**KHAZAR UNİVERSİTY**

**Faculty:** **Natural Sciences and Engineering**

**Department:** **Physics and Electronics**

**Specialty:** **Electronics and Automation**

**MASTER`S THESIS**

**SUBJECT: DEVELOPMENT OF ULTRASONIC MEASURING DEVICES (SENSORS) THAT DETERMINE THE LEVEL OF LIQUID IN TANKS**

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## INTRODUCTION

**Relevance of the research topic.** Information measurement system is a set of functionally related measurements, measuring transducers and other technical means used to measure one or more physical quantities located at different points of the controlled object. It is characterized by a set of functional integrated measurement, calculation and other auxiliary technical means that serve to transform and develop it to be presented to the consumer in the required form.

Information measuring devices consist of a number of elements needed to perform certain functions, such as the conversion of the received signal according to the form and type of energy, stabilization of oscillations, switching of protection circuits from interfering areas, transmission and reception of information, etc. is produced consisting of elements of measuring devices.

Determination of liquid level measurement in different types of tanks can be done using industrial electronics and automation, the principle of operation of such measuring systems is generally the same - one of the main differences when entering information from a measuring sensor into a data processing device based on optical computers is the choice of sensor type. stops.

For this purpose, sensors have been developed that allow to determine the distance to the object and its position with the help of its analog output, where the signal is proportional to the distance to the measured object. Because such sensors are used in many applications (eg, distance to object, thickness measurement, bending and deformation measurement, product profile measurement, centering, and diameter measurement), sensors use different measurement principles (inductive, ultrasonic, or optical) to measure distance. The electrical output signal, which is a unit proportional to the distance to the object being measured, must be determined.

Thus, the dissertation is devoted to the development of an ultrasonic device used in information measurement systems.

**The purpose of the thesis.** The main purpose of the dissertation is to develop new methods and tools for the use of ultrasonic devices in information measurement systems.

**The research object of the thesis** is to study the operating characteristics of the ultrasonic range device used in information measurement systems, and **the subject of the research** is to apply the liquid measuring device in tanks up to 5 meters high using the ultrasonic level measuring device used in information measurement systems.

**The scientific novelty of the work.** Based on the classification of information measuring systems, the structural scheme of these devices was analyzed, taking into account the statistical and dynamic characteristics of information measuring devices. report is given.

**The structure of the work.** The dissertation consists of an introduction, three chapters, a conclusion and a bibliography. The introduction substantiates the relevance of the topic, the purpose of the work, its scientific novelty and practical significance.

**The first section** provides a critical analysis of the existing literature, the classification of means of information measurement systems, a comparative analysis of their statistical and dynamic characteristics by analyzing the structural scheme of measuring devices.

**In the second section**, the structural scheme of ultrasonic distance sensors is developed by defining the elements and characteristics of contactless distance sensors and examining the main parameters of the sensors used, taking into account the main features of ultrasonic distance sensors.

In this section, the principle of simultaneous extraction of a liquid level measuring device from an ultrasonic sensor, the need to change the analog signal, the conversion of an analog signal to a dual signal, the transfer of level information to the operator's indicator and the connection of electronic computing devices RS-232 interface The main features of the implementation have been identified.

**The third section** analyzes the main technical characteristics of the ultrasonic sensor used in the devices to measure the level of filling of the tanks to solve the problems. The principles of selecting the composition of the RISC-processor with a symmetric command system, which allows you to perform operations with the register, are shown in detail.

In this section, taking into account the main features of the input changer and the indication block, their main indicators were reported, the keyboard and communication block, as well as the power block were calculated.

As a result, among the advantages of the ultrasonic liquid level measuring device used in information measurement systems are high relevance and demanding operation, simplicity of its structure, and as a result, simplicity of operation and maintenance.

The dissertation consists of 68 pages and 27 figures. The list of used literature includes 16 titles of literature.

# 1.MAIN FEATURES OF INSTRUMENTS USED IN INFORMATION MEASUREMENT SYSTEMS

## 1.1. Classification of means of information measurement systems

Information measuring instruments are usually classified according to the principles of operation and metrological purpose. Types of measuring instruments include measurements, measuring apparatus, measuring devices and measuring systems.

Depending on the form of presentation of the information signal, measuring instruments are divided into different types according to measuring devices and measuring transducers. Information measuring devices - in the specified range, their classification as a measuring instrument intended for obtaining the value of the measured physical quantity is shown in Figure 1.1.

It is undeniable that that deficit of a systematic approach towards minimizing risks of engineering education causes inefficient projects that are intend to implement information measuring systems. It is possible to develop engineering education software applied for by introduction information measuring systems related to the spesifciations of minimizing risks in a professional fields. The mostly engineers develops invariant models to design and give value the effectiveness of safe adopting automated information measuring system (AIMS). The usage of those models allows that one to minimize economic losses caused by incomplete competencies and taking into account for all engineers in the roll-out process. In a result of the applied different models, the security of implementation can be increased and costs can be reduced by even 35% compared to the traditional ones. Competency models are developed to generate special way dependency which operating with AIMS. As a result of network planning, models allow minimizing economic losses connected with a lack of awareness about educational background, certificates and work experience based on continuous and integrated education. The difference among an ineffective and effective type of single path dependency is more than 10%. The scientists suggest a group of actions which gives the safe operation of computer-aided tools and personnel training for working in new conditions. The application of study things for energy plants in contributes to cheap dealt with safe operation management of information measuring systems counting electricity and energy products.

Information measuring transducers are distinguished by their position in measuring devices and the form of the conversion function. The conversion function expresses the dependence of the output signal of the measuring transducer on the measured physical quantity. The initial measurement converter should be noted here.

Typically, measuring devices are used in quality control, as well as in the determination of metrological characteristics of measuring instruments in metrological services and in scientific research conducted in various laboratories.

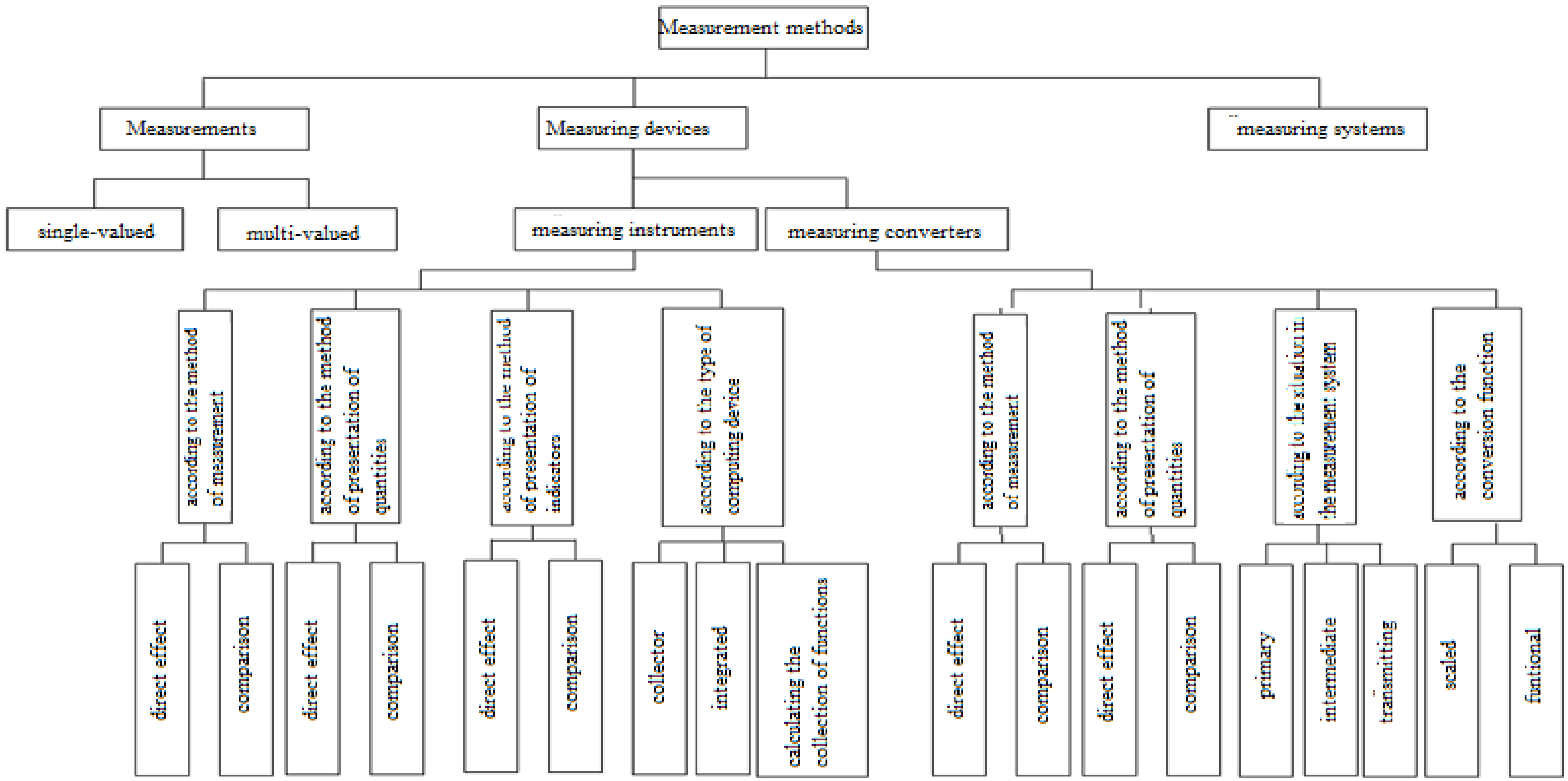
In its simplest form, the measurement system creates a human-readable interface that can be used for simple monitoring. In this simple system, any information must be recorded by the operator. The measurement system may include an electrical interface that allows some of the data to be converted in another format or elsewhere before being submitted to the operator. Information in this configuration is still registered by the operator, but the level of additional complexity allows a certain amount pre-processing must be completed. When working on different conversion technologies, range the initial processing that may be useful should be clarified. As mentioned, this configuration also allows the measurement must be transmitted to some remote location. A simple example might be a read temperature.

It should be clear that there is simply no better way to read a glass thermometer from a control room a few hundred feet from a state or country. But if we convert this measurement into electrical measurement, we have techniques that will allow this information to be transmitted to the remote control room and, under certain conditions, anywhere the world. The third configuration is growing rapidly and is becoming the most common measurement method. With the rapid growth of computing power over the last decade, it has become relatively simple and common to make these readings using a computer system, and then to transmit, scale, and scale data.

The data allows the user to adjust the graphical trend, as well as the raw unit values of the past, adjusted not only for the current moment, but also for a significant part of the measurement history.

Information measurement system (IMS) is a set of functionally related measurements, measuring transducers and other technical means used to measure one or more physical quantities located at different points of the controlled object.

An information-measurement system is a set of functionally integrated measurement, calculation and other auxiliary technical means used in diagnostics, identification, automatic implementation of logical functions of control or processing of measurement data for its reception, conversion and presentation to the consumer in the required form.




Picture 1.1. Classification of measuring

## 1.2. Analysis of the block diagram of information measuring devices

For the convenience of comparative analysis of different combinations of information measuring devices, a certain X input signal can be shown as a converter that converts a Y output signal. Such presentation of information measuring devices allows the analysis of systems to use the results of a well-developed theory of automatic control, where the input and output signals are in the form of certain physical processes characterized by several parameters, then they should be divided into informative and non-informative.

Information measuring devices must consist of several elements needed to perform certain functions [2,5]. Conversion of the received signal according to the form and type of energy, stabilization of oscillations, switching of protection circuits from interfering areas, transmission of information, etc. elements of measuring devices (supports, guide springs, magnets, contacts, transmission mechanisms, etc.) are accepted.

The block diagrams of the directly measuring information measuring devices are given in Figure 1.2 a,b and the block diagram of the comparison devices is given in Figure 1.2 v, q. The former are sometimes called direct conversion gauges, and the latter are called equalization or compensating converter gauges. Measuring devices are used that are rarely used in software equalizers. The block diagram of information measuring devices is unambiguously determined by the conversion method used.

An information measuring device based on a direct converter method (Figure 1.2a) works as follows: the measured physical quantity X enters the sensitive element and there it is converted into another physical quantity needed for future use (eg Figure 1.3 current, voltage, pressure, displacement, force) and is transmitted to an intermediate converter, which either amplifies or shapes the incoming signal. The output signal of the element is transmitted to the measuring mechanism, and after the movement of its elements is determined by means of a recording device, the output signal formed by the information measuring device can be received.

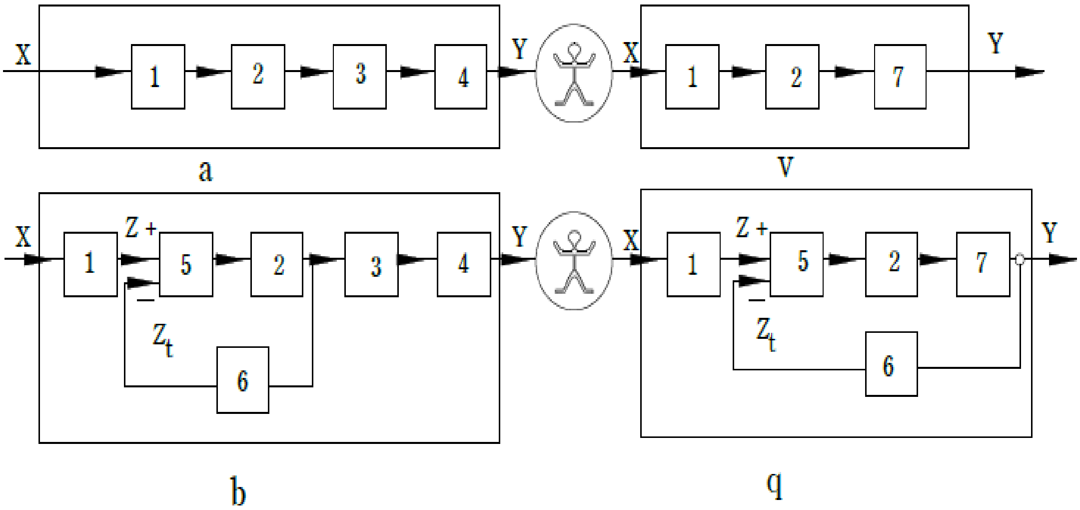



Figure 1.2. Structural schemes of information measuring devices: 1-sensitive element; 2- intermediate converter element; 3-measuring mechanism; 4 - computing device; 5 - comparison element; 6 - reverse converter element; 7 - the last converter element

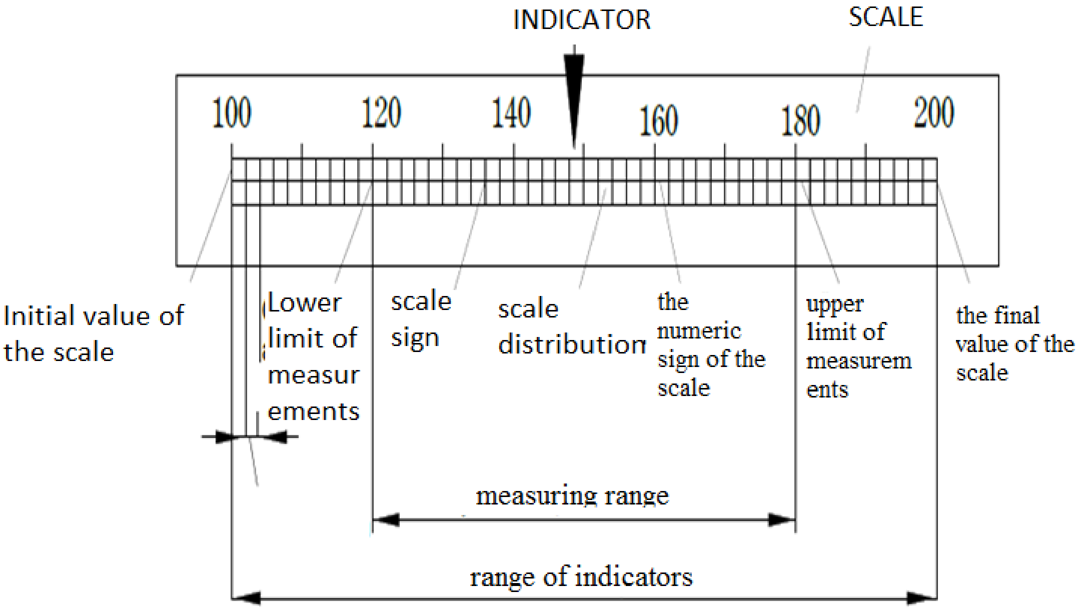



Figure 1.3. Scale diagram of the reporting device of the information measuring device

The value of a number or quantity on the measuring devices of information measuring instruments is called their indication.

The reporting device is provided as a digital board or indicative scale. It is accepted to use a number of concepts for scale reporting devices, and the essence of most of them is easy to understand (Figure 1.3). A schematic of a measuring device based on the balanced conversion method is given in Figure 1.2.

The distinguishing feature of such devices is that they have a negative feedback, where the Z signal generated at the output of the sensitive element is transmitted to the converter, which compares the two quantities at the input with the Z signal at the output and the Zt quantity at the output of the inverter.

At the output of the element, a signal is formed that is proportional to the difference between the values of the quantities Z and Zt, which enters the intermediate converter, and the output signal is transmitted to the measuring mechanism, as well as the input of the reverse converter. Depending on the type of intermediate element, at each value of the measured parameter and at the corresponding value of Z, the difference Z-Zt entering the input of the element can be reduced to 0 or a different value determined in proportion to a very small measured quantity.

Figure 1.2, q shows the block diagrams of information measuring transducers based on the methods of straight and balancing converters, which do not have a measuring mechanism and a recording device. In this connection, it is established that the signal of the measuring transducers is in a form that cannot be received by humans.

At the same time, information measuring transducers must contain the last converter element, which must form the output signal in such a way that it can be transmitted and stored at a certain distance. Otherwise, the initial simple measuring transducer for information measurement techniques must be adapted to the sensitive element. This can only happen in some special cases. In general, the first information measuring transducer differs from sensitive elements by the presence of auxiliary elements, which allows it to be considered as an independent device and to normalize all its features.

### 1.3. Statistical and dynamic features of information measuring devices

In general, the mode of operation of the information measuring device is called static when the values of the input X and Y output signals do not change [5].

The static characteristics of an information measuring device are determined by the dependence of its output signal in static mode on its input signal. The static property is generally expressed by a certain nonlinear dependence, ie Y = f (X).

Information measuring transducers, as well as measuring devices with non-degree scales or values that differ from the value of the measured quantity, have been accepted to call static conversion a conversion function. For information measuring devices, the static property is sometimes called the scale property. Because the determination of a static property is done by recording, the concept of recording feature (grading characteristic) is used for all measuring instruments, which is found in practice by creating a relationship between the output and input quantities of information measuring instruments and presented in tabular, graphic or formula form.

Figure 1.4 shows the static characteristics of information measuring devices. One of the main requirements for the static characteristics of information measuring devices is to ensure that the relationship between the output and input quantities is linear, except in some special cases. In practice, too, the task can generally be accomplished only by a preconceived error.

In addition to static properties, a number of parameters are used to determine the metrological properties of information measuring devices.

Figure 1.4 shows the types of static characteristics.

The indication range is the price area of the scale bounded by the last and initial values.

Information measurement range - (working part of the scale) is the range of values of the measured quantity.

In the special case, the given ranges may overlap. When a signal is applied to a measuring device, the measuring range is called the working range of the conversions.

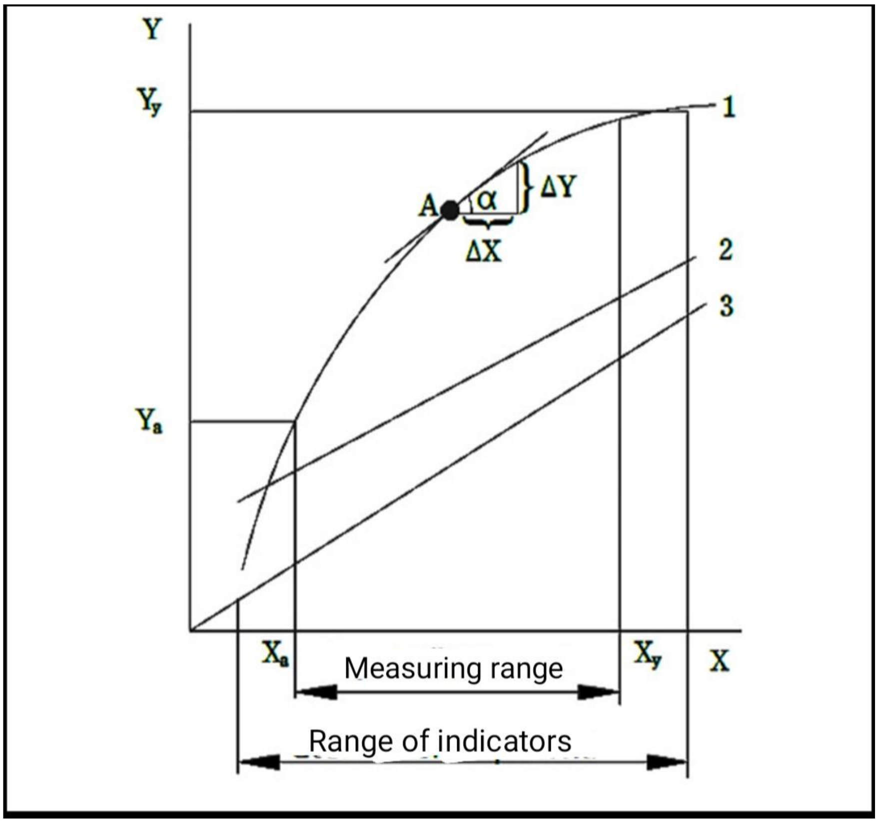



Figure 1.4. Static characteristics of information measuring devices

The upper limit of measurements is the lowest value of the measurement range. From this it is clear that the measuring range is determined by the difference between the upper and lower limits.

$$(X_y - X_a ; Y_y - Y_a).$$

To quantify the effect of the input signal of the measuring device on any Y output signal at any point of the static characteristic, it is necessary to consider the limit of the ratio of ΔY increase to ΔX when ΔX → 0:

$$S = \lim_{\Delta x \to 0} \frac{\Delta Y}{\Delta X} = \frac{dY}{dX}.$$

This parameter S is called sensitivity and is determined by the ratio of the change in the signal at the output of the measuring device to the change in the measured quantity that creates it. Graphically, this tangent is determined by the tangent of the angle of inclination α, drawn from the selected point A of the static characteristic of the touch.

If the static characteristic of a static measuring device is nonlinear (curve 1), its sensitivity will be different at different points in the characteristic, and the scale of the device will be nonlinear. In devices with static characteristics (lines 2 and 3), the sensitivity does not change at each point, and the scale distributions are equal (constant).

In information measuring transducers, the static characteristic is usually defined as follows

$$Y=KX ,$$

where K is the conversion factor and is also determined by the ratio of the output signal of the measuring transducer to the signal generated at the input of the converter, which reflects the measured quantity.

The main parameter of information measuring devices is the value of the division, which is determined by the difference between the values of the quantities corresponding to the notes on the scale [3,4]. Physical distribution value - is determined by the number of digits of the input quantity located on one division of the scale of the device. The value of the fraction is related to the number of divisions of the scale of the measuring device. The latter, in turn, is due to the error of measuring instruments, which is usually represented by accuracy class A. The number of scale divisions of an information measuring device is usually determined from the following relation at the first approximation.

$$n \geq 100(2A) \qquad (1.1)$$

If condition (1.1) is not met, the number of divisions of the scale is chosen so that the value of the division is an integer number of units of the measured quantity.

The threshold of sensitivity is the smallest value of the change in a physical quantity, and it can be measured from it with a given means. In practice, this is the smallest change in the input signal, and this change causes the output signal to change easily. As a rule, the observer who performs the measurement can easily see that the scorpion moves up to half of the scale distribution, so the threshold sensitivity can be considered equal to half of the division. If we take into account (1.1), then the sensitivity limit in the first approximation belongs to the accuracy class A. One of the important conditions for obtaining the measured results (accurately) is to take into account the interaction of the measuring devices with each other and with the measured sample.

A measuring device or converter connected to a measuring sample (object) of information receives a certain amount of energy or power from the sample. A similar situation can be connected to the previous output of the measuring device or the inverter in the circuit. This determines the need to determine the characteristics of the measuring devices, which are used to receive or transmit (transmit) energy in the input or output circuits.

It is accepted to use the concept of input impedance in measuring instruments to characterize this property.

For information measuring transducers, the concepts of input and output impedances have been adopted. In the general case, the impedance Z is the ratio of the generalized N force to W in the generalized case.

$Z=N/W$ .

The relationship between the information parameters of the output and input signals is determined by the time in dynamic mode or the dependence of the output signals on the input signal.

It is accepted to express the dynamic properties of measuring devices by a differential equation or a complex frequency function. (Other characteristics that determine the dynamic characteristics of information measuring devices are given in Table 1.2). The dynamic characteristics of measuring instruments are expressed by the differential equation in the linear part of the static characteristics (for measuring devices with linear static characteristics in the entire range of the converter).

$$a_n \frac{d^n Y(t)}{dt^n} + a_{n-1} \frac{d^{n-1} Y(t)}{dt^{n-1}} + ... + a_1 \frac{dY(t)}{dt} + Y(t) = KX(t),$$

or with a suitable transfer function

$$W(P) = \frac{K}{a_n p^n + a_{n-1} p^{n-1} + ... + a_1 p + 1},$$

$$Y(p)=W(p)X(p) \qquad (1.2)$$

is expressed by.

Here Y (t) and X (t) are the time-dependent functions of the output and input signals of the measuring device; numbers indicating the order of n-derivatives; Y (P) and X (P) are functions corresponding to the output and input signals.

The transfer function W (p) (1.2) can be considered as the coefficient of conversion of information measuring devices in dynamic mode. The transfer function W (p) is an inevitable feature of the inertial properties of measuring devices. It is an expression that allows you to determine by what law the input signals of the information measuring device change over time.

It is more convenient to use the transfer function of information measuring devices when checking (analyzing) the operation of these devices in measuring circuits.

It is usually determined from the time characteristics, ie by changing the output signal h (t) of the measuring device with time. If the input, when a step signal is given, its high value is equal to any XA value, not a unit, then the transition characteristic can be correlated using the output signal expression

$Y(t) = h(t)X_A$

To determine the inertial properties of information measuring devices from the transition characteristics, the concept of a dynamic item, usually derived from the theory of automatic control, is used. The same type of dynamic band transition characteristics and transmission functions are known, which allows to identify the measuring device with any type of dynamic band according to the form of the transition characteristic. Hence, it determines the form of the transmission function of the measuring device being tested. It is accepted to call what is described as identification. Figure 1.5 shows the types of transition characteristics of measuring devices. Due to their simplicity, the input signal of the measuring device XA instantly changes from any X1 to X2 (Figure 1.5 a) in order to obtain the time in zero moments. At the end of the switching process, the Ya value of the output signal of the measuring device varies from Y1 to Y2. It is sufficient to calculate the YA / XA ratio to determine the conversion factor K of the measuring device.

The transition processes shown in Figure 1.5 b, v, q correspond to the amplified (non-inertial) first-order periodic and oscillating manga types. The process shown in 1.5b is typical for electronic measuring devices. The processes shown in Figure 1.5 v, q are for a large number of measuring devices based on direct conversion. The exponential dependence of the curve shown in Figure 1.5 v shows the time constant of the T-quantity. It determines the time it takes for the output signal to reach a new constant value, which occurs when the input signal changes at a constant speed equal to the speed at the moment of gradual change. Used to characterize the dynamic properties of time-constant measuring devices. Due to the tangent error drawn on the transition process curve, the values of the time constant are defined as the time interval, during which the output signal assumes an increase of 0.632YA of its increase (Figure 1.5v). The accuracy of this determination is easily proved mathematically. The dynamic part of the dance, as well as the measuring device with the transition process (Fig. 1.5 g) can be considered as two aperiodic parts with time constants T1 and T2.

In this case, the transition process will be different depending on the ratio of T1 and T2. If $T1 / T2 < 2$, then curves 1 and 2 are shaped, and if $T1 / T2 \geq 2$, the curve takes the form 3 (Figure 1.5 q).

The transition processes shown in Figure 1.5 d, e are typical for cases where the differential equation of the dynamics of the measuring device is of three or more orders. In this case, the measuring devices can be considered as the sum of several typical dynamic parts connected in series.

The measuring device shown in Figure 1.5 e can be thought of as a combination of the time delay part and the oscillation part.

For all measuring devices, it is necessary to determine the Tn settling time (and indications) of the output signal, which is also called the relaxation time. It is the time interval required to complete the switching process in the event of a gradual change in the input signal.

Since all the considered switching processes theoretically end at an infinite value of time, the reaction time Tn is assumed to be such that it approaches a new fixed value of the output signal of the measuring device and passes into a certain zone, which differs by ± 5% from the change value of the output signal.

The reaction time of the information measuring device is determined by the time constant in the following relation:

$$T_n = (3 \div 5)T$$

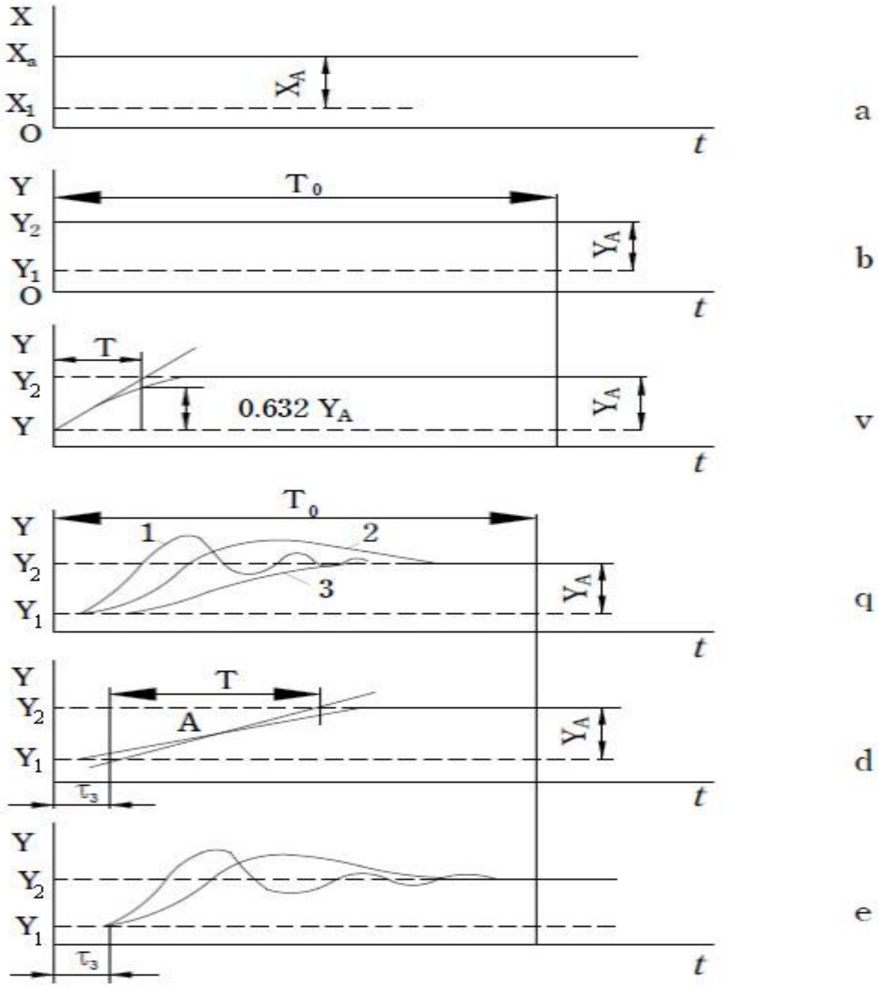



Figure 1.5. Forms of transition processes that are typical for information measuring devices

**1.4. Unified signals of information measuring devices**

In order to solve the problem of providing control and management tools to various industries, the development of methods of regulation and unification of automation tools has begun. These marked the beginning of the creation of the State System of Industrial Equipment and Automation (SIEA). At present, SIEA is quite well developed and continues to improve [5,6]. The success of the establishment of industrial measurement systems on a national scale is determined by the fact that today SIEA serves not only industry, but also science and needs.

The following principles underlie the establishment of SIEA:

selection of the device according to its functional properties;

minimization of the nomenclature of means;

installation of block-module of technical means and aggregate state of systems;

compatibility of devices and transmitters.

The block-module principle of SCDS tools allows the creation of a variety of functionally complex devices from a limited number, simpler unification blocks and modules. Aggregate installation of systems allows the creation of complex measuring devices and systems.

Depending on the type of energy used, auxiliary devices in SCDS measuring instruments are divided into four independent branches: electric, pneumatic, hydraulic and unused auxiliary energy devices.

Table 1.1 shows the unique analog electrical input and output analog signals of SCDS, which are used in the construction of measuring devices.

Table 1.1. SCDS unified electrical analog signals

| Signal type | Physical quantity | Parametrs of signal |
|---|---|---|
| Electric | Constant current | 0÷5; 0÷20; -5÷0÷5; 4÷20 mA |
| | Constant voltage | 0÷10; 0÷20; -10÷0÷10 mV<br>0÷10; 0÷1; -1÷0÷1 mV |
| | Variable voltage | 0÷2; -1÷0÷1 V |
| | Frequency | 2÷8; 2÷4 kHs |

In accordance with the above concepts, the information measuring device can be considered as a special case of the measuring system. Therefore, the following schemes and metrological characteristics of measurement systems are described below. Some general structure diagrams can be distinguished for information measurement systems.

The information measurement system provides simultaneous measurement and recording of all quantities of the object under study (Figure 1.6). In these information measurement systems, measurement data is formed by transmitters and transmitted to the communication channel in the form of a signal. The design of a communication channel can be very different. For example, in the form of three wires, up to the equipment of a complex radio channel, which includes radio transmitters and receivers. Depending on the type of physical quantity being measured, the principle of influence of the transmitter, and the distance at which the information is transmitted, measuring systems may include, in addition to transmitters, intermediate and transmitting measuring transducers.

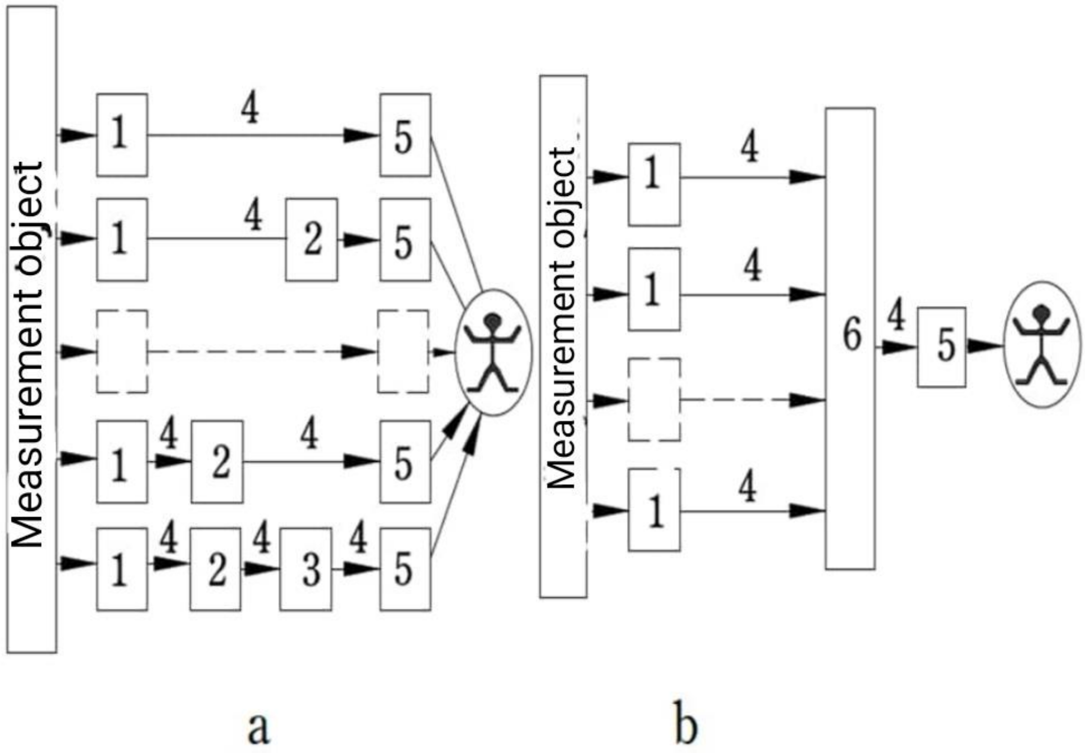



Figure 1.6. Structural diagrams of information measuring systems and measuring devices: 1-transmitter; 2-intermediate measuring converter; 3-speed measuring transducer; 4-communication channel; 5 - information receiver; 6 - switch.

In this case, the measuring transducer can be placed next to the first device, and finally they put the signal in a convenient form or perform a recording.

In information measurement systems, a switch is used to connect transmitters to devices in turn and is considered as an auxiliary device (Figure 1.6, b).

For simplicity, the figure shows a measurement system that contains only transmitters. In general, intermediate and transmission measuring converters can be connected to it. In this case, the signals from the transmitters of all measured quantities must be the same in nature and range, as opposed to the system established by the scheme given in Figure 1.6, a.

The output signals of the transmitters are necessary to enable them to be measured and recorded by the same device, which is now replaced by a computer with an analog-to-digital converter. In the block diagrams of the considered measurement systems, it is necessary to distinguish between the block of the communication channel consisting of transmitters and secondary devices. If the communication channels with the devices of the transmission and measuring systems are normalized with the same parameters, then the former can be considered as converters connected in series with each other.

$$Y = f_n\langle \dots f_3\{f_2[f_1(X)\ ]\ \}\rangle$$

The conversion functions of information measurement systems can be linked as follows. If the conversion functions of the specified converters are proportional to each other, then the conversion function of the measuring system will be as follows: $Y = \left(\ \prod_{i=1}^{n} K_i\ \right)X$

where Ki is the conversion factor of the i-th converter.

The dynamic properties of an information measurement system are determined by the dynamic properties of the transducers it contains. From the point of view of the automatic control theory of the measuring system, it can be considered as a series connection of dynamic parts, so its transmission function can be written as the product of the transmission functions of the converters:

$$W(p) = \prod_{i=1}^{n} W_i(p)$$

When information about the accuracy classes of measuring devices included in the measurement system is known (they can be considered as converters for easy analysis), then the following expression is used to estimate the error of the measurement system connected by sequential connection of n-number converters:

$$\gamma = \sum_{i=1}^{n} \gamma_i\ , \qquad (1.3)$$

here $\gamma_i$ is the error of the i-th converter.

(1.3) - the estimation of the error obtained in measurement systems is maximal, because it is assumed that the maximum errors of the same value occur at different values of the measured physical quantities in all measuring devices that make up a particular system. In order to obtain the errors of the measurement systems more realistically, they use the method of collecting the errors of the converters:

$$\gamma = \sqrt{\sum_{i=1}^{n} \gamma_i^2}$$

In this case, it is assumed that the errors of all converters do not depend on each other, the laws of error distribution are the same for each converter, and the value of the permissible limits of the applied error determines the boundaries of this distribution. If the conversion functions of the measuring devices included in the measurement system are not linear, then to estimate its error;

$$\gamma = \sqrt{\sum_{i=1}^{n} W_i^2 \gamma_i^2}$$

Here Wi is the coefficient of influence of the i-th converter, determined by its conversion function.

# 2. DETERMINATION OF BASIC PARAMETERS OF ULTRASOUND RANGE DEVICE USED IN INFORMATION MEASUREMENT SYSTEMS

## 2.1. Summary of contactless distance sensors

The rapid development of electronic and computer technology has laid the foundation for the widespread automation of various processes in industry, scientific research and everyday life. The realization of this ground was determined by the capabilities of the devices to obtain information about a significantly regulated parameter or process, ie the functions performed by the sensors.

Sensors are considered to be one of the main control elements of modern technology, converting the measurement parameter into an output signal, quantifying and evaluating them.

Determination of fluid level in different types of tanks can be performed using industrial electronics and automation tools [6,11].

The principle of operation of such measuring systems is generally the same - the information from the measuring transducer (sensor) enters the data processing device based on optical electronic computers. One of the main differences is the choice of sensor type.

Volumetric, optical and ultrasonic sensors are widely used to measure the level of liquids and granules. The latter is of great interest, as there is a wider use sector in this area.

The basis of the level of management of technological processes in many industries is related to their measurement.

Modern systems of production automation require statistical and informational information that allows them to estimate the cost, prevent losses, optimize the management of the production process, increase the efficiency of raw materials.

The ever-increasing demand for this information leads to the need to use tools that provide continuous measurement, rather than simple alarms, in their circuits to ensure control.

The first contactless distance sensors only provided information about the presence of an object in front of the sensor, such as a discrete signal ON / OFF. These very simple sensors are still widely used in various industries. At the same time, in order to solve more complex problems of automation of technological processes, engineers need additional information about the condition of the measuring object.

For this purpose, sensors have been developed that allow to determine the distance to the object and its position with the help of its analog output, where the signal is proportional to the distance to the measured object. Such sensors can be used in many applications (for example, determining the distance to the object, measuring thickness, measuring bending and deformation, measuring the profile of the product, centering and measuring the diameter).

Sensors can use different measurement principles to measure distance: inductive, ultrasonic or optical. However, all of them have an electrical output signal, which is a unit proportional to the distance to the measured object.

Inductive sensors. Inductive distance sensors detect the distance to conductive metal objects: metals such as aluminum, steel, brass. Because the principle of operation of inductive sensors is based on the determination of mutual induction currents, such sensors are very resistant to the effects of non-metallic objects and obstacles, such as dust or machine oil. Modern technology allows you to create an inductive sensor with analog output with a diameter of 6 mm and a measuring distance of 2 mm. Sensors with such high resolution and fast timing find use in many high-speed tasks [13].

However, despite the very high accuracy, the resolution and adaptation time, a significant inaccuracy of 3% to 5%, poses a problem. To counteract this, some manufacturers define the output signal of the sensor as a polynomial function that affects the mathematical signal. However, with the help of this function, many modern controllers allow you to program a more accurate measurement algorithm.

However, for example, at a distance of 0.4638 mm, the output signal will be 5 mA. The problem with linearity can be solved by using the integration of the sensor microprocessor. This method allows you to linearize the output characteristics of the sensor and significantly reduce the nonlinearity. For example, an inductive sensor with a diameter of 12 mm and a measuring distance of 0-4 mm and a built-in microprocessor has a linearity of more than 0.4%.

Ultrasonic sensors. The principle of operation of ultrasonic distance sensors is based on the propagation and measurement of ultrasonic pulses, as long as the sound pulse is reflected from the measuring object and returned to the sensor. In this case, the solution reaches up to 0.2 mm.

Due to this, the piezoresistive transducer can serve both as a reflector and as a receiver of ultrasonic pulses. Depending on the conditions of use, there is a need for single-switch ultrasonic distance sensors.

Such a converter emits a short ultrasonic pulse before. At the same time, the sensor starts an internal timer. The timer stops when the ultrasonic pulse reflected from the object returns to the sensor. The elapsed time between the moment of propagation of the pulse and the moment when the reflected pulse returns to the sensor is the basis for calculating the distance to the object. Full control of the measurement process is performed with the help of a microprocessor that provides high measurement linearity. The most important application features of ultrasonic sensors are the need to measure their distance to such complex objects as, for example, granular objects, liquids, grains, transparent or, conversely, strong reflective surfaces. In addition, relatively large distances can be measured with ultrasonic sensors, thus maintaining their limited dimensions, which can be important for a number of applications.

However, ultrasound sensors also have a number of limitations. First of all, it is foam and other objects that absorb a lot of ultrasonic waves. Such absorptions greatly reduce the measured distance.

Highly curved surfaces also reduce distance and measurement accuracy, as ultrasonic waves propagate in different directions. Ultrasonic sensors emit pulses in the form of a wide cone, which limits the need to measure the distance from other objects to small objects by increasing the level of obstacles. These objects can also be located in the field of view of the sensor. Some ultrasonic sensors have a conical angle of only 5%. This allows them to use smaller objects, such as bottles or ampoules, to measure.

Optical sensors. There are many different ways to measure the distance to an object with the help of optics: for example, laser interferometers, light-reflecting sensors and radar-type optical sensors. Each type of sensor has its strengths and weaknesses. Laser interferometers have a large measuring range and an accuracy of a few nanometers, but these devices are very expensive and complicated to operate.

Sensors with scattering and analog outputs can measure a wide range of distances, but because they work with reflected light, they can cause problems when measuring distances to reflected and painted objects.

Radar-type optical sensors are mainly laser-type, they can measure large distances, but their principle of operation is based on measuring the time of light propagation from the sensor to the object and back, allowing to measure with a limited resolution of 2-3 mm.

The vast majority of industrial measurement issues range from a few microns to several tens of meters. In this case, the sensors must work on objects far from ideal: small, multi-colored, high-speed displacement and complex structural surfaces. Distance laser sensors operating on the principle of optical triangulation are most suitable for such purposes.

The principle of operation of optical distance sensors is as follows: the laser sends a beam through a lens, which is reflected from the object and is focused on a line of photodiodes that convert the light signal into an electrical signal. Any change in the distance to the object leads to a change in the angle of the reflected beam, which means that the reflected beam occupies the positions of the reflected beam on the photodiode. The microcontroller processes the signal from the photodiode line and converts it into an analog electrical signal. A more important quality of such distance sensors is the high accuracy of measurement and the compatibility of large distances measured. Most manufacturers offer sensors with a resolution of 1 μm to 1 mm. However, high accuracy is possible only at relatively short distances. So, for example, an accuracy of 1 μm at a distance of 1 meter can hardly be obtained.

All laser range sensors allow integrated or generalized measurements to reduce the effects of noise. In this case, many measurements of the distance to the object are made, and then the result is summarized, thus increasing the accuracy of measurements. However, high accuracy requires large-scale measurements, which increase the overall measurement time. Thus, for example, a typical measurement time is 0.1 s to ensure an accuracy of 1 μm.

## 2.2. Summary of ultrasonic distance sensors

This section describes methods for measuring distances using ultrasonic sensors based on the principle of measuring signal transit time. In this case, the signal reflected from the object is processed at the same point - as in the scattering.

Such a method is directly related to the detection method. At the TO time moment (Figure 2.1), the ultrasonic transmitter transmits a stream of signal-DT continuous pulses, which propagate rapidly in the environment. When the signal reaches the object, part of the signal is reflected and reaches the receiver at time T 1. The electronic circuit of the test processing unit measures the time T 1- TO and determines the distance to the object.

It can be used as a circuit that uses the same header sensor for propagation and reception to measure distance, where propagation and reception are two different ends.

One-headed measurement scheme. There is a significant drawback to a single-head measurement scheme. The disadvantage is that after the scattering of the pulse pack, it must first take some time for the scattering membrane to calm down in order for the reception to work. This interval is called the "dead" time of the sensor.

The presence of "dead" time means that single-head ultrasonic distance meters have a zone called "blind", ie when the object is located too close, the reflected packet is measured so fast that it does not pass from the transmitter to the receiver and the object can not be detected.

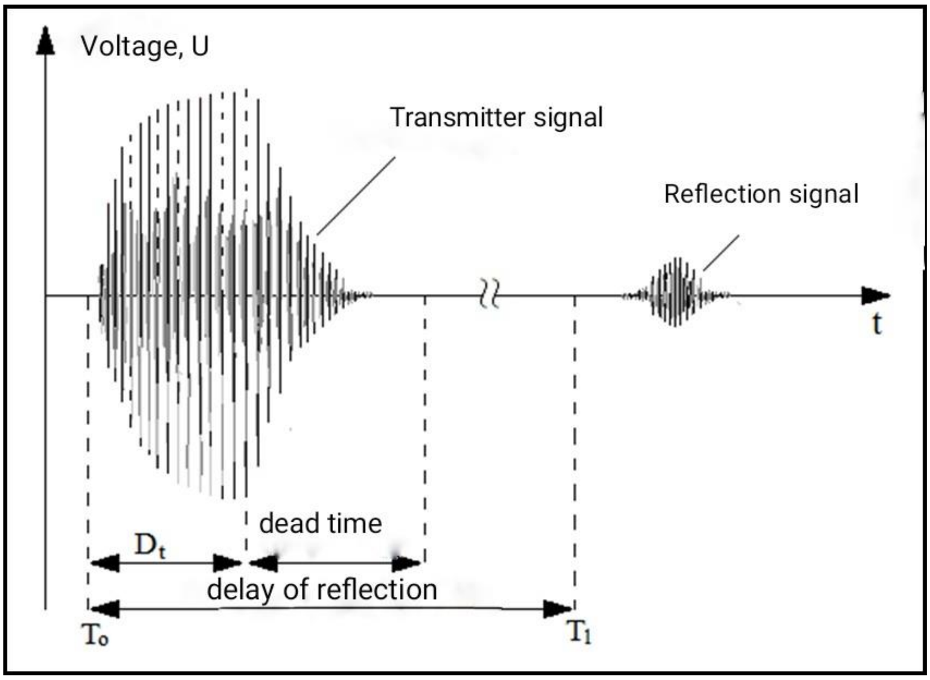



Figure 2.1. Characteristics of signals in the sensitive element of an ultrasonic sensor with a single-head measurement circuit

The longevity of the transmitter-receiver switching processes depends on many factors, such as the internal attenuation of the signal, the total ripple mass, the characteristics of the illuminating material and the mechanical design of the sensor. For example, Pepperl + Fuchs 1m and 6m reaction zones For traditionally designed ultrasonic sensors, the "blind" zone limits are 0.2m and 0.8m. This corresponds to 1 ms and 5 ms of "dead" time.

The functional diagram of the direct detection sensor is shown in Figure 2.2.

The inductor circuit of the transmitter is activated by the emitting (starting) pulse, which produces a series of pulses with an amplitude of 250 V. This input (starting) pulse blocks the input of the receiver amplifier. After switching off (disconnecting) the spreader, the receiver exits the block. Receiving the receiver takes 300 μs, which is less than calming down the transmitter, so the receiver's parameters do not affect the unit of the "blind" zone. When an object is in the control zone with sufficient reflection capacity (specifically), the reflected acoustic signal affects the high-frequency alternating current in the membrane. This voltage is processed by analog signal detection methods - limited, amplified, detected and entered into the comparator. An increase in the value of the detection limit with this voltage is a signal of the presence of the object in the control zone. The electronic circuit records the time interval elapsed from the moment the transmitter is activated and generates an output electrical signal proportional to this time interval. It maintains a digital interface with the outside world.

Noting the arrival of the first reflected signal, the control circuit delays the formation of the next trigger pulse, waiting for the possible arrival of reflected signals from more distant objects in the control zone.

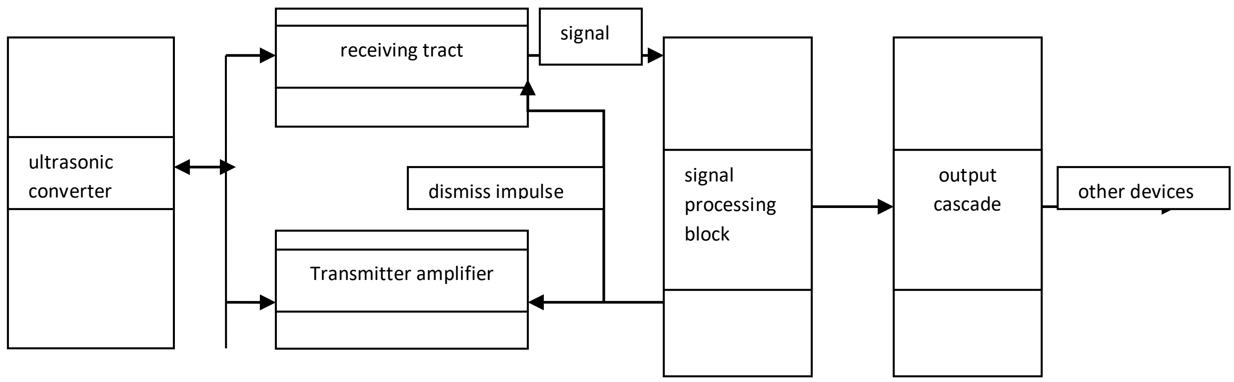



Figure 2.2. Block diagram of the ultrasonic sensor with a combined diffuser and receiver.

Two-headed measurement scheme. The blind zone can be significantly reduced by using a circuit where two separate sensor heads are used as a distributor and a receiver. In this case, the same resonance for the transmitter and receiver

it is necessary to ensure the maximum sensitivity of the circuit by choosing the right frequency.

Limit tracking. Special attention is paid to minimizing the parameters of the "dead" zone, as it is the most important parameter of the ultrasonic sensor and determines its success in the market in many respects. To do this, the method of tracking the value of the detection threshold is used. During the transition process at very close distances, the signal manages to cross the path between the sensor and the object several times. The detection accuracy is significantly reduced due to the distortion of the reflected signal. In this case, the error of the method increases rapidly with decreasing distance to the object. This necessitates a compromise between detection sensitivity, the probability of false alarms, and the accuracy of distance measurement.

Figure 2.3 explains the detection range tracking method (for very short distances). It consists in the fact that the limit voltage of the detector transmitted to the comparator is formed by the repetitive shape of the "tail" of the packet of pulses received when the vibration of the membrane is extinguished, and by the voltage that changes over time.

Figure 2.4 shows oscillograms showing the phenomenon of repeated reflection of a signal from an object in the interval between packets of sounding pulses of the transmitter.

Figure 2.5 shows an event that occurred during the presence of an object in the “blind” zone using a tracking threshold. The problem is that the detector "does not know" which of the reflected signals has repeatedly exceeded the detection limit. The second of the signals shown in the figure is considered to be marked, which led to a doubling of the actual distance to the object. However, this is unacceptable: the sensor is installed and installed in such a way that objects do not fall into the "blind" zone.

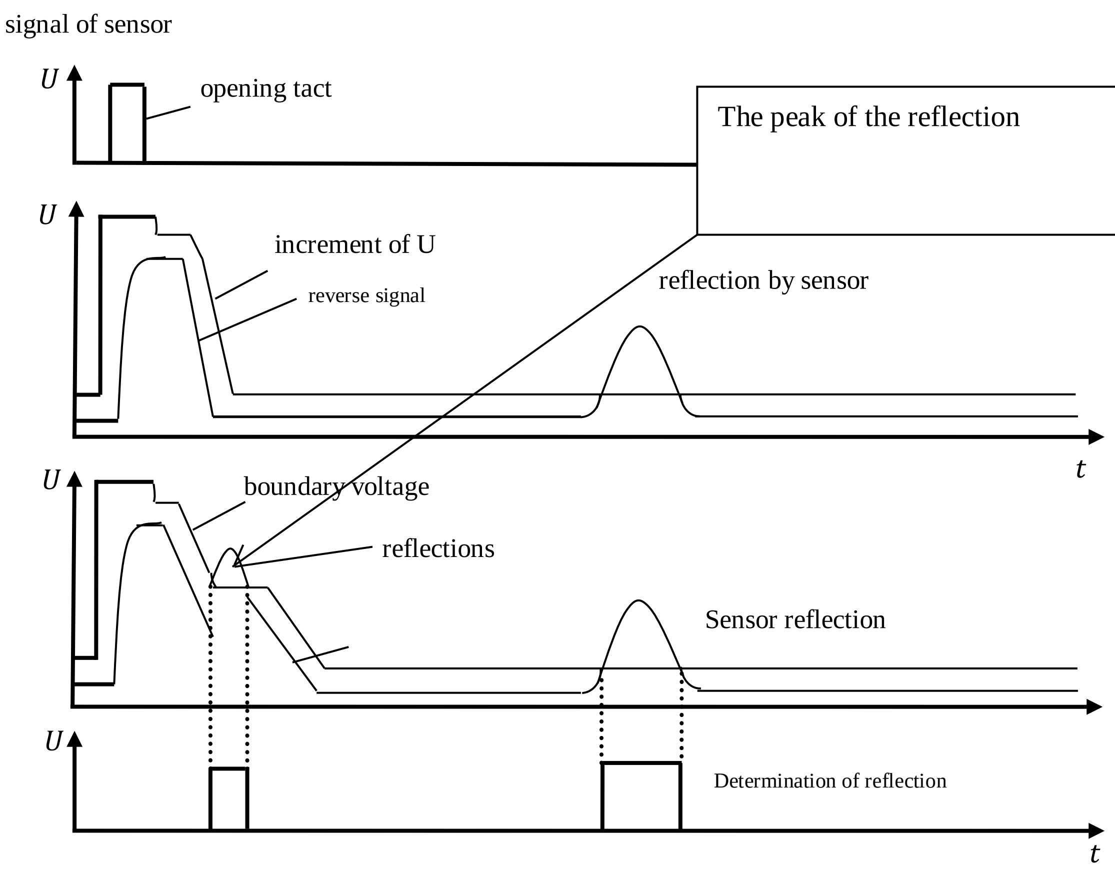



Figure 2.3. Methods of tracking the limit by reducing the "dead" time of the sensor

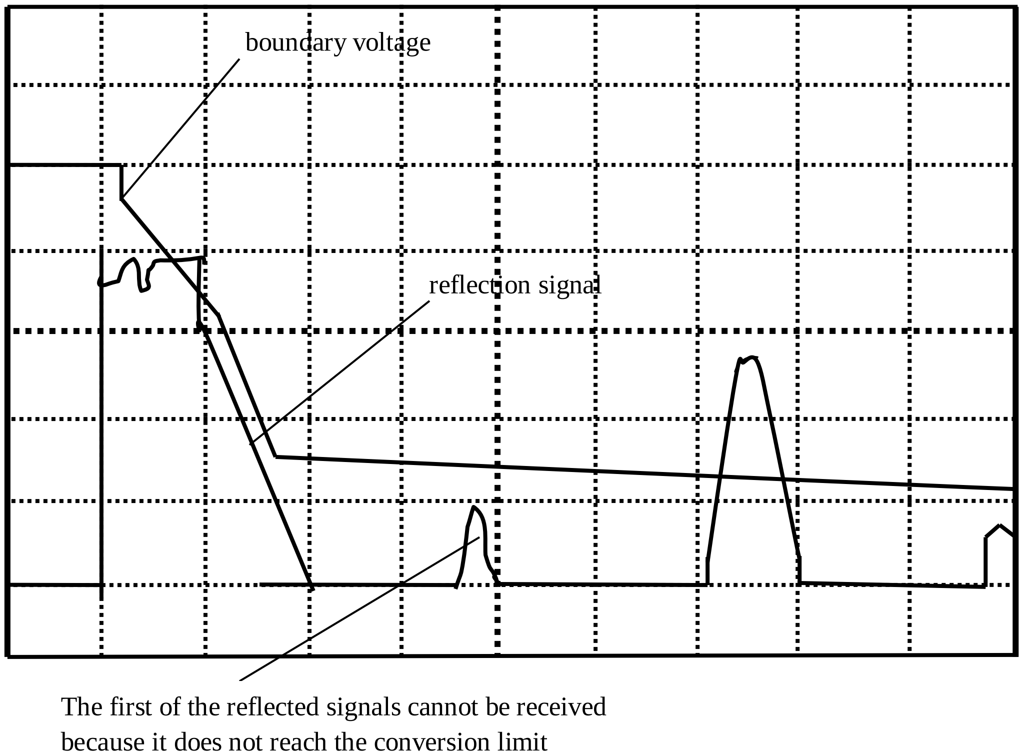



Figure 2.4. The effect of multiple reflections on a large distance to an object

analog function

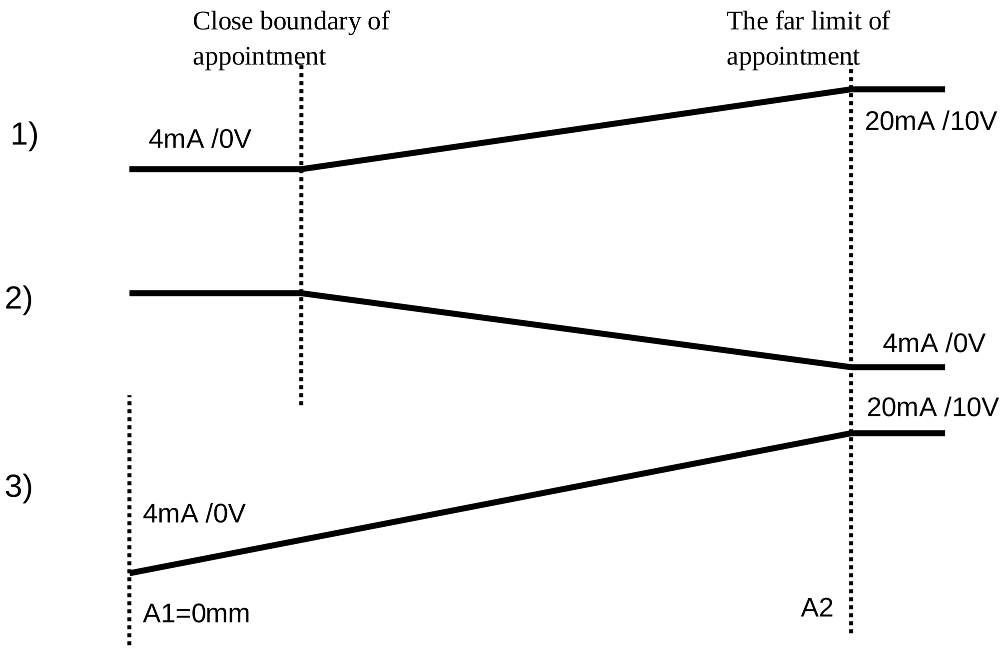



Figure 2.5. The effect of multiple reflections during the presence of an object in the "blind" zone

Figure 2.6 shows the subsequent deterioration of accuracy with the approach of the object. The voltage on the sensor takes the form of a smaller toothed comb, which continues to increase with incorrect distance measurement. Approximate distance characteristics of ultrasonic sensors are shown in Table 2.1. The use of the impact threshold tracking method allowed to reduce the "blind" zone by 2-2.5 times. However, the use of sensors close to the boundary of the "blind" zone requires perfect processing. Therefore, the characteristics of the remote sensors show both the probing range and the setting range in Table 1. Probing range refers to the range of detection distances determined only by the physical capabilities of the sensor (intensity of the transmitted beam and its direction) and the parameters of the sample object. Setup range is a range of distances where the sensor is adjusted "in place" for optimal use in a particular application (taking into account the characteristics of the object and its orientation relative to the sensitive element of the sensor).

Table 2.1. Characteristics of sensors with built-in function of reduced "blind" zone and adjustment range

| Distance, mm (frequency) | “Blind” zone, mm | Sounding range, mm | Installation range, mm |
|---|---|---|---|
| 500 | 0...30 | 30...350 | 50...500 |
| 2000 | 0...80 | 80...2000 | 12...2000 |
| 4000 | 0...200 | 200...4000 | 240...4000 |
| 6000 | 0...350 | 350...6000 | 400...6000 |

Direct detection ultrasonic sensors are provided with a set of tools that allow elastic setting of the near and far limits of the measuring window.

**Fighting obstacles.** Adjustable limits of the modifier After the object is detected, the signals displayed later in the control window lead to malfunctions.

To eliminate this, the amplifier of the receiving device with amplification conditions is closed after the detection of the object. At the extreme distances, the amplification of the observation window probe is maximal.

When the sensors of many companies have an adjustable limit of the converter - at the same time exo-signals coming from the environment's positive objects - it allows you to set up a device against interference.

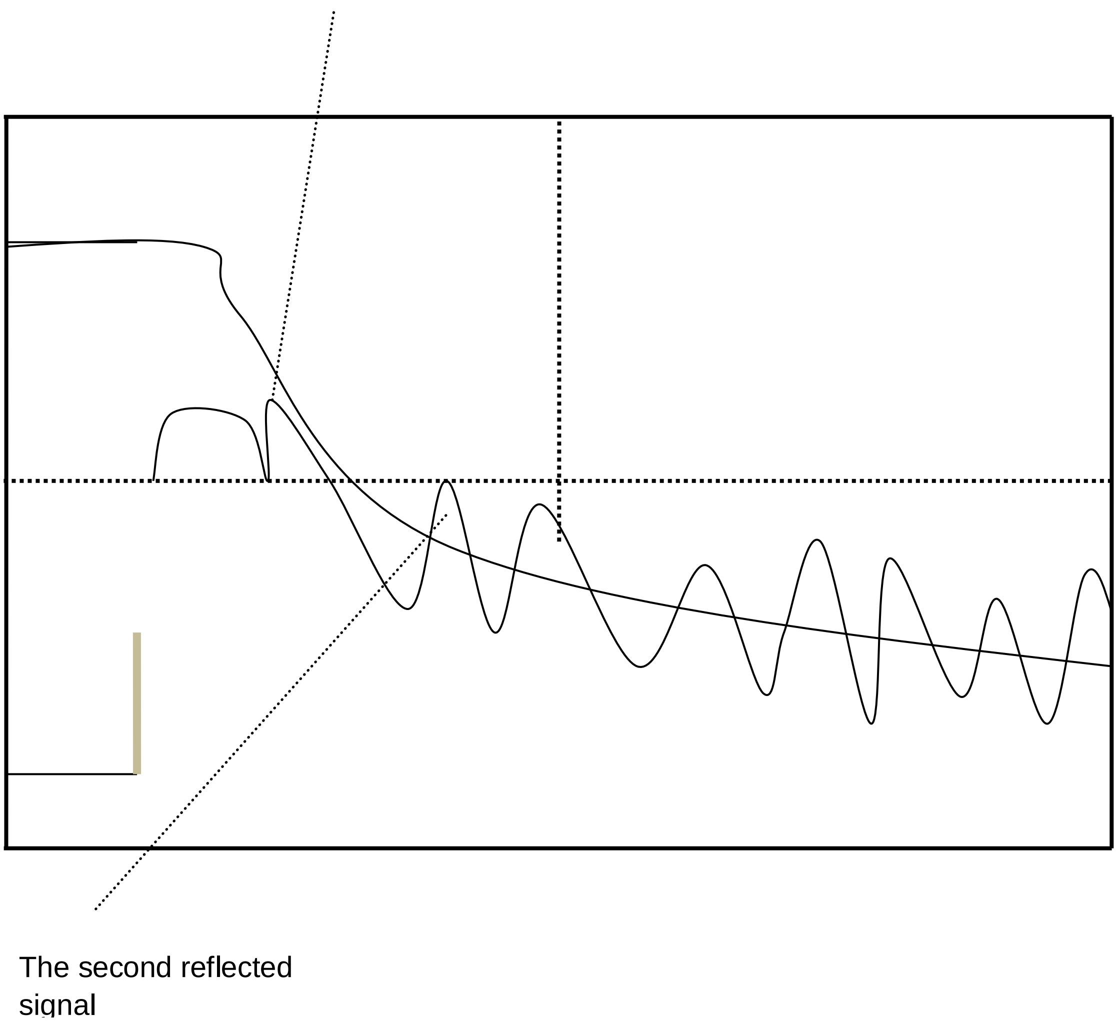



Figure 2.6. Loss of measurement accuracy in the next approach of the object

One of the advantages of modern ultrasonic sensors is the function of repelling exo-signals from disturbing objects.

Using these possibilities, it is necessary to take into account the possible additional effects of the adjustable threshold, in particular, the reduction of sensitivity caused by the reduction of sound radiation and the reduction of the reaction zone.

**Adjustable cycle time.** An additional measure of repulsion of numerous reflected and background signals is an increase in the duration of the activation pulse and, consequently, a packet of scattering pulses. This leads to the fact that the vibration amplitude of the scatter does not increase suddenly, but increases over time. The ratio between the continuity of the propagating impulse and the maximum pressure of the propagating solid medium is used to match the energy of the propagator to the distance to the object. For small distances to the object, the duration of the pulse decreases. However, the effect of signals reflected from foreign objects located in the operating zone at large distances from sensitive surfaces (sensor surface) is reduced.

**Corrections of measurement results.** The result of determining the time of signal transmission from the object is some scattering due to changes in the propagation medium. The effect of obstacles can be mitigated by calculating the results of the measurements - statistical processing of the variance and discarding the results with a very large deviation from the mean.

For applications requiring high measurement speeds, a simplified obstacle setting algorithm can be used. For example, the difference between the last two units of measurement is calculated and stored. The measured distance is considered real, the last two measured differences are slightly different. Objects accelerated in this way can actually be detected. If the measurement difference is zero, it is an indication that the object is motionless; the constant difference indicates the movement at a constant speed; the variable difference indicates that the object is moving rapidly.

**Synchronization**. The reception and transmission phases are adjusted in time to further overcome obstacles at a certain distance to the detected object. Such synchronization is used in retroreflective detection when the distance from the source to the reflector is known. Synchronization signals control the amplifier of the receiving tract of the sensor with a variable gain.

**Source of measurement errors and environmental impact.** A common problem of distance measurement based on estimation of signal transmission time is the dependence of the measured time on the sound propagation speed [7,11]. The speed of sound in the air is affected by a number of factors - the temperature, atmospheric pressure, humidity and the composition of the atmosphere. To fully take into account all these factors, it would be possible to use a set of sensors that study the weather and calculate the speed of signal propagation in the air on the basis of the obtained data. However, it is very complicated and expensive. In practice, it is sufficient to compensate for the effect of temperature, as temperature has a greater effect on the speed of sound propagation. However, this method does not take into account the temperature change (rise and fall) within the measurement window.

Good results are obtained by the use of reference sensors, which determine the real speed of sound based on the propagation time of the signal reflected in the reference range. Determining the speed of sound propagation can be done by connecting working sensors or by means of external (main, main) devices that process information.

**Cross obstacles.** When the near-frequency ultrasound sensors are located in front of each other, the processing device cannot distinguish whether the signal it receives is an echo signal or a signal from another transmitter. It can be seen that the sensors mounted on each other in the reaction zone can interfere with each other. There are various ways to reduce such interactions.

It is a method of heating sensors operating at different transmission frequencies. However, this method is inconvenient in that it requires the design of a rotary switch for each of the operating frequency sets.

The best way to avoid interaction is to use a pulse coding method. It consists of different ultrasonic sensors emitting (scattering) a package of sounding pulses that are not equal in time, but in a certain time sequence, it should be taken into account that each ultrasonic sensor has its own individual time sequence. These sequences are formed by strictly defined matching codes. Each receiver selects its own transmitter code.

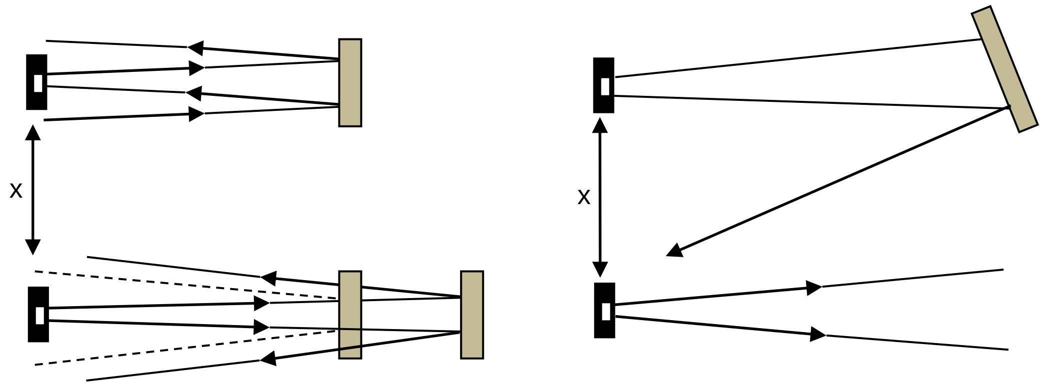
This method is good in that a working proximity sensor cannot work without interaction. The disadvantage of this method is that the transmission of codes takes more time than conventional pulse packers, and the maximum frequency of the sounding control zone is reduced.

Another inevitable possibility of sensor interaction is the use of fixed but different clock frequencies.

**There are rules for identifying safe operation issues.** These rules must be followed to avoid sensor interactions. The real required X distance at which the sensors will need to be located may depend on the position and orientation of the object on the sound cone. If the orientation of the object is unfavorable (say, the reflected beam "illuminates" the neighboring sensor), then it is necessary to increase the distance X (Figure 2.7). If the sensors are located opposite each other, an interval of XX according to Figure 9 is recommended.

**Synchronization of sensors.** Synchronizing the receiving and transmitting phases of the sensor at a certain distance to the object already considered in the relevant chapter also helps to protect against cross-barriers.

**Work characteristics.** One of the additional means of combating cross-obstacles from multiple sensors is the synchronization of the sensors themselves in parallel or multiplex mode. In parallel mode, the synchronization of the inputs of all sensors is combined and controlled at the same time.




| Detection zone mm | X |
|---|---|
| 60...300 | 0,15 |
| 200...1000 | 0,6 |
| 800...6000 | 2,5 |
| 300...3000 | 1,2 |
| 500...4000 | 2,0 |
| | 2,5 |

Figure 2.7. Interaction of adjacent sensor

In the multiplex mode, the sensors are activated in turn according to the cyclic law.

In this mode, the time of the probing cycle is equal to the sum of the time cycles of the individual sensors (if the sensors are of the same type, the cycle time simply increases so much that the sensor operates in multiplex mode).

**Working conditions and characteristics of the object.** Objects detected by ultrasound sensors can be solid, liquid or powder. The characteristics of the surface of the object affect its reflectance (property) and are considered necessary for the processing of the reflected signal by the sensor. The ideal reflection provides all smooth surfaces that are at right angles to the ultrasound cone and have some area exceeding the minimum given in the data readings. Reliable detection is possible in the event of scattering of reflection angles within ± 3 °. The shape of the object does not matter. It is important that the cross-section of the area of the object falling into the reaction zone of the sound cone is not less than that specified in the technical parameters of the sensor.

Such properties of the material - transparency, color or external coating of the surface (polished and unpolished) do not affect the accuracy and reliability of detection.

Depending on the operating frequency of a particular sensor, the roughness of the surface can lead to distortion of the reflected signal. In practice, the following rule is adopted: If the maximum height of the surface roughness is less than the height of the sound wave, the reflection will be mainly directional.

If the height of the roughness is greater than the height of the sound wave, the reflection will be mostly diffuse.

It should be noted that the transition from directional reflection to diffuse reflection is smooth. The presence of both diffuse and directional reflection between the value of roughness and the values shown in the table is given as a result of reflection. The share of diffuse reflection increases with increasing roughness. The presence of rough surfaces on the object leads to a reduction in the area of impact of the ultrasound sensor.

Significant irregularities are caused by large deviations of the angle of inclination of the surface from the ideal position, if the distance of the object is such, then the sensor reacts to the diffuse arrangement of the reflected signal. As a result, for example, the filling of the container in coarse materials can be controlled when the surface deviates from the ideal position by 45 °. Of course, the sensor should be located close to the object (Figure 2.8).

In practice, the following objects are best detected with ultrasonic sensors:

smooth and solid objects placed at right angles to the subject of sound;

solid rough objects, which cause diffuse reflection, regardless of the orientation of their surface;

the surface of liquid materials if they scatter no more than 3 ° perpendicular to the axis of the sound cone;

The worst are:

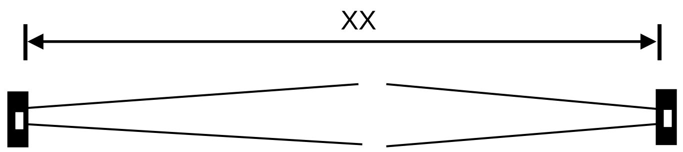
materials that absorb ultrasound waves - felt, cotton, wool, foam, hard textiles;

Materials with a temperature above 100 ° C;

It is necessary to use obstacle sensors to detect such materials (ultrasonic absorption method).

Table 2.2. Reflection properties of uneven surfaces

| Receiver frequency KHs | The degree of roughness of the surface of the object, which gives a "full-directional" reflection | The degree of roughness of the surface of the object, which gives a "fully diffuse" reflection |
|---|---|---|
| 65 | <1 | >25 |
| 85(90) | <0,8 | >20 |
| 120(130) | <0,5 | >13 |
| 175 | <0,4 | >10 |
| 375 | <0,2 | >5 |




| Detection zone mm | X |
|---|---|
| 60...300 | 0,15 |
| 200...1000 | 0,6 |
| 800...6000 | 2,5 |
| 300...3000 | 1,2 |
| 500...4000 | 2,0 |
| 4000...6000 | 2,5 |

Figure 2.8. Safe distance between sensors located opposite each other

**Detector characteristics**. When using ultrasonic sensors, one of the main causes of obstructions is the improper parameters of the object, which prevent the effect of exo-signals from objects near the sensor. In this regard, the manufacturers in the catalog indicate the detector characteristics for more responsible sensors. With the help of detector characteristics it is possible to estimate: which objects, in which zones can determine the detection signal.

To measure the characteristics of the detector, a set of reference objects is used at right angles to the beam of the sound cone. The collection includes the following objects:

700 × 700 flat plate (usually this contour covers the entire detection area);

100 × 100 mm flat plate (standard) for measuring technical passport parameters);

160 mm diameter plastic pipe covered with felt (gold, silver) (standard “trousers”);

Wooden (wooden) detail with a diameter of 25 mm (test object to determine the differential travel, under which the distance between the start and release points of the sensor when moving the part back and forth).

It is necessary to ensure that the sensor works properly so that there are no foreign objects within the detection limits. The object to be detected must be located within the guaranteed limits of the detection zone, taking into account its shape, dimensions and surface characteristics.

**Improving probing conditions.** For a reliable search of the object, a quality reflected signal must be provided on the sensor membrane of the sensor. The creation of good conditions for reflection from the object for the full implementation of the work significantly improves the reliability of the entire detection system.

The ideal surface of the object should be large enough and flat. The conditions of reflection, as mentioned, are affected by the inclination of the surface reflected on the axis of the sound cone. A slope of no more than 3 ° to the axis of the sound cone is considered permissible. Problems can occur when working with circular objects and corrugated surfaces (for example, the surface of a liquid when mixed).

Granulated and scattered materials can also be detected by ultrasound.

The surface of the scattered materials should not be inclined 45 ° to the axis of the sound cone. The size of the grain or the roughness of the surface determines the unit of diffuse composition of the exo-signal that can be detected by the sensor.

However, the diffuse composition weakens rapidly as the distance from the sensor increases, making it difficult to reliably detect the object.

They use a beam deflection system built with the reflection assembly to provide the necessary inclination of the surface reflected to the axis of the sound cone. The direction of the ultrasound beam can be easily changed by reflection from elementary deflectors made of virtually any material.

The intersection of the detection zone does not actually change if the deflectors are large enough and the beam does not deviate more than twice. Deflectors require precise installation. Thus, for example, the sensor can be placed away from aggressive environments or cross the area covered by foreign objects.

### 2.3. Basic parameters of different types of sensors

Analog output sensors. The value of the time of transmission of the ultrasonic signal is formed in the receiving tract of the sensor as an analog signal. Manufacturers offer combined detection sensors with both converter and analog output. These sensors need to have a boundary task of the measurement window within the detection range [9].

In different models of sensors, the analog output can provide a 4… 20 mA output current signal or a voltage output level of 0… 10V. There are also sensors with automatic output type (current / voltage) depending on the type of load.

The dimensions of the measuring window can be adjusted on different models of sensors:

with two potentiometers;

through coded modifiers;

by instruction of parameters via interface.

**Digital interface sensors.** Digital signal processing sensors are available, where a digital interface with an external device is designed for information processing. Usually RS-232 interface is used. The presence of a digital interface necessitates the possibility of meaningful dialogue between the sensor and the control device, which increases the flexibility of the use of the sensor and allows its full use [10].

The digital interface allows you to enter the parameters required for signal processing. This can include the limits of the detection range, the type (type) of the output of the converter, the normally closed or normally open conditions, the coding mode (continuous or one-time), and the environmental parameters (eg temperature measured in the detection zone).

With the help of a sensor it is possible to monitor the presence of the object in the detection zone and determine the distance to it. The sensors also have two additional switching outputs.

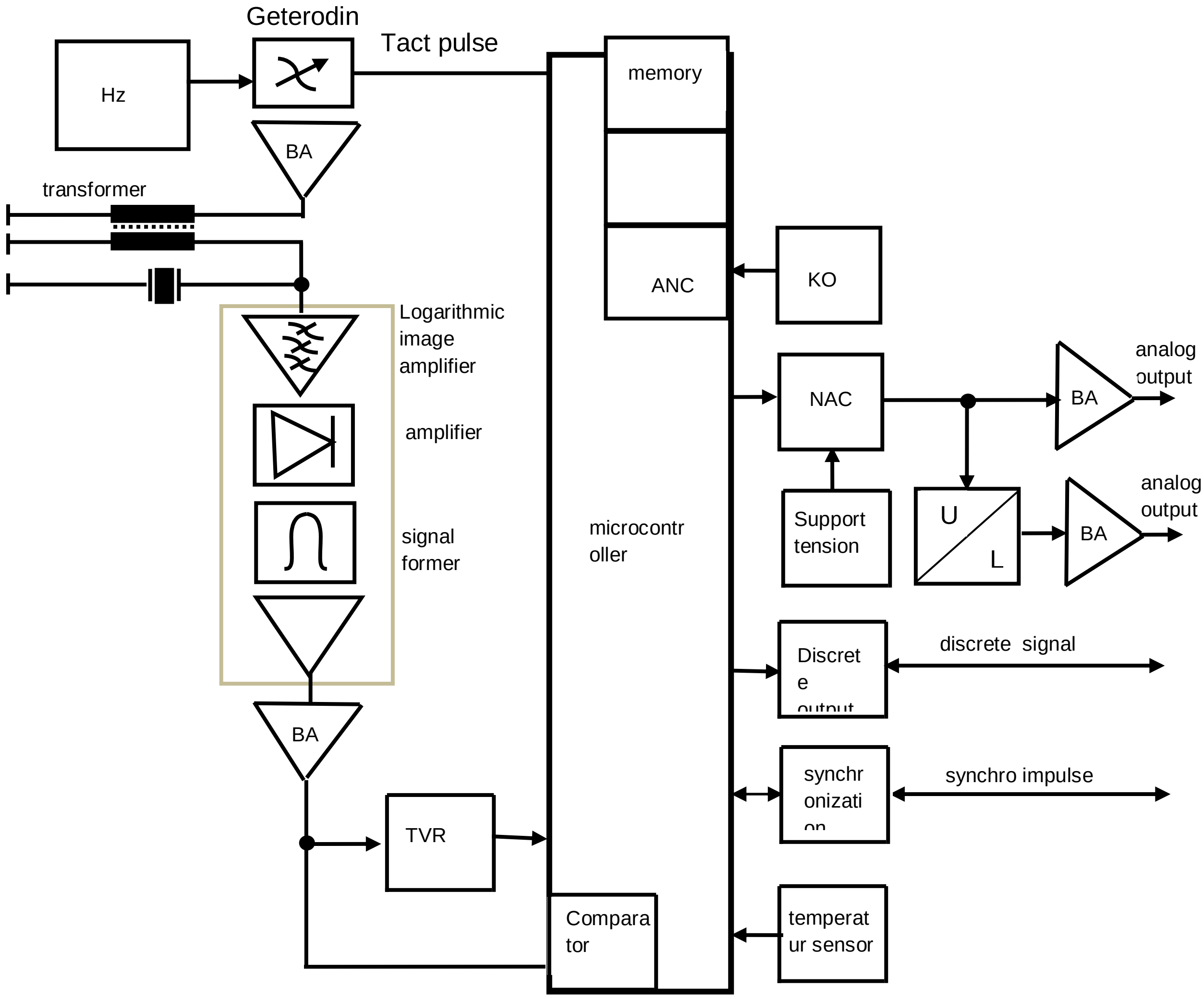
**Intelligent sensors.** In addition to environmentally sensitive controller-adjustable parametric sensors, there are also sensors with self-learning capabilities. They have the ability to remember the diagram of the reflected signal when the configuration process is activated. When the configuration is complete (the teach-in process), the reflected signals that are re-entered are compared with the memorized signals. The sensor only responds to those reflected signals, which differ from those in memory. In this way, the effect of foreign objects in the detection range can be ruled out.

The latest generation of ultrasonic sensors is characterized by the possibility of installation in M12 and M18 size housings with a total length of 70 and 75 mm and very small volumes, thanks to the maximum use of the capabilities and achievements of microelectronics. Numerous complex functions have been implemented in such a small volume: teach-in (initial configuration), synchronization, temperature compensation, etc. The sensors provide contactless detection of objects in the range of 30 ... 400 mm and 50 ... 500 m. Figure 2.9 shows the functional diagram of the UB500-18GM75 -...- V15 Y3-sensor. Example of use of intelligent sensors: specially designed devices to determine the filling level of the tank store the signal reflected in the empty tank. In this case, all reflections from the technological equipment, such as mixers, heating fins and emergency traps installed in the tank are recorded. As the level filling changes, the reflected images are compared on a case-by-case basis. Objects that do not participate in the initial configuration are considered "detected". Accidental interference signals are excluded during accurate inspection.

Table 2.3 shows the technical characteristics of the sensor for measuring the level in small tanks (given).

Table 2.3. VC 500-D1 series ultrasonic sensors for temperature compensation, three-relay output level detection

| | |
|---|---|
| Detection range | 60...550 mm |
| “Blind” zone | 0...60 mm |
| Response time | 10 seconds (relay) <1 second (LEDs) |
| Electrical parameters | |
| Working voltage | 10...252 V constant current<br>20... 252 V 47...63 Hs alternating current at the frequency of the network |
| Operating parameters | |
| Working temperature range | -20...+60C |
| Degree of protection | IP65 |
| Connection method | V7,7 plug connector of contacts |
| Outputs | Code to order |
| 3 relay outputs | UC 500-D1-3K-V7 |




CO-configuration output; TVR-threshold voltage regulator;

BA-buffer amplifier

Figure 2.9. Functional diagram of the latest generation UB50018GM75-V15 ultrasonic sensor

**Resolving capacity.** The time of arrival of the exo-signal in the receiving tract is determined with an accuracy of 1 µs (or for 1,085 µs sensors controlled by a microcontroller on RS 232). This corresponds to a physical solubility of 0.172 or 0.186 mm. The sensors of the VC ... series are equipped with a 12-degree (category) ADC, so the possible resolution is maintained if the distance between the near (A1) and far (A2) limits does not exceed the measurement range.

## 2.4. Development of a block diagram of ultrasonic distance sensors

Figure 2.10 shows the block diagram of the device. It consists of the following main blocks: microcontroller (CC), input switch (GD), keyboard, indication block, sensor, personal computer communication unit (PCB). The microcontroller is designed to control the process of extracting indicators from the sensor.

Briefly, let's look at the approximate working principle of the device. The analog signal enters the input converter from the sensor. This converter converts the signal from the sensor into a level signal received by the analog-to-digital converter (ARC) of the microcontroller. Thus, GD harmonizes voltage levels. The modified signal enters the ARC input of the microcontroller. Here, the analog information signal from the sensor is converted into a digital code processed by the MC. The codes read on the microcontroller will be written to the data memory after the change. The microcontroller then asks for the keyboard code, ie checks the keystrokes, displays the current level of the level, if one of the keys was pressed, it begins to work with the pressed keys and then outputs the required information. The personal computer communication unit is designed to connect to a code converter (DC) device from one of the standard interfaces. Thus, there is a possibility that, if the relevant software is available, the staff monitors the operation of the device with the help of a computer, as well as repeats the indication of the filling level of the tank on the display screen. This level significantly expands the possibility of automating the control process.

Based on the results of the analysis and analysis obtained, it is important to determine the main requirements for the elements included in the device. It is necessary to use an ultrasonic sensor designed for special use in reservoir filling level measuring devices with appropriate design and electrical performance. The supply voltage of the sensor is standard, constant voltage -10 ÷ 30V, output signal-analog, level dependence-line of output voltage from the measured distance. The impact zone can be up to 5 meters.

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The output switch must match the output voltage level of the sensor and the output voltage of the MK.

The indication block is used to display information about the level of filling of the tank in X, XX format as decimal digits.

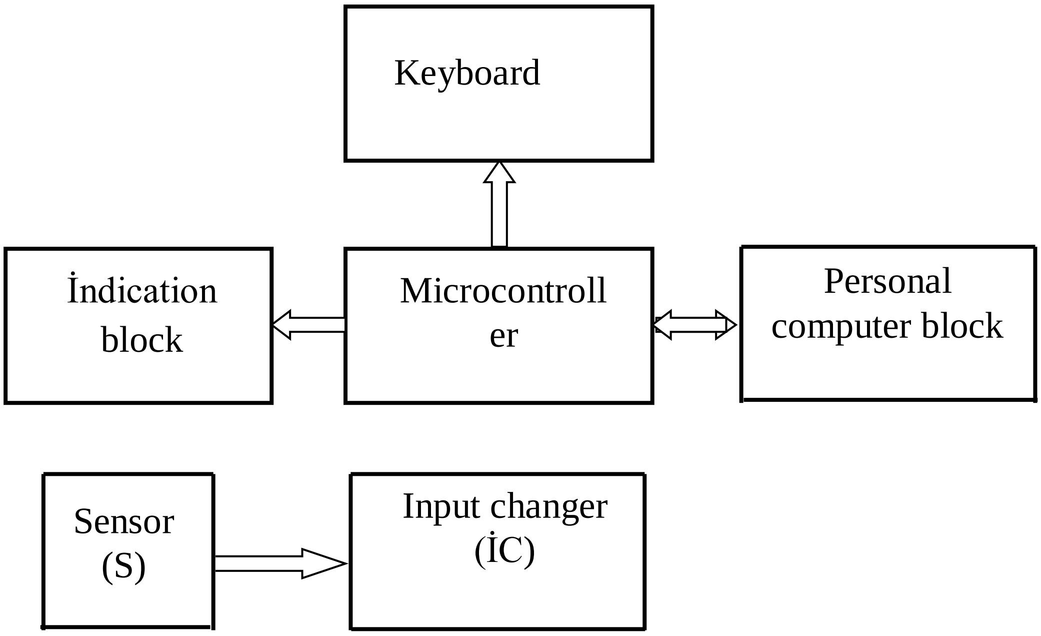


Figure 2.10. Block diagram of ultrasonic distance sensors

Thus, it is important to use an indicator consisting of three LED seven-segment indicators based on the set tasks.

The keyboard consists of only one key, the pressing of which is performed to set the calculation level of the filling level of the tank to zero.

Modern single-crystal microcontrollers are very functional, which allows you to avoid the use of giant hardware solutions in the device - external analog - digital converter, external memory, various converters and coordinated elements, all of which are part of OEHM and often implemented with software. The microcontroller is the main functional node in that device. Its model is selected based on the tasks set.

# 3. DEVELOPMENT OF ELECTRIC PRINCIPAL SCHEME OF ULTRASOUND RANGE DEVICE USED IN INFORMATION MEASUREMENT SYSTEMS

## 3.1. Selection of ultrasound sensor

Ultrasonic sensors work by sending sound waves that echo from the target and return to the transmitter. The term ultrasound refers to any sound wave above human hearing or above 20 kHz. This method is very accurate and we have developed a line of sensors with an accuracy of 0.25% of the detected range.

Since the speed of sound is constant, in a stable atmosphere, the time from the explosion to the return of the sound is measured and converted into distance. The sensor's microprocessor calculates the distance and converts it into a level indicator, volume measurement, or flow rate. It also compensates for temperature and filters the signal.

Common uses for ultrasonic level sensors are level, volume, and flow monitoring. Other uses include detecting the presence or absence and measuring the object.

Ultrasonic level sensors are usually very small, require little maintenance, and are easy to send and install. Each of our ultrasonic sensors has a microprocessor, which allows for better control. In addition, they do not come into contact with the target substance, which prevents accumulation and damage.

Ultrasonic sensors require an unobstructed air column between the sensor and the target. Anything that changes the direction of the signal or acts as a swallow or a false surface can cause erroneous readings. This can be caused by physical obstacles, excessive foam, heavy fumes, thick dust and light dust.

The extinguishing tube can be used to keep or direct the signal around obstacles or to reduce surface foam. A more powerful sensor can also be used to amplify the signal. However, our continuous float level transmitters, submarine pressure transducers, or level switches may be the best in these scenarios.

Most of our ultrasonic sensors are designed for use in level applications ranging from 4 inches to 50 feet. They are used both indoors and outdoors, and can control cold and hot weather. Automatic temperature compensation is standard on each model.

Our ultrasonic level sensors are relatively easy to program and usually perform well in less than 30 minutes. This process is very simple and our technical support is ready to help you in case of any problems.

There are three basic settings you can adjust:

- Pulse Power and Sensitivity
- Filtering and Response Time
- Departure and Travel Points
- Pulse Power and Sensitivity

Pulse control allows you to fine-tune sound wave bursts for optimal detection for your application. The sensitivity setting allows you to control how hard the sensor listens to echoes. Simply put, pulse power is like controlling the volume in a speaker, and sensitivity is like controlling the volume in a hearing aid.

It is important to adjust both. You just want to increase your heart rate as much as you need to get a good return signal. If you keep it in high mode all the time, it will wear out faster, like the speaker exploding with excessive noise. Unlike a speaker, an ultrasonic transducer - the part that generates and receives sound waves - will not explode, but will wear out over time.

So, if your heart rate is as high as possible to get a good return signal, it means that your sensors are not strong enough. You need a longer range of ultrasound to keep your pulse parameters in a happy environment. This will give you a better signal and increase the life of your level sensor.

Sensitivity parameters are related to the reception of echoes. If you have to increase your sensitivity too much, you will start to receive unwanted echoes and erroneous readings. Having to keep your sensitivity too high is either a sign of a low pulse power setting, a target absorbing or transmitting your signal, or a sensor with a very short measuring range.

Balancing pulse power and sensitivity is critical for reliable measurement and continuous sensing. The good news is that you will be able to use AutoSense, which automatically adjusts your heart rate and sensitivity to optimal settings.

Filtering and Response Time. It is easy to filter out unwanted echoes with your ultrasonic level sensor with a few different settings. You can control the maximum and minimum detection distances, the average of your readings and the speed of response to variable levels.

Determining the maximum and minimum detection distances simply causes the sensor to ignore any echo outside that range. The minimum detection distance is controlled by extending the gap distance, which is a short distance in front of the sensor face where nothing can actually be detected (see individual sensor features). If you ignore static or mobile objects in the distance, the maximum distance setting is useful.

Averaging your readings is one way to correct your level changes. If you don't have a perfectly motionless surface that moves very slowly to detect, you'll need this feature. Any amount of turbulence or uneven motion on the surface and the average is very valuable. Simply tell the sensor how many samples (single read) you want on average. The more patterns you select, the smoother the effect.

Controlling the speed of response to variable levels is very useful for filtering out a lot of noise. This parameter is called the distance you select in front of and behind the window or current distance reading. This is a window that moves after the current accepted reading. Along with the window, you will set the number of samples that the sensor must detect in the window before confirming it as a new level. In fact, you cause your sensor to check the level changes twice before presenting them to you as output.

Both average and Windows settings can speed up and slow down response time. If you have a fast moving target, you want to be careful here. A lower average and a more empty window are required to make quick changes to your readings.

Departure and Travel Points.Setting up your output on our ultrasonic level sensors is a simple process to determine your maximum and minimum output values. But that's not all. The most popular series has the option to include 2 installed at NPN travel points.

Travel points help you easily control pumps, signals and valves. Manufacturers do not include travel points on ultrasonic level sensors, which forces you to spend a few hundred dollars more on the module. It is offered not only built into the sensor, but also at no additional cost.

From time to time we come across users who have tried very interesting things with ultrasonic sensors - even if expresses some doubts. They've been used in everything from race cars to apple harvesters, and some are more successful than others. However, most of our ultrasonic level sensors are used to detect liquid level, open channel flow or presence and create an object profile where they work very well.

Liquid level. The most popular application for ultrasonic level sensors is to measure the level of fluid in the body, whether in a tank, well, pit or lake. It is easy to measure the volume if it is the container line. In non-linear vessels, a circle diagram is often used to adjust the reading as the level rises and falls

The ultrasonic level sensors are mostly extremely sensitive (0.25% of the detected range) and are suitable for most measurements other than storage transfer applications. Most of the ultrasonic devices are specifically designed for level measurement.

Solid Level. Another very popular application for ultrasonic sensors is solid level detection. This is in stark contrast to detecting liquid levels, as solids do not provide a flat, solid target. The target is usually uneven and soft. However, ultrasound sensors still often work well.

The trick is to use a dual-range sensor, which is really needed. This gives a stronger signal, which will give a better echo for your sensor to measure. It must also rotated the sensor assembly so that it is perpendicular to the seating angle.

Measuring levels with solids has always been difficult. While new and legacy technologies promise optimum performance, ultrasound will continue to be the foundation for continuous non-contact measurement.

Ultrasonic level sensors shouldnt be used in light dust or particularly dusty environments. The softness of the light dust will absorb most of the audio signal and the dust will scatter the signal in the air before returning to the sensor. If you want to expect a good reading after the dust has settled, you may still prefer to use ultrasound in a dusty environment.

Open channel stream. Another excellent compatibility for ultrasonic sensors is open channel flow. Open channels are the main means of transporting, filtering and measuring water. It is used in open channel flow monitoring, water treatment plants, environmental monitoring and irrigation channels.

The ultrasonic level sensors are often combined with a suitable controller for flow calculations over open channels. It is preferred because of its durability in open environments where reliability is important. Several of our models are compatible with this program.

Availability Detection and Object Profile. There are many technologies designed to detect objects and control the movements of machines and robots. Ultrasonic sensors are very suitable for some. It is possible to show an example that, the car wash industry relies heavily on ultrasonic sensors to detect vehicles and monitor the movement of brushes.

Ultrasound level sensors are good in most of these applications because of their ability to handle adverse conditions. In dirty or wet environments where targets move quite slowly, the required object detection is potentially suitable for ultrasonic sensors. It is possible to take an example such as IRU-2000 series which has designed for these programs.

We define the level of the material in the container like the height column of the liquid or material inside container or reactor. The symbol for the level is the letter h and is measured in meters, h (m). There are multiple ways to measure levels. Generally used level converters are: mechanical level converters, electrical level converters, pressure level meters, voltage level meters, and the ultrasonic level measurement way. The useage of ultrasound make you to measure the level without any kind of contact. This way is used to measure the level of liquid and tender material. With the help of ultrasound sensor sends a packet of ultrasonic signal. There are reflections of the ultrasound signal on the edge of the air and liquid or tender material. The equipment measures the time it takes for the emitted ultrasound signal to travel from the sensor to the container level and back. By taking advantage of acoustic speed and measured time, it can determine the filling case of the container.

The most popular methods for generating ultrasound can be: piezoelectric,also magnetostrictive, electrostatic, electrodynamic methods, at the same time mechanical and thermal stimulation. The most commonly used are the piezoelectric ultrasonic sensors are used. They operate at frequencies between 40 kHz to 250 kHz. The ultrasound sensor in this device operates at a frequency of 40 kHz. When it comes to acoustic speed sound can propagate to all environments like a longitudinal wave. The speed of a sound wave depends on the characteristics of the environment in which it propagates.

For longitudinal waves, the wave equation implies the following expression:

$$v = \sqrt{\frac{E}{\rho}} ,$$

in here E is the modulus for the elasticity and ρ can be considered as the density of the material. With this equation we can be calculated for finding the acoustic speed. Acoustic propagation in multiple environments can be described by the following expression:

$$v = \sqrt{\frac{B}{\rho}} ,$$

here B is the volume for the modulus of elasticity, also ρ fluid is density. Volume modulus of elasticity fluid can be defined as:

$$B = - V * \Delta P \setminus \Delta V = \rho * \Delta P \setminus \Delta \rho$$

and explains the relative volume changes while pressure is changed. The modulus of elasticity can be depend on the type of thermodynamic process for gas. When sound propagates between gases, the pressure and volume change very rapid, so heat transfer is not taken into consideration. Therefore, we can assume that gas compression and also expansion will be considered adiabatic processes. A feeling that inevitably accompanies the design, construction, and use of any structure, including hydraulic structures, is a limited and unavoidable uncertainty – uncertainty resulting from the limited accuracy of ground surveying or regarding the intensity of impacts. natural or other random factors. Hydraulic structures, the purpose of which is permanent or seasonal water dams, are subject to soil degradation by filtration and aging of building materials. Their design must also take into account exposure to extreme natural conditions such as hydrological or seismic events.

However, this uncertainty is offset by the margin of safety, which is the result of the load factors and building material parameters assumed for the design, which is guaranteed at all stages of construction and use . Thanks to the margin of safety factor, it is possible to implement risk management procedures both during the construction of the structure and during its operation.

The purpose of the risk management procedure is to make the most efficient use of the margin of safety, depending on the current configuration and intensity of the effects to which the object is exposed, and to take appropriate protective measures if the margin is close to breach. previously. Precise risk assessments require reliable and robust assumptions that can only be made if the monitoring system is reliable and properly designed. Such a system should ensure the control of processes that have a material impact on the safety of the structure and its immediate surroundings, while observing a required level of accuracy. Its reliability should guarantee reasonable (structural) redundancy to ensure mutual verification of the results of observations during the operation of the structure.

The monitoring system must be able to provide alerts as well as provide data to develop better models of object behavior. The warning function is mostly based on standard procedures aimed at providing information about the current load and response of the structure and ground to external influences according to the quantitative criteria provided by the designer. These criteria usually take the form of threshold values (eg information threshold, warning threshold and emergency threshold) associated with the characteristic and design values of the designed loads and/or the serviceability conditions of the structure. Achieving or exceeding certain thresholds usually requires the routine initiation of certain standards and necessary preventive actions, notification and warning procedures, etc. It is related to.

Through data that provides a function, it can be determined whether ongoing monitoring processes conform to design assumptions, and estimates are updated if large deviations are detected. In addition, current and future safety levels can be verified, potential hazards can be identified, and necessary preventive measures can be recommended. For the function to be performed properly, the designer, contractor, and service personnel must cooperate closely on a long-term basis. The scope of this collaboration includes the verification and evaluation of multi-year monitoring results, the assessment of potential hazards and, if necessary, the formulation of detailed recommendations regarding necessary changes to the facility operation plan, periodic service limitation, monitoring changes. system, etc. The main tasks of the expert team are to carry out regular visual inspections, to interpret the observation results as they are and to explain the reasons for significant deviations from the predicted values, as well as to update the threshold values for the purposes. take advantage of the alert function. The safety of these missions, their continued serviceability and their importance in eliminating losses due to possible failures increase in proportion to the level of uncertainty in terms of the gradual change of soil inspection and parameters, technical conditions and precision of construction. possible values and mutual configurations of short-term and long-term variable loads.

The ultrasonic displacement measurement method can presented here was developed by Ultrasystem. This way uses a working principle similar to that applied to the scientific echo sounder. Changes, which included the adoption of updated solutions in terms of electronic system configurtion, as well as the application of specially designed ultrasonic transducers, resulted in unmatched micro-scale accuracy and extremey high long-term stability. The advantages of the method inlude large-scale measurement of liquid levels (from one millimeter to many meters), very high resolution, linear properties over the entire measuring range, and the absence of mechanical moving elements in the sensor structure eliminating the zero shift and hysteresis effects of other sensor types).

Observations and tests on more than 100 sensors at various facilities and laboratory conditions between 1990 and 2019 provided that the unique stability of the ultrasonic inclinometer is better than one arc second and the resolution is better than 0.01 arc seconds. . (arsec—5 μm/m) for slope measurements (with 1–3 m core distances). Such sensors have been installed at a number of hydraulic plants in Poland . Over the past dozen years, the observed slope at these facilities has never been greater than 0.1 degree (typically 0.02 degree) and 0.01 dgree for annual and circadian cycles. The data obtained with the use of sensors and the result compilation principle show that the sensors have very high accuracy and stability characteristics. Therefore, the working principle of the those and the processing of the measurement results are explained in detail in here.

The use of two measuring channels allows you to set the temperature inside the rectifier without adding an additional thermometer. This is very practical in many ways. Thanks to this solution, it is possible, for example, to compensate for the effect of thermal expansion of the fluid (this is especially important for hydrostatic rectifiers) and to establish a result / temperature correlation. At a specified Lo distance between the transducer and the fixed wall, the pulse duration in the reference channel can be calculated as follows:

$$To = 2 \cdot Lo / V$$

The speed of sound is a function of temperature. For example, for the fluid used in the device, in the appropriate temperature range, this is a linear function of temperature and

$$V = Vo \cdot (1 + \alpha \cdot temper)$$

Vo - sound speed at 0 ° C,
α — temperature-dependent rate of change of sound and
temperature - temperature in ° C.
After setting the To value, you can calculate the temperature using the following formula
temp = (1 / α) · (To (0 ° C) / To - 1)
where To (0 ° C) means travel time at 0 ° C.

The parameters α and To (0 ° C), which are constant values characterizing the sensor, are determined during the device calibration procedure.

All measuring vessel is provided to sensors that measure the level with accurate temperature measurements. This makes it possible to compensate for thermal expansion in case of temperature differences of the sensors. With the help of measuring the liquid level, displacement between the ship's mounting points can be determined. If both vessels are mounted on a single block (for ex, concrete or stone structures), the corrective bend shows itself as a gauge, the base of wich is determined by the distance between the vessels. In the case of classic inclinomters with a compact design, the stability of he mounting screws on which the sensor is fixed to the ground is a real problem due to the narow distance of the mounting screws (usually about 10 cm). This probem is quite negated in inclinometers consisting of two measuring vessels located at a considerable distace from each other (usually starting 1 m to 5 m).

Ultrasonic sensors used in devices to measure the level of filling of tanks are released by many manufacturers. Let's focus on the product of Pepperl + Fuchs.

Let's choose the LUC4 model, which is more suitable in terms of characteristics, from the wide range of sensors released by this company.

LUC4 ultrasonic sensors are specially designed to measure the level of both liquid and granular materials.

The Teflon coating of the sensor body allows it to be used in corrosive liquids. Allows the installation of sensors in places where there are other elements or poles of the internal structure of the tank, falling into the measuring zone of masking of stationary objects. The sensor is also equipped with means to compensate for the effects of temperature changes. In addition, additional external probes can be installed, which control the temperature of the measured surface, regardless of the conditions of the sensor mounting location, thus minimizing errors with frequent temperature changes. The appearance of the LUC4 sensor is shown in Figure 3.1.

The main technical characteristics of sensors from the LUC 4 series are shown in Table 3.1.

The connection diagram of the sensor is shown in Figure 3.2.

The graph of the distance dependence of the output signal level is given in Figure 3.3.

A distance of less than 0.3 meters is a "dead zone" for the sensor.

Figure 3.1. Appearance of  LUC4 sensor

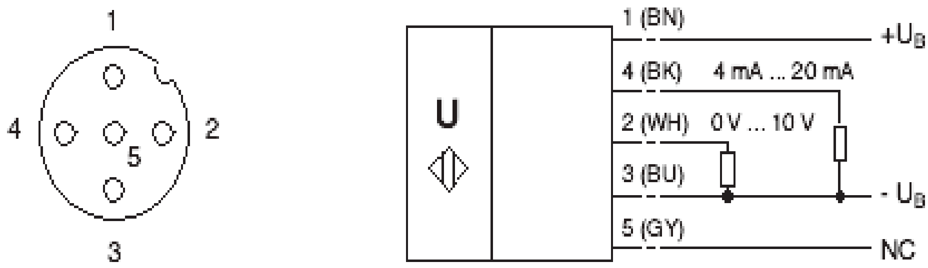


Figure 3.2. LUC 4 sensor connection diagram

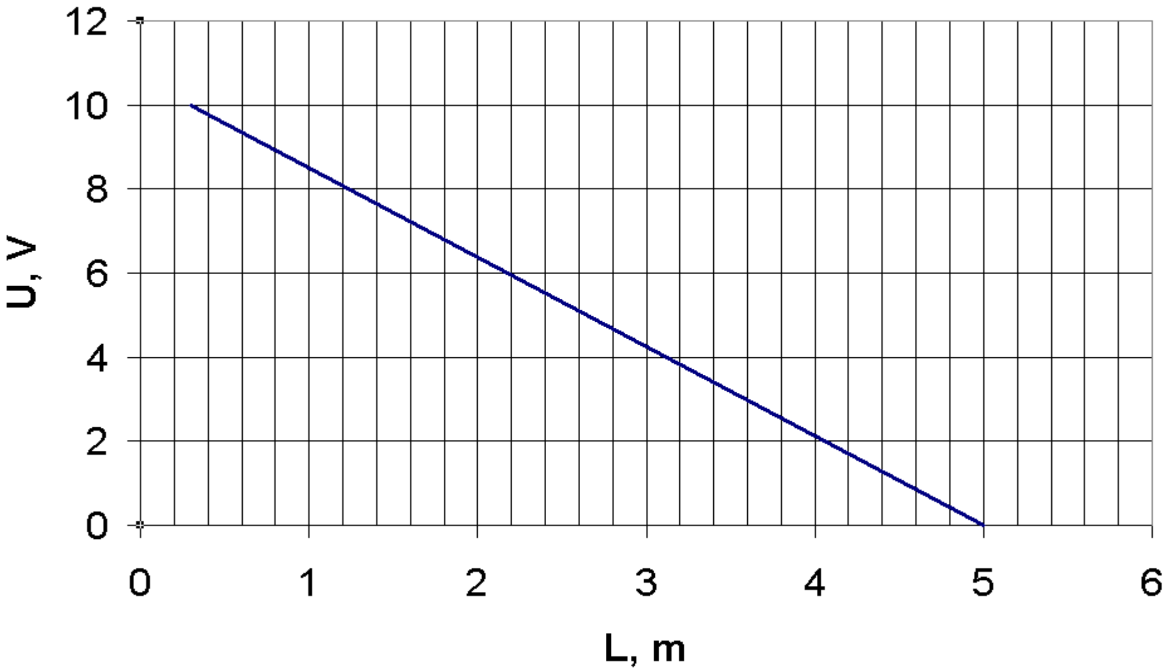


Figure 3.3 Graph of the output signal level (surface) distance dependence

Table 3.1 Basic technical characteristics of LUC 4 sensor

| | |
|---|---|
| Measuring range | 03...5 m (for liquids) |
| Accuracy | 0.5% in the full measurement range |
| Solving ability | 2 mm |
| DC voltage supply | 10...30 V |
| Output signal | Unified current 4 ... 20 mA (R <500 Ohm), 0 ... 10 V (R> 1 kOhm) |
| Indicators:<br>Working mode | Green LED<br>Red light emitting diode (with 2Hs flash) |
| Permissible ambient temperature | -25..+70$^o$C |
| Permissible storage temperature | -40...+ 85$^o$C |
| Permissible temperature of the controlled medium | -25...+ 70$^o$C |
| Working pressure | Atmosphere |
| Body material | Polibutentereftalat (RBT) |
| The material of the surface of the source | Politetraftoretilen(PTFE) |

## 3.2. Selection of microcontrollers

Of the many types of microcontrollers available, microcontrollers from the PIC family, manufactured by Microcip, are the most suitable for solving the task [10,14].

Microcips from the PIC family of microcontrollers combine all advanced technologies: user-programmable electrical programming, minimal power consumption, high efficiency, well-developed RISC architecture, functional completeness and minimal dimensions, a wide range of products. .

PIC microcontrollers have a symmetrical command system RISC-processor, which allows you to perform operations with any register using the free method of addressing. The user can store the results of the operation in the accumulator itself or in the second register used for the operation. High-speed execution of commands in PIC microcontrollers is achieved through the use of dual-core Horvart architecture instead of the traditional fonneyman organization.

The Harvard architecture is based on a set of registers with address fields and dedicated tires for command and information. The input of the microcontroller (all resources, resources, resources, such as the output port, memory window and timer) consists of physically implemented hardware registers. Let's choose microcontrollers from PIC18FXXX series.

PIC18FXXX is a family of high-efficiency microcontrollers with a wide command system (75 commands) and a 10-degree analog-to-digital converter (ARC) operating at frequencies up to 40 MHz. They have the ability to address up to 32 words of code and 4 Kbytes of data memory installed in the 31-level hardware memory command, and up to 2 MB of external memory software. The extensive RISC core of the microcontrollers from that family has been optimized for use with the new C compiler. When designing the device, PIC 18F252 28-output high-speed FLASH microcontrollers are grade 10 ARC. The main characteristics of this microcontroller:

optimized architecture and command system for writing programs in C language;

the command system is compatible with commands from the PIC16C, PIC17C, and PIC18C families;

linear address area memory program 32 kbytes;

linear address data memory area 1.5 kbytes;

up to 10MIPS;

clock frequency from DC to 4MHz;

Clock frequency in PLL mode from 4MHz to 10MHz;

16 level teams, 8 level information;

suspension advantage (primacy) system;

8x8 machine shot in the area of a machine circuit.

Characteristics of peripheral modules:

high loading capacity of input / output parameter;

three inputs of external cuts;

TMRO module 8/16 degree timer / 8 degree programmable meter;

TMR 1 module: 16 degree timer / meter;

TMR 2 module: 8 degree timer / meter with 8 degree period register;

TMR3 module: 16 degree timer / meter;

Second clock signal generator based on TMR 1 / TMR 3;

CCP two modules.

The outputs of the CPP module can work as follows:

16 degree catcher, maximum solubility 6.25 nsan (TCY / 16) -16 degree comparison, maximum solubility 100HC (TCY);

rate from 1 to 10 bits, maximum frequency 156kHs @ 8 bits, 39kHs @ 10 bits;

leading serial synchronous port module (MSSP);

3-conductor inferface SPITM (maintains 4 modes);

12 CTM (leading and conducting mode);

The USART addressing module is the backbone of the RS-485 and RS-232 infarction;

The PSP module is the leading parallel port.

Analog peripheral modules:

10 degree ARC module;

high rate of change;

development of ARC module of microcontroller in SLEEP mode;

DNL = ± lsb, INL = ± sb;

low voltage programmable detector (PLVD);

generation of interruption is possible when a voltage drop is detected;

programmed discharge with a decrease in supply voltage.

Features of microcontrollers:

Deleting 100,000 guaranteed circuits / writing a memory program;

1,000,000 guaranteed circuit deletion / recording of EEPROM indicator memory;

the possibility of self-programming;

discharge during power connection (POR), connection of power timer connection (PWRT), and generator discharge timer (OST);

separate WC timer with RC generator;

program code protection;

low power consumption mode and SLEEP mode.

The selection of the operating mode of the clock generator includes: XPLL (from the main generator) and the second generator (32 kHz);

on-circuit programming on a single-supply voltage 5V two-transmission line (ICSP);

two-wire line in-circuit rectification (ICD) metal-dielectric semiconductor (MDY) technology;

high-speed energy-saving MDY technology;

full static architecture;

wide supply voltage range (from 2.0 V to 5.5 V);

industrial and extended temperature ranges.

Figure 3.4 shows the location of the microcontroller outputs, and Figure 3.5 shows its conventional graphic symbol.

### 3.3. Calculation of input switch and indication block

The output information signal of the sensor is a constant voltage + 0 ÷ 10V, the maximum input voltage is equal to the supply voltage (V_n) of the controller АЦП ОЭВМ PIC18F252, ie 5V. Thus, the problem of the input converter is to reduce the output voltage (V_a) of the sensor by a factor of two.

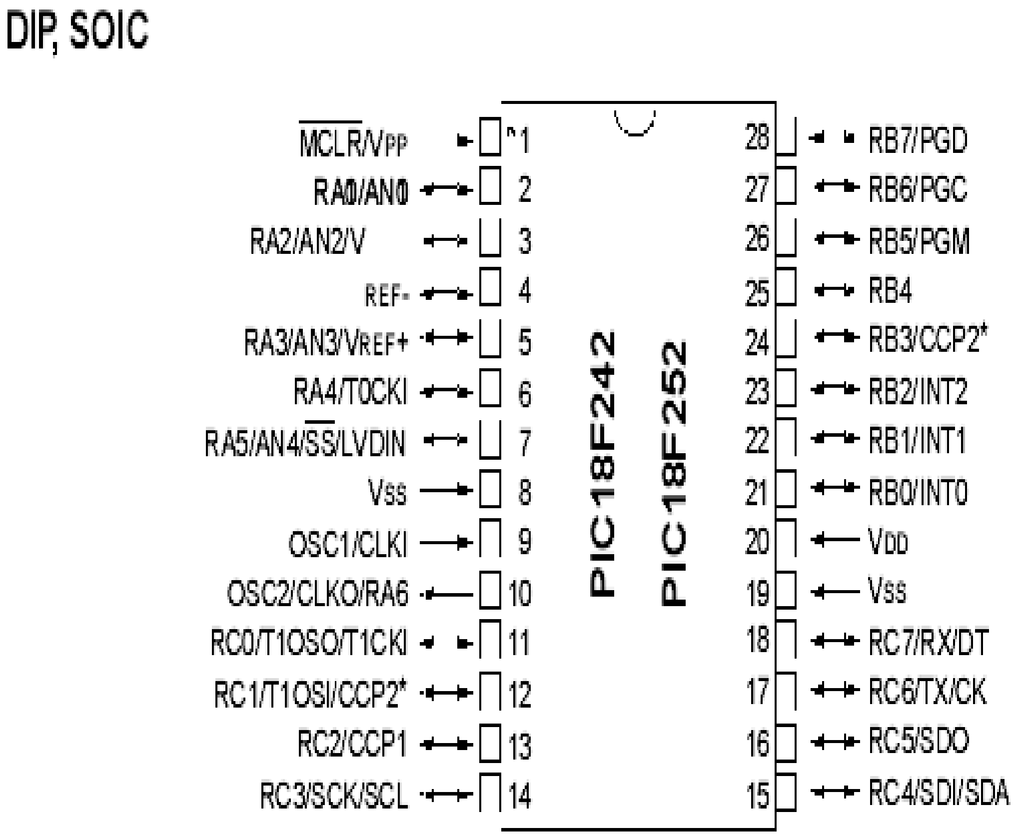


Figure 3.4. Location of microcontroller outputs

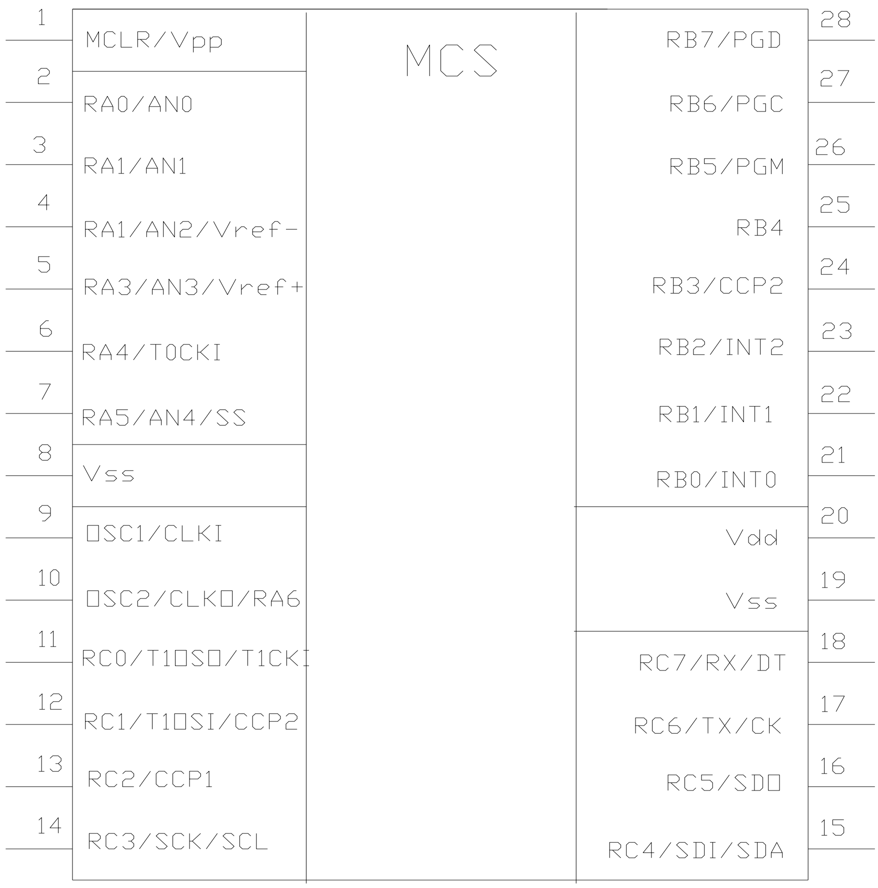


Figure 3.5 Conventional geographical indication PIC18F252

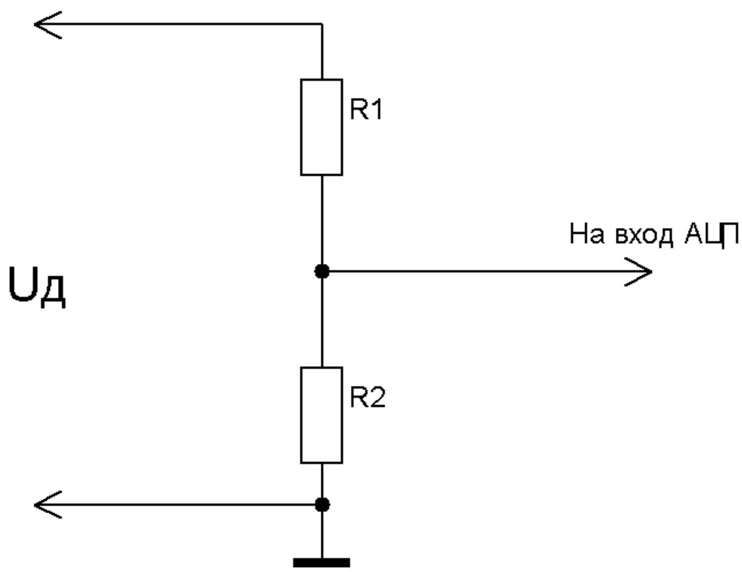


Figure 3.6. Input changer circuit

It is a voltage divider resistor for the best realization of the problem. Figure 3.6 shows a schematic of the input switch.

From the expressions (3.1) and (3.2) we find the nominals of resistors R1 and R2.

$$V_э = 2M_{ANC} \qquad (3.1)$$

$$(R1 + R2) \cdot I = 2 \cdot R2 \cdot I \rightarrow R1 + R2 = 2 \cdot R2 \rightarrow R1 = R2 \qquad (3.2).$$

Let's choose the nominals of resistors R1 and R2 at 100 kOhm. In this circuit, it is necessary to use the most accurate dividing resistors of the type C5-53Ф-0,125-100kOhm ± 0,05% to ensure the accuracy of the converter.

The indication block should provide information on the level of filling of the tanks in the form of decimal digits in the format X, XX meters. Thus, as can be seen from the problem, it is important to use an indicator consisting of three LED seven-segment dot indicators. The indication is dynamic.

Figure 3.7 shows the schematic electrical diagram of the indication block.

The A-H segments of the LED seven-segment indicators are connected to the outputs of the microcontroller post RB7-RBO B, respectively, and the indicators are transmitted to the ports that serve the display and are packaged in BCD format. To implement the circuit of the indication block, select the seven-segment LED indicators with red light emission ALC333A. The choice of LED indicators is due to the fact that they have a number of advantages over liquid crystal and vacuum luminescences - a good degree of visibility of indicators at a considerable distance and in the dark. This shows that liquid crystal indicators, as well as indicators with lower energy consumption, can not provide, unlike vacuum luminescence indicators. ALC333A height 12 mm, current consumption of each segment $I_{cs}$ = 20mA, supply voltage $V_{qg}$ = 2V.

The ports of the PIC18F252 microcontroller have a large enough load capacity, so the segments of the indicators have no amplifier.

without elements, they connect directly to the MK outputs. Resistors R5-R13 give the required $V_{qg}$ = 2V for each segment. VI1-VT3 biopolar transistors are used as switches from the RCO-RCO2 ports to select a specific indicator with a control signal, thus fulfilling the dynamic mode of indication.

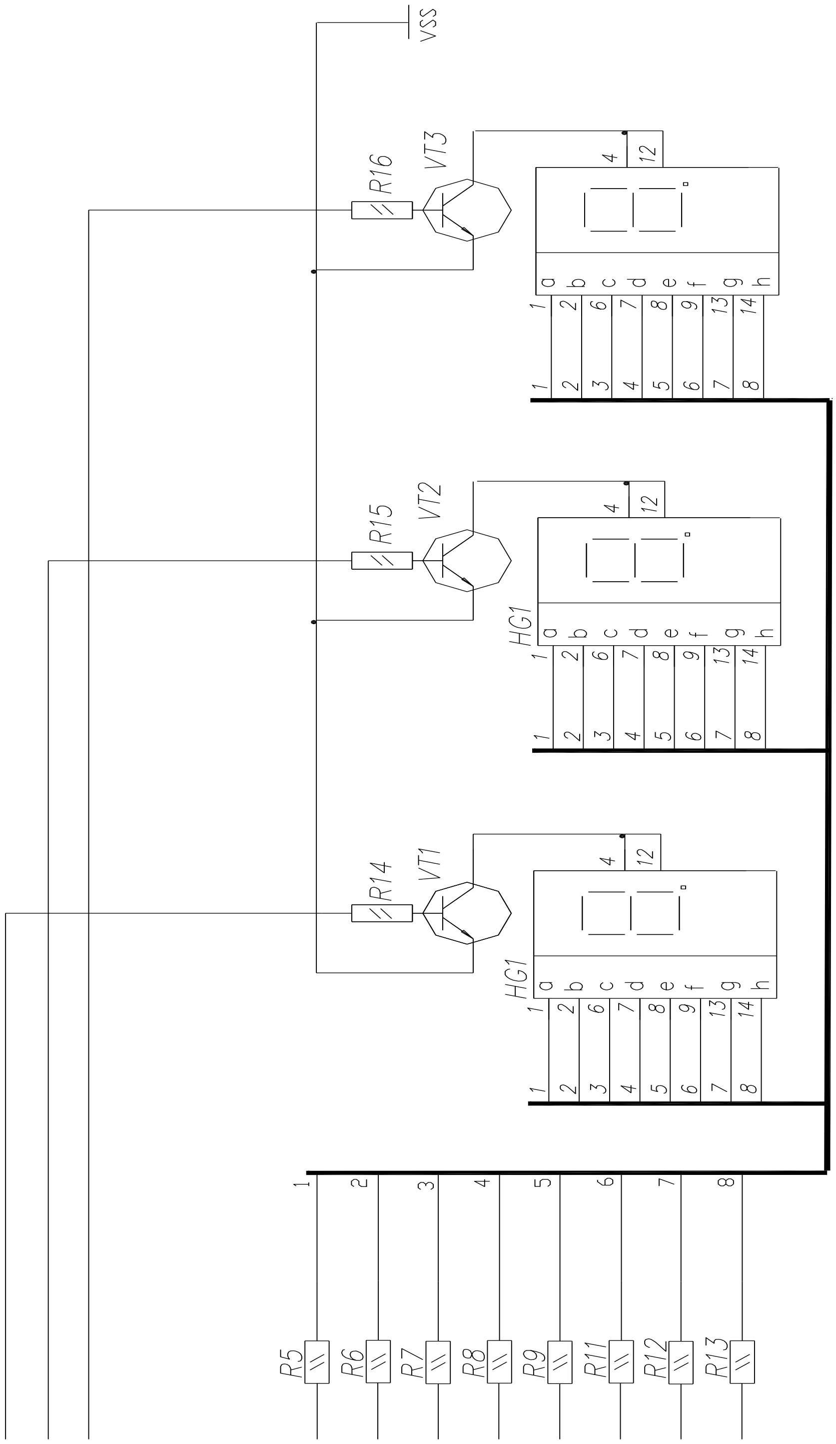


Figure 3.7. Schematic of the indication block

We choose KT814A transistors to implement the circuit. We choose resistors R5-R13. Let's calculate the nominals of resistors R5-R13

$$V_R = U_{MKçıx} - V_{ke} - V_{gd} \ , \qquad (3.3)$$

Where,

Voltage of the logical unit at the outputs of U_MK output-MK, voltage drop in the V_R-resistor, voltage drop in the segment of the indicator V_gd

Considering the value of V_R = 1V

$$R = \frac{V_R}{I_{cs}} \qquad (3.4)$$

Where is the voltage dissipated by the segment of the I_cs-indicator. Thus R = 50 Ohm. We choose the resistor C2-33-0,125-50 Ohm ± 1%.

In the base circuits of transistor switches, select resistors R14-R16 with a nominal value of 470 Ohms, type: C2-33-0,125-470 Ohms ± 1%.

### 3.4. Keyboard and communication block calculation

The keypad consists of only one button, which, when pressed, connects to the zero point (calculation point) of the liquid level in the tank. Figure 3.8 shows the electrical schematic diagram of the device.

The signal from the button enters the RA4 port of the microcontroller. The keypad consists of a key SB1 and a resistor R3. Resistor R3 prevents short-circuiting of the "ground" supply chain at the open contact of the SB1 switch. Thus, if the input resistance of the microcontroller post is very high, then a fairly large resistor can be selected. Let's stand on the resistor type C2-33-0,125-510 kOh ± 1% for the nominal 510 kOhm.

Resistor R4 forms the discharge circuit of the microcontroller. The nominal value recommended by the manufacturer of this resistor, microcontroller is 4.7 kOhm. Therefore, let's choose a resistor of the type C2-33-0,125-4.7 kOhm ± 1% within the specified price range. In this case, the value of the quartz resistor is 4MHz. Capacitors C4 and C5 are part of the typical wiring diagram of a PIC microcontroller and 16pF is recommended by the microcontroller manufacturer. Based on this price, we choose K71-4-16pF ± 5% 250V capacitors. Capacitor C6 performs high-frequency filtering in the supply circuit of the microcontroller. We choose its nominal from the recommended range-100 pF, type: K71-4-100 pF- ± 5% 250V.

The personal computer communication unit allows the device to be connected to a personal computer or other device via the RS-232 interface. The PIC18F252 microcontroller has a built-in support within that interface, but the Rx / Tx output signal levels of the microcontroller do not match the levels that adjust the RS-232 interface specification. Alarm levels

A special chip is used to adapt. The block diagram adapted with the code converter is shown in Figure 3.9.

According to the RS 232 protocol, the reception / transmission signals of the Rx / Tx indicators are transmitted from the corresponding outputs of the microcontroller from the MAX232 chip to the COM port of the computer, which adjusts the signal level. The bus driver / receiver is designed to implement the MAX232 RS - 232 communication interface, and especially in applications where power supply + 12V is difficult. The given UC is especially useful in autonomous power supply applications, as the very low mode with low power consumption built into the UC reduces power consumption by up to 5 mkW. Table 3.2 shows the main characteristics of the MAX232 chip.

Figure 3.10 shows the internal scheme of the IC MAX 232, MAX232A and the external appearance of the body.

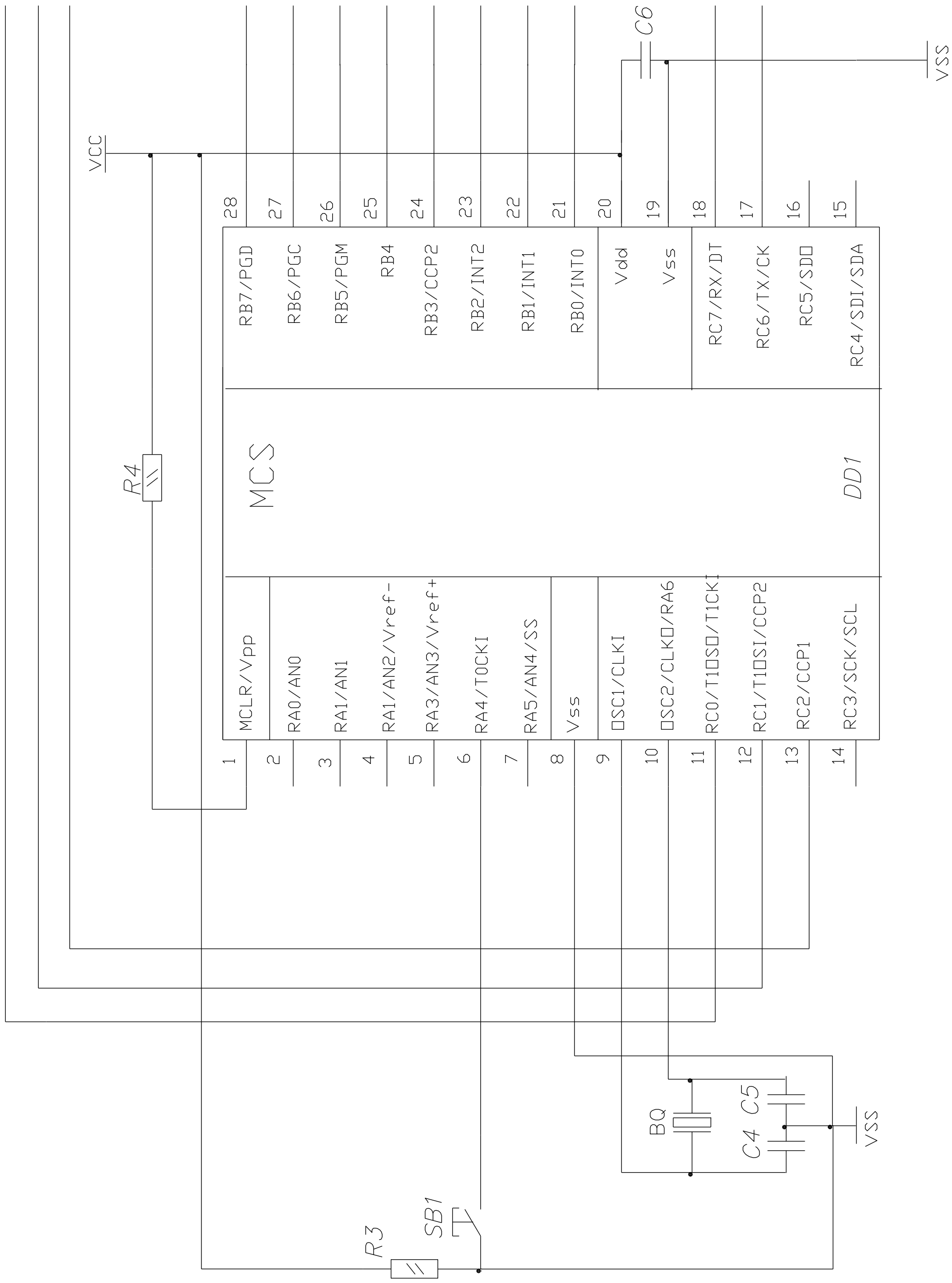


Figure 3.8. Microcontroller connection diagram and keyboard block

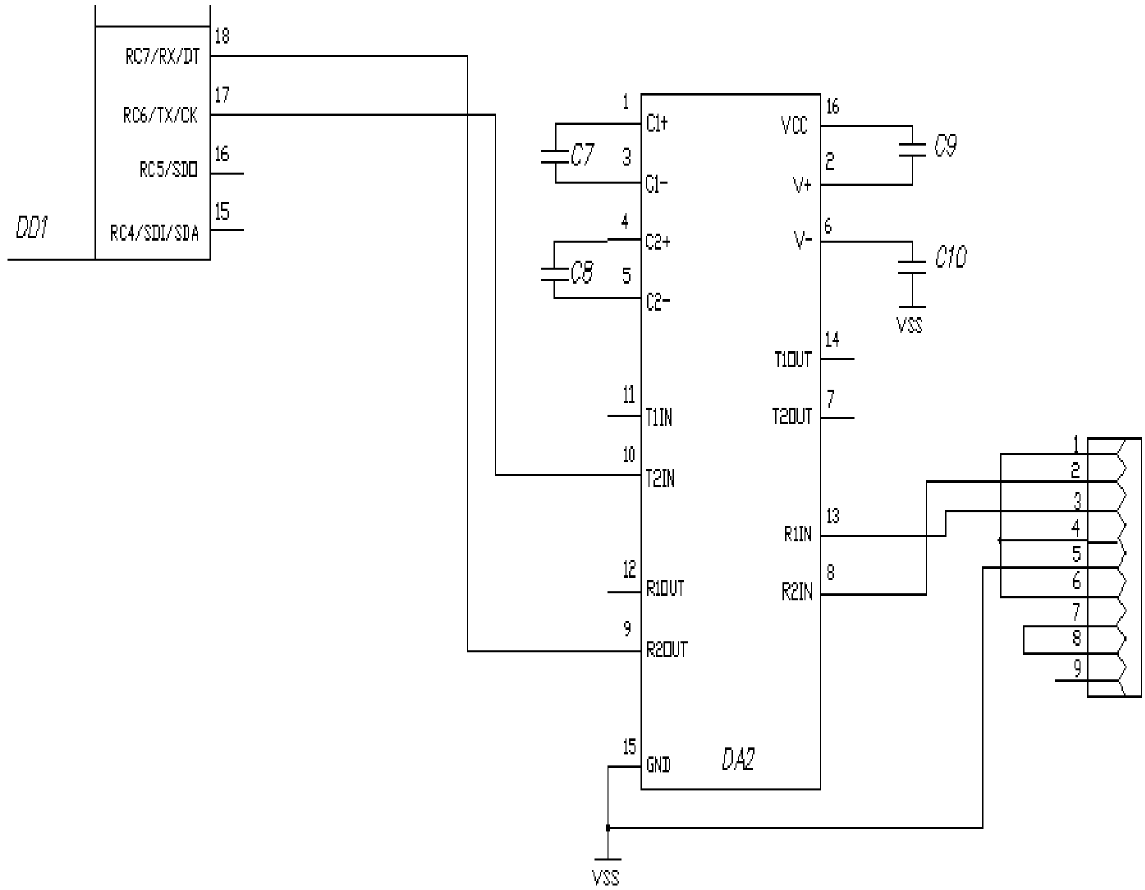


Figure 3.9. Block diagram adapted with a code converter

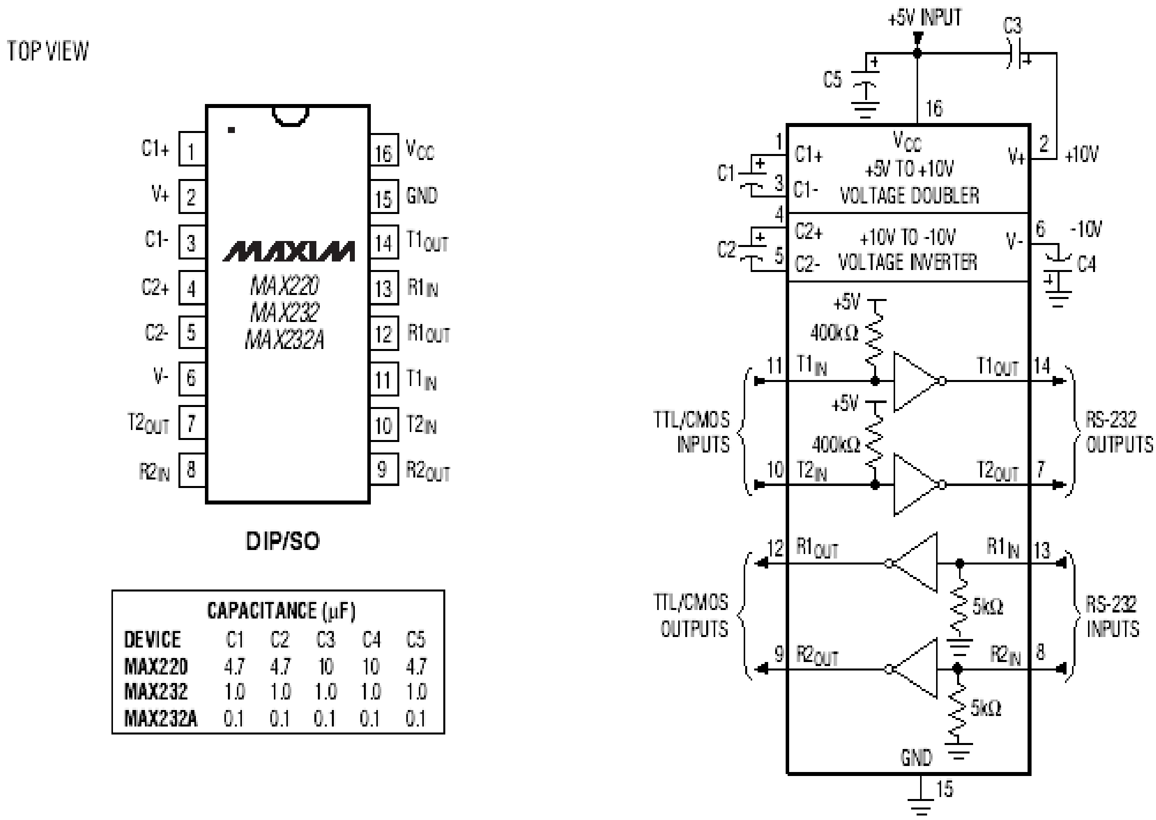


Figure 3.10. MAX 232, MAX 232A external circuit body appearance and internal connection diagram

Table 3.2. Basic characteristics of MAX232 and MAX232A chips

| Type | Power supply | Receivers/ transmitters | Capacity | SHDN və Three-state | Dafa Rafe (kbps) |
|---|---|---|---|---|---|
| MAX 232 | +5 | 2/2 | 4x1.0 | № | 120 |
| MAX 232 A | +5 | 2/2 | 4x1.0 | № | 200 |

The MAX232A chip has a higher throughput than the MAX232, so Maxim's
It is more expedient to use the integrated circuit MAX 232A.

The nominal manufacturer of capacitors C7-C10 is recommended by the manufacturer and we choose a capacitor of type 0.1 MKF ± 10% 250V. Demolition SXI-standard disassembly type RS-232 DB9F.

### 3.5.Calculation of power supply

The designed device uses two supply voltages: + 5V to power the digital part of the device and + 24V to power the ultrasonic sensor. The use of unstable voltage to power the sensor is due to the fact that the sensor has a built-in voltage stabilizer [15,16]. The electrical schematic diagram of the power supply unit is shown in Figure 3.11.

To select the elements of the power supply, determine the current consumed by the elements of the circuit, for convenience, transfer the indicators to Table 3.3.

Thus, since the indication is dynamic in Table 3.3, the current consumed by only one seven-segment indicator is collected.

The maximum current consumed by the ultrasonic sensor is 50MA.

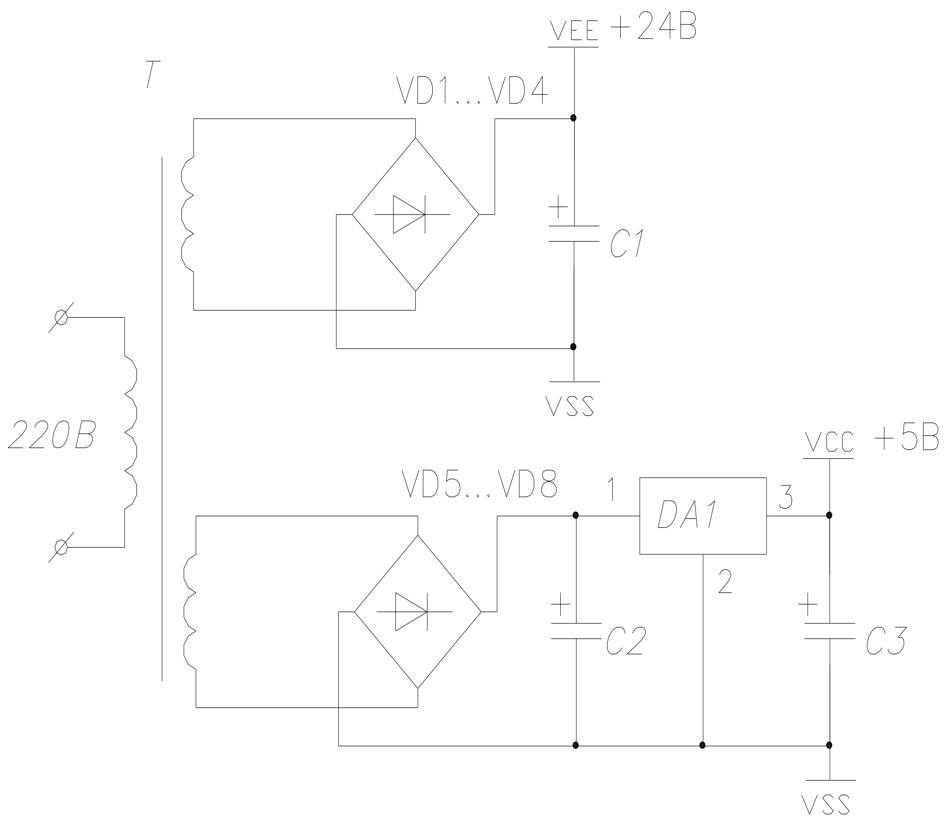

Figure 3.11. Electrical schematic diagram of the power supply unit

To stabilize the +5 voltage, we choose the K142 EH5A (DA1) integrated stabilizer, which maintains a maximum current equal to 3A, but an external analogue which can also be used in the LM 7805. To rectify the alternating voltage, we use VD1-VD4, VD5-VD8 diode bridges KC 402A with a maximum rectified current I_direct = 1A.

Table 3.3. Voltages consumed by IMS at + 5V

| Position | Name | Amount | Maximum current consumption (mA) |
|---|---|---|---|
| DD1 | PIC18F252 | 1 | 2 |
| DA2 | MAX 232A | 1 | 10 |
| HG | ALC333A | 1 | 160 |
| Total | | | 172 |

We choose capacitors C1 and C2 with a capacity of 1500 mkF, type K50-18-1500 mkF ± 10% 25V. We choose capacitor C3 with a capacity of 1 μF, type K50-3A-1 μF ± 10% 250V.

Let's choose a transformer:

5V for the voltage of the second winding: U2 (+5) = 9V;

For 24 V: U2 (± 24) = 24V.

We choose a small-sized transformer with a maximum winding of not less than 300 mA for the second winding, as the device consumes less energy.

# CONCLUSION

As a result of the master's thesis, a device for measuring the liquid level with an ultrasonic range used in information measurement systems was developed.

The following results were obtained in the master's dissertation:

1. The model and structural scheme of the device is developed, on the basis of which its principal scheme is calculated.

2. The ultrasonic liquid level measuring device provides sequential signal output from the ultrasonic sensor, conversion of analog signal to dual signal, output of level information to the operator's indicator and connection to electronic computing devices via RS-232 interface.

3. Among the advantages of the device should be noted the high relevance and demanding requirements of operation, simplicity of its structure, and as a result, simplicity of operation and serviceability.

All of the above reflects the prospects for the application of this device not only in the implementation of autonomous level measurement, but also in other automation devices.

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