Massachusetts Institute of Technology
Department of Electrical Engineering and Computer Science
6.1151 Microcomputer Project Laboratory Spring 2024

Independent Inquiry (II) Proposal

If you are taking the 15 unit 6.1151, the final project has added features described in your (II) proposal.

Issued: February 6, 2024 Due: February 15, 2024

The Independent Inquiry or "II" requirement engages you to think about aspects of an engineering problem that are beyond the typical scope of a conventional 6.115 final project. This can be an exciting way to explore an engineering problem or a class of engineering problems with more freedom and time than might be available for a typical 6.115 final project. You receive an additional 3 units for taking 6.1151 (as opposed to 6.115). This extra time, about 3 hours a week for each week of the term, should be used to explore and learn about an added dimension of a final project problem. It is expected that the independent inquiry compliments and includes your final project in a holistic way, expanding your learning in an area of study that you choose which is relevant to the Microcomputer Project Laboratory.

The Independent Inquiry involves five elements:

1. **An II proposal**, described below, that puts your work and your planned final project in context. This proposal is due on the due date shown above.
2. Identification of **at least one reference book or paper** that will guide your II studies.
3. **Steady progress** studying your reference(s) on the II each week of the term.
4. Later in the term, a **minimum 15 page, typed (e.g., Word or LaTex), one inch margins, 10 point font, II Final Report in addition to the final project notes taken in your lab notebook.**
5. **Demonstration of your II build or construction** at the Final Project Checkoff along with your 6.115 microcontroller circuitry.

Your II proposal, due on the date indicated above in the first two weeks of the term, should clearly lay out these elements and distinguish your II work from a conventional 6.115 final project. We understand that you are just starting in 6.115(1), and that the course material and possibilities are new to you. You are not expected to lay out the exact details of the "6.115-component" of your II final project in this proposal. You are expected to have a general sense of what you are looking to build, and a reasonable sense of what you will be exploring for your II in addition to the final project circuit work.

For example: you might be interested in music and stereo audio reproduction. The "standard 6.115" elements of your final project might involve the design and construction of a digital signal processing system for making sounds effects for a really rocking stereo. For the II additional component, you might be interested in exploring how speakers are designed and made so that they sound great with your sound effects electronics. Your II proposal, therefore, should clearly lay out your plans for learning about physical loud speakers, how they are designed, how they are constructed, and how you will build a demo unit based on your investigations to compliment and add to your final project.

The same ideas said a different way: generally, if you are taking the II version, you are looking to "add" a 3 unit project (3 hours a week all term) that uses an additional reference or references and looks at something "related to" but "not the same as" the 6.115 material. In the hypothetical example attached, the "hypothetical student" is proposing to look at the design and construction of audio speakers with a text book and a build - not generally material we discuss in 6.115 - to make an additional amplifier project that would "go with" their likely 6.115 final project proposal, in this case a digital sound effects processor.The two pieces, the II project and the 6.115 final project, are like a Reese's peanut butter cup – the pieces are intended to be able to be demonstrated separately, but also pair well together. Modular! That way, if one piece does not work well – e.g., let's say the "chocolate" 6.115 sound effects processor did not work – then you could still demo the "peanut butter" speakers with a signal generator. And, if the speakers never worked, then you could still play the happy sound effects processor through a different speaker in the lab. If both pieces work – the ideal situation – then they can be demonstrated together at final project time (as a full Reese's cup).

Using this "sound effects and speakers" idea as an example, the following pages show what a typical II proposal should look like. It should clearly delineate the "6.115 final project" elements and the "II additional elements," at least one key source material (book, paper, etc.) you will use, and what you will build for the II. The II proposal should be two pages long and include diagrams for the 6.115 project and the II component.

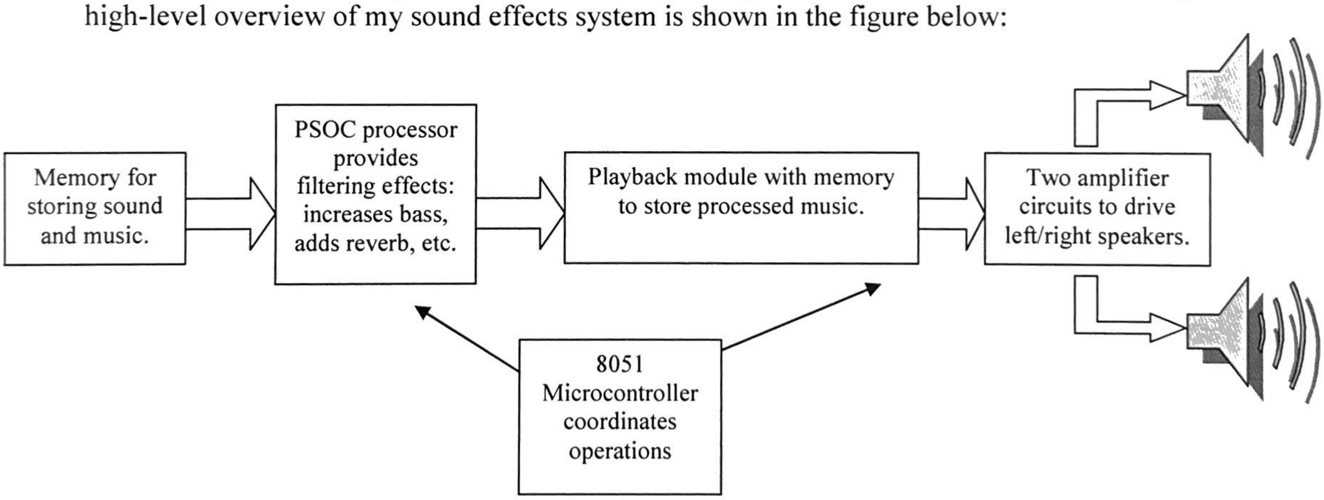
Following this “stereo amplifier and speakers” example proposal is a **second** example proposal, this time a sounds effects processor (6.115 component) and an exploration of a tube amplifier (II component).

Sound Effects Processing System
6.1151 Independent Inquiry Proposal
Steven B. Leeb
February 10, 2024

My 6.1151 Independent Inquiry project will explore the creation of a sound effects processing system for audio playback. My project will have two broad parts. The first part will be a more-or-less traditional 6.115-style project involving the design and construction of a digital signal processing system for recording, modifying, and playing back sounds and music. I expect to learn more about relevant circuits and techniques as the term progresses, and will have a better idea of the circuit details for my final project proposal later in the term. I am showing some speculative thoughts about the sound processing system in the first section, below. The second part will involve the design and construction of one or two stereo loud speakers. The proper design of these speakers will be the subject of my II expansion. I am a member of the MIT hobby shop, and will work throughout the term to design and construct my speaker demonstration. At the final project demonstration, I intend to pair my speakers with the sound effects processing circuits I will build for the final project, and demonstrate the entire system in operation according to my design specifications.

6.115-style Final Project Component:

For my final project, I expect that I will build something that is based on our MINMON operating system. I will add new options to MINMON that will allow my final project to record sound, filter the sound in interesting ways, add interesting effects like reverberation, and play back the sound. I may add graphical displays and a user interface to control the system. It is early in the term, and I expect that the details will change as I learn more in class. Notionally, a high-level overview of my sound effects system is shown in the figure below:



I intend to use the two processors we will study in the class to create the overall system. The 8051 will provide control and user interface. The more powerful PSoC will provide digital signal processing and sound effects.

Independent Inquiry Component:

For my II component, I am excited to learn how loud speakers work, and how they can be made to sound great. I plan to use the classic text book:

"Acoustics," by Leo Beranek, American Institute of Physics, published 1986

as a primary source reference to guide my studies. I will be reading at least chapters 1 through 5 during the course of the term. I expect to use this material to design a loud speaker, and I will construct at least one example based on my calculations. I will use my hobby shop membership (or EECS EDS, etc.) during the term to construct my system.

In particular, I am especially interested in understanding the differences between the two general design approaches illustrated below:

In the typical design shown on the left, several speakers are included in the same packaged system. Why? Are there acoustic advantages to having the speakers all in one "box"? Is each speaker driven by a separate amplifier (e.g., six amplifiers for the speakers shown in the left figure)? Or is each box use for either a left or right channel, requiring a total of two amplifiers?

Alternatively, what are the advantages of the "satellite" speaker design shown on the figure in the right? Why are the satellite speakers small compared to the "main box" in the back? Where should these speakers be located with respect to one another, and how are they driven by amplifiers?

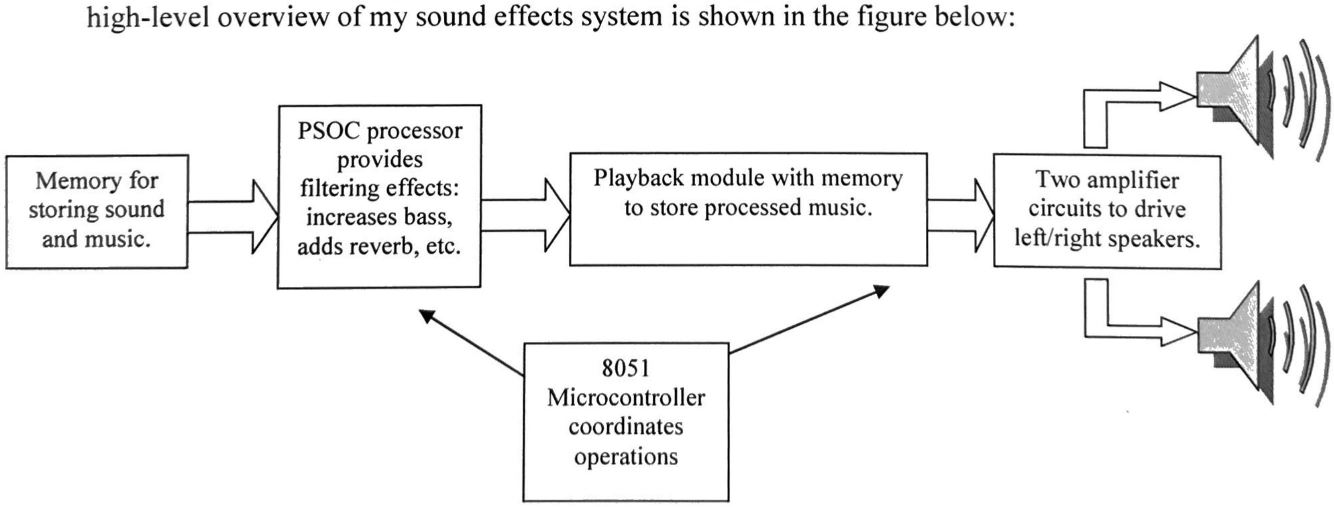
I intend to explore these questions, find answers, build at least one example to go with my amplifier circuit, and develop a minimum fifteen page final II report in addition to my final project writeup that explains my findings and design.

SECOND EXAMPLE: Sound Effects Processing System
6.1151 Independent Inquiry Proposal
Steven B. Leeb
February 10, 2024

My 6.1151 Independent Inquiry project will explore the creation of a sound effects processing system for audio playback. My project will have two broad parts. The first part will be a more-or-less traditional 6.115-style project involving the design and construction of a digital signal processing system for recording, modifying, and playing back sounds and music. I expect to learn more about relevant circuits and techniques as the term progresses, and will have a better idea of the circuit details for my final project proposal later in the term. I am showing some speculative thoughts about the sound processing system in the first section, below. The second part will involve the design and construction of a tube amplifier. I will explore whether or not the tube amplifier is a reasonable pre-amplifier for a FET amp, or vice versa, or compare them stand-alone with each other. For the final project demonstration, I intend to compare my amplifiers and specifically the outputs using my oscilloscope to collect output waveforms and Matlab (or Python or similar) to compare frequency response.

6.115-style Final Project Component:

For my final project, I expect that I will build something that is based on our MINMON operating system. I will add new options to MINMON that will allow my final project to record sound, filter the sound in interesting ways, add interesting effects like reverberation, and play back the sound. I may add graphical displays and a user interface to control the system. It is early in the term, and I expect that the details will change as I learn more in class. Notionally, a high-level overview of my sound effects system is shown in the figure below:



I intend to use the two processors we will study in the class to create the overall system. The 8051 will provide control and user interface. The more powerful PSoC will provide digital signal processing and sound effects.

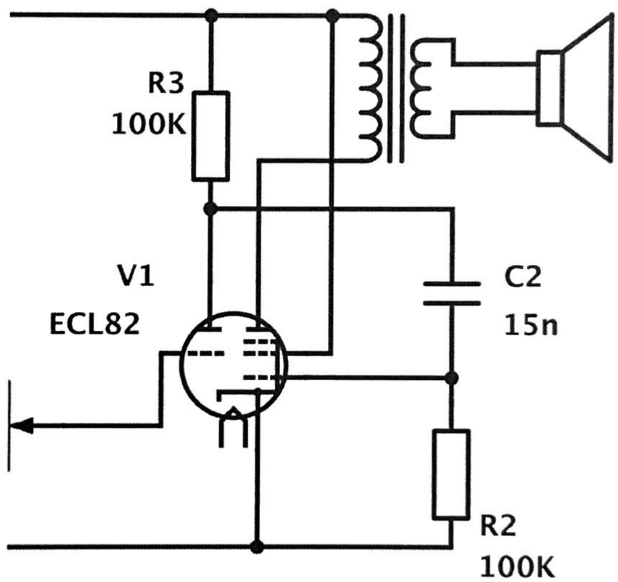
Independent Inquiry Component:

For my II component, I am excited to learn how tube amplifiers work, and how they sound compared to FET amplifiers. I plan to use the great text book:

"Valve Amplifiers" by Morgan Jones, published by Newnes, in 2012, available from Amazon

as a primary source reference to guide my studies. I will be reading at least chapters 1 through 5 during the course of the term. I expect to use this material to design a low-voltage tube amplifier, and I will construct at least one example based on my calculations. I will use the course parts order near the time of the final project to order custom parts for the tube amp at reasonable prices (about $25, I estimate) for the final amp.

In particular, I am especially interested in understanding the operation of a single tube amplifier like the one shown below from an online reference:
(https://hackaday.com/2014/11/03/low-voltage-tube-amp-is-great-for-beginners/)



Can a single tube provide reasonable sound quality? What level of power amplification can I achieve? Voltage amplification? What voltage rails are necessary to run the amplifier? How can I design or modify a design to run at the low voltages permitted (less than 15 volts from my kit power supply) for the final project? I intend to explore these questions, find answers, build at least one example to go with my amplifier circuit, and develop a minimum fifteen-page final II report that explains my findings and design.