EUROPEAN JOURNAL OF BIOMEDICAL AND PHARMACEUTICAL SCIENCES
http://www.ejbps.com

ISSN 2349-8870
Volume: 8
Issue: 9
446-448
Year: 2021

EFFICIENT IMPLEMENTATION OF CONTROLS FOR GRADIENT AMPLIFIER IN MRI SYSTEM

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Article Received on 01/07/2021 **Article Revised on 21/07/2021** **Article Accepted on 11/08/2021**

ABSTRACT

Development in NMR fields has taken a new turn with the development of MRI System. NMR principle involves energy transfer and emission by electrically charged nuclei at a particular radio frequency after application of an external magnetic field. The main objective of this description is to provide details regarding implementation of controls for Gradient Amplifier System. Gradient amplifier NG 500 is connected to the MR systems through any available protocol for operating the gradient functionality. This communication helps in individual tuning of the three coils, offset compensation of the axes. It also provides the profile generation tool to input dummy waveforms to the amplifier and observe the generated current and voltage waveforms in oscilloscope.

KEYWORDS: *Gradient Amplifier, MR System, Interface.*

I. INTRODUCTION

When the MRI system is in a resting state and not actually producing an image, the magnetic field is quite uniform or homogeneous over the region of the patient's body. However, during the imaging process the field must be distorted with gradients. A gradient is just a change in field strength from one point to another in the patient's body. Gradients are simply loops of wire or thin conductive sheets on a cylindrical shell that lies just inside the bore of an MRI machine. When an electrical current passes through these coils, the result is a secondary magnetic field. This gradient field distorts the main magnetic field in a slight but predictable pattern. This causes the resonance frequency of protons to vary in a function of position. The main function of gradients is to allow spatial encoding of the MRI signal, but is also critical for a wide range of physiologic techniques. Examples includes MR angiography, diffusion ad perfusion imaging.

II. Literature survey

The process to produce an MR image includes nuclear alignment, RF excitation, spatial encoding, and image formation. In simple terms, a magnetic resonance imaging (MRI) system consists of five major components: a magnet, gradient systems, an RF coil system, a receiver, and a computer system. To form an image, it is necessary to perform spatial localization of the MR signals, which is achieved using gradient coils. In modern MRI, gradient coils are able to generate high gradient strengths and slew rates are required to produce high imaging speeds and improved image quality. MRI also requires the use of gradient coils that generate magnetic fields, which vary linearly with position over the imaging volume. Gradient coils for MRI must therefore have high current efficiency (defined as the ratio of gradient generated to current drawn), short switching time (i.e., low inductance), gradient linearity over a large volume, low power consumption, and minimal interaction with any other equipment, which would otherwise result in eddy currents.

III. METHODOLOGY

In this system, we have been provided with the technical documents regarding information for interfacing the gradient system through various modes. We have 3 interfaces: NGToolSuite software, Optical connection interface, and a 15 pin control connector. After establishing connection with the system, we can have an overlook of the internal blocks of the system, the tuning of each coil can be performed, offset compensation of the system, through serial to RS422 converter, we establish the LabVIEW connection and we try sending echo command through serial port. We can also access various registers in the NgCtrl register, which reflects the state and control signals in system control module of the amplifier.

IV. Implementation techniques

1) NG Tool Suite interface

The Gradient Amplifier system is three axes system, which can be used in a MRI system to control the X, Y and Z gradient coils respectively. It has RS422-based interface intended for control and diagnostics of MRI system host. This communication interface uses the RS-422 electrical standard that has UART protocol to transfer characters between the Gradient amplifier and National Instrument compact RIO (NI-cRIO) controller.

Fig. 1: NG 500 model.

Rs232 To Rs422 converter

This converter is suitable for convenient RS232 to RS422 conversion. It has a supply voltage range of 10-30V and a 16-bit resolution.

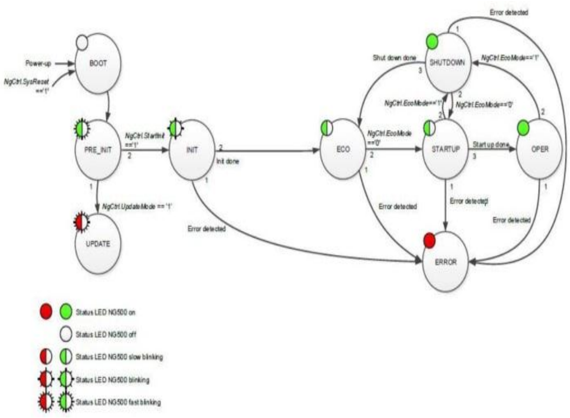

Fig. 2: NG500 State diagram.

We create a DHCP server, through which IP address is assigned to the system and it is connected in the network. The software has provided us with numerous functionalities like tuning of each coil, offset compensation, profile generation tool, and few status registers that helps us in traversing of amplifier through its various states.

Doorbells

Doorbells send by the GA are used for system error and warning notifications. The CLKSYS_ISET is added to the GA and can be selected by the ClkSync mux for system clock synchronization through the optical interface. This clock of 100 kHz is generated by the ClkGen using the optical interface Multicast-Event (MCE) symbols. The MCE symbol is a standard Serial Rapid IO symbol for synchronizing systems sent at 100 kHz speed. Current setpoints written to the *SpIsetMod[X, Y, Z]* registers are buffered in FIFO[X, Y, Z]. Each FIFO can hold up to 512 current setpoint samples, which can be used for pre-buffering samples and bursting samples into the FIFO.

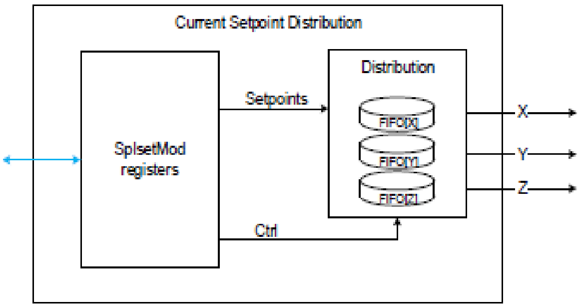

Fig. 3: Current Setpoint distribution block diagram.

Specific formulae for bandwidth calculation for MCE and current setpoint transaction are provided accordingly.

2) *CN_CONTROL connector*

There is a provision of CN_CONTROL for provision of enable and interlock inputs as well as for command transfers that happens in telegram frame format transfer.

Pin	Mnemonic	Dir	Type	Remarks
1	*RS422_TX_P*	O	RS422	Positive NG500 communication interface Tx, MRI system host Rx.
2	*RS422_RX_P*	I	RS422	Positive NG500 communication interface Rx, MRI system host Tx.
3	*GND*	-	-	Ground.
4	*ENABLE_IN_P*	I	Table 3.5	Positive external hardware enable input.
5	*INTERLOCK_IN_P*	I	Table 3.6	Positive system interlock input.
6	*INTERLOCK_OR_IN_P*	I	Table 3.6	Positive system interlock override input.
7	*FAULT_OUT_P*	O	Table 3.7	Positive fault output.
8	*IO_SUPPLY*	O	PWR	Positive power supply output for control signals.
9	*RS422_TX_N*	O	RS422	Negative NG500 communication interface Tx, MRI system host Rx.
10	*RS422_RX_N*	I	RS422	Negative NG500 communication interface Rx, MRI system host Tx.
11	*ENABLE_IN_N*	I	Table 3.5	Negative external hardware enable input.
12	*INTERLOCK_IN_N*	I	Table 3.6	Negative system interlock input.
13	*INTERLOCK_OR_IN_N*	I	Table 3.6	Negative system interlock override input.
14	*GND*	-	-	Ground.
15	*FAULT_OUT_N*	O	Table 3.7	Negative fault output.
C	Chassis	-	-	Chassis is connected to housing.

Fig. 4: Control connector pins.

Telegram frame format

A transaction is always started by the host transmitting a telegram frame (Tlg) and the Gradient amplifier replies with a reply telegram frame (TlgRpl). It benefits read and write commands allow access to all memory mapped registers of the gradient amplifier, same or auto increment the address and the heartbeat protection is optional; only until after the first heartbeat is detected the heartbeat monitoring is started and missing heartbeat result is an error.

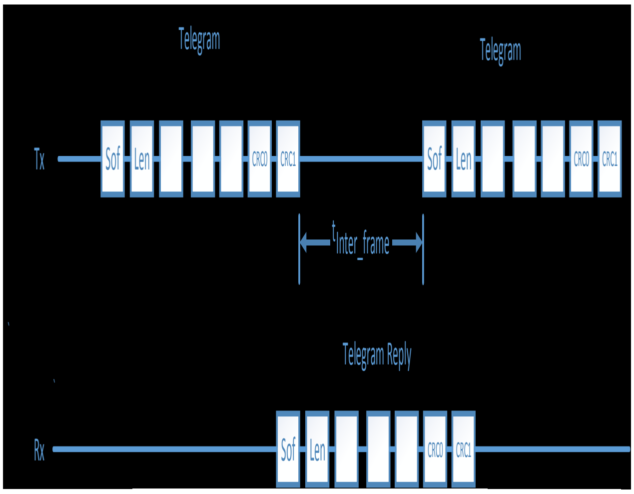

Fig. 5: Telegram frame format.

Lab view

labview is systems engineering software for applications that require test, measurement, and control with rapid access to hardware and data insights. LabVIEW offers a graphical programming approach that helps you visualize every aspect of your application, including hardware configuration, measurement data, and debugging. That makes it simple to integrate measurement hardware from any vendor, represent complex logic on the diagram, develop data analysis algorithms, and design custom engineering user interfaces.

V. RESULT AND DISCUSSION

Basically, we have seen overview of the system internals, how it is operated via various communication interfaces. The tuning was done for all the three individual axes. Adjustment in linearity corrections, tuning parameters, compensating few current generation parameters leads to changes in magnitude and phase graphs of frequency response of each axis. These graphs are monitored to ensure the minimization of eddy currents. The figure shows the NGToolSuite interface, similarly, through serial interface, the LabVIEW code implementation of various command transfers.

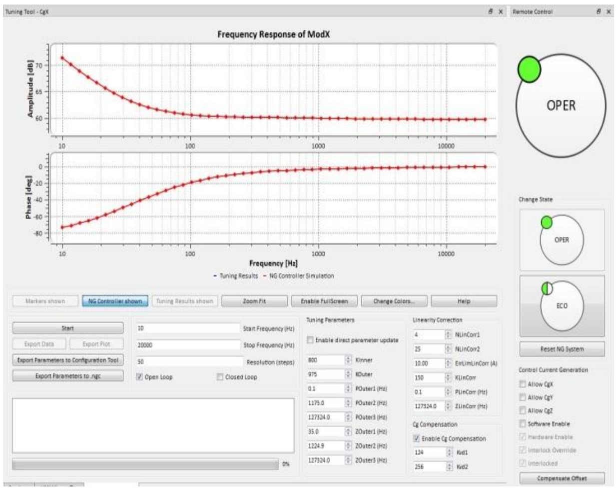

Fig. 6: Tuning process in NG Tool Suite.

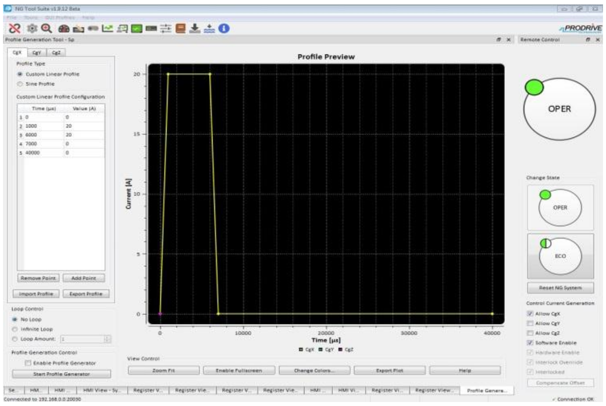

Fig. 7: Profile generation tool.

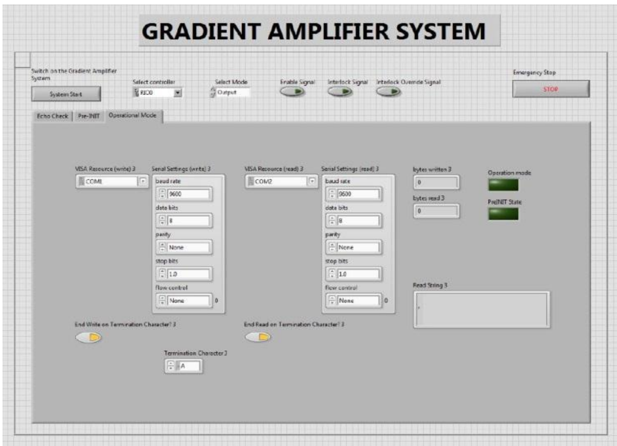

Fig. 8: labview HMI.

The hardware used in LabVIEW approach was National Instruments cRIO controller, with NI 9401 module for hardwired signal generation enabling purpose. The state machine register read/write flow will lead us to operation mode. The commands are transmitted serially through RS232 to RS422 converter to the gradient amplifier.

VI. CONCLUSION

In this Paper, we have briefly explained hardware mode of interface with Gradient Amplifier. The further work will include upgradation of LabVIEW code for full functionality of the system which will lead to independent operation of the system.

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