

МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
ЧЕРНІГІВСЬКИЙ НАЦІОНАЛЬНИЙ ТЕХНОЛОГІЧНИЙ УНІВЕРСИТЕТ

До друку дозволяю на підставі
правил друкованих видань

Проректор ЧНТУ з НІР
В.В. Кальченко

Живлення РЕА
МЕТОДИЧНІ ВКАЗІВКИ
ДО ВИКОНАННЯ РОЗРАХУНКОВО-ГРАФІЧНОЇ РОБОТИ
ДЛЯ СТУДЕНТІВ НАПРЯМУ ПІДГОТОВКИ
6.050902 „РАДІОЕЛЕКТРОННІ АПАРАТИ”
УСІХ ФОРМ НАВЧАННЯ

Всі цитати, цифровий та фактичний матеріал, бібліографічні відомості перевірені, запис одиниць відповідає стандартам

О.О. Гусев

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MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
CHERNIHIV NATIONAL UNIVERSITY OF TECHNOLOGY

POWER SUPPLY FOR RADIOELECTRONIC EQUIPMENT

GUIDELINES

FOR HOME PRACTICE ON DISCIPLINE “POWER SUPPLY FOR
RADIOELECTRONIC EQUIPMENT”
FOR ALL STUDENTS
6.050902 „ RADIOELECTRONIC APPARATUS”

CHERNIHIV CNTU 2016

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Content

Introduction	4
1 Task	5
2 Theoretical background	7
3 Example of the task solution	10
4 Demands for report	14
Recommended sources	15

Introduction

These guidelines provide instructions for home practice on discipline "Power supply for radioelectronic equipment". Guidelines are designed for the students' specialty "Radioelectronics apparatus". It can also be used for the training of engineers bachelor and other professions that have in their curriculum similar subject.

Guidelines consist of variants of task, theoretical background, examples and calculation requirements for report. These tasks cover the part of the course devoted to the dc-dc converters. The N- is an integer number that will be given to the students by the lecturer according to the variant.

The example of calculating one of the options task. This work should be done by students independently using reference literature and lectures on discipline along with information given in this guidance.

1 Task for home practice

V1.N

The converter topology is given in Figure 1.1. Please define the value of the passive components and semiconductors according to the specification:

- Input voltage range: (6 V-12 V)*N;
- Output voltage: (12 V)*N;
- Output voltage ripple is 5 %;
- Input current ripple should be not higher than N*10 % for full input voltage profile and nominal power;
- Switching frequency 10kHz*N;
- Nominal power: 100 W.

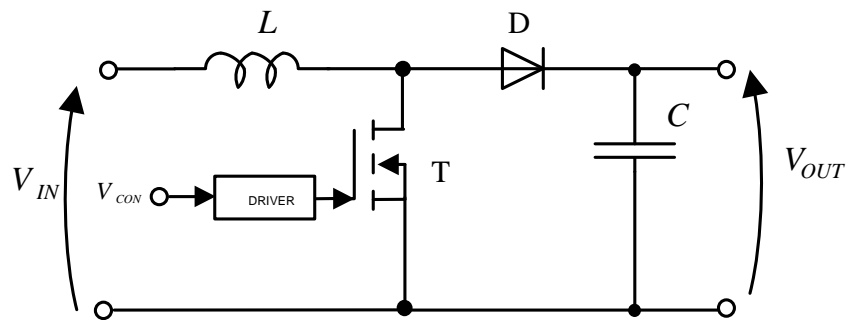


Figure 1.1 – Boost converter

V2.N

The converter topology is given in Figure 1.2. Please define the value of the passive components and semiconductors according to the specification:

- Input voltage range: (12 V-24 V)*N;
- Output voltage: 12 V*N;
- Output voltage ripple is 5 %;
- Nominal power: 100 W*N;
- Switching frequency 10kHz*N;
- Estimate the duty cycle range of the control signal.

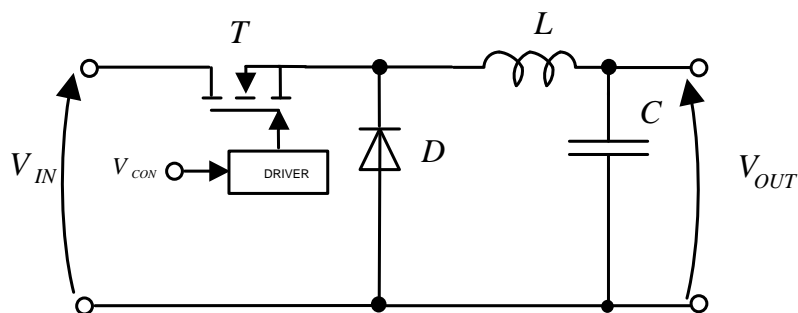


Figure 1.2– Buck converter

V3.N

The converter topology is given in Figure 1.3. Please define the value of the passive components and semiconductors according to the specification:

- Input voltage range: $(24\text{ V}-48\text{ V}) * N$;
- Output voltage: 12 V;
- Output voltage ripple is 5 %;
- Nominal power: 100 W;
- Switching frequency $10\text{kHz} * N$;
- Magnetizing current ripple should be not higher than $N * 10\%$ for full input voltage profile and nominal power.

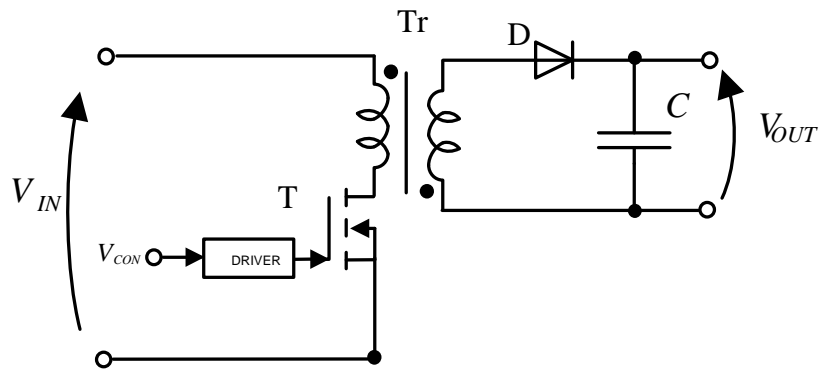


Figure 1.3 – Flyback converter

V4.N

The converter topology is given in Figure 1.4. Please define the value of the passive components and semiconductors according to the specification:

- Input voltage range: $(24\text{ V}-48\text{ V}) * N$;
- Output voltage: 12 V;
- Output voltage ripple is 5 %;
- Nominal power: 100 W;
- Switching frequency $10\text{kHz} * N$;
- Estimate the duty cycle range of the control signal.

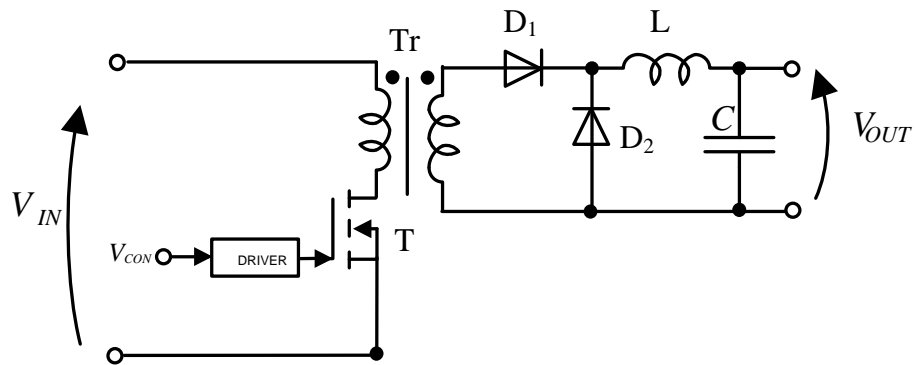


Figure 1.4 – Forward converter

2 Theoretical backgrounds

Classification of dc-dc converters

A dc-to-dc converter is an electronic circuit or electromechanical device which converts a source of direct current (dc) from one voltage level to another. It is a type of electric power converter. Dc-dc power converters are employed in a variety of applications, including power supplies for personal computers, office equipment, spacecraft power systems, laptop computers, and telecommunications equipment, as well as dc motor drives.

The generalized classification is shown in *Figure 2.1*.

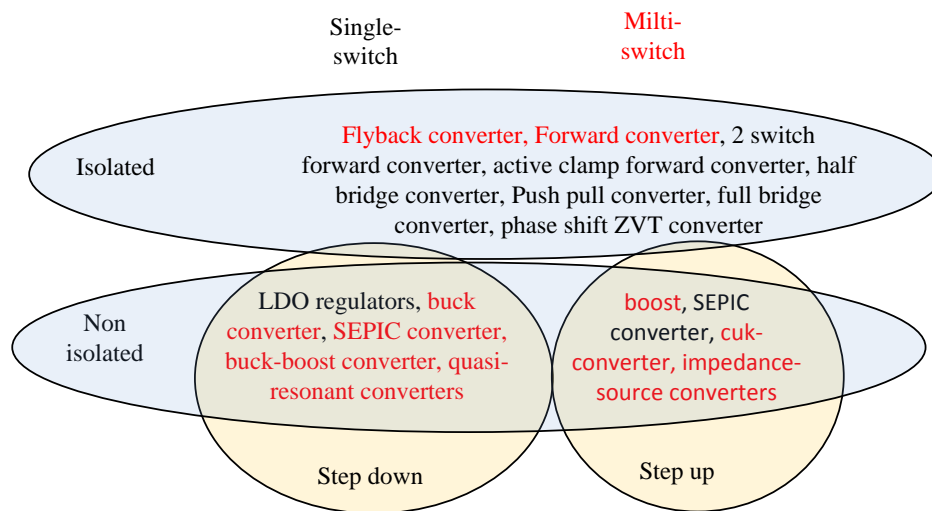


Figure 2.1 – Classification of dc-dc converters

It can be seen, that all dc-dc converters can be classified according the amount of active switches (transistors), isolated or non isolated solutions and voltage ratio between input and output side.

Example of the pulse dc-dc converters

The general example of the pulse boost dc-dc converter is depicted in *Figure 2.2*.

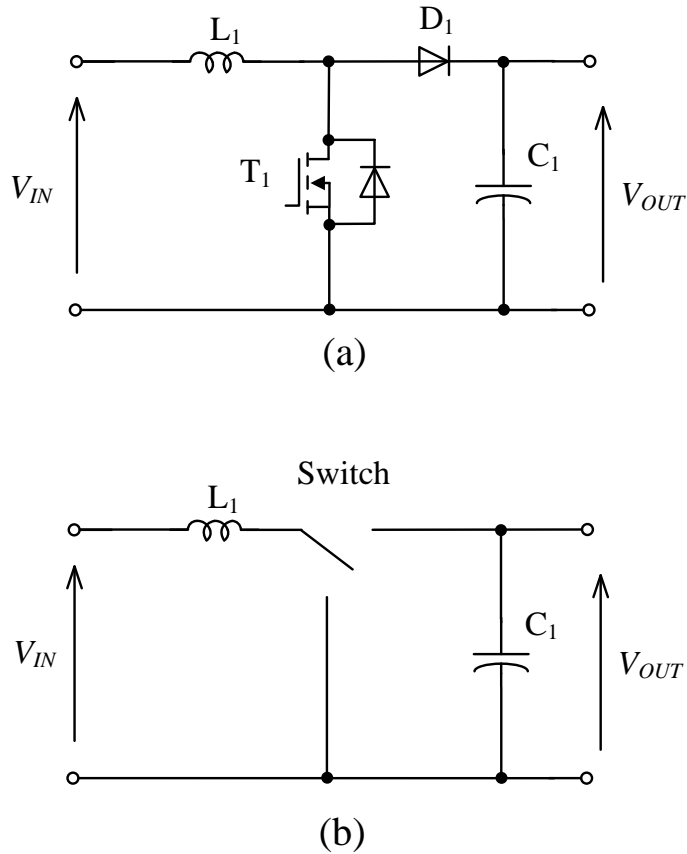


Figure 2.2 – Example of the pulse dc-dc converter

In particular, the *Figure 2.2a* shows the circuit realized by means of MOSFET transistor and diode, while *Figure 2.2b* shows the ideal equivalent circuit where semiconductors are represented as ideal switch. The input to a dc-dc converter is an unregulated dc voltage V_{IN} . The converter produces a regulated output voltage V_{OUT} , having a magnitude (and possibly polarity) that differs from V_{IN} . For example, in a computer off-line power supply, the 120 V or 240 V ac utility voltage is rectified, producing a dc voltage of approximately 170 V or 340 V, respectively. A dc-dc converter then reduces the voltage to the regulated 5 V or 3.3 V required by the processor. High efficiency is invariably required, since cooling of inefficient power converters is difficult and expensive. The ideal dc-dc converter exhibits 100% efficiency; in practice, efficiencies of 90% to 95% are typically obtained. This is achieved using switched-mode, or chopper, circuits whose elements dissipate negligible power. Pulse-Width Modulation (PWM) allows control and regulation of the total output voltage. This approach is also employed in applications involving alternating current, including high-efficiency dc-ac power converters (inverters and power amplifiers), ac-ac power converters, and some ac-dc power converters (low-harmonic rectifiers). The operation principle is illustrated in the *Figure 2.3*. It can be divided into the two main equivalent circuits. In particular, *Figure 2.3a* shows the circuit when transistor is conducting. During this stage the energy is storing in the inductor. During next time interval, that is shown in the *Figure 2.3b* the transistor is stopped conducting and energy is transferring to the output side. It is very common for any kind of pulse converters where flow of energy is discontinuous.

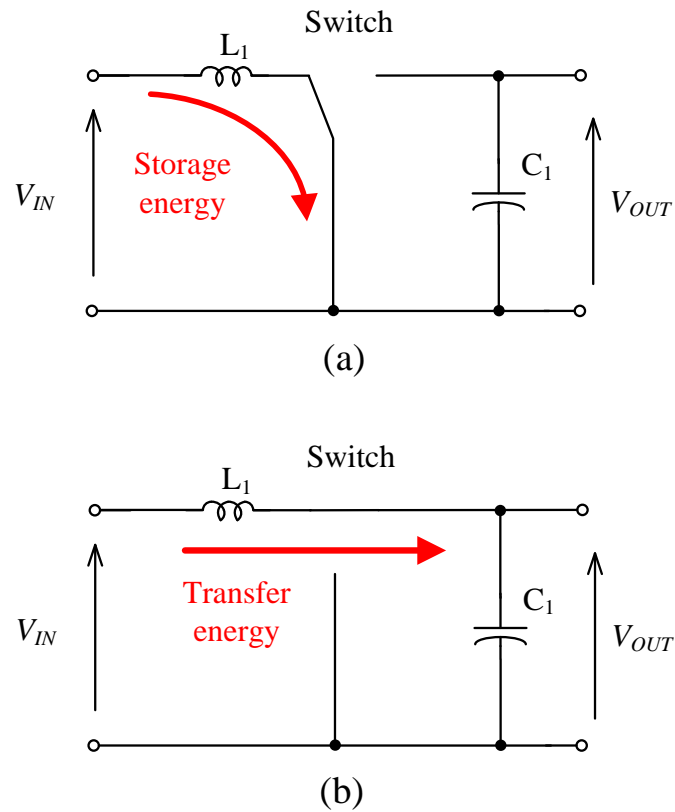


Figure 2.3 – Ideal equivalent circuits of the boost converter

Non ideal equivalent circuit is shown in Figure 2.4. It corresponds to the Figure 2.4, but with real semiconductors that have static losses. It should be noted that dynamic losses should be taking into account as well and is a topic of discussion of the advance course.

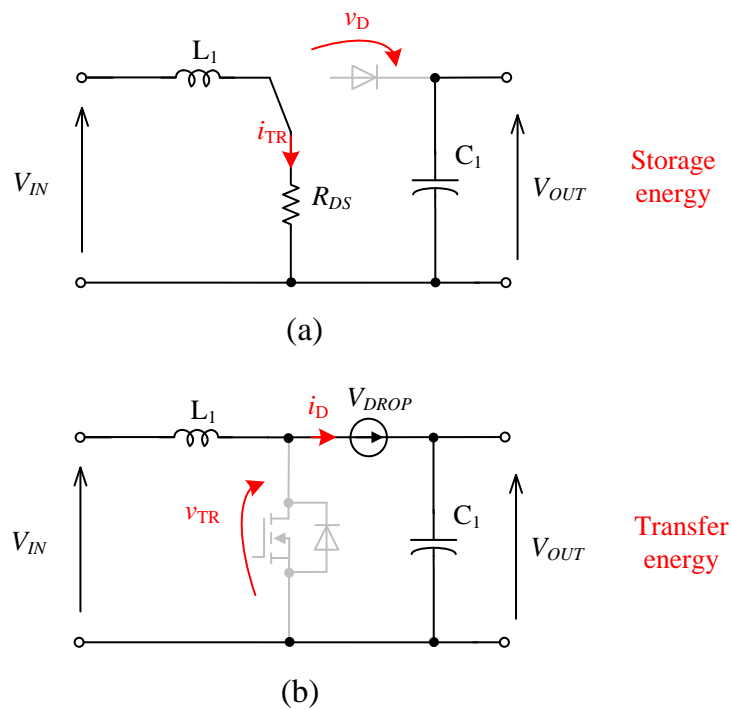


Figure 2.4 – Non ideal equivalent circuits of the boost converter

3 Example of task solution

3.1 Input data: variant 4; $N=2$.

The converter topology is given in the Figure 1.4. Please define the value of the passive components and semiconductors according to the specification:

- Input voltage range: 48 V-96 V;
- Output voltage: 12 V;
- Output voltage ripple is 5 %;
- Nominal power: 100 W;
- Switching frequency 20kHz;
- Estimate the duty cycle range of the control signal.

The operation mode of the converter can be divided in the two equivalent circuits illustrated in Figure 3.1.

The first time interval corresponds to the conducting transistor. As a result the input voltage through transformer is applied to the output side.

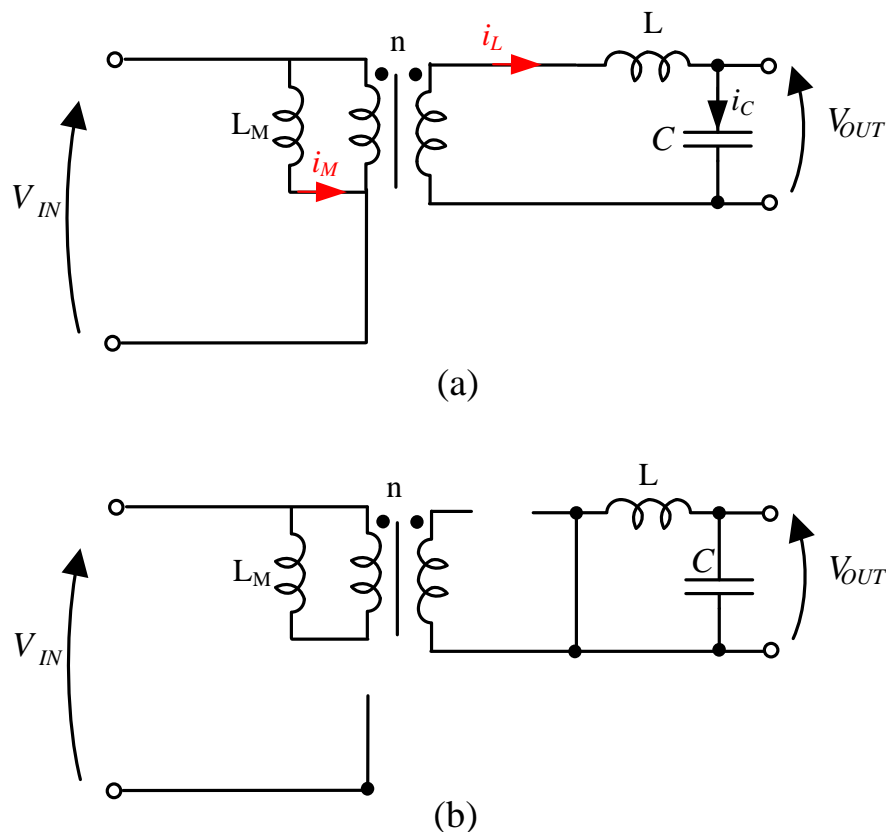


Figure 3.1– Equivalent circuits of the forward converter

In order to demonstrate operation principle the main waveforms are shown in Figure 3.2.

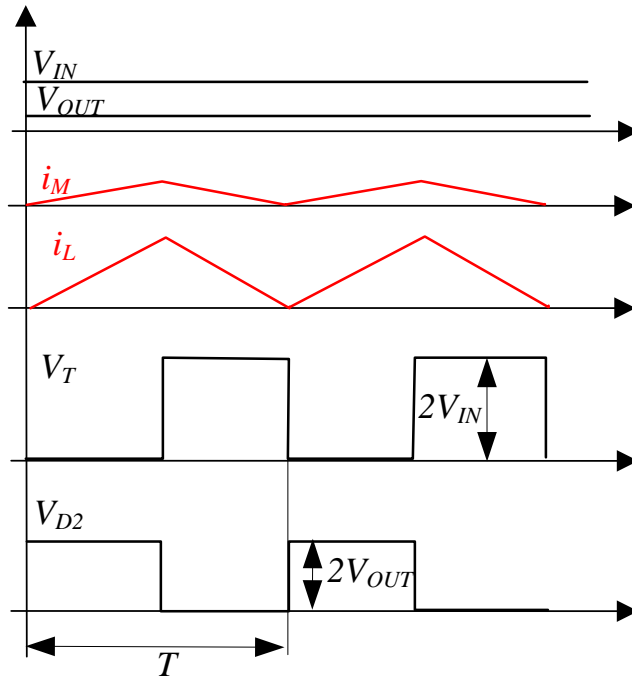


Figure 3.2 – Idealized waveforms

Calculating of the turns ratio for the transformer:

$$n = \frac{V_{IN}}{V_{OUT}} \left(\frac{\gamma}{1-\gamma} \right); \quad (3.1)$$

where γ - duty cycle of the switch signal. We will calculate n for the case, when $\gamma = 0.5$ and $V_{IN} = 72 \text{ V}$: $n = 72/12 = 6$.

It corresponds to the middle input voltage. It is assumed the duty cycle is in the middle point as well.

Calculating of the magnetizing inductance:

Taking into account that transformer is represented by equivalent circuit in *Figure 2.4* and neglecting leakage inductance, the peak to peak magnetizing current ripple can be represented:

$$\Delta I_m = \frac{V_{IN}}{L_m} \cdot \gamma \cdot T, \quad (3.2)$$

where T - switching period. $T = 1/F_s = 1/(20 \cdot 10^3) = 0.05 \text{ ms}$. It should be noted that value of magnetizing inductance should be as large as possible. In practical application it has finite value.

From another hand, the average input current is expressed as:

$$I_{IAV} = \frac{P}{V_{IN} \cdot \gamma}. \quad (3.3)$$

Finally $I_{IAV} = 100/(72 \cdot 0.5) = 2.78 \text{ A}$ and ripple factor is expressed as:

$$K = \frac{\Delta I_m}{I_{IAV}} = \frac{V_{IN}^2}{p \cdot L_m} \cdot \gamma^2 T. \quad (3.4)$$

Taking into account that ripple factor is predefined parameter, the magnetizing inductance can be expressed as:

$$L_m = \frac{V_{IN}^2}{K \cdot p} \cdot \gamma^2 T = \frac{72^2}{0.2 \cdot 100} \cdot 0.25 \cdot 50 \cdot 10^{-6} = 3.2 \text{ mH}. \quad (3.5)$$

Calculation of the output filter:

The required desired output voltage ripple factor K_{OUT} is defined as:

$$K_{OUT} = \frac{\Delta V_C}{V_{OUT}}. \quad (3.6)$$

The voltage ripple ΔV_C across the capacitor can be analyzed similarly. The capacitor voltage ripple can be expressed as:

$$\Delta V_C = \frac{1}{C} \int_0^{T\gamma} i_C(t) dt. \quad (3.7)$$

In order to find the required value of the capacitance of C to maintain the desired output voltage ripple factor the capacitor current has to be defined.

From *Figure 3.1b* it can be seen that capacitor current is defined by inductor current i_L and output current i_{OUT} :

$$i_C = i_{OUT} - i_L. \quad (3.8)$$

The ripple of inductor current can be defined from *Figure 3.2b* taking into account that output voltage is applied to the inductor:

$$\Delta I_L = \frac{V_{OUT}}{L} \cdot \gamma \cdot T, \quad (3.9)$$

Taking into account the condition that current can not drop to zero and taking into account power balance condition:

$$I_{OUT} = \frac{P}{V_{OUT}} = I_{AV}, \quad (3.10)$$

where I_{AV} is the average value of the inductor current. The value of output filter can be defined as:

$$L \geq \frac{V_{OUT}^2}{2 \cdot p} \cdot \gamma T = \frac{12^2}{2 \cdot 100} \cdot 0.5 \cdot 50 \cdot 10^{-6} = 18 \mu H. \quad (3.11)$$

$$C = \frac{\gamma^2 T^2}{4 \cdot L \cdot K_{OUT}} = 174 \mu F. \quad (3.12)$$

It can be seen that capacitor and inductor of the output filter has mutual influence on each other.

After passive components estimation, the semiconductors must be selected according to their peak values of the voltage and current. *Figure 3.2* shows that peak voltage on the secondary side diodes is equal to the double of the output voltage. Peak voltage of the transistor is equal to the double input voltage.

This type of semiconductors suits this application:

1. ALF08N20V MOSFET Transistor, N Channel, 8 A, 200 V;
2. STTH2002DI Fast / Ultrafast Diode, Single, 200 V, 20 A, 1.1 V, 16 ns, 175 A.

It should be noted, that in practical application the overrate is typically equal to the 1.4 and higher. Also, the final decision usually is a compromise between cost of semiconductors and efficiency.

4 Requirements for report

The home practice work should be framed according to the requirements ДСТУ 3008-95 and ЄСКД.

The structure of the report

Title page

On the title page indicate the name of the institution, department name, the name of discipline, name, who has done and verified the work, city and year.

Content

The home practice work's content, which should include all sections except the title page specifying the page numbers, is reproduced. Calculation part of report is divided on sections, that corresponding to the finish stages of the work. Page number on the title page is not specified, but when page numbering it is considered.

Goal and objectives letter

Individual task from the teacher to a student is given in this letter.

Calculation part

It consists of sections, each of which contains a description and the results of the task points of the home practice, given in section 3, also intermediate conclusions. Comments to the work must be sufficient in order the lecturer was confident in a student understanding the content of the performed work and features of the application used software packages. The number of significant digits in intermediate and final results should provide a compactness of record and high enough accuracy of calculations, which a student can estimate and cite in conclusions.

Conclusions

A detailed analysis of the work, its compliance with goals and objectives conducted. To make partial conclusions after each phase of the work is recommended, therefore the final conclusions will be generalizing and rather short. A student can note his own original solutions, additional calculations and validation, which emerged while he worked on the home practice, and suggestions for its improvement.

Reference list

Literature that has been used when performing calculations-graphic work is listed. Desirable the references in the working text were on them.

Recommended sources

1. Ефимов И.П. Источники питания РЭА, 2002. – 136 С.
2. <http://www.powerelectronicsconsultant.com>
3. Семенов Б.Ю. Силовая электроника. Для любителей и профессионалов. – Москва, 2001. – 340 С.
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6. Robert W. Erickson, Dragan Maksimović. Fundamentals of Power Electronics. Second edition. – Kluwer Academic Publishers. 2001. – 881 Pages.