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Practical Project in Linear Design Course During COVID-19

Dr. Kenny Fotouhi, University of Maryland Eastern Shore
Mahdi Joseph Fotouhi, University of Maryland Eastern Shore
Joel Michael Tomlinson, University of Maryland Eastern Shore

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Abstract

Practical project design in the Linear Course in the Department of Computer Science and Engineering Technology is intended to be a real-world experience to help students to gain knowledge during the step-by-step project performance from beginning to completion. This would allow them to build confidence, a sense of accomplishment, and ownership and makes them prepared and ready for taking the next design course in the following semester.

The highlight of this paper demonstrates challenges and accomplishments of students and faculty performing a hands-on design project during the COVID-19 pandemic. As many engineering and technology courses rapidly transitioned to online or distance learning modality, the struggle to generate the same active learning environment online was challenging. After students returned to on-campus courses in hybrid or socially distanced laboratories, the learning environment was modified to reflect this change as well.

The project is selected to be challenging in regards to high current delivery and has a practical application with other laboratory experiences, with the following output voltages, currents, Load Regulation (+/- 5%), and Line Regulation (+/- 10%) requirements.

i. + 9V at 1.5A,
ii. -9V at 1.5A,
iii. and 5V at 2A.

In order for students to accomplish their projects, they would be expected to follow the required steps and procedures and utilize the knowledge and experiences they have gained:

i. Design the project using circuit analysis to come up with the required components,
ii. Specify parts and components,
iii. Order parts using an online catalog,
iv. Cost analysis,
v. Design the layout,
vi. Assemble the parts and components,
vii. Test and verify the completed project's performances following the given percentage of regulation, and
viii. Submit a written report according to the *Journal of Computers in Education*.

This paper describes students' projects, details of their experience and the successes, and effects of COVID-19 on their projects and lesson learned, and shows a few pictures of the finished products.

Keywords: engineering technology, engineering design process, DC regulated power supply, capstone course, Covid-19

Introduction:

According to George Dieter (2013), a Fellow and the Past President of the American Society for Engineering Education (ASEE), there are many different types of designs for different reasons as follows:

- Innovation Design - to achieve a need or create a seed of new technology,
- Adaptive Design - to satisfy new solutions to the existing needs,
- Redesign - to improve the existing project with lower cost or better shape or lower weight, and
- Selection Design - to employ different supplies/vendors to have higher quality, lower cost, and better performances.

He summarized "the challenges presented by design environment is to think of the four C's of design:

Creativity

- Requires the creation of something that has not existed or existed in the designer's mind.

Complexity

- Requires a decision on many variables and parameters.

Choice

- Requires making choices between many possible solutions at all levels from basic concept to the smallest detail of the shape.

Compromise

- Requires balancing multiple and sometimes conflicting requirements." [1]

Virtually all electronic devices in today's electronic equipment are powered by DC sources, some by battery and others by a DC power supply. Much of this equipment requires not only a reliable DC source but one that is well-regulated and filtered. The quality of a power supply determines how the device will function and operate properly.

This paper will explain and demonstrate how to utilize the engineering design process from the beginning to a successful design and construct a variable DC-regulated power supply and case enclosure.

Design of the Project

The ideal DC power supply would generate a constant voltage output regardless of the variation in the power line, load current capabilities, high efficiency, and cost-efficient.

The necessary main components of this project are:

- Step-down transformer: converting the AC line to the lower, safer and desirable voltages,
- Rectification: converting the incoming AC line to DC voltage,
- Filtration: smoothing out the ripple during rectification,

- Regulation: control the output to a constant value irrespective of line, load, and temperature changes, and
- Power Supply Casing: the housing of all assembled components within a physical box for ease of transport.

Student Project Development During the Covid-19 Pandemic

The Covid-19 pandemic negatively impacted many aspects of secondary and post-secondary education institutions. Many higher education institutions rapidly navigated to new instructional methods for teaching project-based learning courses. This modified pedagogy changed how students managed project time, received and reviewed instructional materials, and competition of tasks and assignments. An engineering design course study by Miranda et al. (2022) suggests the Covid-19 pandemic negatively impacted design courses due to the historical pedagogy of instructor-led courses not focusing on self-regulated learning.

Students in a linear design course very closely interact with the instructor for assignment and completion goals and objectives of the course. The research study Miranda et al. (2022) does indicate self-regulated learning is an important aspect of student learning in a design course. The study indicated the Covid-19 pandemic did increase the efficacy of student-regulated learning in a linear design course

Circuit Analysis

Since there are three distinct voltage outputs in this project, to reduce the redundancy, a sample of calculation is done here for +9 V supply to show how the selection of components is carried out here.

A 120/24 Volt center-tapped transformer is selected. The secondary voltages that is converted to DC voltages would be:

- V_{DC} = [Sqr (2) x 12v – 0.7] = 16.27V

With +/-10% high Line Regulation in AC line:

- V_{DC} = [Sqr (2) x1.1(12) -0.7] =17.97V
- V_{DC} = [Sqr (2)x.9(12) -0.7] = 14.57V

The variable voltage regulator of LM 317 is selected for +9 V. LM 317- TO-3 Metal packaging has an output voltage that varies from +1.2 to +37V with a max current of 2.5A with a typical load current of 1.5 A. The max input-output voltage differential for LM 317 is about 40V and the minimum would be 3V. It is assumed the minimum voltage drop across any regulator should be 3V.

To determine the remaining circuits' value and selection of components are as follows

i. Diodes with 3A are selected for all rectification that provides a minimum of 150% to 200% safety operation.
ii. Surge resistor R_S= 17.97/30 A= 0.6 Ohm.

The minimum input voltage to the regulator to produce an output of +9V would be +12V and the minimum DC voltage of the rectification circuit is 14.57V which would allow a maximum ripple on the filter capacitor (14.57-12V) of 2.57V.

To determine the size of capacitor C = (1.5A x 8ms)/ 2.57V = 4669 uF, the 4700 uF is selected. The regulator power dissipation of and capacitor calculation to smooth ripple for other voltages and of heat-sink section and size also is carried out by students.

Since the LM 317 is a viable regulator, the output voltage is determined by using a potentiometer of R_2 and fixed resistor of 220 Ohm as shown in circuit $V_{out} = V_{Ref} (1+ R_2/R_1)$. Following is a sample circuit designed by a student

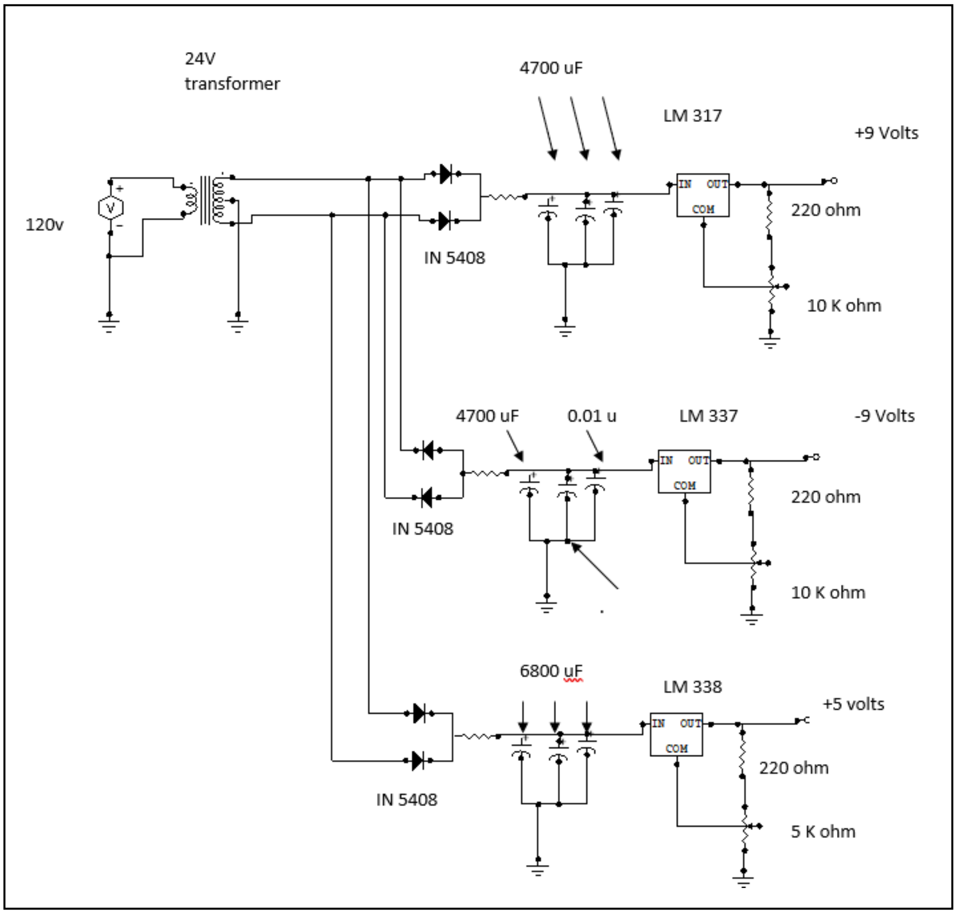

Figure 1 ***Power Supply Design Schematic using CAD***

Upon completion of the calculations and schematic design, the students are tasked with developing Bill of Materials (BOM). The BOM is derived from manufacturer catalogs and online manufacturer data sheets provided by electronic component and part distributors. The criteria for the BOM development are the following:

1. Student name and BOM title
2. Vendor Name and Contact Information
3. Description of the component or part.
4. Part number
5. Manufacturer number.
6. Quantity
7. Single item cost
8. Total cost.

Power Supply: Bill of Material Example

			Design Challenge			
		Parts List Regulated Power Supply				
Company Name: Jameco						
Company Telephone: 1-800-831-4242						
		Address: Jameco Electronics1355 Shoreway RdBelmont, CA 94002				
No.	Description	Part #	Manufacturer #	Qty	Cost	Total
1	24 CT	221365	GTR-22404	1	$29.95	$29.95
2	Rocker Switch	316048	R13-66B-G-02	1	$1.49	$1.49
3	Recovery Rectifier	677812	1N5408G	6	$0.13	$0.78
4	Fuse AGC 3A	69439	FUSE 3A-R	1	$0.39	$0.39
5	3AG Fuse Block	1711963	03540801ZXGY	1	$1.49	$1.49
6	Electrolytic	609553	UVZ1H102MHD	2	$0.89	$1.78
7	Electrolytic	158432	R2200B50-R	1	$1.59	$1.59
8	Electrolytic	29831	R1/50	3	$0.16	$0.48
9	Linear Adjustable	192284	LM338T	2	$2.19	$4.38
10	AdjustableRegulat	23819	LM337T	1	$0.75	$0.75
11	TO-220 Heat	326713	531102B02500	3	$0.99	$2.97
12	Bare Phenolic	616690	22-516	1	$4.19	$4.19
13	Connector Barrier	230990	4-140	4	$4.25	$9.96
14	Ohm 1/2W	29197	24N-5K-15R-R	3	$1.59	$4.77
Company Name: Amazon						
Company Telephone: 1 (866) 749-7538						
	Address: 410 Terry Ave N, Seattle 98109, WA					
15	Power Plug	AMI-M11AG-1S-6-B	Altran Magnetics	1	$5.85	$5.85
16	Wire Termi Crimp	B01M0QT0MF	Elite.M	1	$14.68	$14.68
17	Output Plug Jack	B01G0PLING	Cess	1	$8.49	$8.49
Company Name: Digikey						
Company Telephone: 1 (800)-344-4539						
	Address: 701 Brooks Avenue South, Thief River Falls, MN 56701 USA					
18	RES 0.68 OHM			10	$0.55	$5.59
	Total Cost				$99.58	

Table 1. *Power Supply: Bill of Material Example*

The next step of the project is to design an enclosure to house all components. This step is done based on students' creativities, innovations, the uniqueness of their design and the personal choices to arrange their components and assemble them to complete the project.

Following are a few examples of the finished designed Power Supply design with housing enclosures.

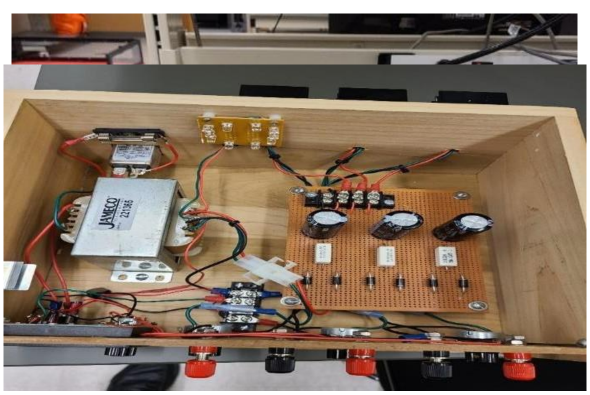

Figure 2: ***Student power supply design: example 1***

Figure 3: ***Student power supply enclosure design: example 2***

Figure 4: ***Student power supply enclosure design: example 3***

Figure 5: ***Student power supply enclosure design: example 4***

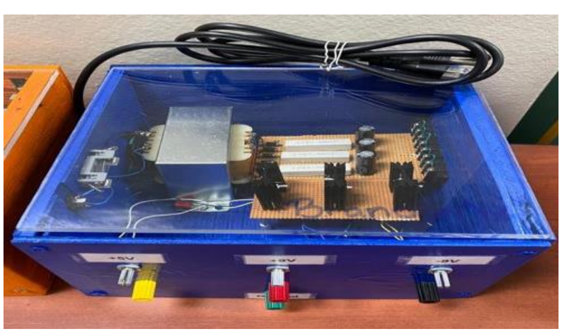

Figure 6: ***Student power supply enclosure design: example 5***

Figure 7: ***Student power supply enclosure design: example 6***

Data Collection and Verification

To effectively achieve the completion of the DC-regulated power supply, it is required to run tests to confirm that the students actually completed the projects successfully as intended and verify its performance and functionality. All three voltage outputs (-9V, 9V, and 5V) are tested unloaded, and then loaded. A Fluke digital multimeter (DMM) is used to verify the output. The verification of the power supply capability delivers **1.5 A for one minute for +9V and -9V.** A simple loading circuit of 6 individual 1- Ohm, high power wire wounded, 10W resistor in series is used. To verify the supply of **5V with 2A for one minute**, another loading circuit is made of multiple high-power resistors equivalent to 2.5-ohms.

Following are two tables of verification of the power supply's performance with regards to unloaded and loaded of the different output voltages:

Table 2: ***Results from Unloaded and Loaded Tests.***

	-9V	+9V	+5V
Unloaded	-8.98V	+8.99V	+5.01V
Loaded	-8.92V	+8.80V	+4.97V

Table 3: Percentage of Load Regulation

	-9V	+9V	+5V
Loaded	0.66%	-2.1%	0.79%

The data gathered and exhibited on both tables provides proof that the project design criteria was met for each output. The measurements in Table 1 show the voltage drops during ***one-minute*** test runs. Table 2 demonstrates the load regulation calculations and proves that the percentages are low and acceptable. This means the results are practically accurate and acceptable and the goal of successfully design, constructing, and verification is accomplished.

Project Evaluation

The following rubric was developed to evaluate the students' project's accomplishments.

Figure 10: ***Student Design Grading Rubric***

Linear Circuit Design Grading Rubric

Name:________________________________ **Date:** ______________________________

Category	Scoring Criteria	Total Points	Score
Project Completion	The project was completed and finalized by 10/30/20.	25	
Planning	The student has two completed progress reports.	10	
	A prototype phase was implemented before final design.	15	
Operation	Less than 5% voltage drop after 30 Seconds on +9V @ 1.5A	25	
	Less than 5% voltage drop after 30 seconds on -9V @ 1.5A	25	
	Less than 5% voltage drop after 30 seconds on +5V @ 2A	25	
Design Organization and Parameters	The box dimensions were 8in by 8in by 5in tall	5	
	All wired connections are sealed, secured, or capped	5	
	No exposed leads of components that could cause a potential short	5	
	All components are secured and not susceptible to vibration	5	
	The input voltage to the transformer has an inline fuse.	5	
Score	**Total Points**	**150**	

OBSERVATION and CONCLUSION

This project is the first exposure of the students to many expectations of any real-world project demands, designs, ordering parts, and all other expectations.

Lessons learned:

1. In order to reduce the danger and risk as well as prevent harm to students, the use of the electrical saw and other dangerous machines in the laboratory was limited to the faculty and laboratory technicians to help students with their need of cutting for their power supply enclosure.

2. For a better appearance, the power supply enclosure is made from PVC. Dimensions were 8-inch length 8-inch width and 5-inch height. The enclosure is a housing for the step-down transformer, rectifier, DC filter, and a regulator. With this information, a schematic was developed and assisted in mapping out a circuit plan. The case was prefabricated by the instructor which ensures accuracy.

3. Students created social and technical support structures for this design project differed from pre-COVID 19 classes. Since students are social distanced, the social invitation to examine or assist in identifying faults or issues was limited. The linear circuits design course during Covid-19 courses demonstrated limited or modified student interactions pertaining small work groups of students analyzing, discussing, and strategizing design methodologies. This event led to a more idea and design innovation on the individual learner as opposed to the collective.

Students' Perspectives on the Project

1. The total duration of time to research, design, construct, and test the power supply is 15 weeks.

2. My lack of knowledge and experience with making a DC-regulated power supply could result in potential complications.

3. The power supply must not exceed 120VAC or an electrical failure could occur.

4. The power supply must have three output terminals of 9V @ 1.5A, -9V@ 1.5A, and 5V@ 2A to properly function.

5. The power supply case must be 8 inches in width, 8 inches in length, and 5 inches in height or the power supply will not properly fit.

6. The potential quality of materials could affect the desired outcome.

7. There was no set budget for the project, so this leaves the possibility of a lack or abundance of supplies.

8. Due to Covid-19, there is a lot of uncertainties in whether we will have access to

resources to successfully complete the project.

In conclusion: The practical project in linear design course, was intended to be a challenging, practical and exposure them to real-world projects, demands and expectations. It provided them with methodology and opportunity for students to figure out how to go about to convert unregulated AC to DC to ensure that the output remains constant even if the input changes still outputs have to stay constant with given regulation. The parameters given included three output terminals of 9 Volts at 1.5 Amps, -9 Volts at 1.5 Amps, and 5 Volts at 2 Amps and designing a housing and carrying case. After completion of project students learn following tasks, and how to:

- Design the project using circuit analysis to come up with a required component,
- Specify parts and component,
- Cost analysis,
- Order parts using on-line catalog,
- Design the layout,
- Assemble the parts and component,
- Test and verify the completed project's performances following the given percentage of regulation, and
- Submit a written report according to the *Journal of Computers in Education.*

At the beginning of projects there many questions and frustrations with their designed power supplies, because they did not perform as expected and did not deliver the expected currents and they have to change components and heatsink to make them to verify their performance. On a positive note students who succeed projects as it were expected many of them, would like to keep the project as personal use or show it to future employers.

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