

RESEARCH BENCH FOR ELECTRICAL MACHINES

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Abstract. Research bench was developed for electrical machine tests basically in generator mode. It consists of two parts. The first part holds the drive DC motor, researched machine and DC motor drive module, the second part holds the measurement panel, voltage and current transformer block and load rheostats. While the drive motor runs the researchable machine, the measurement panel displays the amounts of four physical values: voltage, current, frequency and temperature. The main developments within this bench are: DC motor drive, which is single phase controlled rectifier; frequency counter and frequency counter based RMS voltmeter. The IC MC14553BCP is used as 3-decade counter/driver/multiplexer which is the simplification key in frequency counter circuits. As RMS detector in voltmeters IC LTC1966 is used, which gives low cost and high precision performance. The measurement transformer block allows measuring the voltage and current in three phases just by switching the phase selector.

Keywords: controlled rectifier, frequency counter, voltage-to-frequency converter, AC/DC converter.

Introduction

In the research center work with its target to discover some innovative construction features of brushless DC machines was introduced. Towards the bench the following demands were introduced:

- to provide variable speed drive of the researched machine;
- to provide machine loading with three phase resistive variable load;
- to provide direct reading of current, voltage, temperature and frequency measurements.

The constructive basis of the bench is a specially designed two part table which is made of 15 mm laminated chipboard. The first part contains both electrical machines: brushed DC motor Π-41M and the researched machine. The first part also contains variable speed drive – single phase controlled rectifier. The second part contains Digital multimeter and brushed DC motor control elements in one panel. The task for the authors of the paper was to design the electrical part of the research bench which can be described as sum of the following functional units (Figure 1):

- brushed DC motor;
- variable speed drive;
- current and voltage transformer block;
- digital multimeter and control panel (MAC panel);
- power circuit relay commutator;
- load rheostats.

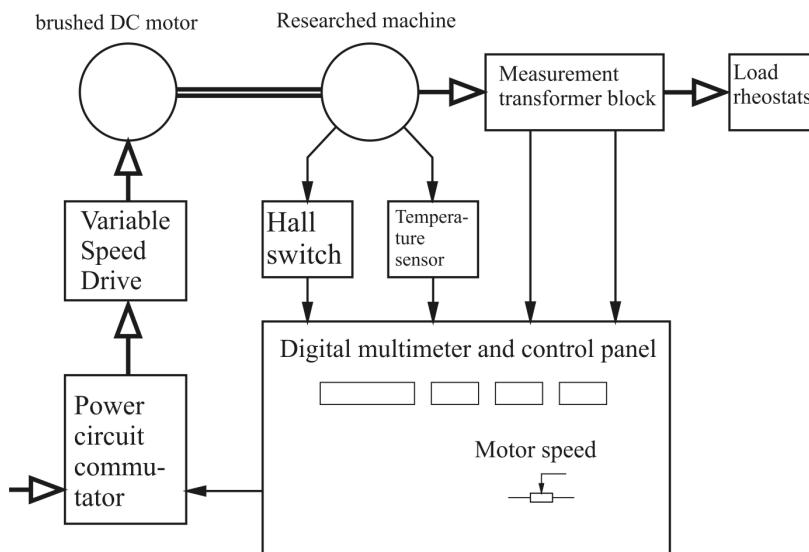


Fig. 1. Block diagram of bench electrical part

Brushed DC motor

Brushed DC: Π-41M with the following parameters serves as the driving motor for the research bench:

- rated power: 3.9 kW;
- rated voltage: 220 V;
- rated current: 23.2 A;
- rated speed: 1500 RPM;
- field circuit type: compound;
- mass: 84 kg.

According to the data book [1] the closest model to Π-41M by the parameters is Π-42Υ4 which has the efficiency 74 % at compound field circuit connection. The efficiency changes are small while the speed remains in range between 1500 RPM and 3400 RPM. This motor allows also shunt and series field circuit connections.

For stable rotation speed there should be shunt field circuit, but easy power metering is possible using compound field circuit.

Variable speed drive

Variable speed drive in this case is the single phase controlled rectifier. Its control circuit generates trigger pulses for thyristors according to

DC control voltage at input. DC control voltage is delivered through a cable from the potentiometer which is built into the digital multimeter and motor control panel (MAC panel). Circuit schematic of variable speed drive is given in Figure 2 but schematic of its control circuit is given in Figure 3.

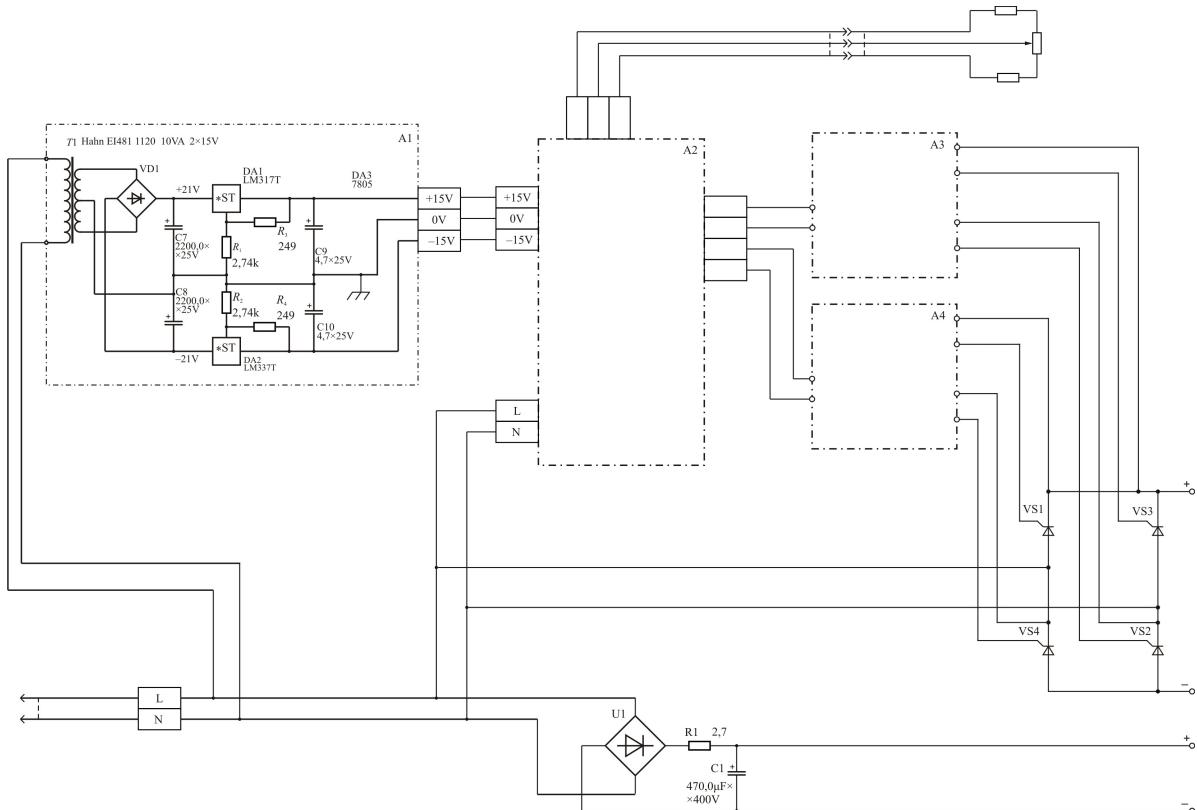


Fig. 2. Full circuit schematic of variable speed drive

In the control circuit board classical analogue structure is used [2] – one channel contains triggering pulse former DA4, VT3, voltage comparator DA3, externally excitable saw tooth voltage generator DA2, VT1 and a unit of grid synchronization DA1. Pulses from the triggering pulse former are delivered to pulse transformer boards A3 and A4. The pulse transformer serves as insulator

between the control and power circuit. Maximal voltage at the rectifiers output is reached when the input voltage is 5 V but minimal voltage at rectifiers output is reached when the input voltage is 10 V.

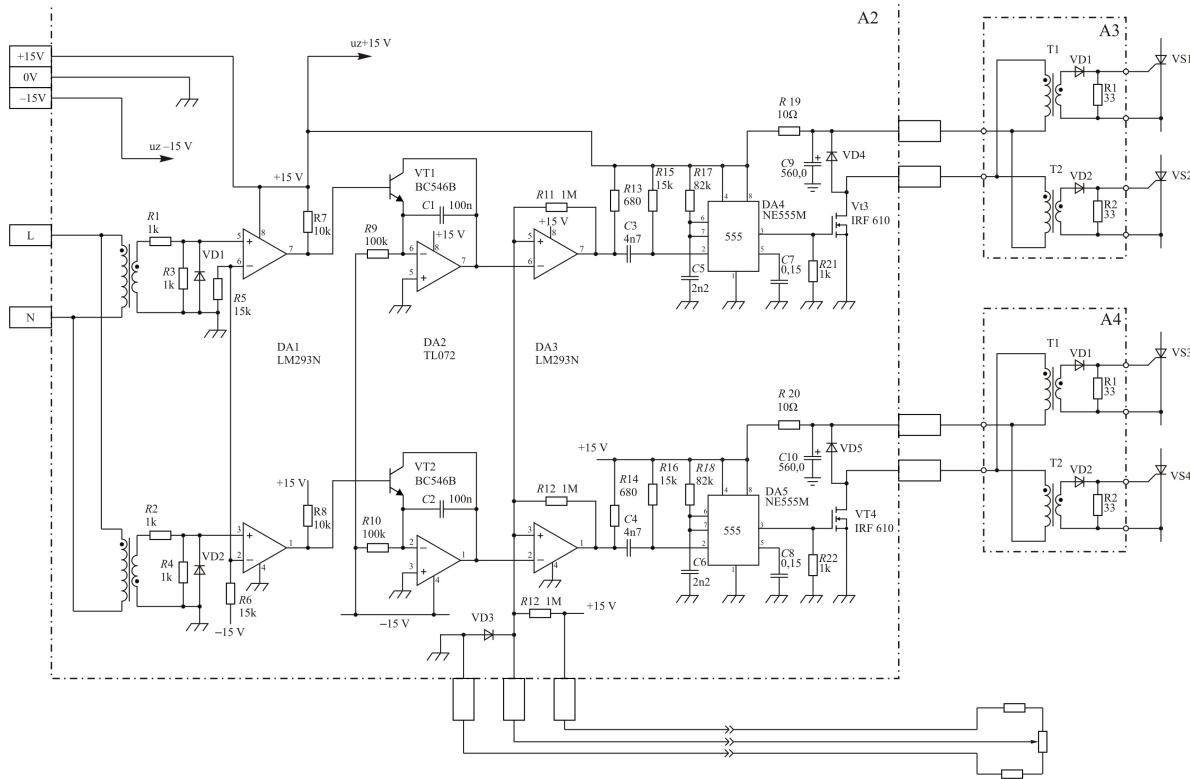


Fig. 3. Circuit schematic of controller board of Variable speed drive

The field circuit supply channel is formed from a bridge rectifier connected directly to AC 230 V grid and from filter R1C1 at the rectifiers output. The voltage at the capacitor C1 with some load is about 300 V. That is why a field circuit rheostat with at least 36Ω resistance is necessary for the given brushed DC motor operation.

Instrument transformer block

This transformer block was made for measurement circuit insulation and for current and voltage scale conversion. Its circuit schematic is given in Figure 4.

For current measurement 5 toroidal laminated iron core transformers are used: three of them convert phase currents, one converts zero-sequence current (phase vector sum), one measures current in the neutral wire. The two last mentioned occurred less useful than the first three, so they are not depicted schematically.

The primary winding contains one turn (for toroidal core one turn is just straight wire going through toroid hole without bending over). The secondary winding is formed from 50 turns and it is loaded with $0.51 \Omega \pm 1\%$, 1W shunt resistor. As a result we get 1 V @ 50 A.

As voltage transformers three 0.5 VA power supply transformers with 230 V/9 V rated winding voltages are used. Outputs of these transformers are calibrated by using three adjustable voltage dividers, each divider has two independently adjustable outputs. The lower output has the resulting conversion ratio 1 V @ 1000 V, upper output – 1 V @ 100V.

Digital multimeter and brushed DC motor control panel (MAC panel)

1. Introduction. The digital multimeter and brushed DC motor control panel (MAC panel) are in fact serving as Human-Machine Interface for this bench. It gives direct reading of four measured values: current, voltage, frequency and temperature. MAC panel also contains a variable speed drive control voltage potentiometer and relay commutators on/off switch.

As numerical displays red color LED 7-segment displays are used. MAC panel contains the following units:

- four frequency counters;
- three voltage-to-frequency converters;
- two AC/DC converters (IC LM331);
- reference clock generator (IC LTC1966);
- frequency counter controller circuit (IC CD4521BE);
- phase selector, voltage range selector, “hold” switch;
- motor speed potentiometer and on-off switch.

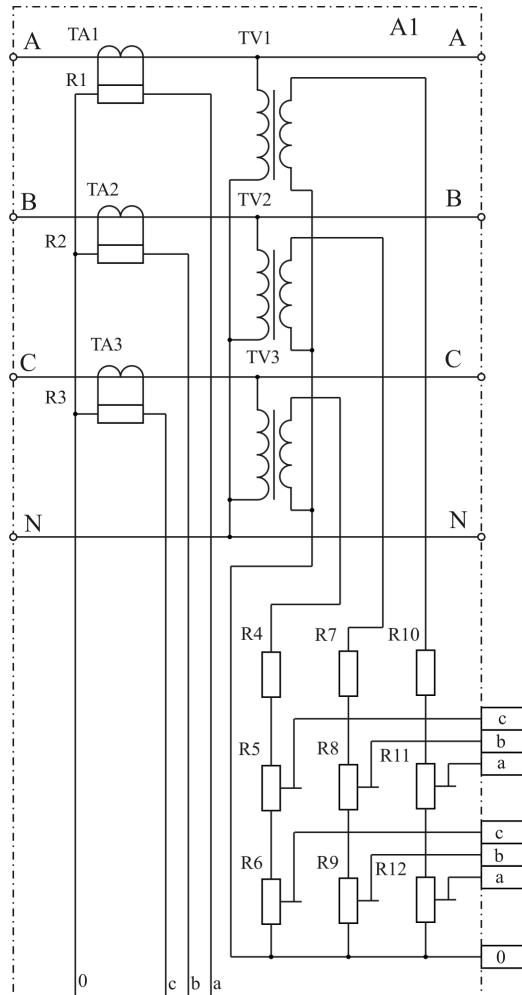


Fig. 4. Circuit schematic of instrument transformer block

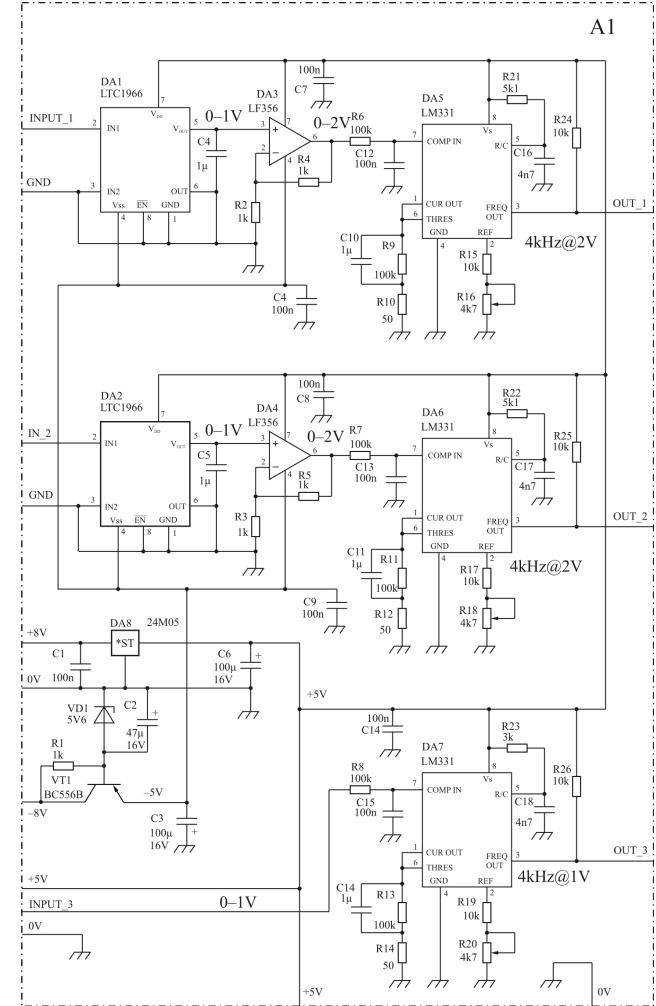


Fig. 5. Circuit schematic of VAC converter board

The multimeter functional units are distributed on 4 circuit boards. Beside them there is an external power supply module, which converts AC 230V into splitted ± 8 V voltage.

The MAC panel functional units are distributed on circuit boards in the following order:

- VAC measurement converter board A1 (ICs LM331 and LTC1966);
- Reference clock and controller board A2 (ICs CD4521BE and 74HCT132);
- VAC display board A3 (voltmeter, ammeter and thermometer displays ICs 74HCT4511N, MC14553BCP and 74LS02);
- Frequency counter board A4 (ICs 74HCT4511N, MC14553BCP and 74HCT132).

The digital multimeter and brushed DC motor control panel is the most complex part of the research bench due to the multimeter construction features. The multimeter complex construction in the authors' opinion is justified by the following factors:

- The total cost of electronic components is lower than the comparable complex of four commercial multimeters (each commercial multimeter uses only one range in the same time);
- Commercial multimeters are not suited for mounting on common closed panels;
- Most of the low cost multimeters have no TRUE RMS measurement function.

2. VAC converter board. AC voltages which are proportional to the current in the measured circuit are delivered to VAC converter board A1 (Figure 5) from the current and voltage transformer block.

Those low level AC voltages are converted into proportional DC voltages by using ICs DA1 and DA2 (LTC1966). Those DC voltages are delivered to voltage-to-frequency converters DA5, DA6 (LM331). Pulses generated at outputs of these converters are delivered to appropriate inputs of VAC display board. IC LTC1966 is described in reference [3], but IC LM331 is described in reference [4]. Integral temperature sensor LM 35DZ forms voltage which is proportional to the centigrade Celsius scale. Power supply $\pm 5V$ voltage stabilizer elements DA8, VD1, VT1 lay On the VAC converter board.

3. Reference clock and controller board. This board (A2 in Figure 6) generates 0.5 Hz clock pulses which are delivered to the frequency counter board A4 and it generates 2Hz clock pulses which are delivered to the VAC display. This board also generates control pulses at LE and MR outputs. Those pulses are delivered to the VAC display board for counter IC control.

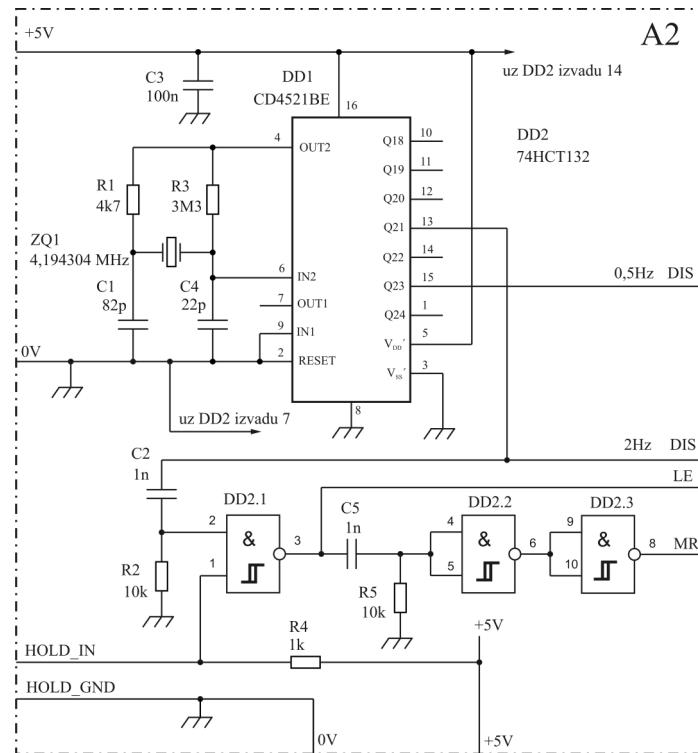


Fig. 6. Circuit schematic of reference clock and controller board

4. VAC display board. The VAC display board (A3 in Figure 7) receives a pulse-frequency modulated signal in its three inputs and displays the values of these frequencies at three 3-digit displays. Each display is completed with overflow indication through LED. Core of each frequency counter is 3-decade counter and multiplexer MC14553BCP. BCD code from the counter/multiplexer output is converted into 7-segment code through 74HCT4511N.

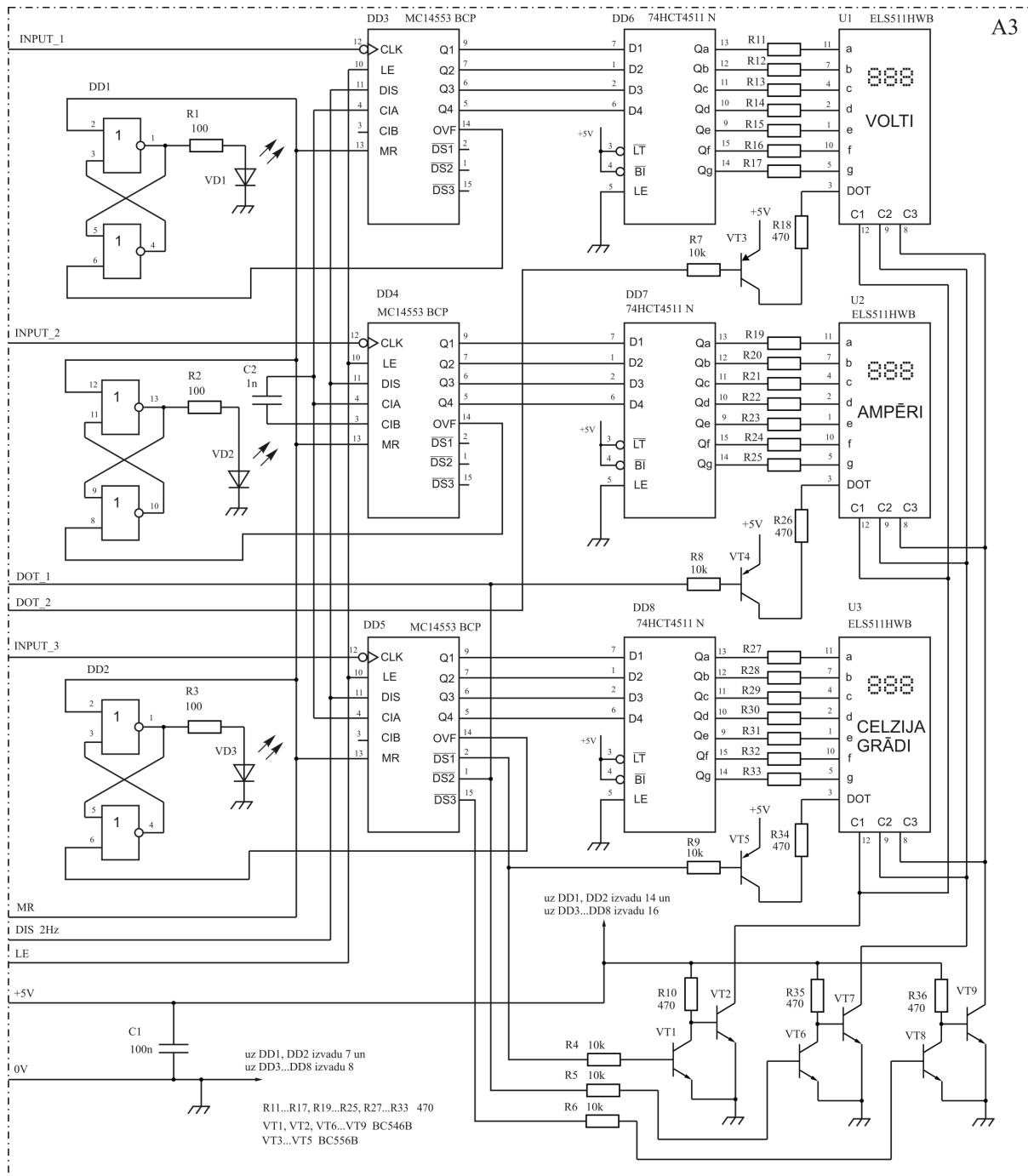


Fig. 7. Circuit schematic of VAC display board

5. Frequency counter board. This board (A4 in Figure 8) consists of two in series connected 3-digit frequency counter circuits forming one 6-digit frequency counter. The board has its own controller IC 74HCT132. However, it has no overflow indicator. As an example for this board the circuit from reference [5] served.

The pulses with machine EMF frequency are received from rotor magnet field through Hall switch TLE4935 L.

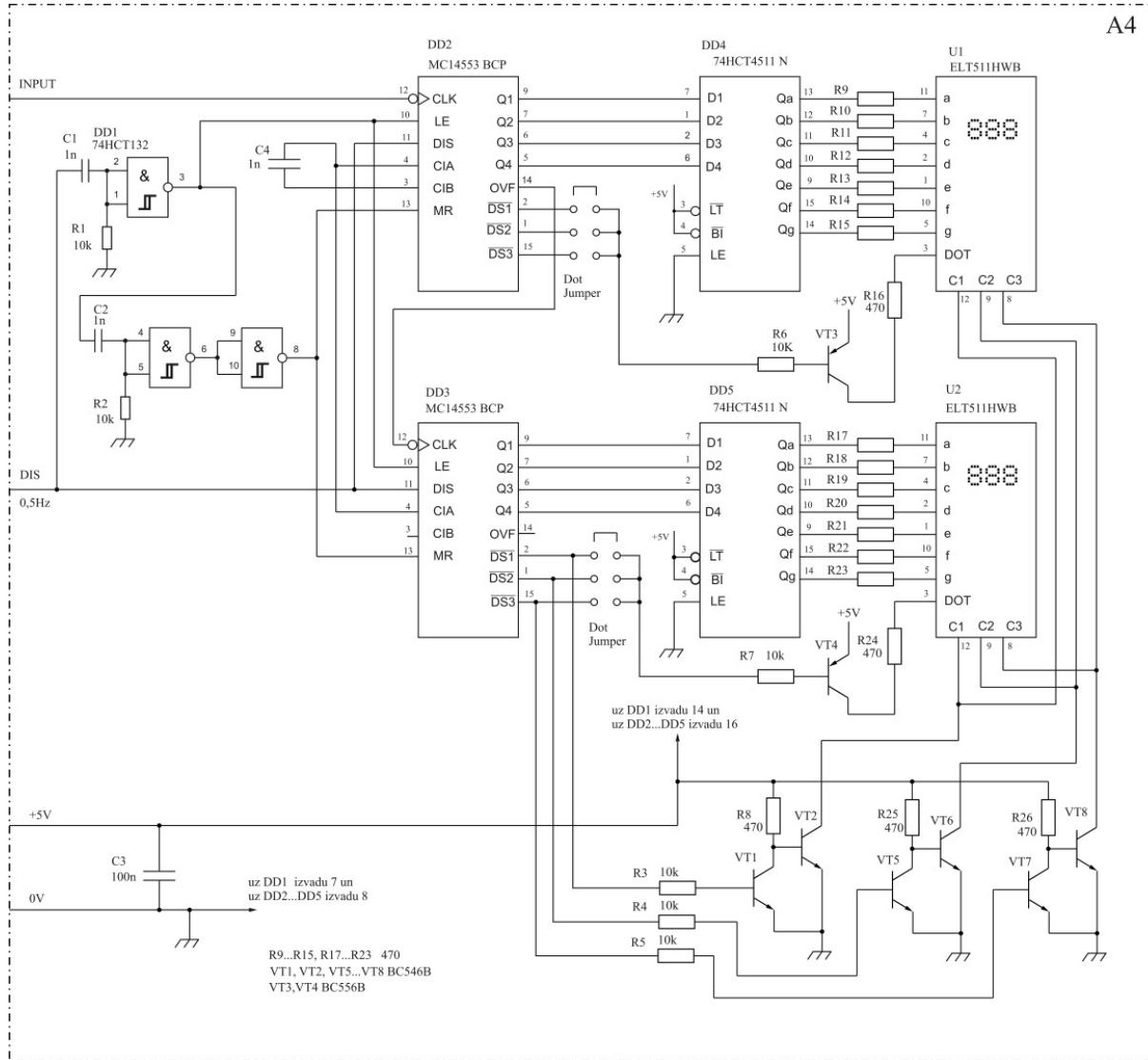


Fig. 8. Circuit schematic of frequency counter board

6. Power supply module. The main component of external power supply is the transformer. The transformer secondary voltage is rectified through two half cycle rectifiers. As a result this circuit gives ± 8 V splitted voltage on its two capacitors (Figure 9). Resistors R1 and R2 take part of the power dissipation and reduce power dissipation on the stabilizer IC.

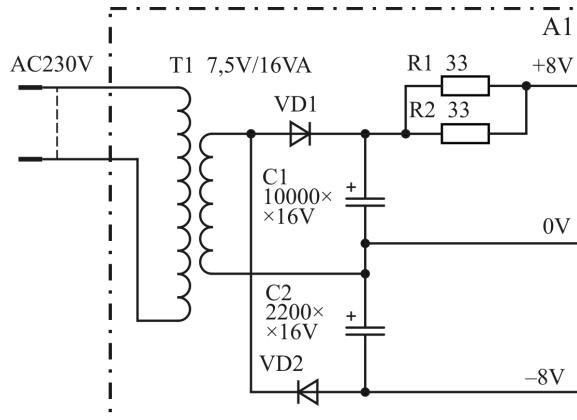


Fig. 9. Circuit schematic of external power supply module

Power circuit relay commutator

This commutator serves as a switch for the brushed DC motor and for the researched machine. Power relay has DC 24 V coil and it is equipped with power MOSFET. So, the relay can be switched by using 5 V logic levels.

Rheostat module

When the researched machine is operated in generator mode, the rheostat module which consists of three adjustable rheostats is being used as a resistive load. The rheostats are connected in WYE and have $50\ \Omega$ resistance value for light load and $11\ \Omega$ resistance value for heavy load.

Integral sensor

For rotor magnet field pickup the Hall switch TLE4935 L is used. It has binary output with NPN open collector circuit.

The temperature sensor LM35DZ generates voltage with the transfer coefficient $10\text{ mV/}^{\circ}\text{C}$ and the output is 4mV at zero degrees.

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