Digital Control of a FFC NMR relaxometer

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In a FFC-NMR experiment to measure the spin-lattice relaxation time the sample is submitted to different Zeeman fields at different times, allowing measurement of the magnetization decay with time at a low magnetic field, but detecting the NMR signal when the sample is submitted to a magnetic field which provides good signal-noise ratio (SNR) measuring conditions. Classical solutions use an analogue PID controller to control the Zeeman field in FFC experiments.

A step forward, taking advantage of the features offered by low cost microcontrollers, it is to implement a digital controller. Concerning a digital version of a PID controller, a discrete algorithm has to be implemented. The digital control system for a FFC power supply has to fulfill the technique requirements, as for instance:

- to read the feedback measurements from a field/current sensor;
- to detect and produce TTL pulse signals (0-5 V square wave) that command the field transitions;
- to send a pulse signal to activate the detection system after the upward transition;

The main feature of this project was to develop a digital control system capable of modulating the Zeeman field of a FFC-NMR relaxometer. In order to modulate the magnetic field, the magnet current is controlled throughout the semiconductors of the relaxometer power supply. This was accomplished with the use of a Microchip dsPIC30F4013 microcontroller and implementing some additional filters and driving on-chip peripherals to interface with sensors and power electronic devices. The program developed configures the microcontroller unit (MCU) core and several peripherals required for the application. The sequence of control operation starts with a timer interrupt, enabling the Analog-to-Digital conversion of the signal from the field/current sensor placed near the sample inside the magnet. The result of this conversion is compared with a predetermined digital reference. The error difference between these two values is then minimized as the PID algorithm adjusts the control system output.

The software and hardware were designed to allow fast transitions as required in a FFC-NMR measurement. The experimental test results were obtained for liquid crystal 5CB and the ionic liquid [BMIM]BF4. Results suggest that a low cost digital control system can be integrated in the relaxometer power supply system.

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