IPRO 344- Spring 2008

Improving Energy-Efficient and Offering Quality Audio for Mobile Devices

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1.0 Objectives

1. Study commercially available Class D amplifiers with a focus of audio quality and noise.
2. Study and comparison of commercially available conventional Class AB/B amplifiers with similar specifications and constraints.
3. Build a Class D amplifier using readily available circuits/subsystems.
4. Continue research on an observation of voltage requirements in Class D amplifiers
5. Examine McDonald's current audio environment and apply the obtained knowledge to help provide a global business solution to their drive through ordering systems

2.0 Background

2.1 IPRO 344

IPRO 344 was founded by Dr. Wong for the Fall 2007 semester with a stated long term purpose of studying and improving technologies for use in low-power mobile audio applications. IPRO 344 had been outlined as the first in a multi-semester project, with each subsequent semester building on the work of the previous semesters and a final objective of providing a diverse and complete toolkit for low-power mobile audio applications.

The current trends in social-electronic integration are indicative of a level of "Ambient Computing". That is, providing users with electronic services independent of their physical location or condition. Examples of this new form of integration can be seen in everything from cell-phones, portable music players, portable gaming devices, laptops, personal digital assistants (PDAs), and most recently smart-phones. For this entire generation of new devices, one of the most critical design factors to emerge is that of power efficiency. Users are demanding smaller and lighter devices, more features and more powerful processing power, and longer battery times. Unfortunately, improvements in the power density of consumer level batteries are significantly lacking behind user demands, bringing about the increasingly urgent need for exceptionally energy-efficient technologies upon which the next generation of devices can be built.

For the scope of this semester's IPRO, we will focus on the amplification stage of mobile audio applications. Final Signal amplification for mobile audio devices can reasonably be in the range of several watts, and can make up significant portions of a devices power budget. Furthermore,

traditional amplifiers are limited by a tradeoff between low efficiencies and audio distortion. Lower efficiencies further increase power consumption, and require additional hardware to dissipate waste heat, while higher distortion levels are considered unacceptable by many users.

Amplifiers are classified into letter grades based on what parts of the original waveform are amplified. In most audio applications, Class B and Class AB amplifiers are used. However, as an alternative amplifier design, Class D amplifiers are beginning to emerge as an ideal solution to the tradeoffs of traditional amplifiers. Traditional amplifiers have output devices that conduct even when "off." This dissipates power, which means there is zero percent efficiency during this time. This lowers the maximum efficiency of these amplifiers.

Class D amplifiers operate on analog principles. They represent the maximum theoretical efficiency of any audio amplifier, with a minimum of audio distortion. Their high efficiency is achieved because they require less power from the power supply, and this requires a smaller heat sink. Also, Class D amplifiers have high power levels and small design. They have two output states "on" and "off" instead of one. In the "on" state, current flows through the device when no drain to source voltage is present. This means that the power dissipation is theoretically zero. In the "off" state, current through the device is zero. Figure 2.1 shows the efficiency for Class AB and Class D amplifier.

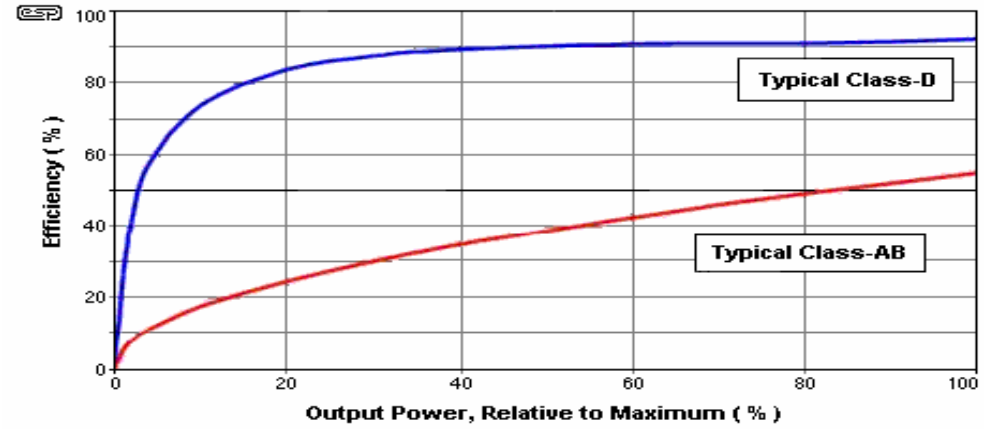

Figure 2.1: Efficiency Comparison for Class AB and Class D Amplifier

Historically, the usage of Class D amplifiers has been limited by their complexity compared to other amplifier types, and their sensitivity to electromagnetic noise. However, modern improvements and design methods are making Class D amplifiers a more attractive alternative.

Both the benefits and complexity of Class D amplifiers stem from their unique design. Traditional amplifiers function by selecting portions of the input waveform and amplifying them with transistors or vacuum tubes before outputting the new waveform. Class D amplifiers, however, function by re-encoding the entire input waveform into a new signal type, which is then amplified, and finally decoded by means of a passive filter. Most Class D implementations utilize a high frequency pulse-width modulation for their encoding, which allows for higher efficiency in amplification (as the transistor/vacuum tube is only ever completely "on" or completely "off") and still impose a minimum of audio distortion.

2.2 Special Cooperation - The McDonalds Project

McDonalds needs improvement in their driving-thru system. Our team could contribute the technology on audio system improvement. McDonald's concerns with its drive through system may stem from a number of sources. To begin with the equipment may be dated and has not been upgraded for some time. From a customer's perspective, the issues that need to be addressed are:

2.2.1 Order Accuracy: It reduces the efficiency of a busy Drive Through by 40% if an order needs to be retaken. Hence, clarity on both ends of the system is necessary. Some factors are important to ensure this:

- Sound Quality / Noise Reduction
- Sound Amplification
- Speaker and Microphone

2.2.2 Drive-Thru Experience: According to surveys, one bad experience at a drive-thru can bring negative influence to the customer's purchase at McDonalds thus resulting in reduction in profits. The requirements range from a well organized menu, to the order taker's pleasantness and verification of the order correctly, readiness of the order and so on. In out project, over this semester and the next couple we will try to focus on:

- Efficient Speech Recognition: Either improve the current McDonald's system by changing amplifiers, preamplifiers, microphone positioning and the choice of microphone on both ends of the

drive through so that the order taker can recognize various accents with more clarity and the customer can understand the order taker.
● Order Record and Processing: Our team might look into the possibility of the order being recorded and processed quicker using speech recognition.

This semester our focus will be twofold. Primarily, we will revisit our previous goals of attaining higher efficiency using various techniques such as Dynamic Power and heat sinks. Also, we will be trying to increase sound quality for our prospective sponsor, McDonald's, by using noise reduction techniques. To be effective in this endeavor, we will also make a field trip to understand the setup and constraints of their current drive-thru system.

3.0 Methodology

IPRO 344 will be conducted as a continuous research project, with team members focused on learning about Class D amplifiers: their potential application in the field of low-power audio devices, as well as potential improvements in the field of low power audio amplification. Also, field research will be conducted to understand McDonald's drive-thru system. Exact tests and testing procedures will be researched and developed throughout the course of this IPRO. High levels of student-faculty interaction will ensure work continues in a positive direction at all times, while individual, recurring, and peripheral tasks will be handled by assigned sub-teams. Sub-team assignment was voluntary, with team members being allowed positions in multiple sub-teams. Additionally, all team members are encouraged "cross sub-team boundaries" whenever possible to provide assistance, input, and assist in overall integration.

A summary of assigned Sub-Teams is as follows:

Team Leader: Govind Wakhlu

Research Team
Members:
Gil-su Choi, Michael Mikulka, Hwansung Cho, Govind Wakhlu
Description:

The Research team consists of all members of the IPRO 344 team, and is charged with the task of continual research in relevant fields of study as directly by faculty. This field involves researching commercially available Class D amplifiers. It is compared with Class A, B, and AB amplifiers. Team members may be required to regularly report findings to the entire IPRO.

Webpage Team

Members:

Jarrod Godfrey, Donald Spears, Yujin Park, Cheng Sun

Description:

The Webpage team is charged with the responsibility of designing, deploying, and maintaining a public webpage displaying information relevant to IPRO 344 and the field of Low-Power Audio devices.

Documentation Team

Members:

Yu Zhang, Noh Hyup Kwak , Nastasja Terry, Donald Spears

Description:

The Documentation team is responsible for creating, maintaining, and posing all IPRO and IPRO related documents through official channels.

Purchasing Team

Members:

Michael Mikulka, Nastasja Terry

Description:

The Purchasing team is responsible for reviewing, proposing, and acting on all team purchase requests, as well as maintaining documentation on all purchases and any necessary budget reports.

Implementation Team

Members:

Chang Song, Jarrod Godfrey, Hwansung Cho, Govind Wakhlu, Gil-su Choi, Noh Hyup Kwak, Michael Mikulka

Description:

The Implementation team is responsible for assembly, operation, and maintenance all equipment studied as part of this IPRO, including Evaluation boards, commercially purchased amplifiers, amplifier components, audio sources and loudspeakers.

Tools and Media Team

Members:

Cheng Sun, Yu Zhang, Donald Spears

Description:

The Tools and Media Team is responsible for the assembly, operation, and maintenance of instrumentation used throughout the IPRO as well as the preparation of acquired data for presentation.

Poster Team

Members:

Yujin Park, Yu Zhang, Govind Wakhlu, Hwansung Cho

Description:

The Poster team is responsible for creating a professional summary-poster to be used during team presentations and during IPRO day.

Logistics & Attributes Team

Members:

Nastasja Terry , Govind Wakhlu

Description:

The intention of the Logistics & Attributes team is to put the team's activity in sync with the programs of the IPRO office (IPRO Calendar of Events). Members of the Logistics & Attributes team are to advocate for their IPRO as well as keep track of programs team members have attended.

4.0 Expected Results

The desired result of this IPRO is a survey of the potential applications of Class D amplifiers in the field of low-power audio devices. As this is a purely research IPRO, the exact results of our work are almost impossible to determine, but may include any of the following:

- A list of commercially available Class D amplifiers along with their suitability in various applications
- A comparison of commercially available Class D amplifiers with traditional Class B and AB amplifier offering of comparable type.
- A list of outstanding issues or necessary developments discouraging the use of Class D amplifiers in low-power audio applications.
- Design and build a Class D amplifier using conventional circuits/subsystems.
- Test the Class D amplifier.
- An analysis of a scratch-built Class D amplifier and/or a description of issues preventing the construction of such an amplifier with available resources.
- A list of specific improvements or specifications for Class D amplifiers to improve performance in low-power audio applications.
- Other relevant documentation to be used in the further development of low-power audio devices.

5.0 Project Budget and Acquisitions

Table 5.1 explains the proposed budget for all the items that will be bought or otherwise obtained this semester for our IPRO. This is a rough estimate for our expected acquisitions. Items listed as ordered last semester have not yet arrived but we will be following up on their shipment and expect to receive them with semester with minimal additional cost, if any. We hope to receive McDonald's-type speaker hardware from that company; if we do not, then it will not be acquired.

Product	**Price**
Bitscope	Ordered Last Semester
Breadboards	$30

Drive-Through Speaker/Microphone System	Receive from Sponsor
Evaluation boards + Shipping & Handling	$250
IPRO Day Supplies	$100
Low Noise Microphone	$200
Media Player	$100
PC with Various Upgrades	Ordered Last Semester
Power Supply	$150
Public Address Type Speakers	$100
Supplies for Class D amplifier filter	$30
Total Harmonic Distortion Analyzer	$1000
Various Tools/Hardware for Circuit Construction	$100
Total	**$2060**

Table 5.1: Proposed Budget and Acquisitions

Table 5.2 explains the finalized items that we will order in the first round. It does not include shipping and handling. Some items which have not yet been ordered from specific locations are not listed.

Product #	Seller	Description	Price	Phone Number
MAX9714EVKIT	Maxim-Ic	Class D amplifier EVM	$50	888-629-4642
MAX9776EVKIT+	Maxim-Ic	Class D amplifier EVM	$50	888-629-4642
TPA3101D2EVM	T.I.	Class D amplifier EVM	$49	972- 644-5580
TPA1517DWPEVM	T.I.	Class AB amplifier EVM	$49	972- 644-5580
Total			**$198.00**	

Table 5.2: Items to be Purchased and their Prices

6.0. Schedule of Tasks and Milestone Events

The MS Project was used to create the project timeline shown below (See Figure 6.1). The major milestone events include buying evaluation and testing equipment, designing and building Class D amplifier, and IPRO deliverables.

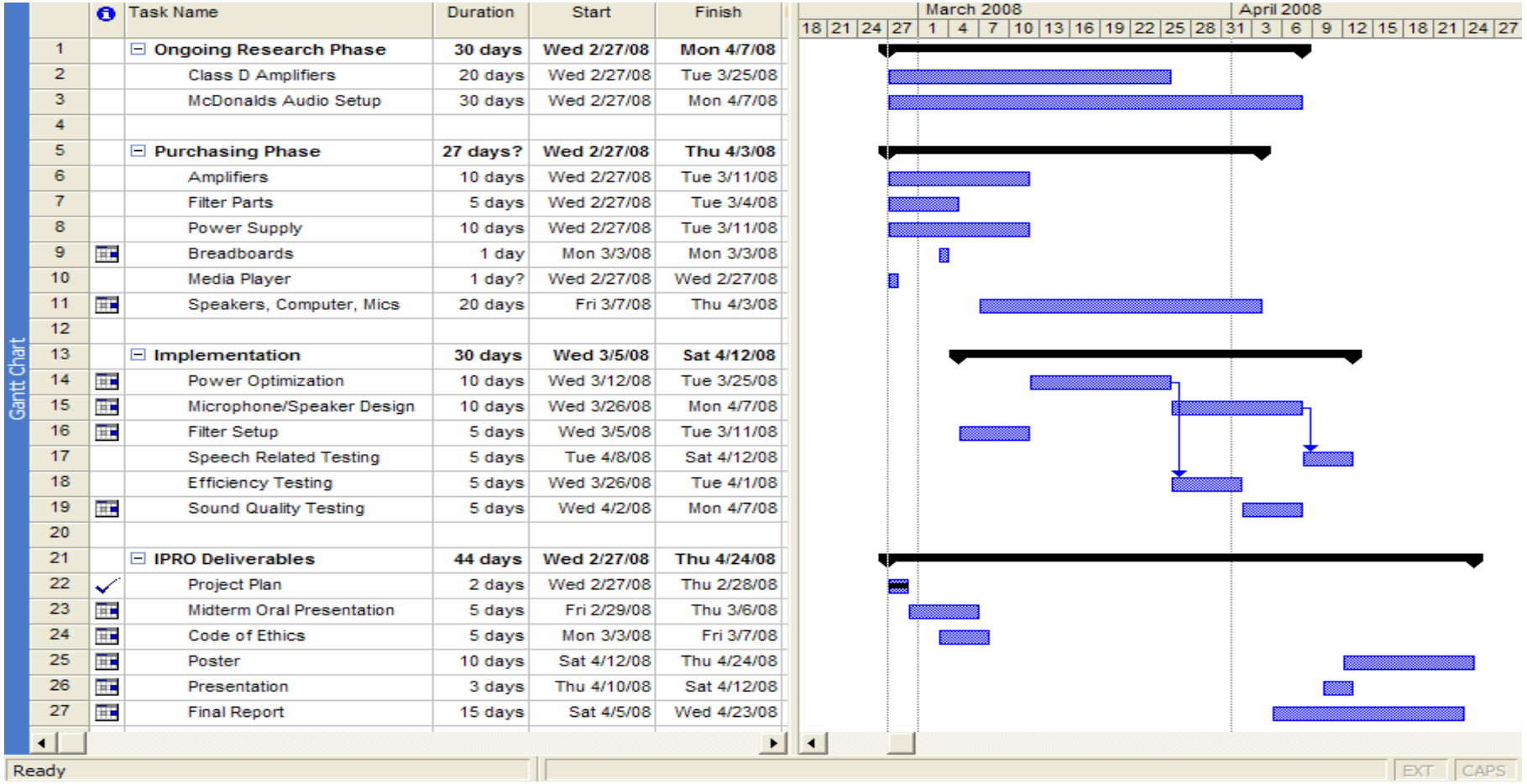

Figure 6.1: Project Timeline

7.0 Individual Team Member Assignments

Our faculty advisor is Dr. Thomas Wong. He is a professor in the Electrical and Computer Engineering Department. His research interests include areas of millimeter-wave communication systems, transient phenomena, propagation effects on high-speed devices and microwave integrated circuits, microwave measurements and charge transport in solids.

We are glad to have Dr. Riley and Dr. Bauer who are advisory faculty for the team on speech quality evaluation and usability assessment, which are relevant to the application of audio systems to speech communication and client interactions in a retail facility.

Our team members (See Table 7.1):

Name	Major	Skills
Choi, Gilsu	Electrical Engineering	Basic knowledge about amplifiers, Computer skills, analytical and experimental skills
Cho, Hwansung	Electrical Engineering	Skills are Basic knowledge about amplifiers, Computer skills, Organizing and Analytic Skills
Godfrey, Jarrod	Computer Science	Programming knowledge, Basic electronic knowledge, Web Development, Organizational Abilities
Kwak, Nohhyup	Electrical Engineering	Circuit Analysis, Amplifier Knowledge, Computer Skills
Mikulka, Michael	Electrical and Computer Engineering	Basic knowledge about amplifiers, computer skills, analytical skills, organizational abilities
Park, Yujin	Architecture	Graphic and web design skills
Spears, Donald	Computer Science	Computer skills, Web Development, engineering problem solving capabilities, Basic electronic knowledge
Song, Chang	Electrical Engineering	Basic knowledge about amplifiers, Computer skills, Organizing and Analytic Skills
Sun, Cheng	Electrical Engineering	Analog and digital circuit analyzing, Photography, video editing web site constructing skills
Terry, Nastasja	Mechanical Engineering	Strong problem solving skills, basic electronic knowledge, organizational skills, materials background
Wakhlu, Govind	Electrical and Computer Engineering	Amplifier Knowledge, Audio Equipment Testing Experience, Procurement Experience, Computer skills
Zhang, Yu	Technical communication and information design	Usability testing, technical editing document design and design of poster.

Table 7.1: Team Members, their Majors and Sills

We have 8 different sub teams. The responsibilities for team members have already been discussed. Our faculty advisor and teaching assistant (T.A.) coordinate and review sub team/individual team member task activities.

Our T.A. is Tao Shen. He is a graduate student whose research interest is Electronics and Electromagnetics.

8.0 Designation of Roles

A. Assign Meeting Roles

- Minute Taker: Donald Spears and Yujin Park
- Agenda Maker: Dr. Thomas Wong
- Time Keeper: Dr. Thomas Wong

B. Assign Status Roles

- Weekly Timesheet Collector/Summarizer: Everyone is responsible for keeping track of their own timesheets.
- iGROUPS: Dr. Thomas Wong