APPLIED ELECTRONICS, Co Ltd.

USER MANUAL

A power supply for the magnetron sputtering systems
APEL-M-5PDC

Please, carefully read this instruction before use and save it.

Contents

1. Introduction

Thank you for purchasing the power supply APEL-M-5PDC series!
Before operating, please read this operation manual carefully. The manual should then be stored for future reference in case of operating difficulties or functional descriptions.

2. Function

The power supply APEL- M-5PDC is designed for supply regulated voltage DC and pulsed current for the magnetron sputtering systems up to 5 kW which are used in the process of vacuum deposition of thin film coatings.

Operating conditions:

1) Temperature of air from a minus 10 to plus 25 ^{0}C;
2) Relative humidity of air up to 95 % at temperature plus 25 ^{0}C.

The power supply is made in a standard (19 inches) case.

Can be used in a vacuum sputtering system, as well as for scientific purposes in the study of vacuum discharges.

3. Safety precaution

Place the power supply only in closed rooms with controlled temperature and humidity.
Before turning on the power supply must be grounded through the terminal located at the back panel "⏚"

For maintenance and repairs are not allowed contact with current-carrying
elements, as on a power supply terminal block, there is an alternating voltage (200 V) and a output voltage amplitude up to 650 V.
Do not attempt to service this power supply yourself. Please refer any service to the service centre.
Be sure to turn the unit off and disconnect the AC power cord before maintaining the unit.

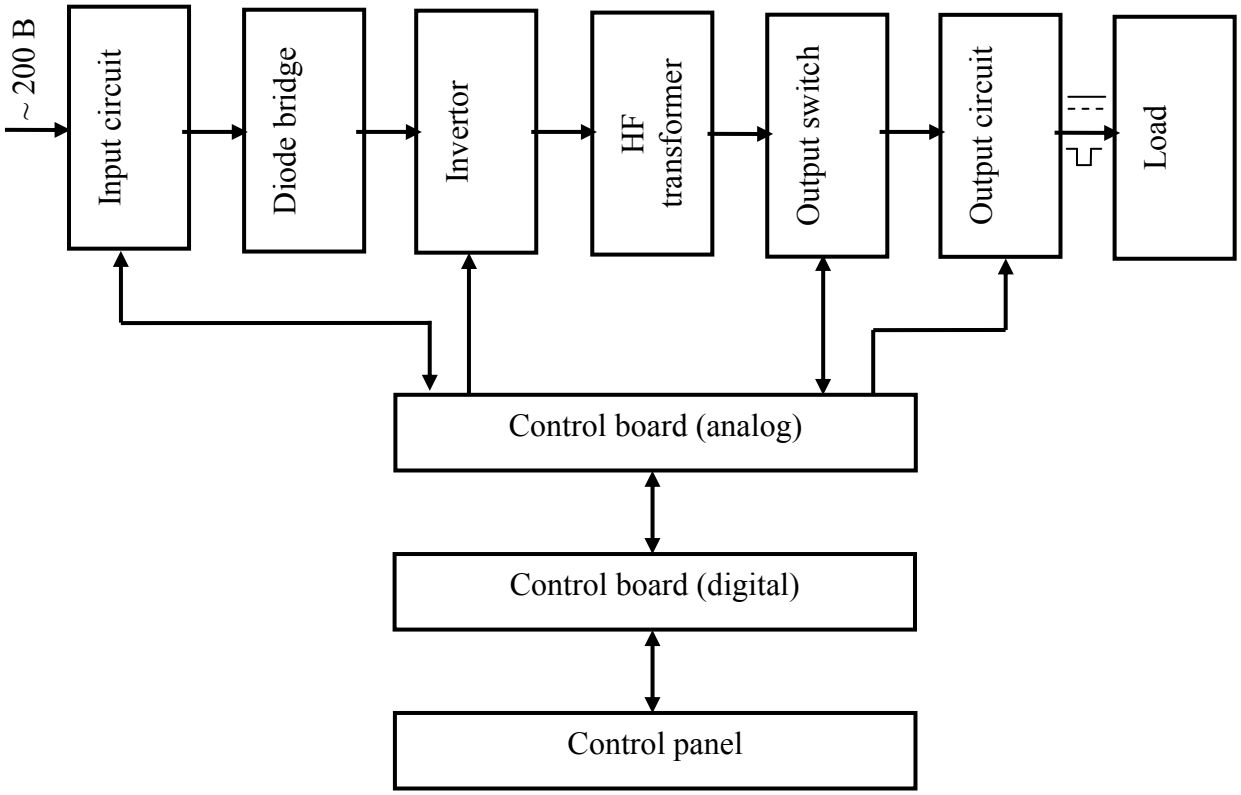
4. Package contents

A delivery set includes:

- Power supply APEL-M-5PDC;
- Connection cable for three-phase mains (3 meters)
- Output cable for the load supply (3 meters);
- User manual;
- Diagram manual.

5. Operating principle

The power supply is built according to the schematic of the resonant inverter, which converts the voltage mains frequency in regulated output voltage. This device can work in stabilizing the voltage, current, or power. response time of the arc control less that 0.5 microsecond



Pic. 1. Block-schem of APEL-M-5PDC.

Input circuit commutes 3-phase voltage on the rectifier unit, then handing power to the control units and cooling system. The inclusion consist of two steps for smooth charging the input capacitance of the inverter through a rectifier.

The inverter is a transistor bridge, which converts the DC voltage at the input capacitances to the AC sinusoidal. This voltage is passed through a resonant circuit to step-up transformer, which acts as a galvanic isolation between input and output source.

Output switch transfers energy to the output circuit, and serves to protect the power supply from short circuits, arcs, as well as to implement a pulsed mode.

The output circuit consists of 2 throttles, switching between them can change the output inductance, therefore adapting the source for the correct operating mode (continuous or pulsed).

The operation of all units controlled by the control board, which is served by Target pulse to the inverter (with a maximum frequency equal to the frequency of the resonant circuit) and the output key. In addition, this board receives and converts the feedback signal for stabilizing the voltage, current, or power and a protection signal from the output key.

The controller board gives signals to the control board, for an interactive control of the source.

6. Specification

Table 1. Performance specification for APEL- M-5PDC

Characteristic	Value
Output voltage	3x200V, 50/60 Hz
Output power	5 kW
Power consumption	5,6 kW
Output voltage adjustment range	65 - 650 V
Control range of the average output current	0,1 - 8 A
Control range of the average output power	0,5 - 5 kW
An amplitude of the ignition impulse	1000 V
Output voltage type	Negative DC or pulsed
Control range of the impulse frequency	1 - 100 kHz with step 1 kHz
Control range of the duty factor	10 - 80 % with step 1%
Stabilization mode	by voltage, current, or power
Stabilization accuracy	<5%
The amplitude of the current protection	12A in DC mode 10 A in pulsed mode
The reaction time for arcing	<0,5 microsecond
Indication	LCD display
Cooling	Air
Blocking input	Yes
Weight	20 kg
Case	4 U, 19”
Interface	RS 485

7. General guidance before use

7.1. Unpacking of power supply

For power supply unpacking it is necessary to open the top cover of a transport box, after removing steel belts from a box and to take out the power supply. The operational documentation and power cables are laid inside the transport box. After unpacking power supply to check up completeness according to section 3. By external survey to be convinced of absence of defects and breakages.

At repeated packing PS together with power cables and the operational documentation are packed into a polyethylene film and are located in a transport box. Amortizing materials in a transport box are pads and supplementary sheets from goffered cardboard or foam.

7.2. Installation procedure

It is necessary to make external survey:

- Completeness according to section 3;
- Absence of visible mechanical damages;
- Presence and durability of fastening of control systems;
- Cleanliness of sockets, connectors and plugs.

7.3. Setting-up procedures

Before you begin, carefully examine the technical description and operating instructions, as well as get acquainted with the location and purpose of management and control on the front and rear of the unit. Then to place the power supply at the desk and providing conditions for the natural ventilation.
Set "Network" switch on the back and switch on the front panel to the bottom position. Set grounding on the device and connect AC 3-phase output cables.

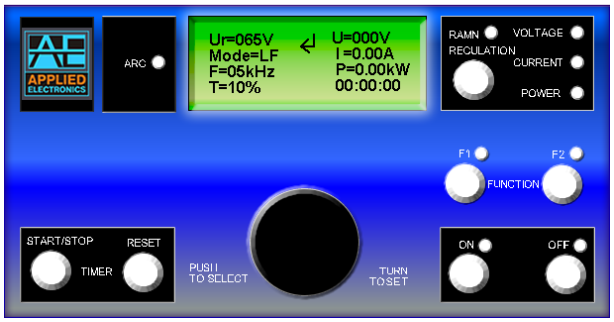
Note: a terminal “+” is connected with the ground inside a case of the power supply.

8. Operating procedure

8.1. Start-up procedures

Automatic main switch and power switch set at the up position, it’s should light up the LCD display and LEDs on the front. Set using encoder the options and modes.
By REGULATION button choose a stabilization mode of voltage, current, or power

8.2. Arrangement and appointment of control and adjustment



Pic. 2 Power supply control panel

Control panel buttons function

	Output voltage, on and off buttons:
"ON"	After pressing the button On, output voltage is applied
"OFF"	After pressing the button Off, output voltage is removed
	Timer control buttons
"TIMER START/STOP"	Start/stop timer
"TIMER RESET"	Timer reset
	Other buttons:
"F1"	Switch synchronization mode
"F2"	Not used
"REGULATION "	Chose a stabilization mode: by power, current, or voltage

Note: Activation of the button, take place after release
*(*pressing followed by a LED indicator and a single sound signal*).*

LED indication

"ARC"	Arc defense LED. Lights when the magnetron discharge passes at an arc shape, or the current exceeds the maximum value of the magnetron
"RAMP"	Indicator of compliance with the current value of voltage, current, or power setpoint. If the indicator blinks, the discrepancy exceeds 10%, which indicates the failure mode in chamber. For example, you set the mode at stabilization current value of 6A, but this current is not achieved at the maximum output voltage (1000V).
	LED of the chosen stabilization mode
"VOLTAGE"	Voltage
"CURRENT"	Current
"POWER"	Power

Encoder operarion

Encoder - control knob for changing the output power source parameters

Rotation	Decrease / increase the selected parameter
Pressing	Choosing a variable parameters

8.3. Information in LCD display

Pic.3 LCD display at the work mode, impulse (right) and DC mode (left)

Information on the LCD display in impulse (left) and DC (right) modes

Information about the state of the power supply is reflected in two columns by 4 rows. The left column is information about the set parameters of power source in the right column - information about current settings.

Symbol Description		Symbol Description
Ur, (Ir, Pr)=000 V A setting of the stabilized parameter, for changing turn the encoder. Depending on the selected mode of stabilization is reflected a setpoint voltage (Ur), current (Ir), or power (Pr)		**U=000 V** Current value of the output voltage
Mode= LF (DC) Indicator of the working mode: pulse mode with a low frequency or DC mode, for changing turn the encoder. If the power supply is in work a regime change is not possible	↵	**I =0.00 A** Current value of the output current In pulse mode is a value of an average current
F=00 kHz A setting of the impulse repeat frequency in the pulse mode, for changing turn the encoder. If the power supply is in work a frequency change is also possible. In DC mode is not available.		**P=0.00 kW** Current value of the output power. In pulse mode is a value of an average power
T=00% Duty cycle, for changing turn the encoder. If the power supply is in work a duty cycle change is also possible. In DC mode is not available.		**00:00 (min:sec)** Timer
The cursor indicates the parameter that will vary with the rotation of the encoder. Moves by pressing the encoder.		

8.4. Sockets and slots arrangement

Pic. 4 Power supply back panel

An appointment of the installation connectors and terminals

POWER	Automatic power switch
A B C	Terminals for the mains (AC 3-phase)
N	Neutral
"+ –"	Terminals for the load
RS-485	Connectors of remote control and blocking contacts (connected in parallel)
⏚	Grounding

8.5. Power supply in use

The power supply control can be performed locally or a from remote control via RS-485.

9. Design

Power supply APEL-M-5PDC is design as a separate portable unit. Elements of the unit's body are held together with screws.

Partial disassembly:

- Unscrew 4 screws on the top cover unit;
- Remove a bottom cover if it needs
- Assembly in the reverse order

10. Circuit scheme description

10.1 Force diagram description (Annex B)

The power supply is connected to the 3-phase network through an automatic switch A1. When switching button A4 closes contactor K1, turn the electric supply on, block A5, which feeds the fans, control board and the controller. The input capacitance of the inverter A7 begins to charge through a resistors R1 and R2 . Then from the control board comes impulse to a drivers contactor A3, which switch on a contactor K2. Resistors are shorted and the inverter is fed full voltage through a rectifier A2. Resistor R3 is connected via contactor K1 on a normally closed contact. R3 is a discharge resistor for the capacitance of the inverter.

Inductance L1 and the input capacitance of the inverter input is a surge filter.

The inverter is a transistor bridge, which converts the DC voltage at the input capacitances to the alternating sinusoidal (inverter circuit in Appendix 2.1). Each part of the inverter is controlled by 2-channel driver, A14 and A15 (Annex 2.2).

Transformer TR1 performs the function of electrical isolation, but also increases the input voltage to the required level. Choke L4-inductance of the resonant circuit.

Output switch A17 (Annex 2.3) transfers energy to the output circuit, and serves to protect the power supply from short circuits and to implement a pulsed mode. Management by driver output switch A16(Annex 2.4).

The output circuit consists of 2 chokes L2 and L3, switching between them can change the output inductor, thereby adapting the source for the correct operating mode (continuous or pulsed). Switching occurs downstream contactor K3, which is controlled by the driver A12(Annex 2.5).

The work of all blocks controlled by the control board A8, which gives a target pulse to the inverter (with a maximum frequency equal to the frequency of the resonant circuit) and the output switch. In addition, this board receives and converts the feedback signal for the stabilization of voltage and current. And a protection signal from the output switch to suspend an operation of the inverter.

Analogue controller A9 generates signals to digital controller, providing interactive control with the remote A11 (raising output parameters, switching modes of operation) and carries the indication.

10.2 Control logic and drivers description (Annex C)

Voltage stabilization schematic:

Voltage divider is installed at the output capacity, which serves as a voltage sensor. From low-resistance part of the voltage divider is taking off a voltage(1 - 10V), and is put on the connector XT9. Next is a divider arrangement for fine-tuning the signal from the sensor voltage. DA1, O1, DA5 consists of 2 operational amplifiers (op amp), which function as input and output buffers for the opto-coupler O1(following the documentation requirements for IL300). O1 is a linear optocoupler, the input voltage is equal at its output. Optocoupler is needed for galvanic isolation of circuit control board and power schemes. Microcircuits power supply is galvanically isolated.

The output signal of the sensor voltage DA5 follows on the operational amplifier DA2, and on the controller board to convert and display as an values of output voltage through a repeater DA6. If the level will exceed 10 V, the comparator DA11 will put "0" input circuits DD6: 2, which turns off the inverter control. At the input of the comparator 2, the reference voltage 10V is formed by resistor R13, at the input 3 a resistor R29 is setting to exceed 10V. DA2 has 2 inputs: 2 output signal from the DA5, to pin 3 signal from the controller board. The signal from the controller board is a setting (a constant voltage -10V). DA2 converts both signal Vout = (U2-U1) x Koc, where U2 -setting, U1 - signal from the voltage sensor, Koc - coefficient. of feedback. If U2 <(=) U1, Vout is reset to 0. Koc is given by nominal resistance R2 (100k, which corresponds to Koc = 10). A time constant of the feedback (~ 10ms) is determined by the capacitor C1. A voltage reference diode at the output is set for the limiting an output voltage to 10V.

DA2 output goes to analog switch DA3, which is managed by a board of control, which works like a normal key. DA2 output goes to analog switch DA3, which is managed by a board of control, which works like a normal key. If pin 1 will be put "0" - this means that pins 2 and 3 are closed (according to the selected mode).

From DA3 signal is applied to the converter voltage-frequency DA8,which in the presence of voltage at the input generates a square wave.
If the input voltage increases - increases the output pulse frequency to the maximum, which is set by the clock.

The clock generator is a multivibrator, built on a 3-logic elements"2NAND" DD9 :1-9: 3. A frequency range is selected by the resistor R32 and capacitor C30. Resistor R33 adjusted the frequency (200 kHz).

At the output of is a trigger DA8 DD3: 2, which serves to disable the inverter control: pin 1 connector XT17. Through the intermediate cascades required for other parts of the scheme, which will be described below, includes a trigger DD3: 2. If the trigger input 2 DD3:2 set to "0", it means that its output will be a constant "0". An integrated circuit "2I" DD4:1 will expose the constant "0" on the output - this means a ban on the passage of impulses from the DA8.

Gate multivibrator DD1:1 is located after DD4:1. At the output of 5 and 12 are always "0" and "1", respectively. It is included so that at the input 9 by changing from "1" to "0" - 5 is formed at the output of a single pulse of "0" to "1", the output 12 of the "1" to "0" duration determined by the RC - chain of C16, R53 (~ 6us). The output of the gate multivibrator is connected to the trigger DD3: 1, which switches between an inverter control channels (O3-O6, O4-O5). The maximum operating

frequency of the inverter is determined by the half-frequency clock generator. Control arranged through the optocouplers O3-O6

Current stabilization schematic:

1. Stabilize the current scheme is similar to the voltage stabilization circuit.

For the current stabilization standard current probe is used, which is powered from the control board by bipolar ± 15V and provides an output DC voltage of 1 -10V to connector XT13. Next is a divider R20, R27 for fine-tuning the signal from the sensor voltage. Immediately after the divider signal via repeater DA10 displayed on the controller board.

Then the signal applied to the operational amplifier DA4, which has 2 inputs. The second output signal from the current sensor goes to pin 3 with the controller board. The signal from the controller board is a setting (a constant voltage - 10V). DA4 converts both signals on the basis of Vout = (U2-U1) x Koc, where U2 - setting, U1 - the signal from the voltage sensor, Koc - coefficient. of feedback.

If U2 <(=) U1, Uout is reset to 0, otherwise it is a formula. Koc is set by nominal resistance R21 (100k, which corresponds to Koc = 10). A capacitor C4 is determined by the time constant of the feedback. Stabilitron at the output is set to limit the output voltage to 10V.

Similarly, stabilization scheme for voltage from the output DA4 , signal applied to the voltage-frequency converter via analog switch, which is included in the current stabilization mode.

Power stabilization schematic:

- the multiplier DA7 fed signals from the sensors voltage and current, where they multiply and get "feedback signal power." Further, the same modes of stabilization of current and voltage at the input of the operational amplifier is fed DA9 setting for power and signal from the multiplier.

Output switch control:

The control is performed by signals from the controller board: depending on the mode of the source (continuous or pulsed) through the connector XT15. Signals have logical form (DC mode - fixed signal amplitude 5V, LF mode pulse sequence with a given frequency and duty cycle). Through intermediate stages, and served optocoupler plug XT10 and then on the switch driver.

Power supply protection:

When driver output key protection is activated on the connector XT12 comes with a driver signal "fault". At the output of the optocoupler O10 find a permanently logical "1", and when ignited the optocoupler LED is reset to "0". This signal goes to the monostable DD8: 2, which includes the decay of the input 1 is included at the time determined by R9 and C27. This time - the time intervals between tripping of protection, it adjusts to the desired value resistor R9 (2-3ms).

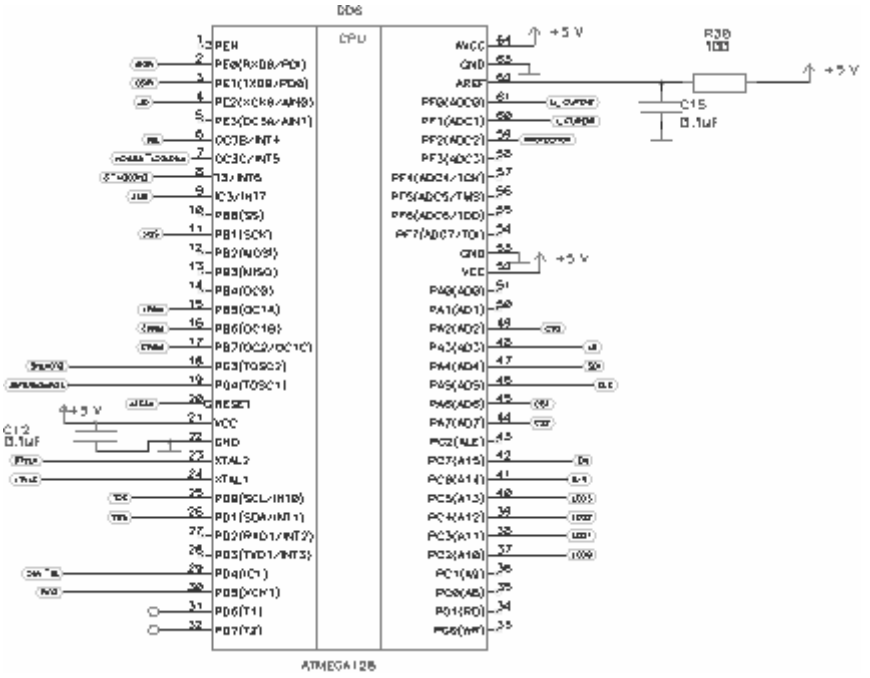
Monostable generates the outputs of 13 and 4, "1" and "0", respectively. The signal from the output 4 goes to the input of DD2:2, which breaks the chain of key management, and therefore stops the work, as well as DD7: 3, which stops the inverter. The outputsignal 13 goes to the controller board to display the current protection on the panel display and resets the current set point, exposing the "1" at pin 16 DA3 (in the case of mode stabilization by current).

Other:

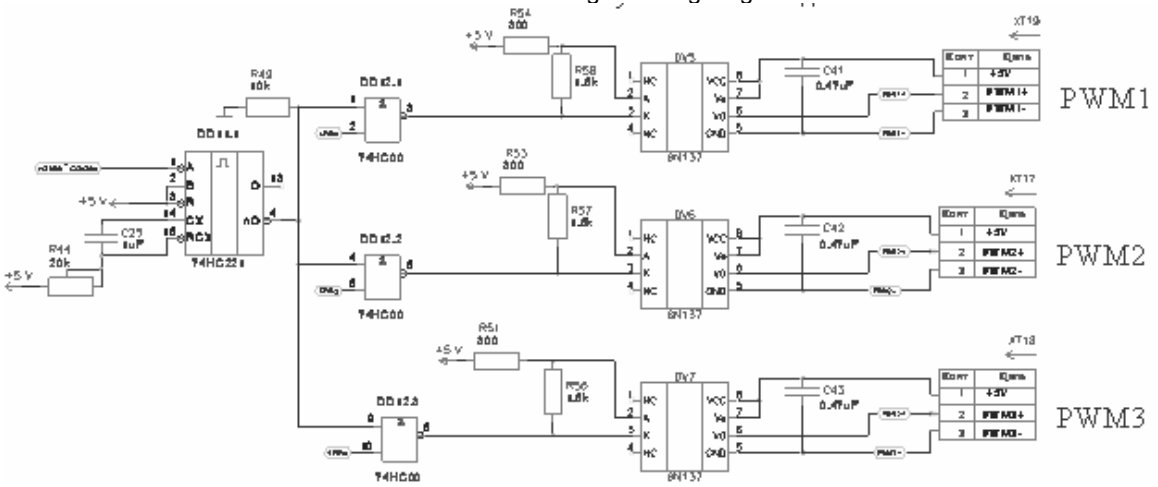
The scheme was built DD1: 2 is used to test the inverter control circuit phase adjustment. To do this, jumper J2. And closing the findings J1 generate one-time control pulses. DD6: 1 is used for generating control pulse to activate the contactor through time 1s after power source.

10.3 Controller scheme description

Controller schematic is in the annex 4.



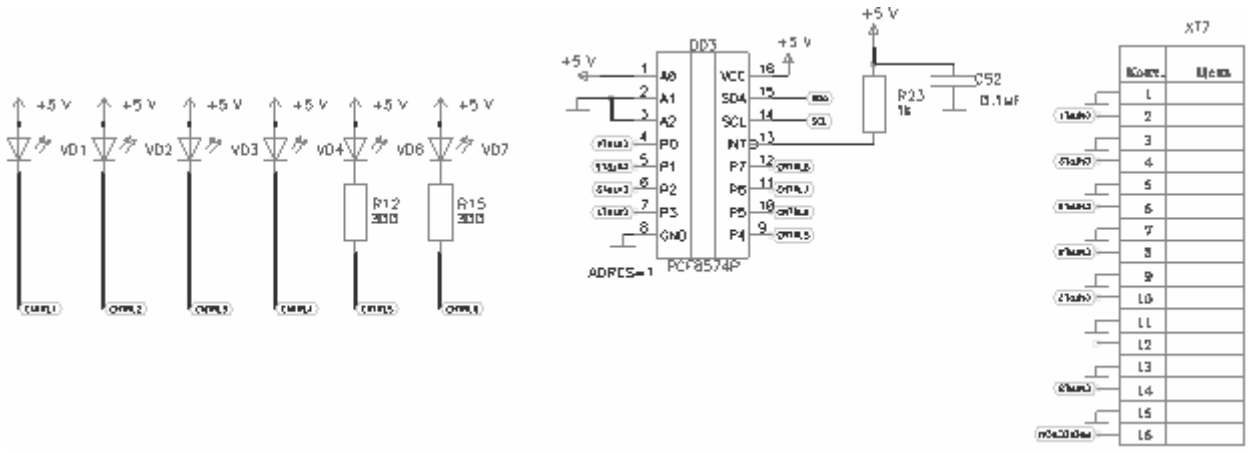
Pic. 5 Microcontroller Atmega128. Signal generation:



Pic. 6 Scheme of control signals formation for output switch

Forming of the output switch control signals making by the chipCD74HC221E.
At the inputs R and B is always 1, the output pulse occurs at the transition from 1 to 0 on the input A.
In the absence of signal PROTECT_SWITCH, formed an impulse low duration of about 10 ms. Control signals are generated by the key of these pulses and the control signal (PWM1) to the microcontroller, which receives the input of the chip 74HC00.
The received signals are sent to the input circuits 6N137 for their separation.

An outputs of the digital socket:



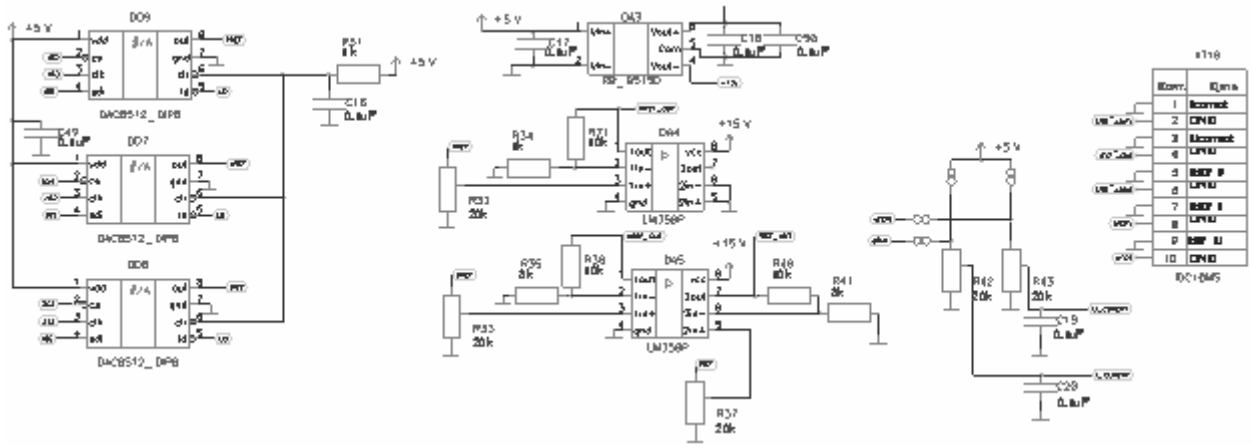
Pic. 7 The chain of reference voltage

Reference voltage:

- reference voltage transferred from the microcontroller to the DAC. Then the voltage is amplified and fed to the input of the control board (Uref, Iref).

Output meterage of current and voltage:

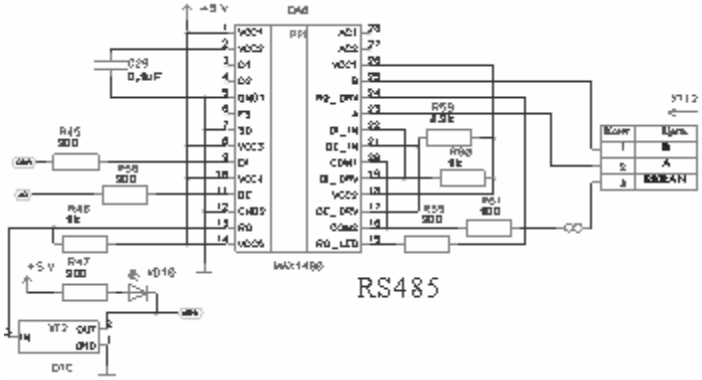
- from the control board receives two signals from current and voltage sensors (Ucur, Icur). Which are served through dividers to the controller and displayed on the LCD.



Pic. 8 Scheme of reference voltages formation and receiving voltage and current data

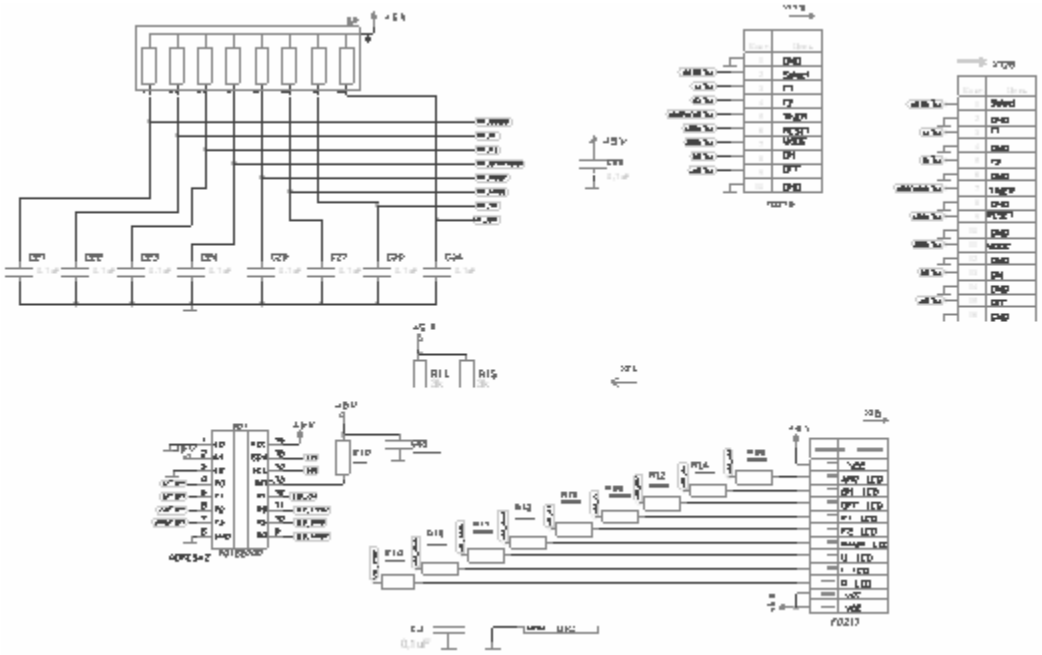
Power supply control:

- source control and data transfer to PC via RS-485 interface by using chip MAX1480.



Pic. 9 The scheme of organization and management (interface RS485)

Circuits mode is determined by state input and control signals. Outputs A and B of a chip included by setting 1. If outputs are enabled, the device acts as a transmitter. If on the contrary, then the receiver.
Survey of button on the front panel implement by the controller through an expander.
Each button is accompanied by sound signals



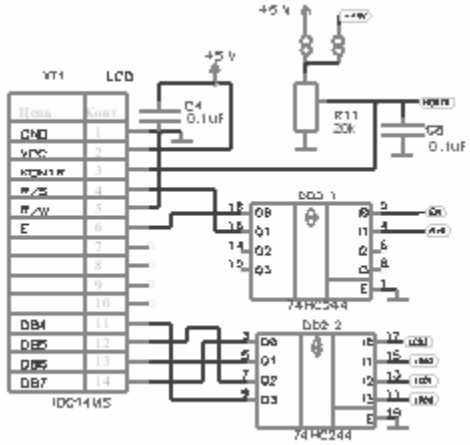
Pic. 10 Wiring diagram for control panel buttons, encoders and buzzer

The source control is implemented by encoder rotation, which changes supports the current, voltage or power, and switch an operation modes of the source (pulsed and DC).

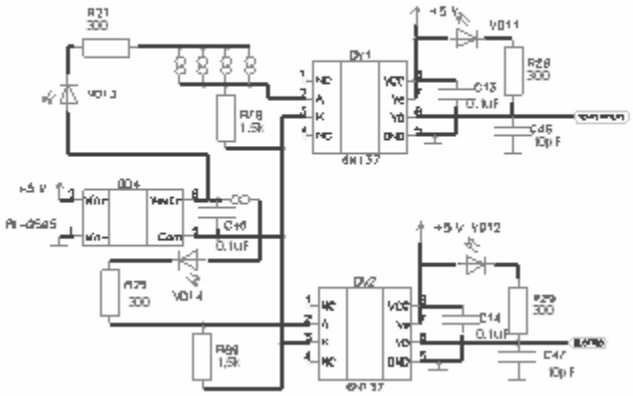
Current Data on LCD:

- Data transfer via the LCD chip 74HC244.

Blocking:

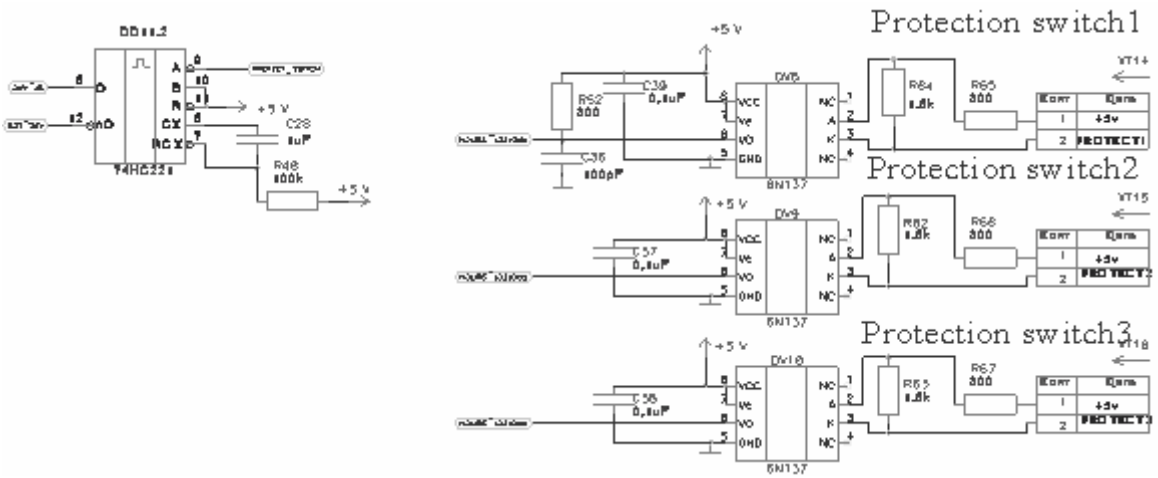


Pic. 11 Wiring diagram of the LCD display



Pic. 12 Scheme of blocking arrangement

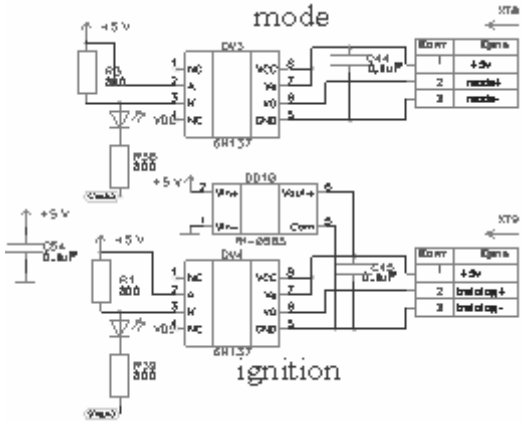
Blocking is required to interrupt operation of the source in case of emergency situations related to termination of water supply to the magnetron, hot items, etc. This is determined by internal or external additional sensors. The sensors are working in switching mode and activated when the gap shorted. A signal at the input by the optocouple transmitted to microcontroller, which turns off the source.



Pic. 13 Button connection schematic

When activated the arc protection from the control board, the stop signal arrives to the output switch. At the output of the optocoupler is formed the "0" signal with a result that a one-shot circuit is triggered. Which generates two signals: one goes to the panel display (LED is lit «arc»), the other on the microcontroller (stops the output key to time determined by the monostable).

An ignition and the output switch



Pic. 14 An ignition control schematic

The controller generates ignition control pulses (30ms with a pause of 1s), which run through the optocoupler to ignition.
An inductance is changed by the output switch with switching modes (impulse or DC)
A control impulse is given by the controller through the optocoupler to the output switch driver.

11. Troubleshooting

Do not attempt to service this power supply yourself. Please refer any service to the service centre.

Be sure to turn the unit off and disconnect the AC power cord before maintaining the unit.
Most possible problems and instructions for their removal are shown in the tabl. 2

Table 2. Most possible problems and instructions for their removal

Problem	**Possible reason**	**Suggested Solution**
LCD display works incorrect or didn't work	Interference induction	Check case grounding
Power supply works only in DC mode (output voltage in impulse mode is similar DC mode)	Fault of output switch transistor	Replace output switch transistor
There is no flick when the power supply switchs in impulse mode.	1) Contactor's driver works incorrect 2) Open circuit	1) Needs to check and repair a drivers board 2) Search the open circuit

12. Maintenance

Maintenance works are should be at least 1 time a year. For the maintenance of a device during term of its operation needs to include following works:
a) External survey of the device condition;

1. Check a fastening of control and adjustment units
2. Check a completeness of the device;
3. Check a condition of paint and galvanic coverings;

b) To survey an internal state of an assembly and a components is carried out after the warranty period. A fastening of the units, remove a dirt and corrosion.

Note: The dust from the power supply is recommended to remove by the household vacuum cleaner.

13. Storage regulation

The power supply, arrived to the customer for long storage, contains in the transportation box in capital heated premises with the temperature of air from 5 to 300C at relative humidity up to 85 %. In premises for storage there should not be a dust, steams of acids and alkalis, causing corrosion. At commissioning it is necessary to release the device from packing and to put in normal conditions within not less than one hour.

14. Transportation

Transportation of the power supply to the consumer in transport container can be carried out by all types of transport without acceptance of additional measures at the temperature of air from minus 50 to plus 500C.

In the process of transportation the protection of the device against falling, atmospheric precipitation and dust should be provided. It is not supposed racking and turning over the device.

15. Guarantee maintenance

The manufacturer guarantees that the product APEL-M-5PDC conform to requirements of technical documentation. follow all terms and rules of operation described in this manual.

Guarantee period 2 years after shipping.

This limited warranty covers manufacturing defects in materials and workmanship encountered in normal, and shall not apply to the following, including, but not limited to: damage which occurs in shipment; delivery and installation; applications and uses for which this
product was not intended.

Annex A. Interface controller RS485

Using RS 485 interface is possible to control the power supply from PC. Synchronization is available only on the bottom connector.
Assigning RS 485 connector pin:

Pin	Designation	Function
1	A	Receive
2	B	Transmit
3	GND	Ground
4	Blocking+	Blocking+
5	Blocking -	Blocking -
6	Synch. out -	Synch. out -
7	Synch. out +	Synch. out +
8	Synch. in -	Synch. in -
9	Synch. in +	Synch. in +

Table 1. Coupling parameters

Element			Control object
Interface			RS-485
Rate of exchange			19200 BPS
Protocol			Modified ModBus RTU
Digit capacity			8-Bit binary-number system
Method of interaction			Half-duplex
Communication parameters	Symbol table		No
	Number of stop bits		2
	Data format		8
	Mode of inspection	Parity check	No
		Formatting check	No
		Checksum	Always available - CRC

Push OFF button and turn on power supply to check the port address. If necessary, you can change the actual port address using encoder. For the saving a new address push OFF button one more time.
The power supply is controlled by remote PC with modified Modbus RTU protocol. Actual protocol using two function F3 and F6, power supply address on default equal 1.

Table 2. F3 function

Data	Address Slave(1)	Function(3)	Numbers of registers	Upper byte CRC	Lower byte CRC
Byte number	1	2	3	4	5

F3 function can be read in the following form:

Table 3. Inquiry answer (F3 function)

Data	Address (Master)	Function (3)	Numbers of registers	Upper byte Ucur	Lower byte Ucur
Byte number	1	2	3	4	5

Upper byte Icur	Lower byte Icur	Register LED	Register STATUS	Upper byte CRC	Lower Byte CRC
6	7	8 (tabl. 4)	9(tabl. 5)	10	11

Note: Function F3 can be readied in 15 ms after last operation.

Table 4. Register LED

Byte number	Value
0	LED on, current stabilization
1	LED on, voltage stabilization
2	Output LED on “stand by” (Ramp)
3	Not used (F2)
4	LED, power supply ON
5	LED, power supply OFF
6	LED, synchronization ON
7	LED on, stabilization by power

Note: LED is glow if byte value is equal zero.

Таблица 5. Register STATUS

Byte number	Value
0	Run mode 0-DC mode 1-HF mode
1	Not used
2	Not used
3	Locking 0-OFF 1-ON
4	Not used
5	Not used
6	Not used
7	Not used

The power supply controller works correctly if:
1 Port address is correctly defined
2 Checksum is correctly defined
3 Working address is 255

The power supply parameters realize by F6 function

Table 6. F6 function

Data	**Address (Master)**	**Function (6)**	**Register address (Upper byte)**		**Register address (Lower byte)**
Byte number	1	2	3		4 (табл. 7)
Data	**Upper register**	**Lower register**	**Register (always zero)**	**Upper byte CRC**	**Lower byte CRC**
Byte number	5	6	7	8	9

An equivalence between register address (lower byte) and register value is in the next table.

Table 7. An equivalence between register address (lower byte) and register value

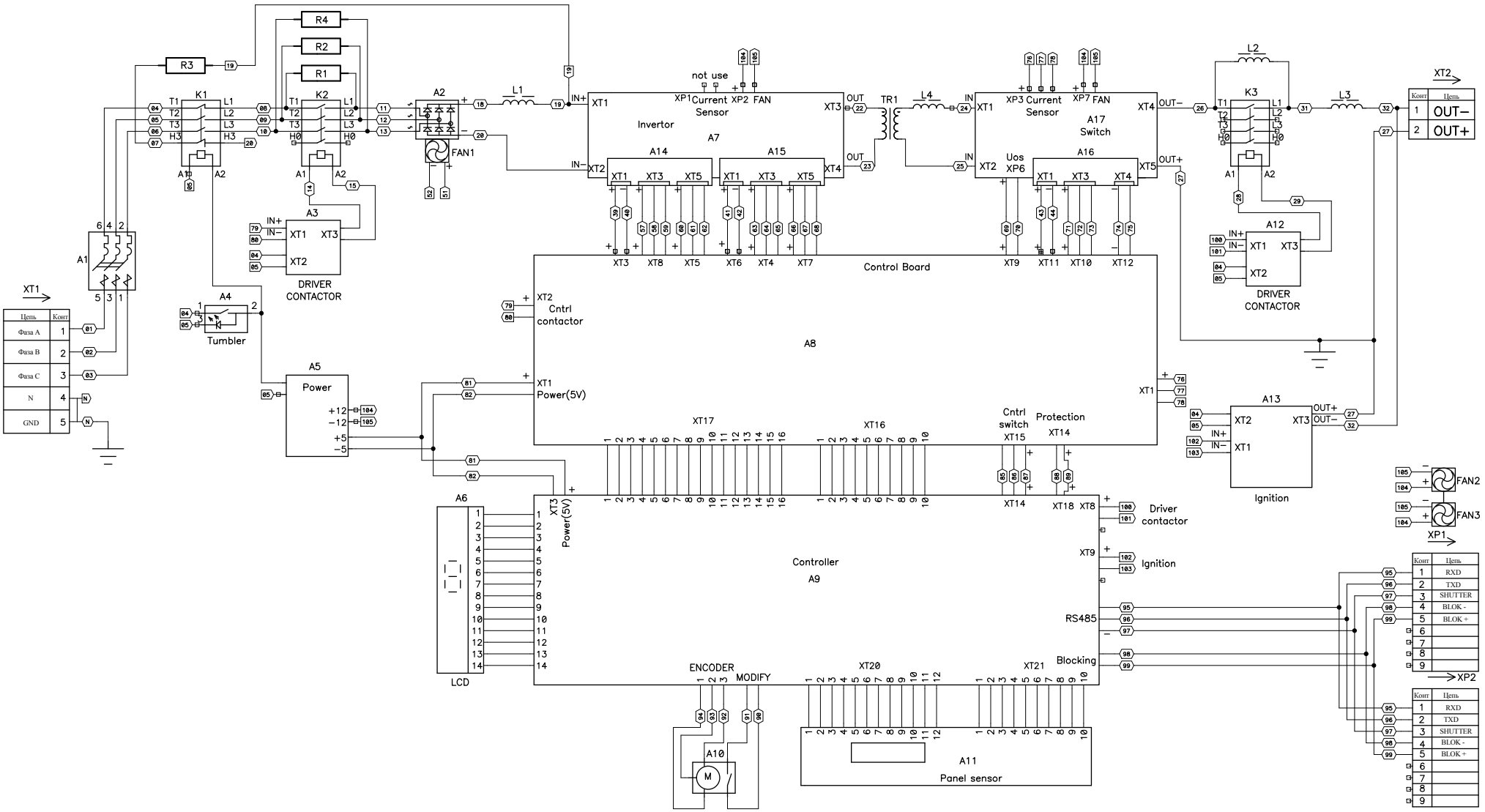
Data	**Equivalence**
0	Not used
1	Register status (quantized input) 0- ON 1- OFF 2- Not used 3- Reset the timer 4- HF mode 5- Synchronization mode is turning off 6- Synchronization mode is turning on 7- DC mode
2	Register mode switcher 0- voltage stabilization 1- current stabilization 2- stabilization by power
3	Setting value (voltage) 100 ..650 (100-650 V)
4	Setting value (current) 10..80 (1.. 8A)
5	Setting value (Power) (5..50) (0.5..5 kWt)
6	Setting value (frequency) 1..50 (1..50kHz)
7	Setting value (time of the impulse) 10..80 (10..80%)

Checksum function complies with ModBus RTU standart.
An example calculation is given below:

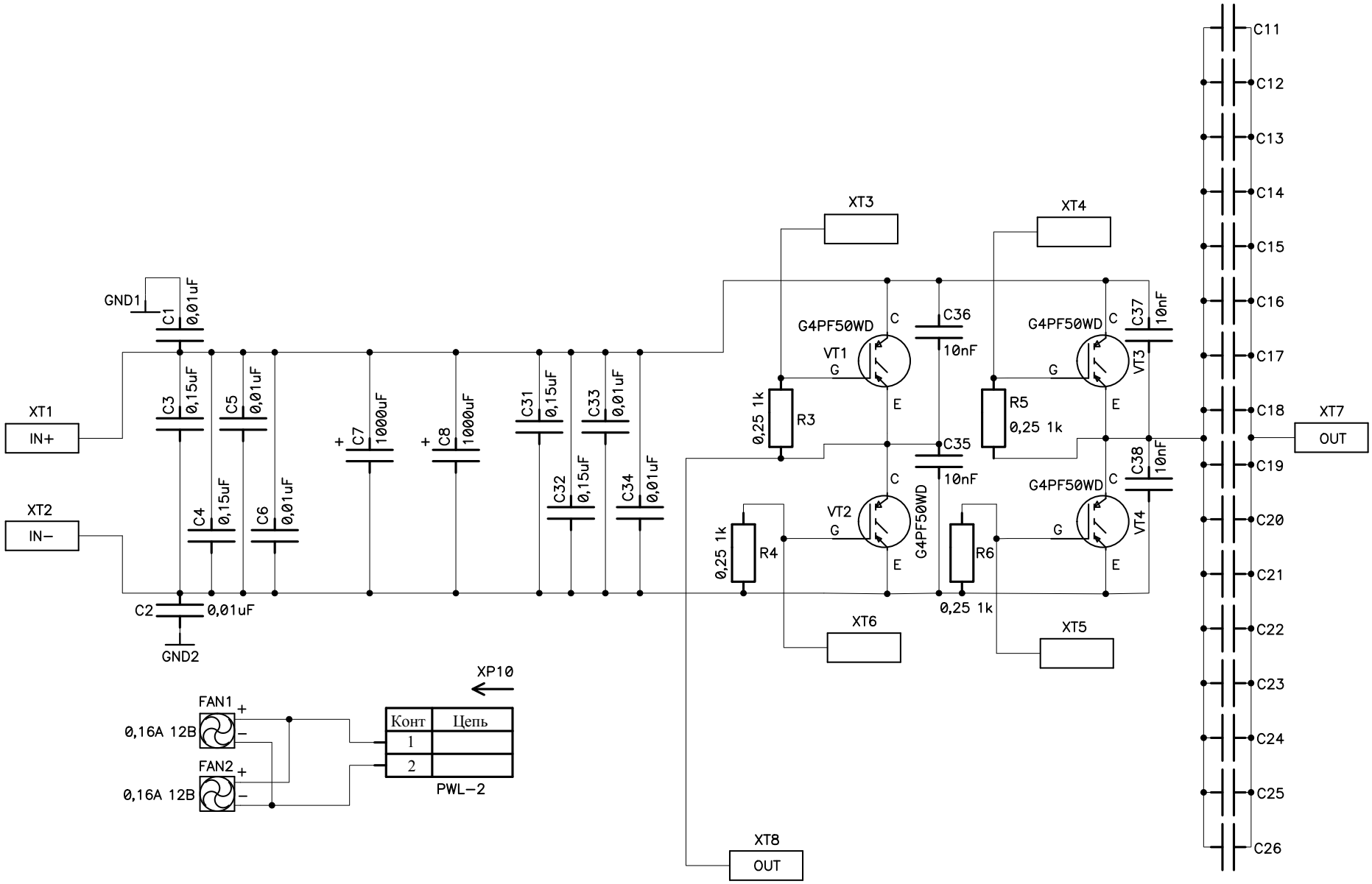
```
// CRC - cyclic redundance check – only in RTU mode
unsigned int mbfCRC(int cnt,unsigned char volatile * buf)
{
      int     i,j;
      unsigned f;
mbCRC  = 0xFFFF;
for (i = 0; i<cnt; i++)
        {
        mbCRC  = mbCRC ^ buf[i];
        for (j = 1; j <= 8; j++)
                {
                f = mbCRC & 0x0001;
```

```
                mbCRC = mbCRC >> 1;
                if (f) mbCRC = mbCRC ^ 0xA001;
            }
        }
f= mbCRC >> 8;                                  //**     Reverse byte order.
mbCRC = (mbCRC << 8) | f;
return(mbCRC);
```

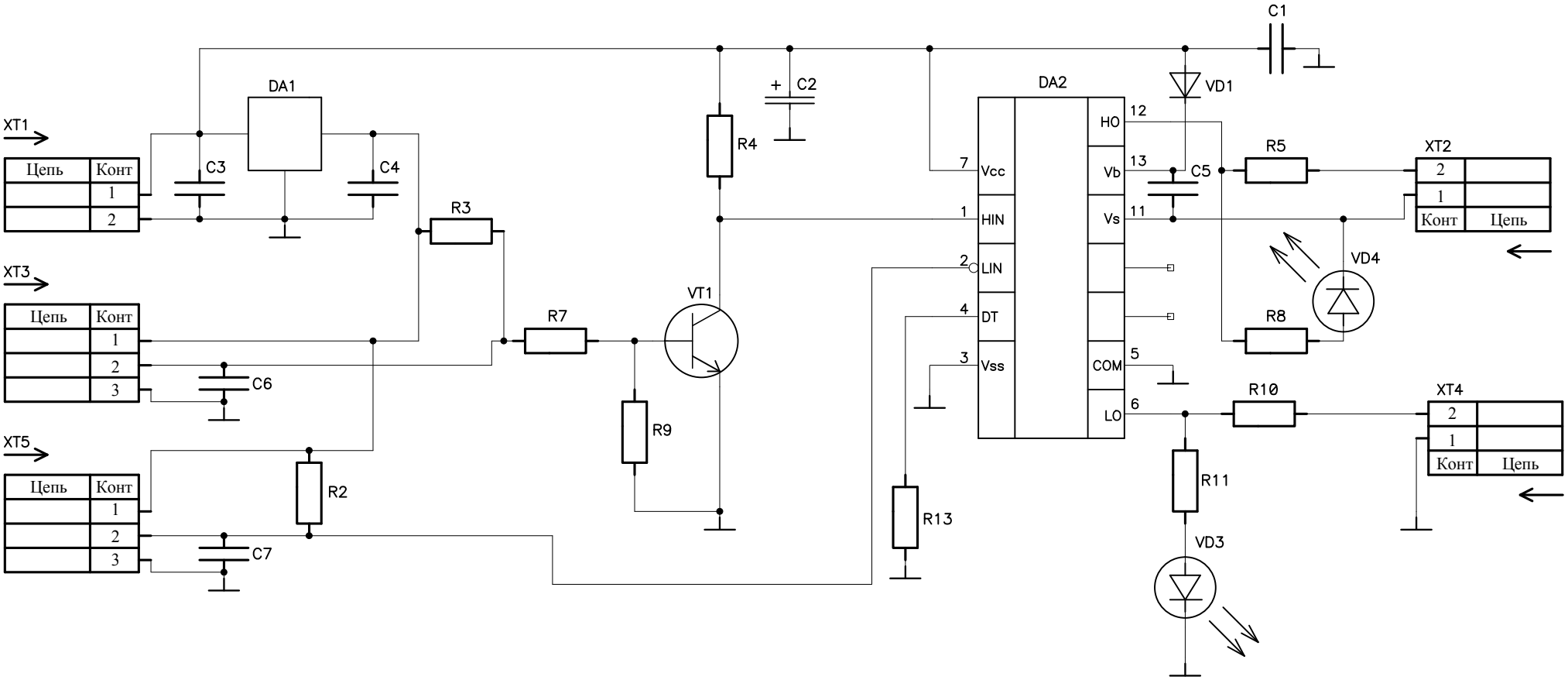
Annex B. Force diagram



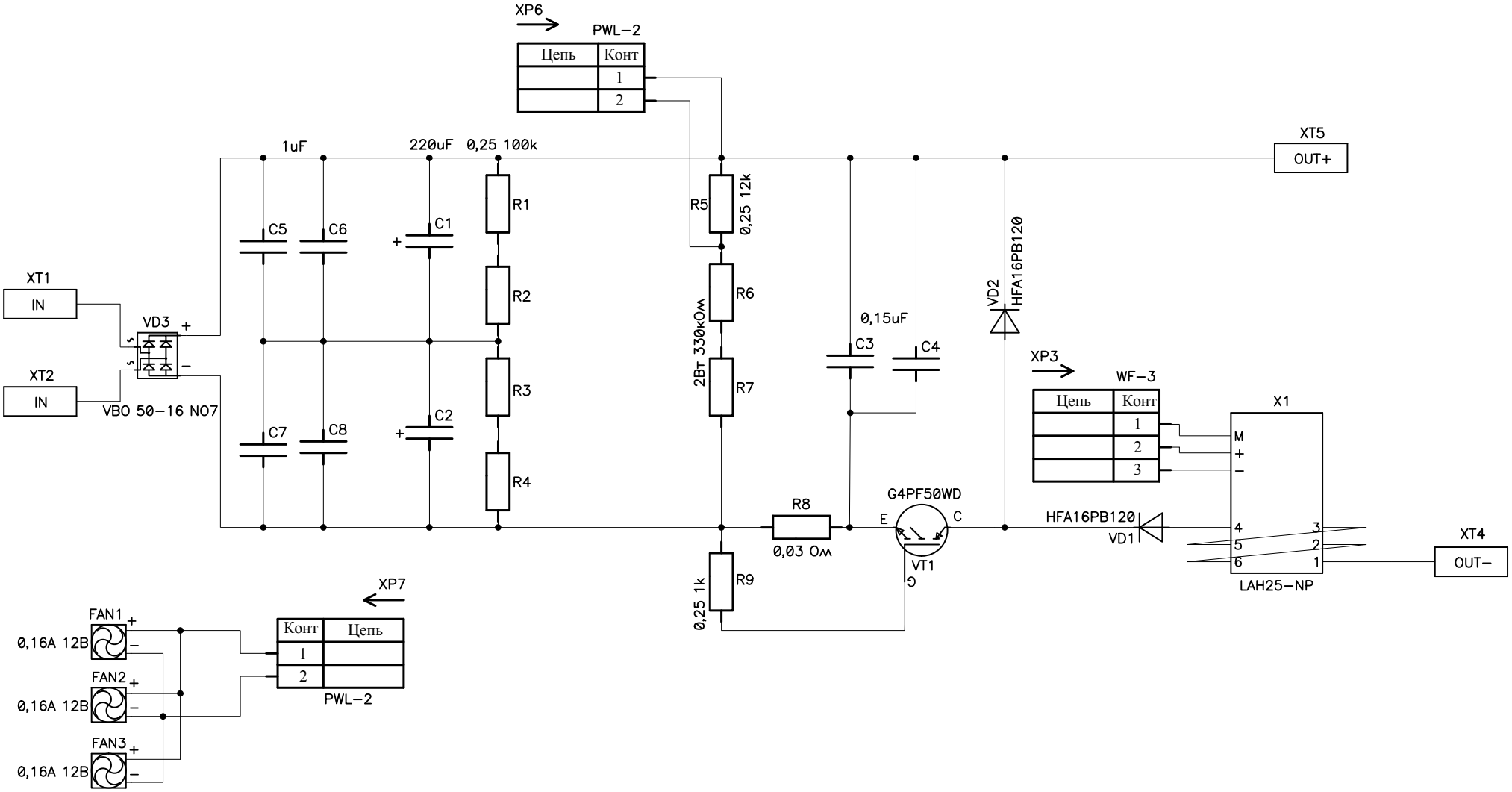
Annex C. Inverter schematic



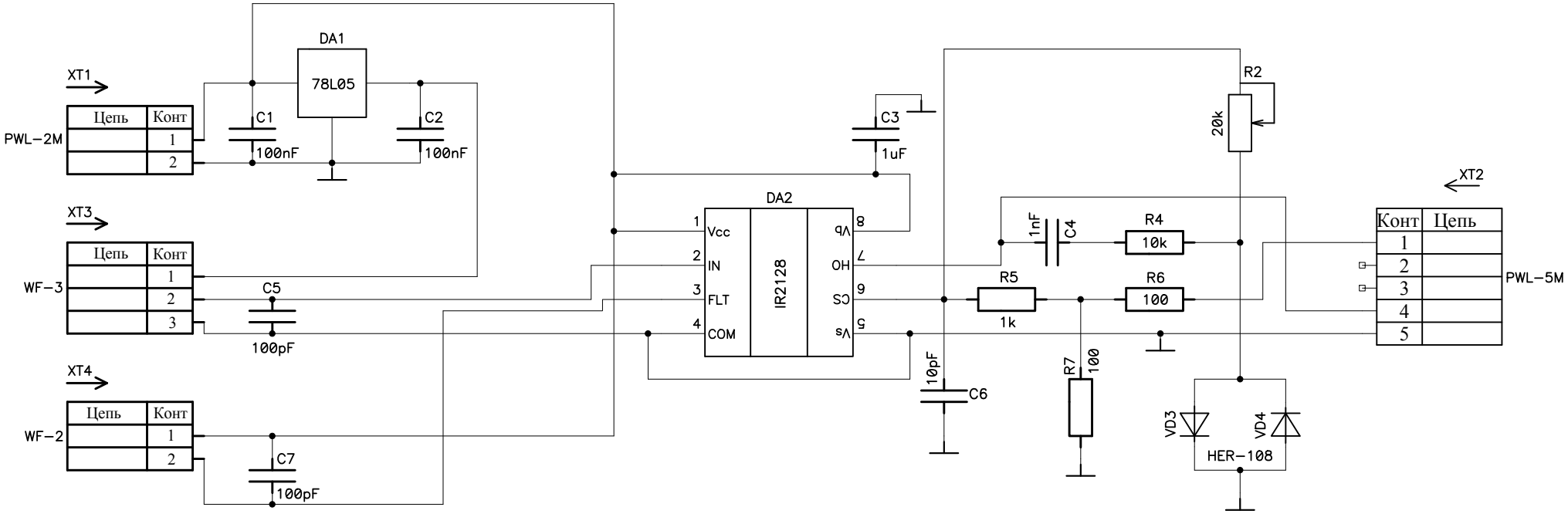
Annex D. Inverter driver



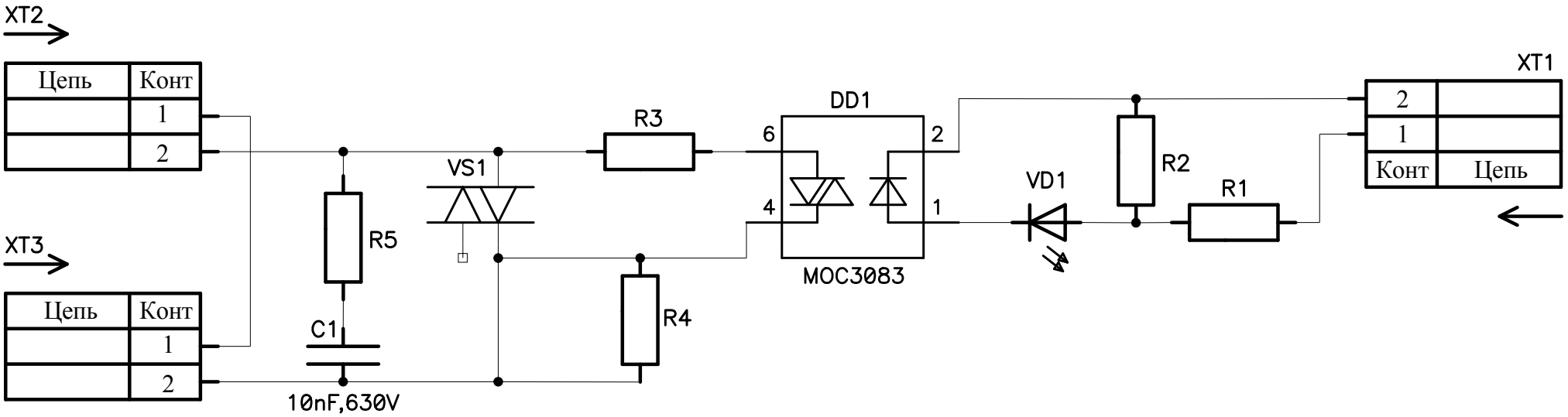
Annex E. Output switch schematic



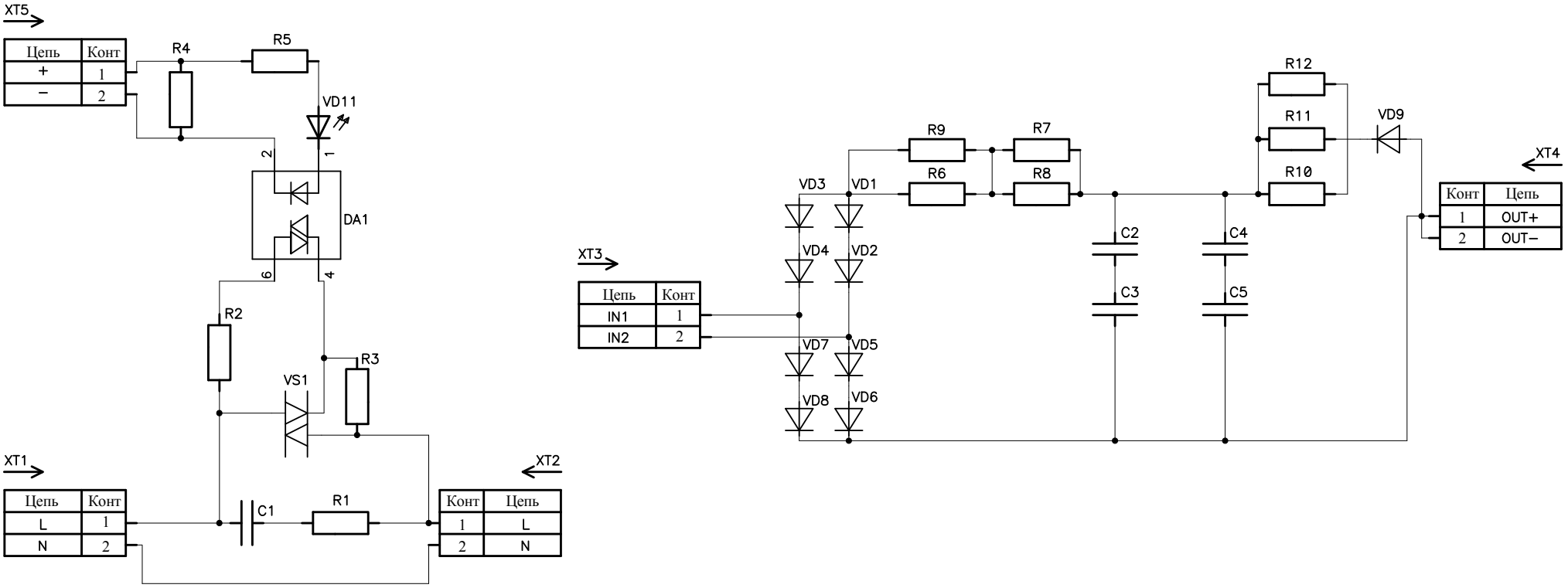
Annex F. Output switch driver



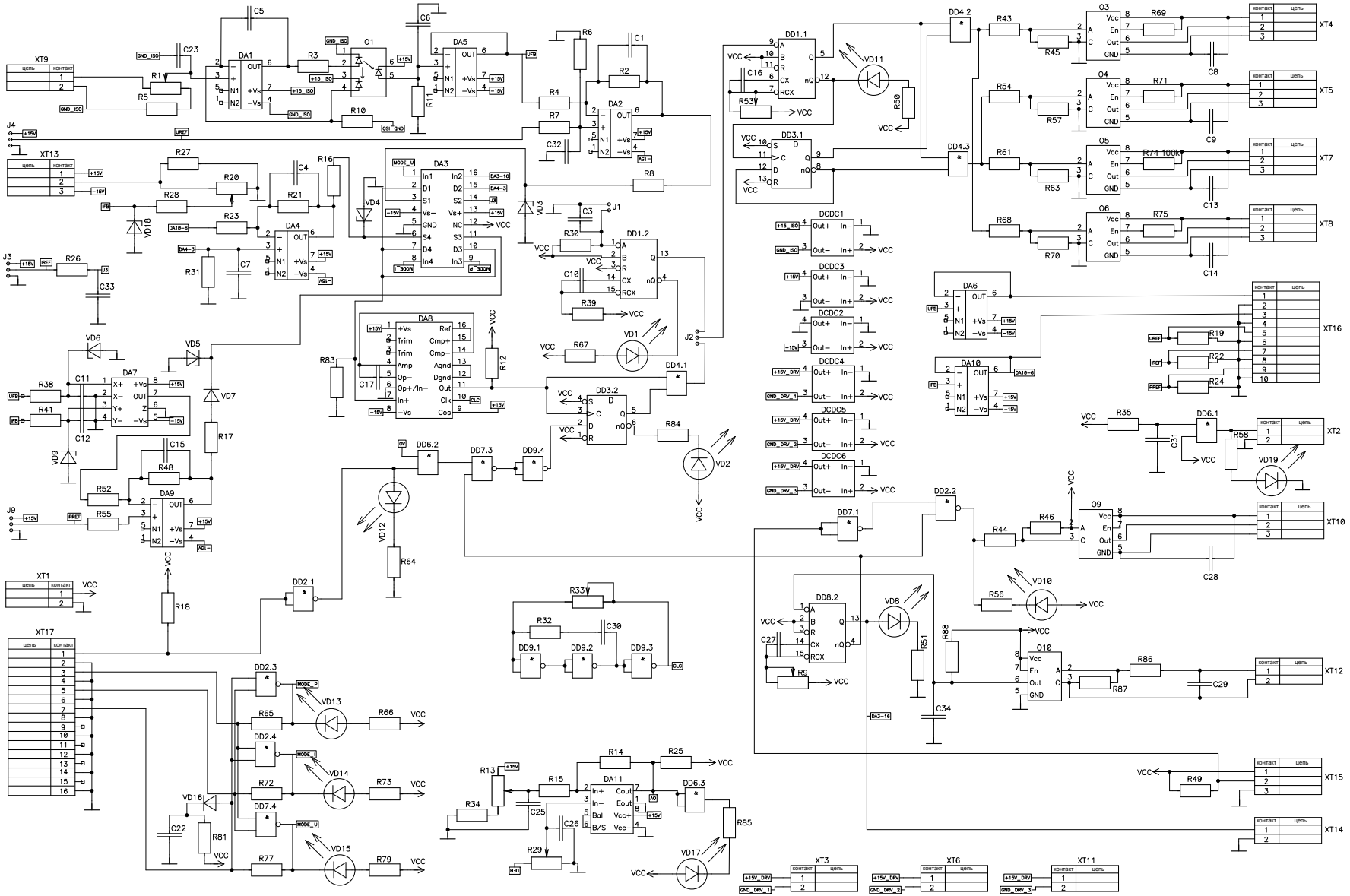
Annex G. Contactor's driver



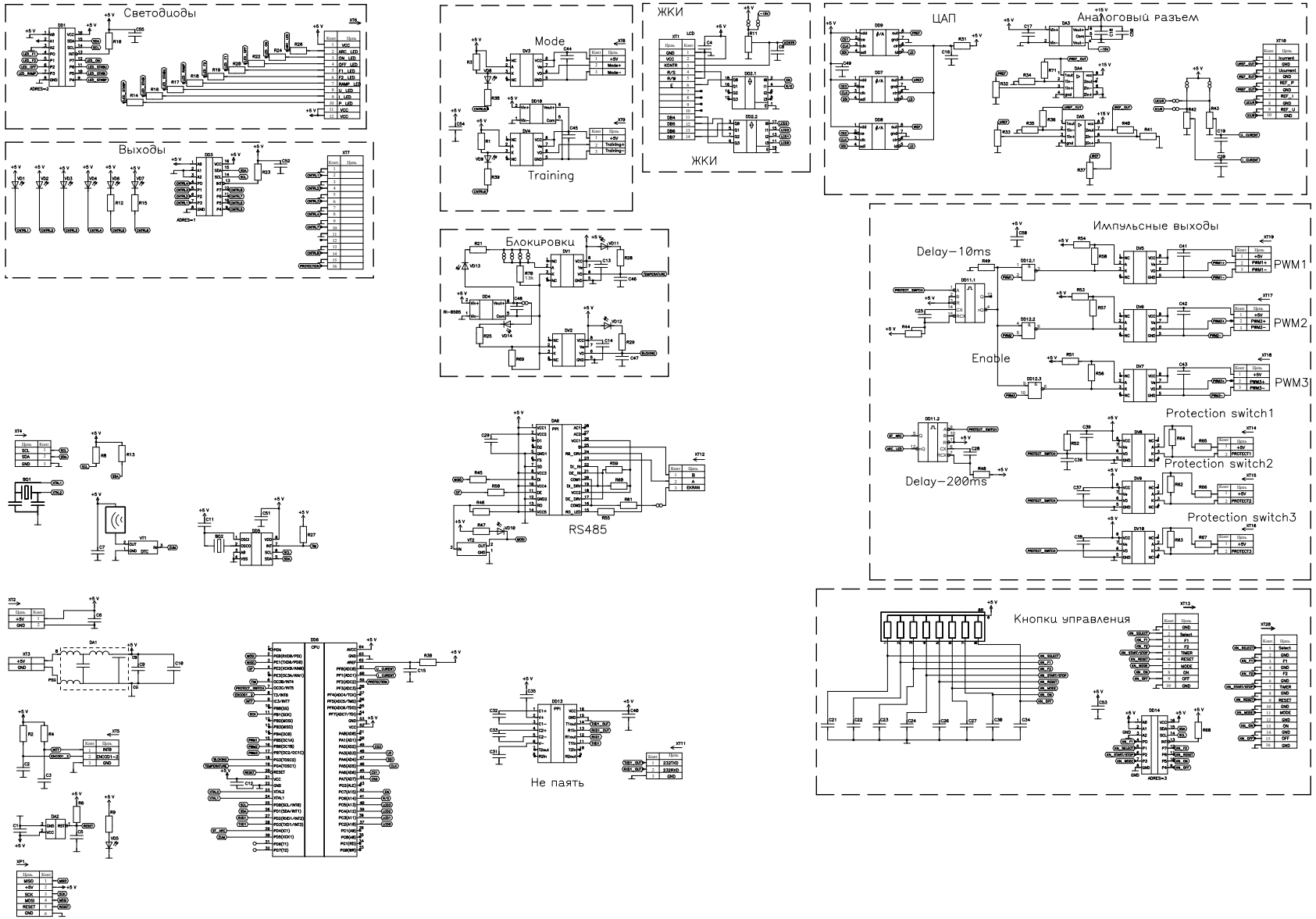
Annex H Ignition board schematic



Annex I. Analog controller schematic



Annex J. Digital controller schematic



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