



RadioProcessor-G™

Owner's Manual



SpinCore Technologies, Inc.
<http://www.spincore.com>

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I. Introduction

Product Overview

The RadioProcessor Model G™ is an enhanced version of SpinCore's versatile RadioProcessor™ design. The RadioProcessor-G greatly expands upon the already extensive capabilities of the original RadioProcessor with the inclusion of three channels of user controlled gradient outputs. For more information on the general operation of the RadioProcessor, please refer to the RadioProcessor manual, which can be found on this webpage: <http://www.spincore.com/products/RadioProcessor/RadioProcessor.shtml>

The state-of-the-art design of the RadioProcessor-G allows it to serve as a complete system-on-chip solution for Magnetic Resonance Imaging (MRI), Nuclear Magnetic Resonance (NMR) applications in gradient enhanced spectroscopy and diffusion measurements, and Nuclear Quadrupole Resonance (NQR) experiments with spectrometer frequencies from 0 to 100 MHz (refer to the RadioProcessor manual for more details). The system integrates SpinCore's high-performance PulseBlaster™ timing engine for agile control of internal system components as well as TTL pulse/pattern generation for control of any external hardware.

The RadioProcessor-G:

- Is a system-on-chip solution for MRI, NQR, and NMR applications, integrating excitation and acquisition components onto a single PCI card.
- Contains three analog output channels that allow for applications requiring pulses of varying amplitude and timing.
- Directly captures and digitally demodulates IF/RF signals. The desired baseband bandwidth is user definable through software.
- Generates completely formed RF excitation pulses as well as high resolution digital control signals.
- Maintains signal coherence between excitation and acquisition systems at all frequencies.
- Autonomously averages baseband signal data between multiple acquisitions.

This unique digital system is housed on a small form factor PCI card, providing users with a compelling price/size/performance proposition unmatched by any other device on the market today.

System Architecture

Figure 1 presents the architecture of the RadioProcessor-G, which consists of four major components: the data acquisition core, the excitation core, the gradient control core, and the PulseBlaster timing engine, which provides high-resolution timing control for the entire system.

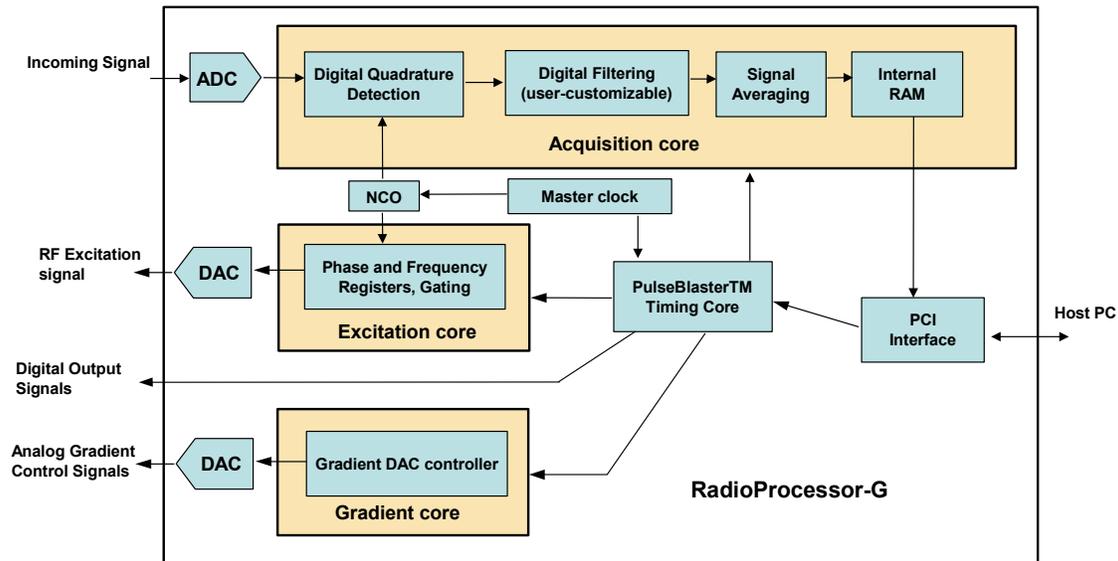


Figure 1: RadioProcessor Model G Architecture. The master clock oscillator signal is derived from an on-chip PLL circuit typically using a 50 MHz on-board reference clock.

The acquisition core captures an incoming RF signal using a high-speed, high resolution Analog to Digital converter (ADC). This signal is then demodulated digitally using quadrature detection, and is then filtered to reduce the signal to baseband. The detection and filtering system is highly configurable and can easily be customized by the user for a wide variety of applications. The baseband signal can then be stored in an internal RAM. This data is then available to be retrieved by the host computer at the user's convenience.

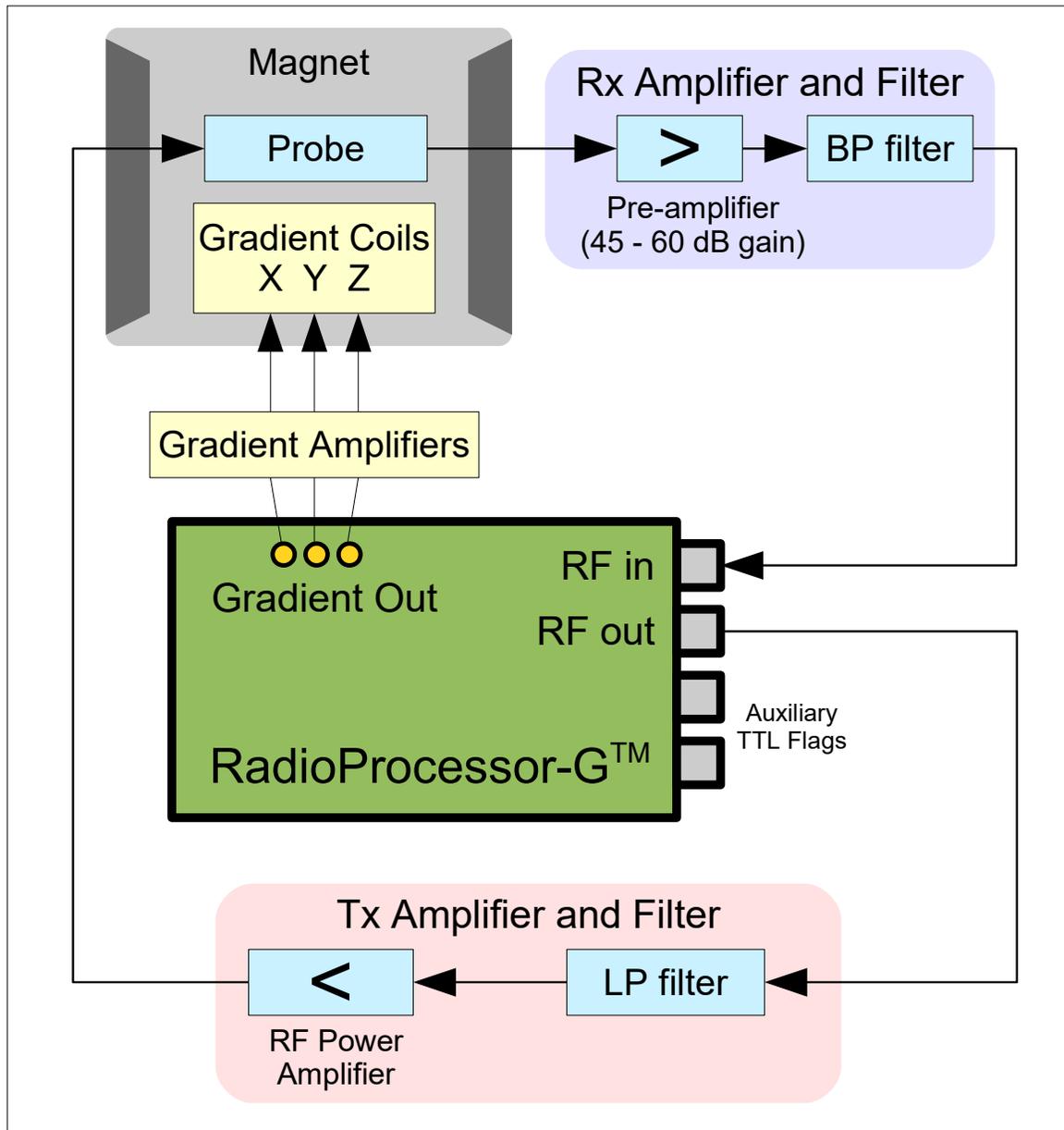
The excitation core can produce both RF Analog signals as well as digital outputs. The RF output is generated using an internal DDS (Direct Digital Synthesis) core, and can generate frequencies from DC up to 150 MHz. The generated signal is converted to the Analog output by an on-board digital-to-analog converter (DAC) This DDS core also drives the detection of the acquisition core, so signal coherence is maintained between acquisition and excitation cores.

The gradient core controls three analog outputs that can be used to generate pulses with customizable durations and varying amplitudes of both positive and negative voltages. A standard application of the RadioProcessor-G uses these outputs to control the gradient coils for an MRI system, but they can also be used for gradient enhanced spectroscopy or diffusion applications.

At the heart of the system is the PulseBlaster™ pulse/pattern generator timing core, which uses a robust instruction set designed to allow the creation of complex pulse sequences with ease. This timing core controls all aspects of the systems functionality, such as triggering data acquisition, controlling the frequency and gating RF output, etc. This core also controls the high resolution programmable digital outputs for controlling external hardware. Four digital outputs are available by default.

Example Application - MRI

A major application for the RadioProcessor Model G is Magnetic Resonance Imaging. Using the RadioProcessor Model G, a complete NMR/NQR system can be constructed with the addition of an RF power amplifier, a gradient amplifier, and a pre-amplifier. An example setup is shown below in Figure 2.



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Figure 2: Typical application of the RadioProcessor Model G. By adding an RF power amplifier, a gradient amplifier, and a small-signal pre-amplifier, a complete MRI system can be built.

RadioProcessor-G

If you are building a system with the RadioProcessor-G, SpinCore Technologies Inc. can also supply an RF power amplifier and pre-amplifiers, if desired. SpinCore also offers a complete mobile NMR system, the iSpin-NMR, that can perform NMR/NQR experiments immediately out of the box. Please visit our website for more details.

Using the setup as described above with an 11.8 MHz permanent magnet, a sample image of a 5 mm test tube filled with household cooking oil and two glass capillary tubes was obtained as shown below. This was accomplished using a gradient echo pulse sequence to collect data for the 128 x 128 pixel image. The image can be seen in Figure 3.

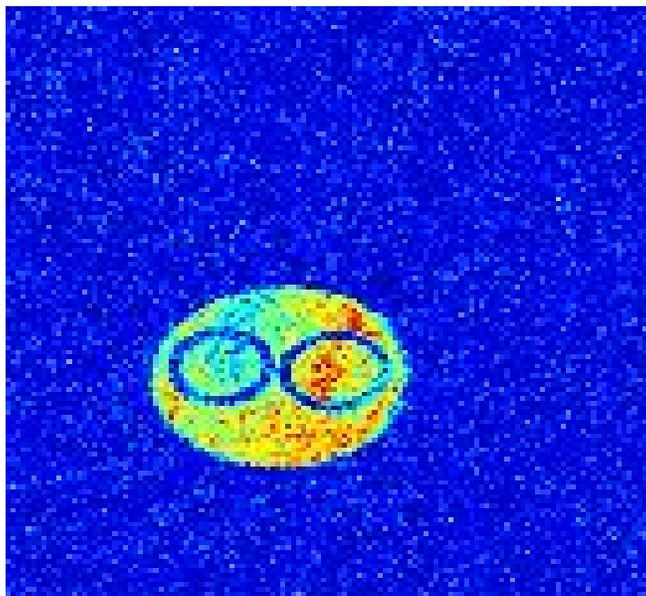


Figure 3: Sample MRI image of a 5 mm test tube containing two glass capillaries and filled with cooking oil.

Specifications

Table 1: Product Specifications.

| <i>Parameter</i> | | <i>Min</i> | <i>Typ</i> | <i>Max</i> | <i>Units</i> |
|--------------------------------------|--------------------------------------|------------|--------------------|--------------------|--------------|
| Analog Input | Input Frequency Range | 0 | | 100 | MHz |
| | A/D Sampling Precision | | | 14 | bits |
| | Input Voltage Range (peak-peak) | | | 1.13 | V |
| | A/D Sampling Frequency | | 75 ⁽¹⁾ | | MHz |
| RF Analog Output | D/A Sampling Rate | | 300 | | MHz |
| | D/A Sampling Precision | | | 14 | bits |
| | Output Voltage Range (peak-peak) | | | 1.2 ⁽²⁾ | V |
| | Phase resolution | | | 0.09 | deg. |
| | Frequency resolution | | 0.28 | | Hz |
| Gradient Analog Output | Output Voltage (1 kOhm load) | -3.3 | | 3.3 | V |
| | Update rate | 66.6 | | | ns |
| | Resolution | | 16 | | bits |
| Digital Output | Number of Digital Outputs | | 4 | | |
| | Logical 1 output voltage | | 3.3 ⁽²⁾ | | V |
| | Logical 0 output voltage | | 0 | | V |
| | Output drive current | | | 25 | mA |
| | Rise/Fall time | | | < 5 | ns |
| Digital Input (HW_Trig, HW_Reset) | Logical 1 Input voltage | 1.7 | | 4.1 | V |
| | Logical 0 Input voltage | -0.5 | | 0.7 | V |
| Data acquisition | Spectral width (SW) of acquired data | 72 Hz | | 9.4 MHz | |
| | # Complex points | 1 | | 16k | |
| Pulse Program | # of Instruction words | | | 2048 | words |
| | Pulse resolution ⁽³⁾ | | 13.3 | | ns |
| | Pulse length ⁽⁴⁾ | 66.6 ns | | 693 days | |

Notes

- (1): If the signal to be detected is very close to ¼ of the sampling rate, there will be aliasing during the detection process. To alleviate this, a slightly higher or lower clock speed can be used.
- (2): This is the value seen without using termination. When the line is terminated with 50Ω, the output voltage will be reduced by as much as half.
- (3): Pulse resolution equals one clock period of the PulseBlaster Timing Core clock oscillator.
- (4): Minimum pulse width is five clock periods of the PulseBlaster clock oscillator. Maximum pulse width is 2⁵² clock periods of the PulseBlaster clock oscillator.

II. Board Installation

Installing the RadioProcessor-G

To install the board you must complete the following three steps:

1. Download and install the latest MRI SpinAPI software packages on your computer. MRI SpinAPI is available at: <http://spincore.com/products/RadioProcessor-G/>
 - MRI SpinAPI is a custom Application Programming Interface package developed by SpinCore Technologies, Inc. MRI SpinAPI is designed to be used only with the RadioProcessor-G. MRISpinAPI can be utilized using C/C++.
 - MRI SpinAPI can be supplemented with the 'MRI SpinAPI Examples' package. A shortcut to the location of these files is created automatically in the Windows Start Menu at **"Start>Programs>SpinCore>MRI SpinAPI"**.
2. Shut down the computer. Insert the RadioProcessor-G card into an available PCI slot and fasten the PC bracket securely with a screw.
3. Turn on the computer and follow the installation prompts.
4. In order to ensure the maximum accuracy of data acquisition for the RadioProcessor-G, the `adc_offset.exe` program needs to be run. This program will produce a value that you will need to use to configure the ADC of the RadioProcessor-G, so please record this value for future reference. For more details as to how to utilize the ADC Offset in a program, please refer to Section IV. Example Gradient Echo MRI Experiment in this manual.

Testing the RadioProcessor-G

The simplest way to test whether the RadioProcessor-G has been installed properly and can be controlled as intended is to run a simple test program. `Example_1.exe` that accompanies the MRI SpinAPI Examples package (located at `C:\SpinCore\MRI SpinAPI` if the default installation directory was used) will produce a pulse with an on time and an off time of 500 ms on the two digital out BNCs with a duty cycle of 50%. This sequence will be repeated indefinitely until the program is exited by pressing any key after the board begins running. These outputs can be observed on an oscilloscope to confirm operation of the digital outputs.

`Example_2.exe` can be used to test the analog gradient outputs. Run the program and observe the three channels on an oscilloscope to check correct operation according to the program's description. This program will repeat until the program is exited by pressing any key. The board will be programmed one last time, triggered, and reset to zero the analog outputs.

After these two examples have been run, the `2D_MRI.bat` sample program can be run to test full functionality. This sample program can also be used to simply test the RF output. A description of the gradient echo pulse sequence and sample program can be found in the next section.

NOTE: There are additional programs in this folder. More information on these programs can be seen in the "Tips on obtaining data using the gradient echo example" section.

III. Creating Custom Pulse Programs

Getting Started

The quickest way to become acquainted with writing programs for your RadioProcessor-G board is to go through the example programs included with the MRI SpinAPI Examples package, which can be found on the SpinCore website at <http://spincore.com/products/RadioProcessor-G/>. It includes three example programs that demonstrate the functionality of the RadioProcessor-G. The .c code for these files contain descriptions of the programs.

Procedure for Writing a Pulse Program

The RadioProcessor-G is a highly versatile excitation and acquisition system, and as a result there are many possible approaches to programming the board; however, most applications will follow six basic steps:

1. Initialize the MRI SpinAPI.
2. Load the frequency and phase registers with desired values, and define the shape of carrier and envelope signals.
3. Specify data acquisition related parameters.
4. Specify all parameters that control the timing of the experiment, i.e., pulse times, delays, etc.
5. Trigger the pulse program. The experiment will then proceed autonomously.
6. Retrieve the captured data from the board at any time without interrupting the acquisition process.

These steps are described in detail below. Please note that all of the functions described in this manual are also detailed in the MRI SpinAPI Reference Manual, which is included in the MRI SpinAPI software package available from the RadioProcessor-G product page on the SpinCore website.

Step 1: Initialize MRI SpinAPI

Before the parameters for a pulse program can be written, the MRI SpinAPI must be initialized by calling these two functions:

```
spmri_init()  
spmri_set_defaults()
```

Step 2: Define RF Output Parameters

In order to output an RF signal, the phase, frequency, amplitude and shape of a carrier signal and an envelope signal must be defined. The actual RF output is produced by multiplying these two signals together. The amount of registers available is detailed in Table 2 below.

Table 2: Available DDS registers.

| Register Bank | Number of Registers |
|--------------------|---------------------|
| Carrier Frequency | 16 |
| Carrier Phase | 16 |
| Envelope Frequency | 8 |
| Amplitude | 4 |

Important Considerations:

- By default, the shape of the carrier signal is a sin wave, so unless a non sinusoidal signal is desired for output, only the frequency, phase, and amplitude of the carrier signal must be defined.
- If no envelope shaping is required, then the 7th envelope register can be used. When this is done, the carrier signal is sent to the output without being multiplied by the envelope signal.
- When making a shaped RF pulse, it is important to set the envelope frequency register to 7 before the pulse, as this will make certain the phase starts at zero.

Relevant MRI SpinAPI functions:

Carrier signal related:

```
spmri_set_frequency_registers()  
spmri_set_phase_registers()  
spmri_set_amplitude_registers()  
spmri_set_carrier_shape()
```

Envelope related:

```
spmri_set_envelope_frequency_registers()  
spmri_set_envelope_shape()
```

Step 3: Data Acquisition Parameters

The acquisition system of the RadioProcessor-G is very similar to that of the original RadioProcessor. More information on the general operation of the acquisition system can be found in the RadioProcessor manual.

Once the RadioProcessor-G has been instructed to acquire data, there are two parameters that will influence the length for which data will be recorded; these are the Spectral Width and the Number of Points.

Spectral Width is the bandwidth of the captured data, which can also be thought of as the frequency at which data is recorded.

Number of Points is the amount of complex baseband points that will be captured. The maximum amount of points that may be recorded is 16384.

Acquisition Time for a scan can be calculated using the Spectral Width and the Number of points. The relationship is:

$$\text{Acquisition Time} = \frac{\text{Number of Points}}{\text{Spectral Width}}$$

In order for data to be acquired as accurately as possible, it is important to set the DC offset for the ADC to be set to a proper value. To determine this value, you must run the program entitled `adc_offset.exe`, which is included with MRI SpinAPI package, after your RadioProcessor-G has been successfully installed. You will then be given a number, which can then be used to properly set the ADC DC offset for data acquisition.

Relevant MRI SpinAPI functions:

```
spmri_set_num_samples()  
spmri_set_num_segments()  
spmri_setup_filters()  
spmri_set_adc_offset()
```

Step 4: Specify Parameters of the Pulse Sequence

To program a pulse sequence into the RadioProcessor-G, there is one primary function that must be used:

```
spmri_mri_inst()
```

The parameters of this function are defined in Table 3.

Table 3: SPMRI_MRI_INST Parameters.

| Parameter | Description |
|---------------------------|--|
| double dac_amp | specifies the amplitude of the selected DACs on a scale of 1.0 to -1.0, where 1.0 is the highest positive amplitude and -1.0 is the most negative. |
| char dac_addr | selects which DACs will be updated. Multiple DACs can be selected at one time. |
| char write | selects which DACs will have new amplitude data written. This will not cause a new values to be seen at the output. Multiple DACs can be selected. |
| char update | selects which DACs will have updated outputs. The outputs will reflect the amplitude data that was last written. Multiple DACs can be selected. |
| char clear | clears the write and update registers of the selected DACs, causing them to cease outputting data. Multiple DACs can be selected. |
| int freq | selects the frequency register that will be used for the carrier signal. |
| int tx_phase | selects the phase register that will be used for the carrier signal. |
| char tx_en | enables RF output if set to 1. RF output will be disabled if set to 0. |
| char phase_reset | resets the phase to the of the carrier signal to the initial value. |
| char trigger_scan | enables data acquisition when set to 1. |
| char envelope_freq | selects the frequency register that will be used for the envelope signal. If register 7 is used, envelope shaping will be disabled and the phase will be reset for the envelope frequency registers. |
| int amp | selects the amplitude register that will be used for the carrier signal. |
| char cyclops_phase | not supported on the RadioProcessor-G. Set to 0. |
| UINT64 flags | specifies the state of the digital outputs, whether high or low. |
| DWORD data | the data field for the PulseBlaster opcode. |
| char op | the opcode for the PulseBlaster instruction. See Table 3 for more information. |
| double delay_ns | the duration of the PulseBlaster instruction. |

Step 5: Trigger the Pulse Program

Once the pulse program has been stored in the memory of the RadioProcessor-G, it can easily be started and stopped by the MRI SpinAPI functions listed below:

```
spmri_start()  
spmri_stop()
```

Step 6: Retrieve Acquired Data

Acquired data from the RadioProcessor-G can be retrieved from RAM. This process is very similar to that of the RadioProcessor. For more information, please see the RadioProcessor manual.

Useful References

MRI SpinAPI Reference Manual

The MRI SpinAPI, which can be downloaded on the SpinCore website, includes a document that gives an in-depth description of all the functions available in the API. If you are unsure of how a particular function in an example program works, please refer to this document, which is titled “SPMRI_API_Reference_Manual.”

RadioProcessor Manual

The RadioProcessor-G API is a modified version of the RadioProcessor API, so many of the functions are similar, excluding those that were added to allow configuration of the gradient outputs. For more information on the RadioProcessor API, please refer to the SpinCore RadioProcessor manual, which is available on the SpinCore website at this location:

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

IV. Example Gradient Echo MRI Experiment

The RadioProcessor Model G comes with multiple sample programs. One of these programs is a gradient echo MRI pulse sequence. A diagram of the pulse sequence can be seen in Figure 4. The program is a .c file that is compiled into a .exe that requires command line arguments. There are included Windows batch file scripts that handle those arguments so that scans can be run by simply editing the .bat file and then double-clicking it in Windows. The below steps will guide you through using the gradient echo example program.

1. Download and install the latest MRI SpinAPI package.
2. Connect the RadioProcessor-G as shown in Figure 2. Note that all components shown in Figure 2 may be purchased from SpinCore Technologies.
3. Edit the 2D_MRI.bat batch file by right-clicking and selecting 'edit' and save the batch file when finished. The parameters of interest for this experiment are described below.
4. Run the 2D_MRI.bat file by double-clicking. Once the 2D_MRI.bat file has completed, new files (*.fid, *.txt, *.bmp) will be created in the directory from which the batch file was executed. The bitmap will be an image such as the one in Figure 3.

outputFilename: A string of text that is used to name all of the files generated by GradientEcho.exe

nPoints: Number of points acquired per acquisition period.

nScans: Number of times the entire sequence is performed.

nPhases: Number of different phase levels to run the scan for

spectrometerFrequency_MHz: Frequency of the RF excitation pulse in MHz.

spectralWidth_kHz: The desired spectral width in kHz.

linebroadening_value: A value that adjusts the amount of line broadening in the final image. 0 corresponds to no line broadening and 5 is a lot of line broadening.

RF_Shape: Denotes the shape of the RF pulse. A value of 0 is a hard pulse. A value greater than 1 is a sinc with RF_Shape many lobes.

amplitude: The amplitude of the RF pulse. Valid values range from 0.0 to 1.0.

pulseTime_us: The duration of the RF pulse in microseconds.

transTime_us: The delay between RF excitation and phase gradient application.

phaseTime_us: The duration of the phase gradients in microseconds.

gradientEchoDelay_us: The delay between switching the readout gradient's direction and data acquisition.

repetitionDelay_s: The delay between acquisition and the next RF pulse in seconds.

tx_phase: The phase of the RF excitation pulse in degrees.

blankingBit: The bit connected to the blanking/de-blanking pin of your RF amplifier. This is designed for SpinCore's power amplifiers. More information on the amplifiers can be found at <http://www.spincore.com/products/RFPA/RF-Power-Amplifier.shtml>

blankingDelay_ms: The amount of time to de-blank the amplifier before the RF pulse starts.

adcOffset: The adc DC offset specific to the current board.

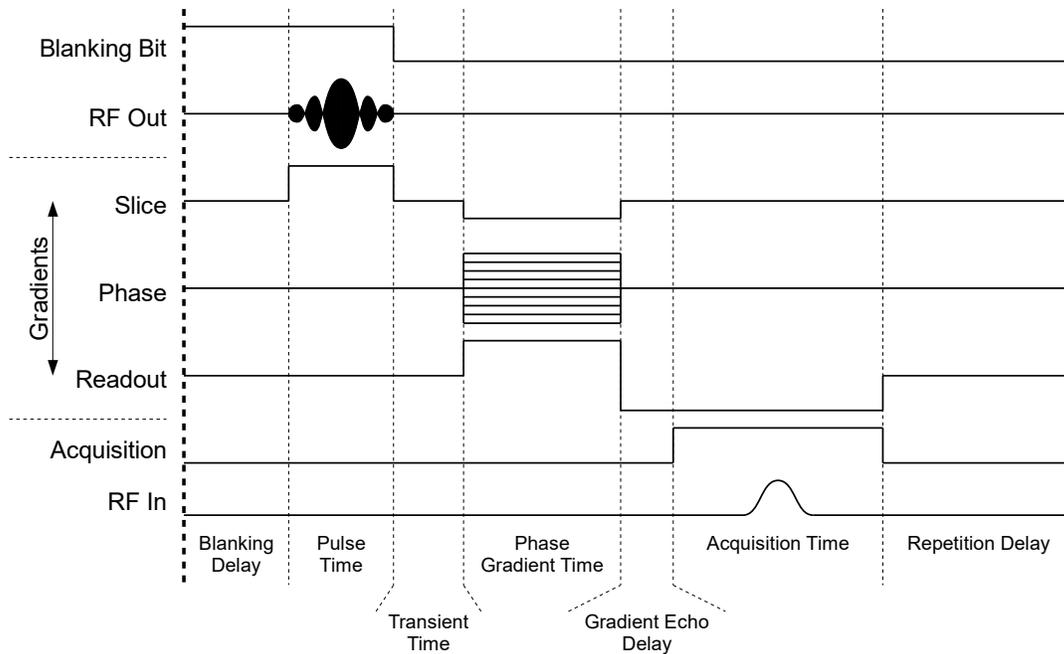


Figure 4: General timing diagram of the basic gradient echo sequence (not to scale). A single scan is performed as follows: A de-blanking TTL pulse is applied to allow for RF Power Amplifier warm-up (Blanking Delay), and then a single RF pulse (hard or shaped) is applied to the sample for a specified amount of time (Pulse Time). At that same time, the slice gradient is applied for slice selection. The high voltage induced on the sample coil is allowed to ring down (Transient Time), after which all three gradients are applied (Phase Gradient Time). A period of time is waited to account for rise time of the gradient amplifiers (Gradient Echo Delay). The readout gradient coils then produce a gradient echo that is acquired by the RF in of the board (Acquisition Time). The acquisition time is determined by the number of points and the spectral width. After acquisition, the sample is then allowed to relax for a time (Repetition Delay). This scan procedure is then repeated for next phase gradient amplitude until all of the data has been acquired.

Tips on obtaining data using the gradient echo example

There are multiple Windows script (batch) files along with the gradient echo example program that can be used to check scan parameters without doing an entire MRI pulse sequence with multiple phase amplitudes.

FID

FID.bat has delays and acquisition parameters set by default to aid in inspecting the FID. The FID is seen using this pulse program by turning off all of the gradients, shortening the phase delay time and the gradient echo delay time, setting the number of points to a large number, increasing the spectral width, and reducing the number of phases to 1. By inspecting the FID, you can find an approximate value for T2* which will determine how long of a delay you can program before your expected gradient echo.

FID_Readout

FID_Readout.bat has delays and acquisition parameters set by default to aid in inspecting a single gradient echo. This is best used to make sure that your acquisition parameters are sufficient for a full MRI scan. By running a single phase of the full MRI scan, you can check a single echo to make sure it looks good before continuing. When running this batch, make sure you have your readout gradient on and your phase gradient off.

To get a good signal, make sure to set acquisition parameters (`nPoints` and `spectralWidth_kHz`) so the acquisition period is centered on a point in time that still has a strong signal in the FID example. Select a `phase_time` parameter that corresponds to one half of the time from the end of the RF pulse to the desired center of acquisition. That will set the amplitude of the readout gradient to approximately -1.0 for dephasing, and 1.0 for phasing resulting in the strongest echo possible.

V. Connecting to the RadioProcessor-G

PCI RadioProcessor-G Board Connector Information

There are two main connector types on the RadioProcessor-G board: the BNC connectors and the SMA connectors – see Figure 5 below. BNC connectors are mounted on the PCI bracket and are available outside of the computer. The SMA connectors are mounted on-board and are available inside the computer only.

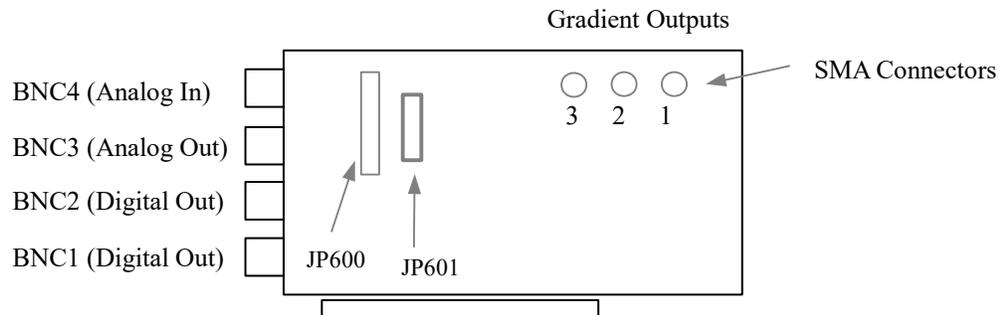


Figure 5: RadioProcessor-G PCI Connector Locations.

BNC Connectors

The four BNC connectors provide the primary interface with the RadioProcessor-G PCI board. All headers are impedance matched to 50Ω. BNC4 is the Analog Input, used for data acquisition. BNC3 is the Analog Output port. BNC2 and BNC1 are both general purpose digital outputs which can be controlled through the pulse program.

The analog output connector (BNC3), is not equipped with an interpolating filter. This allows for maximum flexibility in output frequency, but it means that the output may appear somewhat quantized if no filter is used at the output. To eliminate this behavior and obtain a smooth RF pulse, the user should filter the output with a band-pass or low-pass filter which will cut off the undesired frequency components above the intended RF signal.

When using coaxial transmission lines, please terminate the lines with a 50 ohm impedance. See Figures 6 and 7 below.



Figure 6: Left: BNC T-Adapter (F M F) and Right: BNC (M) 50 Ohm Impedance.



Figure 7: BNC T-Adapter on oscilloscope with coaxial transmission line connected on the left and BNC 50 Ohm Impedance connected on the right, to terminate the line.

SMA Connectors

There are three SMA connectors on the RadioProcessor-G board, all of which are used for gradient voltage outputs. Please note that in the Gradient Echo Experiment, as well as in the MRI SpinAPI, the gradient outputs are labeled as follows: output 3 is the Slice Gradient; output 2 is the Phase Gradient, and output 1 is the Readout Gradient.

Hardware Trigger/Reset Header (JP601)

The shrouded IDC header JP601 is the Hardware Trigger/Reset connector. This is an input connector, for hardware triggering (HW_Trigger) and resetting (HW_Reset). Please reference Figure 8 and Table 4 below. The recommended mating connector for header JP601 can be obtained through Digi-Key Part Number: 1658527-4-ND.

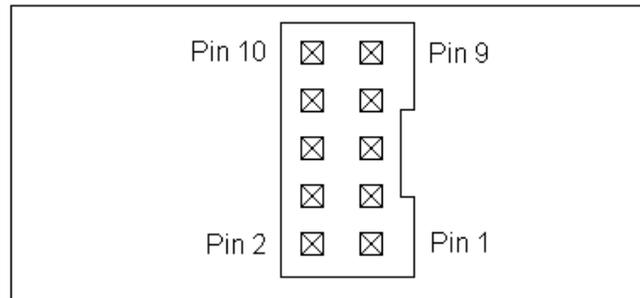


Figure 8: JP601: Hardware Trigger/Reset Header pin out

Table 4: Shrouded IDC Output Header J601 signal list.

| Pin number | Function |
|------------|----------|
| 1 | Reset |
| 2 | Ground |
| 3 | Trigger |
| 4 | Ground |
| 5 | LED0 |
| 6 | Ground |
| 7 | LED1 |
| 8 | Ground |
| 9 | LED2 |
| 10 | Ground |

HW_Trigger (pin 3) When this input is set to logical 0 (for example by shorting it with pin 4), a hardware trigger is produced. This has the same effects as issuing a trigger through software, although the hardware trigger is more precise, since there are no software latencies involved.

HW_Reset (pin 1) When this input is set to logical 0 (for example by shorting it with pin 2), the pulse program is reset.

Digital Output Header (JP600)

The unshrouded male header labeled JP600 contains two digital outputs and eight ground pins. Figure 9 and Table 5 provide visual explanations of the pinout. The recommended mating connector for header JP600 can be obtained on Digi-Key, Part Number: 1-1658526-1-ND.

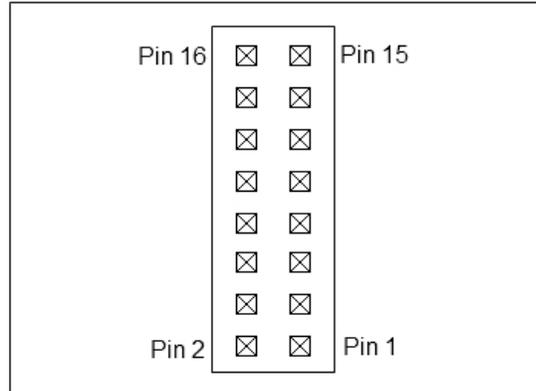


Figure 9: Unshrouded IDC Output Header J600

Table 5: Unshrouded IDC Output Header J600 signal list.

| Pin number | Function |
|------------|---------------|
| 1 | Output 3 |
| 2 | Ground |
| 3 | Output 4 |
| 4 | Ground |
| 5 | Not Connected |
| 6 | Ground |
| 7 | Not Connected |
| 8 | Ground |
| 9 | Not Connected |
| 10 | Ground |
| 11 | Not Connected |
| 12 | Ground |
| 13 | Not Connected |
| 14 | Ground |
| 15 | Not Connected |
| 16 | Ground |

Related Products and Accessories

1. Consider PBDDS line of products for second channel excitation or decoupling. For more information, please visit our RF and Arbitrary Waveform Generation section on our Products page - <http://spincore.com/products.shtml#rfgeneration>.
2. Consider iSpin-NMR for your complete, mobile NMR unit. Please visit our iSpin-NMR webpage for more information - <http://spincore.com/products/iSpinNMR/iSpin-NMR.shtml>.
3. Consider magnets and probes. For more information, please visit <http://spincore.com/products/Magnets/NMR-Permanent-Magnets.shtml>.
4. Consider complete MRI system in a small single-bay enclosure. Please inquire with SpinCore Technologies through our contact form, which is available at <http://spincore.com/contact.shtml>.
5. If you require an Oven Controlled Clock Oscillator (sub-ppm stability) or broadband pre-amplifier, please inquire with SpinCore Technologies through our contact form, which is available at <http://spincore.com/contact.shtml>

Contact Information

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Document Information

Revision history is available from SpinCore.