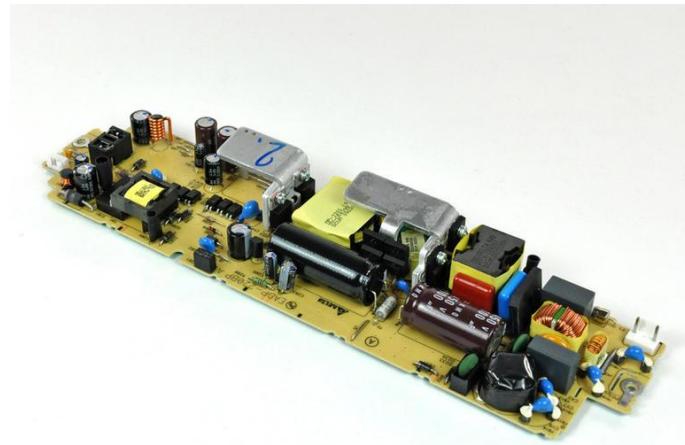




EEEEE2046: Energy Project Overview 2022-23

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1.0 Introduction

The Energy project complements a lot of the material covered in the first semester of the EEEE2045 module (Energy Conditioning and Control). During the project you will further your skills in the design, construction and testing of circuits, especially power electronics and particularly a Two Switch Forward DC/DC converter circuit.

This document is written as a guide to the project and gives information on its objectives. Although you will be given supporting documents and workshops in areas relevant to the project, you will not be given instructions in what to do. It is your job, as a group, to plan, research and execute the work required to meet all the project objectives.

2.0 Project Ethos

The aim of this project is not just to teach you practical power electronics and control. It is also to further develop your skillset as engineers. This includes group work, which is extremely common in all aspects of engineering. The planning of the project is down to you as a group- you will not be guided (at least not significantly) through the objectives required to complete the project.

Although, as stated above, the project is complemented by the content of EEEE2045 and the project workshops/lectures, this is not the only source of information. In some cases, as a group you will need to research solutions and methods for solving some of the problems. During each project week, you will work solely on the Energy project- how you use this time, and how you approach the objectives is completely your responsibility.

Remember, the whole year long project module is worth 40 credits- 20 credits for each project. This means that you should spend around 200 hours on the Energy project. As a result, you should be meeting regularly outside of the project weeks in order to keep the project progressing and to meet the submission deadlines for the project (see later).



3.0 Project Aim

The main aim of the project is to design, construct and test a fully controlled Two Switch Forward Converter with a regulated output voltage. This topology of Switch Mode Power Supply (SMPS) is very common in computing power supplies.

Figure 1 shows the concept. Here we have a 230V, 50Hz “mains” supply. This is stepped down to 30V using a 50Hz step down transformer. This step-down stage would normally be carried out at high frequencies inside the converter (see EEEE2045) but in this case it is utilised to give us an AC source which is at a safe voltage level for the undergraduate laboratory.

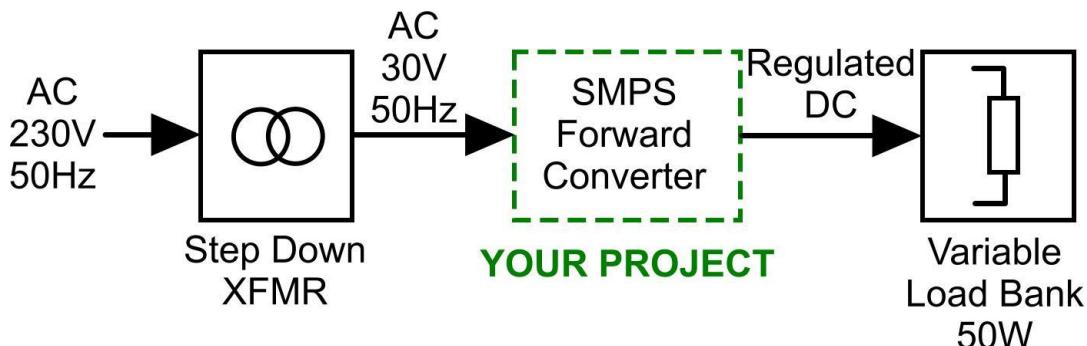


Figure 1- Project Block Diagram

This means that we essentially have a 30V (RMS), 50Hz AC input for our converter. After this AC source, we have the Switch Mode Power Supply (SMPS) that will be developed by each group. This is then connected to a 50W variable load bank. The overall aim of the project is to produce a stable, regulated output voltage across this load bank, regardless of the load applied (within the 50W limit).

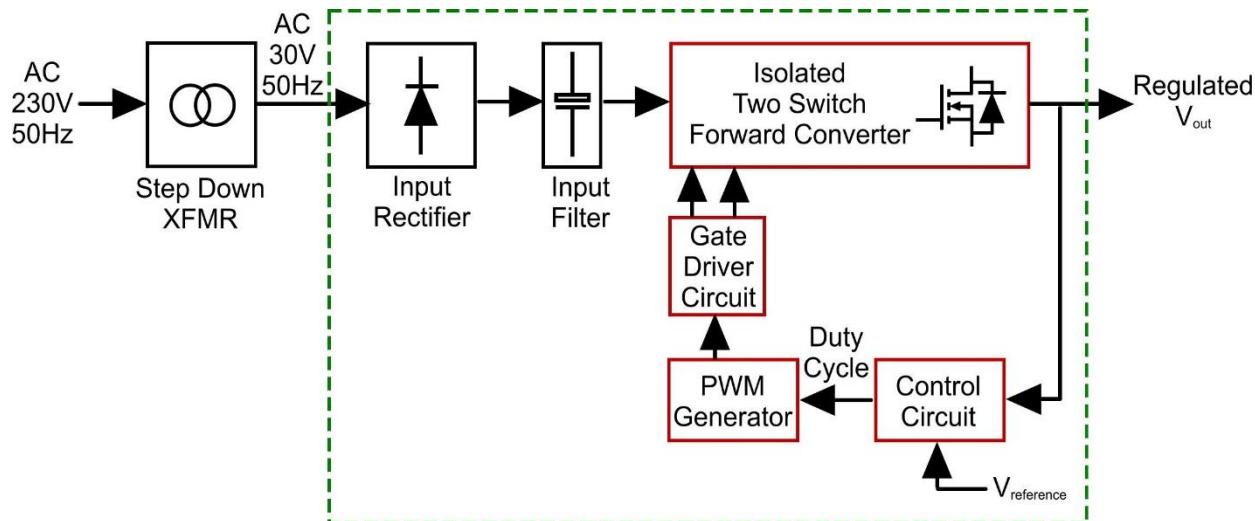


Figure 2- SMPS block diagram

A slightly more detailed block diagram is given in figure 2. Here, further components of the SMPS that will be designed and built are shown. This includes all the control and PWM generation hardware which is required to operate the circuit and meet the regulated output voltage objective.



4.0 SMPS Specification

The specification for the converter is given in the table below. Note that the group will need to make some engineering decision in some areas e.g., switching frequency, nominal duty cycle, transformer turns ratio etc. You must justify these decisions!

Power rating (P_{max})	50W
Input Voltage for basic testing	35Vdc
Input voltage AC (Step Down XFMR)	230Vac @ 50Hz- (30Vac isolated)
Output voltage	8Vdc
Output voltage ripple (peak to peak)	<0.1V
Load resistance at discontinuous output	R= Resistance @ 15% of P_{max}
Current threshold	
Switching Frequency	75 – 105kHz (Your choice!)

5.0 Project Objectives

The project comprises several objectives. Some weeks it may be possible to achieve more than one objective, some weeks less so. The practical objectives will be signed off at the end of the project (see later).

The main piece of simulation software that you will use in this project is PLECS. You should have come across PLECS when simulating and analysing simple passive circuits in year 1. During the Energy project, you will be using many more of the advanced features of PLECS- the software was originally designed for efficiently simulating switching power electronics.

The following sub-sections describe the main objectives of the project.

Objective 1 –Individual PCB Design for converter

Ki-Cad, an opensource schematic capture and PCB layout package will be used for this task. (see Moodle for support documents)

Each member of the group will design a two layer PCB of the power stages of the SMPS. The minimum required elements are: the input diode bridge, input capacitor, power MOSFETs and diodes, transformer, inductor, output diodes and output capacitor. A Ki-Cad schematic of the circuit will be provided, and you will need to design the PCB for this circuit. You will need to consider supply, load and gate drive connections (for example). There will be some slides and handouts on Moodle to support this work- you should follow the advice given carefully.

Each member of the group will produce a PCB and this will be marked according to the rubric for the PCB task (this will be made available). Once submitted the group PCBs will be checked by an assessor who will pick the one with the least number of mistakes for manufacture. You will be individually marked for your submissions but will only have the one we select manufactured. This work is set before the project begins to allow us to have the PCBs manufactured and returned for use by the second project week.



Objective 2 – Simulation: Open Loop Converter

You will first need to do some analysis to determine the values for the main components in the circuit- duty cycle, transformer turns ratio, output filter components. You will have to refer to your notes from semester one of EEEE2045 (Jon Clare's notes).

Once designed, you will then create a simulation using PLECS to validate your converter design with a 35V dc input voltage source. For this objective, there is no requirement for feedback control and the duty cycle of the switches can be manually varied to explore the operation of the circuit and the component values you have selected through your analysis.

Once satisfied that your converter is working you should make the circuit more realistic by using real values for voltage drops etc. on the passive and active components. The result of the inclusion of these components will be clear, make sure that you understand what is happening.

Finally, you should add the transformer and rectifier as the input circuit (remove the dc source and replace with a capacitor) and test operation again. Does the inclusion of the AC derived affect anything?

Objective 3 – Simulation/Practical: Gate Driver and PWM circuit, thermal analysis in PLECS

For this objective you will design, simulate and construct gate driver and PWM generation circuits. This will form part of your SMPS control circuitry and will be required to be used during later objectives. The design and construction of a magnetic component (gate drive transformer) will be required (see supporting documents). Finally, you must use appropriate waveform values from PLECS to determine (calculate) the size of heatsink that you think the circuit would need for the semiconductors.

Objective 4 – Practical: Individual PCB Design for converter, magnetics design and build

Study the documents on the main transformer and inductor design- build and test these components using the LCR bridge in the lab. The design of the transformer and the inductor must be verified using the magnetic components available in PLECS.

Objective 5 – Practical: Populate the PCB and test

For this task you will have received your group manufactured PCB. Populate this and test “open loop” as you have in your objective 2 simulations. Think about the best way to approach populating and testing this board- remember issues you may have had in the year one practical work and during semester one of this module.

Objective 6– Simulation: Closed Loop Output Voltage Control

For this objective you will further develop your open loop simulation by application of suitable feedback methods to control the output voltage (see support documents). The output voltage should be maintained within specification under changes in load. The supply can be implemented as an ideal 35 V dc voltage source initially. Then, once satisfied with its operation- change to the rectified ac source and verify operation. For the design of the control components, you will need to use Matlab- see support documents.



Objective 7 – Practical: Closed Loop voltage control

Finally, you will implement your closed loop control design on the control board (this will be provided) experimentally, collect results and make measurements to validate your control design. This can be done using the bench top power supply as the power source. Note that the bench power supply will not be able to provide full power to the load. Once satisfied with results, change to the rectified AC source, and re-validate.

6.0 Learning Resources

Along with the EEEE2045 lectures on Power Electronics and Control, the project will be supported by several document packs that will be uploaded onto Moodle as the project progresses. These are:

- PCB Design support documents
- Week 1 Worksheet
- PWM Generation and Gate Driver Circuit
- Gate Drive Transformer
- Main Transformer Design
- Inductor Design
- Forward Converter Control

There are also other documents and videos on the Moodle page which may be helpful for the project. Make sure you fully explore Moodle! Also, make sure you attend all of the project workshop lectures.

7.0 Project Organisation and Planning

The release of the project guidance documents will give you a hint as to how the project should be progressing. The following should be used as a guide (plan your own project!!):

Project Week 4	Objectives 1 & 2
Project Week 5	Objectives 3 & 4
Project Week 6	Objectives 5 & 6

Note that there are also firm deadlines scattered across these project weeks (see next section). These submissions will be assessed and as a result, failure to submit will incur the usual coursework penalties. You are responsible for planning and executing the work each week.



8.0 Assessments

The assessments for the project, as well as their deadlines, are given below:

Energy Project Assessments			
ID	Type	Weighting	Assessment Due
Viva Voce	Project Viva	40%	Spring Exam Period
CW1	Individual PCB Design	15%	8/2/23 3pm
CW2	Group converter design report	15%	22/2/23 3pm
Practical A	Individual Demonstration of hardware	15%	w/c 8/5/23
Practical B	Final Functionality and Construction quality	15%	w/c 8/5/23

These deadlines must be met, or the standard penalties will be applied for late submissions. Some of these submissions will be made on Moodle- details will be given during the project.

Assessment Details

The following is a breakdown of the requirements for the assessments listed above.

- 40% Project viva voce**

The main individual assessment for the energy project will be an individual viva. This will take the form of a 20-minute informal interview where you will be asked questions about the project work and your design decisions.

- 15% Individual PCB Design**

You will be given a schematic for the two-switch forward converter which you must use to design a PCB for this circuit. Every group member will submit a PCB design and receive an individual mark. The PCB from each group with the highest mark will be sent for production. This will be populated and tested as part of the practical objectives.

- 15% Group converter design report**

Report summarising and justifying your design choices, component values and selection. Initial open loop simulation results verifying your design are to be presented. You should demonstrate that your converter can operate at minimum and maximum load and with both the dc and transformer fed input. A comparison should be made for the ideal simulation and the one with realistic components. More details are available on the week one handout.

- 15% Practical A: Individual Demonstration of Hardware**

At the end of the project the groups will set up their experimental hardware. Each member of the group, individually, will then show the operation of the converter working and answer questions on the various elements of the practical work. An individual mark will be given, based on this discussion. More details will follow towards the end for the project.

- 15% Practical B: Final Functionality and Construction Quality**

As part of the Practical A assessment the group will be given a mark based on the quality level of the construction and the successful operation of the circuit.



9.0 Project Components

Below is a list of the components that will be available for use in the project. In some cases, there are choices that need to be made between various components that have the same functionality. Components chosen for use on the PCB will be assessed as part of the PCB task- not all of the components available are a good choice for the application!

Type	Part Number
MOSFET	FDS89141
MOSFET	IRFI530NPBF
Diode	BYV25FX-600
Diode	BYG20J
Rectifier	VS-KBPC606PBF
Rectifier	MBRB3030CTLG
Rectifier	STPS20H100CFP
Rectifier	NTSJ20100CTG
Capacitor	ECA2AM102
Capacitor	ECA2AM471
IC	TC4425AVPA
IC	UC3524AN
IC	ACS712ELCTR-05B-T

Type	Part Number
Toroid Core	TN13/7.5/5-3C90
Toroid Core	TN14/9/5-3C90
ETD 34 Core	B66361G0000X187
ETD 34 Core	B66361G0500X187
ETD 34 Core	B66361G1000X187
Winding Wire	EN 60317/20 20 AWG
Winding Wire	EN 60317/20 21 AWG
Winding Wire	EN 60317/20 23 AWG
Winding Wire	EN 60317/20 26 AWG
Winding Wire	EN 60317/20 28 AWG
Winding Wire	EN 60317/20 30 AWG
Winding Wire	EN 60317/20 32 AWG
Transformer	100VA 2 Output 30V ac
Resistor	W24-22RJI

**Dr Al Watson,
Updated January 2023**



Appendix A

AC Supply

Figure A1 shows the schematic of the AC supply that will be used for full power testing in the project.

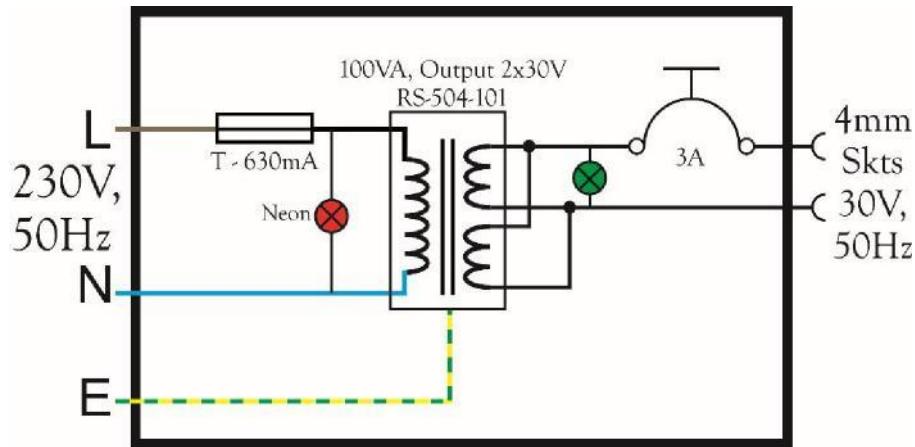


Figure A1: AC based supply for converter testing

Output Load Bank

The schematic of the load bank which is required for testing the power supply circuit is shown in figure A2 below.

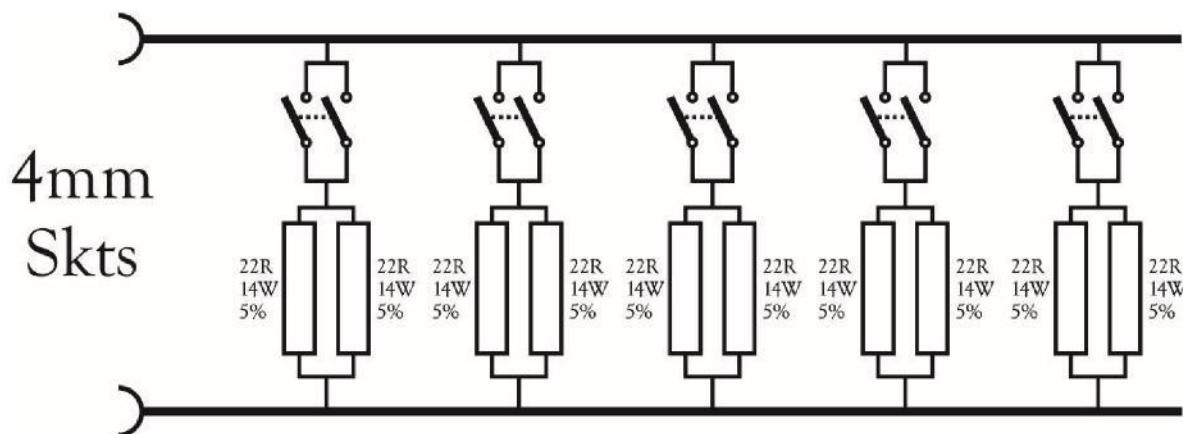


Figure A2: Load configuration for testing the power supply