NANYANG TECHNOLOGICAL UNIVERSITY

EE2073 Project Report

Automatic Volume Control for Audio Amplifier System

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1. Project Report

1.1 Required Questions

1.1.1 During the audio amplifier system testing in week 9, did you observe a constant or changing VUoutput3(VRMS) values? According to the close-loop control circuit, please analyze the phenomenon you observed.

We observed changing VUoutput3 values, that would roughly follow the Vpp (audio output) values – as our audio output increased, so would VUoutput3, and as it decreased, so would VUoutput3.

Our system is a closed loop system, essentially one including a feedback loop, in which the VU meter serves to measure the output signal from the PA subsystem. VUoutput3 (Appendix 2.1.2) is part of this feedback look, feeding into our DAQ and then our software to then tweak the audio input signal at the VCA through Vc. This will result in a modified audio output, which is exactly what we want our audio amplifier system to do.

Our changing VUoutput3 values then make sense: as our audio output levels change, so did the VUoutput3 change to reflect that. This gives the software the information needed to tweak the Vc output accordingly, to result in a constant desired audio level.

1.1.2 Can you suggest methods to lower down the noise level of audio amplifier system?

We experienced relatively low noise when testing our device. We only heard noise when the set-point volume was very high. There are ways, however, to reduce the noise level of the audio amplifier system.

It's important to remember that there is already some noise suppression implemented in our hardware. In our VCA, for example, we add a capacitor near the DAQ output to there is integrated internal capacitance to suppress power supply ripple noise. There are also resistors also at differential amplifier to enhance CMRR (common-mode rejection ratio), to reject common-mode signals (signal present at both terminals). A method to lower down noise ratio by modifying hardware would be to modify these capacitors and resistors, but that may be impossible or tedious as we'd have to modify components inside the VCA IC chip.

A more efficient way to lower down the noise level of our audio amplifier system would be to implement better algorithms in our software or optimizing our DAQ. Our DAQ's anti-aliasing filter must be optimized to remove as much unwanted noise as possible from our signal. We must also optimize our reconstruction filter to make sure the signal output is what we need it to be.

1.1.3 On the front panel of your volume controller, there are black needle and a red needle. What do the two needles indicate? Do they show the same response rate to your volume adjustment? What determines the following rate of the red needle and how can you improve or optimize it?

The black needle is the user controlled volume level – the desired volume level. The red needle is the actual volume level read by the DAQ. As we adjust our desired volume level, the black needle immediately moves, and the red needle should (and does!) follow closely behind, with maybe less than a half second response time. This is heard in our speaker: as we adjust the volume, we can hear the noise go up and down as we move our volume knob, just a little bit after we move the knob.

There is, however, still a noticeable difference between the response rate of the needles. The following rate of our red needle is mostly determined by the efficiency of our automatic volume control vi, specifically the step size. The following rate of the red needle can then be improved by improving our software. The initial step size in the lab manual is 0.001, but by trial and error our team found that a step size of 0.01 would increase the converging rate without making the output too unstable. We can also use a better controller algorithm to improve our following rate, or use a timed loop to make sure our program runs as fast and as efficiently as possible.

1.1.4 When testing the automatic volume control for audio amplifier system with music, you can see in the front panel that the red needle often fluctuates around the black needle. Please explain your observation.

Music does not have a set frequency or volume throughout the song. Some sounds in a song may be very high pitched, or very quiet, and some may be loud and low pitched – take, for example, Queen's Bohemian Rhapsody, where some parts sound almost like whispers, other parts of the song are loud guitar solos, some are very low voices and others are almost shriek-like. Thus, the red needle, measuring the output signal volume of the song, will change accordingly with this frequency range, and will suddenly move around the set volume (black needle) when there is sudden change in the volume or frequency of a song.

We noticed that if the loud part of the song continues for a little bit, the volume of the song will be adjusted to the set-point volume. This leads me to think that more fluctuation will happen with a lower following rate of the red needle. This makes sense – the faster our audio amplifier system can adjust to the set-point value, the less sudden changes in volume will affect the output volume. Not having an extremely fast following rate is not necessarily bad though: as long as the actual volume does fluctuate closely around our set-point volume, it may even be desirable to let the needle fluctuate to not modify the artist's choice too much in slightly altering volume in different parts of a song.

1.1.5 When testing your audio amplifier system, did you encounter the overheating problem of power amplifier (PA) or Volume Control Amplifier (VCA)? What reasons do you think that lead to this issue? Please suggest possible approaches to address the overheating problem.

Our PA and VCA IC chips heat up after listening to music for a while (two or three songs in we could feel noticeable overheating of the chips). The main reason for this, I believe, is due to the non-ideal nature of our components, especially our op amps.

An ideal op amp has infinite voltage gain when multiplying the differential input voltage and the open loop voltage. It has infinite input resistance (meaning no current enters the op amp through the input terminals) and zero output resistance (current leaves the op amp perfectly to amplify as much as possible. Clearly, there is always innate resistance in a real component, and never infinite resistance. This means some current enters the op amp in our IC chips, and some current/charge gets retained. When we use our circuit for a while, this accumulation of charge leads to energy to be dispersed as heat.

An important thing to consider, then, when implementing our chips is to make sure they are properly grounded to that as much accumulated charge as possible can leave the chips. This could also mean to ground the chips separately, and to make sure not to clutter the circuit when building it to make sure there is maximum heat dissipation to the air instead of heat accumulation in the components. This is especially important for the PA subsystem, which deals with high current. Finally, another solution to deal with overheating of the chips if they are to be used continuously for a long time is to add a heat sink on them – basically, something that can absorb heat out of the chip when overheating does occur by maybe placing it directly on top of it.

1.2 Optional questions

1.2.1 The chip of voltage control amplifier (VCA) SSM2018T is an old-fashioned production. Suppose now we want to replace or upgrade the hardware, please try to find a commercial chip to replace SSM2018T while maintaining the operation of our volume control system (you can make corresponding adjustments on overall circuit design and show this in report).

One option would be to change the chip to a differential current output version, the SSM2118T. This would allow for "low noise summing"[1]. This new chip would allow for

[1] "Trimless Voltage Controlled Amplifiers SSM2018T/SSM2118T Data Sheet."

minimal changing of our original circuit. We would basically need to add an external current-to-voltage converter, which is integrated into the SSM2018T chip but not in the SSM2118T chip. The data sheet for the SSM2118T chip recommends using OP275 as said current-to-voltage controller.

Another option would be to use a THAT 2181 series Voltage Controlled Amplifier[2], which are high performance VCAs. They allegedly offer low signal distortion over a wide range of signal levels. Using this chip, however, would require substantial adjustments to our original circuit, as the outputs are more complicated than the SSM2018T chip.

1.2.2 The whole circuit includes two amplifier subsystems, the voltage controlled amplifier (VCA) and the power amplifier (PA). Why do we need two amplifiers? What are the purposes of using VCA and PA respectively? Can the two amplifier subsystems be replaced by one subsystem?

It may seem redundant to use two amplifiers, but by understanding what each one does, we see why they are both necessary.

The first amplifier in out automatic volume controller is the VCA. This subsystem controls automatic voltage gain. Mainly, it is the subsystem in out automatic volume controller that handles the main voltage amplification, delivering a high-level voltage amplification. This subsystem handles the volume control of the system.

The PA however, though it does have some low-level voltage gain, voltage amplification is not its main purpose. The PA instead handles current amplification to power our signal through the speaker. This makes sense when we consider that our speaker's resistance is very low (our lecturer, Yvonne Lam, said some good speakers have a resistance of less than 1 Ω). To drive our signal through a low resistance of 0.01Ω with a voltage of 1V we'd need a current of 10Amps if we go by Ohm's Law.

Thus, we need both subsystems as they perform different tasks: one handling the volume level by increasing voltage, and the other increasing the current to drive the speaker.

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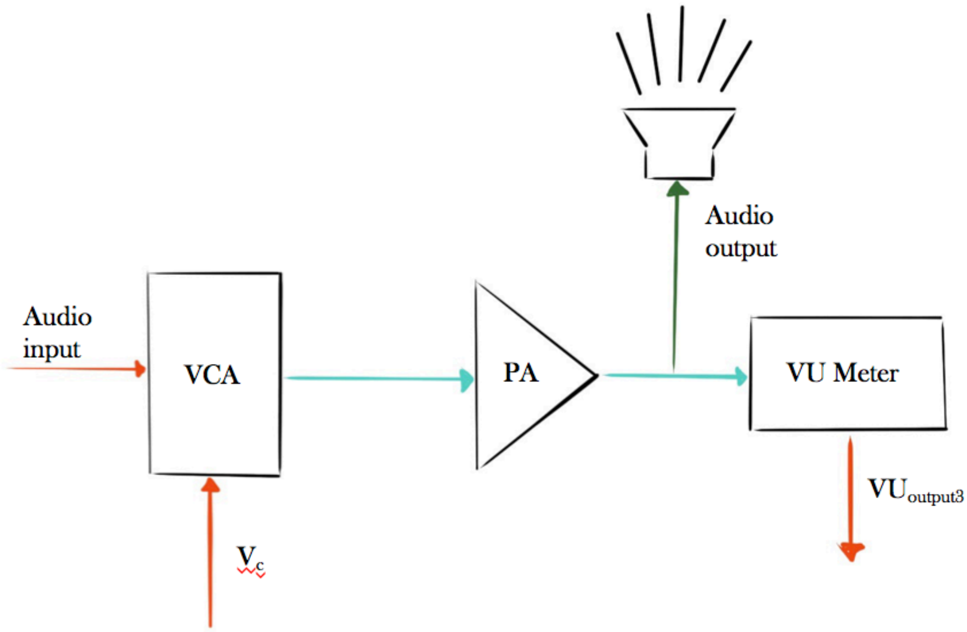
[2] "THAT 2181 Series Datasheet."

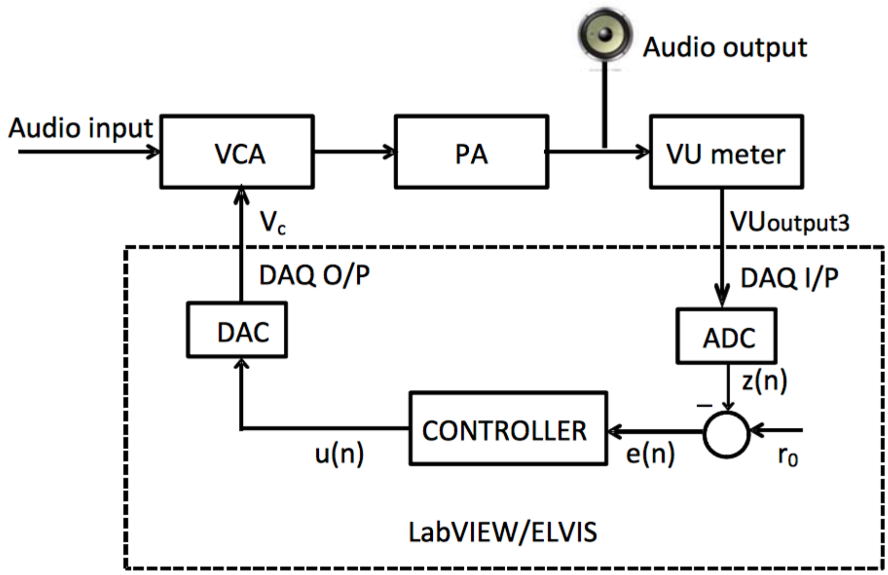
2. Appendix

2.1 Main Component Diagrams and Schematics

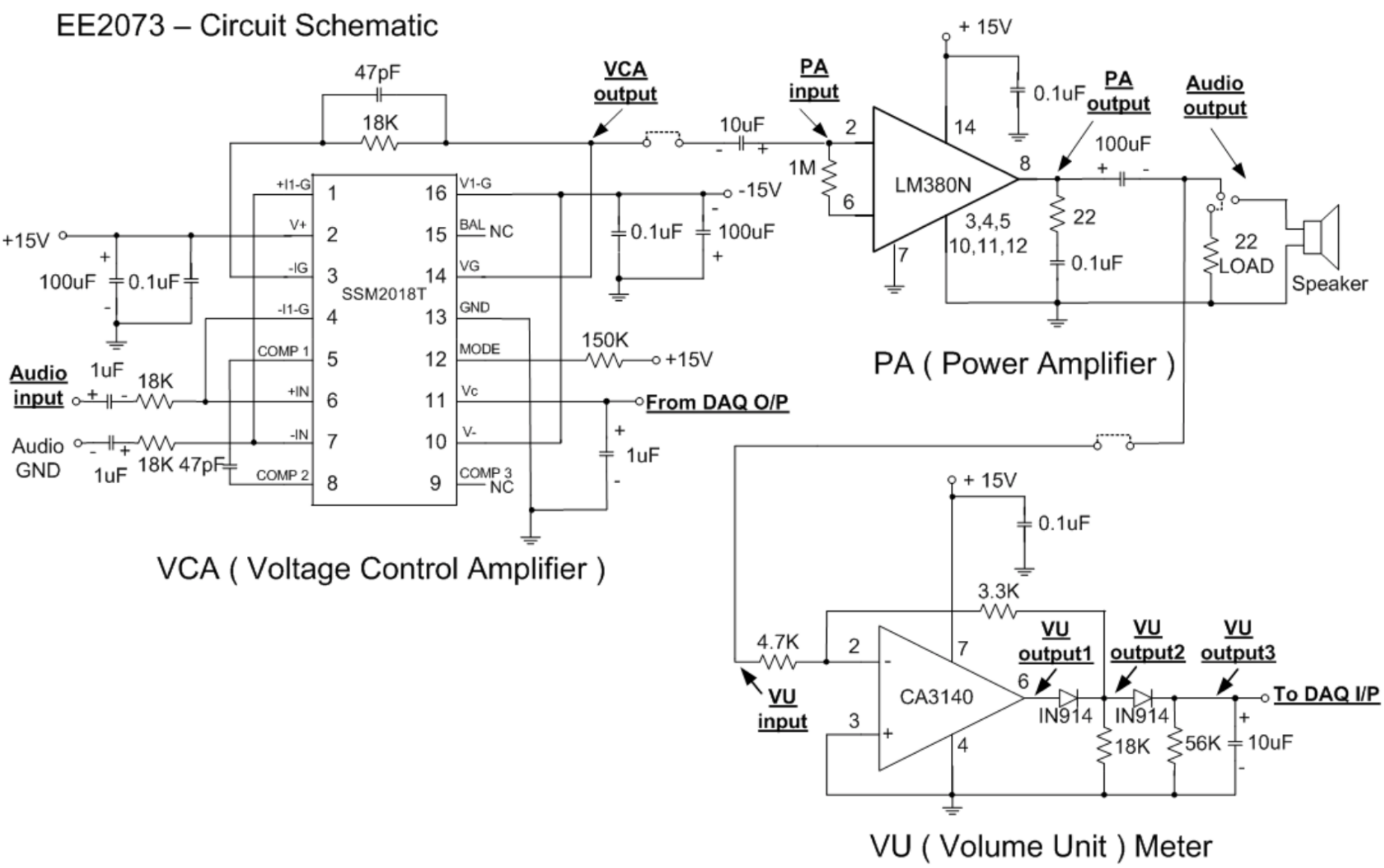
2.1.1 Audio Amplifier System Diagram – Manual Volume Control



2.1.2 Audio Amplifier System Diagram – Automatic Volume Control



2.1.3 Circuit schematic



Audio Amplifier System

3. References

[1] EE2073 Project Manual

[2] EE2073 Lab Manual

[3] "THAT 2181 Series Datasheet." Accessed April 9, 2017. http://thatcorp.com/datashts/THAT_2181-Series_Datasheet.pdf.

[4] "Trimless Voltage Controlled Amplifiers SSM2018T/SSM2118T Data Sheet," n.d. Accessed April 9, 2017.