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Design of Control System for the Transmitter of iFTEM Type Time-domain Fixed-wing Airborne Electromagnetic Survey System

[1] Yong Guo, [1] Zhiqiang Yang, [1] Xiaoling Zhong, [2] Junfeng Li, [2] Wenjie Li

[1] Chengdu University of Technology; No. 1, Dongsan Road, Erxianqiao,
Chenghua District, Cichuan Province, 610059, China

[2] Institute of Geophysical and Geochemical Exploration, CAGS;
No. 84, Jingguang Road, Langfang City, Hebei Province, 065000, China

[1] Tel.: 028-84078283, fax: 028-84078283
E-mail: guoy@cdut.edu.cn

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Abstract: To meet the need of a transmitter of domestic iFTEM type time-domain fixed-wing airborne electromagnetic survey system, we design a control system based on PC104 bus for iFTEM system. This system consists of a driving signal generator, synchronization control system, protection control system, voltage, current monitoring and transmitter waveform monitoring. In the design, we use WinDriver to develop a driver for the PC104 driving signal generator and design a practical control panel for the control system by using LabVIEW. The control system has advantages of small size, high reliability and being easy to operate. Experiments shows that our system is stable and reliable, achieves controlling over the transmitter of iFTEM system, and holds its reference value in research of domestic time-domain fixed-wing airborne electromagnetic method. *Copyright © 2013 IFSA.*

Keywords: Time-domain fixed-wing airborne electromagnetic survey system, Transmitter, Control system, PC104, WinDriver, LabVIEW.

1. Introduction

In 2007, Institute of Geophysical and Geochemical Exploration of CAGS began the research on iFTEM system; iFTEM system is a time-domain fixed-wing aircraft electromagnetic survey system. Time-domain fixed-wing aircraft electromagnetic method takes a flying fixed wing aircraft as the carrier, produces a large transmitting magnetic moment through the transmitter loop wired around the aircraft, thus to stimulate the earth to produce a secondary induction field, and then uses the electromagnetic field theory to analyze this secondary field response in order to get the geological information of hundreds of meters depth [1]. Advantages of this method include high speed, being free of ground conditions (such as sea, river, lake and desert), relatively uniform working accuracy, and being able to work in the case of complex terrain conditions. Now this method is gaining more and more attention in the geophysical field.

After half a century of development, foreign time-domain fixed-wing airborne electromagnetic method and the instrument system have become mature. Now systems widely used over the world and getting good results in practical applications are GEOTEM, MEGATEM and MEGATEMII system developed by Canadian Fugro [2, 3], TEMPEST system from the Joint Research Centre of the Australian mineral exploration [4] and the SPECTREM system from South African Anglo American Corporation (AAC) [5]. So far the method has found good application in mineral resources exploration [6], large area geological mapping [7], hydrogeology, engineering geology [8], expedition and environmental monitoring [9]. However Chinese domestic time-domain fixed-wing airborne electromagnetic method and its instrument industry have been left behind many other countries. In 1970s, Changchun College of Geology, Heilongjiang Geological Bureau and some other institutions did research and developed the first set time-domain airborne electromagnetic system M-1 induction pulse transient airborne electromagnetic instrument. In 1977, M-1 gained national recognition [10], but because of various reasons, the system had not been able to put into actual production. Since then our country has not carried out any related research. So far our country still does not have a time-domain fixed-wing airborne electromagnetic survey system in real production.

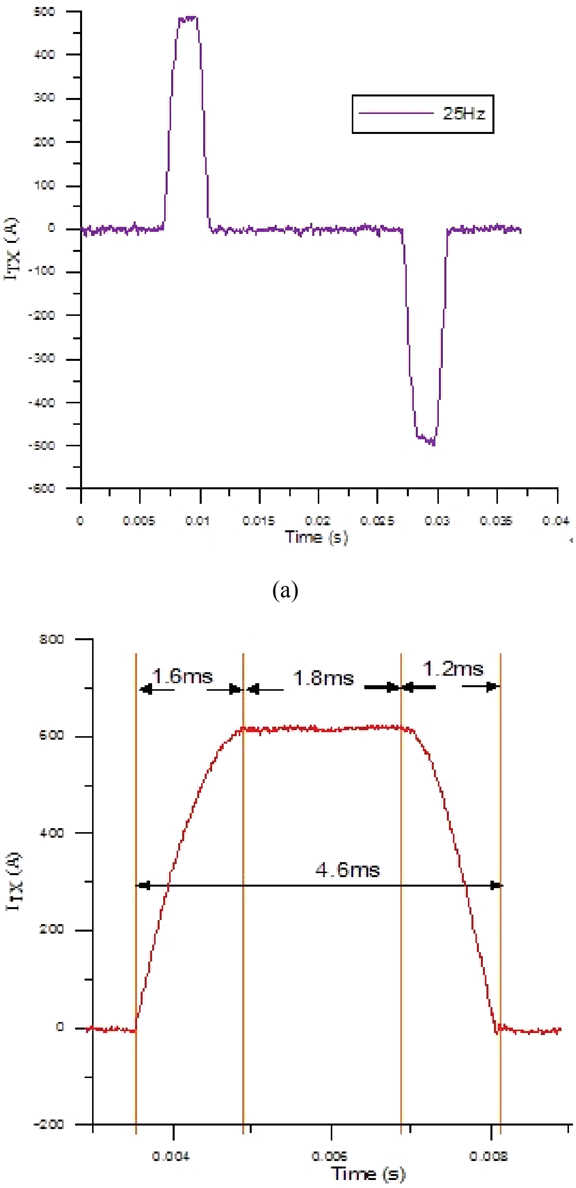
iFTEM type time-domain fixed-wing airborne electromagnetic exploration system described in this article, is funded by national high technology research and development Program, "Airborne geophysical survey system" sub-topic "Time-domain fixed-wing airborne electromagnetic exploration systems research and development". iFTEM systems are divided into transmitters and receivers. In the paper we mainly discuss the control system of a transmitter. The control system which is the core of a transmitter, must have the ability to control the transmitter waveform, to protect the transmitting system when transmitter errors appear, to keep receiver and transmitter in pace, to monitor the voltage, currents and the transmitter waveform in real-time. Our control system is based on PC104 bus, has advantages of small size, high reliability and operational easiness.

2. Introduction of the Transmitter

iFTEM's transmitter waveform is bipolar combination wave, base transmitter frequency being 12.5, 25 or 50 Hz. When the base frequency is 25 Hz, the transmitter waveform is shown in Fig. 1 (a); in Fig. 1 (b), we can find that the waveform is composed of rising edge, flat top, falling edge.

Fig. 2 shows transmitter architecture. The functions of each module are described below.

1) The core of the transmitter is the full-bridge inverter circuit. Full-bridge inverter circuit converts direct current into bipolar AC [11]; at the same time the full-bridge inverter circuit is also the power section of the transmitter. IGBT which is the power component switching converter is the core of the full-bridge inverter circuit, thus DC power is converted into bipolar pulse alternating current in order to achieve a large power output.



(a)

(b)

Fig. 1. iFTEM's transmitter waveform (25 Hz example).

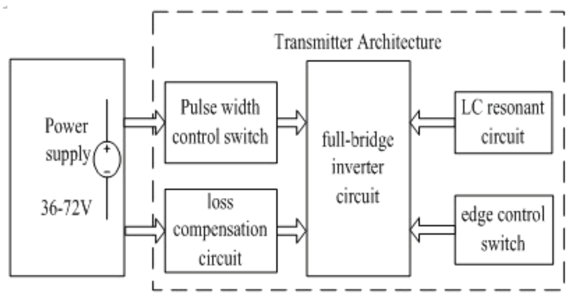


Fig. 2. Transmitter Architecture.

2) During the transmitter on-time, the high-voltage power stored in super capacitors is released into the transmitter loop; the current of the transmitter loop rapidly rises, and then forms the rising edge of transmitter waveform. An edge switch signal controls the rising edge time.

3) During the transmitter off-time, by a resonance circuit, the power of the inductance in the transmitter loop is stored into super capacitors, resulting in the falling edge of the transmitter waveform. We design a LC resonant circuit in iFTEM system.

4) When the transmitter current reaches the maximum value, in order to maintain a high current in the transmitter loop, we use the low-voltage power to supply continued flow for the transmitter loop, and then form the flat top of the transmitter waveform. The time of the flat top is controlled by a pulse width control switch signal.

5) Due to energy loss in the transmitter loop, in order to make the transmitter to achieve a large transmitter power, we must pre-charge resonant capacitors during the transmitter off-time. We design a loss compensation circuit to complete the task.

The driving signals used in the control system are shown in Fig. 3. Trigger is a synchronization signal of iFTEM system. Trigger can be provided by the transmitter or receiver, Trigger's frequency is 12.5, 25, 50 Hz optional. S1 and S2 are the switch control signals of the full-bridge inverter circuit, their phase being reverse, S1 and S2 controlling four IGBT of full-bridge inverter circuit to alternately turn it on. Then the bipolar waveform will appear in the transmitter loop. S3 controls the rising edge of combination wave and controls the rising time of transmitter waveform. S4 controls the pulse width of the combination wave and controls pulse width time of transmitter waveform. S5 is the switch control signal of loss compensation circuit, controlling the charging time of super capacitors. S3, S4 and S5 are all based on the rising edge of Trigger for the trigger edge, delay time and pulse width time are adjustable.

3. Control System of the Transmitter

The control system consists of driving signal generator, protection control system, synchronization control system, voltage and current monitoring and the transmitter waveform monitoring (Fig. 4). The driving signal generator, protection control system and synchronization control system work on the PC104 signal generator card, while the monitoring of voltages, currents and the transmitter waveform work on the PC104 data acquisition card.

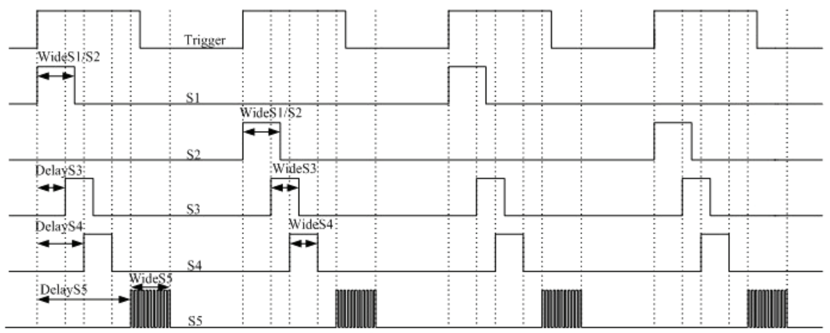


Fig. 3. The driving signals used in the control system.

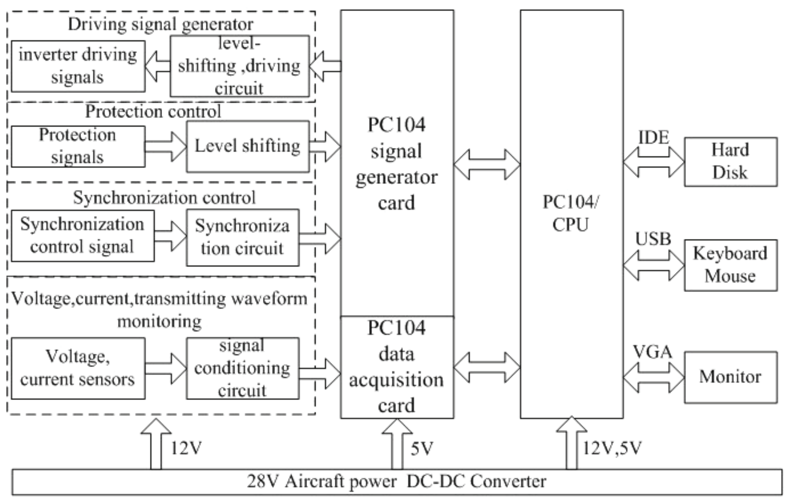


Fig. 4. Hardware structure of control system.

All modules required for the 12 V and 5 V power are supplied by aircraft power whose voltage is 28 V, which will be converted to 12 V or 5 V by DC-DC converter. The core of the control system is PC104/CPU module. When PC104/CPU module is connected to the hard disk, keyboard, mouse and monitor, a micro-computer is composed, and then users can operate the PC104 control system as easily as to operate their own PC, so users can quickly grasp the use of the PC104 control system. Signals generated by PC104 signal card are sent into the transmitter after passing level-shifting circuits and driver circuits, then become the inverter driving signals of the transmitter; external protection signals enter PC104 signal card after passing level-shifting circuits, then if the external protection signals are effective, the signal card will shut down the transmitter; the synchronization control is that the receiver produces a “Trigger” signal of signal generator card; voltage, current monitoring and the transmitter waveform monitoring are implemented by the PC104 data acquisition card. After passing the voltage and current sensor and signal conditioning circuit, voltages, currents and the transmitter waveform signals are sent into the PC104 data acquisition card. In addition, when the transmitter is running, the transient current will bring the electromagnetic interference to the control system, so each unit should be independent so Opto-isolation method is applied to weaken the interference of electromagnetic.

In the control system, the PC104/CPU module is Em104P-i8523 from Taiwan ARBOR Co., Ltd, and the PC104 data acquisition card is PM518 data acquisition card of Beijing ZTIC Co., Ltd. In the control system the driving signal generator is the most important part. Control system requires the driving signal generator not only to have the function of signal generator, but also to have the function of synchronization control and protection control, so users need to design dedicated signal generator for the control system. Below we will focus on the driving signal generator.

Design the driving signal generator for the control system is based on PC104 bus, the driving signal generator is designed as a PC104 signal generator card (Fig. 5).

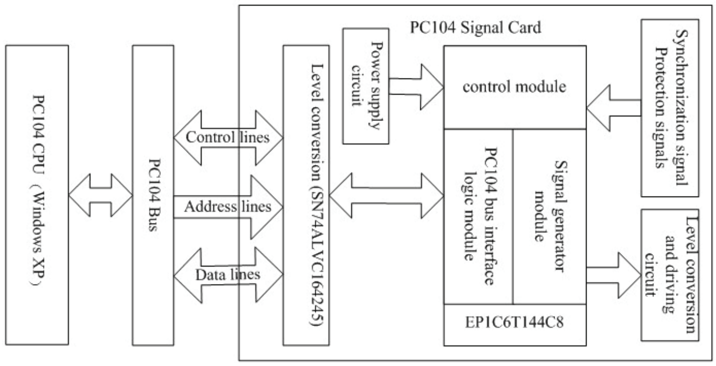


Fig. 5. Hardware structure of the signal generator.

PC104 signal card communicates with PC104 CPU by PC104 signal lines. The signal lines used in PC104 signal card are control lines, address lines and data lines. Signal lines must be level-shifting so as to communicate with FPGA chip of PC104 signal card. PC104 signal card’s main task is completed by FPGA (EP1C6T144C8), including the PC104 bus interface logic module, signal generator module and control module. PC104 bus interface logic module completes the PC104 bus logic decoding and sequential circuits. FPGA’s IO output level is 3.3 V, with pin’s driving capability being only 24 mA (Altera Corporation 2008), but the transmitter requires the signal level to be 12 V, and driving capability not to be less than 200 mA, so the output signals need to go through level conversion and driving circuit before being sent into the transmitter. When external protection signals are effective, the signal card shuts the transmitter down. The signal card also controls the transmitter and receiver to keep pace.

Develop of PC104 signal card drive: On Windows XP, users cannot access hardware directly from the application level (user mode), where software development is usually done. Hardware can only be accessed from within the operating system itself, utilizing software modules called device drivers. In order to access PC104 signal card from the application level, we must develop a device driver for PC104 signal card. Often users use a certain driver development tool to develop device drivers, and then users’ applications can access hardware. In a variety of device driver development tools, WinDriver from Jungo Co., Ltd is a rising star, which is well known for being simple and efficient, cross operating systems and good compatibility. You do not need to have any device driver knowledge, nor do you have to be familiar with operating system kernel programming, DDK, ETK or DDI/DKI. Using WinDriver only, you can develop a highly efficient device driver within a very short time.

Fig. 6 shows WinDriver architecture [12]. WinDriver provides two driver development modes: user mode and kernel mode. In user mode, users can directly use the WinDriver's driver template, without any deep understanding on the knowledge of hardware or Windows kernel. Neither understanding of development of device drivers nor operating system-related knowledge is necessary. For convenience I developed the PC104 signal card's driver in user mode.

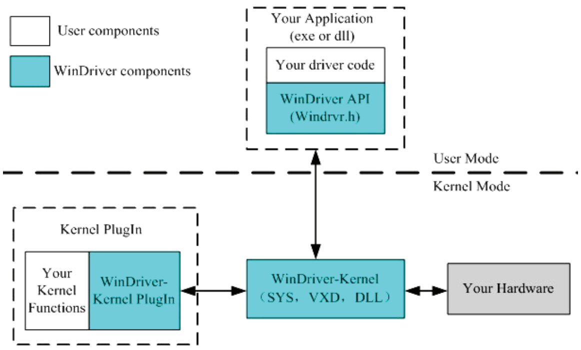


Fig. 6. WinDriver Architecture.

Fig. 7 shows running processes of the driver program. Firstly, the card calls OpenDevicePM( ) function to turn on the signal generator, and then calls initialization InitPM536( ) function and the following three interrupt routine functions:

PM536_IntIrq5Enable (hPM536, PM536_IntIrq 5HandlerRoutine)

PM536_IntIrq7Enable (hPM536, PM536_IntIrq 7HandlerRoutine)

PM536_IntIrq12Enable (hPM536, PM536_IntIr q12HandlerRoutine)

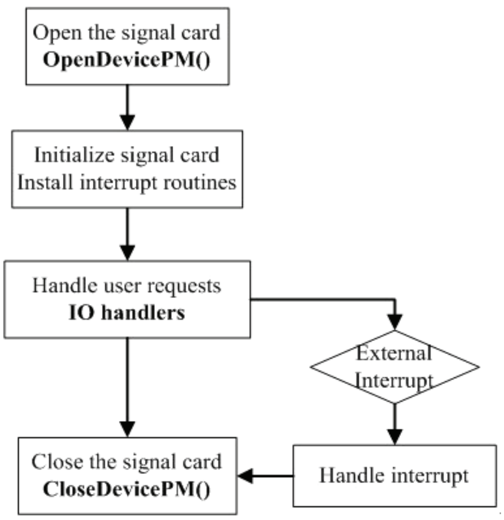


Fig. 7. Drivers running processes.

After completing the signal card initialization and interrupt routine installation, the program can handle users' requests to the signal card. User requests are always IO reading or writing through IO handlers. If the external interrupts (IRQ5, IRQ7 and IRQ12) are effective, they will be handled first, and finally function CloseDevicePM( ) is called to turn off the signal card.

4. Panel Design of Control System

The panel of control system implements the function of setting parameters of the signal generator, waveform display and other functions required by the control system. The control panel must be user friendly, operationally stable. We select the U.S. NI LabVIEW virtual instrument software to design the panel. LabVIEW (Laboratory Virtual Instrument Engineering Workbench) is a product of National Instruments, being one of the most important tools internationally and most widely used in data acquisition and control system development environment. LabVIEW is also used in instrument control, data acquisition, data analysis, data display system. Its programming language is graphical language (G language), and it is designed for test engineers rather than professional programmers. Using LabVIEW programming is very convenient, man-machine interface being intuitive and friendly, with powerful data visualization analysis and instrument control capabilities and other features.

The control panel consists of waveform display panel, power, rulers, coupling panel, voltage, current display panel, waveform recorder button, the transmitter switch, internal and external trigger buttons, parameter settings dialog box and other components (Fig. 8). Waveform storage path, waveform frequency, pulse width and edge width can be set at the preferences dialog. User can also set the PC104 data acquisition board, the number of acquisition channels, sampling frequency and sampling points. The parameters set by the user can be saved, so if the user wants the same setting next time, he or she only needs to import the saved parameter file.

Control panel running processes is shown in Fig. 9. When the system starts to boot, a login screen pops up. Only when the correct user name and password are entered, can the user login. After successful login, the initialization of the signal card and data acquisition card are completed. Before turning on the transmitter, users may need to reset the transmitter waveform parameters, data acquisition card parameters, internal/external triggering options, and determining synchronous control signal is provided by the transmitter or receiver. After completing parameter setting, users can turn on the transmitter. When the program is running, users can save the transmitter waveform at any time. Remember not to reset internal/external trigger when program is running. During program running process, if users need to reset the transmitter waveform or data acquisition parameters, they must make sure that the transmitter has been turned off.

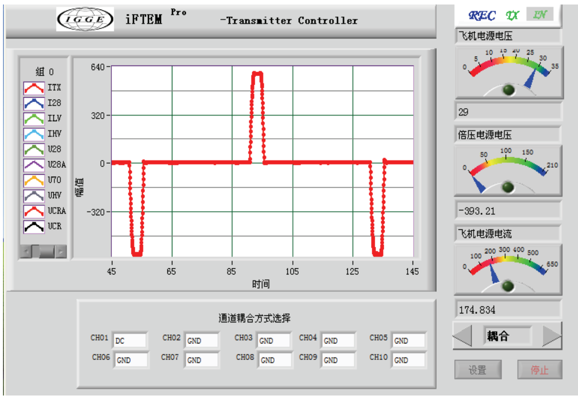


Fig. 8. The panel of control system.

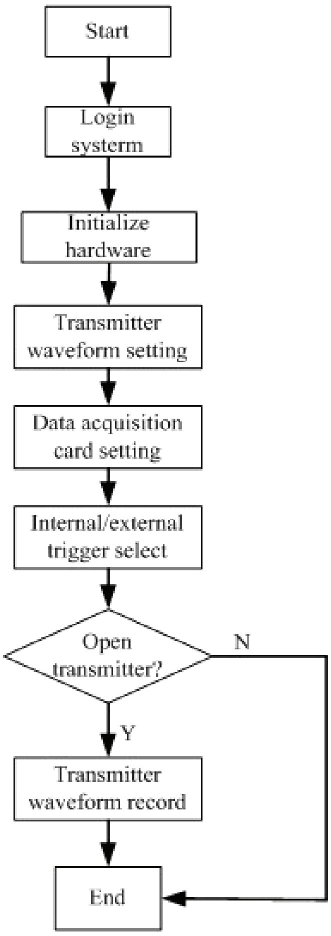


Fig. 9. Control panel running processes.

6. Conclusions

Experimental results show that through PC104 bus in the control system of iFTEM transmitter, waveform control, synchronization control, protection control, voltage, current and transmitter waveform monitoring are implemented well together, with small size, high reliability and scalability obtained at the same time. Our work contributes to the research of domestic time-domain fixed-wing airborne electromagnetic method.

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