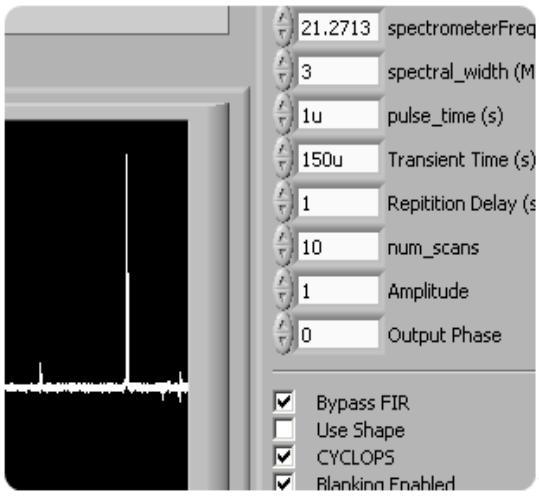
SpinCore RadioProcessor –

CPMG

LabVIEW Extensions

User's Manual



SpinCore Technologies, Inc.

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I. Overview

The SpinCore RadioProcessor LabVIEW Extensions (PBLV-RP) provide the functionality of programming and controlling RF generation and acquisition capabilities of the RadioProcessor boards as well as viewing and processing the data using the simple NI LabVIEW graphical programming interface. The package contains basic subVIs that can be used to include PulseBlasterDDS interaction from your own LabVIEW programs, as well as some complete example VIs. Additionally, all of the examples are available as stand-alone applications to control.

The CPMG VI for the RadioProcessor can quickly and easily perform CPMG NMR experiments. It is modeled after the original RadioProcessor VI, so the two interfaces operate in a very similar manner. The front panel shown in Figure 1 has all the scan parameters needed to control the CPMG, as well as the scan status feedback and data graphs. The scan parameters are used in the back-end code (known as the block diagram) and access the C functions that control and run the CPMG for the RadioProcessor board. The LabVIEW block diagram provides a one-to-one equivalent of the corresponding C code, without having to write code.

Note: For information on using the the Digital Pulse Generation functionality of the board in LabVIEW, please see the PulseBlaster LabVIEW Extensions documentation. (http://www.spincore.com/support/PBLV/PBLV_Manual.pdf). For information on using the DDS only functionality of the board please see the PulseBlaster-DDS LabVIEW Extensions documentation (http://www.spincore.com/support/PBLV/PBLV_DDS_Manual.pdf)

The Example VIs are described below.

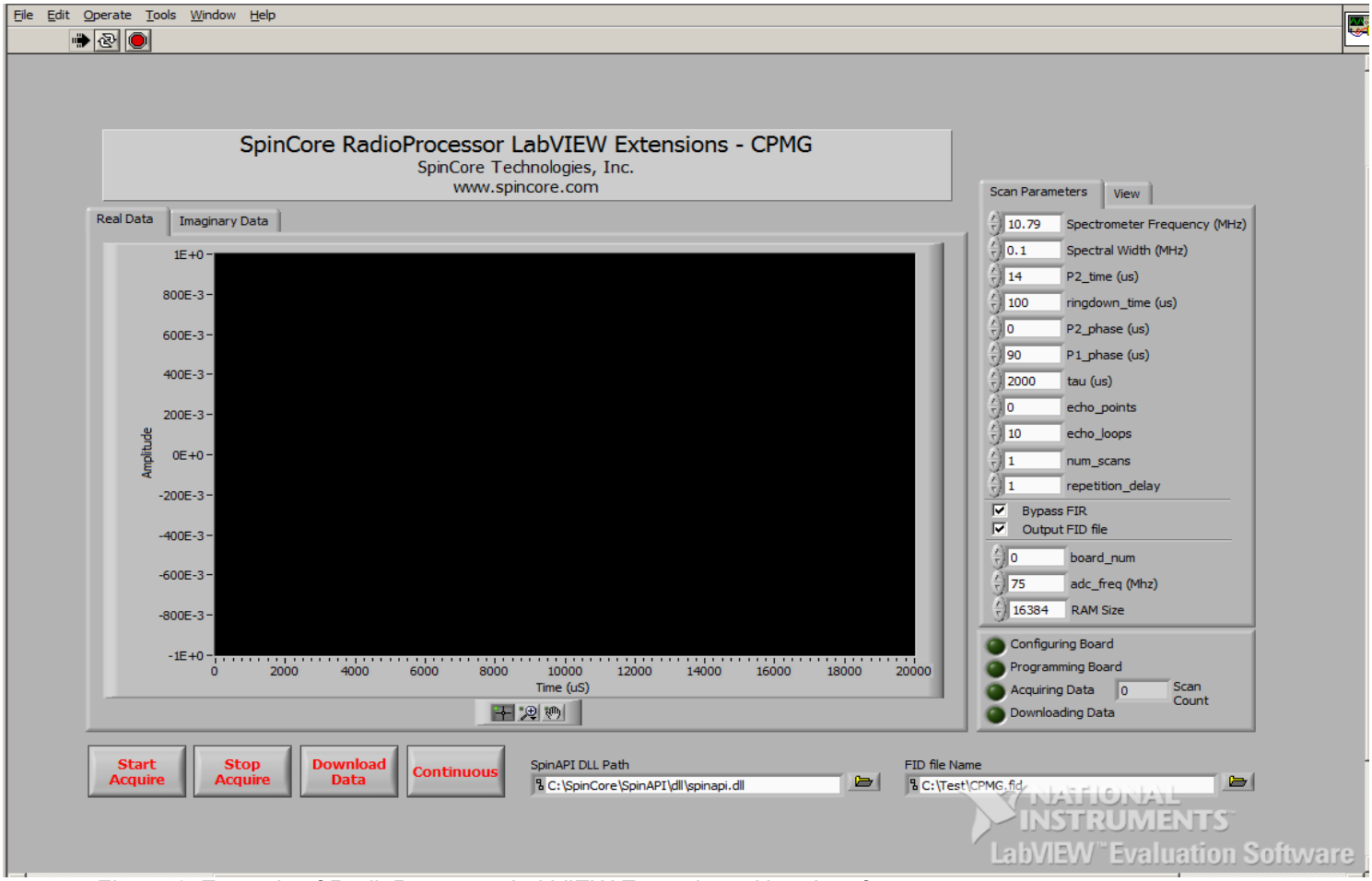

Figure 1: Example of RadioProcessor LabVIEW Extensions User Interface

II. Installation

There are two methods of using the RadioProcessor LabVIEW Extensions. The first method is a set of stand-alone executables which will control the RadioProcessor boards with a simple, intuitive interface with no other necessary knowledge of LabVIEW programming. The second method is a set of LabVIEW VIs which can be used with the LabVIEW Development platform to create custom programs using the PBLV-RP interface.

Method 1: Stand-Alone Executables

In order for PBLV stand-alone executables to work, the following must be installed:

- SpinCore Driver Suite - Please see the SpinCore Driver Suite Installation Guide (http://www.spincore.com/CD/Setup/instructions.htm) for more information.
- National Instruments LabVIEW Run-Time Engine 8.6 (http://www.spincore.com/support/PBLV/LVRTE86std.exe) - Note if you have LabVIEW 8.6 or later installed, this is not needed.
- LabVIEW PulseBlaster Extensions Stand-Alone executables
  - An updated list of the stand-alone executables can be located at http://www.spincore.com/support/PBLV/RP.shtml

Method 2: Customizable VIs

In order for PBLV-DDS customizable VIs to work, the following must be installed:

- SpinCore Driver Suite - Please see the SpinCore Driver Suite Installation Guide (http://www.spincore.com/CD/Setup/instructions.htm) for more information.
- National Instruments LabVIEW 8.5 or later - If you do not have an installation of LabVIEW 8.5 or later installed, you may download a 30-day evaluation (https://lumen.ni.com/nicif/us/lveval/content.xhtml) of the Development software.
- LabVIEW PulseBlaster Extensions
  - An updated list of the PBLV_RP packages can be located at http://www.spincore.com/support/PBLV/RP.shtml

III. General Information

Running CPMG NMR

The RadioProcessor CPMG NMR VI is an all-in-on RF Generation and Acquisition environment for use with the SpinCore RadioProcessor boards. There are two methods of running the CPMG NMR program. If you do not have a copy of LabVIEW 8.2 or later installed on you computer, or you prefer to use an all-in-one stand-alone application, you should use method 1. See section II above for instructions on installation. To run the program, simply run the executable file on your computer.

If you have LabVIEW 8.5 or newer installed on your computer, you may use method 2 as described above. When you download the PBLV-CPMG package, unzip the contents into a directory on your computer and run the file "PBLV_RP_CPMG.lvproj" to open the LabVIEW project. In the project, navigate to MyComputer>Examples>PBLV_RP_CPMG.vi and open the file. When the VI opens, click on the run button at the top of the window to start the CPMG NMR example.

> **NOTE:** The CPMG NMR program may not fit on your screen. In order to view the whole program it is suggested that you change your system display to a higher resolution. Alternately, the program can be resized by dragging the corner of the window, but doing so may cause undesirable warping of the front panel objects.

Performing a scan sequence

To perform a scan sequence using the CPMG NMR VI, you must first set up the scan parameters by adjusting the controls in the Scan Parameters tab on the right of the front panel. Each of these parameters are discussed in detail in the next section. You must also ensure that the SpinAPI DLL Path control at the bottom correctly points to spinapi.dll as installed on your system. Also if you want to save the data to disk, make sure that the FID File Name control is correctly set, and the "Output FID file" check box is checked.

> NOTE: On your initial scan, you must make sure that the spectrometer frequency is set to match your magnet and system setup. Initially the SF is set to the magnet in the SpinCore Technologies Lab and will probably not match your system setup. If you are working with the customizable VIs, you can change the default value of the SF control so that each time you start your program you will not have to change this value. To do so, right click on the SF numeric control, select Data Operations>Make Current Value Default, and save your VI.

When you are ready to perform a scan, click on the "Start Acquire" Button at the bottom of the front panel. The VI will then correctly configure and program the RadioProcessor board and then start the acquisition. The current progress of the scan is shown at the bottom right (See Figure 2). When the scan is complete, the "Start Acquire" button will raise. You can also stop the scan at any time by clicking "Stop Acquire." When you want to view the data that was acquired during the scan, clicking the "Download Data" button will download the time domain data from the RadioProcessor. At this time, the graph scales will also be adjusted and the FID file will be written (if "Output FID file" is selected). NOTE: Data can be downloaded at any time, even if all scans have not completed. After the data download is complete, you may view the real or imaginary data by selecting the appropriate tab at the top of the graphs.

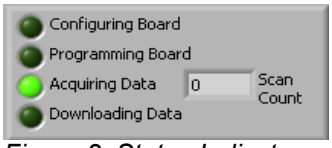

Figure 2: Status Indicators

Scan Parameters

The Scan Parameters tab includes all of the parameters required to generate and acquire data for CPMG NMR on the RadioProcessor boards. Following is a description of each parameter. More information on CPMG and the CPMG parameters can be found here (http://www.spincore.com/CPMG/).

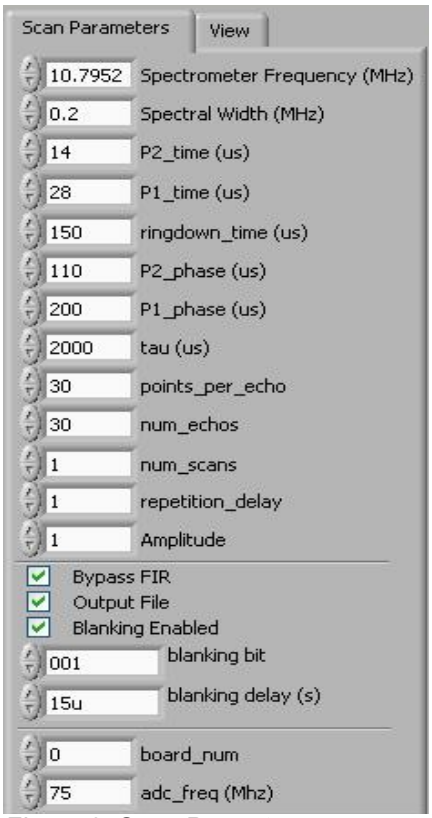

Figure 3: Scan Parmaters

- Spectrometer Freq – Spectrometer Frequency (in MHz). This is the frequency of the transmitter (should be set exactly on resonance).
- Spectral Width – Spectral Width of the baseband data in MHz.
- P2_time – Pulse length of the initial 90 degree pulse (must be greater than or equal to 0.065 us).
- P1_time – Pulse length of the 180 degree pulses (must be greater than or equal to 0.065 us).
- ringdown_time – Ringdown time (or dead time) after the 90 degree pulse (must be greater than or equal to 0.065 us).
- P2_phase – Phase of 90 degree pulse.
- P1_phase – Phase of 180 degree pulse (should be offset by +90 degrees from the P2_phase value).
- tau – 2*tau is the time between 180 degree pulses
- points_per_echo – Number of points to capture at the top of each echo. Set to 0 to do a continuous scan.
- num_echos – Number of echoes to produce.
- num_scans – Number of times to repeat the scan.
- repetition_delay – The amount of time to allow sample to relax after each scan.

- Bypass FIR – Incoming data will not pass through the FIR filter. This eliminates the need to decimate by a multiple of 8. This is useful to obtain large or very small spectral widths, or in circumstances where the FIR is deemed unnecessary. Please see the RadioProcessor manual for more information about this option.
- Output FID file – With this option selected, the scan data will be written to an FID file after the data is downloaded to the PC. FID files can be viewed using Felix for windows. More information about this software can be found here (http://spincore.com/CD/RadioProcessor/felix/Felix_Instructions.html).
- Blanking Enabled – Use TTL power amplifier blanking. With this enabled, the RadioProcessor will set the TTL bit(s) as specified in "blanking bit" to high while the transmitter is enabled and then set the same bit(s) low when the transmitter is disabled.
- Blanking Bit – hexadecimal representation of the TTL bit to use for power amplifier blanking.
- Blanking Delay – Length of time to wait with the blanking bit turned on before enabling the transmitter. This will compensate for the time the power amplifier needs to "warm up" before the RF pulse can be generated.
- Board Num – Board number to use for the NMR scan. If you have more than one SpinCore board installed in your system they will be numbered starting at 0. PCI boards will be listed first starting from the closest slot to the processor and then USB boards are listed after these. Experimentation might be necessary to accurately determine which number refers to which physical board.
- ADC Frequency – The frequency (in MHz) of the crystal oscillator on your RadioProcessor board. This value should always be 75 MHz unless a custom design with a different ADC frequency is being used.

Data Graphs

The data graphs are the largest part of the CPMG NMR front panel and display the scan data that is downloaded from the board. There are 2 different views which can be changed by selecting the appropriate tabs at the top (see Figure 1).

- Real Data – shows the real time domain data. The x-axis can be displayed in either microseconds or points by selecting the appropriate option under the process tab on the right.
- Imaginary Data – shows the imaginary time domain data. The x-axis can be displayed in either microseconds or points by selecting the appropriate option under the process tab on the right.

The graphs can be moved and manipulated in order to examine the data. To do this you must use the graph palette which is a set of three icons at the bottom of each graph (see Figure 4). The icons are:

- Cursor Movement Tool – Unused.

- Zoom — Zooms in and out of the display. click the Zoom button and select from the following options, clockwise from the top left, to zoom in and out of the graph (see Figure 5):
  - Zoom to Rectangle — With this option, click a point on the display you want to be the corner of the zoom area and drag the tool until the rectangle covers the zoom area.
  - X-zoom — Use this option to zoom in on an area of the graph along the x-axis.
  - Y-zoom — Use this option to zoom in on an area of the graph along the y-axis.
  - Zoom In about Point — With this option, click a point you want to zoom in on. Press and hold the <Shift> key to switch between Zoom In about Point and Zoom Out about Point.
  - Zoom Out about Point — With this option, click a point you want to zoom out from.
  - Zoom to Fit — Use this option to autoscale all *x*- and *y*-scales on the graph or chart to view the entire graph.
- Panning Tool — Drags the plot and moves it around on the display.

Figure 4: Graph Palette

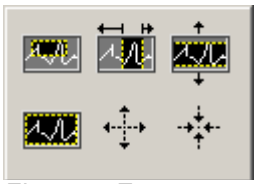

Figure 5: Zoom Palette

NOTE: The x-axis scale marker on the graph may not show 0 Hz or any other helpful frequency divisions. This is a problem with manipulating the scales on LabVIEW charts or graphs. To show more helpful frequency divisions, simply select the panning tool and slightly move the graph in any direction. This will fix the scale until you close the CPMG NMR program.

View Tab

The View tab has some options for viewing the graphs (See Figure 6)

- Time Domain Data Units – Changes the x-axis units of all time domain graphs to either microseconds or points.

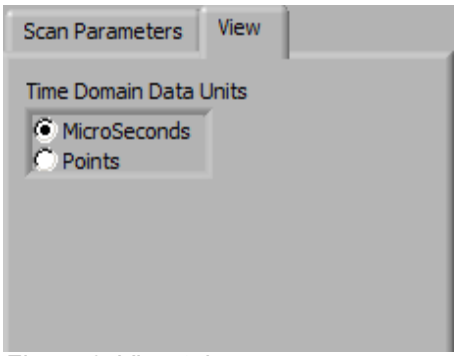

Figure 6: View tab

Other Front Panel Controls

There are some other important controls on the front panel of the CPMG NMR VI (see Figure 7):

- SpinAPI DLL Path – This points to the spinapi.dll file that is installed on the PC. By Default this file is installed to C:\Program Files\SpinCore\SpinAPI\dll\spinapi.dll but if this was installed in a different location, the path to it must be changed.
- FID File Name – The location and name of the FID file to be saved to disk (if "Output FID file" is selected). If the file or directory does not exist, it will automatically be created. NOTE: If a file with the same name exists, it WILL BE OVERWRITTEN. If you would like to create new files for each scan, ensure that you change the file name before each scan is started.
- Start Acquire – Pressing this button will configure and program the board based on the parameters specified, and then start the acquisition. The status will be shown on the LEDs on the right of the screen and the scan count is displayed. When the scan is complete, all LEDs will turn off and the Start Acquire button will pop back up.
- Stop Acquire – Pressing this button during a scan will stop the acquisition regardless if all scans have completed.
- Download Data – This will download all scan data from the RadioProcessor board. This can be done at any time regardless of if the scan is complete or not.
- Continuous – Continuously programs the board, acquires a scan, and downloads the data until the Continuous button is pressed again. While the scans are taking place, any of the parameters can be altered and the process functions can be run.

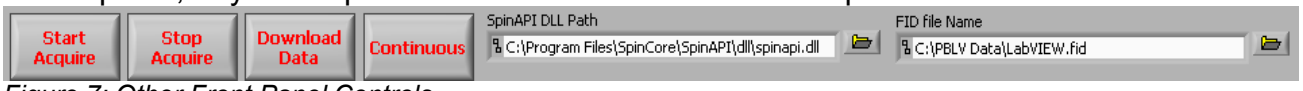

Figure 7: Other Front Panel Controls

Error messages

Errors may result from two sources, either SpinAPI or LabVIEW. Errors resulting from SpinAPI have an error code 0 and the error message is of the form "Error 0 occurred at <some SpinAPI error message>." If the error message is unclear, you may check the

SpinAPI documentation for more information, or contact SpinCore Technologies for assistance. Following are some common error messages that can be seen:

- No Board Present – there are no RadioProcessor boards installed in your system. If using USB RadioProcessor, ensure that the board has power and the USB cable is connected to your system.
- Board number out of range – board_num is greater than the number of boards detected in your system. The maximum board number is the number of boards in the system minus one (Board numbering starts at 0).
- dec_amount out of range – one of your scan parameters is inappropriate for the board you are using (most likely the spectral width). Try changing the scan parameters or unselecting "Bypass FIR" to clear this error.
- Instruction delay is too small to work with your board – one of your time controls are too short for the board. Try increasing the time to a value large enough for your board. See the manual for your specific board for more information.
- Your version of the RadioProcessor does not support data acquisition. - Data acquisition has been disabled on your version of RadioProcessor. Contact SpinCore Technologies for assistance in upgrading your board.
- Board does not support DDS shape capabilities – Shaped pulses have been disabled on your version of RadioProcessor. Contact SpinCore Technologies for assistance in upgrading your board.
- Data transfers must be a multiple of 8k points – You are using a USB RadioProcessor which can only download a multiple of 8k data points. You can still acquire data at a different number of points, but when you download the data, you must change num_points to an appropriate value.

Errors with any other Error Code than 0 are LabVIEW related errors. Error 7 usually occurs when the path to spinapi.dll is incorrect and should reflect the location of this file. For other errors please view LabVIEW's documentation or contact SpinCore Technologies for more help.

Advanced VI Customization

For users with LabVIEW 8.2 or later installed, you can use the VIs included in the project to write your own RadioProcessor programs. Almost all of the SpinAPI functions are included in the package and can be used just as in C and are name accordingly (e.g. the C function pb_init() is represented with the VI pb_ini.vi). See the SpinAPI documentation for more information on each of these functions. There are also some other VIs used in the CPMG NMR VI that are not SpinAPI functions:

- build_inst_rp – combines the RadioProcessor instruction parameters into a Instruction cluster for use with other RP VIs (see SpinAPI documentation on pb_inst_radio_shape() for more information on the instruction parameters).
- ConfigureBoard.vi – configures the board for programming.
- ProgramBoard.vi – programs all frequency and phase registers, and programs the instruction memory with the Single Pulse NMR program.

Any of these VIs can be combined or changed to match the users specific needs. Following is information on some of the LabVIEW programming techniques used in the PBLV extensions to help better understand the flow of the program.

Path Terminals

All of the SubVIs have path input and output terminals. This is a reference to the path where spinapi.dll is installed on the PC. The default is C:\Program Files\SpinCore\SpinAPI\dll\spinapi.dll however this may be changed depending on the installation. All subVIs should have the path in connected. For ease of programming, the path terminals can be daisy chained since all subVIs point to the same dll. See Figure 8 and Figure 9 for an example of chaining these terminals.

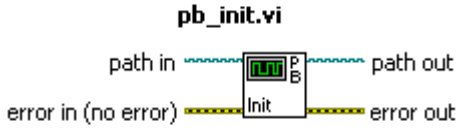

Figure 8: Path and error terminals

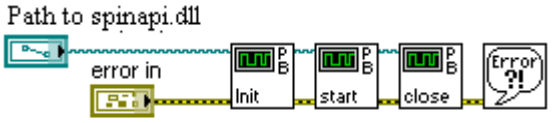

Figure 9: Example of chaining path and error terminals

Error Terminals

All of the SubVIs have error input and output terminals. When a VI is built, the error out terminal of a subVI should be connected to the error in terminal of the following subVI. These terminals are used to help facilitate sequential execution of the functions, as well as provide debugging information to the user if an error occurs in the VI. See Figure 8 and Figure 9 for an example of these terminals. When chaining, the order of the subVIs corresponds to the order in which the functions will be called.

LabVIEW Program Flow

The LabVIEW Block diagram is set up to independently control all major functions (Start Acquire, Stop Acquire, Download, etc) using while loops running in parallel. Within each loop is another loop that continuously waits for the specified button to be pressed. Once the button is pressed, the inner loop will exit and program flow will be passed to the chain of subVIs. After the chain of functions complete, program flow will return to the inner loop to wait for the button again. An example of this is shown in Figure 10.

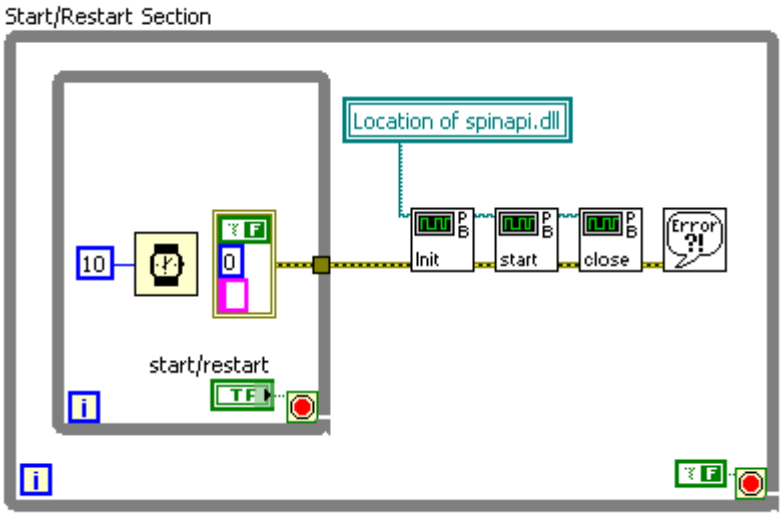

Figure 10: LabVIEW Program Flow Example

IV. Contact Information

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