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THEORY AND PRACTICE OF SCIENCE: KEY ASPECTS



ROME, ITALY

19-20.06.2022



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TABLE OF CONTENTS

REGIONAL ECONOMY

Kostyshyn O.		ECOLOGICAL AND ECONOMIC SUBSTANTIATION FOR THE DEVELOPMENT OF TERRITORIAL COMMUNITIES IN UKRAINE	7
Serbov M.		MODEL OF REGIONAL MANAGEMENT OF ECOLOGICAL AND ECONOMIC SYSTEMS OF FRESHWATER RESOURCES IN THE CONDITIONS OF SUSTAINABLE DEVELOPMENT	25
Комліченко О.О. Ротань Н.В.		РИНОК ПРАЦІ УКРАЇНИ: ТЕНДЕНЦІЇ ФУНКЦІОНУВАННЯ В УМОВАХ ВОЄННОГО СТАНУ	41
Павлик В.П.		ДИФЕРЕНЦІАЦІЯ УМОВ ІНКЛЮЗИВНОГО РОЗВИТКУ СІЛЬСЬКИХ ГРОМАД	47

INTERNATIONAL ECONOMICS AND INTERNATIONAL RELATIONS

Ахундова А.Г.		ОСНОВНЫЕ НАПРАВЛЕНИЯ ТРАНСНАЦИОНАЛИЗАЦИИ НЕФТЕГАЗОВОЙ ОТРАСЛИ АЗЕРБАЙДЖАНА	64
Данилов В.Я. Жиров О.Л. Ярошенко О.Р.		ЗАСТОСУВАННЯ ГЕНЕРАТИВНО ЗМАГАЛЬНИХ МЕРЕЖ ДЛЯ ПРОГНОЗУВАННЯ ВАЛЮТНОГО РИНКУ	72

MANAGEMENT

Giguashvili G. Makasarashvili T. Orjonikidze N.		QUALITY MANAGEMENT MECHANISMS IN GEORGIAN HIGHER EDUCATION INSTITUTIONS	80
Stashkevych O.		FEATURES OF MANAGEMENT DURING THE WAR	91
Шевкоплясова А.		ОТКРЫТИЕ ЕДИНОГО ИНФОРМАЦИОННОГО ЦЕНТРА ПОЛИКЛИНИКИ В РАМКАХ ПРОГРАММЫ УПРАВЛЕНИЯ КАЧЕСТВОМ МЕДИЦИНСКОЙ ПОМОЩИ	96

FINANCE AND CREDIT

Sushkova O.		THE MODEL OF THE FISCAL POLICY ECO-CONSCIOUSNESS INDEX	105
Карменова С.У.		ЗАКУПКИ СПОСОБОМ ИЗ ОДНОГО ИСТОЧНИКА ПРЕДУСМОТРЕННЫЕ ЗАКОНОМ РЕСПУБЛИКИ КАЗАХСТАН "О ГОСУДАРСТВЕННЫХ ЗАКУПКАХ"	117
Реверчук С.К. Творидло О.І.		БАНКІВСЬКІ ДОХОДИ В УМОВАХ ФОРМУВАННЯ ЦИФРОВОЇ ЕКОНОМІКИ УКРАЇНИ	121

PEDAGOGY AND EDUCATION

Senik L.N. Ragrina Z.M.		COGNITIVE APPROACH IN TEACHING READING OF FOREIGN MEDICAL STUDENTS	146
Tursunova M.U.		INTERACTION OF UNIVERSAL AND REGIONAL SPECIALIZED MECHANISMS OF COOPERATION OF STATES IN THE FIELD OF EDUCATION	151
Yurchuk L. Yanenko L.		INNOVATIVE APPROACHES TO FOREIGN LANGUAGE COMMUNICATIVE COMPETENCE FORMATION	157
Чикурова О.Я.		ФОРМУВАННЯ САМОПРОЦЕСІВ ОСОБИСТОСТІ УЧНІВ ПОЧАТКОВОЇ ШКОЛИ ЯК КОМПОНЕНТІВ ВМІННЯ САМООРГАНІЗАЦІЇ НАВЧАЛЬНОЇ ДІЯЛЬНОСТІ	167

PHILOSOPHY AND COGNITION

Качуров Е.В. Качурова С.В.		КАЗУС ГЕГЕЛЬ. ПОВОРО	177
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THEORY AND PRACTICE OF SCIENCE: KEY ASPECTS

Яненко Л.П. Юрчук Л.В.		ЛИШЕ ІНТЕГРАЛЬНА НАУКА ВРЯТУЄ СВІТ	199
RELIGIOUS STUDIES			
Bazyk D. Zavalii A.		RECEPTION OF TRYPILLIA HERITAGE IN NATIVE FAITH MOVEMENT OF UKRAINE IN THE CONTEXT OF ETHNO- CONFESSIONAL IDENTITY	209
Ernazarov O.		THE IMPORTANCE OF RELIGIOUS VALUES IN ENSURING SOCIAL STABILITY (ON THE EXAMPLE OF JUDAISM, CHRISTIANITY AND ISLAM)	220
Usmanov I.S.		THE CONCEPT OF SUFI FIQH IN THE BOOKS OF AL-HAKIM AT-TIRMIDHI	225
SOCIOLOGY AND SOCIETY			
Белова Н.В.		СОЦИАЛЬНОЕ КОНСТРУИРОВАНИЕ СЕМЬИ И БРАКА В СССР В 20-Е ГОДЫ XX ВЕКА	231
PHILOLOGY AND LINGUISTICS			
Aleksandruk I.		PECULIAR FEATURES OF COLOR TERMS CONTAINING PROPER NAMES IN THE ENGLISH LANGUAGE	247
Hasanova J.F.		CLASSIFICATION OF PHRASEOLOGICAL UNITS IN LINGUISTICS	256
Вороніна М.Ю.		СПОСОБИ РЕАЛІЗАЦІЇ КАТЕГОРІЇ ЕМОТИВНОСТІ У КИТАЙСЬКОМУ МЕДІАПРОСТОРІ (НА ПРИКЛАДІ САЙТУ SINA WEIBO)	263
Кузьмич О.А.		ФОНОГРАФІЧНІ ЗАСОБИ МОВИ ЯК ІМПЛІЦИТНИЙ ІНСТРУМЕНТАРІЙ ІНФОРМАЦІЙНОГО ВПЛИВУ	273
Сокіл Б.М.		ТОВАРИСТВО «ДНІСТЕР» ТА ПИТАННЯ ФУНКЦІОНУВАННЯ УКРАЇНСЬКОЇ МОВИ ЯК УРЯДОВОЇ	280
LITERARY STUDIES			
Науменко Н.В.		ФОРМОЗМІСТОВІ ЕЛЕМЕНТИ ЯПОНСЬКОГО ДЗУЙХІЦУ В СУЧАСНІЙ УКРАЇНСЬКІЙ ЛІРИЦІ	283
Рубан А.А.		ГЛАЗА КАК ЗЕРКАЛО ДУШИ В РОМАНЕ И. С. ТУРГЕНЕВА «РУДИН»	299
LAW AND INTERNATIONAL LAW			
Кобко-Одарій В.С.		ПРАВОВИЙ МЕНТАЛІТЕТ І ПРАВОВА МЕНТАЛЬНІСТЬ: ЩОДО ПИТАННЯ СПІВВІДНОШЕННЯ	307
Макаренко О.О.		ІСТОРИКО-ПРАВОВИЙ АНАЛІЗ ДІЯЛЬНОСТІ СУБ'ЄКТІВ ЗАПОБІГАННЯ КРИМІНАЛЬНИМ ПРАВОПОРШУНЕННЯМ У ФІНАНСОВІЙ СФЕРІ В УКРАЇНІ	313
ARTS, CULTURAL STUDIES AND ETHNOGRAPHY			
Білінська О.А.		МУЗИЧНЕ МИСТЕЦТВО І ВІЙНА (ВІД ПОЧАТКУ XX СТ. ДО СЬОГОДЕННЯ): НА ПРИКЛАДІ СПОГАДІВ ОСИПА ЗАЛЕСЬКОГО	328
MEDICINE AND PHARMACY			
Гадаев А.Г. Туракулов Р.И. Пирматова Н.В. Эшонкулов С.С.		ОСОБЕННОСТИ ТЕЧЕНИЯ ХРОНИЧЕСКОЙ СЕРДЕЧНОЙ НЕДОСТАТОЧНОСТЬЮ, ПЕРЕНЕСШИХ COVID-19 ПО ДАНЫМ РЕТРОСПЕКТИВНОГО АНАЛИЗА ИСТОРИЙ БОЛЕЗНИ	338
Молдаязова Л.Т. Ракишева В.А. Бердешева Г.А. Жиенгалиева А.Н. Жубаниязова А.С.		САНИТАРНО-БАКТЕРИОЛОГИЧЕСКИЙ КОНТРОЛЬ ЗА БЕЗОПАСНОСТЬЮ ПИЩЕВОЙ ПРОДУКЦИИ ЖИВОТНОГО ПРОИСХОЖДЕНИЯ В АКТЮБИНСКОЙ ОБЛАСТИ	349

Утегенова Ж.А. Джолдыбеков Т.С. Шолахов Ж.Ж. Жауынбеков А.Т.		КЛИНИЧЕСКИЙ СЛУЧАЙ ИНТРАОПЕРАЦИОННОГО СЛР В ПРОН-ПОЗИЦИИ У ДЕТЕЙ С НЕЙРОХИРУРГИЧЕСКОЙ ПАТОЛОГИЕЙ	356
GEOLOGY, MINERALOGY AND SOIL SCIENCE			
Мачуліна С.О.		НОВІ МЕТОДИЧНІ ПРИЙОМИ ВИВЧЕННЯ ЦИКЛІЧНОСТІ У КАРБОНАТНИХ ВІДКЛАДАХ	360
NATURE MANAGEMENT, RESOURCE SAVING AND ECOLOGY			
Ivaniuta S.		NEW THREATS TO ENVIRONMENTAL AND NUCLEAR SECURITY DUE TO RUSSIAN MILITARY AGGRESSION AGAINST UKRAINE	366
Войтків П.С. Іванов Є.А.		ЕКОЛОГІЧНЕ ОЦІНЮВАННЯ СТАНУ ЗЕМЕЛЬНИХ РЕСУРСІВ БРОДІВЩИНИ	373
ENERGETICS			
Філатов В.І. Топал О.І. Голенко І.Л.		ПОРІВНЯЛЬНІ ХАРАКТЕРИСТИКИ ГЕНЕРУЮЧИХ ПОТУЖНОСТЕЙ ТА ЇХ ОДНОЧАСНИЙ ВПЛИВ НА РОБОТУ ЕНЕРГОСИСТЕМИ УКРАЇНИ	386
AGROTECHNOLOGIES AND AGRICULTURAL INDUSTRY			
Нагорний С.А. Криворучко Ю.І. Чалий О.І. Чалая О.С. Косенко С.Ю.		ТЕХНОЛОГІЧНІ РОЗРАХУНКИ ДІЛЬНИЦІ ВІДГОДІВЛІ СВИНЕЙ НА ПРОМИСЛОВОМУ КОМПЛЕКСІ	395
GENERAL ENGINEERING AND MECHANICS			
Fursina A. Kruzhnova S.		SPHERICAL SHELL VIBRATIONS WITH A HOLE-TYPE DAMAGE	403
Борозенець І.О. Шило С.Г. Несміян О.Ю.		МЕТОДИКА ЕКСПЕРИМЕНТАЛЬНОГО АНАЛІЗУ ЕФЕКТИВНОСТІ ДІЯЛЬНОСТІ ОПЕРАТОРІВ ПУНКТУ УПРАВЛІННЯ ПІД ЧАС ЧЕРГУВАННЯ	409
Гуран Ю.А. Кононенко М.А. Габльовська Н.Я. Габльовський Б.Б.		ДО ПИТАННЯ РЕАЛІЗАЦІЇ ВИМІРЮВАЛЬНОГО КОНТРОЛЮ ВОЛОГОСТІ ЦЕМЕНТУ ОПТИЧНИМ МЕТОДОМ	422
Кошель О.О.		ВАРІАНТИ ВІДНОВЛЕННЯ НИЖНЬОЇ РАМИ ДУМПКАРА (ВАГОНА-САМОСКИДА) З МЕТОЮ ПОДАЛЬШОЇ МОЖЛИВОСТІ ПРОДОВЖЕННЯ ТЕРМІНУ ЕКСПЛУАТАЦІЇ	431
RADIO ENGINEERING, ELECTRONICS AND ELECTRICAL ENGINEERING			
Biliuk I. Savchenko O. Shareyko D. Havrylov S. Fomenko A.		PULSE POWER SUPPLY FOR 3D PRINTER	437
Yavisya V.S. Lysenko O.I. Tachinina O.M. Ponomarenko S.O. Sushyn I.O.		PROTOTYPE OF COMMUNICATION SYSTEM FOR MARS EXPLORATION	448
Магомедова М.С. Почерняев В.М.		ІМІТАТОР ТИМЧАСОВИХ ЗАВМИРАНЬ БАГАТОПРОМЕНЕВОГО КАНАЛУ ЗВ'ЯЗКУ	459

MODELING AND NANOTECHNOLOGY		
Muhamediyeve D.T.  Rustamov E.	FORMAL STATEMENT OF THE DECISION-MAKING PROBLEM	462
INFORMATION AND WEB TECHNOLOGIES		
Muhamediyeve D.T.  Abdul-Azalova M.Y.	APPLICATION OF THE THEORY OF FUZZY LOGIC FOR ANALYSIS OF MANAGEMENT SYSTEMS OF BUSINESS PROCESSES OF AN ENTERPRISE	467
Данилов В.Я.  Зарицький О.О.	ВИКОРИСТАННЯ МЕТОДІВ МАШИННОГО НАВЧАННЯ ДЛЯ КЛАСИФІКАЦІЇ СЕРЦЕВИХ ЗАХВОРЮВАНЬ ЗА ДАНИМИ ЕКГ ТА ЗАСТОСУВАННЯ СУЧАСНИХ ГЕНЕРАТИВНО ЗМАГАЛЬНИХ МЕРЕЖ ДЛЯ ЗБІЛЬШЕННЯ НАВЧАЛЬНОЇ ВИБІРКИ	472
Данилов В.Я.  Олійник Б.О.	ПРОГНОЗУВАННЯ ЦІН БІРЖОВИХ АКЦІЙ НЕЙРОННИМИ МЕРЕЖАМИ	479
ARCHITECTURE, CONSTRUCTION AND DESIGN		
Arsenieva N. 	FEATURES OF BIM TECHNOLOGIES IN GEODETIC WORKS	486
MILITARY AFFAIRS AND NATIONAL SECURITY		
Важинський С.Е.  Коломійцев О.В. Ніколаєв І.М. Третяк В.Ф. Закіров З.З. Черненко П.В. Олійник Н.О. Живець Ю.М. Шумигай О.В.	ДОРОЖНЯ КАРТА СТВОРЕННЯ ВІТЧИЗНЯНИХ ЗЕНІТНИХ РАКЕТНИХ КОМПЛЕКСІВ	493
Морозов І.Є.  Манжура С.А. Гащук О.В. Полончук В.А.	СИСТЕМА ЛОГІСТИЧНОГО ЗАБЕЗПЕЧЕННЯ ПІДРОЗДІЛІВ НАЦІОНАЛЬНОЇ ГВАРДІЇ УКРАЇНИ ПІД ЧАС УЧАСТІ У МІЖНАРОДНИХ ОПЕРАЦІЯХ З ПІДТРИМАННЯ МИРУ ТА БЕЗПЕКИ	504
Фаррахов О.В.  Лисиченко К.Г. Лисиченко О.Г.	ЗАПОБІГАННЯ НЕСАНКЦІОНОВАНОМУ ПЕРЕМІЩЕННЮ ДЖЕРЕЛ ІОНІЗУЮЧОГО ВИПРОМІНЮВАННЯ. ОСНОВНІ ВИМОГИ ДО СИСТЕМ КОНТРОЛЮ	510



RADIO ENGINEERING, ELECTRONICS AND ELECTRICAL ENGINEERING

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PULSE POWER SUPPLY FOR 3D PRINTER

Abstract. *The work is devoted to the design of a pulse power supply for a 3D printer. A functional diagram of the power supply has been developed. Based on the functional diagram, a schematic diagram of the power supply was built, a circuit board was made and the power supply was assembled. The transformer was also calculated and modeled using MATLAB.*

Keywords: *3D printer, control system, power supply, feedback.*

The 3D printer is a peripheral device that performs 3D printing by layer-by-

layer formation of a physical object according to a given digital 3D model. 3D printers are used for both household and professional prototyping of objects. Today, in addition to conditionally "standard" equipment, there are developments and designs that print food, printers are used in medicine, and printers are capable of printing low-rise buildings and small structures.

The 3D printer power supply, which is used to power the extruder heating, table heating, stepper motors and electronics, needs special attention.

The purpose of the work is the design and manufacture of a power supply for a 3D printer [1]. To achieve this goal, the following tasks were identified in the work:

- make a functional diagram of the power supply
- develop a 3D printer power supply circuit and justify the choice of its elements
- calculate and manufacture a pulse transformer
- make a power supply and explore the dynamics of its work

Among the many existing circuits of switching power supplies, reciprocating ones are considered to be the most common. Network reciprocating voltage converters with a power of up to 150 W can be assembled using three output microcircuits of the TOP22x series from Power Integrations.

The proposed power supply can be used to power the power circuits of 3-D printers, industrial robots, CNC machines, as well as in other technical devices of electromechanical systems.

The aim of the work is to create a 12 V 12 A power supply for power circuits of 3D printers [2, 3, 4], which has voltage stabilization and current limiting.

To solve this problem, a functional diagram of the power supply was constructed, which is shown in Fig.1.

Any switching power supply creates radio interference, and as a result, the main problem is to ensure electromagnetic compatibility with other electronic equipment. Due to the principle of operation, switching power supplies are a source of various electromagnetic defects and flaws. To prevent this, an input filter was assembled, assembled on elements L1, C1 and C2 (Fig. 2), it protects the power supply and the network from mutual high-frequency and impulse defects.

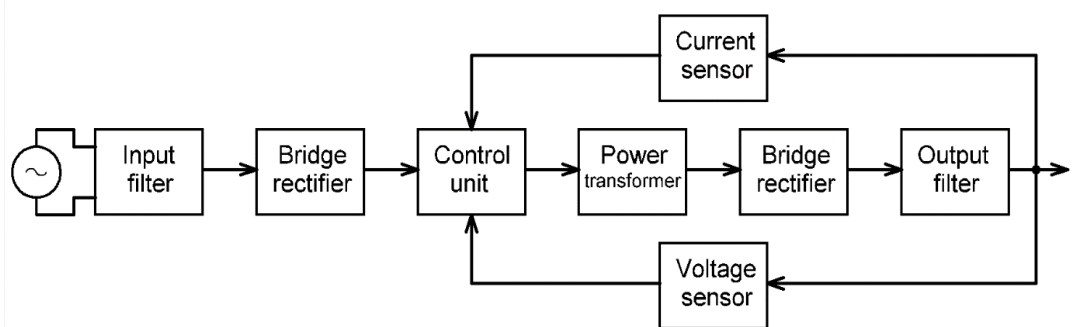


Fig.1. Functional diagram of the power supply:

**1 - input filter; 2 - bridge rectifier; 3 - control unit; 4 - power transformer;
5-bridge rectifier; 6 - output filter; 7 - current sensor; 8 - voltage sensor**

Almost all switching power supplies and rectifiers with capacitor filters have one significant drawback. When the power is on, the filter capacitor is in a discharged state, and its time is charged. During this time, a current is supplied that can exceed the operating parameters by several times (in some cases even tens of times). This is detrimental to many circuit elements inside the power supply, as well as to connected circuits. There are many different solutions for limiting current surges, but they all have advantages and disadvantages. The easiest way to deal with such current pulses is to include an NTC (inversely coupled) thermistor in the circuit.

At rest (power off), the thermistor is at ambient temperature and has a high resistance.

At the moment of switching on, the current pulse is extinguished by the high resistance of the "cold" NTC thermistor. In the process of further exposure to current, the thermistor heats up and switches to an operating mode in which it has a low resistance, which means that it will have almost no effect on the operation of the entire power supply circuit.

The thermistor resistance is calculated based on the amount of current we plan to limit:

$$R_{NTC1} = \frac{(U \cdot \sqrt{2})}{I}$$

Power is supplied through a diode bridge assembled on diodes VD1, VD2,

VD3, VD4. The diodes must have a reverse voltage of at least 400 V. In addition, the diodes must withstand the surge current when the power supply is turned on.

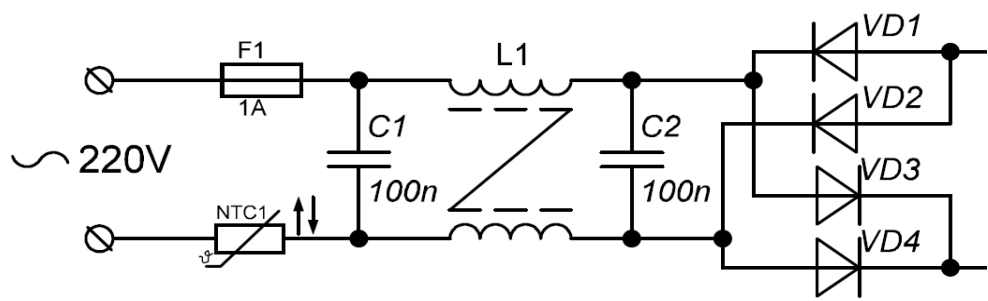


Fig. 2 – Input filter with diode bridge

The TOP22x microcircuit includes a powerful high-voltage transistor and all the necessary control circuits for it (Fig. 3). This is, first of all, a master oscillator operating at a fixed frequency of 100 kHz, from the three outputs of which signals of the required shape are taken. The signal from output 1, fed to the input of the AND-NOT element, determines the maximum possible duty cycle D_MAX. Short pulses on output 2 set the flip-flop to a single state, turning on the output transistor.

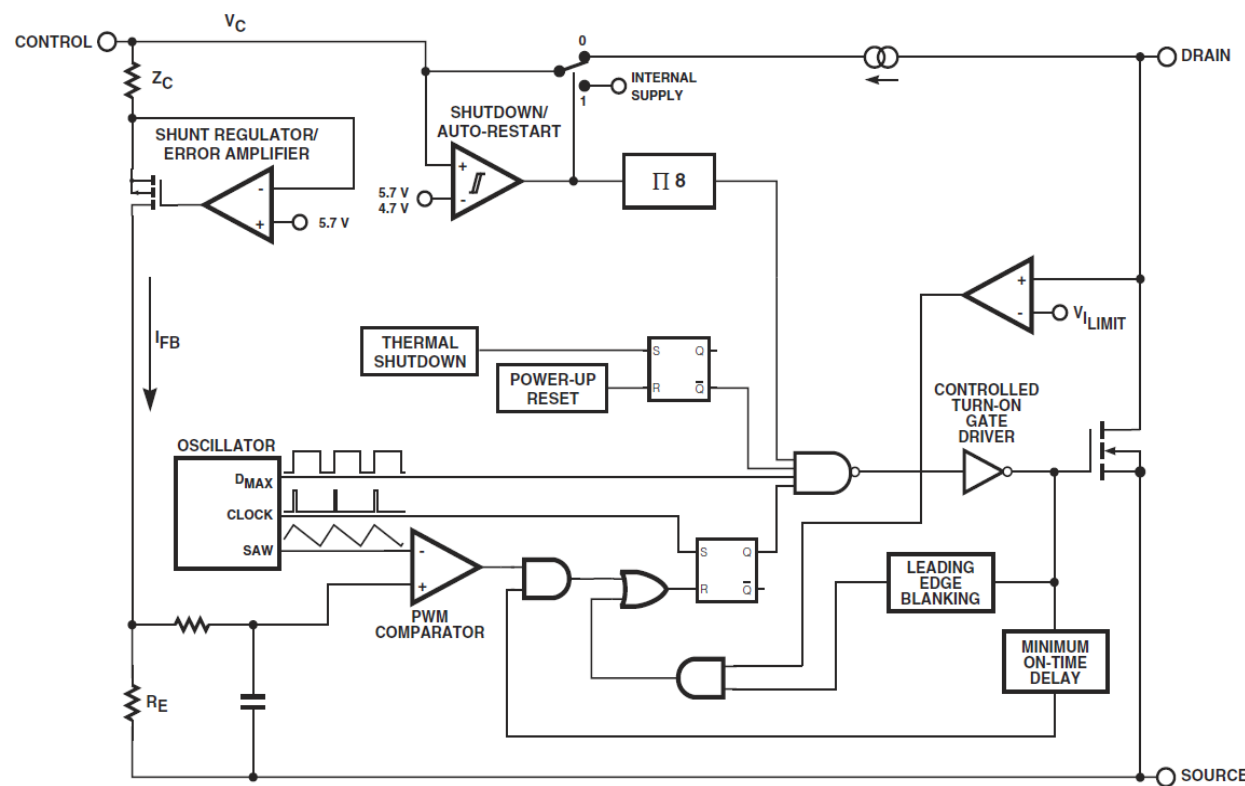


Fig. 3 – The structure of the TOR227 chip

In normal operation, the trigger is reset by an inconsistency signal at the output of the PWM comparator. A triangular voltage is supplied to one of its inputs from the output of the generator 3, to the other - a voltage proportional to the excess voltage at the control input "Control" of the 5.7 V level microcircuit, which implements pulse-width modulation (PWM). The field-effect transistor at the input of the operational amplifier and the resistors Z_C1 and R_E provide a stable rated transfer coefficient exceeding the signal level of 5.7 V to the input of the comparator.

TOP22x microcircuits are available in DIP packages with eight pins, of which six are combined (P suffix), this is a leakage pin, and in a TO-220 package with three pins (Y suffix)

The calculation of the converter on microcircuits of the TOP22x series is simple. It begins with the selection of the required microcircuit. On fig. 4 and 5 show curves facilitating this choice; 4 for the output voltage of the converter 12 V. The required output power $P_{OUT}=U_{OUT} I_{OUT}$ is plotted along the horizontal axis on the graphs. The solid lines of the graphs correspond to different microcircuits of this series.

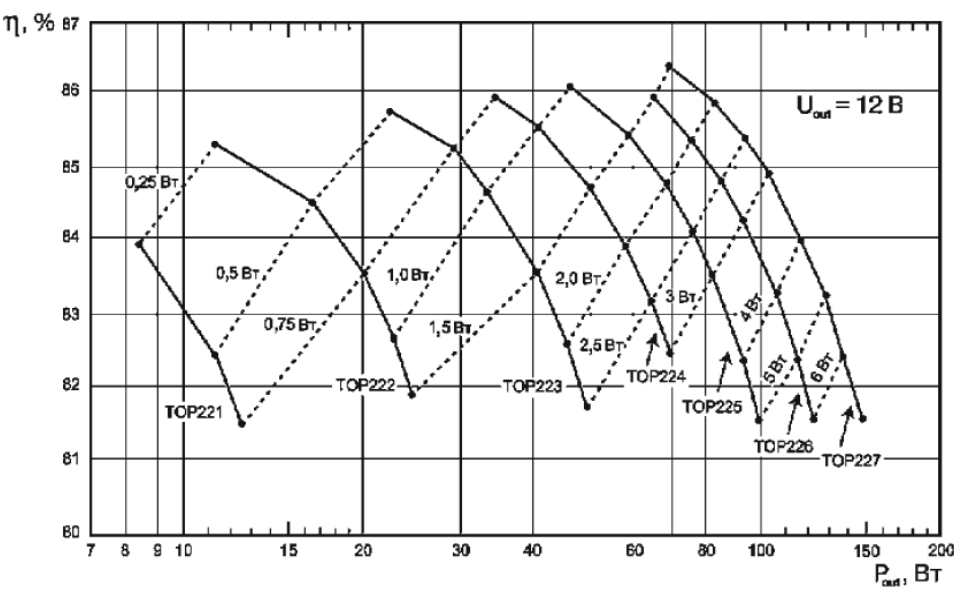


Fig. 3 – Types of curves for output voltage 12V

All calculations of the converter are carried out for a heavier version, and it (with one exception) takes place at a low input voltage. Graphs fig. 3 are built for a

mains voltage of 230 V - 15%, i.e. for 195 V AC. In the domestic network of 220 V with a tolerance of 20%, the minimum voltage is 176 V and the calculation must be carried out specifically for him. With such a voltage on a particular microcircuit, it is possible to build a converter with a slightly lower output power than at 195 V. The correction factor K_{Π} , which determines the decrease in permissible power, is found from the graph in Fig. 5. For a mains voltage of 176 V, it is about 0.94. This means that it is necessary to choose a microcircuit that provides output power in excess of the required one by a factor of $1/0.94=1.06$.

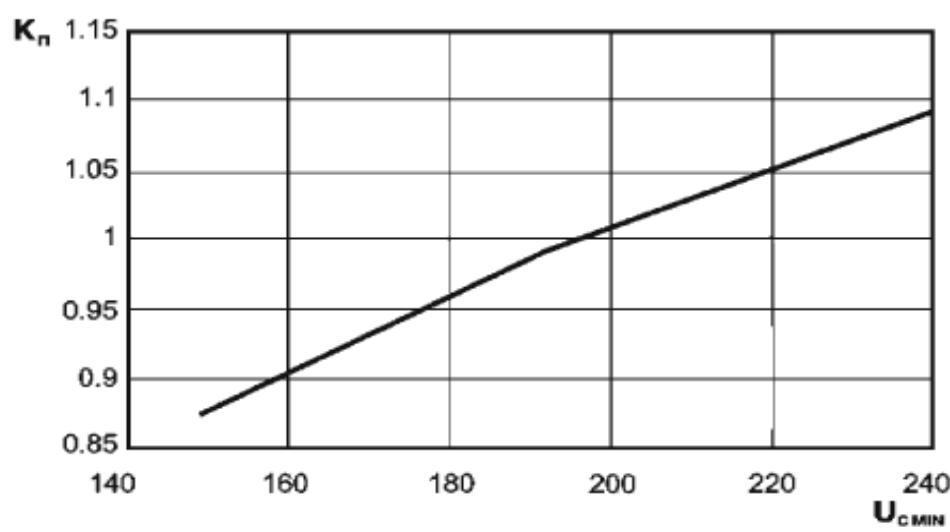


Fig. 5 – Graph for determining the correction factor

Then you can proceed to the calculation of the power transformer, so below we present some calculation parameters [5].

The switching frequency f determines the pulse period T :

$$T = \frac{1}{f}$$

The period together with the duty cycle determines the duration of the pulse of the open state of the key

$$t_i = qT$$

The maximum output power of the converter is equal to the product of the load current and the voltage on it:

$$P_{OUT_max} = V_{OUT_max} I_{OUT_max}$$

The maximum converter power consumption P_{IN_max} is given by the maximum output power divided by the efficiency:

$$P_{IN_max} = \frac{P_{OUT_max}}{\eta}$$

where P_{OUT_max} maximum inverter output power

The inductance L_1 of the primary winding is determined by the ratio:

$$L_1 = \eta \frac{(V_{IN_min} q_{max})}{2P_{OUT_max} f}$$

where f – operating frequency

V_{IN_min} – input voltage

q_{max} – the maximum value of the fill factor of the converter controller

P_{OUT_max} – the maximum value of the fill factor of the converter controller

η – efficiency

The maximum current through the primary winding is determined by the formula:

$$I_{w1_max} = \sqrt{\frac{2P_{OUT_max}}{f\eta L_1}}$$

The inductance of the secondary winding is determined by the ratio:

$$L_2 = \frac{(1 - q_{max})^2 (V_{OUT_max} + V_{VD})^2}{q_{max}^2 V_{IN_min}^2} \frac{L_1}{\eta}$$

where V_{OUT} – output voltage;

V_{VD} – voltage drop on the open diode.

The ratio of the number of turns of the secondary and primary winding is calculated by the ratio:

$$k = \frac{N_1}{N_2} = \frac{q_{max} V_{IN_min}}{(1 - q_{max})(V_{OUT_max} + V_{VD})} \frac{\sqrt{\eta}}{1}$$

The maximum current through the secondary winding is calculated by the formula:

$$I_{w2_max} = kI_{w1_max}$$

If the gap is planned to perform independently, the value of the inductance per turn can be calculated by the following formula:

$$A_E = \frac{A_{E(0)} \cdot L_E}{\mu_E \cdot g}$$

where $A_{E(0)}$ – value of coil inductance for core without gap (from specification)

L_E – the length of the midline of the core

μ_E – initial core magnetic permeability

g – introduced gap

Consider the formula for the effective magnetic permeability of the core:

$$\mu_E = \frac{l_E}{g}$$

Substituting the values obtained in the calculation part in the substitution scheme, which is shown in Figure 6, we obtain the values of the transient characteristics of the power supply.

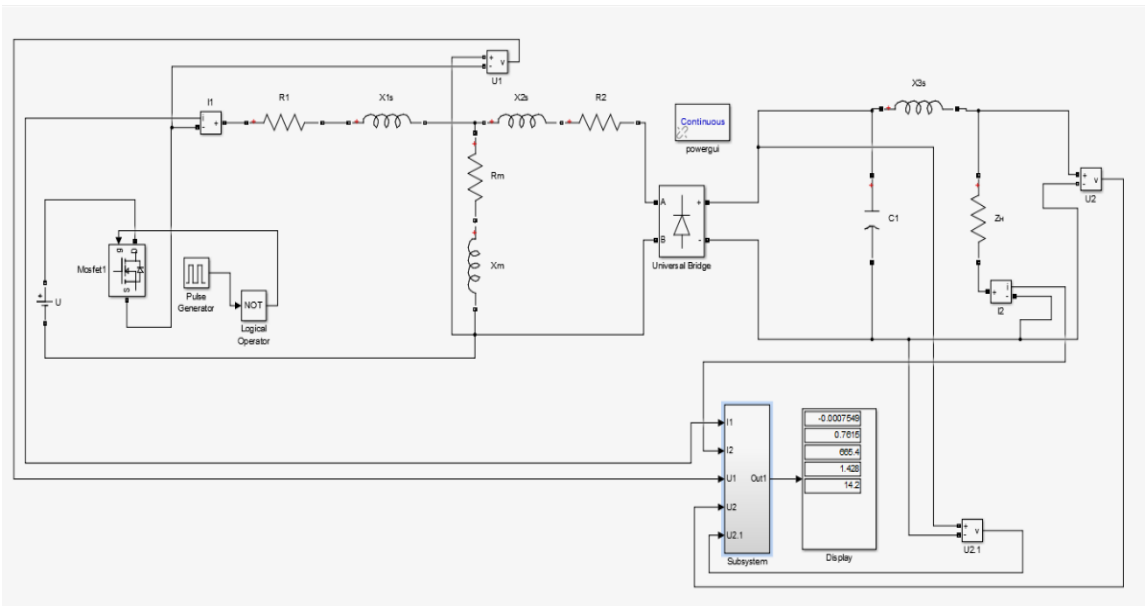


Fig. 6. Transformer replacement scheme in the power supply

After modeling the system, we obtained graphs of transients, which are shown in Figure 7.

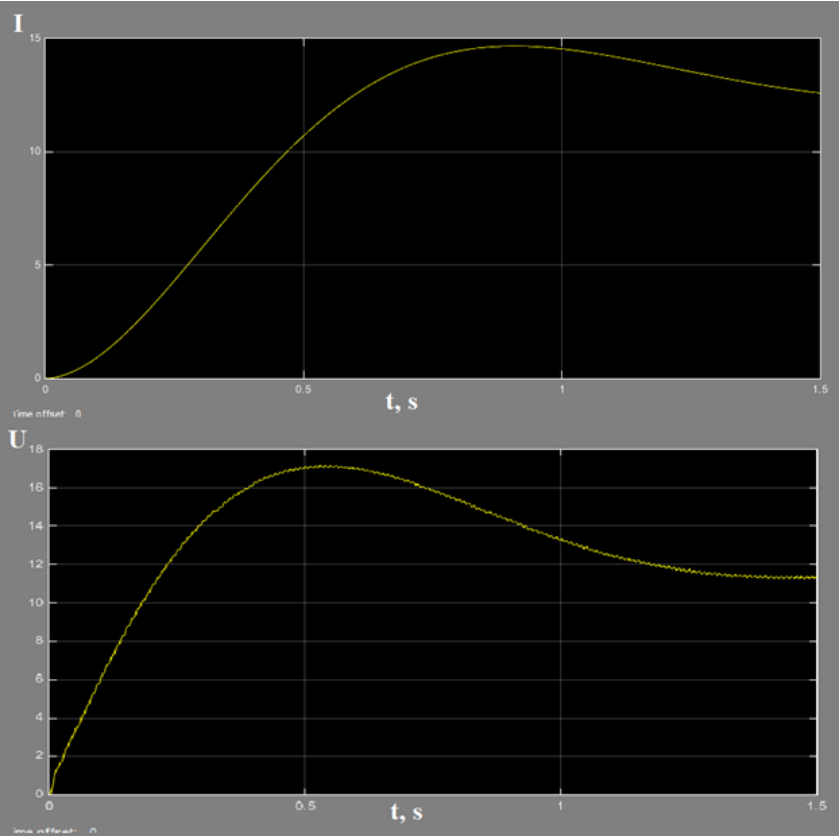


Fig. 7. Current and voltage at the output of the power supply at a load of 90%

From the above characteristics was built a schematic diagram of the viewing unit 3-D printer, which is shown in Fig.8.

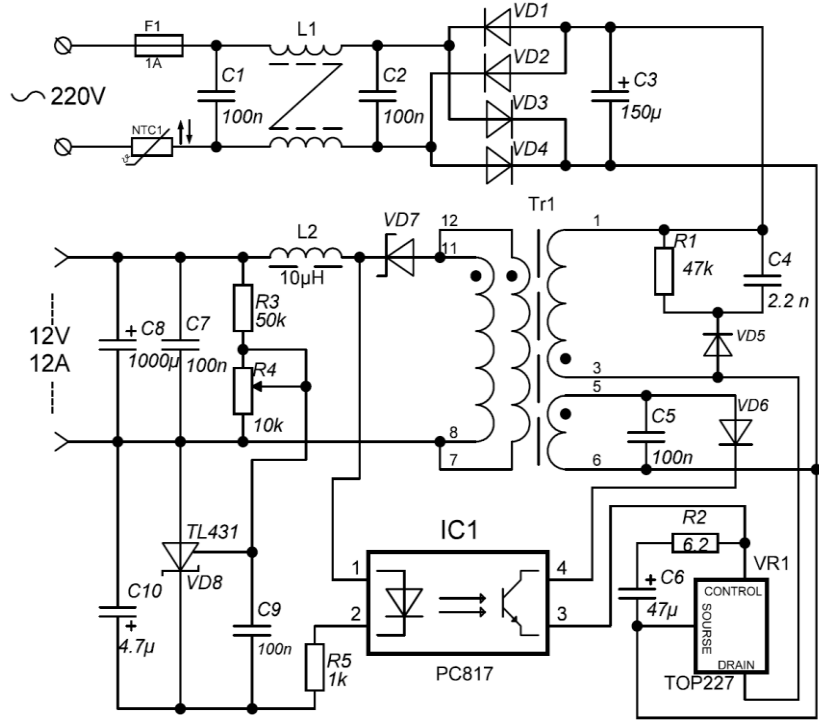


Fig. 8. Schematic diagram of the power supply

The wiring diagram is shown in Figure 9.

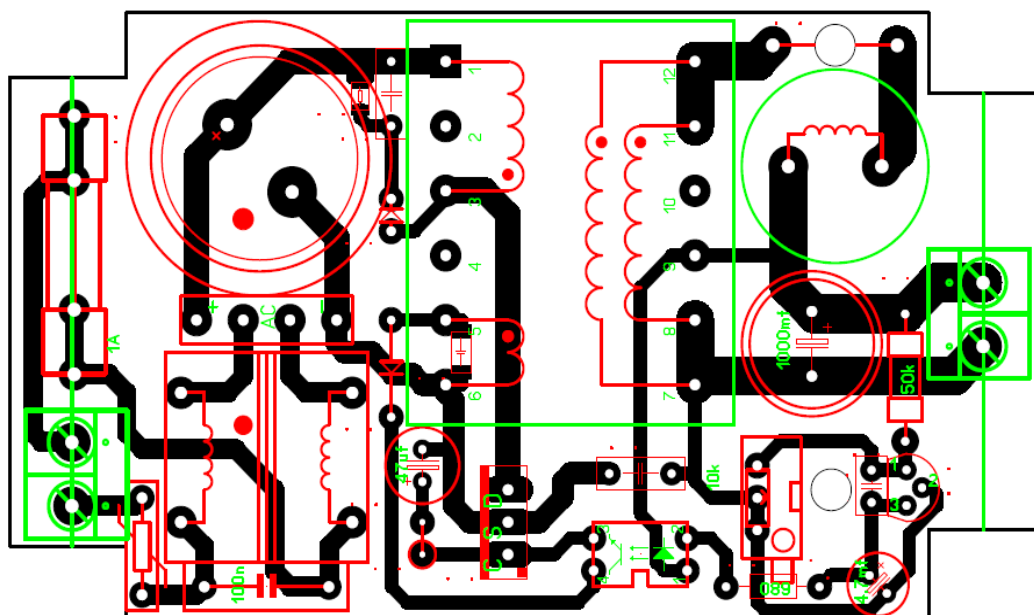


Fig. 9. Wiring diagram of the power supply

The completed power supply is shown in figure 10.

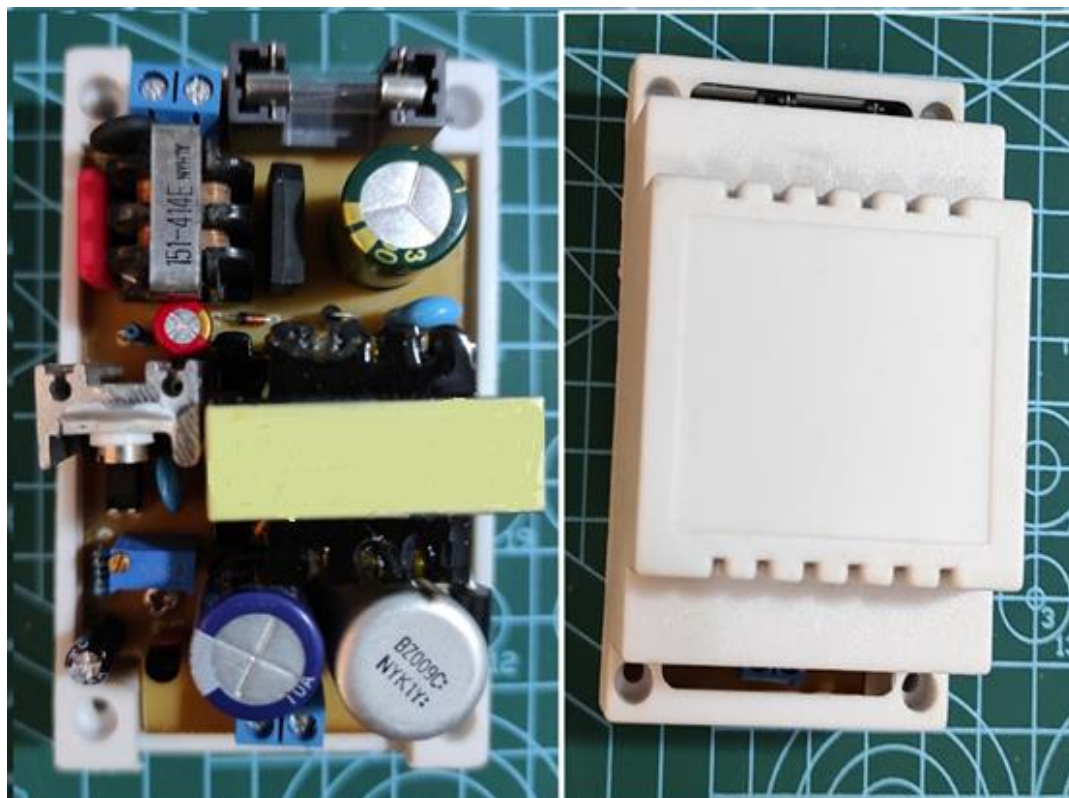


Fig. 10. Completed power supply

Conclusions:

In the work, a power supply circuit for the power circuits of a 3D printer designed for a current of 12 A and a voltage of 12 V was designed. Also, voltage stabilization and current limiting were added to the circuit.

To solve this problem, the TOR227 microcircuit was used in the power supply unit of the power circuits of ship equipment.

In the work, a transformer was calculated for a switching power supply. The equivalent circuit of the transformer was also simulated in the MATLAB 14 program, which showed the operability of the developed power supply.

After all calculations and simulations, a power supply was made.

The proposed scheme refers to the power supply of power circuits of 3D printers, laboratory stands for the study of elements of automation systems, industrial robots, CNC machines, as well as in other technical devices of electromechanical control systems for electric drives. It provides the necessary parameters of electrical energy and protection of automation systems.

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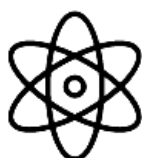
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