Measurement of the Levels and the Density of Liquids in the Ship Reservoirs by Magnetic Levitation and Buoy Measuring Device

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Abstract: ***At present greating improved devices in the field of control measuring technigue is very actual and impotant. As a result of its context measuring the level and density of liquid in the ship reservoires by magnit levitation and buoy level gauge are considered in the article. The principle of magnetic levitation has a lot of advantages. One of them is that the levitating object, which plays the role of a sensitive element, can be placed on a variety of the measuring cameras that enable the researcher to localize the factor of interest and exclude all others. This enables to measure the measurements are carried out in the most various environments encompassing this object such as the fluid or gas environment, the different temperatures and pressures, in the vacuum, in the air and in the sea ships, in the tankers, liquids and e.t.c.***

Keywords: measurement devices, system, a magnetic levitation, buoy level gauge, fluid level, density of the liquid

1. Introduction

The basis of our research work is the measurement of the level and density of the fluid with magnetic levitations, the measuring high levels. The aim of the study is to investigate the magnitude and density of the liquid in different reservoirs by the measuring magnetic levitations, measuring high levels. The principle of magnetic levitation has a lot of advantages. One of them is that the levitating object, which plays the role of a sensitive element, can be placed on a variety of the measuring cameras that enable the researcher to localize the factor of interest and exclude all others. This enables to measure the measurements are carried out in the most various environments encompassing this object such as the fluid or gas environment, the different temperatures and pressures, in the vacuum, in the air and in the sea ships, in the tankers, liquids and e.t.c.

The buoy measuring device consists of the solenoid, the measuring camera, the levitating dart junction, the high frequency inductive transmitter, solenoid current control unit. Additionally, the magnetic suspension with the same design, aluminum made of mechanical contact with fixed magnets, grayed partitions located on measuring cameras, thermistors for obtaining temperature compensation, signal inputs from the inputs of the microcontroller to the inputs and other inputs, and the output is connected to the level indicator.

At present, the creation of new devices in the field of control and measurement equipment mean is of great importance. The relevance of this topic is the elimination of deficiencies and improvement, of previously created instruments, as well as the use of new techniques the latest achievements of electronics which allow the running processes to finish quickly and accurately. On the other hand, it requires a high reliability as well. Particularly there are strict requirements devices which are used in marine applications, including ship repairing and building.

The aim of the present work is to research the possibility of measuring the level (parts of the volume filled up with liquid) and the density of liquids of densitometer by means of magnetic levitation and displacer.

The work deals with the comprehensive solution of the problem - modeling in terms of physics, math, design concept of an electronic circuit and software for a microcontroller that performs direct visualization of the results in the continuous mode of operation of the device.

The principle of operation of such devices is based on magnetic levitation [1], i.e. balancing by two forces - the force of gravity acting on displacer placed partially or completely by liquid to be measured, and the magnet traction force by the electromagnet. The instrument has two displacers - the first ball the second rod. The dimension of the first displacer does not play a significant role. To measure the density of the fluid, the first displacer is placed completely by liquid. To measure the filled portion of the volume (steam boilers of ships tank in tankers etc.) of the liquid, part of the second displacer is placed in fluid while the rest is located above the liquid surface. Let’s assume for simplicity that the second displacer is an inert metal cylinder. The height of the second displacer is equal to the depth of the second volume, which is filled up with liquid.

A preferred feature of this method is that the working devices by this principle have minimal moving parts.

The essence of the above method can be briefly described as following. A magnet is rigidly connected to the first displacer for measuring liquid density or filled up portion of the liquid volume. The permanent magnet is placed in the zone of permanent magnet traction. When the weight of suspended body is changed, of the inductive sensor, sends a signal to current regulator device in order to alter the amount of electrical current flowing through the solenoid coil.

Let us consider above-mentioned processes in detail. The first stage unit is determined using the fluid density. Let's assume that the first magnet is rigidly connected to the first displacer and the winding core, which detects a small displacement of the magnet (Fig.1). Let a minimal part of the volume be filled up with liquid. In this case the displacer has a small size (for example, a ball with a diameter of several centimeters) and stored (floats) in the liquid. Assume that the operating forces are applied to the magnet.

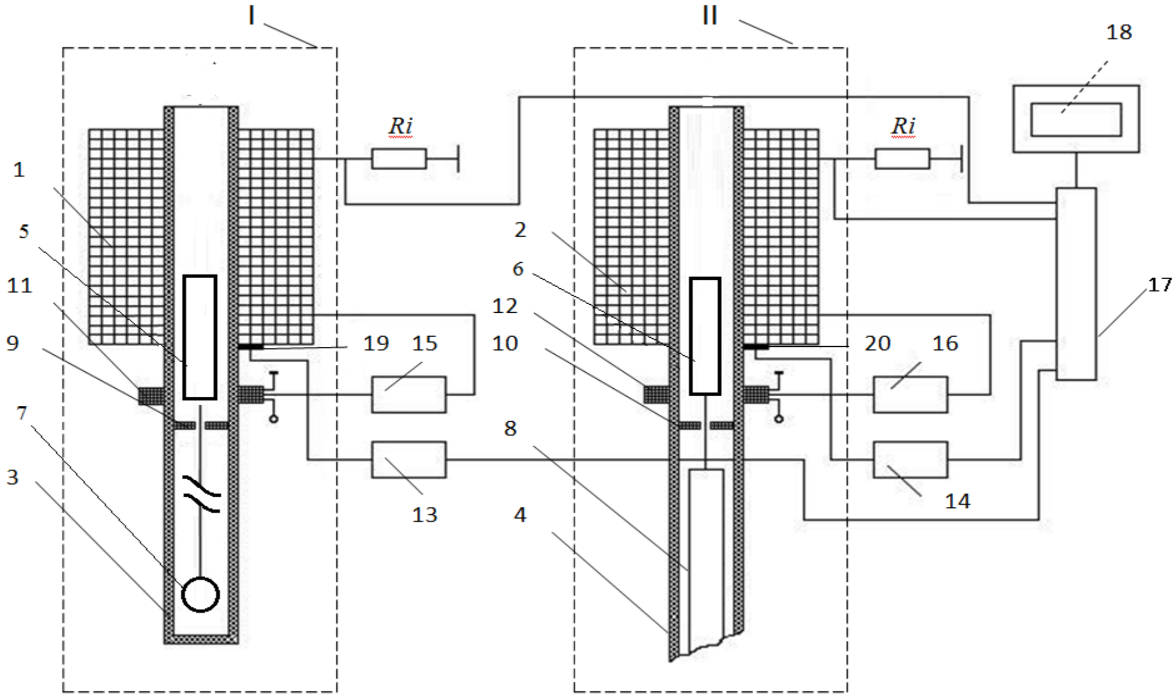

Figure 1: Scheme for measuring level and density of liquid gauge by means of magnetic levitation device and displacer

For this case

$$F_T - F_A - F_Э = 0 \quad (1)$$

Here, F_T - gravity and F_A - Archimedes force acting on buoy, $F_Э$ - force of electromagnet acting on the magnet. $F_T = m_b g = \rho_b g V_b$, $F_A = \rho_l g V_b$ and $F_Э = K_0 \cdot I_c$ (here m_b, ρ_b, V_b - the mass, density and volume displacer, respectively, g - acceleration due to gravity, ρ_{zh} - density of the liquid, R_0 - a coefficient, which depends on the parameters of the first electromagnet, I_c - current, which flows through the coil of the first electromagnet) from the process equation (1) we get [1]:

$$\rho_b g V_b - \rho_l g V_b - K_0 \cdot I_c = 0 \quad (2)$$

From here:

$$\rho_b - \rho_l = \frac{K_0}{gV_б} \bullet I_s \quad (3)$$

And so

$$\rho_b - \rho_l = \frac{A}{R_a} U_x \quad (4)$$

Here, the $A = \frac{K_0}{gV_б} \cdot I_c \cdot R_a$ (R_a - a resistance which is connected in series wound electromagnet), U_x - the voltage drop across the resistance R_a, which corresponds to a current flowing through the electromagnet winding.

In the absence of liquid the force of Archimedes doesn't influnce and buoy hangs in the atmosphere. In this case, the expression (4):

$$\rho_b = \frac{A}{R_a} U_m; \qquad \rho_l = 0 \quad (5)$$

Here, U_m - the maximum value of the voltage drop across the resistor R, which corresponds to the current flowing through the coil of the electromagnet, in the acts of liquid.

In the presence of liquid the force of Archimedes and buoy sails in the (inside) of liquid. In this case, the expression (4):

$$\rho_b - \rho_l = \frac{A}{R_a} U; \qquad \rho_l \neq 0 \quad (6)$$

Here, U - a voltage drop across the resistor R_a, which corresponds to a current through the solenoid coil in the case of presence of the liquid.

From the expression (5) and (6) it is obtained

$$\frac{\rho_b}{U_m} = \frac{\rho_b - \rho_l}{U} \quad (7)$$

From here

$$\rho_l = \rho_b - \frac{\rho_b}{U_m} . U \quad (8)$$

Knowing the value of ρ_b, U_m, U - using the expression (8) ρ_l - the liquid density it can be determined.

After determining ρ_l - the fluid density using the second displacer the level of the liquid as a part of the volume can be determined.

In this case, considering that $F_T = m_b g = \rho_b g V_b$, $F_A = \rho_l g V'_b$, the FA and $F_e = K'_0 \cdot I_c\, m_b$ here, ρ_b, V_b, - the mass, density and the total volume of the displacer, respectively, g - accelerating gravity, ρ_l - liquid density, V'_b - volume displacer which is in fluid K'_0 - several coefficients which depend on the parameters of the second electromagnet, I'_c – current power, which flowing through the coil of the second electromagnet) from equation (1) we obtain [1]:

$$\rho_b g V_b - \rho_l g V'_b - K'_0 . I'_c = 0 \qquad (9)$$

Carrying out the same conversion as in the first case, we obtain:

$$\rho_b V_b - \rho_l V'_b = \frac{K'_0 . I'_c}{g}$$

$$\rho_b V_b - \rho_l V'_b = \frac{B}{R_b} U'_x$$

Here, (R_b – some resistance which is connected consequently to wound electromagnet), U'_x - voltage drop at the resistance R_b, which corresponds to the current flowing through the electromagnet winding.

$$\rho_b V_b = \frac{B}{R_b} U'_m ; \qquad V'_b = 0$$

Here, U'_m - the maximum level of the voltage drop across the resistor R_b, which corresponds to the current flowing through the coil of the electromagnet, in the absence of fluid filling the volume.

$$\rho_b V_b - \rho_l V'_b = \frac{B}{R_b} U'; \qquad V'_b \neq 0$$

Here, U'- a voltage drop across the resistor R_b, which corresponds to the current flowing through the solenoid coil in the case of a liquid filling into several parts of volume.

$$\frac{\rho_b V_b}{U'_m} = \frac{\rho_b V_b - \rho_l V'_b}{U'}$$

$$\frac{U'}{U'_m} = 1 - \frac{\rho_l V'_b}{\rho_b V_b}$$

In this expression, considering the shape of the displacer cylinder, it is possible to go up to the displacer height h, submerged in liquid, which corresponds V'_b, and of H, the full height of the displacer, which corresponds to V_b. Full height of H also corresponds to the height of the volume.

$$\frac{U'}{U'_m} = 1 - \frac{\rho_l}{\rho_b} \cdot \frac{h}{H}$$

$$\theta = \frac{h}{H} = \frac{\rho_b}{\rho_l} \cdot \left(1 - \frac{U'}{U'_m}\right) \qquad (10)$$

This expression (10) shows the ratio of the height of the filled part to the full height of the filling volume. It should be noted that the expression (10) is valid those cases in which the horizontal cross section of the filling volume does not depend on the height required.

Knowing ρ_b, ρ_l, U'_m, U'- using the expression (10) the ratio of the height of the filled to the full height of the filling volume can be determine $\theta = \frac{h}{H}$.

At present, the development of digital electronics allows the visualization of the results of a formula (8) and (10). In the expressions (8) and (10) there is dependence on the voltage drop U_m, U and U'_m, U'respectively. As mentioned above, U_m and U'_m have maximum level of voltage drop across the resistors R_a and R_b.

The visualization of the results can be carried out using the display and microcontroller. It is known that the microcontrollers have an operating voltage - voltage supply. In addition, to measure (to compare) the signal microcontrollers have reference voltage. In particular, the supply voltage is taken as the reference voltage and the signal, voltage is compared with this voltage. Choosing R_a and R_b, one can get the maximum voltage drop value U_m and U'_m, which is equal to the reference voltage. Typically, this is carried out using the variable resistor, since a variable resistor (extreme conclusions) is connected in parallel to the resistor R_a or R_b. From the average output of the variable resistor U_c signal voltage is taken. At the maximum current value flowing through the resistor R_a or R_b, variable resistor is adjusted so that the average output of the variable resistor, the value of the signal voltage may be equal to the reference voltage.

To validate the results of the calculations and stimulation of the schemes (formulas (8) (10)) developed by us using the program «Proteus 7 Professional» principal electrical scheme is prepared, which uses two variable resistors for the signal 0 to 5 V, that corresponds to the current flow through electromagnets ATMEGA8 microcontroller to convert the received signals to the measured values with the help of the program compiled by us, and liquid crystal display LM016 to display the results.

In the circuit diagram (Figure 1) RV1 and RV2 variable resistors serve to obtain a voltage from 0 to 5V, which corresponds to the current flowing through the electromagnets. These signals, which correspond to the density of the fluid and the filled part of the volume supplied to the terminals PC0 and PC1 (0 and 1 outputs of port of C) ATMEGA8 microcontroller. The button, the resistor R2 and the output PC6 are used to reset (command RESET) ATMEGA8 microcontroller. Port B (PB0 conclusions, PB1, PB2, PB4, PB5, PB6 and PB7) is used for the liquid crystal display LM016 to display the obtained results.

The microcontroller ATMEGA8 using the compiled program produced certain operations (periodic registration conclusions voltages PC0 and of PC1, calculation formulas (8) and (10) ρ_l - fluid density and θ - filled part of the volume of the liquid, the conclusion of the results on the display). The whole operation takes place in the second cycle, it may take a few thousand cycles, depending on the selected clock ATMEGA8 microcontroller. Clock frequencly and other settings of microcontroller ATMEGA8 are determined using «CodeVisionAVR» software.

For the operation of schematic diagrams a program for the microcontroller via «CodeVisionAVR» program was compiled by us.

In the compiled programming: constant (material density and height of the buoy), variable (value signals PC0 and PC1 findings), the name of the display, configuration and pin assignments and the formula for calculating are included. The data (signals or variables) come with the findings of PC0 and PC1 and the resulting values are used for calculations. The first fluid density is computed. In the second step. Using obtained values of the fluid density the filled part of the fluid volume in percentage is computed.

In compiling the program, formula (8) and (10) for calculating ρ_l - fluid density (table, line 69) and θ - filled part (table, row 76) the volume of the liquid. Are included because of the lack of character ρ_l and θ, in a structured program of replacement ρzh made on D and θ to H, which are displayed on the display.

The drafted by the program using the programming is recorded on the memory ATMEGA8 microcontroller.

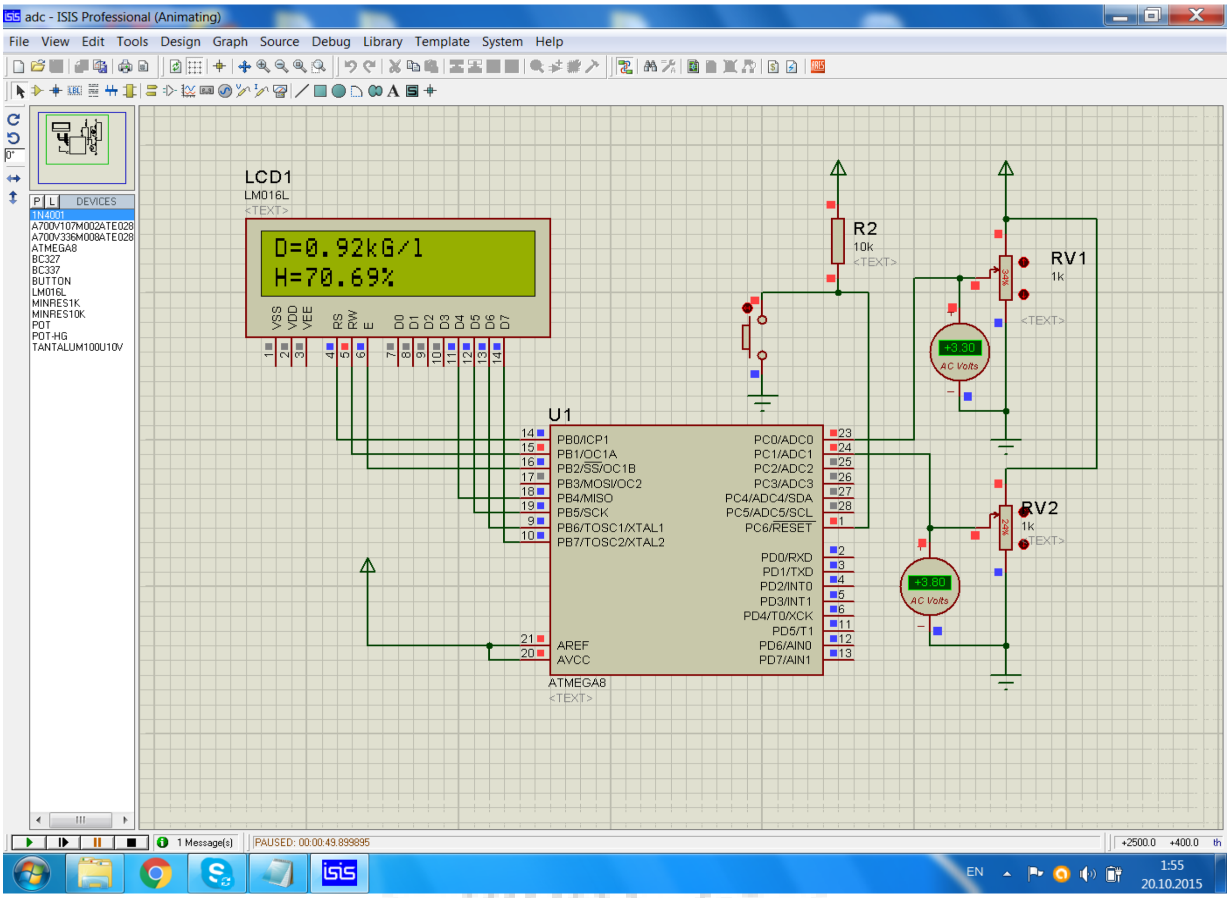

Figure 2: Schematic diagram of the device for measuring the level and density of the liquid.

2. Summary

With the help of the formulas on the PORT C0 turns microcontroller and the analog signal inputs PORT C.1 necessary transformations taking over the tensions and the volume of the measured fluid density ρ filling level of interest rates is determined with great accuracy in continuous mode. The formulas for calculating the results of the test are correct, "Proteus 7 Professional" program variable resistors, microcontroller and liquid crystal display were assembled using the principal electric scheme. The fundamental operation of the electric scheme "Code Vision AVR" - the program was designed for microcontroller checked.

References

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Table

```
1.	/*****************************
2.	This program was produced by the
3.	CodeWizardAVR V1.25.9
Professional
4.	Automatic Program Generator
5.	© Copyright 1998-2008 Pavel
Haiduc, HP InfoTech s.r.l.
6.	http://www.hpinfotech.com
7.	Project :
8.	Version :
9.	Date : 22.05.2015
10.	Author : F4CG
11.	Company : F4CG
12.	Comments:
13.	Chip type : ATmega8
14.	Program type : Application
15.	Clock frequency : 4,000000 MHz
16.	Memory model : Small
17.	External SRAM size : 0
18.	Data Stack size : 256
19.	*****************/
20.	#include <mega8.h>
21.	// Alphanumeric LCD Module
functions
22.	#asm
23.	.equ __lcd_port=0x18 ;PORTB
24.	#endasm
25.	#include <lcd.h>
26.	#include <delay.h>
27.	#include <stdio.h>
28.	#define start PORTD.7
29.	#define sbros PORTD.6
30.	//** Глобальные переменные ****
31.	char lcd_buffer[33]; //Буфер обмена
LCD
32.	int ch_1; //Переменная хранения
данных ADC0 канал 1
33.	int ch_2; //Переменная хранения
данных ADC1,канал 2
34.	//int ch_3; //Переменная хранения
данных ADC2, в зависимости от количества
каналов
35.	//int ch_4; //Переменная хранения
данных ADC3, в зависимости от количества
каналов
36.	//int ch_5; //Переменная хранения
данных ADC4, в зависимости от количества
каналов
37.	float V1,V2,V,E;
38.	float D,X,Y;
39.	#define FIRST_ADC_INPUT 0
40.	#define LAST_ADC_INPUT 1
41.	unsigned int
adc_data[LAST_ADC_INPUT-
FIRST_ADC_INPUT+1];
42.	#define ADC_VREF_TYPE 0x00
43.	// ADC interrupt service routine
44.	// with auto input scanning
45.	interrupt [ADC_INT] void
adc_isr(void)// Wizard необходимо изменить
если каналов больше чем 2канала
46.	{
47.	register static unsigned char
input_index=0;
48.	// Read the AD conversion result
49.	adc_data[input_index]=ADCW;
50.	// Select next ADC input
51.	if (++input_index >
(LAST_ADC_INPUT-FIRST_ADC_INPUT))
54.	delay_us(10);
55.	// Start the AD conversion
56.	ADCSRA|=0x40;
57.	}
58.	void adc_convers(void)
59.	{
60.	ch_1= adc_data[0]; //Запись в
переменную ch_1 результата ADC 1-го
канала
61.	ch_2= adc_data[1]; //Запись в
переменную ch_2 результата ADC 2-го
канала
62.	//ch_3= adc_data[2]; //Запись в
переменную ch_2 результата ADC 3-го
канала
63.	//ch_4= adc_data[3]; //Запись в
переменную ch_2 результата ADC 4-го
канала
64.	//ch_5= adc_data[4]; //Запись в
переменную ch_2 результата ADC 5-го
канала
65.	lcd_gotoxy(0,0);
66.	V1 =
(float)ch_1*0.0048828;//размерность для
вольтметра
67.	//V=(V/5)*100;
68.	X=2.7;
69.	D=X-X/5*V1;
70.	//D=6;
71.	sprintf(lcd_buffer,"D=%1.2fkG/l" ,
D);
72.	lcd_puts(lcd_buffer);
73.	lcd_gotoxy(0,1);
74.	Y=2.7;
75.	V2 = (float)ch_2*0.0048828;
76.	V=(Y/D)*((5-V2)/5);
77.	if(V2<=5*(1-D/Y))
78.	{
79.	V=1;
80.	}
81.	E=V*100;
82.	sprintf(lcd_buffer,"H=%1.2f%% ",
E);
83.	lcd_puts(lcd_buffer);
84.	}
85.	void start_sbros(void)
86.	{
87.	start=0;
88.	sbros=1;
89.	delay_ms(1000);
90.	sbros=0;
91.	start=1;
92.	delay_ms(30000);
93.	start=0;
94.	sbros=1;
95.	delay_ms(1000);
96.	}
97.	// Declare your global variables here
98.	void main(void)
99.	{
100.	// Declare your local variables here
101.	// Input/Output Ports initialization
102.	// Port B initialization
103.	// Func7=In Func6=In Func5=In
Func4=In Func3=In Func2=In Func1=In
Func0=In
104.	// State7=T State6=T State5=T
State4=T State3=T State2=T State1=T
State0=T
114.	=T State1=T State0=T
115.	PORTD=0x00;
116.	DDRD=0xFF;
117.	// Timer/Counter 0 initialization
118.	// Clock source: System Clock
119.	// Clock value: Timer 0 Stopped
120.	TCCR0=0x00;
121.	TCNT0=0x00;
122.	// Timer/Counter 1 initialization
123.	// Clock source: System Clock
124.	// Clock value: Timer 1 Stopped
125.	// Mode: Normal top=FFFFh
126.	// OC1A output: Discon.
127.	// OC1B output: Discon.
128.	// Noise Canceler: Off
129.	// Input Capture on Falling Edge
130.	// Timer 1 Overflow Interrupt:
Off
131.	// Input Capture Interrupt: Off
132.	// Compare A Match Interrupt:
Off
133.	// Compare B Match Interrupt:
Off
134.	TCCR1A=0x00;
135.	TCCR1B=0x00;
136.	TCNT1H=0x00;
137.	TCNT1L=0x00;
138.	ICR1H=0x00;
139.	ICR1L=0x00;
140.	OCR1AH=0x00;
141.	OCR1AL=0x00;
142.	OCR1BH=0x00;
143.	OCR1BL=0x00;
144.	// Timer/Counter 2 initialization
145.	// Clock source: System Clock
146.	// Clock value: Timer 2 Stopped
147.	// Mode: Normal top=FFh
148.	// OC2 output: Disconnected
149.	ASSR=0x00;
150.	TCCR2=0x00;
151.	TCNT2=0x00;
152.	OCR2=0x00;
153.	// External Interrupt(s)
initialization
154.	// INT0: Off
155.	// INT1: Off
156.	MCUCR=0x00;
157.	// Timer(s)/Counter(s)
Interrupt(s) initialization
158.	TIMSK=0x00;
159.	// Analog Comparator
initialization
160.	// Analog Comparator: Off
161.	// Analog Comparator Input
Capture by Timer/Counter 1: Off
162.	ACSR=0x80;
163.	SFIOR=0x00;
164.	// ADC initialization
165.	// ADC Clock frequency:
125,000 kHz
166.	// ADC Voltage Reference:
AREF pin
167.	ADMUX=FIRST_ADC_INPUT
| (ADC_VREF_TYPE & 0xff);
168.	ADCSRA=0xCD;
169.	// LCD module initialization
170.	lcd_init(16);
171.	// Global enable interrupts
172.	#asm("sei")
```

52. input_index=0; ADMUX=(FIRST_ADC_INPUT | (ADC_VREF_TYPE & 0xff))+input_index;
53. // Delay needed for the stabilization of the ADC input voltage
	105. PORTB=0x00;
	106. DDRB=0x00;
	107. // Port C initialization
	108. // Func6=In Func5=In Func4=In Func3=In Func2=In Func1=In Func0=In
	109. // State6=T State5=T State4=T State3=T State2=T State1=T State0=T
	110. PORTC=0x00;
	111. DDRC=0x00; // Port D initialization
	112. // Func7=In Func6=In Func5=In Func4=In Func3=In Func2=In Func1=In Func0=In
	113. // State7=T State6=T State5=T State4=T State3=T State2
		173. while (1)
		174. {
		175. adc_convers(); //Чтение результатов ADC преобразования
		176. //start_sbros();
		177. };
		178. }

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