Development of PLIC-based time synchronization device

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Abstract. The article discusses a method of receiving and processing signals using a programmable logic integrated circuit in order to reduce the cost of time synchronization equipment. These actions are considered by the example of the «Beta» time signal. A method for receiving and processing a signal is described, based on the given structural diagram of the project. The installation was assembled and an experiment was conducted in accordance with the described parameters. The data obtained during the experiment in the form of graphs (spectral analysis of the signal, decoding of the Morse code and the information structure of the signal) are also presented. According to the results of the experiment, it is clear that the received signal from the “Beta” exact time service radio transmitter was received and processed without loss, as evidenced by the spectral analysis, as well as further decoding of the signal. The device fully complies with the set conditions and can be used in banking, metrology, as well as mobile operators, which will significantly reduce their costs. The assembled installation can be used in banking, metrology, and also by mobile operators, which will significantly reduce their time synchronization costs.

1. Introduction
Time synchronization (TS) provides that all devices in the network have a single time [1, 2]. When using the TS, you can synchronize various moments, for example, the beginning and end of a certain event [3]. TS is used in the next fields (figure 1):

- In the banking sector where it is extremely important to observe the accuracy of time in the operation of ABS and credit conveyors in connection with the requirements of the Central Bank and the security services of the banks themselves.
- In procedures related to confirmation of acceptance / transmission of electronic signatures, transactions.
- During the process control procedures.
- In telecommunication network devices in which the process of processing various data or information flow in real time is performed, in order to ensure synchronous execution of individual internal technological processes.
- When connecting a conversation to a certain number of subscribers.
The relevance of applying time synchronization in telecommunication networks directly depends on the development of billing systems (a set of processes and solutions that is responsible for collecting any information), control and monitoring systems for various applications, computer systems, as well as improving methods for using digital telecommunication devices and metrological support [2, 3].

The devices that carry out the TS include Parma RV 9.01, Sprint-M, Chl2400, etc. [4 - 6] The cost of these devices is high, which is their main drawback [7, 8].

The above described confirms the relevance of developing a TS device using programmable logic integrated circuit (PLIC), which will help significantly reduce the cost of equipment for time synchronization, which is the purpose of the work [9, 10].

2. Reasons and justification for the selection of equipment

Time synchronization devices are usually used by large organizations and have a high cost, but there is another way to receive signals from the exact time services using PLIC.

Programmable logic integrated circuit is an integrated circuit used to create configurable digital electronic circuits. Unlike conventional digital microcircuits, the PLIC logic is not determined during manufacturing, but is set through programming.

PLIC is selected from the following considerations [11, 12]:

- High frequency of functioning.
- High working capacity and productivity.
- Low price per one transistor.
- The availability of advanced computer-aided design systems.
- The possibility of one-time work on a large number of independent tasks.
- The universality of skills and knowledge (when switching to other models of the microcontroller and changing the manufacturer of the microcontroller, it is necessary to refer to its documentation when knowledge of PLIC design languages provides the ability to communicate with any microcircuit).
- Independence of blocks (blocks in HDL depend only on input signals. A developed and debugged module will continue to work correctly, regardless of how the project grows. Nothing from the outside will affect the correctness of its operation from the inside).
The structural diagram of the project is described in Figure 2, which shows the antenna, analog-to-digital converter (ADC) and programmable logic integrated circuit.

The PLIC implements a controlled generator of harmonic oscillations, which generates samples of the sine and cosine, with the possibility of tuning in a certain frequency range, and transfers them to the multipliers. Also, a digitized signal from the ADC gets onto the multipliers.

The first step is the process of oversampling to a lower frequency. A CIC filter (decimator) is used, which allows you to lower the sampling frequency by tens to hundreds of times.

Further, since the decay of the frequency response of the CIC filter is shallow, it is necessary to use a filter with a finite impulse response FIR. The received data after the CIC and FIR filters are transmitted to the PC via the RS-232 serial port, and the signal samples are transmitted from the PC to the RS-232 serial port in order to cyclically process the signal.

3. Experimental part
The “Beta” time service is used to verify the functionality of the assembled installation [13]. This service operates in the CIS in the range of extra-long frequencies (radio waves with a wavelength of over 10 km) at a frequency of 25 kHz according to a certain schedule.

Using the developed device, it is necessary to obtain a signal from the radio transmitters of the exact time service with the aim of processing the signal inside the PLIC, decrypting it, and also checking the integrity of the received reference time markers.

The time response of the received signal using PLIC is shown in Figure 3.

![Figure 2. Structural diagram of the project.](image-url)
The frequency response of the received signal is shown in Figure 4. According to the spectral analysis, it can be seen that the signal spectrum is concentrated at a frequency of 25 kHz, which corresponds to theoretical information.

It is known that the “Beta” service signal has the structure: translation of the callsign in the form of Morse code and translation of the 10 pps time code with reference time markers of 0.1, 1, 10 and 60 s. The signal will be decrypted in parts - decoding of the call sign and decoding of the time code. Using the Hilbert transform, an envelope of the signal is formed, by which you can determine the moments of the point, dash and pause of the call sign. The Morse code signal with the call sign is shown in Figure 5. The Morse code conversion algorithm is written using the received signal.
The resulting call sign and the result of its decoding are presented in Figures 6 and 7, respectively. The conversion program is written in Matlab [14], where dots, dashes and pauses are replaced with numerical values 0, 1 and 2, respectively, which makes it easier to decrypt.

![Morse code signal](image)

**Figure 5.** Morse code signal.

![Call sign in the form of Morse code](image)

**Figure 6.** Call sign in the form of Morse code.

![The result of decoding Morse code](image)

**Figure 7.** The result of decoding Morse code.

The time code of the signal of the exact time service has a theoretical information structure, which is shown in Figure 8.
Figure 8. Information signal structure (theory).

The information structure of the signal obtained experimentally is shown in Figure 9. It can be concluded that it completely repeats the form of the theoretical signal structure.

Figure 9. Information structure of the signal (practice).

Using the received signal, it is possible to synchronize the receiver with the sender in time using time markers.

4. Conclusion
As a result of this work, an PLIC-based time synchronization device was developed. According to the results of the experiment, it is clear that the received signal from the “Beta” exact time service radio transmitter was received and processed without loss, as evidenced by the spectral analysis, as well as further decoding of the signal.

The device fully complies with the set conditions and can be used in banking, metrology, as well as mobile operators, which will significantly reduce their costs.

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