The development of digital device for current, voltage, power measuring and simulation results in proteus environment

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Abstract. At the present stage of development of the electric power industry, an important aspect is not only the reliable measurement of the values of alternating current and voltage, but also the convenience of representing the measured values. For this purpose, digital microprocessor devices are used, which allow not only to present the measured values in a convenient form, but also provide the ability to memorize and store series of measurements. This article presents the development of a digital device for measuring alternating current, voltage and power in single-phase AC circuits. In addition, the article presents the result of simulation of this device operation in the PROTEUS environment.

The digital microprocessor device will allow to measure alternating single-phase current, voltage and active power. To achieve this goal, the developed digital device must perform the following necessary functions:

- measurement of the effective current value and voltage at the load;
- active power measurement;
- implementation on the LCD of the effective value of voltage, current, active power;
- range of the measured current in the circuit: 0-25 A;
- range of network voltage variation 220 ± 20 V;
- measurement error should not exceed 1-2%.

In accordance with the functions performed, the block diagram of the digital device contains the following blocks:

- microcontroller (MC);
- MC power supply;
- liquid crystal indicator (LCI);
- current transformer (CT);
- voltage transformer (VT);
- protective shutdown block.

In order to implement this digital device, it is necessary to interconnect the fundamentals of electrical engineering and computer technology. According to [1], this connection is defined as the interaction of...
elements of electrical engineering and computer technology in the physical world during the transfer of energy and information, for their interpretation, analysis and mutual transformation.

The implementation of the digital device is based on discrete measurements of ongoing in time current values and voltage at the load by replacing their integral ratios with sums [2]:

for effective voltage value:

\[ U = \sqrt{\frac{1}{T} \int_{0}^{T} u^2 dt} \rightarrow \sqrt{\frac{1}{T} \sum_{1}^{n} u_i^2 \Delta t}; \]

for effective current value:

\[ I = \sqrt{\frac{1}{T} \int_{0}^{T} i^2 dt} \rightarrow \sqrt{\frac{1}{T} \sum_{1}^{n} i_i^2 \Delta t}; \]

for active power:

\[ P = \int_{0}^{T} u \cdot i \ dt = \Delta t \sum_{1}^{n} u_i i_i, \]

where \( n \) is the number of measurements of instantaneous values \( u_i, i_i \) for the network period \( T = 20 \) ms.

If it is necessary to measure the total and reactive powers, the equivalent sine wave method is used:

for full power:

\[ S = U \cdot I; \]

for reactive power:

\[ Q = \sqrt{S^2 - P^2}. \]

The development of digital and programmable systems should consist of measuring sensors and software for processing and storing information [2].

To ensure sufficiently high measurement accuracy, the number of measurements of instantaneous values of \( n \) should be selected on the basis of the maximum allowable clock frequency of an analog-to-digital converter (ADC).

Given that when measuring these values, it is necessary to convert the electrical signals of the sensors to digital form, the microcontroller should include an analog-to-digital converter (ADC). In most existing microcontrollers, the ADC converts the instantaneous values of unipolar analog signals. In this regard, the complex should include a device that provides a shift of these signals by an amount determined by the maximum possible amplitude of the negative half-wave of the signal. In this case, the total amplitude value of the input signal should not exceed the maximum allowable input voltage of the ADC \( (U_{\text{limit}}) \). Usually this value is indicated in the technical specifications of the microcontroller. Based on this, the output voltages of the current and voltage sensors are determined.

Thus, in addition to the above blocks, the block diagram should include an input voltage level offset block relative to the common bus of the microcontroller with zero potential, as shown in figure 1:
where $U_{\text{signal}}$ - a signal that undergoes discrete digitization; $U_{\text{shift}}$ - a signal bias voltage level; $u_{\text{input A/D}}$ - a total signal to the ADC; $U_{\text{limit}}$ - maximum allowable input voltage of the ADC; $u_{\text{input A/D}} = U_{\text{signal}} + U_{\text{shift}} \leq U_{\text{limit}}$ - offset signal.

**Figure 1.** Timing graphs of the bias of a multipolar signal relative to the zero-voltage level MC.

Consequently, it is necessary to provide for the operation of calculating the bias voltage in the program for calculating the instantaneous values of voltage and current.

The $U_{\text{shift}}$ voltage value can be set by an external source of stabilized voltage, which provides power to the MK using a voltage divider.

To implement the digital device, a block diagram has been drawn up, which is shown in Figure 2.

**Figure 2.** Block diagram of the digital device.

The problem of a signal input via the ADC is that the microcontroller has only one ADC device and 8-channel multiplexer, for registering current and voltage it is necessary to switch the multiplexer
channel cyclically from 0 to 1 and back. For each switching of the multiplexer, conversion and calculations in the ADC interrupt handler function, a certain time is spent leading to a phase delay between the digitized instantaneous values of the voltage and current signals. Thus, in addition to removing the constant component, it is necessary to remove phase delays in switching the ADC channels and the conversion itself.

When developing the digital device for measuring alternating current, voltage and power, special attention should be paid to the choice of measuring current transformer and voltage transformer, as well as their connection to the input of the ADC of the microcontroller.

A voltage transformer is used as a voltage sensor, as it allows for galvanic isolation of the microcontroller input with an alternating voltage network.

A current transformer is used as a current sensor, which also provides galvanic isolation of the network with MK inputs.

To connect a current transformer and a voltage transformer to the microcontroller, it is necessary to provide for a shift in the voltage levels of the VT and CT in order to exclude the appearance of negative polarity voltage at the ADC input. The applied circuit carrying out the necessary shift of voltage levels is presented in Fig. 3, where TV is the measuring step-down voltage transformer, TT is the measuring current transformer, w1 is the input winding of TV, w2 is the measuring winding of TV; R1 and R2 are the resistances of the Ushift bias voltage divider; R3 is the resistance of the CT shunt, R4 and R5 is the output voltage divider TV, which determines the required voltage level at the ADC input. The input buffers of all pins are constructed according to the Schmitt trigger scheme and for all inputs there is the possibility of connecting an internal pull-up resistor between the input and the VCC power bus.

![Figure 3. Connection diagram of voltage and current transformers.](image)

To describe the principle of operation of the digital device for measuring alternating current, voltage and power, figure 4 presents a block diagram of a control program. The program is written in a high-level programming language C [4], which has a number of advantages over other programming languages. When programming microcontrollers, it is necessary to use the mechanisms for universalizing the creation of programs proposed in [5,6], the developed conversion system “The language of the programming automation system is a universal algorithmic language”. Similar devices can be implemented on the basis of the Arduino hardware platform, presented in [7,8].
Figure 4. The block diagram of the control program of the digital device for measuring alternating current, voltage and power.
To demonstrate the operation of the digital device, a schematic diagram of the device in the Proteus software environment is presented.

Proteus is a software package for modeling microcontrollers, simulating virtual systems, designed for industrial and educational use [9]. Proteus integrates circuit simulation, animated components, and microprocessor models to facilitate collaborative modeling of finished designs based on microcontrollers. Proteus allows to develop and test projects before creating a physical prototype [10]. The simulation results allow to analyze the operation of a microprocessor device based on graphs [11]. The virtual tools considered in [12] provide simplicity and convenience of simulation of microprocessor devices.

To imitate current and voltage sensors, 2 sources of sinusoidal voltage V1 and V2 with a DC component offset of 2.5 V were used (figure 5).

![Oscillogram of sinusoidal voltage sources V1 and V2](image)

**Figure 5.** The oscillogram of the sinusoidal voltage sources V1 and V2.

The fundamental scheme of the device and the simulation result in the Proteus software environment are presented in figure 6.

![Fundamental scheme of the device and simulation result](image)

**Figure 6.** The fundamental scheme of the device and the simulation result in the Proteus software environment.
This digital device allows to measure the values of alternating single-phase current, voltage and active power with high accuracy. It can be used in industry to convert analog signals from measuring instruments to digital form. Also, this device can be used not only with a current transformer, but also with minor changes in the program code of the microcontroller and the electrical circuit with other current meters considered in [13], for example, such as a Hall sensor and Rogowski belt.

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