption per logic bit operation needs to be reduced as much as possible, to handle even higher integration densities. But the present switching energy of transistors in complex circuits with more than one billion transistors cannot be reduced any more, because a certain gap between the switching energy and the noise floor is required to avoid switching errors [2]. The only possibility is to reduce the operation temperature of the circuits, which will proportionally reduce the thermal noise. Lower operation temperatures offer a high potential to reduce the switching energy of semiconductor circuits by a factor of 10-100. The situation is even better for the material class of superconductors. The phenomenon of superconductivity is closely related to low temperatures. In the last 100 years, the research in low temperature physics was pushing the lowest temperature limit down to very low values of only a few millikelvins above the absolute zero point. The transition, where a normal conductor turns into a superconductor, takes place at the so called critical temperature. The research in material science had great success in finding new materials with higher and higher critical temperatures. There is a very popular hope, sometimes called the Holy Grail of Physics, to find a room temperature superconductor. Such a material will be for sure of great interest for some applications including magnetically levitated super-fast trains, efficient magnetic resonance imaging (MRI) systems, lossless power generators, transformers, and transmission lines, etc...

This situation is different in the field of electronics and highly integrated circuits. Devices are based on Josephson junctions with a very low switching energy and at the same time a very high speed. In the case of digital electronics, one can estimate that a superconducting circuit is about 10 times faster and consumes 10.000 times less energy than an equivalent CMOS circuit. The single bit switching energy of a Josephson junction is in the order of 10^{-18} Joule, which is about 10.000 times lower than state-of-the-art CMOS transistors. Such a low switching energy makes the junction also susceptible to thermal noise, but the typical operation temperature of liquid helium (4.2 Kelvins) provides enough margin to enable stable error-free operation [4]. A futher increase of the operation temperature, for example to 60 Kelvins, requires an increase of the switching energy, which makes them less attractive in comparison to CMOS technology. Especially in the case of high integration density, the increased power density will cause serious problems with proper cooling of the superconducting chip and leading to the same conflict mentioned at the beginning.



Gate delay time versus gate energy [3]. The thermal noise limit is indicated by the kTR line, where RSFQ is the fastest technology with the lowest switching energy.

The reduction of power consumption of any computational system requires a reduction of the operation temperature to values below the boiling point of liquid Nitrogen. This general trend offers a strong impact for superconductive electronics since this temperature can now be obtained with compact cryocoolers. Nevertheless, a hypothetical room temperature superconductor with nice metallic properties cannot improve the operation temperature of superconductive electronics to temperatures above about 77 Kelvins.

[1] L. B. Kish. End of Moore's law: thermal (noise) death of integration in micro and nano electronics. Physics Letters A, vol. 305, pp. 144, 2002.
[2] K. Natori and N. Sano. "Scaling limit of digital circuits due to thermal noise", Journal of Applied Physics, vol. 83, pp. 5019, 1998
[3] International Technology Roadmap for Semiconductors, http://public.itrs.net/
[4] P. Bunyk, K. Likharev, D. Zinoviev, "RSFQ technology: physics and devices," Int. Journal of High Speed Electronics and Systems vol. 1, pp. 257, 2001

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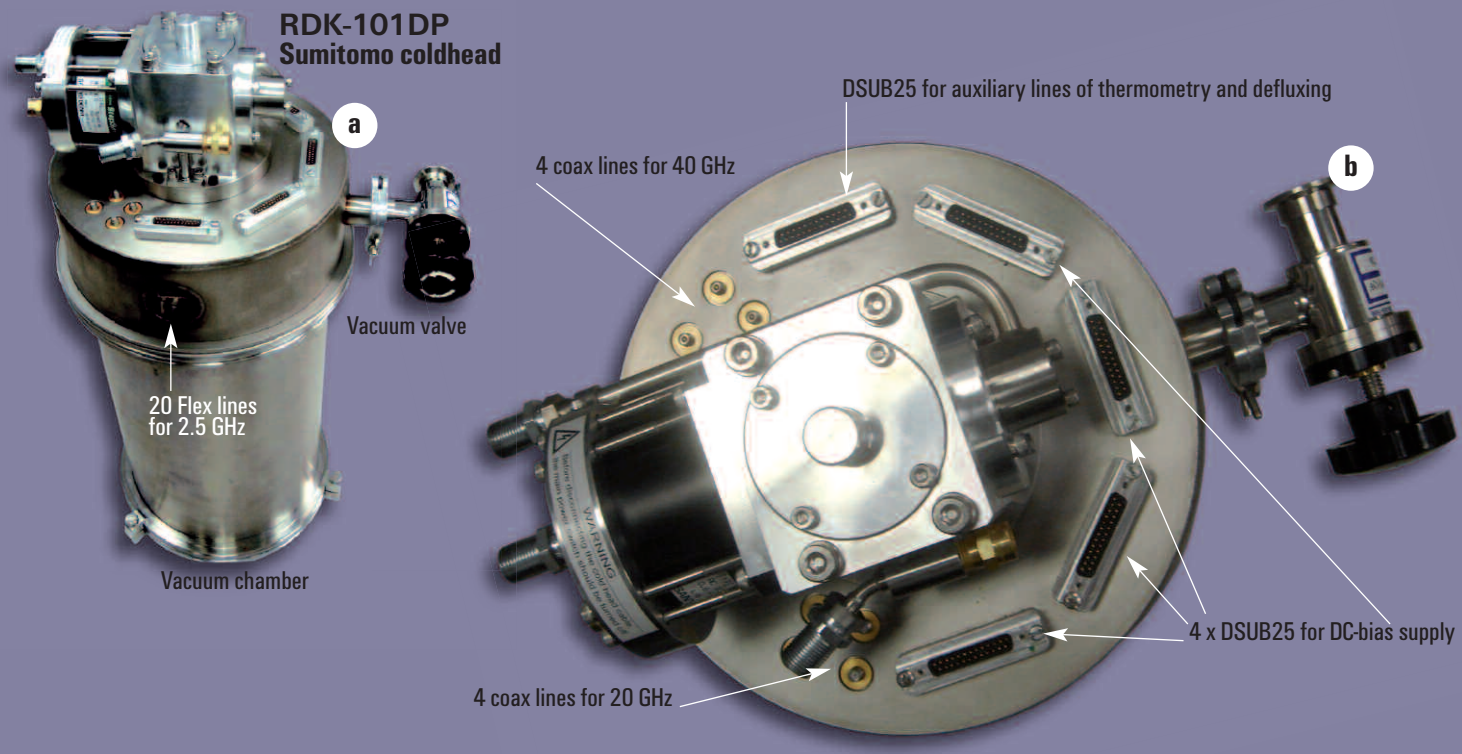


a *Overview of cryo-package mounted on RDK-101DP Sumitomo cold head.*
b *Top view with electrical vacuum feed through connectors for 5x25 DC channels, 2x20 flex lines (2.5 GHz), 4 coax lines (20 GHz) and 4 coax lines (40 GHz).*

Superconducting Technology Highlight

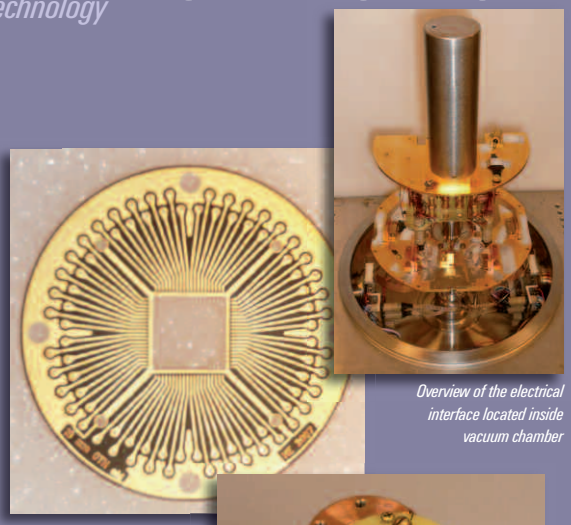
LHe free cryo-package for RSFQ circuits at Chalmers University of Technology

by Dr. Vadim Shirotov & Prof. Anna Herr
Chalmers University of Technology, Sweden

Chalmers University in collaboration with Hypres Inc. (USA) has developed cryocooler based testbench for Rapid Single-Flux-Quantum (RSFQ) circuits. The system is aimed for experimental verification and practical demonstration of RSFQ circuits with complexity up to 10000 Josephson junctions on 10x10 mm^2 chip. From the beginning it was designed to be general purpose and user friendly, that means flexibility for different circuit type and easy circuit mount.

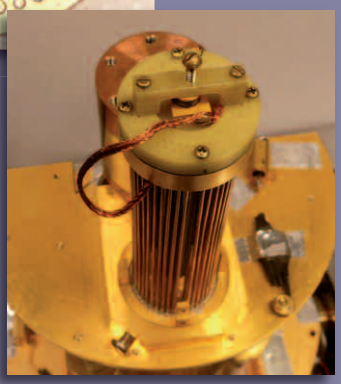
It is built on the base of a commercially available cryocooler: Sumitomo Model CNA-11C, cold head RDK-101DP with a helium damper, which reduces the temperature oscillations down to 30 mK. This cryocooler model has relatively low cooling power but nevertheless is applicable to be used with superconducting digital electronics circuits. The electrical interfaces of this system have the following specifications: 50 DC bias supply lines for a total current up to 2.5 A; 40 Input/Output lines for 2 Gbps data rate; 4 clock lines with 40 GHz bandwidth; 4 data lines with 20 GHz bandwidth; 4 output lines with LNAs for an asynchronous memory interface with 2 GHz bandwidth. The special design of a chip holder (see right figure) with multilayer Be-Cu pressure contact PCB provides the relative flexibility to match different types of circuits and, together with multi-layer mu-metal magnetic shields, guarantee a rather good protection of the RSFQ circuits from the external magnetic field with a damping by a factor higher than 1000.

With the whole electrical interface assembled, but without any electrical signals applied, the cooling down time is about 8 hours with a cooling power of about 100 mW for the 4 K stage and of about 3 W for the 50 K stage. An additional sample holder for 20x20 mm^2 Multi Chip Module with 112 electrical signal lines is under development.



Overview of the electrical interface located inside vacuum chamber

Multilayer Be-Cu pressure contact PCB



10x10 mm2 chip holder with 80 signal lines

Past Events

by Dr. Pascal Febvre
University of Savoie, France

WORKSHOP ON EXPERIMENTAL ASPECTS OF SUPERCONDUCTING ELECTRONICS

April 6-8, 2009 - Chambéry, France

> Following the fifth RSFQ design workshop that took place at the University of Technology of Ilmenau (Germany) in July 2008 and the first S-PULSE technology training workshop located at the Institute of PHotonic Technology (IPHT, Jena, Germany) in September 2008, the first workshop dealing with experimental considerations associated to Superconducting Electronics has taken place in Chambéry (Savoie, France) from April 6 to April 8, 2009.

> This workshop, supported by the S-PULSE project of the 7th Framework Programme of the European Commission, by the Division of European and International Affairs and the "Bonus Qualité Recherche (BQR)" programme of the University of Savoie, has gathered 26 participants from 6 countries: England, France, Germany, Japan, South Africa and Sweden. Besides, one participant from Sweden contributed to an oral talk through a teleconference.

1. Technological characterizations for foundries

This session was dedicated to the presentation of an overview of the fabrication techniques of the European Superconducting Electronics Foundry (Fluxonics Foundry) and of the extraction of parameters for the design of Superconducting Electronics circuits. Some automatic method of testing of the superconducting circuits under the influence of magnetic fields has also been presented.

2. Characterization of detectors & qu-bits

This part dealt with experiments and studies connected to the development of quantum limited detectors: resonators for readout and detector applications, characterization of Superconducting Single Photon Detectors (SSPD) for quantum cryptography, use of superconducting & semiconducting oxides for terahertz imaging, readout system for flux qubits at 10 mK and development of long Josephson junctions for investigation of kappa-fluxons.

3.Interfaces & cryogeny

This long session was dedicated to the main issues connected to the interfaces between cryogenic Superconducting Electronics circuits and the external room-temperature world. The focus was put on the case of digital circuits.

Dr Hideo Suzuki from the International Superconductivity Technology Center - Superconductivity Research Laboratory (ISTEC-SRL) in Japan presented the progress of the interface circuit and cryopackaging technologies for Rapid Single-Flux-Quantum (RSFQ) circuits in Japan. The results of the investigations of several types of Superconducting Electronics output driver circuits were emphasized, as well as the optical input technology using photodiodes operating at 5 K, and cryocooled systems based on cryocoolers, cryoprobes, microwave MCM technology and HTc samplers.

A presentation of free maintenance pulse tube cooler for cooling around 8 K developed at the Division of Low Temperatures of CEA-Grenoble has also been presented, as well as the mounting of Superconducting Electronics integrated circuits for operation in cryocoolers, developed at Stellenbosch University in South Africa. The experimental system under development at Chalmers University of Technology in Sweden to measure RSFQ circuits has been presented via teleconference.

Experimental analysis of a digital high-speed output driver for RSFQ circuits, microwave antennas used to transmit signals from a cryogenic system and the measurements of a digital SQUID system to detect the magnetic signature of Earthquakes are the other topics that have been presented.

4. Interfaces with design softwares and discussion

During the last day of the workshop took place a live demonstration of the Superconducting Electronics digital and analogue circuit design and layout software, NioCAD, developed in South Africa. It was the opportunity to discuss the other needs connected to the design of Superconducting Electronics circuits, comprising in particular the use of design softwares to interact with data acquisition softwares to compare experimental with simulation results. Also, the future combination of more evolved analog circuits combined with digital ones will require design tools that are not currently available, and whose development is really needed.

Group picture of the first Savoie workshop, April 6-8, 2009, Chambéry, France

Finally a discussion on future prospects for digital & microwave interfaces took place before closing of the workshop. An important topic was connected to the issues associated with the magnetic shielding of Superconducting Electronics circuits. Digital circuits, that carry the digital information through quanta of magnetic flux, need a careful shielding. So far, though proper operation of complex circuits is established in the laboratory, some studies are still needed to find ways to make them robust enough to operate in any environment in a reliable way, even in presence of strong external perturbations.

The second point that has been raised is linked to the studies that are still needed in order to find a efficient way to transmit the output signals to room-temperature processing units without comprising too much the thermal budget of the cryocooler system. Though optical and microwave solutions can be used, there are still some issues remaining associated to the development of very complex systems that require many signal output lines and proper interfacing with semiconductor systems, like FPGAs.

At last a complete Superconducting Electronics demonstrator including all the modules that are necessary so it can be directly interfaced with on-the-shelf commercially available equipment would clearly be a positive step in order to convince private companies to take over the development of Superconducting Electronics for specific applications, like in the telecommunication sector.

The 2009 Savoie workshop gathered 26 participants from 6 countries:

> 2 from England (University of Birmingham)

> 14 from France (University of Savoie (4), Université Joseph Fourier Grenoble (1), CEA Grenoble (3), SUPELEC (1), THALES TRT (2), THALES ALENIA SPACE (1))

> 6 from Germany (University of Karlsruhe (2), University of Ilmenau (1) and Institute of Photonic Technology (3));

> 1 from Japan (ISTEC-SRL)

> 2 from South Africa (University of Stellenbosch)

> 1 from Sweden (Chalmers University of Technology) + 1 via teleconference

Upcoming events

>> **EUROFLUX2009 – Avignon, France.**
The second EUROFLUX conference, following the first edition that took place in Naples in September 2008, will take place in 2009 from September 20 to September 23, in the beautiful city of Avignon in France. The conference aim is to disseminate the knowledge to interested industry and research laboratories in the three principal sub-domains: digital electronics, superconducting sensors and microwave devices and systems. Topics are: LTS and HTS junctions, SQUIDs and SQUIDs applications (magnetometry), Radiation Detectors, Digital circuits and applications, Microwave devices (filters, SQUID amplifiers...), Metrology devices... Abstract submission and early registration are open. Abstract submission deadline is June 1st, 2009. More information is available on the conference website: *www.euroflux.org*

>> **ISEC 2009 and Superconducting SFQ VLSI Workshop - Fukuoka, Japan**
The International Superconducting Electronics Conference (ISEC 2009) will be held in Fukuoka, Japan during June 15-19, 2009, along with the Superconducting SFQ VLSI Workshop. To know more or register, go to *www.isec09.org*.

>> **EUCAS 2009 - Dresden, Germany**
The European Conference on Applied Superconductivity (EUCAS) will be held in Dresden in Germany from September 13 to September 17, 2009. Early registration deadline is July 1st, 2009. More information is available at *www.eucas2009.eu*

>> **CRYOGENICS CONFERENCE Tucson, USA**
The Cryogenic Engineering Conference and the International Cryogenic Materials Conference (CEC/ICMC) will be held in Tucson, Arizona from June 28 to July 2nd, 2009. More information available at *www.cec-icmc.org*.

>> **ASC2010, Washington DC, USA**
The next edition of the Applied Superconductivity Conference (ASC 2010) will be held in Washington DC, USA in August 1-6, 2010. More information available at *www.ascinc.org*.

>> **Second Microcooling Workshop Twente, The Netherlands**
The second Twente Microcooling Workshop will be organized on May 14-15, 2009 at the University of Twente, Enschede, NL. The objective of that workshop will be to discuss progress made with respect to the targets mentioned during the first workshop that took place in April 2008. More information is available on S-PULSE website *www.s-pulse.eu.*

>> **Workshop "Applied Superconducting Electronics in metrology" Braunschweig, Germany**
The first S-PULSE workshop about metrology will be held at PTB (Physikalisch-Technische Bundesanstalt) in Braunschweig in Germany on May 5-7, 2009. This workshop deals with all aspects of metrology related to the use of Superconducting Electronics. More information is available on S PULSE website *www.s-pulse.eu.*

>> **6th Fluxonics design workshop Ilmenau, Germany**
The 6th edition of the Fluxonics RSFQ design workshop will be held in Ilmenau, Germany, on July 27-29, 2009. More information available at *www.s-pulse.eu*.

>> **SEFIRA days - Fréjus, France**
The sixth edition of the French Superconducting days (SEFIRA days) related to Superconducting Electronics and Physics of Superconductors will be held in the city of Fréjus on the french Riviera from May 26th to May 28th, 2009. If you want to attend, present an oral talk or a poster, you can register directly from SEFIRA website *www.sefira.org.*

Announcements

Contributions to this newsletter

If you wish to write an article, mention an event or make an announcement about Superconducting Electronics in this Newsletter, please send the content in text or word format with separate files for pictures (with high resolution: 300 dpi minimum) at the following e-mail address, two months before publication: Pascal.Febvre@univ-savoie.fr

Next publications are planned for September 2009, January 2010 and June 2010.

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