PRO-Q2 Final Design Report (draft)

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EQ2.a
EQ2.c

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1 Summary

[Summary of report]

2 Introduction

In the second year of the Electrical Engineering course at The Hague University of Applied Science, project PRO-Q2 marks the end of the primary programme. All the specific knowledge and skills needed in previous projects come together in this one project with a duration of one semester. Students are presented with the challenge of designing the electric components of a speaker system, expanded with a digital component that adds additional features to the system. This report will offer the reader a detailed look into all of the design aspects of the components realized by team 1 of PRO-Q2, as well as test results and an overview of the total costs of the required materials. After reading this report, one should be able to assemble the functional product as described in the report.

3 The project problem, specifications and preconditions

The project problem introduces the fictional company BARK, a small yet well-known manufacturer of loudspeakers. For some time, BARK has contemplated the development of a series of active speakers using built-in power amplifiers. The market price of these types of speakers have shown a significant reduction in the recent years, thus making it an interesting move for the company. Speakers with this setup offer a range of great advantages, including the avoidance of large speaker cables, the possibility of using cheaper electronic crossover circuits and a straight-forward design of the circuits.

It is likely that buyers of these active speakers also have the intention of buying a high-end stereo preamplifier. These types of preamplifiers are known to be expensive and uncommon. For this reason, BARK developed a new preamplifier to be built into the speaker system. The specifications of the preamplifier have already been established by a previous team.

3.1 The problem

In light of the recent digitization of every electronic product, BARK decided that it also wants the speaker and its electronics to be controlled by a digital system of some sorts. However, being a loudspeaker manufacturer, their knowledge of analogue and digital electronic systems is somewhat limited. A series of researches are to be conducted in order to gain the required knowledge and skills in these fields. The project team is to design an active loudspeaker system and realise a demonstration model according to the specifications and preconditions given. By the end of the project, the live demonstration should prove the correct operation. Documentation and a cost calculation are also to be provided.

3.2 Specifications and preconditions

The specifications and preconditions given by BARK encompass both the analogue as well as the digital part of the to-be-designed system. The following components are described:

- Preamplifier
- Power amplifier
- Power supply
- Digital part

3.2.1 Preamplifier

The configuration of the preamplifier has already been partially determined. The values of the components have to be calculated and additional components have to be implemented in order to make the design of the preamplifier meet the required specifications.

The specifications are as follows:

Overall specifications preamplifier Balance control in flat position, tone (bass and treble) control switched off, volume control at maximum.

1. Input impedance: minimum 100kΩ
2. Output impedance: maximum 100Ω
3. Sensitivity : 2V output voltage in R_L = 20kΩ at 200 mV input
4. Frequency range: 2Hz to 400kHz (-3 dB) at V_{out} = 500mV, R_L = 20kΩ
5. Output voltage: at least 7V sinusoidal with R_L = 20kΩ , f = 1kHz

Balance control specifications

1. Range ±6 dB (within ±0.5dB) difference between right and left channels
2. In flat position +2dB (within ±0.5dB)
3. Approximate logarithmic control function
4. No DC current through the potentiometer nor the wiper

Bass and treble control specifications

1. Treble: Cut-off frequency adjustable between 2.5 and 10kHz. Maximum boost or attenuation 10dB (±1dB) at 2.5kHz. From 100 kHz and up the transfer function must approach value 1 (0dB).
2. Bass: Cut-off frequency adjustable between 100Hz and 400Hz. Maximum boost or attenuation 10 dB (±1dB) at 400Hz. From 10Hz and below the transfer function must approach value 1 (0dB).
3. Approximate logarithmic control functions for cut-off frequencies and boost / attenuation adjustments
4. No DC currents through potentiometers nor wipers
5. **Option**: tone controls are switched on and off without any clicking noises from the speakers

Volume control specifications

1. Approximately logarithmic control function
2. No DC current through the potentiometer nor the wiper

The preconditions are as follows:

1. The potentiometers for balance, bass, treble and volume control are 10kΩ linear.
2. The potentiometers for the adjustment of the bass / treble cut-off frequencies are 10kΩ logarithmic.
3. All the preamplifier's opamps are low noise NE5532 type. The NE5532 is a dual opamp version of the NE5534. Both Multisim and Pspice contain suitable models for the NE5532 and the NE5534.
4. The simulation results of the sub circuits and the preamplifier are represented by the transfer function (amplitude and phase characteristics). These simulation results must be compared with the transfer function gained by measurement. Draw your conclusions.

3.2.2 Power amplifier specifications

1. Input impedance of at least 50kΩ
2. Output power: 15W sine in $R_{load} = 8\Omega$ at 1kHz
3. Frequency range: 10Hz to 100kHz (−3 dB) at $P_{load} = 0.5W$ in 8Ω

For simplicity of design, the power amplifier should be a monolithic component.

3.2.3 Power supply

The power supply must supply all rated voltages and current in the system as to be determined by the project team. The power supply should be constructed using linear regulators. The projected efficiency should be 80% or better.

3.2.4 Digital part

The project team is to determine and develop the functionality of the digital part of the system. BARK mainly deals with analogue electronics, and so the project team is asked to help develop attractive features that are to be implemented within the project's duration. The features should be discussed with the project coach beforehand. The system will consist of at least:

- An ATmega32 microcontroller or similar;
- Some kind of interaction with the analogue part of the system.

4 Design overview

As already hinted, the system primarily consists of four subsystems. They are the preamplifier, power amplfier, power supply and the digital component (referred to as 'DCU' from here on, short for 'Digital Control Unit'). While the design for the preamplifier is already predetermined for the most part, all other parts have to be designed from scratch. An overview of the system's design will be presented in this section, with minor to no additional clarifications on the design itself. The sections that follow will offer a detailed look into the analysis/design of the parts.

4.1 Preamplifier

The design of the preamplifier can be split up in the following parts:

- Balance control
- Tone (bass and treble) control
- Volume control

These parts will be looked at in greater detail separately, figure 1 shows a schematic overview of the entire preamplifier to show the connection between the different parts.

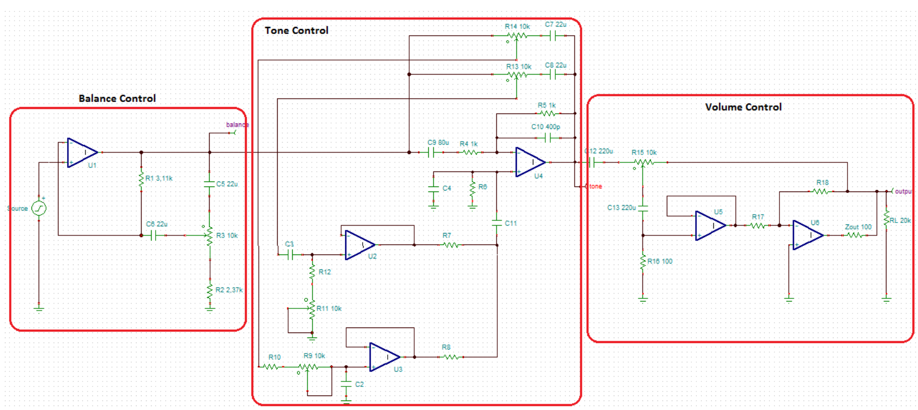

Figure 1: Schematic preamplifier

All parts of the preamplifier have been realized on prototyping boards.

4.1.1 Balance control

The schematic of the balance control is as shown in figure 2.

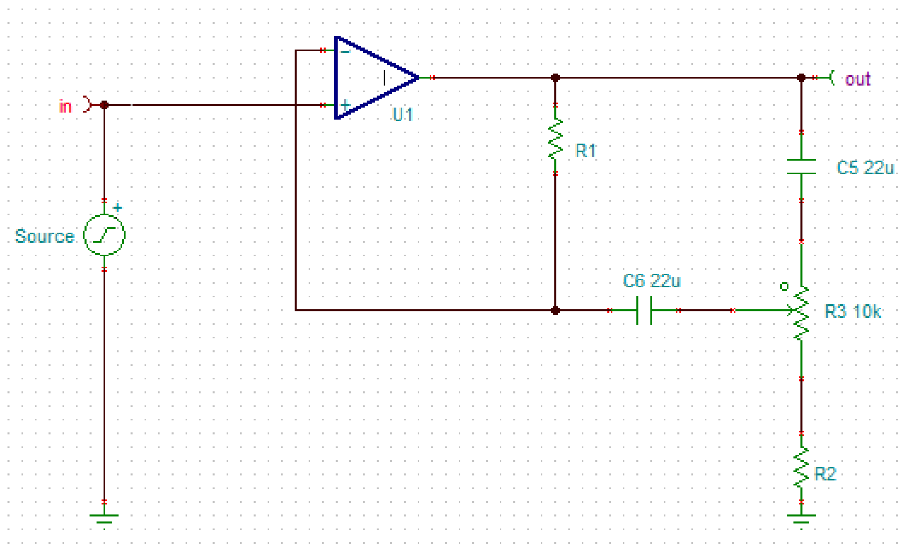

Figure 2: Schematic of balance control

4.1.2 Tone control

The schematic of the balance control is as shown in figure 3.

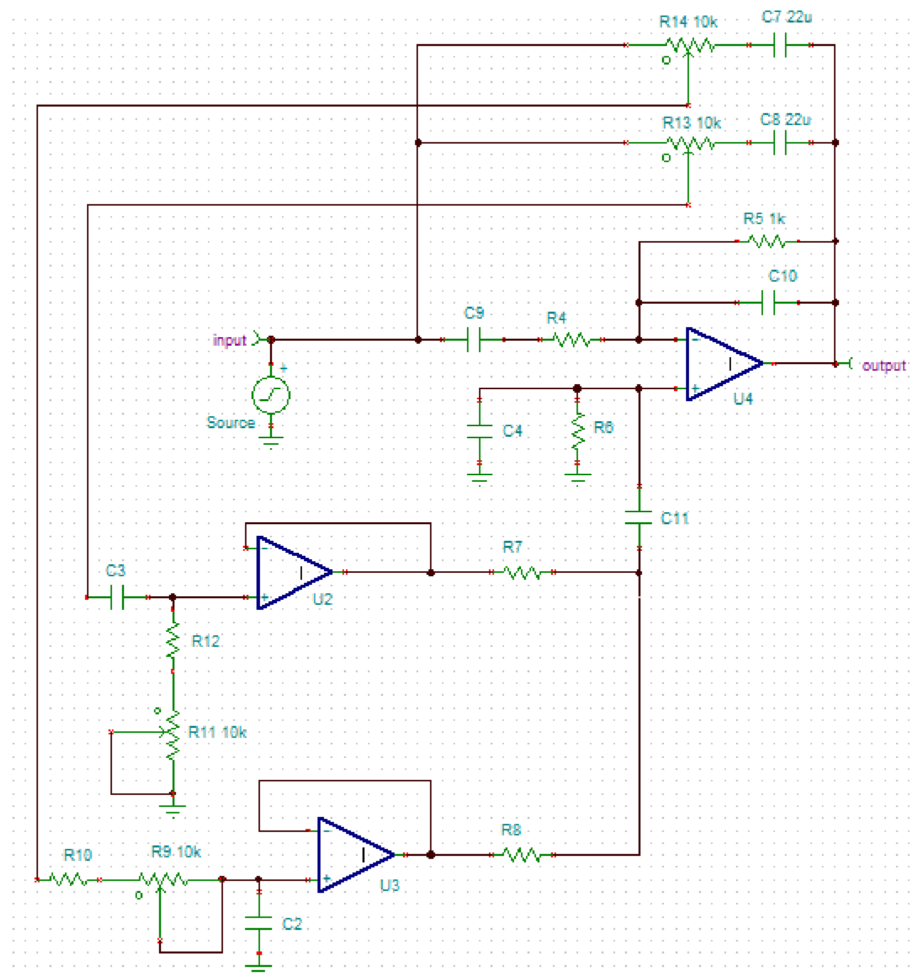

Figure 3: Schematic of tone control

4.1.3 Volume control

The schematic of the balance control is as shown in figure 4.

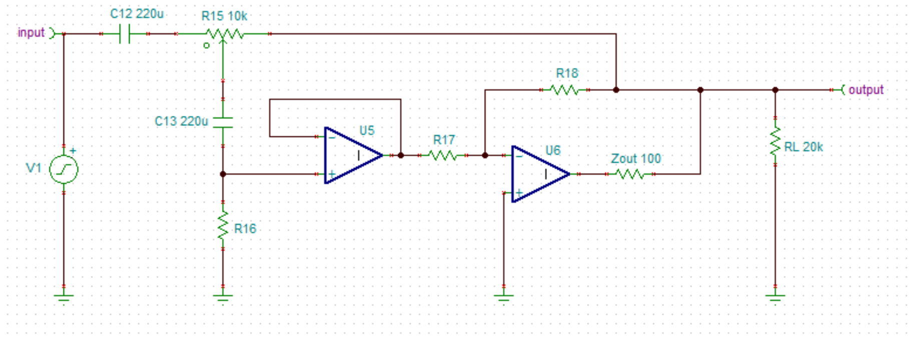

Figure 4: Schematic of volume control

4.2 Power amplifier

The schematic of the power amplifier design is as shown in figure 5.

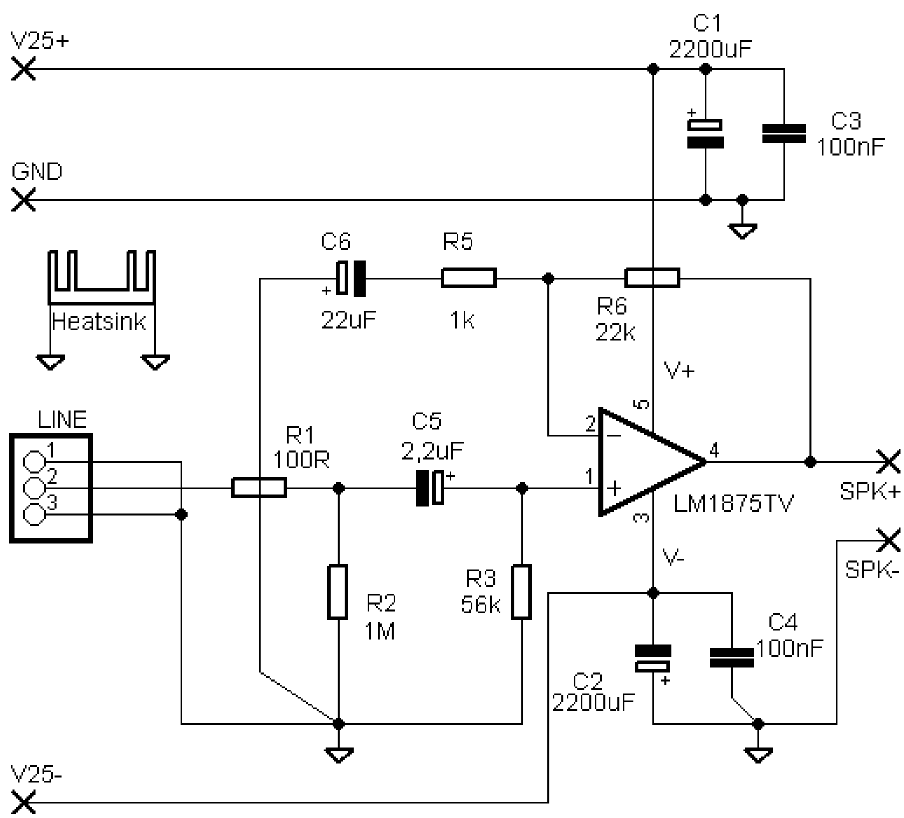

Figure 5: Schematic of power amplifier

Note that pins 1 and 3 of the line-in (named 'LINE' in the schematic) are both connected to ground. This allows for plugging of the mating connector without having to worry about the connector being plugged in the wrong way around. It is also worth noting that a 100Ω resistance is connected in series with the input to protect the amplifier against overvoltage. The added resistance allows the clamping diodes inside the amplifier to deal with any excess voltage.

The PCB design of the power amplifier is as shown in figure 6.

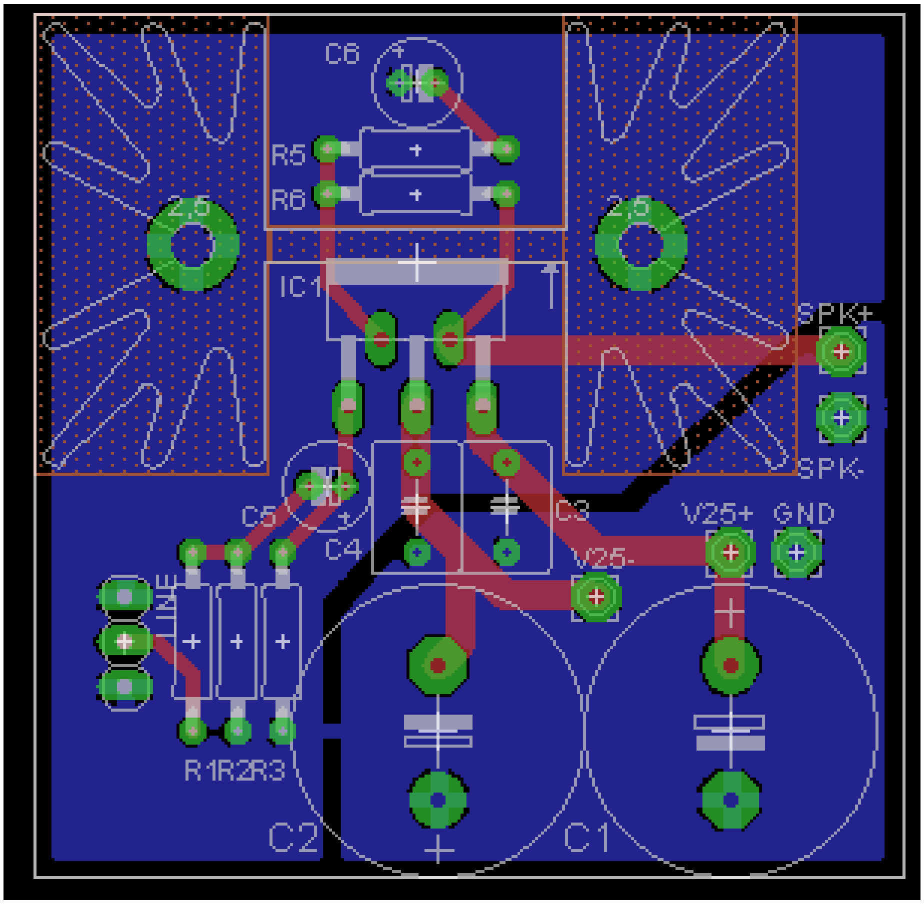

Figure 6: PCB board design of power amplifier

4.3 Power supply

The schematic of the power supply is as shown in figure 7.

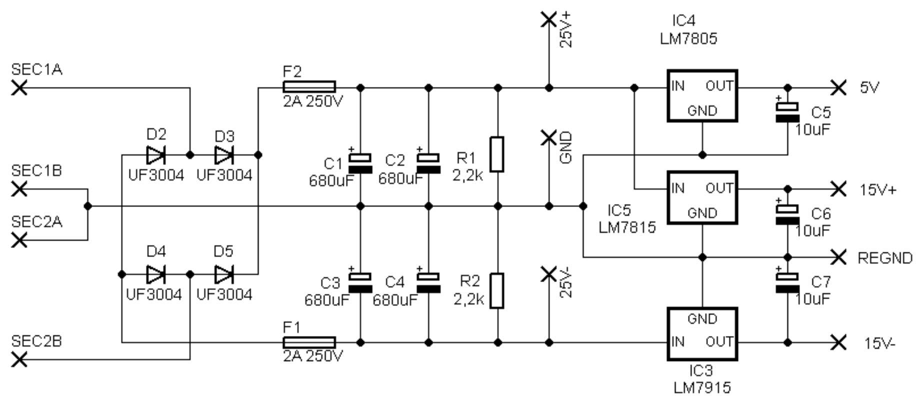

Figure 7: Schematic of power supply

The PCB design of the power supply is as shown in figure 8.

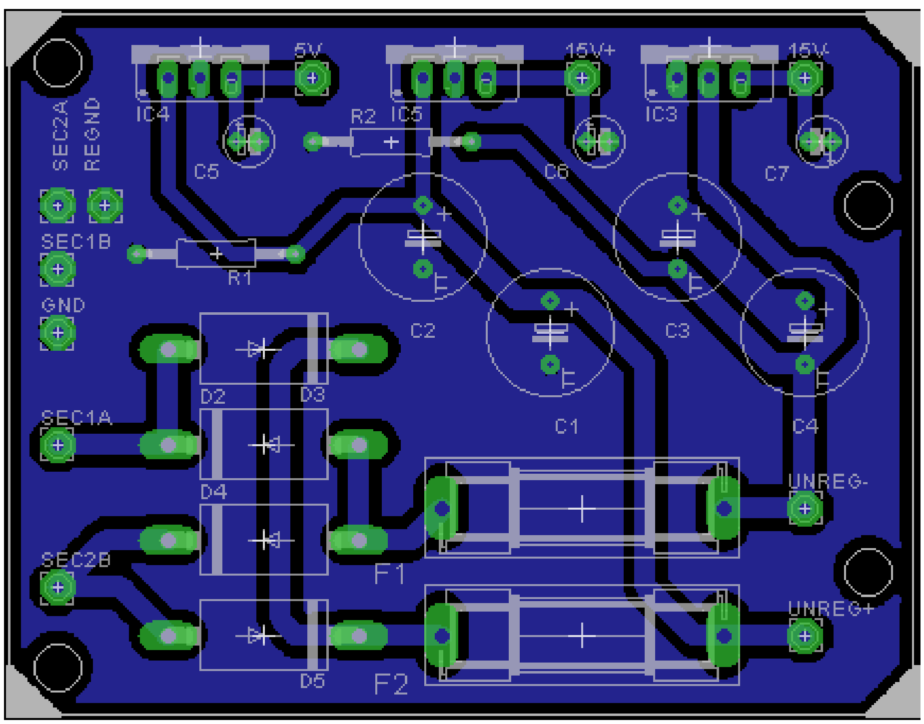

Figure 8: PCB board design of power supply

4.4 DCU

The following features and choices have been chosen/made for the implementation of the DCU:

- For the microcontroller, an ATmega328P will be used since it bears lot of similarity with the ATmega32 which the team is most familiar with.
- The DCU will allow digital control of the balance, tone, bass, treble and volume controls through the use of digital potentiometers.
- MIDI messages will be used to pass commands to the DCU

Figure 9 shows a very basic schematic of the DCU's functionality.

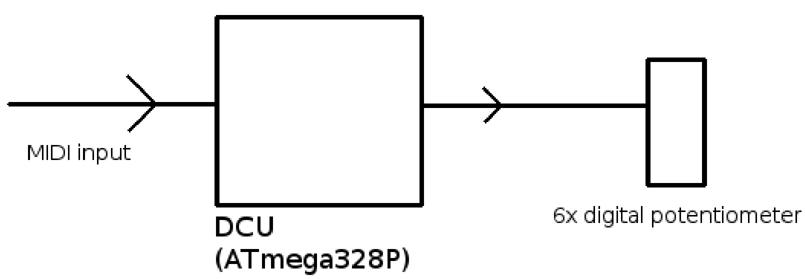

Figure 9: Schematic of DCU

5 Preamplifier analysis

[Indepth analysis of preamplifier including calculations, simulation and measurement results]

6 Power supply design

[Design of the power supply]

7 DCU design

[Design of the DCU]

8 Test procedures and test results

[Description and results of all performed tests]

9 Total costs of system

[Breakdown of the total costs required to build the design]

10 Conclusions and recommendations

[What it says on the tin]