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**The Omega Lab**

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# Welcome

## Overview

Omega-labs are a design-based alternative to the traditional Alpha-labs, which are procedure-based. In most classes, labs are a set of instructions that you follow and report on with an academic journal style paper. But this isn’t what a real-world engineering job is like; most engineers need to come up with their own design and write user manuals and datasheets.

In Omega-Labs, you will have the freedom to design your own circuit based on what you have learned in the course. The requirements of the reports and evaluations of projects will be based on what is generally expected in a job.

Omega-Labs emphasize personal growth, learning from failure, planning, and iterative design. You will not be graded only on the overall functionality of the project. Instead, your grade will be based partially on your ability to meet your goals and incorporate feedback into your project and partially on the functionality of individual building blocks of the circuit and your ability to analyze them.

## How Do Omega Labs Work?

Omega Labs are broken into 3 Milestones, each of which corresponds to a set of concepts. During each Milestone, you will be expected to design a circuit that contains **at least 2 circuit building blocks** from the corresponding course material, and that you will apply the course concepts to analyze your circuit. A building block might be a voltage divider, an amplifier, or a filter. A list of building blocks will be shown later in this document.

In addition to these building blocks, you can also include additional circuits not covered in this course such as digital IC’s, mechanical components, microcontrollers and more. If you don’t know any of the building blocks, you can still do omega-labs!

In fact, that’s where we expect you to start. We expect that your project will evolve throughout the semester as you learn more concepts and building blocks. We will be there to guide you through the process of project planning and making design decisions.

Deadlines for Omega-Labs are broken into 3 Milestones.

At each milestone you must provide:

1. Updated Project Plan
2. 5-Minute Informal Presentation
3. Project Manual
4. Proof of Concepts

Each of these will be explained further in the next sections.

## Switching Between Alpha and Omega Labs

**You don’t have to do Omega-Labs for the entire semester, in fact, you can go in and out of Omega-labs.** Because both Alpha- and Omega-labs are based on the Course Concepts, it’s easy to apply some concepts in your Omega-lab design and use alpha labs to ‘fill-out’ the others as needed. This can mean doing Omega-Labs for only part of the semester. For example, you may do Alpha-Labs for the first Milestones, and Omega-Labs for Milestones 2 and 3. **You can also do multiple small design projects instead of one big design project.**

## Are Omega Labs Right for You?

Unlike Alpha Labs, Omega Labs are not consistent, straightforward, and predictable in terms of difficulty and time. Omega-Labs are potentially unpredictable and require you to be more involved. However, Omega-Labs provide many things Alpha-Labs do not: **the freedom to build whatever you want and the chance to practice what engineers really do: *design***. To decide which Lab is best for you, think about your time constraints for the rest of the semester and what classes you’re taking. Consider too that you could use your Omega-Lab project in another class or independent study. Think about how you learn best as well - do you need a structured assignment to learn, or do you do best by diving in and creatively applying the concepts?

## Grading

You will not be graded only on the overall functionality of your entire circuit; If your whole circuit does not work, you may not lose any points from your lab grade. However, each individual building block must be functional on its own. One purpose of this design lab is to give you a safe space to try new things and fail. By not grading you on the functionality of the whole circuit, we hope to encourage exploration and to allow you to experience and learn from failed designs.

Circuits labs are worth 15% of your overall grade. Grades are given at Milestones, and each Milestone grade is equivalent to 2 Alpha-Lab grades (or 5% of your lab grade). You will be graded based on your progress (have you met your goals, incorporated feedback, and do you know what needs to be done next), your technical accomplishments (functionality of building blocks, design decisions, communication in manual), and your Proof of Concepts. The grade distribution is meant to distribute the grade evenly between mathematical analysis, design, and progress.

**All of the 6 Proof of Concepts together is worth 33% of the total lab grade.**

**TO OPT OUT OF THE FINAL, YOU MUST:**

1. Complete Milestone 3
2. Physically connect/integrate the Milestone 3 Circuit with either the Milestone 1 or 2 Circuit
3. Get at least an 80% on each and every assignment for Milestone 3 and one other Milestone

**If you don’t meet the grade requirement, there will be an opportunity at the end of the semester to optimize your circuit and earn some points back.**

|  |  |
| --- | --- |
| **Assignment** | **Grade Percent** |
| Proof of Concepts | 33.3% |
| Project Manual | 33.3% |
| Presentation | 28.3% |
| ProjectPlan | 5% |

## Deadlines and Deliverables

Omega-Labs are divided into 3 Milestones. A major part of the project is due at the end of each milestone, and minor sections are due halfway between each milestone.

|  |  |
| --- | --- |
| **Due Date** | **Assignment** |
| 01/21/20 | Project Plan |
| 01/29/20 | Proof of Concepts 1 |
| 02/12/20 | Milestone 1 Checkoff:    Proof of Concepts 2    Project Presentation    LTSpice Schematic |
| 02/18/20 | Project Manual 1  Project Plan |
| 02/26/20 | Proof of Concepts 3 |
| 04/01/20 | Milestone 2 Checkoff:    Proof of Concepts 4    Project Presentation    LTSpice Schematic |
| 04/07/20 | Project Manual 2  Project Plan |
| 04/15/20 | Proof of Concepts 5 |
| 04/29/20 | Milestone 3 Checkoff:    Proof of Concepts 6    Project Presentation    LTSpice Schematic |
| 05/02/20 | Project Manual 3 |

# Lab Requirements

## Overview

You will be expected to create a physical circuit of your design as well as a Spice simulation file. You will be graded based on your progress and technical accomplishments. There will only be one Project Manual which will be updated throughout the semester. There will also be a single Proof of Concepts document which will also be updated throughout the semester. The purpose of this is to ensure feedback is incorporated into the report and you have the opportunity to correct your mistakes.

## Deliverables

### Project Plan

The Project Plan is a sheet that is meant to help you plan out your project, and it helps both you and the TA make sure that project scope is reasonable. The Plan asks you to outline what your project is, why you want to do it, what circuits you will need to build, and what goals you want to achieve in each Milestone period. This plan must be approved by a TA before you start your project.

A Project Plan is due at the start of each Milestone Period for those just starting Omega-Labs, and it is due during the Project Presentation for those already in Omega-Labs. The Project Plan is not graded directly but may be graded indirectly during the Project Presentation under the Presentation Grade’s ‘Planning’ Category.

### Presentation

This is an informal presentation to the TA and Professor to demonstrate the functionality of your circuit and discuss progress. In this presentation, you should:

1. Demonstrate functionality of circuit
2. Explain circuit operation
3. Discuss problems encountered and solutions
4. Discuss user feedback obtained and how it was incorporated into the design
5. Support design choices
6. Discuss future plans
7. Have an updated Project Plan for the next Milestone prepared for review

In the Milestone Presentation, you must discuss some user feedback you received on your project. User feedback simply means you had someone outside your group (which could be a TA, classmate, roommate, etc.) use your circuit and received input from them on how to improve it. You should show in your presentation that you have updated your design to incorporate this feedback. **(5-10mins)**

### Project Manual

The Project Manual is not a traditional report. Most reports require discussion of the context of your project: Introduction, Discussion, Conclusion. This reflects what an academic journal paper on experimental results might include, but it isn’t realistic of what it required in most engineering jobs. Technical documentation like that seen in datasheets is more useful for engineers trying to succinctly communicate to each other how their design works and how to use it. This approach is meant to let you focus on communicating only what is essential in an effective way.

**The Project Manual should include:**

1. Description
   1. Complete schematic and block diagram
   2. Description of the operation and intended application
   3. Description of related pre-existing applications and advantages of your design over others
2. Operation and Design
   1. Input and output of each building block **in isolation**
   2. Design Equations (if someone were to redesign the circuit for different conditions, what equations would they use to do that)
3. Integration and Optimization
   1. Describe the overall integration of the building blocks into one circuit
   2. Explain how each building block was designed so they could be connected together
   3. Discuss any issues you had in getting building blocks to work together
   4. Plot overall input and output of the circuit
   5. Pick any TWO components for which you debated using another component and describe how you chose it (ex. why you used a differential op-amp instead of an integrator op-amp)
4. Operating Conditions
   1. Describe situations where the circuit does not work (ex. max voltage, sensor max range, etc)
   2. Describe the limitations of the project
   3. Describe any tradeoffs present in the design (e.g., we can reduce power consumption, but this reduces sensitivity)
   4. Describe how the circuit could be improved to overcome these limitations

An engineer reading the project manual should be able to use it to rebuild and redesign the circuit. It might be a good idea to have a friend read your report first and see if they understand how the circuit works.

### Proof of Concepts

The Proof of Concepts demonstrates that you can apply the mathematical concepts you are learning in the course to your circuit. The Proof of Concepts is meant to be a substitute for the work done in Alpha Labs, however the difference is that you will decide what to analyze based on what you are building. The Proof of Concepts should represent the analysis you’ve done to design your circuit. In each Milestone, you must analyze a total of 4 of the listed Milestone concepts, and 2 of those 4 will be due at each Proof of Concept deadline. For each concept, you should include:

* Header with concept name
* The name of the building block to which it corresponds
* A labelled circuit diagram
* A 1-2 sentence description of how you are applying the concept and what circuit variables you are analyzing to demonstrate it
* A mathematical analysis
* A simulation and plot
* A measurement and plot
* A brief discussion of the results
* An explanation of how this analysis helped in circuit design

See the example entry in the Proof of Concepts assignment document. Keep in mind that these entries do not need to be long - in fact, keep them as brief as possible! **You can apply multiple concepts to the same circuit**. Additionally, you can apply concepts to a circuit not in your final project, say a discarded design, so long as you support that the analysis of that circuit helped you to arrive at your final design.

Finally, like the Project Manual, you will have one Proof of Concepts document that you update over the semester. Any mistake you make on a Proof of Concepts assignment will need to be updated by the next deadline.

## Concept List

For each Milestone, choose 4 of the listed Milestone concepts to analyze for a total of 12 for the entire semester. At a Proof of Concepts deadline, 2 concepts will be due.

**Milestone 1**

Ohm’s Law

Polarity

KVL

KCL

Nodal Analysis

Mesh Analysis

Circuit Reduction of Parallel and Series Resistors

Voltage Divider

Equivalent Sources

Superposition

Thevenin or Norton Circuit

Operational Amplifier as a Comparator

Operational Amplifier as an Amplifier

**Milestone 2**

First-Order Circuit (RC or RL) with Differential Equations:

* Analyze the step response. Provide differential equation and solve for time-domain function f(t) where f is the variable of interest. Provide time constant.

First-Order Circuit (RC or RL) with Laplace/S-Domain Analysis:

* Analyze step response. Provide s-domain circuit, s-domain function F(s), time-domain function f(t). Provide time constant.

Second-Order Circuit:

* Use Differential equations to analyze the step response.
* Use Laplace (s-Domain) to analyze step response.

Op Amp with Capacitive or Inductive Feedback Network

Thevenin or Norton analysis applied to a First- or Second-Order Circuit:

* Use Differential equations OR S-Domain to analyze the step response.

**Milestone 3**

Phasor Analysis

Complex Power

Transformers

First-Order Passive Filter

*Must analyze: Transfer function, Bode plot, Poles and Zeroes, Resonant frequency, Rolloff*

Second-Order Passive Filter

*Must analyze: Transfer function, Bode plot, Poles and Zeroes, Resonant frequency, Rolloff*

Second-Order Active Filter

*Must analyze: Transfer function, Bode plot, Poles and Zeroes, Resonant frequency, Rolloff*

Second-Order Active Filter

*Must analyze: Transfer function, Bode plot, Poles and Zeroes, Resonant frequency, Rolloff*

## Building Blocks (Project Manual)

This is a list of potential building blocks for your project. This list is not comprehensive, and you can get new blocks approved by a TA or Professor in your Project Plan. Each building block can only satisfy a single unit requirement. Each Milestone must include: An Input stage, 2 new **Primary** stage blocks for the corresponding Milestone, and an Output stage. The Input and Output stages can remain the same throughout the semester.

**Input Stage (At Least 1)**

* Sensor
  + IR LED
  + Antennae
  + Photodetector
  + Microphone
  + Temperature Sensor
  + Light Sensor
  + Gas Sensor
* User Interface
  + Buttons
  + Switches
  + Potentiometer
* Power Generator

**Milestone 1 (At Least 2)**

* Digital to Analog Converter (Digital means two DC voltage levels, Analog means range of DC voltage values)
* Inverting Amplifier
* Non-Inverting Amplifier
* Summer
* Difference
* Comparator
* Wheatstone Bridge

**Milestone 2 (At Least 2)**

* Analog-to-Digital Converter (Analog means AC, Digital means DC signal. This circuit includes rectification)
* Monostable Multivibrator (Timed Pulse Generator)
* Astable Multivibrator (Square Wave Generator)
* Differentiator
* Integrator
* Analog Multiplier
* First-Order Passive Filter
* Second-Order Passive Filter
* Phase Shifter

**Milestone 3 (At Least 2)**

* Transformer
* Analog Multiplier
* First-Order Filter
* First-Order Passive Filter
* Second-Order Passive Filter
* First-Order Active Filter
* Second-Order Active Filter

**Output Stage (At Least 1)**

* Solenoids
* LED
* Display
* Motor
* Buzzer
* Antennae

**Data can be an acceptable output if you are analyzing it appropriately. For example, you might make a sensor circuit to collect environmental data. You must get this confirmed by a TA first.**

**Additionally, you may use transistors anywhere in the circuit ONLY for powering high current devices**