A digital NMR spectrometer
Dedicated to Hyperpolarized $^{129,131}Xe$ operating in the mT field regime

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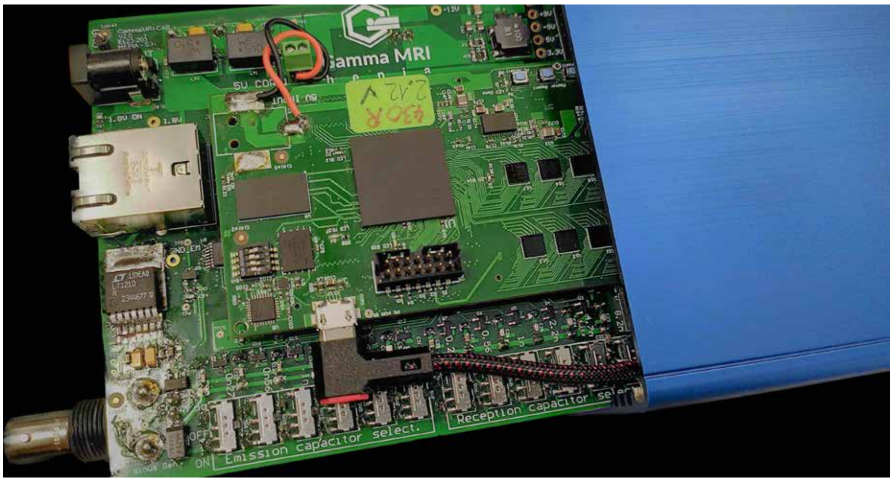


View of the designed PCB

Brief description

We have developed an ultrasensitive digital NMR sprectrometer, including the RF coils, the electronic board and the user interface software. The purpose is to generate a magnetic field during the excitation phase and subsequently to capture the emitted RF signals during their relaxation.

Since the electrical signal to be measured is characterized by exceedingly low amplitudes, the primary challenge encountered is the separation of acquired NMR signals from the background electrical noise.

Key points

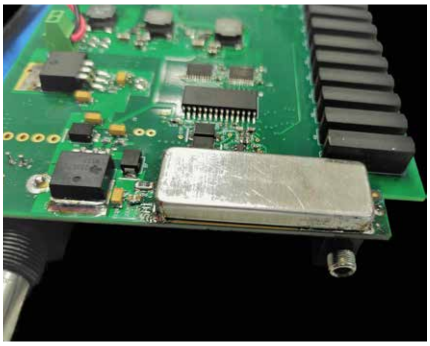
The electronics board assumes the pivotal role of generating an oscillating magnetic field in the order of mT, for disturbing the achieved polarization, acquiring the NMR analog signal from the reception coil during relaxation of nuclear spins to the initial polarization axes, digitizing these signals through an ADC, storing the digitized data and subsequently transmitting them to a PC for visualization, post-acquisition processing and analysis.

As part of the European Gamma-MRI project, our aim was to develop a nuclear magnetic resonance (NMR) system that would generate a magnetic field during the excitation phase of the polarised set of nuclei and then capture the RF signals emitted during their relaxation. At the heart of this system is a digital electronic board with essential components such as an FPGA circuit, a microcontroller and an integrated memory, equipped with Ethernet and USB connectivity to facilitate online data acquisition and visualisation via a connected PC.

The goals of this work are directed towards the advancement of electronics, encompassing both the hardware components and the creation of a user interface. These efforts are specifically aimed at enabling the detection of NMR signals emanating from ^{1}H, ^{129}Xe and any other isotopes in the same range of Larmor frequencies, particularly in the challenging context of very low static magnetic fields.

The NMR signal reception represents the most critical aspect of the system, demanding meticulous attention in selecting components, filtering the power supply and routing the PCB to ensure that electronic noise is minimized. The main challenge lies in the very low amplitude of the signal, which is only a few nV.

Central to this design is a digital electronic board developed by our team. This board embeds a programmable FPGA circuit, a microcontroller, a DDR dynamic memory (512 MB), and both Ethernet and USB connections. It is designed to facilitate data acquisition, storage and transfer of data to a PC for further analysis and processing. A custom mezzanine board has been developed which is equipped with necessary electronics for the current generation to produce the excitation magnetic field for the emission coils and also handles the acquisition and conditioning of the received signal from the receiver coil.



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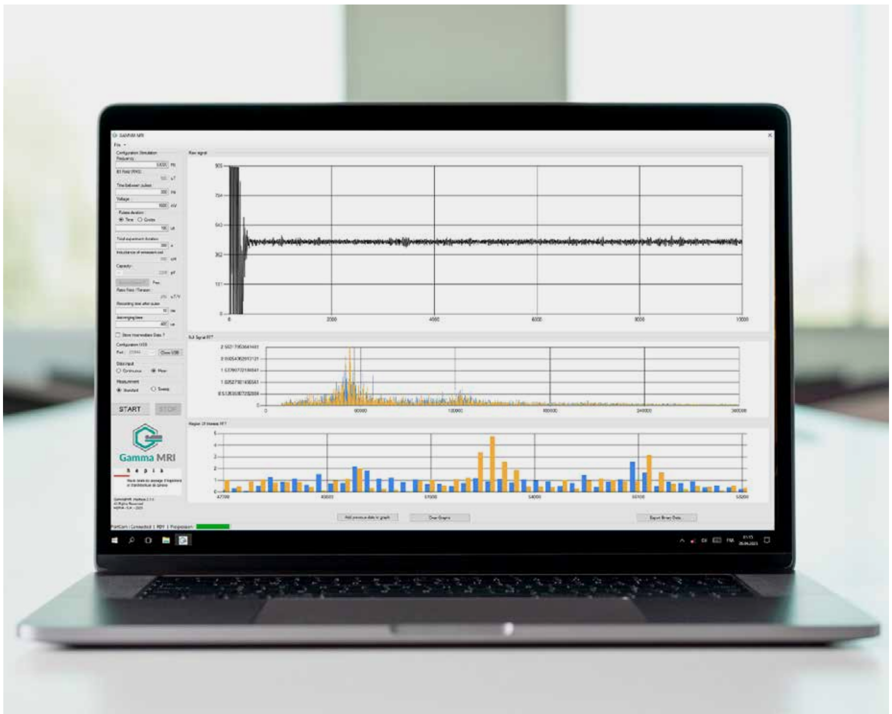

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Output

This research and development work have been financially supported by the European Union's Horizon 2020 research and innovation program under grant agreement No 964644 (GAMMA-MRI).

The electronic schematics, the bill of materials and the board view are available via the following GitHub link: [https://github.com/NicolaGiando/Ultrasensitive_digital_NMR/blob/main].

A scientific article will be published in the IEEE Open Journal of the Industrial Electronics Society.

Legends

1 - Analog acquisition signal
2 - User application interface display