First SPICE Exercise

Fundamentals Of Electronics - a.a. 2018-2019 - University of Padua (Italy)

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1 Audio amplifier

1.1 Voltage gain and frequency domain - Ideal op. amp.

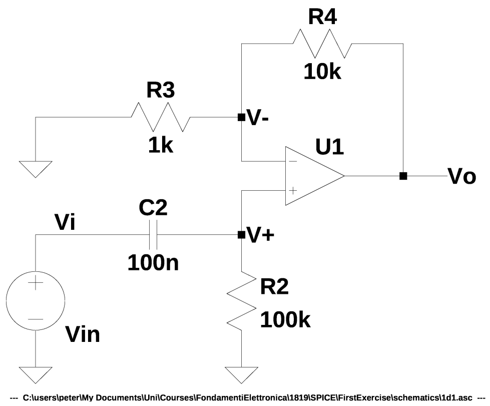

Figure 1: Audio amplifier - Ideal op. amp.

By the analysis of the figure 1's circuit, It's possible to calculate the node V_+ voltage from the ratio of the voltage divider formed by R_2 and C_2, infact the node V_+ voltage is the same voltage of the resistance R_2 (equation 1).

$$V_+(s) = V_{in}(s)\frac{R_2}{R_2 + \frac{1}{sC_2}} = V_{in}(s)\frac{R_2}{R_2 + \frac{1}{sC_2}}\frac{sC_2}{sC_2} = V_{in}(s)\frac{sC_2R_2}{1 + sC_2R_2} \tag{1}$$

The negative feedback produces the virtual short circuit effect, so the V_- and the V_+ voltages have virtually the same value (equation 2), and, because of the fact that the ideal operational amplifier U_1 isn't absorbe current from the V_- and the V_+ nodes, the current of I_{R_4} is the same current of I_{R_3} (equation 3).
The current I_{R_3} is calculated by the Ohm law (equation 4).

$$V_- = V_+ \tag{2}$$

$$I_{R_4} = I_{R_3} \tag{3}$$

$$I_{R_3} = \frac{V_-}{R_3} = \frac{V_+}{R_3} \tag{4}$$

By combining the past considerations it's possible to define the output voltage V_o relating to the voltage input V_{in} (equation 5).

$$V_o(s) = V_+(s) + R_4 I_{R_4} = V_+(s) + R_4 I_{R_3} = V_+(s) + R_4 \cdot \frac{V_+(s)}{R_3} = V_+(s) \cdot \left(1 + \frac{R_4}{R_3}\right) = V_{in}(s)\frac{sC_2R_2}{1 + sC_2R_2} \cdot \left(1 + \frac{R_4}{R_3}\right) \tag{5}$$

Conseguently of the equation 5, the transfer funtion $V_o(s)/V_{in}(s)$ is descripted by the equation 6.

$$\frac{V_o(s)}{V_{in}(s)} = \frac{sC_2R_2}{1+sC_2R_2}\left(1+\frac{R_4}{R_3}\right) \tag{6}$$

Defining K as in the equation 7 and ω_1 as in the equation 8, the transfer function $V_o(s)/V_{in}(s)$ became in the Bode form (equation 9).

$$K = C_2R_2 \cdot \left(1+\frac{R_4}{R_3}\right) \tag{7}$$

$$\omega_1 = \frac{1}{C_2R_2} \tag{8}$$

$$\frac{V_o(s)}{V_{in}(s)} = K\frac{s}{1+s\frac{1}{\omega_1}} \tag{9}$$

Finally it's possible to calculate the frequency domain by the analysis of the transfer function's Bode form (equations 10 and 11).

$$K|_{dB} = 20\log_{10}|K| = \log_{10}\left|C_2R_2 \cdot \left(1+\frac{R_4}{R_3}\right)\right| = -19.1722dB \tag{10}$$

$$\log_{10}|\omega_1| = \log_{10}\left|\frac{1}{C_2R_2}\right| = 2.0000 \tag{11}$$

1.2 Voltage output waveform - LT1028 op. amp.

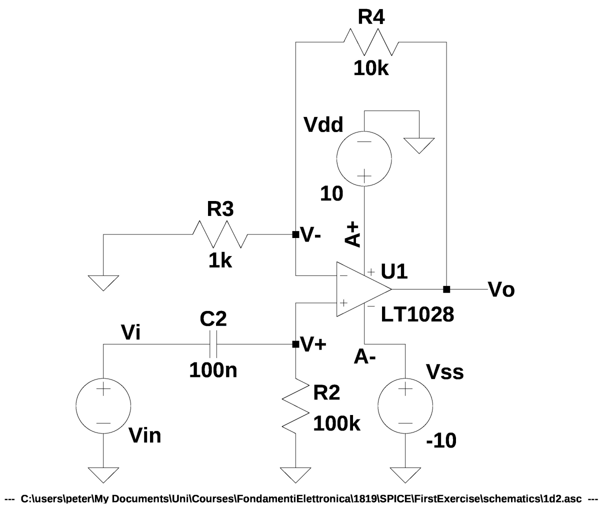

Figure 2: Audio amplifier - LT1028 op. amp.

From now it's considered the circuit of the figure 2.

In order to simulate the waveform output voltage with a sinusoidal voltage input V_{in} with an amplitude of $10mV$ and the frequencies of $1Hz$, $10Hz$ and $10kHz$, it's possible to use a SPICE transient analysis.

1.2.1 Netlist

It's presented the netlist for the SPICE analysis requested.

```
* Audio Amplifier - Waveform
*************************************************************************
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*                     Pietro Prandini - mat. 1097752                            *
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*******************************************************************************

* Libraries
.LIB LTC.lib

* Amplifiers
XU1 V+ V- A+ A- Vo LT1028

* Capacitances
C2 Vi V+ 100n

* Generators
Vin Vi 0 DC 0 AC 1 sin(0 10mV {F} 0 0 0)
Vdd A+ 0 DC 10
Vss A- 0 DC -10

* Resistances
R2 V+ 0 100k
R3 V- 0 1k
R4 Vo V- 10k

* Analysis
.step param F list 1Hz 10Hz 100Hz
.tran 0 250m 0 1m uic

.END
```

1.2.2 Graph

This graph is the output of the last netlist presented. There are three curves, one for every frequency analyzed ($1Hz$, $10Hz$ and $10kHz$).

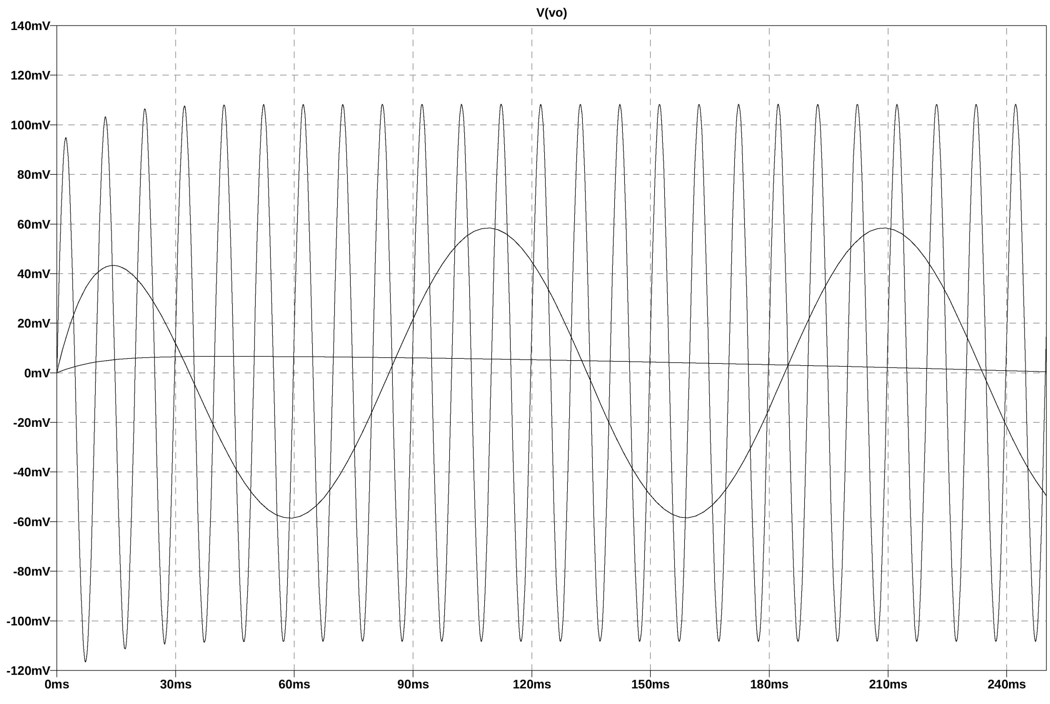

Figure 3: Audio Amplifier - Voltage output waveform

1.3 Bode plot - LT1028 op. amp.

The Bode plot could be generated with a SPICE small signal AC analysis.

1.3.1 Netlist

It's presented the netlist for the SPICE analysis requested.

```
* Audio Amplifier - Bode diagram
*****************************************************************************
* 1st Exercise - Fundamentals Of Electronics - a.a. 2018-2019 - UniPD - 1 of 4 *
*                     Pietro Prandini - mat. 1097752                         *
*                                                                            *
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*****************************************************************************

* Libraries
.LIB LTC.lib

* Amplifiers
XU1 V+ V- A+ A- Vo LT1028

* Capacitances
C2 Vi V+ 100n

* Generators
Vin Vi 0 DC 0 AC 1 sin(0 10mV {F} 0 0 0)
Vdd A+ 0 DC 10
Vss A- 0 DC -10

* Resistances
R2 V+ 0 100k
R3 V- 0 1k
R4 Vo V- 10k

* Analysis
.step param F list 1Hz 10Hz 100Hz
.ac DEC 10 1 100k

.END
```

1.3.2 Graph

The Bode plot generated could be visible in the figure 4. The continuos line represents the module of the transfer function and the dashed line represents the phase.

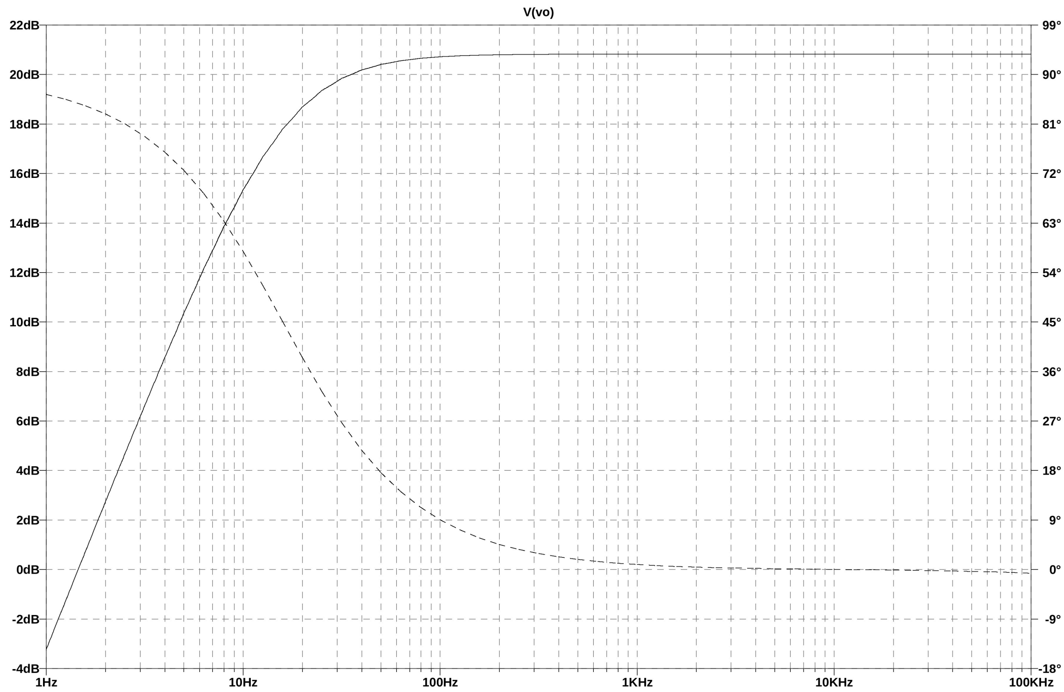

Figure 4: Audio Amplifier - Bode plot

1.4 Saturation - LT1028 op. amp.