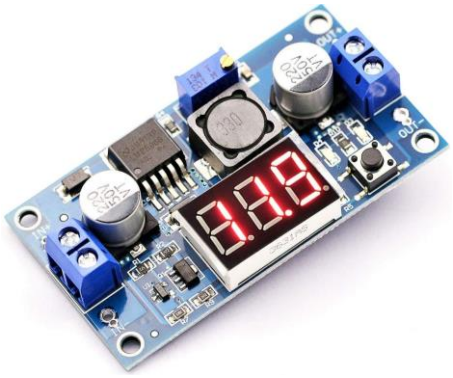
EE328 - Power Electronics Design Project

15V/2A Adjustable Power Supply

Objective:

The power supplies provide a dc voltage, i.e. +5V, +12V etc., for the active components in electrical circuits. They can also be used to charge the rechargeable batteries; such as lead-acid, Ni-MH or Li-ion. Adjustable types of the power supplies are essential equipment for experiments in laboratories. The objective of the project is to design, simulate a 15V/2A adjustable power supply.



Design Problem Statement:

Your design should not cause safety risk for the loads connected to the output. **Therefore, think about possible safety risks and learn how to protect the loads from those risks.** The cost should be as low as possible. Therefore, keep the BOM (Bill of Materials) price of your design as small as possible. Other design specifications are described below in detail.

Design requirements:

1. DC input voltage (Vin) is 24V±25%, i.e. between 18Vdc and 30Vdc.
2. The nominal DC output voltage (Vout) is 15V, but it will be adjustable between 1.5V to 15V by a potentiometer or trimpot.
3. If Vin<18V then the power supply should stop PWM operation which makes the output voltage is zero. For this purpose, an under-voltage lockout circuit should be designed and integrated into the your circuit.
4. The output voltage ripple must be lower than 0.5% at full load (i.e. $\Delta Vo_{p\text{-}p}$<75mV @15V). Consider the ESR of the output capacitor.
5. Short circuit protection (SCP): The device should be protected against the short circuit at the output terminal. After removing the short circuit, device should not start automatically. It should need a disconnection/reconnection procedure of the input voltage source to recover.
6. Overload protection (OVP): The device should be protected against overload. If the load current exceeds the maximum current limit of the power supply (i.e. 2A) for a certain period (at least >100ms) the power supply shutdown suddenly. After removing the overload, device should not start automatically. It should need a disconnection/reconnection procedure of the input voltage source to recover.
7. All the internal supply voltages (i.e. +3V3, +5V and +15V single-ended supplies etc.) required by the internal opamps etc. must be obtained from the input voltage Vin. Using an additional power source is not allowed. (Remember that the input voltage can be as high as 30 V!)
8. Switching mode converter topologies (Buck, buck-boost etc.) should be used in the design. Linear voltage regulator ICs, such as 78xx, LM317 etc., are not allowed.
9. Select suitable components (C, L, Mosfet, diode, opamp, potentiometer, trimpot etc.) from the market that fits your design. Explain in the report what are the reasons of your selection. Some of the online stores for electronic components are www.digikey.com, www.mouser.com, www.ozdisan.com etc.
10. Draw the circuit schematic by KiCad EDA schematic capture (www.kicad.org). Use the selected components from the market. If your component does not included in the schematic library, manually add it to the library.
11. Draw the 2 layer pcb board of the design using KiCad pcb layout. Obtain the 3D view of your pcb from KiCad pcb layout and include it in your report.
12. Generate a BOM list from KiCad EDA schematic capture (Printed circuit board (pcb), aluminum heatsinks, case, screws, bolts and cables etc. will be excluded in the BOM list.). The BOM list should include at least the part number (i.e. TL431 etc.), the schematic reference (i.e. C1, C2, R2 etc.), footprint

of the component (DPAK, SOIC8 etc.), the link to the datasheet page of component and US$ price for 1000 pcs.

13. Calculate the BOM price for your design. Target BOM cost for the design is 10$/converter for 1000 piece. Do not oversize the components, otherwise the BOM price may increase.

Proposal preparation:

- Prepare a proposal for the project, which contains brief information about the project, project team, design requirements, work plan, and project time schedule etc.
- Each team should consist of 3 students, and the task of each student should clearly be defined in the project proposal.
- Select one team member as contact person. The contact person will send the proposal and all other reports on behalf of the team.
- Give a short code name for your project team and use this name for all files. For example, "kelebek_proposal.docx" for proposals, "Kelebek_finalreport.zip" for final report etc.
- Please upload your proposal to the course website by **02.04.2023**

PSIM tests for the design verification (total 20 points):

- Please apply the following tests to your design using PSIM and show the results clearly in your report. Your design must successfully pass all the tests described below.

Test	Test procedure	Points
Test step #1: No load test	Set Vin=18V, Vout=15V and the load resistor is 10kΩ. Adjust the duty cycle and obtain Vo=1.5V and Vo=15V conditions separately. Repeat the test for Vin=30V. Take note the duty values for each test and compare them with the calculated values.	10p
Test step #2: Output voltage ripple test	Set Vin=30V, Vout=15V and the load resistor is 7.5Ω. Adjust the duty cycle so that the output voltage is constant at 15Vdc. The peak-to-peak output voltage ripple should be lower than 0.5% (ΔVo<75mV).	10p
		TOTAL: 20p

LTSPICE tests for the design verification (total 30 points):

- Please simulate your design using real components model in LTSPICE. Apply the following tests to your design and show the results clearly in your report. Your design must successfully pass all the test described below.

Test step #3: Output voltage ripple test #2	Set Vin=18V, Vout=15V and the load resistor is 7.5Ω. Adjust the duty cycle so that the output voltage is constant at 15Vdc. The peak-to-peak output voltage ripple should be lower than 0.5% (ΔVo<75mV). Compare the results with the PSIM results of test #2.	10p
Test step #4: Overload test	Set Vin=18V, Vout=15V and the load resistor is 7.5Ω. After 50ms of the simulation starts, another resistive load of 30Ω is connected in parallel to the load by an extra switch. The device should shutdown after 100ms.	10p
Test step #5: Short circuit test	Set Vin=18V, Vout=2V and the load resistor is 10Ω. After 50ms of the simulation starts, output terminals are short circuited by an extra switch. The power supply should shutdown suddenly.	5p
Test step #6: Under voltage lockout test	Set Vin=17V. The power supply should not start.	5p
		TOTAL: 30p

Project final report (30 points):

- The final report must include the followings;

a. A cover, which includes the course and project name, contact information of team members, duty of each member in the project.
b. Short information about the adjustable power supplies and its technologies**(5p)**
c. Introducing the switching converter topology which is used in the design. **(5p)**
d. Analytical design details and component selection calculations. **(10p)**
e. Verification of design using PSIM and LTSPICE (Tests described above). Compare the results at each step with the calculated values **(50p)**
f. The schematic and PCB (Top and bottom side view and 3D) of your design using KiCad EDA. **(10p)**
g. BOM list and total BOM cost of your design. The goal for BOM is lower than 10$. (The BOM list can be taken from the schematics of KiCad EDA) **(10p)**
h. Conclusion.

- **2 minute demonstration video (10 points):** Max. ~2 min. and 10 MB size. Team members should be listed at the beginning of video, and then design process should be explained shortly. After that, the laboratory test steps should be explained one by one. Each test should be explained by a different team member.

- **Project final report (*.pdf) + simulation files (*.psimsch, *.asc) + demo video (*.mp4)** should be submitted to the course web site as a zip file **until 21.05.2023**.

- IMPORTANT NOTE! The Project reports will be checked against plagiarism automatically by the Turnitin in Egeders. If the turnitin score of the report is higher than 20%, the report will not be accepted and design project score will be zero for that team. Please use your own words to reduce the Turnitin score.

Prof. Dr. Mutlu BOZTEPE, 20.03.2023

Note: If you would like to experience some practical application, you can order an adjustable power supply, then analyze and test its operation at your home. You can check the component values if they are suitable or not. You can use notebook charge adaptor as the input power source that generally has 19Vdc fixed output voltage.