iSpin-NMR™
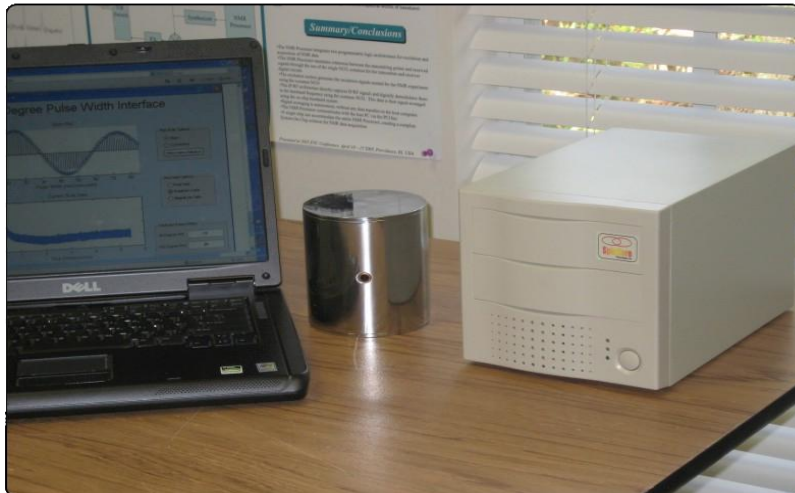
Model GX-35

Part Number: GX-35-mk0 Rev1

Owner's Manual

SpinCore Technologies, Inc.,
www.spincore.com

Congratulations and *thank you* for choosing a design from SpinCore Technologies, Inc.

We appreciate your business!

At SpinCore we try to fully support the needs of our customers. If you are in need of assistance, please contact us and we will strive to provide the necessary support.

Table of Contents

I. Introduction

The iSpin-NMR^{TM} Model GX-35 is SpinCore's broadband NMR (Nuclear Magnetic Resonance) system console built specifically for General Electric Company and packaged into a compact enclosure measuring 340 x 180 x 170 mm^3 and weighing 4.1 kG.

The system features SpinCore's RadioProcessor USB board, a broadband, small-form factor device (100 x 150 x 10 mm^3) designed for high performance, agile NMR applications, including solid-state NMR.

This manual is the primary document describing the iSpin-NMR GX-35 system, calling other relevant sub-documents as required, to provide the complete information on the system and its internal components, including testing, performance and functionality.

Should you have any questions that are not answered in this manual, please contact SpinCore Technologies, Inc. using the contact information section at the end of this document.

Thank you for choosing SpinCore Technologies, Inc. for your NMR needs and please visit us on our website at http://www.spincore.com for the latest information about SpinCore's products!

II. Warnings and Labels

Warning: Use of this product in a manner other than intended can potentially cause damage to the product or result in injury or fire. Please familiarize yourself with the contents of this manual, as well as the labels on the exterior of the product enclosure prior to use. SpinCore Technologies, Inc. holds no responsibility for any damage or injury occuring as a result of product misuse.

Enclosure Labels Descriptions

⚠ **CAUTION: 50Ω Load MUST BE CONNECTED**	Indicates to have the need to have the properly tuned and matched probe attached at all times while operating. Failure to comply may cause damage to the equipment; however, this poses no safety risk to the user.
⏚	Indicates the protective earth ground terminal for the 100 – 240 VAC.
⚠ **DANGER:** High Voltage	Caution should be taken, 100 – 240 VAC present in the immediate area.

III. Product Overview

The block diagram of the iSpin-NMR Model GX-35 system is presented in Figure 1, below. The iSpin-NMR system console contains SpinCore's USB RadioProcessor board, Mini-Circuit's high-speed Transmit/Receive switch, and Miteq's broadband per-amplifier unit followed by a 50 MHz Mini-Circuits low-pass filter. Also in the system console box are the AC/DC and DC/DC power supplies. For specific part numbers, please consult the Bill-of-Materials (BOM) available at SpinCore Technologies, Inc.
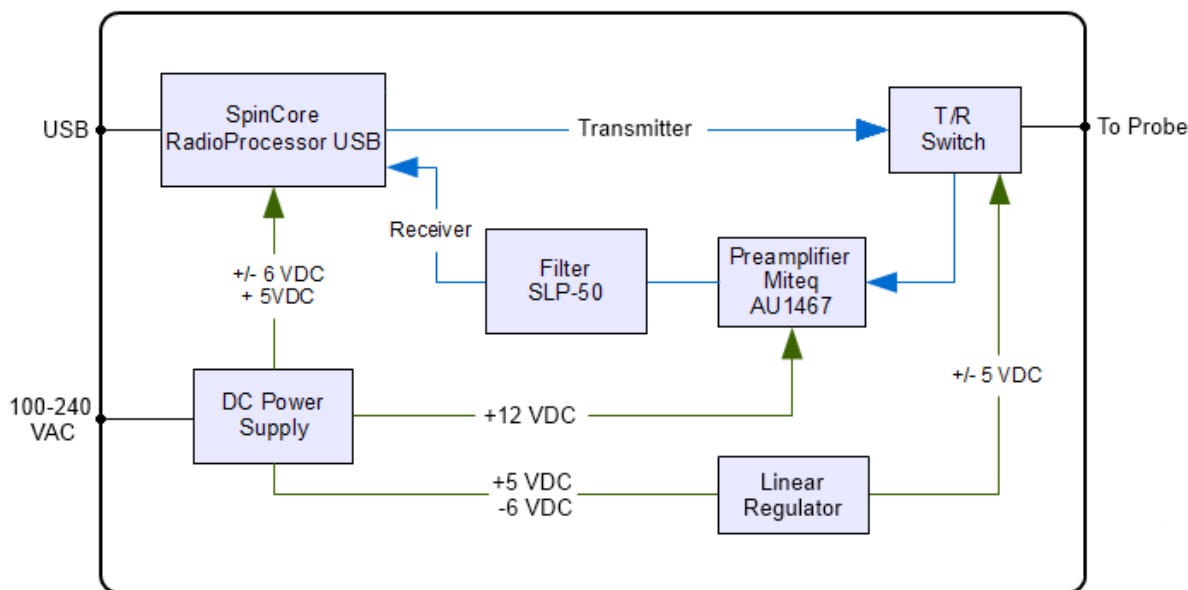
Figure 1: iSpin-NMR Model GX-35-rev1 system block diagram.

For detailed technical information pertaining to SpinCore's RadioProcessor board – the primary component of the iSpin-NMR system, responsible for all digital and analog control and signal processing – or information about writing your own pulse programs and NMR experiments, please refer to the SpinCore RadioProcessor User Manual which can be found at the following address:

http://www.spincore.com/CD/RadioProcessor/RadioProcessor_manual.pdf

RadioProcessor boards, including the firmware, are under revision control. The specific RadioProcessor Board Revision and RadioProcessor Firmware Revision used in iSpin-NMR Model GX-35, Part Number GX-35-mk0 Rev1, are as follows: Board SP7, Board Revision 0, Firmware revision 12-15.

The iSpin-NMR connects to any PC or laptop via USB 2.0. The system can operate under several operating systems. For Microsoft Windows 7 (and XP), the specific USB driver and software package for the RadioProcessor SP7 board, Firmware 12-15 are marked 2012/04/06, also described in details in the RadioProcessor Manual listed above. The most recent software is posted online and can be accessed via

SpinCore's website http://www.spincore.com (under "Software Downloads"). For other SpinAPI versions please contact SpinCore through the "Contact Us" link on SpinCore's website.

    The iSpin-NMR system console is equipped with a universal AC input power supply (100 to 240 VAC) and consumes no more than 80 Watts. The TDK power supply inside the iSpin-NMR console has a CB Scheme test certificate and test report, as well as CE certificate of declaration. The metal enclosure meets FCC/FTZ regulations. The iSpin-NMR system console is RoHS compliant and is intended for operation at room temperature, typically in the range of temperatures from 15° C to 28° C, with a relative humidity limit of 35%-70% (non-condensing), no visible moisture, and at altitudes not exceeding 5 km.

IV. Typical Application

    The iSpin-NMR is typically used for Nuclear Magnetic Resonance (NMR) applications. The connection diagram for NMR applications is depicted in Figure 2, below. In NMR experiments, the sample being studied is placed inside the RF coil of the NMR probe. For NMR signals to be observed, the probe needs to be in a static/constant magnetic field and be tuned to (or capable of operating at) the NMR frequency at the specific field value. The probe is connected with the iSpin-NMR console via a single coaxial cable.

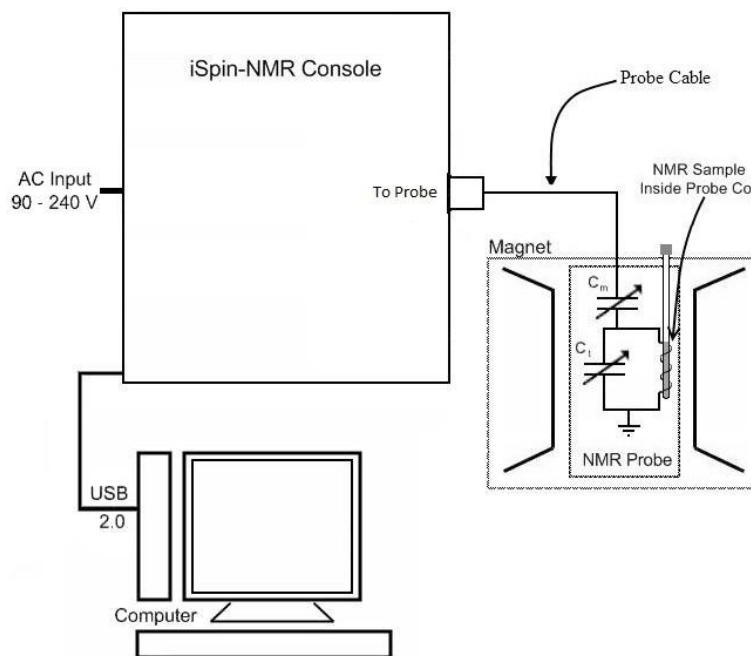*Figure 2: iSpin-NMR Model GX-35 connection diagram for NMR applications.*

    In operation, the iSpin-NMR generates a Radio-Frequency (RF) excitation pulse and then acquires NMR signal from the probe, performing digital detection, filtering and signal averaging autonomously. The required fast switching of the probe between the Tx output and the Rx input is internal to the iSpin-NMR system

console. The switching circuitry inside the iSpin-NMR protect the receiver when excitation pulses are applied while facilitating the isolation of the transmitter's circuitry from the receiver when acquiring the small-signal response from the sample.

For iSpin-NMR Model GX-35, the intended NMR operating frequency is 35 MHz. However, the system is broadband and will operate at any frequency from approximately 1 to 55 MHz (certain limits apply, please consult the Manual of the RadioProcessor board). The lower limit is determined by the specifications of the preamplifer, and the upper limit is determined by the specifications of the 50 MHz low-pass filter used inside the iSpin-NMR system console.

V. Inside Details of the iSpin-NMR

A photograph of the internal components of the iSpin-NMR system is shown in Figure 3, next page, along with short descriptions of each component.

1. **USB RadioProcessor Board:** The heart of the iSpin-NMR system. In the specific iSpin-NMR Model GX-35 part number GX-35-mk0 Rev1, the RadioProcessor firmware code 12-15 is used. The RadioProcessor board generates the completely formed excitation signals, and then captures and digitally processes the NMR signals. Digital detection, filtering, and autonomous signal averaging are standard features, as well as shaped excitation pulses. In the iSpin-NMR system Model GX-35, the RF output of the RadioProcessor is connected directly to the fast Transmit/Receive switch, and the RF input of the RadioProcessor is connected directly to the output of the low-pass filter following a small-signal preamplifier. For more information on RadioProcessor, including performance characteristics from 0 to 100 MHz, please visit the URL http://www.spincore.com/products/RadioProcessor/.

2. **Transmit/Receive Switch:** The T/R switch allows for agile selection between RadioProcessor's excitation pulses and incoming NMR signal. Mini-Circuit's ZYSWA-2-50DR DC to 5 GHz switch is used. The -5 V supply rail is derived from -6 V rail via a linear voltage regulator.

3. **Pre-amplifier and filter:** The supplied Miteq pre-amplifier is broadband, approximately 10 to 600 MHz, and provides in excess of 68 dB gain. A Mini-Circuits low-pass SLP-50+ filter follows the preamplifier in the receiver chain prior to reaching the input of the RadioProcessor board.
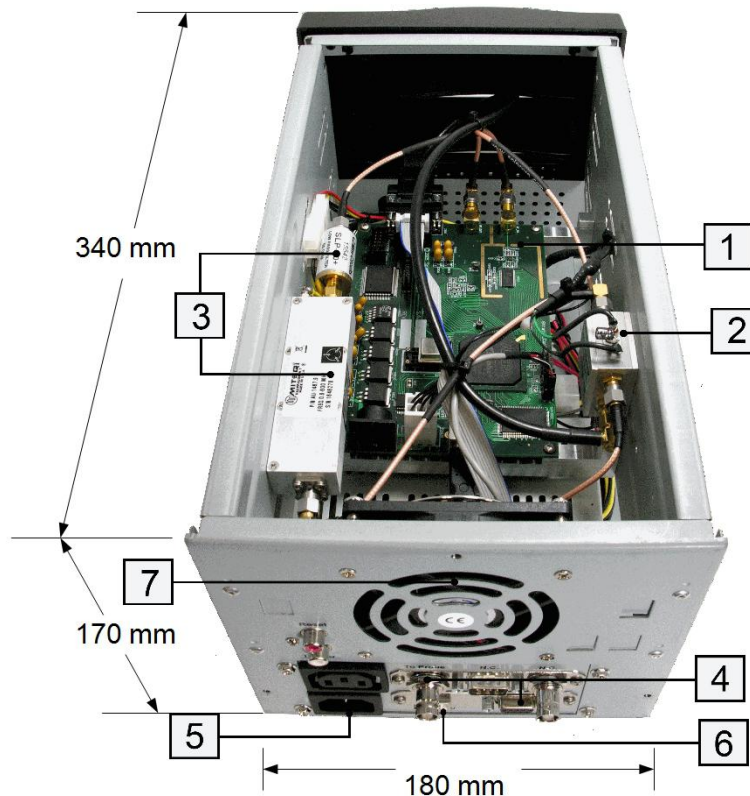
Figure 3: Inside the iSpin-NMR system

4. **A. RF Input/Output "To Probe" Connector:** A BNC Connector is used to connect the probe to the Transmit/Receive Circuitry.

   B. DB-9 Connector: An additional DB-9 type connector is placed at the back of the iSpin-NMR system to expose the TTL output signals from RadioProcessor board for multi-system synchronization or control of any additional peripheral devices.

5. **Universal AC Power Supply:** Power is supplied by a TDK-Lambda 80 W power supply (Part # LS75-12). Accepts 100-240 VAC, 50 - 60 Hz, maximum power consumption 80 Watts, has CB Scheme test certificate and test report, and CE declaration of conformance. No warm-up time needed/present, a sub-second power-on, no user-serviceable fuse, internally protected, will shut-off when overloaded. NOTE: The unit does not contain a manual ON/OFF switch and is always powered on whenever the power cord in connected to the AC power source.

6. **USB 2.0 Interface:** Contains the USB 2.0 interface hardware and firmware.

7. **Large-diameter fan:** Included for efficient heat dissipation and quiet operation.

8. **Ample space inside:** There is sufficient room inside the iSpin-NMR console for an embedded computer, small permanent magnet, or touch screen, if desired.

VI. Connector Information

This section provides descriptions of the external connectors for the iSpin-NMR Model GX-35. Figure 4, below, shows a sketch of the front and back panels of the iSpin-NMR Model GX-35 system.
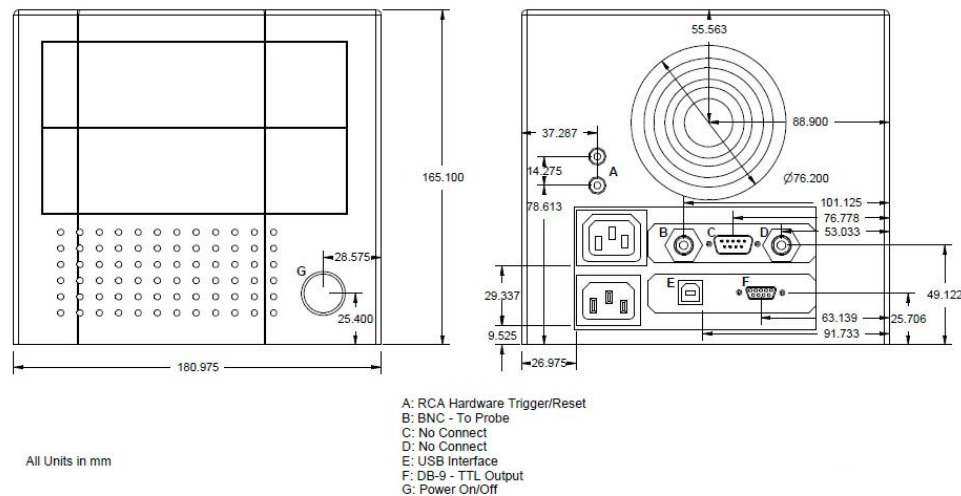
Figure 4: Front (left) and back (right) sides of the iSpin-NMR Model GX-35 (dimensions are in mm). The length of the enclosure is 340 mm. The circle on the front panel is the "Power" switch. The large circles on the back panel represent the fan's exhaust. This exhaust port should not be blocked or covered.

USB Connector

The USB connector is a USB Type-B connector and can easily be connected to a computer via a standard USB 2.0 cable.

To Probe

The "To-Probe" connector is standard BNC jack (female) connector that connects the iSpin-NMR with the probe.

Hardware Reset/Trigger Input Connectors

Access to the hardware reset and hardware trigger lines of the RadioProcessor USB is provided via RCA jacks labeled 'Reset' and 'Trigger'. For more information about the function of these pins, please consult the SpinCore RadioProcessor Manual.

Digital (TTL) Output Connector Pin-out

The iSpin-NMR system console can output four digital signals in the low-voltage TTL standard (3.3 V in the logical high when not under load). The signals are available on the DB-9 (female) connector marked "TTL Out". The pinout of this connector and the corresponding signal names are shown in Figure 5, next page. The maximum drive capability in the logical "1" is 15 mA. The maximum sinking current for a logical "0" is 15 mA. NOTE: TTL signal "Bit 0" is connected internally with the input pin of the Mini-Circuits T/R switching unit.
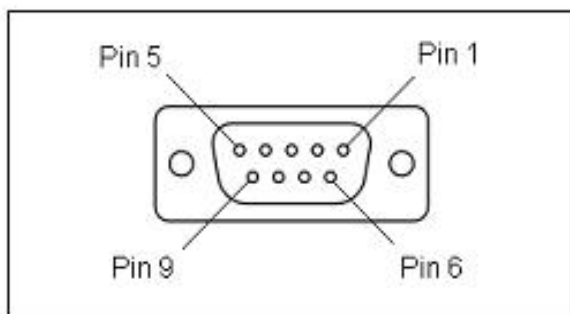
Pin number	Function
1	Flag bit 0
2	Flag bit 1
3	Flag bit 3
4	Flag bit 2
5	Reserved
6	Ground
7	Ground
8	Ground
9	Ground

Figure 5: TTL Output Connector (DB9-female) and signal list.

VII. Using the iSpin-NMR System

1. General Operation Description

The iSpin-NMR is designed to be simple, intuitive, and effective. The following is an outline of how the iSpin-NMR operates for typical NMR experiments.

1. The user inputs the necessary parameters into SpinCore's NMR GUI or alternative software program.

2. When the user begins the scan, the iSpin-NMR generates the NMR excitation pulses depending on the input parameters.

3. During specific intervals in the pulse sequence (typically after the excitation pulse in a single-pulse NMR experiment), the system will acquire the data returned from the sample in the probe. The iSpin-NMR system digitizes the signal and performs digital detection, filtering, and autonomous signal averaging. The processed digital values are stored on the iSpin-NMR console and are available for download to the host computer at the user's convenience.

4. The Transmit/Receive Circuitry will automatically switch between the excitation pulses and the signal input from the probe. The received signal from the sample probe is fed into a low-noise pre-amplifier inside the iSpin-NMR system, and subsequently into the digital receiver on the RadioProcessor board inside the iSpin-NMR system for digitization and digital signal processing.

5. The system continues to scan the specified number of times, automatically averaging the values stored on chip for each scan. Data may be downloaded to the host computer at any time for inspection, visualization, and processing, without interfering with the ongoing data acquisition. The user can download the data received from the RadioProcessor using SpinCore's NMR GUI, SpinCore's non-GUI C/C++ program, or alternative software tools.

6. NMR data is saved on the host computer in three different formats, including ASCII (plain text file), JCAMP-DX, and FELIX for post-acquisition processing, visualization, and analysis.

Later in this document, more description is provided on both the SpinCore scripting method and alternative GUI control interfaces.

2. Testing iSpin-NMR with Test Instruments: Step-by-step Instructions

The iSpin-NMR is tested extensively before shipment and is ready to use for acquisition of NMR signals out of the box. However, it is suggested that the user tests the iSpin-NMR upon delivery to make sure there were no damages during shipment and to become more familiar with the operation and performance of individual components.

Before starting the testing procedure, or before using the iSpin-NMR system for NMR signal acquisition, please create on your computer the necessary software environment by performing the following steps:

1. A). Download and install the SpinAPI driver package available at the address:

   http://spincore.com/support/spinapi/

   NOTE: At the time of this writing, the SpinAPI release is dated 2012/04/06, for both 32- and 64-bit Microsoft Window OS platforms.

   B). Download and install the RadioProcessor Example Programs from the following address:

   http://spincore.com/CD/spinapi_examples/.

2. Create your own new working directory somewhere outside of the SpinCore directory and copy the contents of the SpinAPI RadioProcessor Examples to your new working directory. The SpinCore RadioProcessor directory can be found in the location where you downloaded the SpinAPI Examples.

Transmitter and receiver testing require different hardware set up and cannot be performed simultaneously. The details of each are described below.

A) Testing the Transmitter

To test the *Transmitter*, connect the iSpin-NMR as shown in Figure 6, next page. The oscilloscope needs to be capable of handling input signals up to 100 MHz. If using a high input impedance oscilloscope, connect a 50 ohm terminating resistor to the channel in use at the oscilloscope input. Note that pin-1 on the TTL output DB-9 connector is the so-called de-blanking signal (vide infra) and can be used to trigger the oscilloscope. Turn on your iSpin-NMR system only after making all connections.
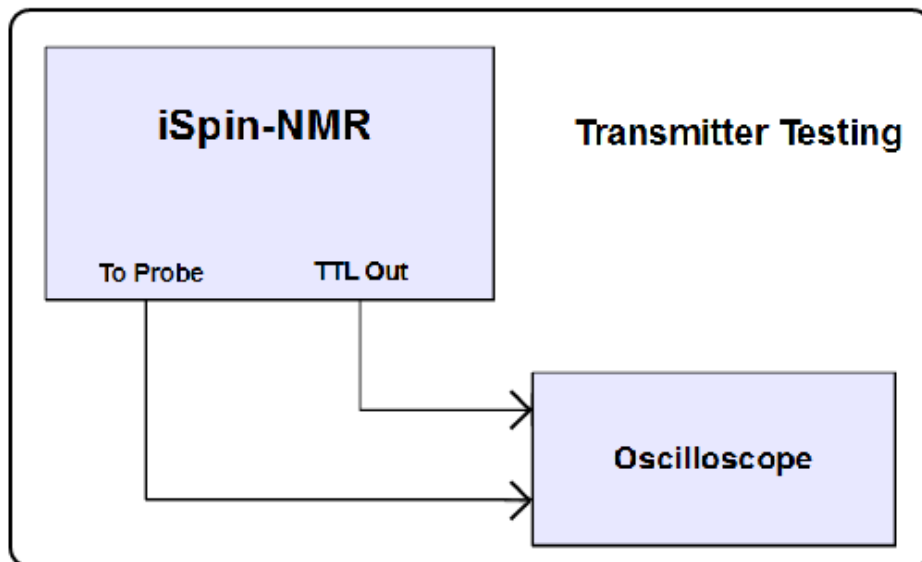
Figure 6: iSpin-NMR setup for the transmitter testing

1. Identify the executable text program GX-35_Tx_Test.exe.   This program has been created to facilitate a quick evaluation of the iSpin-NMR Model GX-35 transmitter's (Tx) output.   The following specific parameters are utilized in this Tx test:

    - SPECTROMETER_FREQUENCY=35.0 (*MHz*).

    - PULSE_TIME=10 (*µs*)

    - REPETITION_DELAY = 0.5 (*seconds*)

    - NUMBER_OF_SCANS = 100

    - AMPLITUDE = 1.0

    - BLANKING_BIT = 0

    - BLANKING_DELAY = 0.001 (*ms*)

2. Run the GX-35_Tx_Test.exe by double-clicking the file.

3. On the oscilloscope, you should see a 35.0 MHz sine wave that is on for 10 µs and repeats 100 times every 0.5 seconds (and then stops). The amplitude of the sinusoid should be no less than 1.5 V peak-to-peak. The maximum expected value can be 3.0 Volts peak-to-peak. The diagram in Figure 7 and screenshot in Figure 8 show what a typical output will look like for this test.
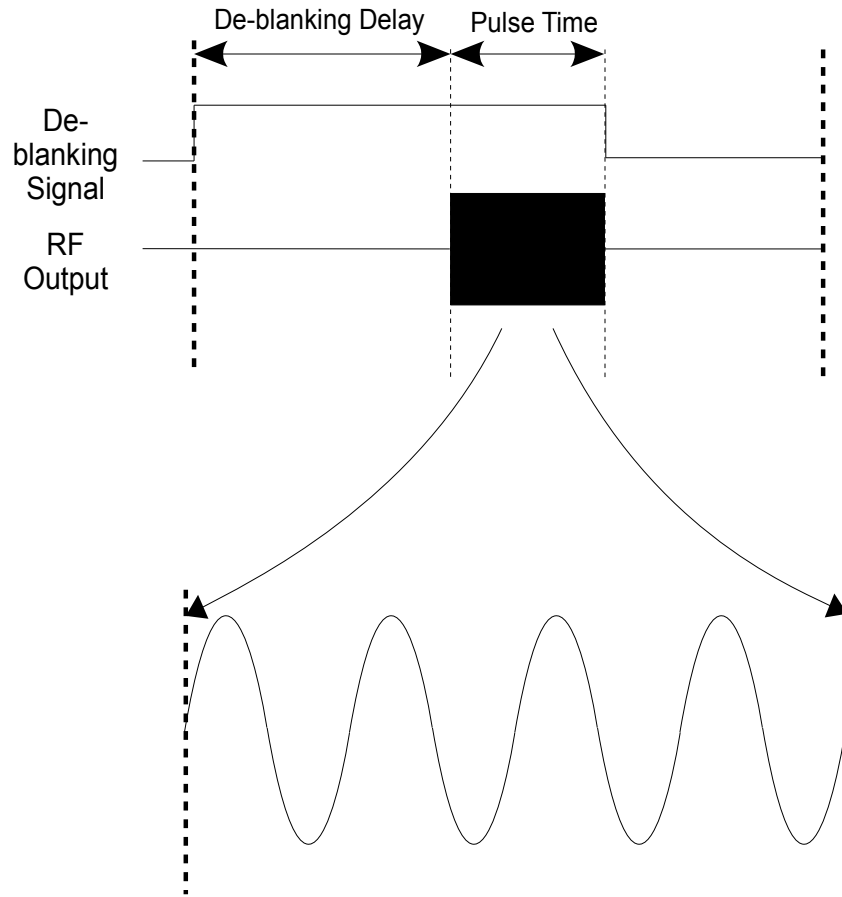
Figure 7: Representation of the oscilloscope output for the iSpin-NMR transmitter test.

Figure 8: Oscilloscope screen-shot capture of the Spin-NMR Model GX-35 transmitter output.

B) Testing the Receiver

To test the **Receiver**, turn off iSpin-NMR and reconnect as shown in Figure 9, below. The RF source needs to be capable of generating a continuous, un-modulated, low-phase noise, sinusoidal signal at frequencies up to 100 MHz. NOTE: The iSpin-NMR receiver is very sensitive and can detect signals less than 1 µV peak-to-peak. The maximum *input* that can be received without distortion is approximately 2.5 mV peak-to-peak. Be sure to attenuate the signal going into the iSpin-NMR so it falls in this range. Turn on your iSpin-NMR system only after making all connections.
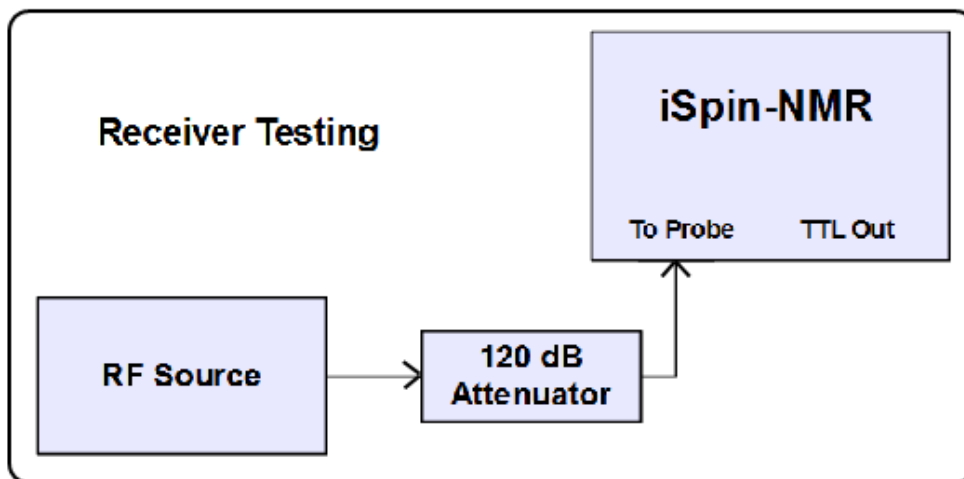

Figure 9: iSpin-NMR setup for receiver testing

1. Identify the executable test program GX-35_Rx_Test.exe.   This program has been created to facilitate a quick evaluation of the iSpin-NMR Model GX-35 receiver's (Rx) performance.   The following specific parameters are utilized in this Rx test:

    •   SPECTROMETER_FREQUENCY = 35.0 (MHz)

    •   SPECTRAL WIDTH = 50 (kHz)

    •   NUMBER_OF_POINTS = 16384

    •   NUMBER_OF_SCANS = 1

    •   FNAME = GX-35_Rx_test

2. Set your frequency source to 35.0 MHz. Notice that this is exactly the same value as the Spectrometer Frequency parameter in the GX-35_Rx_Test.exe program. However, since your RF source and iSpin-NMR use different oscillators, a certain frequency difference between the two sources is expected, up to +/- 100 ppm, or 3.5 kHz, typically below +/- 1 kHz.

3. Run the GX-35_Rx_Test.exe program by double-clicking. This will result in a single-pulse NMR experiment being performed. After the scan has completed, the program will generate three output files (Rx_test.fid, Rx_test.jdx, and Rx_test.txt).

4. Open the 'Rx_test.fid' file using Felix NMR software (available for download at: http://www.spincore.com/support/RadioProcessor/Felix/Felix_Instructions.shtml) and perform the FFT. You should see a single strong peak located between -3.5 kHz and 3.5 kHz. Figure 10, below, shows data captured by the iSpin-NMR system with a signal attenuated by over 100 dB. The time-domain signal is on top (expanded), and the FFT is shown on the bottom.
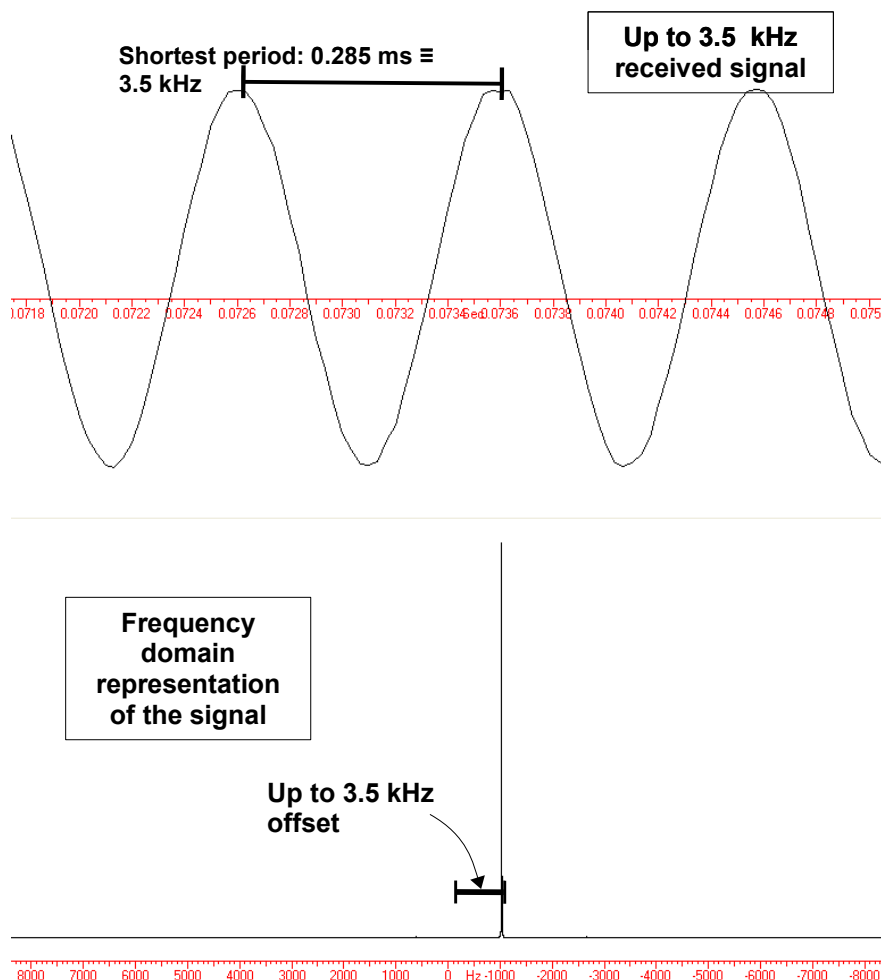

Figure 10: Data received by an iSpin-NMR system performing the Rx test. The input signal is attenuated by over 100 dB and is less than 18 µV peak-to-peak. In this figure, the offset is 1 kHz.

3. Quick NMR Qualification Test: Step-by-step Instructions

In this section, a quick test is presented to obtain NMR data and validate the correct operation of the entire NMR system, including the probe, the magnet, the sample, and the interconnecting cables. Assuming the performance of the magnet+probe+sample is known, this test can be a quick method of validating the performance of the iSpin-NMR system console. For this test, SpinCore created an executable test program, called GX-35_Single_Pulse_NMR_10.8MHz_Test.exe, specifically for the NMR magnet used for quality control testing at SpinCore. The testing procedure is as follows:

1. Connect the SpinCore system as show in Figure 2 earlier in this Manual, see page 6. Assure the probe is in the center of the magnet or at any other location as appropriately marked.

2. Insert into the probe a known sample providing known NMR data in your magnet. Assure the center of the sample is at the center of the probe or at any other location as appropriately marked.

3. Identify the GX-35_Single_Pulse_NMR_10.8MHz_Test.exe and run by double-clicking. Output files will be created in three different formats.

4. Examine the resulting NMR data files. The observed NMR signal should look similar to what is presented in Figure 11 when using the Felix for Windows program.
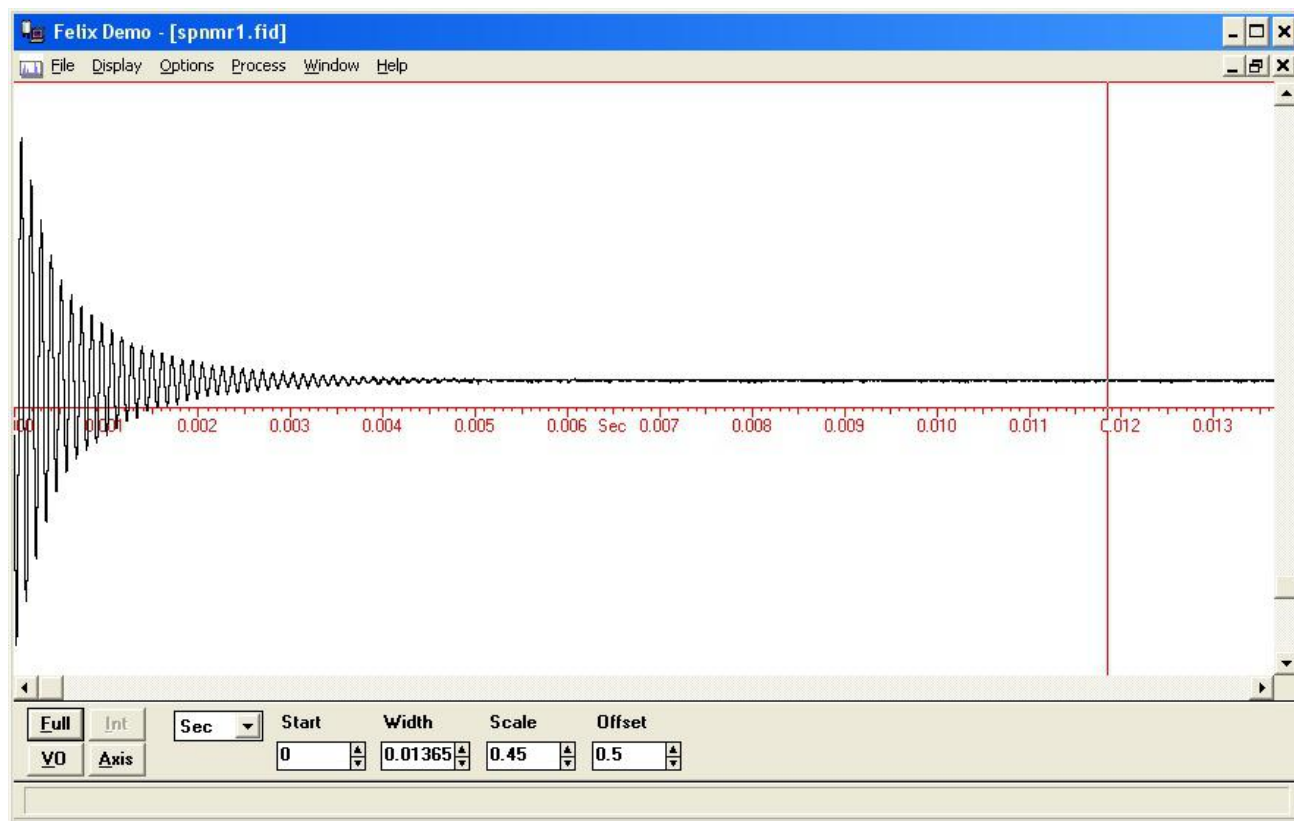

Figure 11: Typical time-domain NMR signal. This specific signal was obtained running 1000 scans every 1 ms at 10.8 MHz using 10 us excitation pulses and a sample of household cooking oil in a plastic tube 28 mm OD and 90 mm in length. Number of points acquired – 4096, Spectral Width 300 kHz.

5. In most instances, you will also perform a Fourier transform on the resulting NMR signal. The FFT of the signal acquired in Figure 11 (previous page) is presented in Figure 12, below.
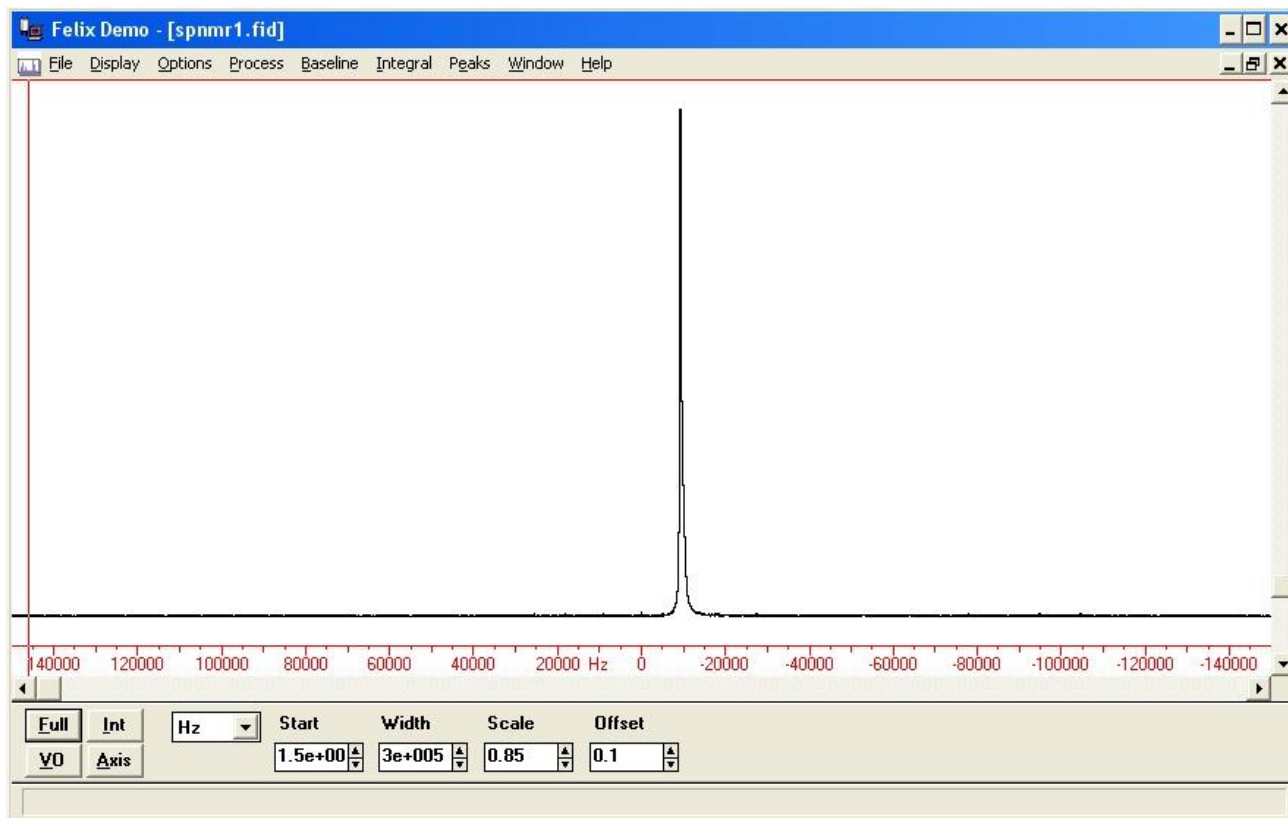

Figure 12: Typical NMR spectrum in a low-resolution low-field magnet. All parameters identical to the previous figure.

4. Conducting an NMR Experiment with the iSpin-NMR using the Scripting Method: Step-by-step Instructions

SpinCore Technologies, Inc., developed a number of executable programs for performing common NMR experiments, including single-pulse NMR and CPMG under a variety of experimental conditions, including varying magnets, frequencies, RF power levels, pulse times, etc., including multiple signal acquisitions in a series of NMR experiments. Those programs are typically called/executed by scripting text files that hold all relevant experimental parameters and experimental protocols. For the single-pulse NMR experiments, the name of the relevant scripting/batch file is singlepulse_nmr_example.bat. The timing diagram in Figure 13, next page, shows all timing intervals relevant to this program.
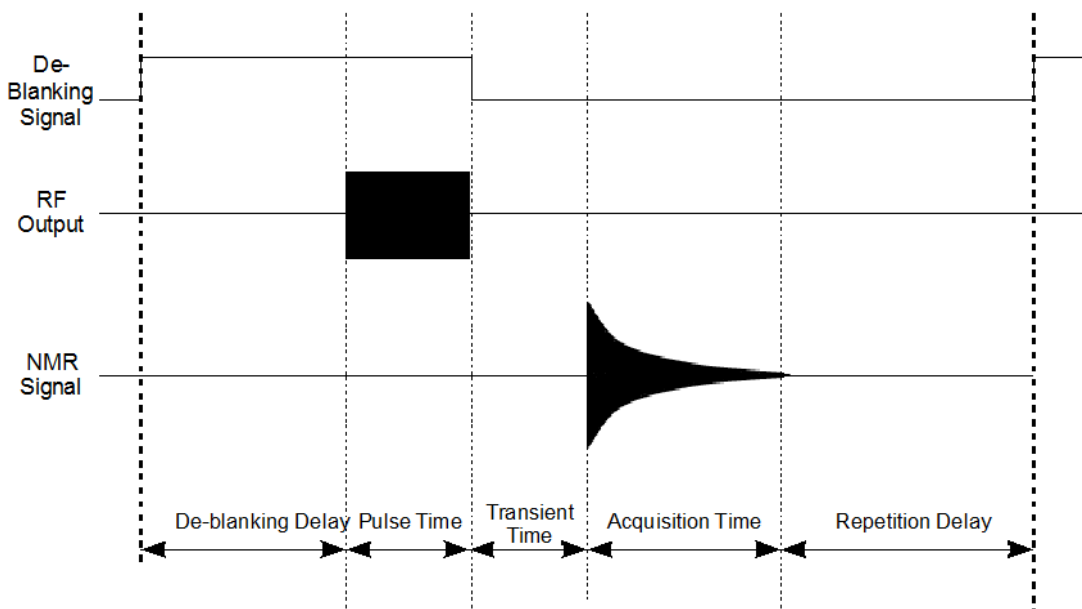
Figure 13: Timing diagram for one single pulse NMR scan (not drawn to scale).

To perform an NMR experiment, edit the singlepulse_nmr_example.bat batch file by right-clicking and selecting 'Edit;' save the batch file when finished. The timing values in the batch file correspond to those in Figure 13 above.

After saving, run the singlepulse_nmr_example.bat file by double clicking. Once the singlepulse_nmr_example.bat file has completed, three files (*.fid, *.jdx, *.txt) will be created in the directory from which the batch file was executed.

Load the Felix file (.fid) in Felix for Windows, or load the .jdx file in any program that supports JCAMP-DX. An easily parsed text file containing the NMR data will also be generated. For information on installing and using Felix to view your .fid files, go to http://www.spincore.com/CD/RadioProcessor/felix/Felix_Instructions.html

The NMR data received should look similar to those presented in the previous sections.

VIII. Alternative GUI Software Interfaces

This section briefly presents two GUI software interfaces compatible with your iSpin-NMR system - written in MATLAB and LabVIEW. Representative MATLAB GUI screenshot, Figure 14, is presented below. Representative LabVIEW GUI screenshot, Figure 15, is presented on the next page.
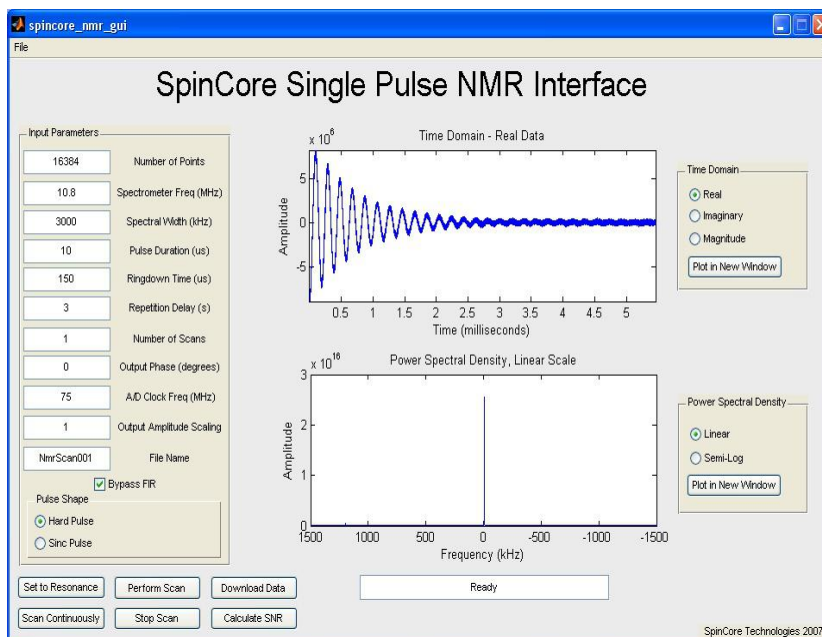

Figure 14: Sample output after running Single Pulse NMR experiment on household cooking oil.

General features of the GUI packages include:

- Run NMR experiments with ease, including Single Pulse, CPMG, and the 90-Degree Pulse-Width Determination
- Change experimental parameters quickly and easily
- Preview data while the experiment is running
- Combine the versatility of the RadioProcessor with the power of the MATLAB/LabVIEW environments
- Quickly find NMR resonance frequency through automatic detection
- 90-Degree Pulse-Width Finder allows quick and simple detection of both the 90 and 180 pulse-width parameters
- CPMG NMR calculates T2 relaxation times for samples with a single exponential
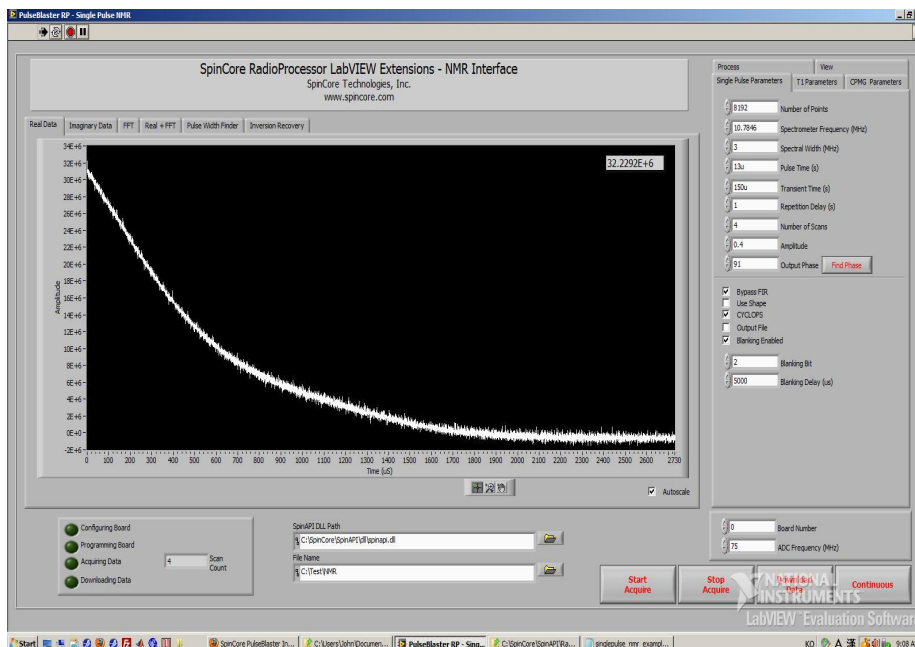- Continuous Scan setting for Single Pulse NMR

Figure 15: Example of RadioProcessor LabVIEW Extensions User Interface.

IX. Related Products and Accessories

1. RadioProcessor: Complete RF Acquisition and Excitation System with Digital Detection, Real-Time Signal Processing and Signal Averaging. For more information, please visit http://spincore.com/products/RadioProcessor/

2. RF Power Amplifiers PA10W, PA15W, PA75W and PA100W. For more information, please visit http://spincore.com/products/RFPA/

3. PulseBlaster: Programmable TTL Pulse Generator / Digital Word Generator and Timing Engine. For more information, please visit http://spincore.com/products/PulseBlaster/

4. SpinCore also offers the following to supplement the iSpin-NMR system:

   • NMR Magnets and Probes.

   • Custom RF Filters and Cables.

   • iSpin-NMR in Rack Mount Enclosure.

   • Oven controlled oscillator with sub-ppm stability.

5. All components of the iSpin-NMR system may be ordered separately. For custom designs, modifications or software development, please inquire with SpinCore Technologies through our contact form, which is available at http://spincore.com/contact.shtml

X. Contact Information

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Gainesville, FL 32653, USA

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Fax (USA):	352-371-8679
Website:	http://www.spincore.com
Web Contact Form:	http://www.spincore.com/contact.shtml

XI. Document Information

This manual is SpinCore document DA-306. All future revisions will be logged in the space below, pending General Electric's approval in writing.

Sub-documents Referenced in this Manual

- Bill of Materials, SpinCore Document Number DA-327, available at SpinCore
- RadioProcessor Manual, available at http://www.spincore.com/CD/RadioProcessor/RadioProcessor_manual.pdf
- SpinAPI Software Package and Documentation, available at http://www.spincore.com/support/spinapi/SpinAPI_Main.shtml
- MiniCircuits T/R Switch Datasheet, available at www.minicircuits.com/pdfs/ZYSWA-2-50DR.pdf
- MiniCircuits 50 MHz Low Pass Filter Datasheet, available at http://www.minicircuits.com/pdfs/SLP-50+.pdf
- Miteq Pre-Amp Datasheet, available at http://www.miteq.com/docs/MITEQ-AU-1467.PDF