Appendix A: Modular NMR Electronic Components and Measurement

The forefront amplifier of the modular NMR RX is VCA2615 from Texas Instruments (Dallas, TX). It features a high input impedance of >100 kΩ and is with variable-gain control of 52-dB range. An operational amplifier OPA842 from Texas Instruments (Dallas, TX) is employed to provide additional gain and convert the differential signal into single-ended for frequency downconversion. Mixers TUF-3HSM+ from Mini-Circuits (Brooklyn, NY) are chosen as the downmixing module. The NMR TX is constructed by simple digital electronics (flip-flops, switches, and buffers) which are products from Texas Instruments (Dallas, TX).

The electrical performances of the NMR electronics were characterized before sample measurements. Figure A.1 shows the gain of the RX measured at different RF frequencies. Sinusoidal RF signals with frequency from 19.9975 to 20.0075 MHz were injected to the RX, and a reference LO signal of 20.0025 MHz was provided for the mixer. The gain of the overall system is stable around 95.7–95.8 dB within ±5 kHz of IF. The gain can be further boosted by increasing the gain of the IF low-pass filter.

For the sensitivity of the RX, the spectrum of the received signal was plotted in Fig. A.2. A 100-nV sinusoidal signal at 20 MHz was injected to the RX. This amplitude is similar to the amplitude of the NMR signal. The frequency of the LO was set at 20.0025 MHz and resulted in an IF of 2.5 kHz. The resulting signal contains a fundamental tone with an amplitude of −20 dBm at 2.5 kHz. The noise floor is 30 dB below the injected signal. Thus, the RX is capable of detecting signal with amplitude down to 100 nV.

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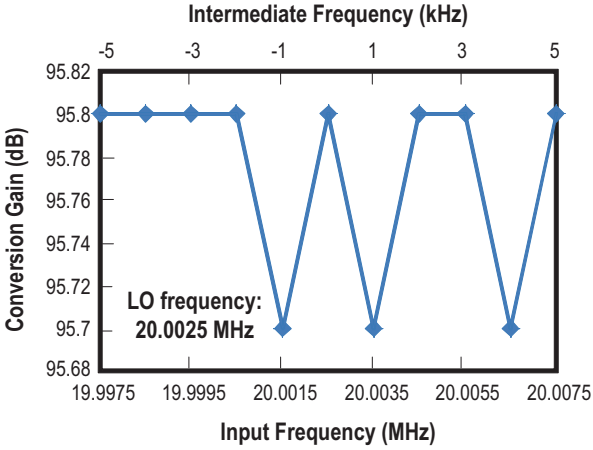

Fig. A.1 Measured gain of the NMR RX

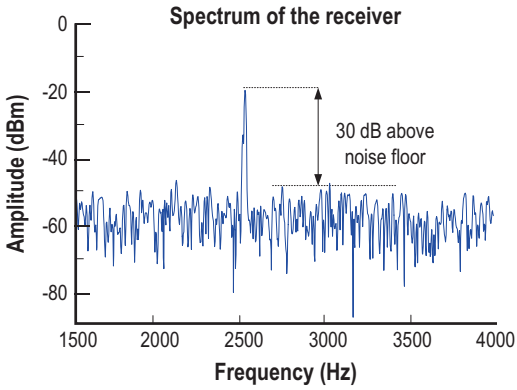

Fig. A.2 Measured output spectrum of the RX with a 100-nV, 20-MHz sinusoidal input

Appendix B: DMF Device and Electronics

A step-up voltage-to-voltage boost converter built up with LM3478 switching controller from Texas Instruments Inc. was used to generate a sufficiently high-voltage signal for electrode actuation. The input power is directly drawn from the FPGA board at 5 V; this act avoids the need of another high-voltage supply for better portability. An oscillator built up with timer ICM7555 from Intersil (Milpitas, CA) is used to generate a square wave of 1 kHz. This square wave is amplified into a 40-V peak-to-peak voltage by a switch pair and then high-pass filtered to remove the DC level for actuating the electrodes. A switch array mastered by the FPGA was used to control the on–off pattern of the electrodes. To reduce the RMS-voltage stress on the electrode so as to minimize the possibility of dielectric breakdown, the driving voltage on an occupied electrode is modulated with on (off) duty cycle of 10% (90%). Exemplified in Fig. B.1, after continuous square wave of 3 s acting on the electrode, the pulse acting on the electrode with the droplet is modulated with a turn on–off pattern of 1:9. This modulation technique allows the electrode to strap the droplet and prevents the dielectric breakdown of the electrode caused by the long-term voltage stress.

The location of each droplet sample is determined by scanning the derived capacitance C_{Elec} of each electrode. As the capacitance between two parallel plates is proportional to the permittivity of its insulating medium, a droplet-occupied electrode will increase the capacitance on the corresponding electrode when compared with the air. In this work, a timer ICM7555 working in the astable mode is used to sense the electrode capacitance. The oscillation frequency of the timer is inversely proportional to C_{Elec}. Thus, the identification of droplet position can be done by counting the pulses available in a fixed period on each electrode.

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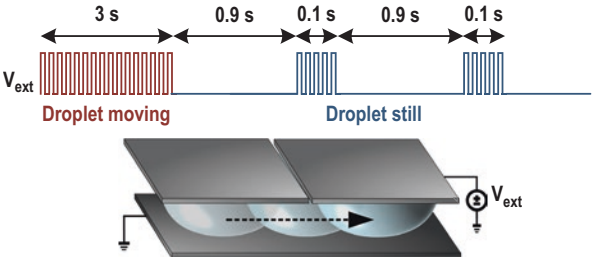

Fig. B.1 Visualized waveform applied to the electrode before and after the droplet arrives at the electrode

Appendix C: Software and Hardware Interface of Micro-NMR Platform

To facilitate the setting of micro-NMR parameters and route optimization of DMF, a graphic-user-interface program implemented in Visual C# was adopted to master the whole micro-NMR relaxometer, including (i) setting the micro-NMR parameters, (ii) displaying the micro-NMR results, (iii) reading the ambient temperature and calibrating the DAC output for magnetic field calibrator, (iv) controlling the switch array for the DMF device, and (v) displaying the vacancy of the electrodes. To this end, an interface is entailed for communications between the FPGA DE0-nano (for hardware control) and the PC (for software computing).

The TTL-232R_PCB module from Future Technology Devices International Limited (United Kingdom) is used to interface between the PC and FPGA. It can read/transmit data from/to FPGA board using the UART (universal asynchronous receiver/transmitter) signals, and the PC will process the data from the module. This protocol can ease the design for both hardware and software levels. As shown in Fig. C.1, the PC sends data to the FPGA using the TTL-232R_PCB module with a unique address. The module will process the command and convert it to a readable format for the FPGA. The FPGA board with a defined address will send the corresponding command to the appropriate module. For instance, if the PC set one of the electrode to "ON" state for the DMF device, the FPGA will recognize this command and set the corresponding output to a high level, which will set the accompanying switch and drive the electrode for droplet actuation. With the PC, all the necessary control of the micro-NMR relaxometer can be simplified into the software level. This can eliminate the use of cumbersome hardware such as the microprocessor, providing a neat platform for controlling the micro-NMR relaxometer.

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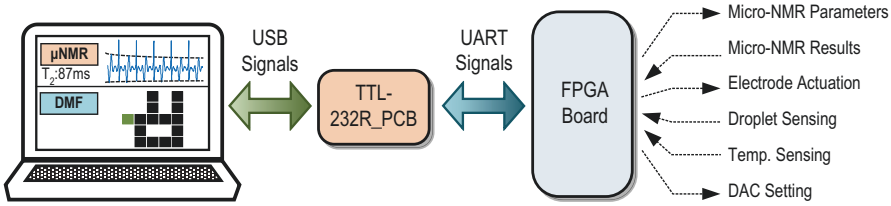

Fig. C.1 The communication between the PC and the FPGA board to drive the micro-NMR relaxometer. It is done by adopting the TTL-232R_PCB module to interfacing between the PC and FPGA board, which mastered the hardware of the micro-NMR relaxometer

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