Affordable Power Supply

DESIGN DOCUMENT

Team 47
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Executive Summary

Development Standards & Practices Used

We will be using both passive and active components for this project, along with linear and switch-mode voltage regulators. The software practices we will use the programming language C to program the microcontroller for our project.

Summary of Requirements

- Input Voltage
    - $24V_{RMS}$AC wall supply
- 4 voltage outputs
    - 2 to 25 VDC
        - 1.5 A max current
        - Standard binding posts output connector
    - -2 to -25VDC
        - 1.5 A max current
        - Standard binding post output connector
    - 0 to 10VDC
        - 1 A max current
        - Standard binding post output connector
    - Fixed 5 VDC
        - 2 A max current
        - Standard USB type A output connector
- Box dimensions of 7 inches long, 4 inches wide, 2 inches deep
- Output display to display the voltage levels

Applicable Courses from Iowa State University Curriculum

EE201, EE230, EE333, EE330

New Skills/Knowledge acquired that was not taught in courses

Selecting a case for the PCB, using a CNC machine, laying out a PCB, designing hardware to support a microcontroller.

Table of Contents

List of figures/tables/symbols/definitions (This should be the similar to the project plan)

1 Introduction

1.1 Acknowledgement

Our team would like to say thank you to Professor Tuttle for advising and financial support in our project. We appreciate all the advice he has given and look forward to working with him more.

1.2 Problem and Project Statement

With Covid-19 limiting lab availability to students, it is difficult for electrical engineering students to work with any hardware because they do not have power supplies to test their circuits. It would be beneficial for students studying electrical engineering to have access to a power supply at home during this pandemic.

The solution for this problem is to design an affordable power supply with a small form factor that any electrical engineering student can easily build and operate from home. This will allow students to perform any hardware labs for their electrical engineering courses without requiring access to an on-campus lab.

1.3 Operational Environment

The operational environment of the power supply will be a students dorm or apartment. These locations may not be as clean and orderly as lab spaces, so the device should be rugged enough to survive being moved frequently. It may also be exposed to other hazards not found in labs such as food and liquids.

1.4 Requirements

The power supply will have four voltage outputs: 1.5 to 25 VDC (1.5A max current), -1,5 to 25VDC (1.5A max current), 0 to 10VDC (1A max current), and 5VDC fixed output (2A max current). The three variable outputs will be accessible through binding posts. The fixed output will be a standard USB type A. The input for the power supply will be a 24-V_{RMS}AC wall supply, with at least 100W input power.

The power supply will have a microcontroller to display output voltage levels, which will be controlled using a rotary encoder. The unit will fit in a case approximately 7 inches long, 4 inches wide, and 2 inches deep. The final cost of the unit should be below 100 dollars.

1.5 Intended Users and Uses

The intended users of the product are electrical and computer engineering students. The uses for the product are to test hardware for electrical and computer engineering courses, more specifically for the hardware laboratories within the courses.

1.6 Assumptions and Limitations

Assumptions:

- The students have some background knowledge on power supplies and how to properly operate them.
- The product will not be used outdoors.
- The end product will be assembled by the ETG, to avoid any malfunctions of the product.

Limitations:

- The end product will be no larger than 8”x5”x3”
    - Client requirement.
- The product cost will not exceed a hundred dollars.
    - Client requirements

1.7 Expected End Product and Deliverables

The deliverables for our product are a working prototype of the product, an instruction manual for building the power supply and how to use it. The prototype will meet all the requirements specified previously. It will come with a PCB, complete set of parts, and a box.

The instruction manual will consist of the list of parts needed to build the power supply and where to purchase them. It will also include a list of instructions for building the power supply and how to operate it.

2 Project Plan

2.1 Task Decomposition

The main tasks that need to be completed for the project are designing the circuitry for the power supply, designing the case for the PCB, setting up and coding the microcontroller, and writing the instruction manual.

The main parts of the circuitry that will need to be designed are the linear regulator circuitry, switch mode regulator circuitry, and microcontroller I/O circuitry.

For designing the case, we will need to design a heat dissipation module to keep our components temperature low, along with the user interface design and placement. Another task to complete on the case is the placement of the PCB and other components to fit into the case.

As for coding the microcontroller, we will need to include initialization, operational code, and fault detection

The instruction manual tasks will consist of creating a list of parts needed to build and operate the power supply. We will also need to create a procedure on how to put together the device, along with how to properly and safely operate it.

2.2 Risks And Risk Management/Mitigation

For circuit design, the main risks are heat dissipation problems for the linear regulators and voltage accuracy and ripple problems for the switching regulators. The probability of these causing operational errors is low, probably around 0.2.

For designing the case, the risks are that the PCB will not fit inside the case with components, or that heat will not properly be dissipated out of the box. The probability of these causing functional errors is also low, around 0.1 if we design our PCB carefully.

For the microcontroller, the risks are that there will be bugs in the code that will not be found in standard testing. The probability of these errors is much higher, most likely around 0.7. In order to tackle this risk, we will need to complete thorough testing of our microcontroller code, including testing multiple inputs and outputs and edge cases.

For the instruction manual, the biggest risks are that our instructions will be hard to understand or misinterpreted, leading to a user error that damages the system. This risk is moderately high, at an estimated probability of 0.5. The best way we can combat this is by making our users manual as clear as possible, and by testing it on actual students in order to observe what common mistakes may be made and how to circumvent them.

2.3 Project Proposed Milestones, Metrics, and Evaluation Criteria

The key milestones for our project will be completing each circuit design element and testing them to ensure accuracy, designing and buying a PCB for our project, coding and testing the microcontroller and display, completing the build of the prototype, and completing the instruction manual. For the circuit design completion, we expect the output voltages to be within a tenth of a volt of the expected output. As for the PCB, we expect it to be fully operational and expect it to fit inside the box.

For the microcontroller and its code we expect the display and rotary encoder to be functional and accurately displays the voltage. The prototype must meet all the requirements and be completely built. This includes the PCB, the user interface and accurate testing results. The instruction manual evaluation will be done by our advisor to verify the information is accurate and easy for the user to interpret.

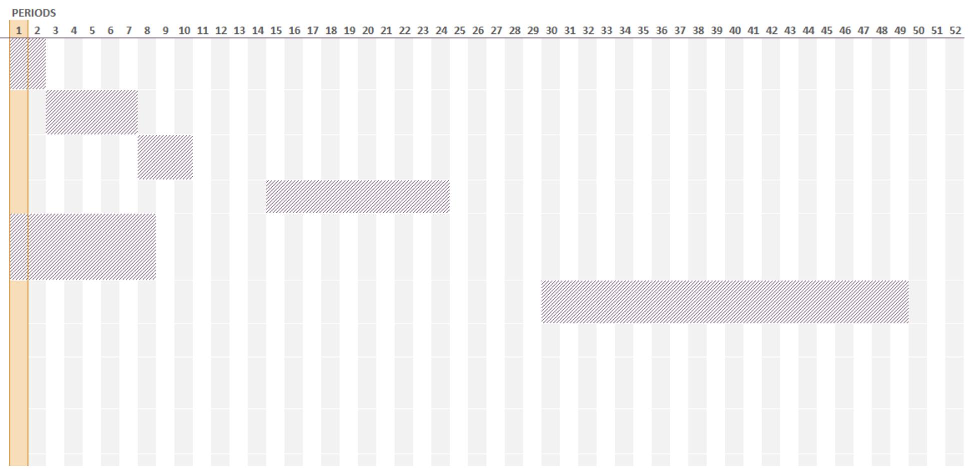
2.4 Project Timeline/Schedule

Project Planner

Select a period to highlight at right. A legend describing the charting follows.

Period Highlight: 1 | Plan Duration | Actual Start | % Complete | Actual (beyond plan) | % Complete (beyond plan)

ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Linear Regulator schematic capture	1	2	1	NA	25%
Swithing regulator schematic capture	3	5	NA	NA	0%
Microcontroller schematic capture	8	3	NA	NA	0%
PCB Layout	15	10	NA	NA	0%
Case selected and mechanical design complete	1	8	1	NA	15%
Mircocontroller programmed	30	20	NA	NA	0%
Build Prototype	60	10	NA	NA	0%
Test and debug prototype	75	15	NA	NA	0%
Write intrustion manual	100	10	NA	NA	0%



2.5 Project Tracking Procedures

The software used to communicate between group members has been google hangouts. To track our progress on each task, an excel spreadsheet was created in google drive to assign tasks to group members and track their progress. For our files, we have chosen to store them in google drive as well so all members have access to all files.

2.6 Personnel Effort Requirements

Include a detailed estimate in the form of a table accompanied by a textual reference and explanation. This estimate shall be done on a task-by-task basis and should be the projected effort in total number of person-hours required to perform the task.

List of tasks	Estimated hours to complete
Linear regulator schematic capture	2

Switching regulator schematic capture	5
Microcontroller schematic capture	3
PCB layout	10
Case selected and mechanical design completed	8
Microcontroller programmed	20
Build prototype	10
Test and debug prototype	15
Instruction manual written	10

2.7 Other Resource Requirements

Our project will require a power supply, a fabricated prototype PCB, all electrical components, a case, output connectors, soldering equipment, and electrical test equipment.

2.8 Financial Requirements

The main financial requirement consists of purchasing the parts needed for the prototype, along with any parts needed for testing. This includes basic components (resistors, capacitors, and operational amplifiers), the case, microcontroller and other components needed for the project. Another cost will be purchasing a fabricated PCB for our prototype.

3 Design

3.1 Previous Work And Literature

Include relevant background/literature review for the project

– If similar products exist in the market, describe what has already been done

– If you are following previous work, cite that and discuss the **advantages/shortcomings**

– Note that while you are not expected to "compete" with other existing products / research groups, you should be able to differentiate your project from what is available

Detail any similar products or research done on this topic previously. Please cite your sources and include them in your references. All figures must be captioned and referenced in your text.

3.2 Design Thinking

Detail any design thinking driven design "define" aspects that shape your design. Enumerate some of the other design choices that came up in your design thinking "ideate" phase.

3.3 Proposed Design

Include any/all possible methods of approach to solving the problem:

- Discuss what you have done so far – what have you tried/implemented/tested?
- Some discussion of how this design satisfies the **functional and non-functional requirements** of the project.
- If any **standards** are relevant to your project (e.g. IEEE standards, NIST standards) discuss the applicability of those standards here
- This design description should be in **sufficient detail** that another team of engineers can look through it and implement it.

3.4 Technology Considerations

Highlight the strengths, weakness, and trade-offs made in technology available.

Discuss possible solutions and design alternatives

3.5 Design Analysis

– Did your proposed design from 3.3 work? Why or why not?

– What are your observations, thoughts, and ideas to modify or iterate over the design?

3.6 Development Process

Discuss what development process you are following with a rationale for it – Waterfall, TDD, Agile. Note that this is not necessarily only for software projects. Development processes are applicable for all design projects.

3.7 Design Plan

Describe a design plan with respect to use-cases within the context of requirements, modules in your design (dependency/concurrency of modules through a module diagram, interfaces, architectural overview), module constraints tied to requirements.

4 Testing

Testing is an **extremely** important component of most projects, whether it involves a circuit, a process, or software.

1. Define the needed types of tests (unit testing for modules, integrity testing for interfaces, user-study or acceptance testing for functional and non-functional requirements).
2. Define/identify the individual items/units and interfaces to be tested.
3. Define, design, and develop the actual test cases.
4. Determine the anticipated test results for each test case
5. Perform the actual tests.
6. Evaluate the actual test results.
7. Make the necessary changes to the product being tested
8. Perform any necessary retesting
9. Document the entire testing process and its results

Include Functional and Non-Functional Testing, Modeling and Simulations, challenges you have determined.

4.1 Unit Testing

– Discuss any hardware/software units being tested in isolation

4.2 Interface Testing

– Discuss how the composition of two or more units (interfaces) are to be tested. Enumerate all the relevant interfaces in your design.

4.3 Acceptance Testing

How will you demonstrate that the design requirements, both functional and non-functional are being met? How would you involve your client in the acceptance testing?

4.4 Results

– List and explain any and all results obtained so far during the testing phase

- Include failures and successes
- Explain what you learned and how you are planning to change the design iteratively as you progress with your project
- If you are including figures, please include captions and cite it in the text

5 Implementation

Describe any (preliminary) implementation plan for the next semester for your proposed design in 3.3.

6 Closing Material

6.1 Conclusion

Summarize the work you have done so far. Briefly re-iterate your goals. Then, re-iterate the best plan of action (or solution) to achieving your goals and indicate why this surpasses all other possible solutions tested.

6.2 References

List technical references and related work / market survey references. Do professional citation style (ex. IEEE).

6.3 Appendices

Any additional information that would be helpful to the evaluation of your design document.

If you have any large graphs, tables, or similar data that does not directly pertain to the problem but helps support it, include it here. This would also be a good area to include hardware/software manuals used. May include CAD files, circuit schematics, layout etc,. PCB testing issues etc., Software bugs etc.