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ALMATY UNIVERSITY OF POWER ENGINEERING AND TELECOMMUNICATIONS NAMED AFTER GUMARBEK DAUKEEV

Electronics and robotics department

PLC TECHNOLOGIES IN INSTRUMENTATION

Methodological guidelines for laboratory work
for undergraduates in EP 6M071600 - "Instrumentation"

Almaty 2022

COMPOSITORS: B. S. Baikenov, A. E. Ayazbai PLC technologies in instrumentation. Methodical instructions for laboratory work for undergraduates in EP 6M071600 - "Instrument making". - Almaty: AUPET, 2022 . - 26 p.

Methodological guidelines are devoted to the study of creating a channel for transmitting information over low-voltage wiring networks based on the KQ-330F microcontroller, which is the main element of household IOT (smart home, fire and security alarm systems) and industrial IIOT systems (dispatch control and monitoring of technological process parameters or SCADA systems , systems of access to computer networks with broadband and high-speed Internet).

The presentation of the material is accompanied by examples on the development of various microprocessor devices, devices and systems based on the ATMega328 microcontroller. For each project, there is a list of required components, a wiring diagram and a listing of C ++ programs.

Methodological guidelines are drawn up in order to consolidate the lecture material and are intended for undergraduates of the specialty 6M071600 - "Instrumentation".

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Reviewer: Associate Professor Baimaganov A.S.

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Introduction

Methodological guidelines are devoted to the creation and modeling of microprocessor devices and systems in the Proteus software environment with a channel for transmitting information over low-voltage wiring networks based on the KQ-330F microcontroller, which is the main element of channel-forming equipment in automation and robotics projects.

The technical capabilities of the KQ-330F adapter, the features of connection and interaction with the Arduino UNO board are described.

The methodological guidelines are designed to acquire practical skills and competencies in the design and creation of real digital devices and systems.

Laboratory work No. 1. Development of a control system for electrical wiring channels

The purpose is to study the circuitry of the KQ-330F modulator module and methods of its connection to conventional control systems based on Arduino.

1.1 Brief information

Consider a system for transmitting messages through wiring channels with information displayed on an LCD screen.

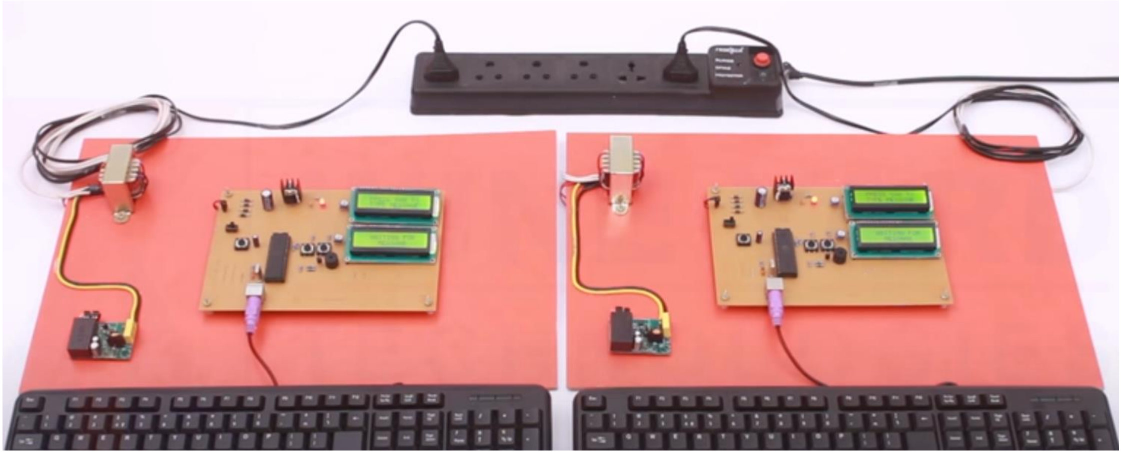

Figure 1.1 - Appearance of the wiring message transmission system

Figure 1.2 - View of the PLC adapter based on KQ-330F

1.2 Order of work

1.2.1 Develop a control circuit for turning on the lighting by wiring

By analogy with the diagram in Figure 1.1, give the connection diagram for the Arduino.

Develop a model of the switching circuit in Proteus: transmitter - button and Arduino; UART channel; receiver - relay, LED, Arduino.

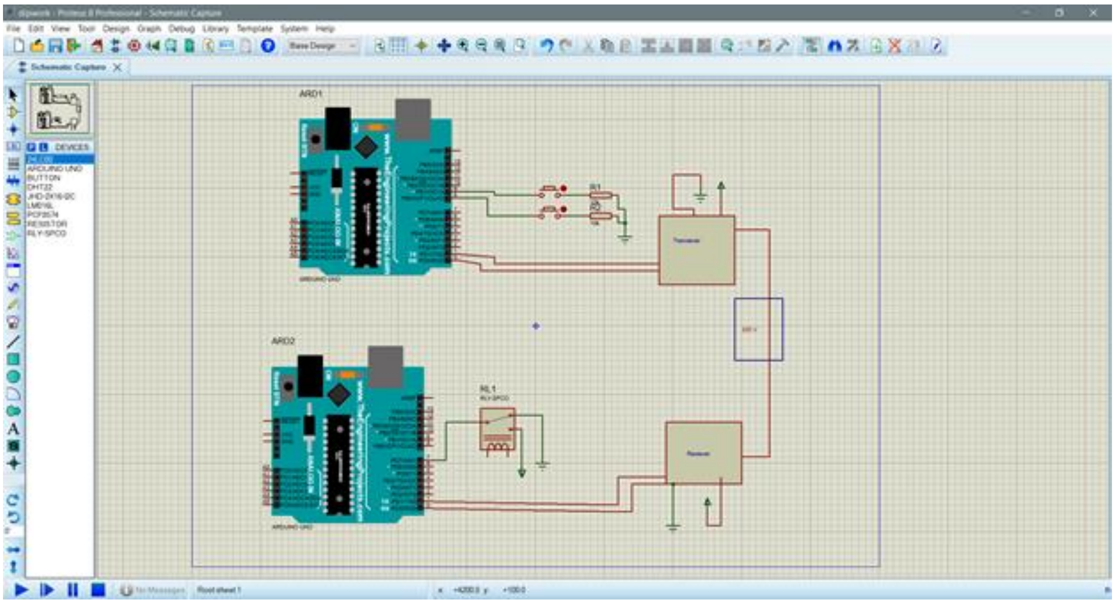

Figure 1.3 - Functional diagram of the PLC transmission channel

1.2.2. Provide a schematic diagram of the KQ-330 microcontroller and a PLC adapter diagram for connecting to the network.

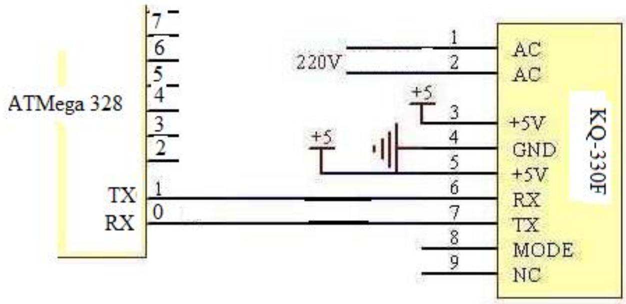

Figure 1.4 - Wiring diagram of the KQ-330F modulator to the ATMega328 microcontroller

1.3 Content of the report

- the purpose of the work;
- block diagram of remote control of switching on the ventilation system by electrical wiring;
- model in Proteus without adapter via UART or SPI channels;
- schematic diagram of the KQ-330 modulator and network connection diagram;
- conclusions.

1.4 Test questions

1.4.1 What is the structure of a PLC transceiver?
1.4.2 What is the format of the transmitted data of the KQ-330F?
1.4.3 What is the maximum size of the transmit buffer?
1.4.4 What is the baud rate of the KQ-330F module?
1.4.5 How long does it take to transfer a data byte?

Laboratory work No. 2. Developed PLC control relay

Purpose of work is to study the characteristics and functionality of the KQ-330F modulator module as a channel-forming device in control systems based on Arduino.

2.1 Brief information

The KQ130F module is a high voltage channel interface, transmits data at 9600 bps, start bit format, 8 data bits, 1 stop bit.

The module uses transparent mode (high level) by means of the MODE pin of the control module or user mode of operation (low level).

Figure 2.1 - External view of the KQ-330F modulator module

There is no need to initialize the programming of the module. However, since the load on the transmission line is heavy, the generated electrical harmonics will inevitably be associated with the transmission line. This module is a highly sensitive carrier module, when the carrier module is in the receiving state, the power line will be covered with generated electrical harmonics, then the module will demodulate the data outputted from the noise of the TX terminal. Therefore, transmission and reception of data must be inserted in the preamble to distinguish between actual transmission of data.

Note: the transmit buffer in the module no longer receives new data, it is filled up to 253 bytes, i.e. transmitted bytes must be less than 253 bytes. User data is continuously sent by the KQ130F module, if the pause time exceeds the time when the module finished sending all data (buffer is empty, the last byte was completely sent), then data can be inserted into the receiving module.

In user mode (MODE = 0), the transmission of asynchronous data (one start bit, 8 data bits, 1 stop bit) takes about 0.09 seconds.

In this operating mode, the user-defined transmission protocol is as follows:

- first byte: the number of bytes to be transferred in 0-250 (excluding the first byte);
- second byte up to n + 1 bytes: user byte data to transfer.

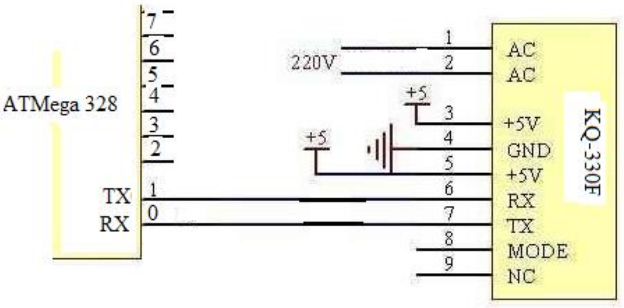

Figure 2.2 - Connection diagram of the KQ-330F modulator to the ATMega328 microcontroller

2.2 Work order

2.2.1 Insert the wiring diagram of the KQ-330F module (Figure 2.2) into the functional circuit for controlling the relay by wiring in Proteus

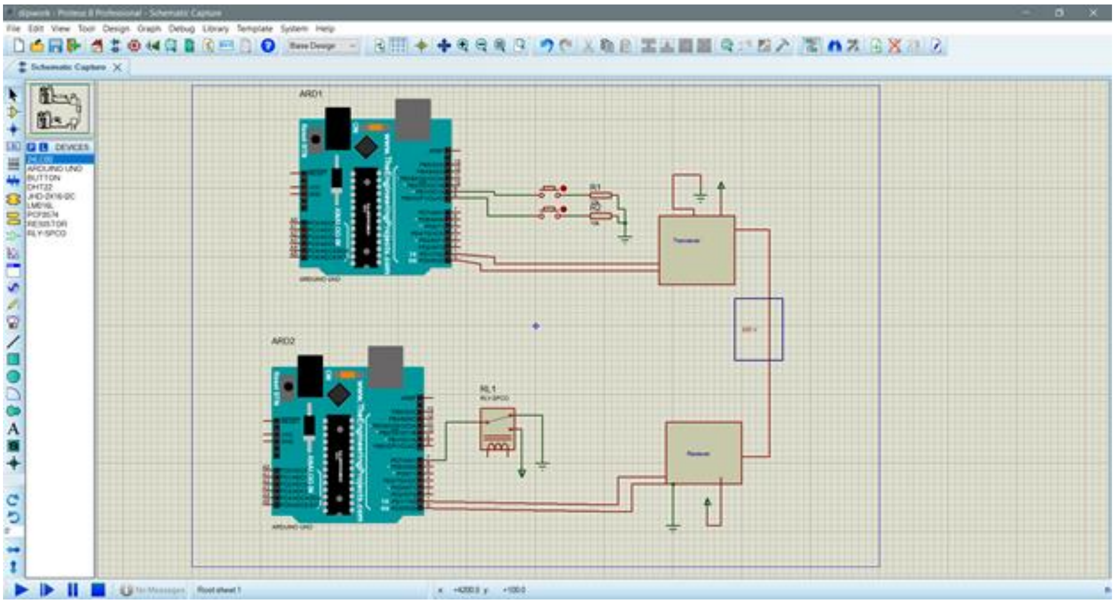

Figure 2.3 - Functional diagram of the PLC transmission channel

2.2.2. Read the listings of the Arduino transmit and receive code and develop program flow diagrams.

Listing 1. Transmitter Code

```
// Sketch transceiver
#include <Wire.h> // i2C Conection Library

int bton = 8;
int btoff = 9;
int btonx = 0;
int btoffx = 0;
int ax;
int data1 = 1;
int data2 = 2;

void setup () {
  Serial.begin (9600);

  pinMode (bton, INPUT_PULLUP);
  pinMode (btoff, INPUT_PULLUP);
```

```
}

void loop () {
   btonx = digitalRead (bton);
   btoffx = digitalRead (btoff);

   if (btonx == 0) {
     ax = 1;
     }

    if (btoffx == 0) {
     ax = 2;
     }
   if (ax == 1) {
     Serial.println (data1);
   }
   if (ax == 2) {
     Serial.println (data2);
   }
  delay (100);
}
```

Listing 2. Receiver code

```
// Sketch reciever
int value1;
int relay = 7;

void setup () {
pinMode (relay, OUTPUT);
digitalWrite (relay, HIGH);
Serial.begin (9600); // opens serial port, sets data rate to 9600 bps
}

void loop () {
  if (Serial.available ()> 0)
    {
        value1 = Serial.parseInt ();
if (value1 == 1) {
  digitalWrite (relay, LOW);
  }
if (value1 == 2) {
  digitalWrite (relay, HIGH);
  }
Serial.println (value1);
```

```
delay (10);
}
}
```

2.3 Content of the report

- the purpose of the work;
- schematic diagram of the KQ-330 modulator and connection diagram to ATMega328;
- schematic diagram of PLC relay control by wiring;
- block diagrams of the code for transmitting and receiving commands;
- conclusions.

2.4 Test questions

2.4.1 What is the main disadvantage of Frequency-Division Multiplexing (FDM)?
2.4.2 What is the name of the modulation method, in which the centers of the subcarriers are placed so that the peak of each subsequent signal coincides with the zero value of the previous ones?
2.4.3 What do the subcarriers undergo before being combined into one signal?
2.4.4 Is a transformer required to connect the module to the 220V power network?
2.4.5 Which arduino module is the KQ-330 modulator connected to?

Laboratory work No. 3. Temperature measurement and reset on LCD

The purpose of the work is to study the characteristics and functionality of the KQ-330F modulator module as a channel-forming device in home control systems based on Arduino.

3.1 Summary

The KQ130F module is a high voltage channel interface, transmits data at 9600 bps, start bit format, 8 data bits, 1 stop bit.

The module uses transparent mode (high level) via the MODE pin of the control module or custom operating mode (low level).

Figure 3.1 - External view of the KQ-330F modulator module

There is no need to initialize the programming of the module. However, since the load on the transmission line is heavy, the generated electrical harmonics will inevitably be associated with the transmission line. This module is a highly sensitive carrier module, when the carrier module is in the receiving state, the power line will be covered with generated electrical harmonics, then the module will demodulate the data outputted from the noise of the TX terminal. Therefore, transmission and reception of data must be inserted in the preamble to distinguish between actual transmission of data.

Note: the transmit buffer in the module no longer receives new data, it is filled up to 253 bytes, i.e. transmitted bytes must be less than 253 bytes. User data is continuously sent by the KQ130F module, if the pause time exceeds the time when the module finished sending all data (buffer is empty, the last byte was completely sent), then data can be inserted into the receiving module.

In user mode (MODE = 0), the transmission of asynchronous data (one start bit, 8 data bits, 1 stop bit) takes about 0.09 seconds.

In this operating mode, the user-defined transmission protocol is as follows:

- first byte: the number of bytes to be transferred in 0-250 (excluding the first byte);
- second byte up to n + 1 bytes: user byte data to transfer.

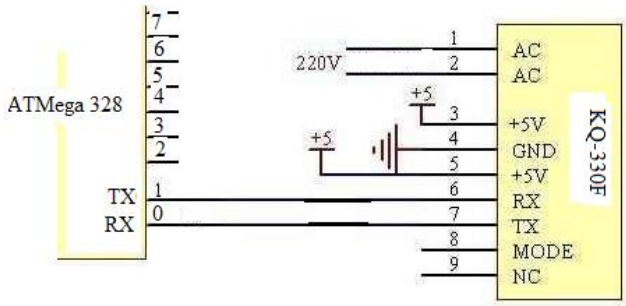

Figure 3.2 - Wiring diagram of the KQ-330F modulator to the ATMega328 microcontroller

DHT22 temperature and humidity sensor has the form

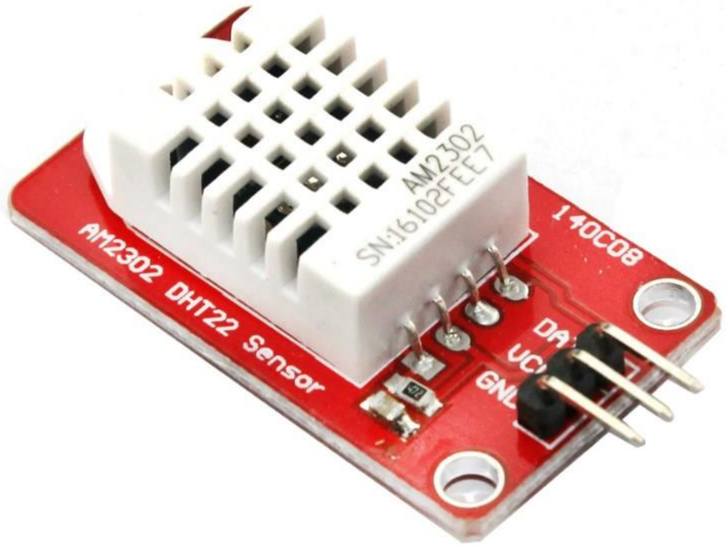

Figure 3.3 - External view of DHT22 sensor

DHT22 - fairly well-known sensors for determining relative humidity and temperature, consist of a capacitive humidity sensor and a thermistor. Also, the sensor contains an ADC for converting analog values of humidity and temperature.

These digital sensors are based on a protocol that uses one open collector wire / bus for communication, so a 5-10kΩ resistor must be pulled up to the positive power supply.

LCD 1602 I2C display looks like

Figure 3.4 - Appearance of LCD 1602 I2C display

LCD 1602 I2C display is a liquid crystal, text, two-line, 16 character spaces in each line, digital I2C indicator with backlight. It is an Arduino module. Each familiarity has a resolution of 8 x 5 dots. The total number of dots on the screen is 1280 pixels. The display backlight is white, LED. The color of the liquid crystals is dark blue. The result is beautiful white text on a blue background. The display is based on the HD44780 controller and is designed to display any text information, in conjunction with Arduino or other controllers. Thanks to the additionally installed I2C port expansion module on the PCF85741 microcircuit, the display has become very easy to connect to any microcontroller. See the picture above for the connection diagram.

3.2 Work order

3.2.1 Insert the connection diagram of the KQ-330F module (Figure 2.2) into the functional diagram of the humidity and temperature sensor reading on the LCD via the wiring in the Proteus.

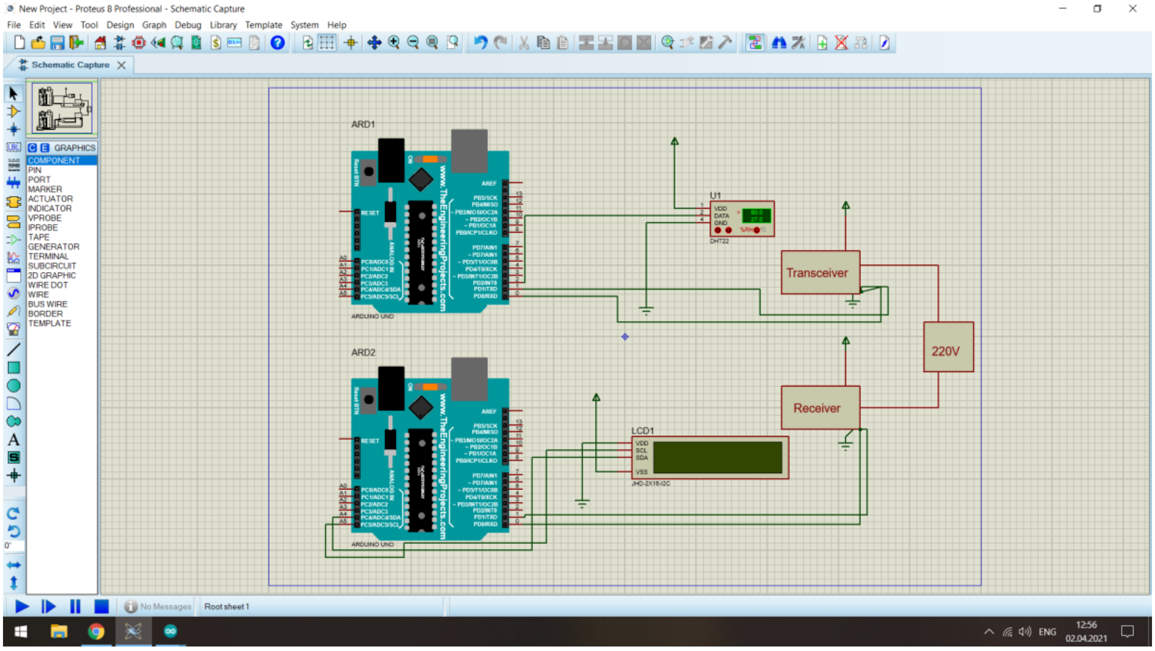

Figure 3.5 - Functional diagram of the PLC transmission channel

3.2.2. Read the listings of the Arduino transmit and receive code and develop program flow diagrams.

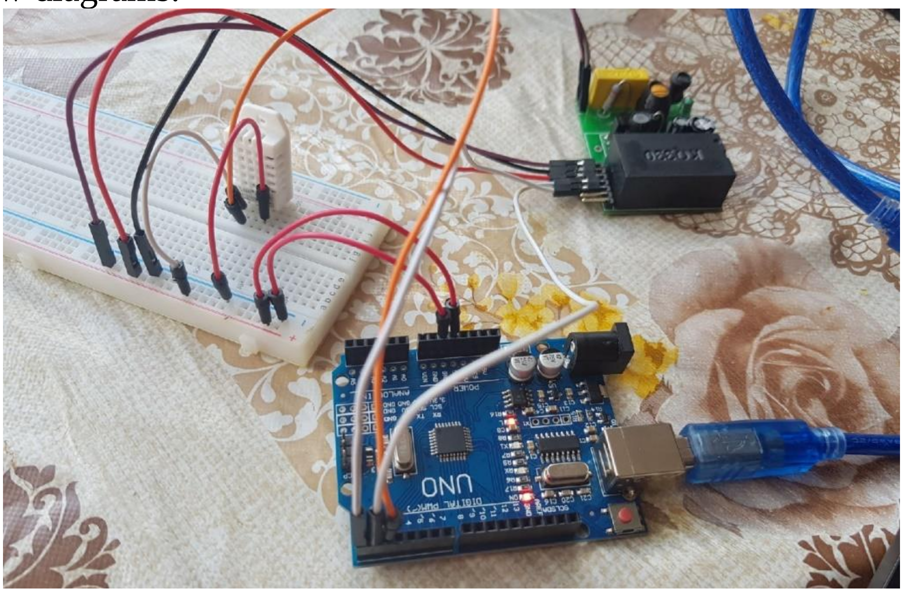

Figure 3.6 - Assembling the transmitter

Listing 3.1 Transmitter Code

```
#include <Adafruit_Sensor.h>
#include <DHT.h>
#define DHTPIN 2
DHT dht (DHTPIN, DHT22);
void setup () {
  Serial.begin (9600);
  dht.begin ();
}
void loop () {
  delay (2000);
  int h = dht.readHumidity ();
  int t = dht.readTemperature ();
  }
  Serial.print ("Humidity:");
  Serial.print (h);
  Serial.print ("% \ t");
  Serial.print ("Temperature:");
  Serial.print (t);
  Serial.println ("* C");
}
```

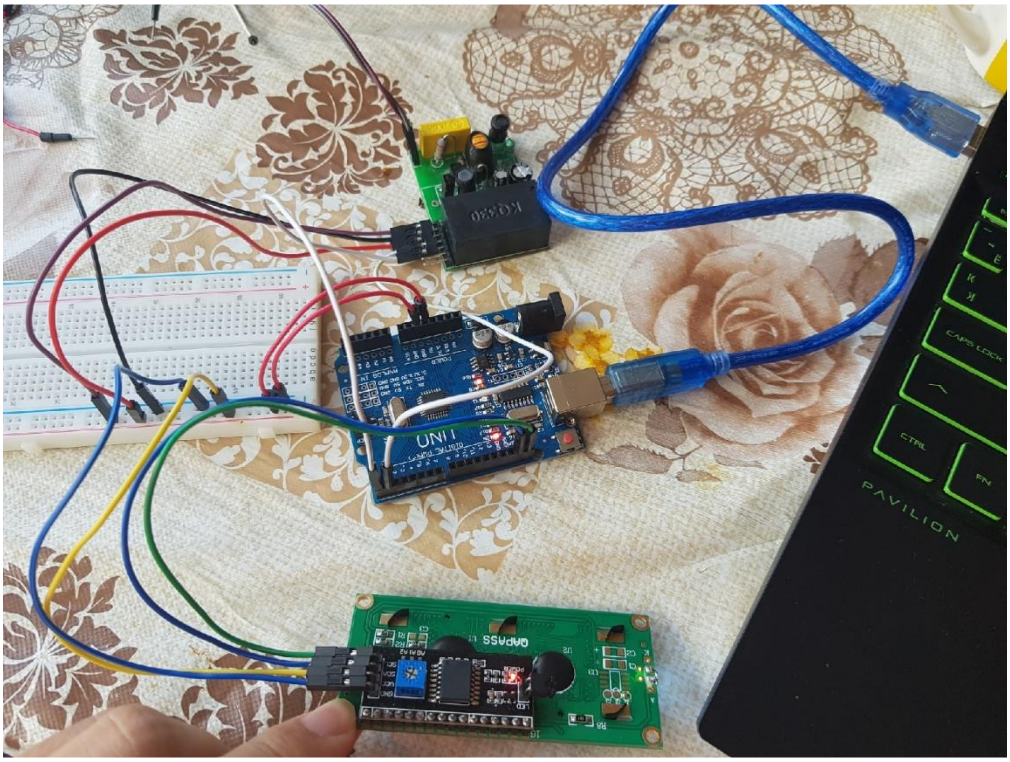

Figure 3.7 - Assembling the receiver

Listing 3.2 Receiver code

```
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
LiquidCrystal_I2C lcd (0x27,16,2);

void setup ()
{
lcd.init ();
Serial.begin (9600);
}
void loop () {
  if (Serial.available ()> 0)
    {
  int h = Serial.parseInt ();
  int t = Serial.parseInt ();
 Serial.println (h);
 Serial.println (t);
  lcd.setCursor (0,0);
  lcd.print ("Temp:");
  lcd.print (t); //
  lcd.print ("C");
  lcd.setCursor (0,1);
  lcd.print ("Humidity:");
  lcd.print (h);
  lcd.print ("%");
 delay (100);
}
}
```

3.3 Content of the report

- the purpose of the work;
- schematic diagram of the KQ-330 modulator and connection diagram to ATMega328;
- schematic diagram of the PLC reading the temperature and humidity sensor using the display on the wiring;
- block diagrams of the code for transmitting and receiving commands;
- conclusions.

3.4 Test questions

3.4.1 What does "last mile" mean for PLC technology?
3.4.2 Can PLC technology be used in the construction of remote video monitoring

systems?
3.4. What is the basis of Powerline technology?
3.4.4 What PLC standard defines high-speed internet access?
3.4.5 What is the name of the method in which a high-speed data stream is split into several relatively low-speed streams?

Laboratory work No. 4. Simulation of generators based on NE555

The purpose of the work is to get acquainted with the simulation of the timer circuit in various modes of operation using the ISIS editor.

4.1 Summary

Timers are devices for accurately setting time intervals. Timers can be analog or digital. The first integral timer NE555 was developed in 1972 by Signetix (USA). Currently, this scheme is considered classic. The functional diagram of the NE555 timer (Russian analog - 1006VI1) is shown in Figure 4.1.

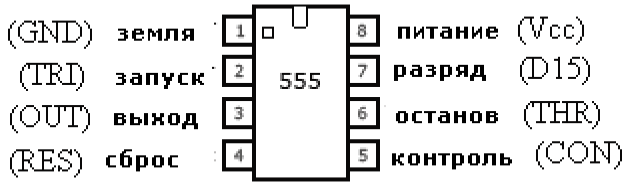

Figure 4.1 - Pin designations (8-Pin) NE555

The timer circuit contains 3 5kΩ resistors, so the microcircuit was named NE555. Power supply from 4.5 to 18 V. The NE555 timer has three operating modes: standby, generator and trigger.

4.1.1 Standby

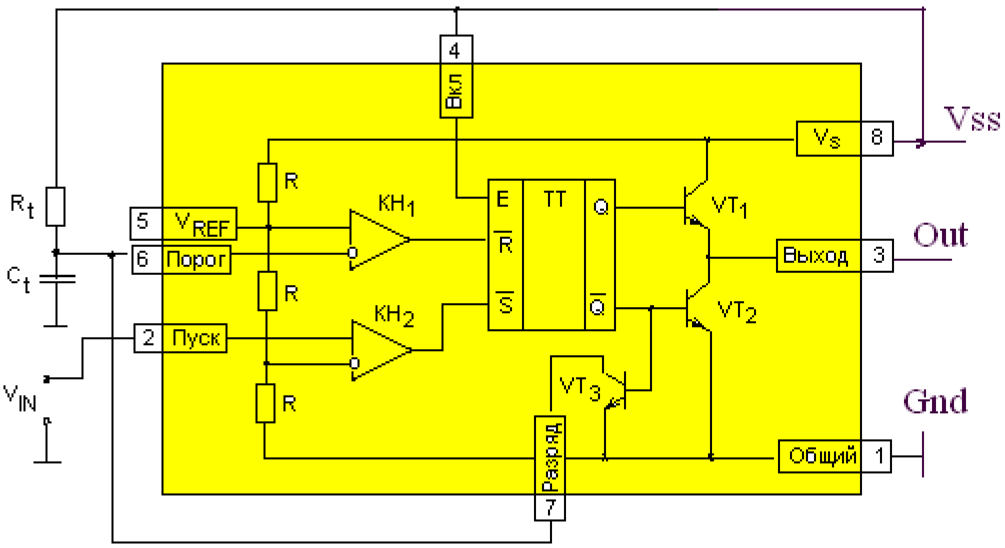

Figure 4.2 - Scheme of NE555 in standby mode

The timer circuit includes two comparators KH1, KH2, and an RS-flip-flop that fixes the state of the output. One of the inputs of each comparator is connected to a voltage divider formed by 3 resistors R = 5 kOhm - hence the name NE555. The voltages on the divider arms are 2Vs / 3 and Vs / 3, respectively. The trigger controls a push-pull, symmetrical output stage on transistors VT1, VT2, providing an output current of up to 200mA. In addition, the inverse trigger output controls the discharge switch on the VT3 transistor. The trigger has a permission input E - 4Pin, when a low level signal is applied to the timer output, the low level is also set regardless of the signal level at the VIN input.

A reference voltage from an external source can be supplied to the non-inverting input of the comparator KH1 (5Pin), connected to the upper stage of the divider, if necessary. This conclusion is not used in practice, therefore, a capacitor C = 0.1pF is connected between this terminal and the ground, which smooths out the noise coming through the power supply circuit Vs.

In standby mode, VIN input to 2Pin Start is high (greater than Vs / 3). In this case, the output voltage of the comparator corresponds to log. 1. For an inverse trigger input, this level is inactive. The voltage Vc at the timing capacitor CT is close to zero, and the output voltage of the KN1 compressor applied to the inverse input of the trigger also has a log level. 1. The trigger is in the storage mode in the state Q = 0, = 1. The transistor VT1 is closed, and VT2 is open. The timer output is low level 0. The VT3 key is closed and maintains the capacitor Ct, in a discharged state.

With a negative short-term drop in the input signal VIN <Vs / 3 (Figure 4.3) at the output of the comparator KH2 for the time of the drop, a logical zero will be established (an active level for the trigger input) and the trigger will switch to the state Q = 1, = 0.

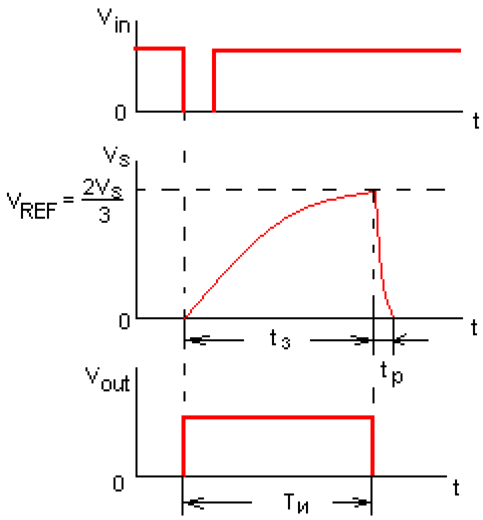

Figure 4.3 - Timing diagrams of the waiting multivibrator on timer

At the same time, the VT3 switch opens, and the capacitor Ct begins to charge through the resistor Rt from the power source Vs. The charge equation of the capacitor Ct has the form

$$R_t C_t \frac{dV_C}{dt} + V_C = V_S. \qquad (4.1)$$

The solution to this equation with zero initial conditions

$$V_C(t) = V_S\left(1 - e^{-\frac{t}{R_t C_t}}\right).$$

The pulse ends when Vc reaches the reference voltage VREF. In this case, the comparator KH1 will switch and transfer the trigger to its original state. The VT3 key will close and discharge the Ct capacitor. The pulse duration Ti at the output is determined from the equation:

$$V_C(T_{\grave{E}}) = V_S\left(1 - e^{-\frac{T_{\grave{E}}}{R_t C_t}}\right) = \frac{2V_S}{3}, \qquad (4.2)$$

from which it follows that

$$T_{\grave{E}} = R_t C_t \ln 3 = 1{,}1 R_t C_t. \qquad (4.3)$$

f during this time another triggering pulse arrives at the input, then the trigger will remain in a single state, i.e. restart during charging t3 of the capacitor Ct is ignored. The timing capacitor Ct is discharged very quickly, although not instantaneously. If the next trigger pulse comes during the discharge of the tp capacitor, the timer pulse duration will be shortened.

The discharge time tp of the timing capacitor Ct, called the relaxation time, is, in any case, much less than the analogous time of the waiting multivibrator on the op-amp.

The circuit diagram of the NE555 timer in standby mode is

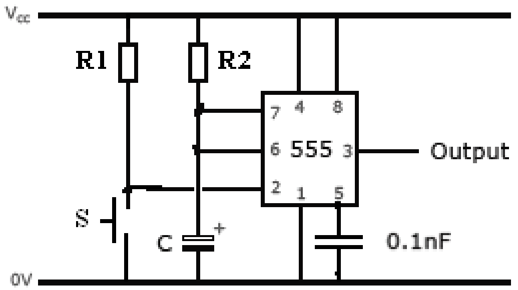

Figure 4.4 - Scheme of NE555 in standby mode

4.1.1.1 Task

By the value of R2 within the specified limits according to the option (table 4.1), determine the delay (deceleration) time or the duration of the output pulse Ti by the formula (4.3). Check the calculated data on the model and draw conclusions about its adequacy (accuracy).

Table 4.1- Range of R2 values at C = 1μF

Вариант	1	2	3	4	5	6	7	8	95	10
R2, МОм	0,5	0,8	1	1,2	1,5	1,8	2	2,2	2,5	3

4.1.2 Generator mode

A diagram of the simplest multivibrator with a duty ratio $0 < \gamma < 1$ is shown in Figure 4.5.

When the potential on the capacitor C reaches the lower threshold of the timer, the trigger input will be set to a low (active) level. The trigger will switch to the log.1 state and the VT3 key will open. Capacitor C starts charging through resistor R1 and open diode VD1, and discharges, as in the basic circuit, through R2. The voltage across the capacitor will reach the upper threshold in the time

$$t_1 = R_1C \ln2 = 0{,}693R_1C. \quad (4.4)$$

In this case, the comparator KH1 will switch, a low (active) level will be set at the trigger input, the trigger will switch to the state Q = 0, and the VT3 key will open. The capacitor will be discharged through the resistor R2, until the voltage across it reaches the lower threshold of the timer. It will happen in time

$$t_2 = R_2C \ln2 = 0{,}693R_2C \quad (4.5)$$

Then all the processes will be repeated. The frequency of the output voltage of the multivibrator will be

$$f = \frac{1}{t_1 + t_2} = \frac{1{,}44}{(R_1 + R_2)C}. \quad (4.6)$$

To reduce the influence of the diode VD1 on the accuracy of the formation of time intervals, the diode VD2 is connected in series with the resistor R2. The relative duration or duty cycle of the circuit pulses is determined by the state

$$0 < \gamma = \frac{R_1}{R_1 + R_2} < 1. \quad (4.7)$$

The timer circuit in MB mode is used to power LED and flash lamps. Below is a model of a multivibrator circuit that generates pulses with $\gamma = 0.5$, called a meander.

In the ISIS program, select the NE555 timer, 1N4003 diodes, CAP10 capacitors, RES40 resistors, an oscilloscope in the components and assemble the circuit (Figure 4.5).

Select the NE555 timer: by clicking on P, the Pick Devices window opens, select the category - Analog ICs and select 555 in the results field (on the right, the DIL08 symbol and case dimensions will appear), click OK at the bottom right, the window is closed and on the main field with the cursor in the desired place we install the microcircuit.

Diode type 1N4003: category - Diodes, subcategory - Rectifiers. The symbol DD41 and the dimensions will appear on the right, click OK at the bottom right, the window is closed and on the main field with the cursor in the right place set the diode.

Non-electrolytic capacitor type CAP: category - Capacitors, subcategory - Generic. The symbol CAP10 and the dimensions will appear on the right, click OK at the bottom right, the window is closed and on the main field, place the capacitor with the cursor.

Resistor type RES40: category - Resistor, subcategory - Generic. After setting on the field, select with the cursor and press the right button, in the window that appears, select the line Edit properties, in the window of which set 1M and press OK.

Oscilloscope: on the right, click on the "Visual tools" icon, select the Oscilloscope and move the cursor, set it on the field by pressing the left button. Hover the cursor over the oscilloscope and right-click to open the Edit Properties window with a drop-down menu, in which check the Exclude from PCB item, then OK. When you start the program, an oscilloscope appears. If the oscilloscope does not open, then you need to move the cursor over its schematic image and click on the right button - in the drop-down menu, click on the Digital Oscilloscope.

Ground and + source: click on the right icon "Terminals", click alternately Ground and Power.

We carefully connect each device in strict accordance with the diagram shown (Figure 4.5).

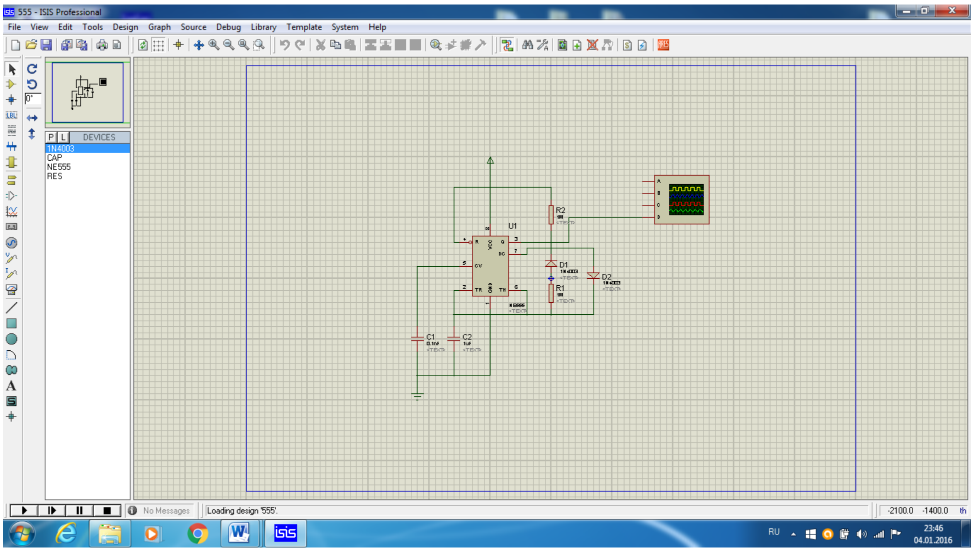

Figure 4.5 - Scheme of a multivibrator in ISIS

When you start the ISIS simulator, a two-channel oscilloscope screen appears (Figure 4.6).

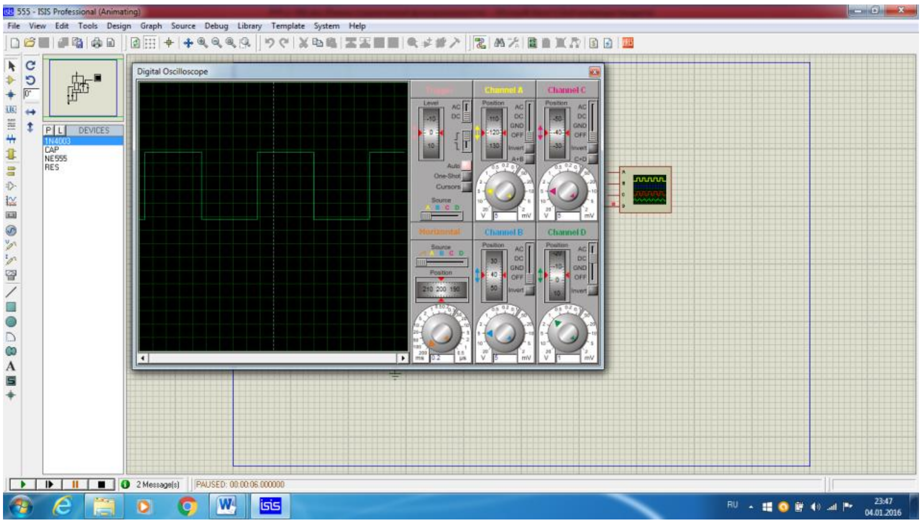

Figure 4.6 - Oscilloscope screen in MB mode

4.1.2.1 Task

According to the value of R2 within the specified limits according to the option (table 4.2) and at R1 = 1 MΩ, determine the duration of the output pulse Ti by the formula (4.5), the duty ratio γ according to (4.7) and the frequency f according to (4.6). Verify the calculated data on the model and draw conclusions about the adequacy (accuracy).

Table 4.2 - Range of R2 values at C = 1μF and R1 = 1MΩ

Option	11	12	13	14	15	16	17	18	19	20
R2, MOм	0,5	0,6	0,7	0,8	0,9	1,0	1,1	1,2	1,5	2

4.3 Content of the report

- the purpose of the work;
- tasks (clause 4.2);
- model of the timer circuit in one of 2 modes according to the option;
- conclusions.

4.4 Test questions

4.4.1 Why does the NE555 timer have 555 in the name?
4.4.2 What is the function of the comparators KH1 and KH2?
4.4.3 What is the generator duty cycle?
4.4.4 What is the function of capacitor C1?
4.4.5 What is the VT3 transistor for?

Laboratory work No. 5. Development of a scheme for switching on lighting on power circuits

The purpose of the work is modeling a device for switching on by lighting on an electrical wiring in the Proteus software environment.

5.1 Summary

Consider a lighting system without Arduino.

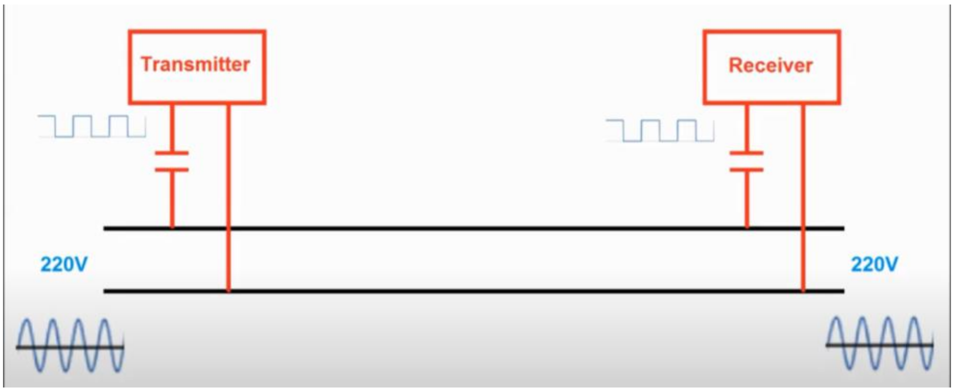

Figure 5.1 - Block diagram of wiring control

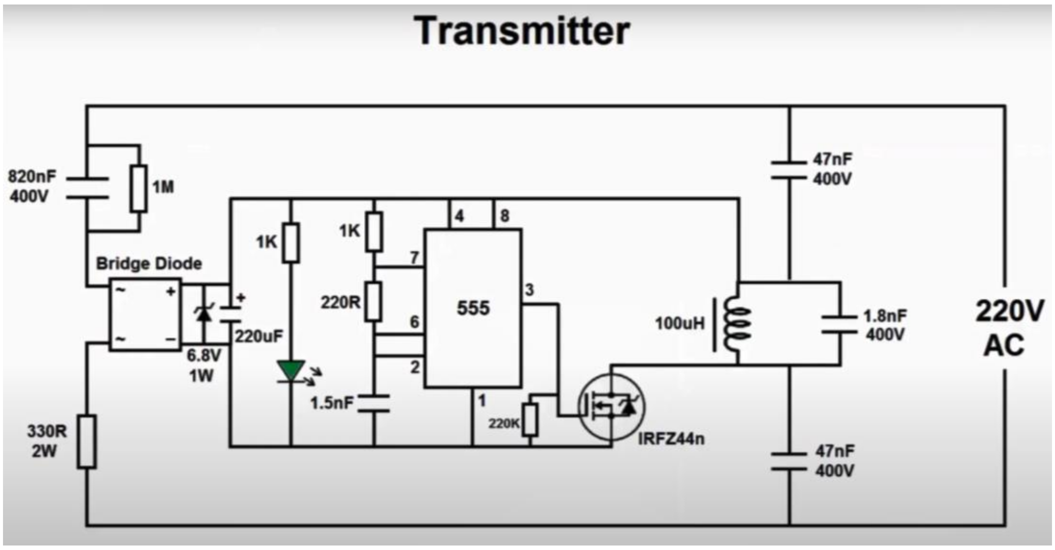

Figure 5.2 - Schematic diagram of the transmitter

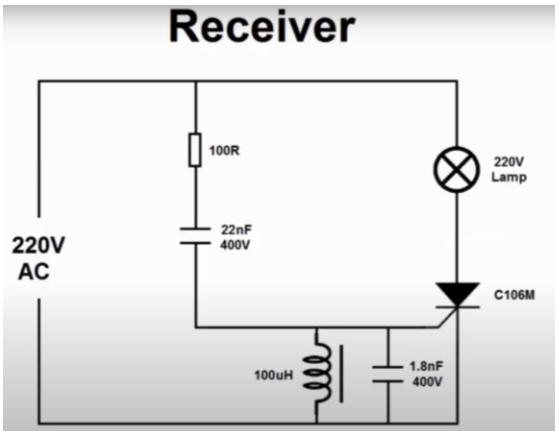

Figure 5.3 - Schematic diagram of the receiver

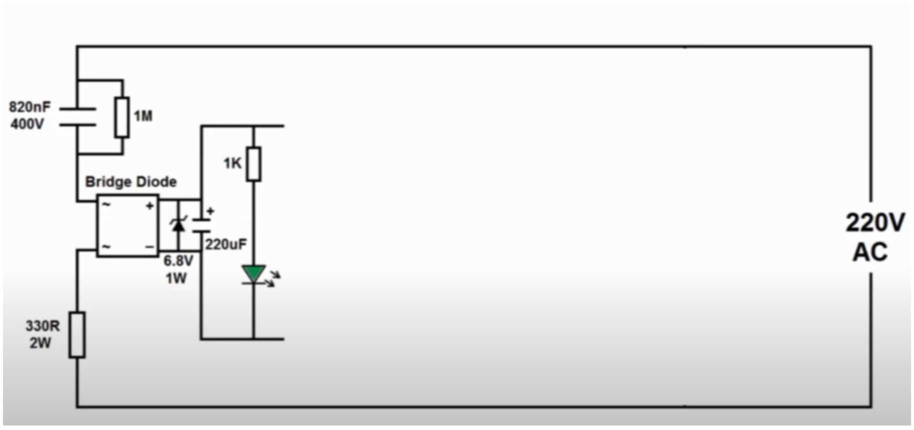

Figure 5.4 - Power supply for analog timer NE555

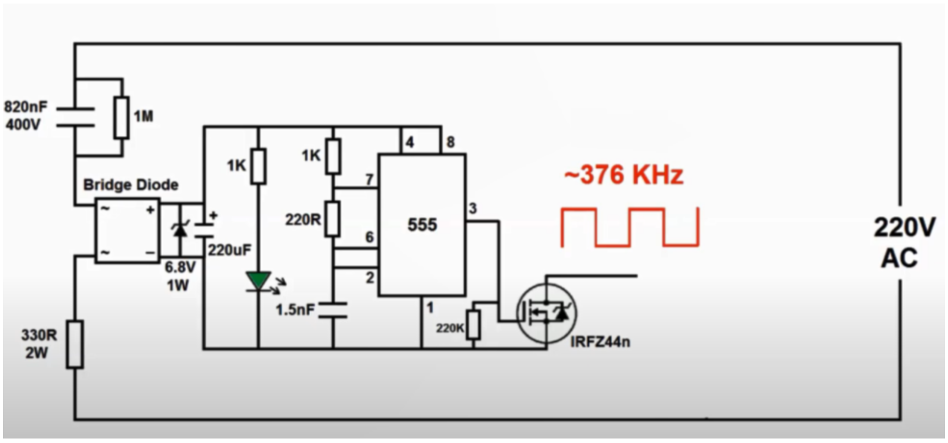

Figure 5.5 - Diagram of a 376 KHz square-angle pulse generator on NE555

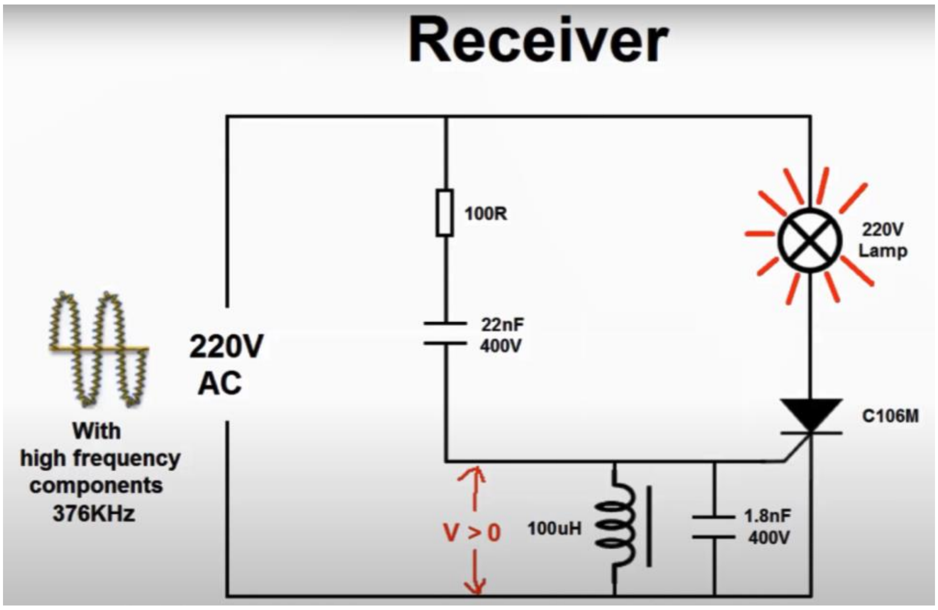

Figure 5.6 - Schematic of a 376 kHz modulated signal receiver

A 22 nF 400V capacitance serves as a high-pass filter for the control circuit of the S106M thyristor.

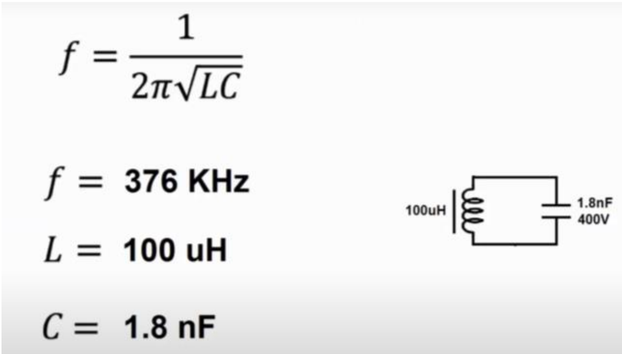

Figure 5.7 - Resonance condition in the control circuit of the C106M thyristor receiver

Figure 5.8 - External view of the transmitter board

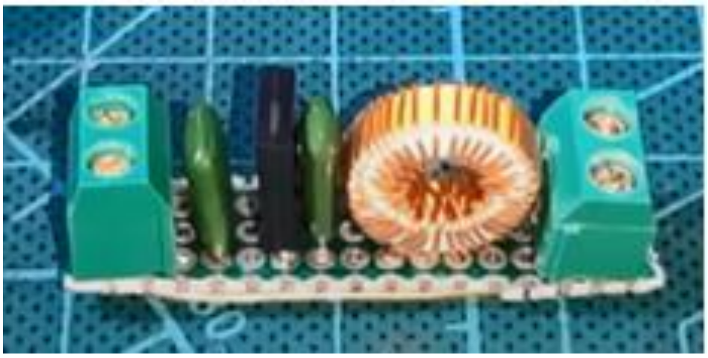

Figure 5.9 - External view of the receiver board

Figure 5.10 - View of the electronic light switch

5.2 Work order

5.2.1 Develop a model of an electronic light switch and a receiver filter with an incandescent lamp in Proteus.

5.3 Reporting

- the purpose of the work;
- model of remote switching on of the lamp by electrical wiring;
- signal diagrams at the generator output and load;
- withdrawals.

5.4 Test questions

5.4.1 How does the remote lighting circuit work?
5.4.2 Which device is a modulator?
5.4.3 What does the modulation frequency depend on?
5.4.4 What is the function of a thyristor?
5.4.5 What are the disadvantages of this scheme?

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