ECONTECHMOD. AN INTERNATIONAL QUARTERLY JOURNAL – 2016, Vol.5, No.4, 73-78

DISTRIBUTION SYSTEM FOR GENERATING SLOWLY VARYING MAGNETIC FIELDS

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Received November 21.2016: accepted December 21.2016

Abstract. The presented system describes a concept for generating slowly varying signals to stimulate biological objects with magnetic field. The system enables independent control of up to 10 induction coil and it generates changeable signal inducing magnetic fields in the range from 0.1 to 150μT and the frequencies from 0.1 to 100 Hz. The proposed system was applied to investigate the influence of magnetic fields with the aforementioned parameters on physical and chemical properties in selected types of fruits.

Key words: magnetic fields, magnetic stimulation, coils.

INTRODUCTION

The developed system of magnetic stimulation, based on inducing slowly varying magnetic fields and applying a microcomputer control module, enables generation of fields with induction ranging from 0.1 to 150μT at varied frequencies from 0.1 to 100Hz. Magnetic fields induced in this way were used to magnetically stimulate three groups of fruit, i.e. apples, strawberries and tomatoes.

Today, there are no doubts that magnetic fields affect living organisms. The effects, briefly speaking, depend only on magnetic field strength and on the characteristics of the living organism [1].

There is a close link between magnetic field changes and the pathways of essential life processes on Earth, manifested in the rhythms of physiological, biochemical, genetic and biophysical processes. Hence, magnetic fields may favourably impact and enhance vegetation of crops [5].

This is because plant organisms may be treated as specific antennas receiving electromagnetic waves from the external environment. As a result of this phenomenon enhanced by resonance effect, frequently very low energy leads to significantly stronger effects [15].

Numerous studies suggest that cell membranes play a part in the perception of the geomagnetic field. A magnetic field, in the range from 0.2Hz to 100Hz, also produces changes in membrane permeability. According to Davson–Danielli model from 1935, cell membrane may be treated as an electrical condenser, filled with an imperfect dielectric, built of two lipid layers, which are enriched, in accordance with Singer and Nicolson model from 1972, with carrier protein molecules floating in it [1].

The magnetic component of a slowly changing field causes ordering action in magnetic dipoles, interacts with moving charges as well as neural networks, and induces generation of rotating currents providing the resonance effect which involves opening of ion channels; it also affects uncompensated electron spins and liquid crystals contained in organisms [16].

Futures were many investigations about magnetic field systems and their influence on living organisms. Gut in 2007 used coil with autotransformer for potatos stimulation [4]. Kornarzynski et al. in 2004, 2005 and 2008 used electromagnet equipment for seeds stimulation [5-8]. Ciesla et al. in 2015 presents their superconducting electromagnet to provide very high magnetic field induction [2]. Marks and Szecowka in 2011 built solenoid system with glycol cooling for potatoes seedlings stimulation [9].

Many researchers using also magnetic systems for water condition improving. Systems like this were presents by: Podlesny and

Gendarz [12, 13], Matwiejczyk et al. [10], Pietruszewski et al. [11], Podsiadlo and Lesniak [14,], also Coey and Cass [3].

The developed magnetic field generator system fills a gap in the market by providing mobile laboratory equipment designed for magnetic stimulation carrying out about stability of magnetic field using the resistant temperature coefficient.

MFG SYSTEM, PARAMETERS AND PURPOSE

The developed MFG (Magnetic Field Generator) system is designed to generate sinusoidal slowly varying magnetic fields, and consists of: CompactRIO-9074 controller; NI 9265 current source modules; magnetic field generating solenoid coils with double-pull four-layer copper wire winding with double insulation, with the cross-section of 0.4 mm; NI PS-15 AC adapter with output power of 120W; a computer with web browser or installed LabVIEW environment; connection cables.

The system enables the generation of magnetic fields with the amplitudes of field-B induction from 0.1 to 150μT, with frequency f from 0.1 to 100 Hz. It also controls up to 10 coils, whose parameters can be programmed independently.

Description of MFG system operation

The operator (client) uses a PC with a web browser (installation of free software Run Time Engine from National Instruments is required) to open the Front Panel of MFG.vi control program.

The operator can change the settings of frequency *f* and magnetic induction *B*, and set the time during which magnetic field will be generated; they can read or save the settings, and check the operating accuracy of the current modules and the power supply of the coil.

The heart of the system is CompactRIO-9074 controller which combines an embedded real-time processor and programmable FPGA matrix. The processor is clocked at the frequency of 400Hz, and has 128MB of primary storage and 256MB of non-volatile storage.

The real-time system is supported by FPGA Spartan-3 provided with 46,080 logic cells, which yields two million logic gates. The controller has 8 slots for interchangeable input/output modules, which are operated by FPGA; that results in high speed, synchronization and the ability to reprogram the individual inputs/outputs.

The system uses five NI 9265 output modules (4-channel current source of 0-24mA and 100k Samples/s).

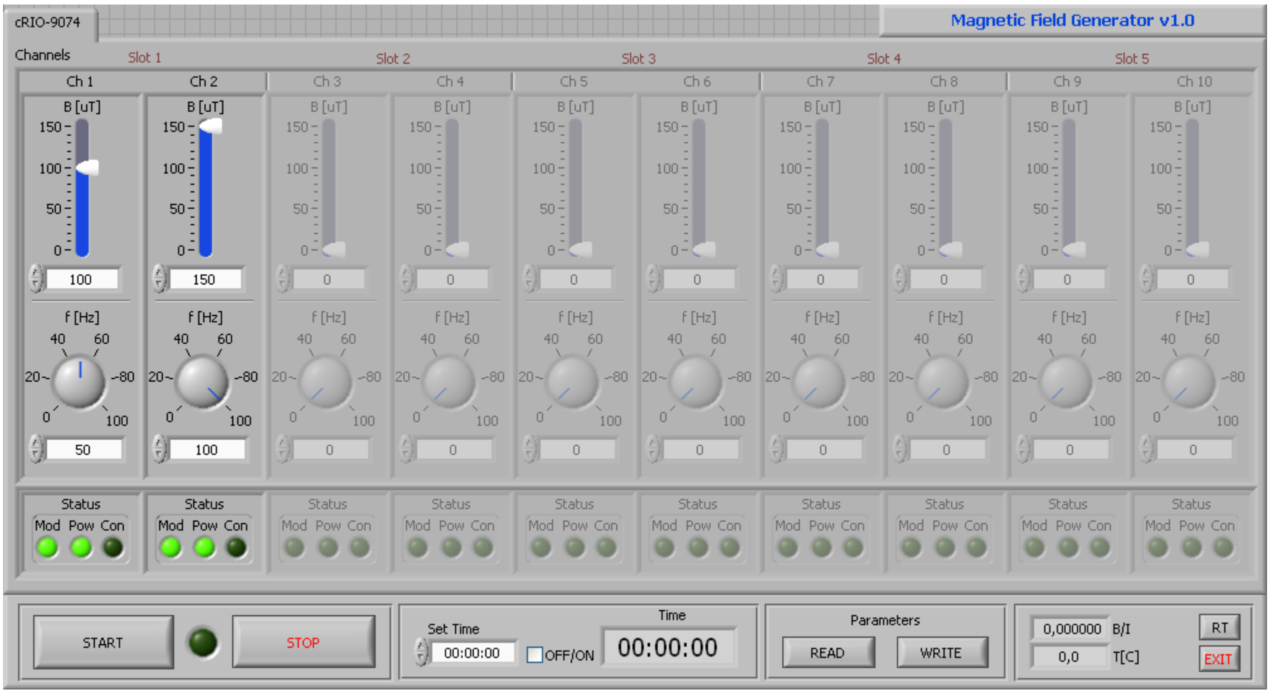

Fig. 1. Control panel for system parameters

Brief description of LabVIEW graphic environment

Programs written in LabVIEW, known as virtual instruments ("vi"), consist of two interconnected layers. The first one, called Front Panel, is an equivalent of the front wall of the device, which features input/output controls: switches, knobs, displays, etc. The second layer called Block Diagram is the actual code of the program, and it is an equivalent of the internal structure of the device, its electric circuit. It shows the interrelations occurring between the Front Panel elements. These relations can be either simple mathematical-logical operations or highly complex functions. Controls and functions are represented by icons linked together by wires, which are used for data exchange between various components. The flow of data along the wires determines the sequence in which the specific parts of the program code are carried out.

LabVIEW provides a convenient and rapid method for programming control and measuring devices. cRIO-9074 controlling software was developed in LabVIEW 2010 environment from National Instruments.

The code of program providing control in the real-time system was created with the use of additional LabVIEW Real-Time Module, and the FPGA matrix was programmed with the use of LabVIEW FPGA Module.

Software description

This software, installed on cRIO-9074, can be divided into two basic parts. The first one is responsible for Host control, real-time system and its main task is to communicate with the client using a built-in web server, to download the settings and to publish the updated parameters on the Front Panel, as well as to pass them on to the code executed by the hardware in the FPGA matrix. The code of this part was implemented in the state machine architecture with two loops responsible for handling the keys and refreshing the readings of the current module status as well as the temperature inside the controller (Fig. 2).

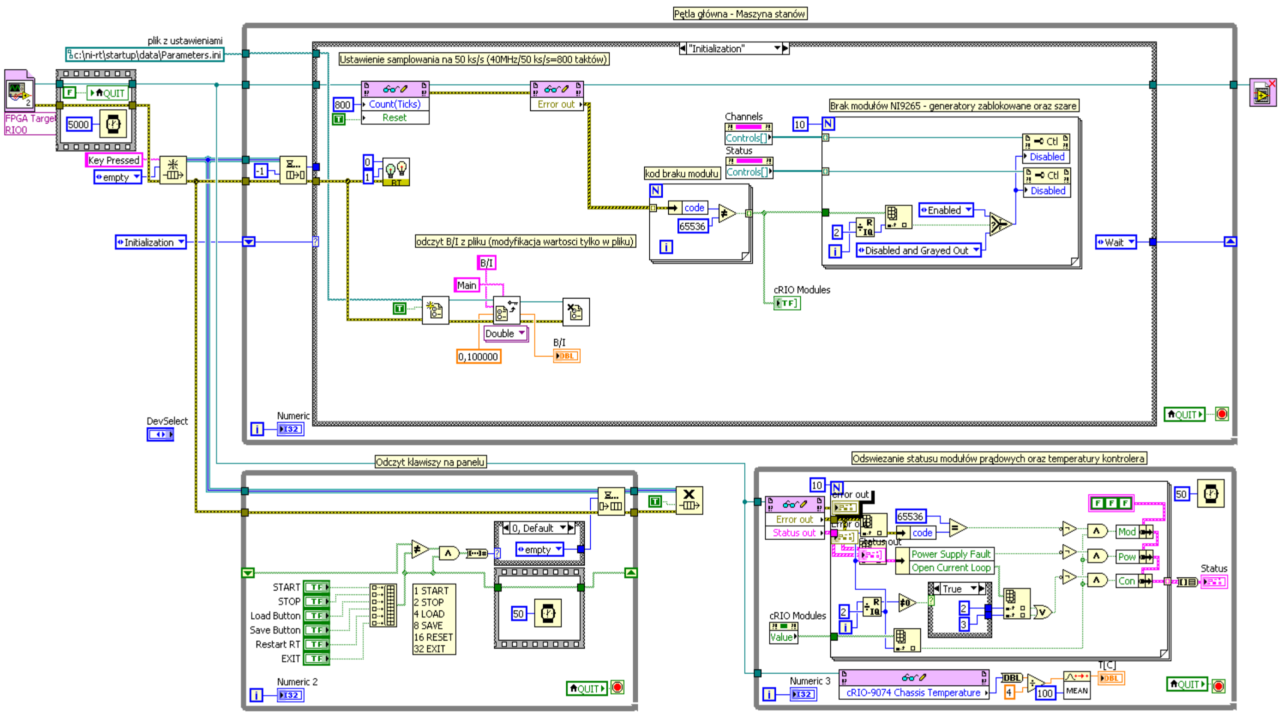

Fig. 2. Code in the state machine architecture responsible for Host control

The second part is the code used for programming the FPGA matrix which produces hardware-managed code generating 10 pairs of independent sinusoidal waveforms with amplitudes and frequencies set by the Host software (Fig. 3).

Samples of the sinusoidal waveform curve can be found in the lookup table. One period contains 1,024 samples. Since the NI 9265 module does not have the feature of generated current direction change, the charge of the current sample (positive or negative value) determines which of the double-pull coil windings is powered. The operating frequency of FPGA system is 40MHz and the main loop executed on it waits 800 clock cycles and is performed at the frequency of 50kHz.

This is the frequency with which current source modules "refresh" their outputs, regardless of the programmed frequency f. This results in smooth sinusoids, simultaneously for all the waveforms, even at extreme settings of frequency f.

Application of the system and preliminary findings

The proposed system of magnetic stimulation was used during the vegetation of crops whereby their fruits were magnetically stimulated a few times, with the use of six 5-minute long doses and with intervals of five days between the consecutive treatment cycles.

The fruits were placed centrally within the coils to ensure uniform distribution of the magnetic field affecting the object (Fig. 4). The findings were analyzed with the use of Vizimag 3.19.

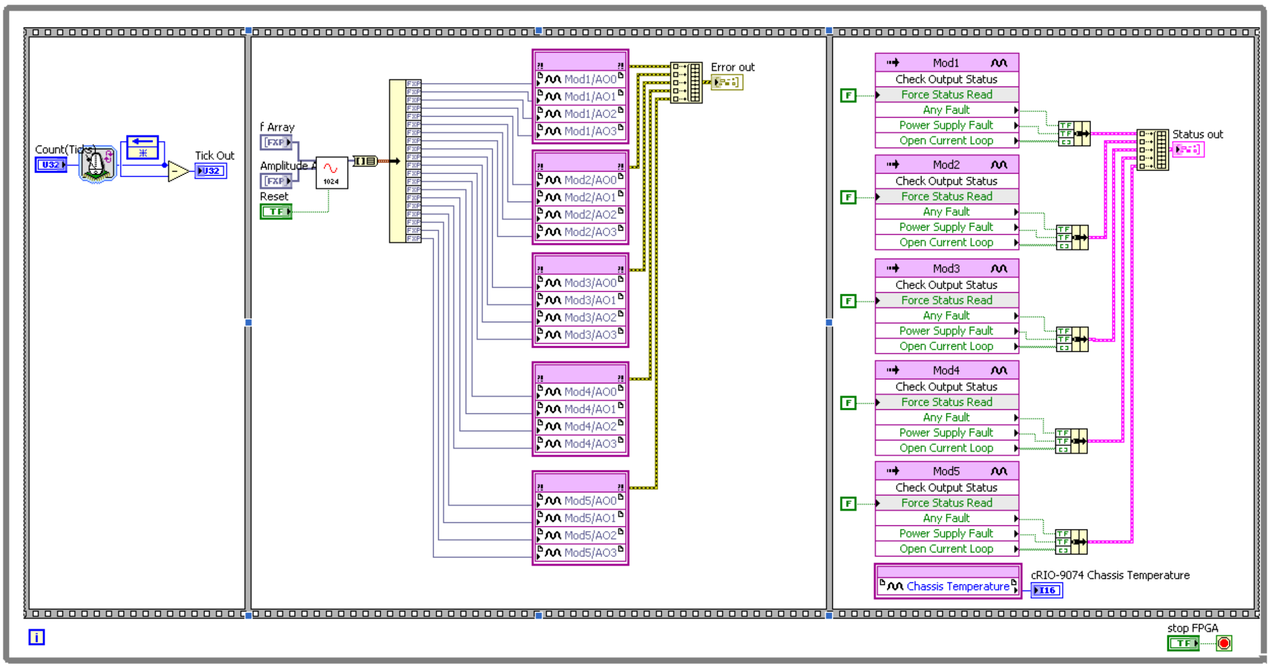

Fig 3. Generating code for the FPGA matrix

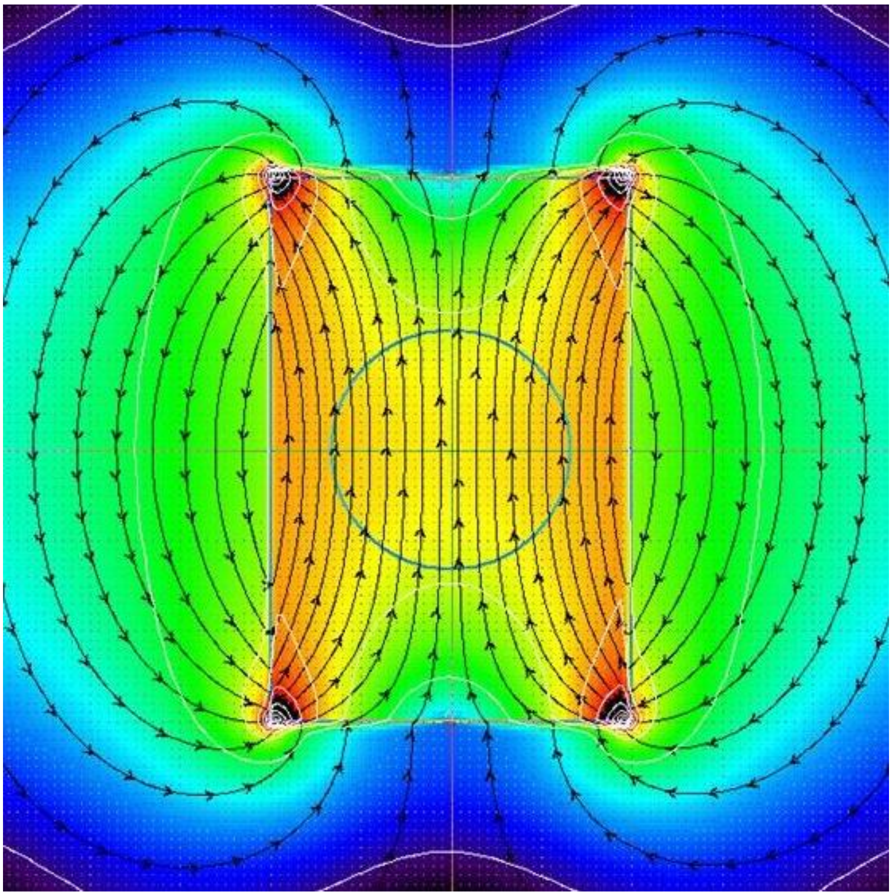

Fig.4. Model distribution of magnetic field in the applied solenoid

CONCLUSIONS

The stimulation treatment led to improved taste of the fruits resulting from increased contents of simple sugars, i.e. glucose and fructose, which were analyzed using a near-infrared Fourier spectrophotometer FT-NIR MPA from Bruker Optics. The proposed magnetic field generation concept has been patented as an invention: A device generating variable magnetic signals to stimulate biological material, under the number P.399624.

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