Measurement Report: Volume Control
PRO-Q2

Daan Conijn, 13023217
Andrew Lau, 13058339
Kevin Oei,13090062
Koen van Vliet, 13093053
Group 1

EQ2.a
EQ2.c

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Contents

1 The objective of the measurement

The objective of the measurement is to get more insight in how the volume control functions and to determine whether it meets the specifications stated in the project book. The measurement is also a preparation for the assessment of the project.

2 Measurement setup

Figure 1 shows the schematic of the volume control. The schematic of the volume control in figure 1 is slightly different from the volume control in the project manual. The capacitors C_{12} and C_{13} are included and these capacitors prevent direct current flowing through the potentiometer and the wiper.

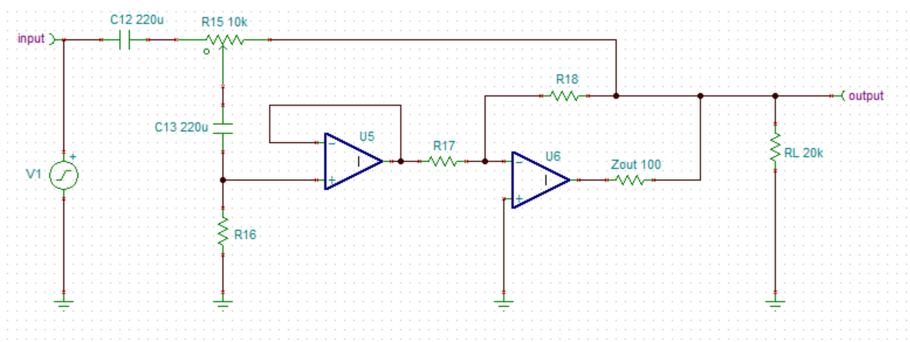

Figure 1: Volume control schematic

The volume control is soldered on a circuit board as seen in figure 2. The potentiometer and the capacitors are not yet soldered on the circuit board. The capacitors and potentiometer are placed on a breadboard and with cables, the breadboard is connected to the circuit board. This way the capacitors and potentiometer can always be replaced in case something is wrong with the capacitors and/or potentiometer. Figure 3 shows the breadboard with the componenents attached.

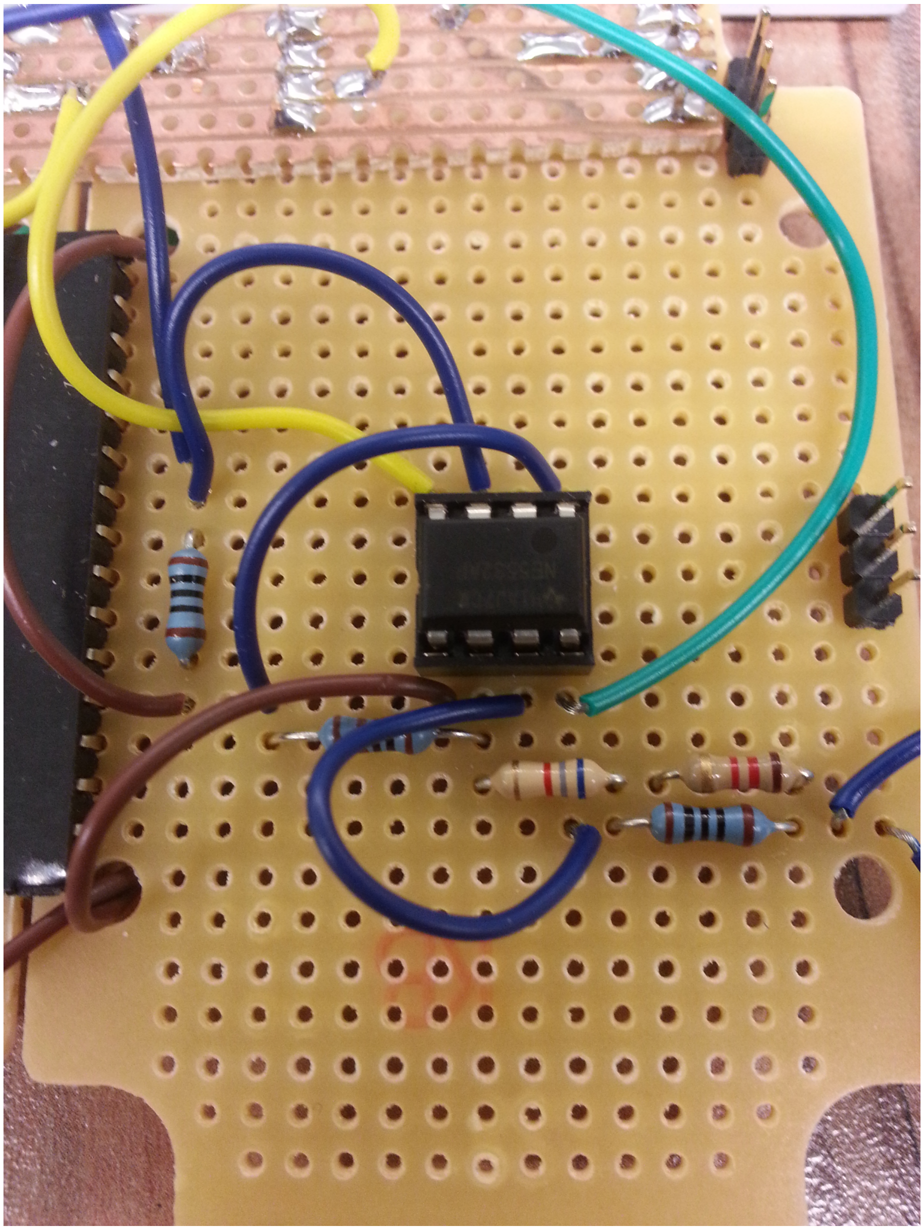

Figure 2: Volume control on a circuit board

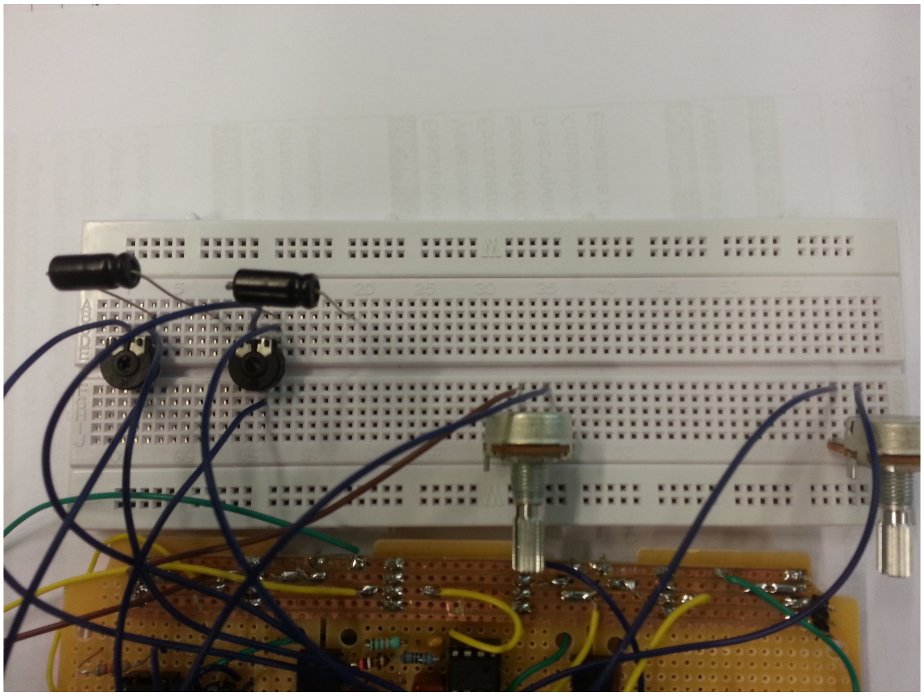

Figure 3: Breadboard with the components attached

The volume control is connected to the following equipment:

- The input of the volume control is connected to a function generator, 'BK PRECISION 4052'. The input signal is a sine with an amplitude of 252mV$_{\text{pk-pk}}$.
- A power supply is connected to the positive (+15V) and negative (-15V) terminals of the amplifiers.
- The signals 'output' and 'input' are measured by using the oscilloscope 'TEKTRONIX DPO2004B'.

3 Specifications

3.1 Overall specifications preamplifier

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

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

3.2 Volume control specifications

- Approximately logarithmic control function
- No DC current through the potentiometer nor the wiper

4 Results

4.1 Calculations

With an input voltage of 200mV, an output voltage of 2V must be acquired with the balance control in flat position, tone (bass and treble) control switched off and the volume control at maximum. With a gain of approximately 1.26 in the balance control and a gain of 1 in the tone control, the voltage at the input of the volume control is approximately equal to:

$$U_{input-volume-control} = 1.26 \cdot 1 \cdot 200mV = 252mV \tag{1}$$

The input voltage of the volume control is now known and because the volume control is at maximum, the voltage at the output of U_5 is equal to the input voltage of the volume control. The values of R_{17} and R_{18} can be calculated.

$$\frac{R_{18}}{R_{17}} \cdot U_{input-volume-control} = 2V$$

$$\frac{R_{18}}{R_{17}} \cdot 0.252V = 2V$$

$$\frac{R_{18}}{R_{17}} = 7.94 \tag{2}$$

The ratio between R_{18} and R_{17} is 7,94. The values of R_{18} and R_{17} can be determined. The following values have been chosen for R_{18} and R_{17}:

$$R_{18} = 7,940\Omega \tag{3}$$

$$R_{17} = 1,000\Omega \tag{4}$$

With the volume control at minimum, the gain should be very low (-∞dB) but that is impossible in practice. Therefore simulations are required to determine what the gain can be if the volume control is almost set to the minimum (99%). The gain with the volume control set almost to the minimum is approximately -50dB. The gain with the potentiometer in middle position (50%) is equal to:

$$17.95dB - (\frac{17.95dB - -50dB}{2}) = -16dB$$

Resistor R_{16} can be calculated to acquire an approximate logarithmic control function:

$$20 \cdot log|\frac{R_{16}}{5,000 + R_{16}} \cdot \frac{7,940}{1,000}| = -16dB$$

$$log(\frac{R_{16}}{5,000 + R_{16}} \cdot \frac{7,940}{1,000}) = -\frac{16}{20}$$

$$\frac{R_{16}}{5,000 + R_{16}} \cdot \frac{7,940}{1,000} = 10^{-\frac{16}{20}}$$

$$R_{16} = 100\Omega \tag{5}$$

4.2 Simulations

The software 'Tina-TI' was used for the simulation of the volume control.

Figure 4 shows the bode plot of the volume control in maximum position.

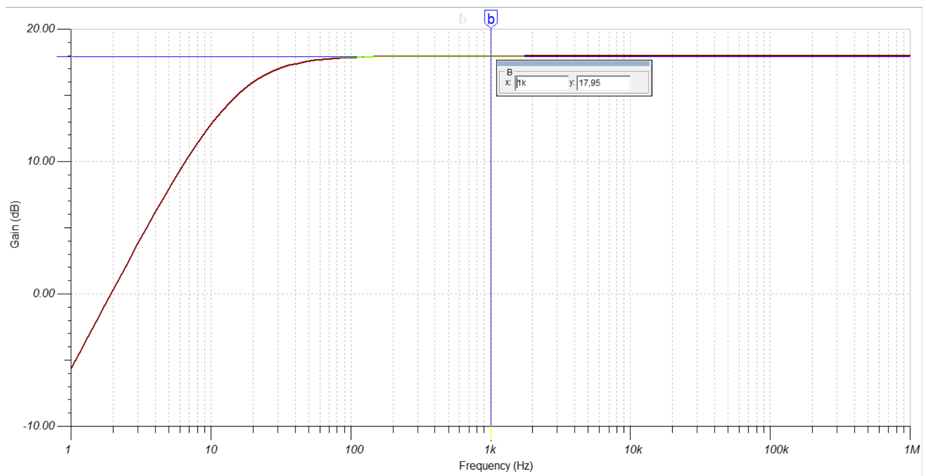

Figure 4: Simulation maximum position

Figure 5 shows the bode plot of the volume control in middle position.

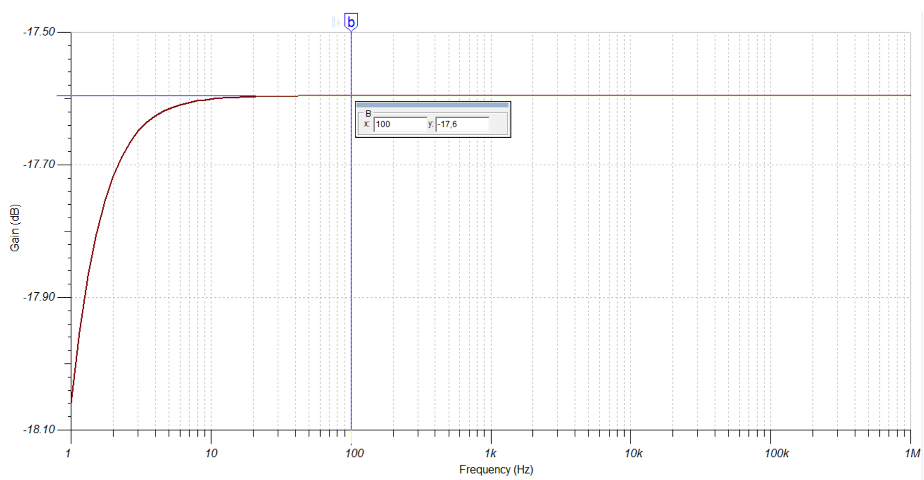

Figure 5: Simulation middle position

Figure 6 shows the bode plot of the volume control in minimum position.

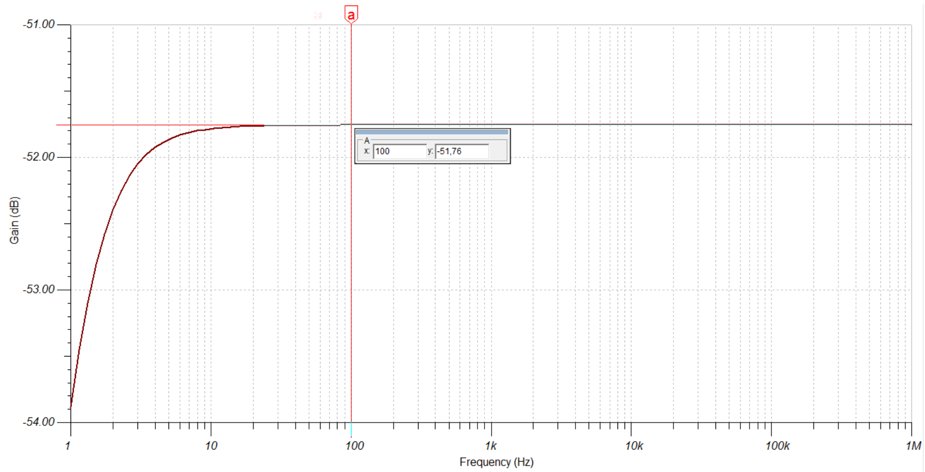

Figure 6: Simulation minimum position

4.3 Measurements

The results of the measurements can be found in the appendix.

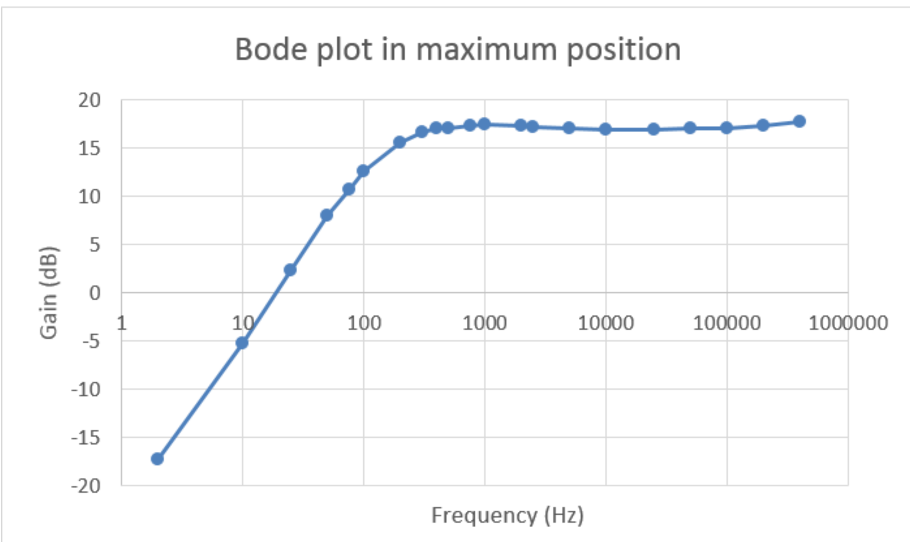

Figure 7: Bode plot in maximum position

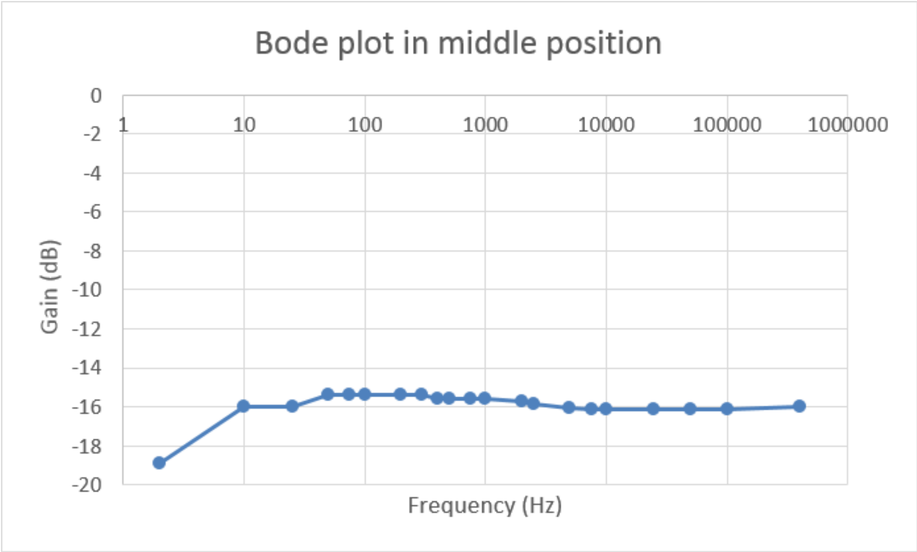

Figure 8: Bode plot in middle position

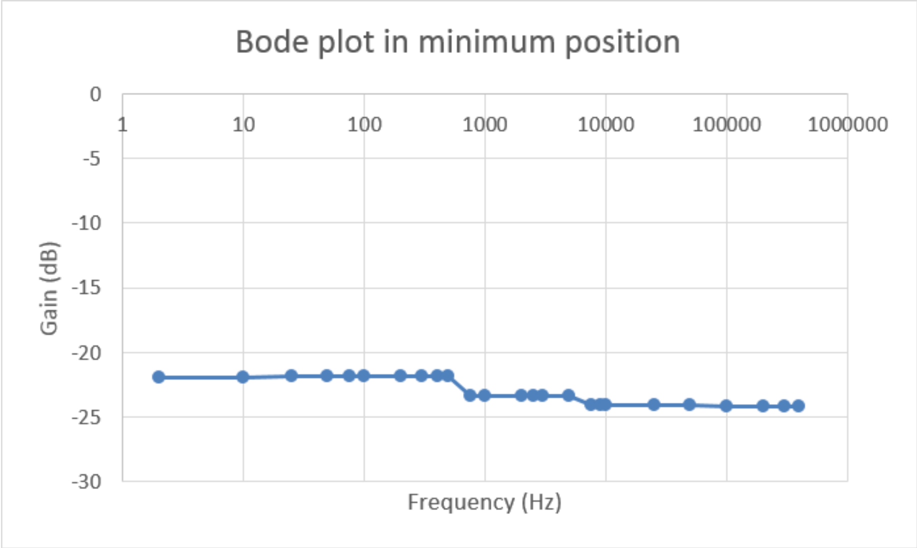

Figure 9: Bode plot in minimum position

5 Conclusion

There are differences between the bode plot provided by the measurements and the bode plot provided by the simulations.

First of all, the gain of the measurement in maximum position (figure 6) begins approximately at -17dB and rises to approximately 17dB. The gain of the simulation in maximum position (figure 3) begins approximately at -6dB and rises to 17.95dB. In an ideal situation the gain should be approximately 17dB throughout the whole frequency range (2Hz-400kHz). The reason for the gain to begin with a negative value, is because of the existing capacitors that ensure a high-pass filter effect.

Secondly, the gain of the measurement in minimum position (figure 8) is approximately 28dB higher than the gain of the simulation in minimum position (figure 5). In an ideal situation, the gain is supposed to be lower than -50dB (probably even $-\infty$dB). A possibility why the gain of the measurement in minimum position is higher than the simulation is of the existing noise that the volume control produce.

There are also simularities between the measurement and the simulations. The gain of the measurement and the simulation are both approximately the same in middle and maximum position at a frequency range of 100Hz-400kHz.

The volume control meets the specifications in maximum and middle position but not in minimum position.

6 Appendix

The results of the measurements of the volume control can be found in the tables below.

Table 1: Measurements minimum position

Frequency (Hz)	V_{in}(mV)	V_{out}(mV)	Gain (dB)
2	0.088	0.007	-21.98769264
10	0.088	0.007	-21.98769264
25	0.088	0.0071	-21.86448647
50	0.088	0.0071	-21.86448647
75	0.088	0.0071	-21.86448647
100	0.088	0.0071	-21.86448647
200	0.088	0.0071	-21.86448647
300	0.088	0.0071	-21.86448647
400	0.088	0.0071	-21.86448647
500	0.088	0.0071	-21.86448647
750	0.089	0.006	-23.42477513
1,000	0.089	0.006	-23.42477513
2,500	0.089	0.006	-23.42477513
5,000	0.089	0.006	-23.42477513
7,500	0.096	0.006	-24.08239965
9,000	0.096	0.006	-24.08239965
10,000	0.096	0.006	-24.08239965
25,000	0.096	0.006	-24.08239965
50,000	0.096	0.006	-24.08239965
100,000	0.097	0.006	-24.17240968
200,000	0.097	0.006	-24.17240968
300,000	0.097	0.006	-24.17240968
400,000	0.097	0.006	-24.17240968

Table 2: Measurements middle position

Frequency (Hz)	V_{in} (mV)	V_{out}	Gain (dB)
2	0.088	0.01	-18.88965344
10	0.088	0.014	-15.96709273
25	0.088	0.014	-15.96709273
50	0.088	0.015	-15.36782826
75	0.088	0.015	-15.36782826
100	0.088	0.015	-15.36782826
200	0.088	0.015	-15.36782826
300	0.088	0.015	-15.36782826
400	0.09	0.015	-15.56302501
500	0.09	0.015	-15.56302501
750	0.09	0.015	-15.56302501
1,000	0.09	0.015	-15.56302501
2,000	0.092	0.015	-15.75393137
2,500	0.093	0.015	-15.84783379
5,000	0.095	0.015	-16.03264692
7,500	0.096	0.015	-16.12359948
10,000	0.096	0.015	-16.12359948
25,000	0.096	0.015	-16.12359948
50,000	0.096	0.015	-16.12359948
100,000	0.096	0.015	-16.12359948
400,000	0.097	0.0154	-15.98502027

Table 3: Measurements maximum position

Frequency (Hz)	V_{in}	V_{out}	Gain (dB)
2	0.088	0.012	-17.30602852
10	0.088	0.048	-5.264828695
25	0.088	0.115	2.324303364
50	0.082	0.206	8.00106736
75	0.078	0.269	10.75315355
100	0.074	0.316	12.60910726
200	0.065	0.393	15.62958387
300	0.061	0.416	16.67526991
400	0.06	0.426	17.02516697
500	0.06	0.431	17.1265204
750	0.059	0.437	17.39258851
1,000	0.059	0.439	17.43225017
2,000	0.06	0.441	17.32574678
2,500	0.061	0.441	17.18217509
5,000	0.062	0.442	17.0606116
10,000	0.063	0.443	16.94126354
25,000	0.063	0.445	16.98038923
50,000	0.063	0.447	17.01933947
100,000	0.063	0.452	17.11595771
200,000	0.063	0.463	17.32480883
400,000	0.064	0.491	17.69803036