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Measurer and recorder of electrical signals for electrical geophysical surveys

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Measurer and recorder of electrical signals for electrical geophysical surveys

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Abstract. To conduct research by electrical prospecting, instruments for measuring and recording electric fields with unique characteristics are necessary. Such recorders should work with signals that vary over a very wide dynamic range, as well as over a wide frequency range. The acquisition of ready-made functionally complete recorders for these purposes is impossible due to the lack of such devices. These devices must work effectively both in standalone mode and in telemetry mode. High accuracy of data binding to absolute time is very important. A set of requirements for these devices requires the development and manufacture of recorders.

1. Introduction

Regular observations of the processes occurring in the Earth's crust allow us to investigate these processes, better understand their possible causes, refine their mathematical models and predict earthquakes [1–8]. Therefore, such observations are important for the theory and have the most important practical applications. The Institute of Laser Physics of the Siberian Branch of the Russian Academy of Sciences and the Geoservice of the Siberian Branch of the Federal Research Center unified geophysical service of the Russian Academy of Sciences with partners participate in such observations using laser rock strain meters [9–12]. Several such developed and manufactured meters are installed in various mountain galleries or mines in Russia and Kazakhstan. Such measurer works the longest in the gallery of the Talaya Observatory near Lake Baikal. However, the registration of rock deformations under the action of external gravitational forces is only part of the information that can be registered. Along with this information, the electronic data acquisition and processing system can also record other valuable measurement results, which include information about temperature, humidity, pressure, as well as signals received from seismic sensors. Based on the results of comprehensive studies, a theory has emerged that the registration of electric fields in different frequency ranges can also provide great material for analysis. In addition, the creation of such a recorder allows for electrical exploration, since the electric fields depend on the composition of rocks and soil at the measurement sites. Thus, the development, research, improvement and implementation of a universal recorder of electric fields are very important tasks.

2. Statement of the problem

The main requirement for the developed recorder is to ensure high sensitivity and high measurement accuracy. Of course, it also requires sufficient speed and convenience of use, which involves its execution only on the basis of digital electronic equipment using modern information technology for data collection and processing.

An additional requirement is to link the measurement results to the exact time. In this case, the accuracy of the autonomous clock of the recorder is in some cases insufficient, it is necessary to synchronize the measurements with the accurate time signals sent by GPS-GLONASS systems. Communication with such systems allows us to bind the measurement results not only to the time scale, but also to the geographical location of the measurement site, which makes this device more in demand for geophysical surveys.

3. The method of solving the problem

To solve the problem, it is proposed to use analog-digital conversion with subsequent processing in a digital device. The device is implemented in the form of software and hardware.

4. The hardware of the device

The functional diagram of the recorder is shown in Fig. 1. The signal from the receiving loop is fed to the input of the analog-to-digital conversion module (ADC_MODULE). The module is controlled via galvanic isolated lines from a programmable logic chip (FPGA), in which control, synchronization and buffering data nodes are synthesized. Data blocks are read by a microcontroller (MCU) in DMA mode. Clocking the system and the ADC is carried out using a precision clock generator (VCTXO). The frequency of this generator is tightly synchronized with the accurate time signals from the GPS / GLONASS module. The recorder controls the recording and signal processing process in accordance with the recorded schedule of sessions corresponding to the schedule of the control unit of the exciting current switch. Work can be carried out both in a completely autonomous mode, and as part of a telemetry group.

As a base processor module containing a microcontroller and an FPGA, a board previously developed for a phase shift meter was used, which was used in a laser strain meter [9–12].
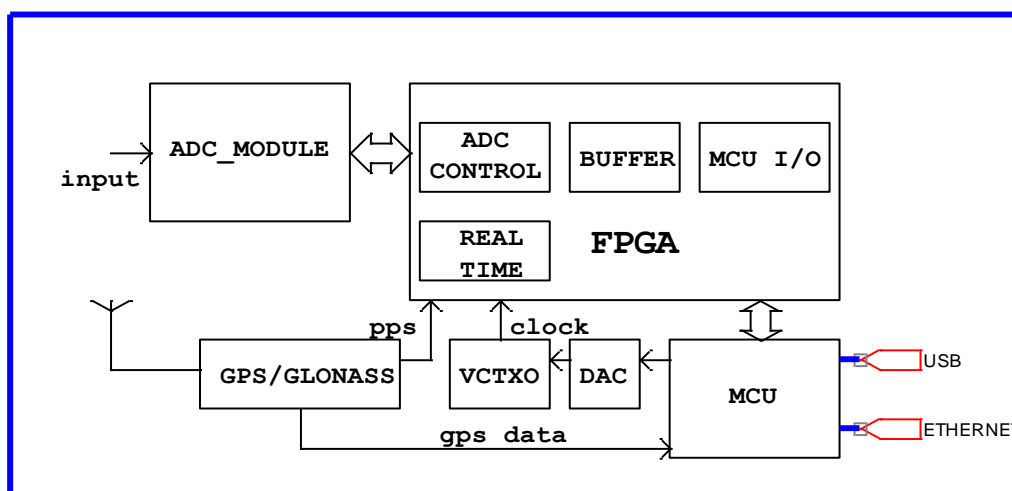

Figure 1. The functional scheme of the recorder

Figure 2 shows the block diagram of the developed analog-to-digital converter module. The input signal is supplied to the protection circuit against static and induced discharges of electric current (DEFRNCE).

Next, the signal is amplified by an amplifier with software-programmable gain (PGA). This amplifier amplifies the differential input signal and, at the same time, significantly suppresses the parasitic common mode. The differential driver performs two functions. This filtering out-of-band high-frequency signals and ensuring the correct operation of the input modulator chip analog-to-digital converter. The signal circuits and the module power supply are galvanic isolated from the rest of the instrument's nodes. This provides effective protection against impulse noise of the measuring part.
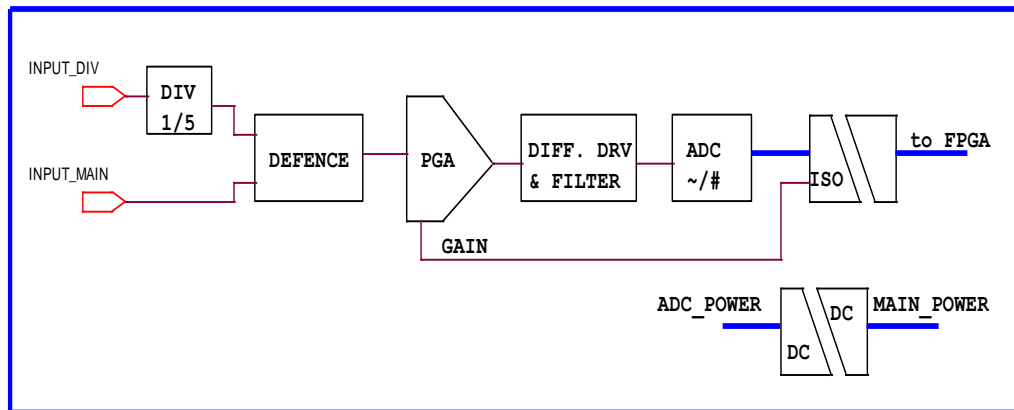

Figure 2. Block diagram of the A-D converter module.

The prototype is manufactured and tested in the laboratory. Programs for the microcontroller are written to implement the processes of collecting, preprocessing, storing and transmitting data. The final debugging of the recorder was carried out and test recordings were made from the generator of signals and PPS signals from the GPS-GLONASS module.

The circuit diagram of the input part of the recorder is shown in Figure 3, and the ADC circuit is shown in Figure 4. Figure 5 shows a general view of the recorder circuit board, whose dimensions are 90 x 90 cm^2.
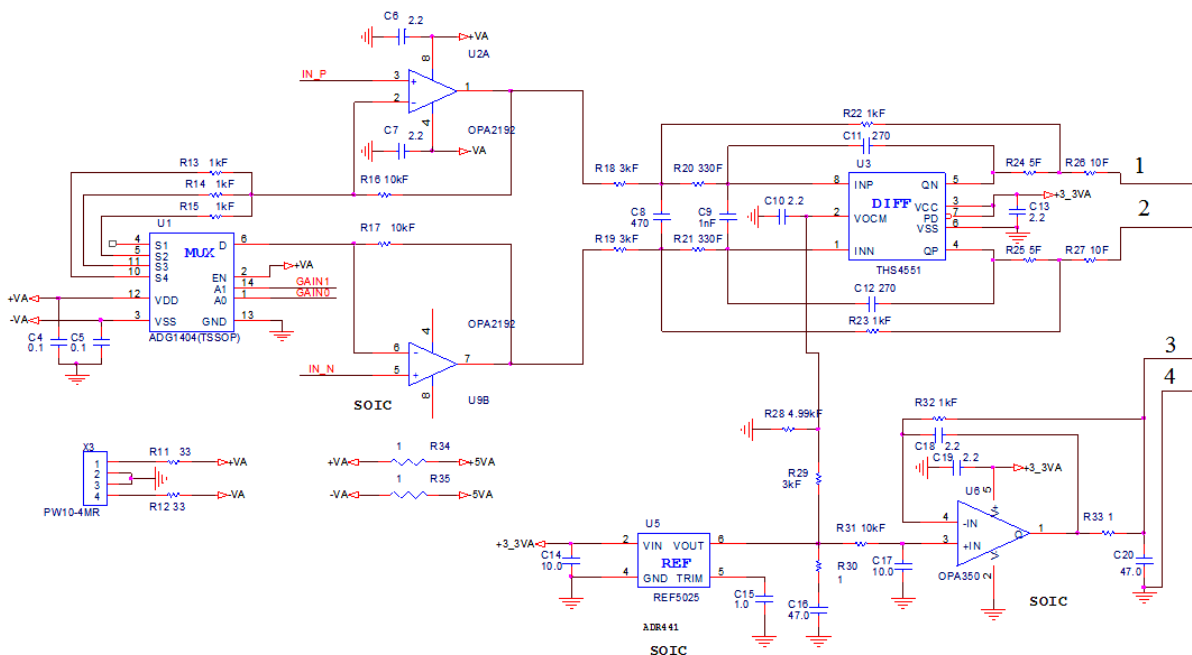

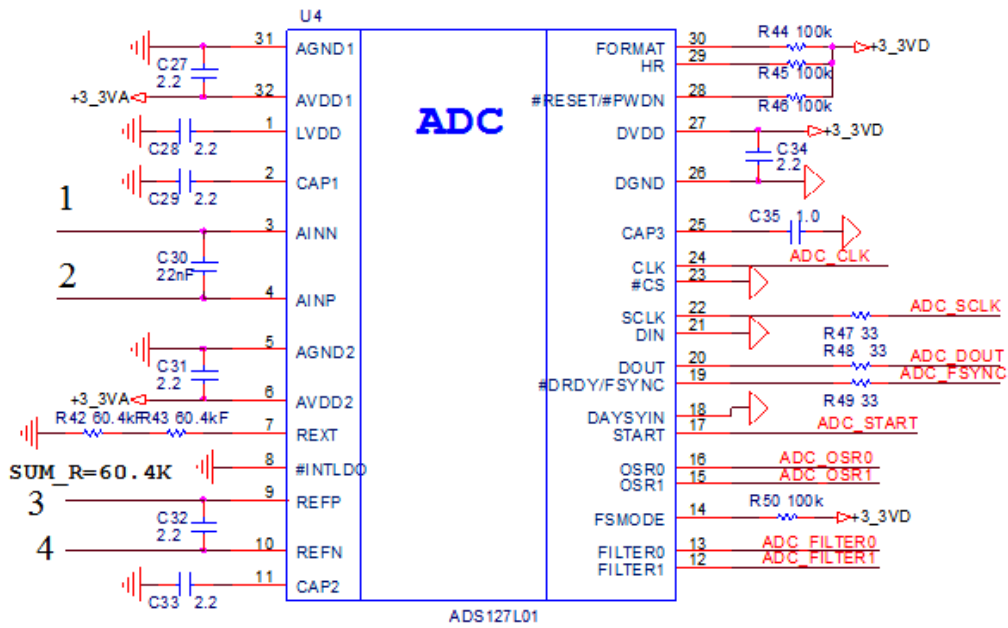**Figure 3**. Schematic diagram of the input amplifiers
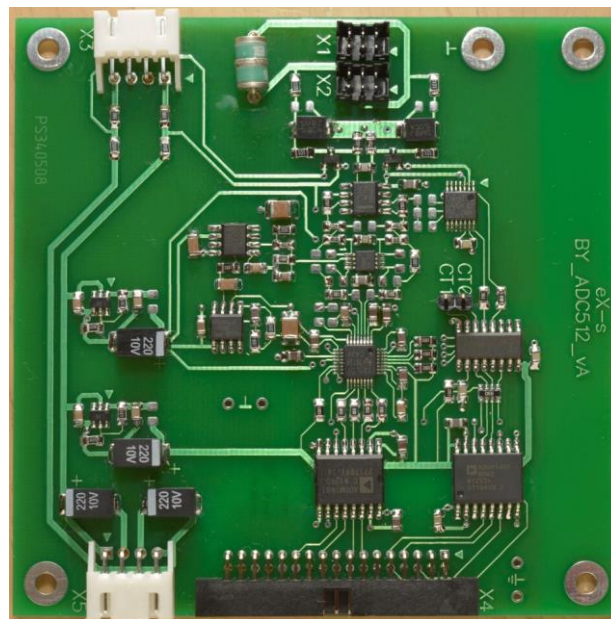
Figure 4. Schematic diagram of the ADC

Figure 5. Printed circuit board with electronic components installed

5. Software for FPGA and microcontroller

Nodes for building a real-time system for accurate synchronization have been developed. The precision oscillator with the ability to electronically adjust the frequency is the source of the clock signal for the ADC and the real-time clock. Using the data received from the GPS-GLONASS module and the PPS pulses, the time routine performs phase generator frequency tuning with an accuracy of no less than 100 ns. Thus, both the analog-to-digital conversion data and the system clock are synchronous with the

absolute time. Also, to meet the requirements for registration frequency, I / O bus timing diagrams were optimized to the requirements of external RAM and FPGA.

The ADC control module allows you to conduct measurement sessions in different modes and different parameters.

Programmatically set session parameters:
1. The absolute start time of each session.
2. Measurement interval.
3. Interval of the pause.
4. Session sample rate.
5. The gain of the input path.
6. The duration of the session.

6. The recorder testing results

The developed recorder has been tested in the laboratory. Table 1 shows the values of the actual parameters of the recorder.

Table 1. Recorder specifications

N	Parameters	Units	Value
1	The number of the channels	Units	1
2	Maximum input voltage	V	
	- direct entrance		$\pm\ 2$
	- through the input divider		$\pm\ 10$
3	Sampling frequency Fd	The number of samples per sec	16, 32, 64, 128, 256
4	Programmable Gains G		1, 4, 16, 64
5	Dynamical range	dB	
	- Fd=16kHz, G=1		118
	- Fd=16kHz, G=16		110
	- Fd=256 kHz, G=1		105
	- Fd=256kHz, G=16		96
6	Frequency bandpass (-3dB)	kHz	
	- Fd=16 kHz, G=1		6.5
	- Fd=256 kHz, G=1		110
7	Accuracy of data binding to absolute time (using an independent GPS receiver)	s	$8 \cdot 10\text{-}8$

In the process of testing, records were made of electrical signals supplied to the input of the ADC module. Figure 6 shows the recording of a harmonic signal from a precision oscillator. Figure 7 shows the PPS / 2 signal recording from an external independent GPS receiver. The registrar is transferred to trial operation to the customer.
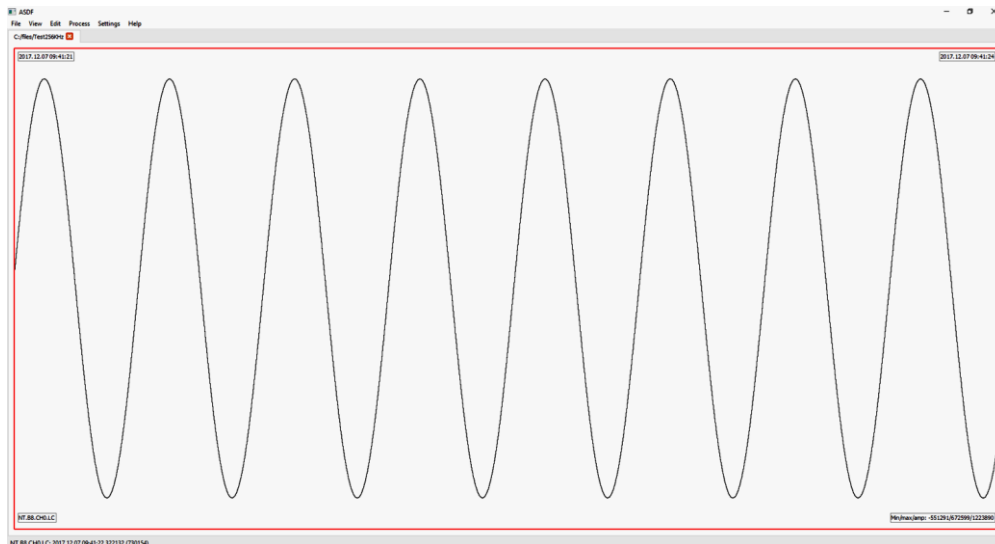

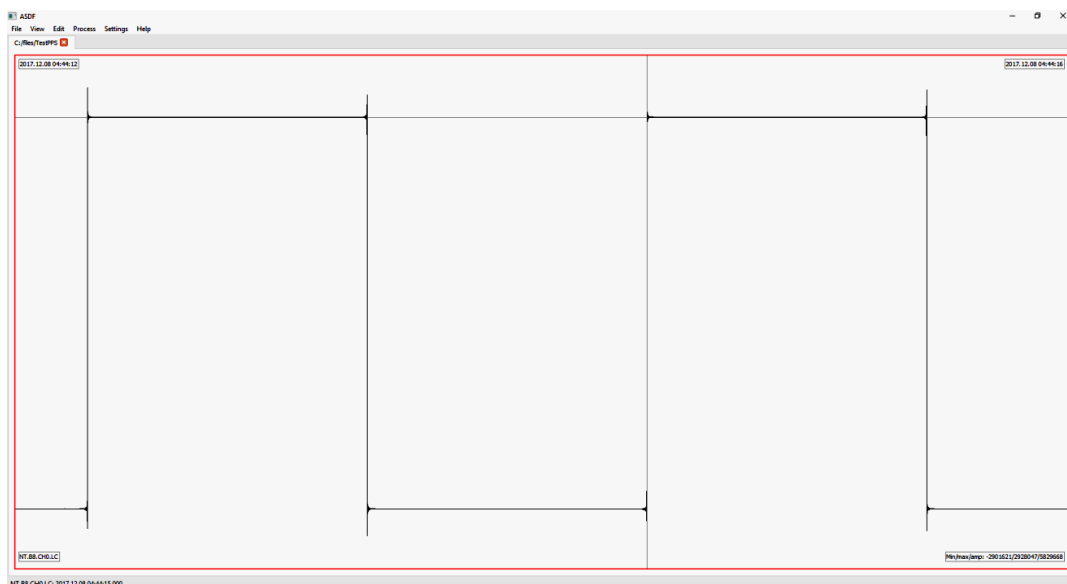**Figure 6**. Recording the harmonic signal from a precision oscillator

Figure 7. Record PPS / 2 signal from the external independent GPS receiver

7. Conclusion

The designed recorder fully complies with the technical requirements set by the customer and potential users. The device is made on a compact printed circuit board, it can easily be placed in a standardized case, including sealed. According to the results of trial operation, additional requirements for ergonomic design can be developed, after which the recorder can be finally developed, including its

design and mass-produced. An important feature of the developed device is the possibility of registering signals in a wide dynamic range and in a wide frequency band.

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