Christopher Bradley

RF Generation and NMR:
Integrating and Miniaturizing Tools for RF Generation and Data Collection

Introduction:

Nuclear Magnetic Resonance uses the spin of an unknown atom's nucleus to determine physical properties about that atom, such as mass.

When a Nucleus is exposed to a magnetic field perpendicular to its axis of rotation, its spin will undergo precession, its orbit will deflect in the direction of this field. The nucleus spin will continue to deflect if the atom notices a change in the surrounding magnetic field, and if this perpendicular field is applied long enough, the nucleus spin could flip entirely.

As a changing electric current causes a changing magnetic field, a material to be tested is inserted into a solenoid through which current is passed. The frequency of this A/C current can be adjusted to match the frequency of the sample nucleus spin. This will cause the greatest spin deflection and is thus this optimal A/C frequency is what physicists attempt to find in NMR experiments. As the nucleus settles back to its initial spin state, it will cause a changed magnetic field, which will interact with the solenoid surrounding it and respectively cause a current to pass through it. This current is what the NMR physicist measures, searching for the greatest current return over a range of generated frequencies.

So one of the important pieces of equipment for these experiments is a frequency or waveform generator capable of producing waves with these frequencies, typically hundreds of megahertz. These are the frequencies of radio waves, thus they are called RF.

The other important equipment is the oscilloscope and computer for data collection, for reading the RF released by the nucleus on spin relaxation. The computer uses Fourier transformations on a number of these RF signals over a frequency range into a single graph of magnitude versus frequency indicating most probable spins.

Procedure:

My work at the NHMFL was in helping replace one of these large individual units with a new device capable of fitting inside a standard desktop computer. All controls for the device are accessed through an application designed to replace the front panel of this waveform generator.

Software Methods:

First I familiarized myself with LabVIEW, a graphical programming language, which will become the interface to the new waveform generator as well as a new electronic oscilloscope, replacing another large external device.

The Oscilloscope was programmed first, not requiring the finalized waveform generator for its own completion. Initially the computer was attached via GPIB cable to an oscilloscope, and a program was written to retrieve the data points displayed on it. Then these data points were converted to amplitude as a function of time. This allows any data entering the GPIB cable to be viewed as a waveform. Then it became a matter of changing from a GPIB card to a PCI card.

The clock belongs to a class of circuits called Transistor-Transistor Logic (TTL) circuits. This class communicates through binary. Low is below .8 Volts, High is above 2 Volts. A 5 Volt power supply, standard for all TTL circuits, allows it to output binary code.

I had to develop a method to talk to the clock through binary. The clock is connected via a 68-pin cable to a GC5050 I/O board, manufactured by the Geotest company. I had to program the voltage of each pin over time, either 5 V (a 1 in binary) or 0 V (a 0 in binary). This is done with a program called DIOEasy, designed to communicate through the Geotest board, that regulates the voltage of the pins over time by selecting the speed the program executes at, then selecting the level of each pin during a given time increment.

The binary code representing voltage levels on pins generated in DIOEasy was then translated to a decimal number for use in the waveform generator program.
This waveform generator program will become the basis for another program, which generates a range of frequencies entered by the user, currently a prototype. This will allow a researcher to scan an inputted frequency range for examining nuclear spin.

Hardware Methods:

The purchased clock that will be replacing the waveform generator was initially attached to a board with dials to manually control frequency, so among the alterations to the clock, it has been removed from this original board and is currently attached to a board designed by Dr. Arneil Reyes for diagnostics, in which the connections from a 68-pin cable are separated and exposed, so each may be used individually. In the final product it will be attached to a card that goes inside the computer.

The task of communicating from the computer through an I/O card and to the clock required modifying a previous version of the connector board Dr. Reyes designed. There had been small imperfections in the board, so the connections had to be traced out to find and bypass faults and accidental grounds.

The clock and connector board were run on a separate D/C power supply during diagnostics but have now been converted to run on the computer's power. The difficulty

in constantly keeping near 5 volts on a battery pack during an 8 hour run time necessitated this.

During prototype testing, it was discovered there is some low frequency interference distorting the output (either ambient from improper shielding or most likely from the rest of the circuit), which will need to be filtered out in the final version of the device, so some resistor banks will be added to reduce this interference. Also, at higher frequency, the amplitude of the signal is observed to drop, from an intended 1 V to less than 1 mV at the upper end of the frequency spectrum. To account for this, an amplifier is being designed into the next circuit.

At lower frequencies the clock produced square waves, which would gradually become more sinusoidal as frequency increased. To create a sinusoidal output from these low frequency square waves, a .01 Microfarad capacitor was placed in the output path, with a 470 Ohm resistor leading to the ground.

Acknowledgements:

National High Magnetic Field Lab:

Dr. Arneil Reyes, *REU Mentor*
Dr. Philip Kuhns
Dr. Jun Lu
Prof. William Moulton
Mr. Andrew Harter

Material Cited:

Hornak, J. P. (1997), *The Basics of NMR*. Accessed July 2004.
http://www.cis.rit.edu/htbooks/nmr/