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5ISS-B1

Analog Part: Transimpedance Amplifier

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Introduction

The output of our gas sensor is a resistance variation. To be able to obtain a measurable and interpretable quantity by our Arduino, we need, for example, to express a current resulting from this variation of resistance when a voltage is imposed. Moreover, the current is too low to be able to measure it effectively (~ 100nA), it is therefore necessary to design a conditioner circuit that can adapt to the voltage range of our Arduino Uno ADC ([1V; 5V]). For that we decided to design a transimpedance amplifier.

I. Characteristics of the transimpedance amplifier

The scheme of this amplifier is as follows:

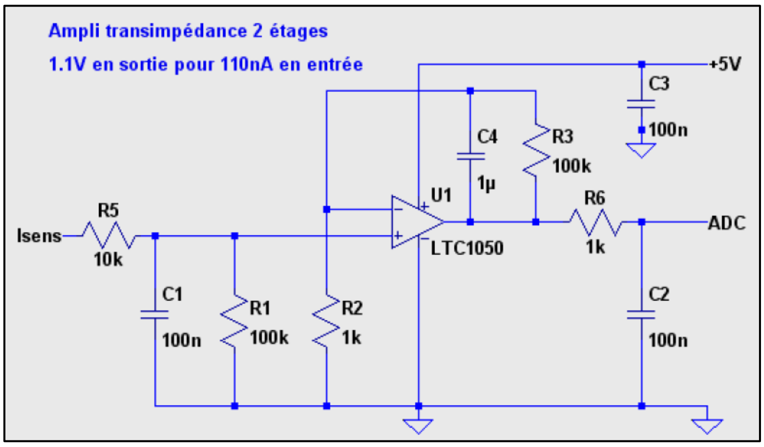

Figure 1: Simulation scheme of our transimpedance amplifier under LTSpice

The measure acquisition is very slow for our sensor, so a bandwidth of 1Hz is enough to extract the relevant information from our sensor.

We can depict 3 parts on the circuit:

- A passive filter on the left (input location) which avoids any RF noise distortion at the input level
- An active filter to have the maximum efficiency, to amplifier the input current
- A passive filter at the output level (corresponding to the ADC) to remove all noises generated inside the circuit during each process of the signal

For the operational amplifier circuit, we can deduct the gain from it. This is an inverter assembly, when the input on the + pin is zero and you are in continuous mode (absence of the C4 capacity).

The gain is then: $A_0 = -\frac{R_3}{R_2} = -\frac{100k}{1k} = -100$

Then we did a transient analysis of the circuit with an input pulse current of 110nA. We can see that we go from 110nA to 1.1V.

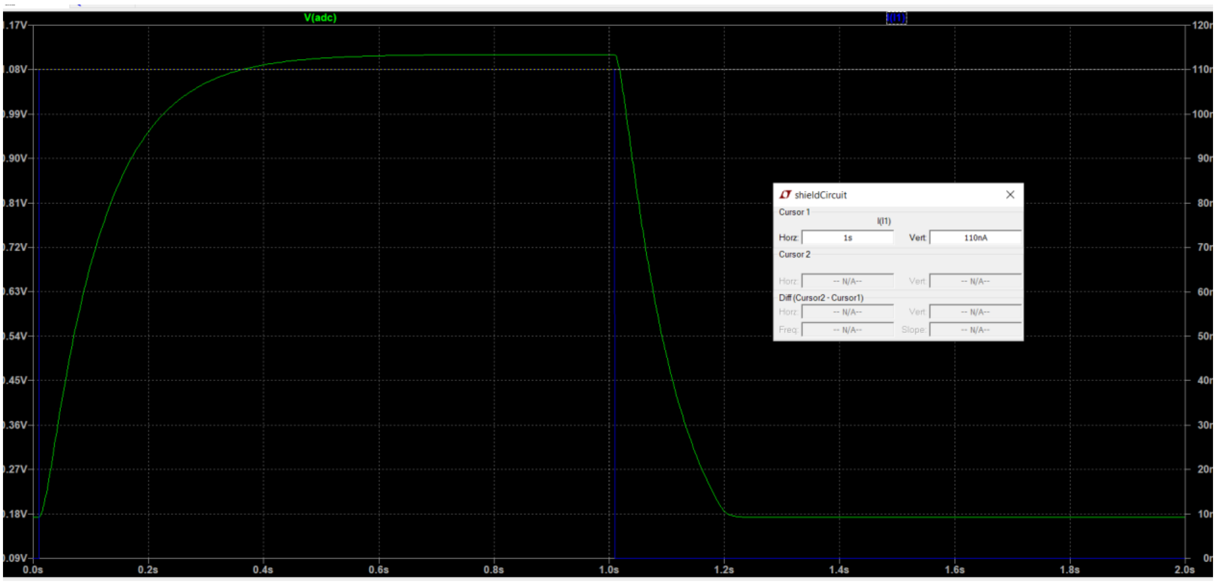

Figure 2: Transient analysis of the circuit under LTSpice

Then, we did a AC analysis in order to identify the low frequency gain. This gain is about 140dB, which is logical because:

$$140dB = 20\log\left(\frac{V_{ADC}}{I_{sensor}}\right) \rightarrow \frac{V_{ADC}}{I_{sensor}} = 10^{140/20} = 10^{7} \rightarrow I_{sensor} = 100nA \; and \; V_{ADC} = 1V$$

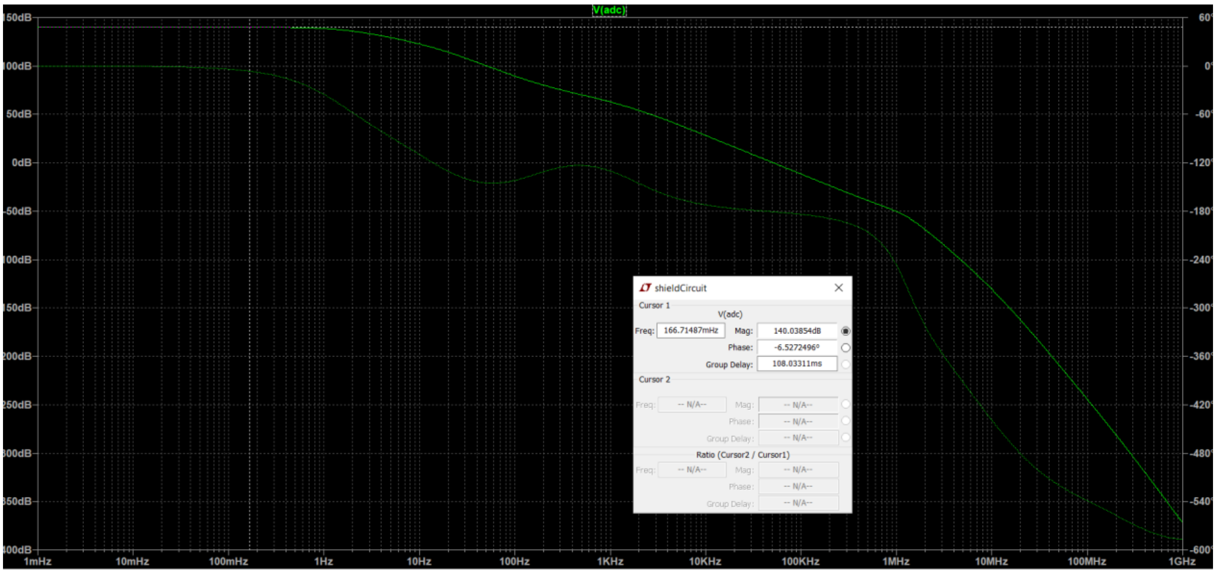

Figure 3: AC analysis of the circuit under LTSpice

II. Analysis of the elements of the circuit

1. Components choice

We choose the LTC1050C for the amplifier circuit. Indeed, according to the datasheet, the maximum offset voltage is 5µV and the maximum offset voltage drift is about 0.05µV/°C. If we suppose that this offset may be amplified, we will have $5\mu V * 100 = 0.5mV$ which is negligible compared to the 10mV at the terminals of R1.

Now regarding the impact of the amplifier input current, the typical input offset current is about ±20pA, so compared to the 110nA, we can ignore it.

So, the LTC150C is suitable for this circuit.

2. Cut-off frequencies and signal attenuation

For each filter we use the following formula to determine each cut-off frequency:

$$f_c = \frac{1}{2\pi.R.C}$$

Then, we can determine the attenuation in dB for specific frequencies:

- 50Hz which corresponds to the current noise
- 7.7kHz which corresponds to the Nyquist frequency (for the ADC of the Arduino Uno)

The maximum sampling frequency usable by the Arduino Uno ADC is 200kHz.

$$f_N = \frac{(\frac{200k}{13})}{2} = 7.7kHz \qquad \text{because} \qquad f_N = \frac{fmax}{2}$$

So, we obtain the following results:

Stage	Theorical fc (Hz)	Simulated fc (Hz)	Attenuation (dB)
n°1 (left)	15.9	16.2	-3
n°2 (center)	1.6	1.6	-3
n°3 (right)	1591	1582	-3
50Hz	x	x	-40
7.7kHz	x	x	-106

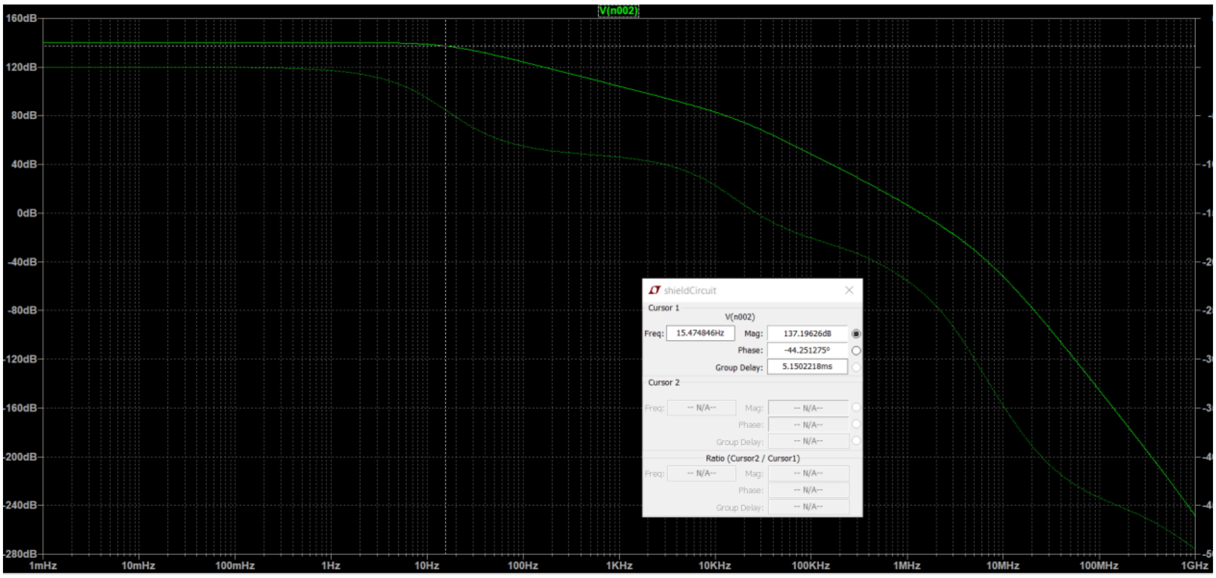

Figure 4: Determination of fc1 under LTSpice

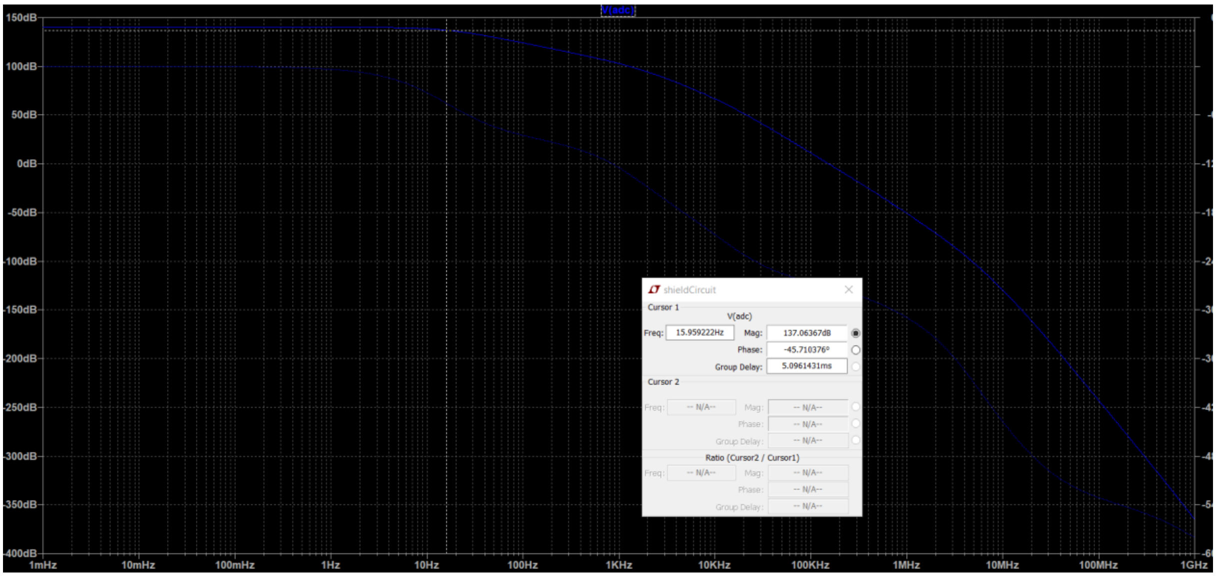

Figure 5: Determination of fc3 under LTSpice

III. Add of a sensor model in our circuit

In this part, we modelized the input with a 5V-powered sensor with conductance ranging from 10 nS to 20 nS in 0.5s. Furthermore, we added a noise voltage source in order to simulate the real conditions for our gas sensor environment. This makes it possible to highlight the interest of filtering at 50Hz.

We design a symbol of our sensor. On the left of the box, both terminals correspond to the gas input, and both right terminals correspond to the electrical terminals of the sensor.

Our sensor contains a low-pass filter to simulate the inertia of the sensor. Then with use a current source to simulate the conductance variation.

The gas sensor model is introduced below.

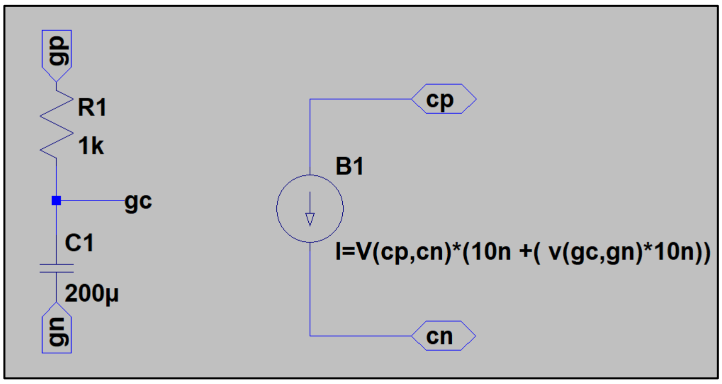

Figure 6: Gas sensor model under LTSpice

The whole circuit is given below.

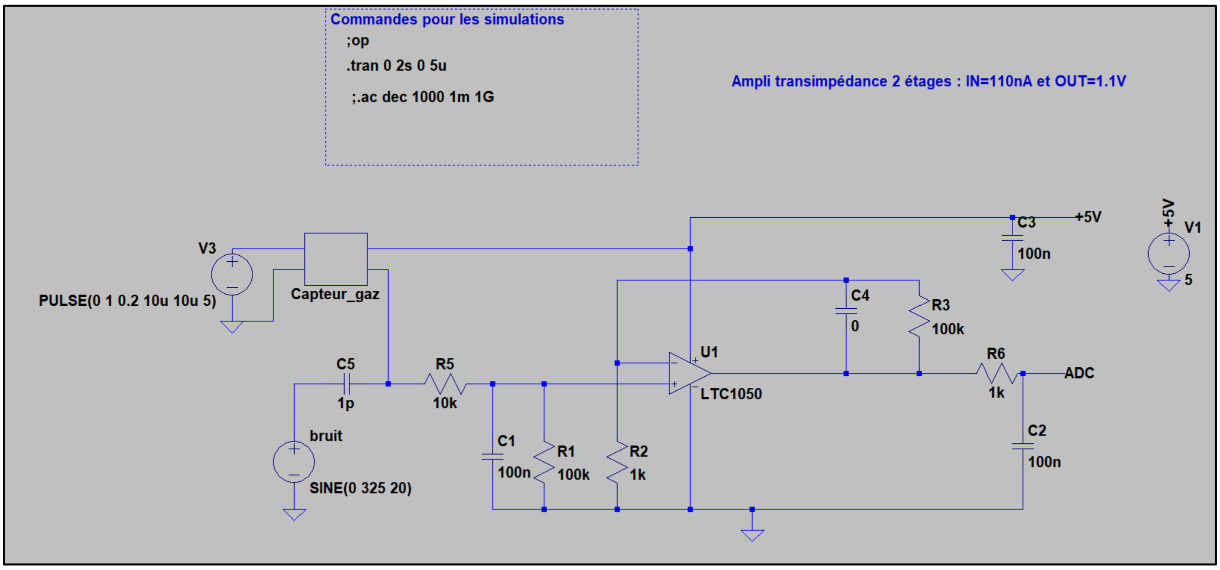

Figure 6: Final circuit under LTSpice