DESIGN OF THE SIGNAL ADAPTER

Eneko Lerma, Robert Griñó, Ramón Costa-Castelló
Departamento de Ingeniería de Sistemas, Automática e Informática Industrial (ESAII)
Universitat Politècnica de Catalunya (UPC)
e-mail: eneko.lerma@estudiant.upc.edu, roberto.grino@upc.edu, ramon.costa@upc.edu
Carlos Sanchis
Mathworks, e-mail: Carlos.Sanchis@mathworks.es

At the beginning of this project, we realized that the output and input ranges of the Arduino do not coincide with the input and output ranges of our plant (LJ Technical Systems). This document briefly explains the different sections of the signal adapter. For this, the following values must be taken into account::

- I/O ranges of the LJ Technical Systems: $[-5, 5]V$
- Output range of the Arduino's DAC: $[0.6, 2.7]V$
- Arduino's analog output range: $[0, 3.3]V$
- Offset: $1.65V$

In order to make the change of the ranges, the signals must suffer a change in gain and an offset compensation both in the measurement channels (A / D conversion) and in the control signal channel (D / A conversion). These two actions are performed separately (in cascade) to reduce the coupling between the two actions and facilitate the analysis by the students.

Output Channels

The input signals to the plants are bipolar, while the signal of the D/A converter of the Arduino Due is unipolar. Therefore, in order to condition it, we first subtract the offset and then amplify its amplitude. To displace the signal through an operational amplifier, a unit gain circuit with a voltage $1.65V$ at the inverting input is used. The amplitude of the signal is changed with the second stage of the circuit having a gain $G_2 = \ fracR_2R_1$.

Specifically, since the plant has an input range of $\pm 5V$ the following values have been chosen $R_2 = 20k\Omega$ y $R_1 = 4k22\Omega$.

The relation between the output voltage and the input voltage is:

$$V_{out} \quad = \quad \frac{R2}{R1(1 + R2Cs)}(V_{in} - V_{ref}) \qquad (1)$$

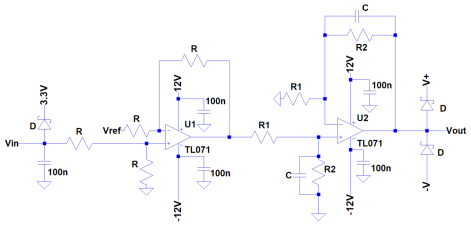

Figura 1: Circuit of the signal conditioner for the output of the D/A converter.

As shown in Figure 1, in the second stage there are two capacitors that allow low-pass filtering, and the cut-off frequency (in HZ) of this filter is:

$$f_c(Hz) \quad = \quad \frac{1}{2\pi RC} \qquad (2)$$

In order to reduce the variety of values in the resistances, we have chosen $R = 20k\Omega$.

With the previous circuit, we obtain the following temporal response:

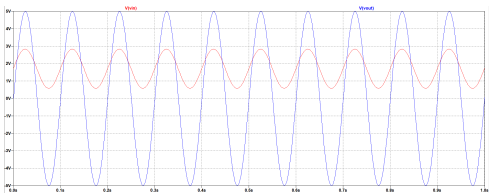

Figura 2: Temporal response of the D/A converter circuit

And the frequency response:

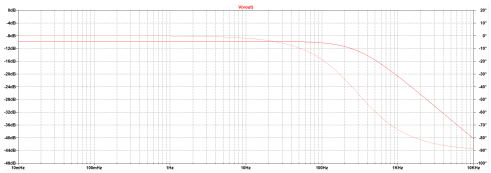

Figura 3: Frequency response of the D/A converter circuit

Input Channels

In the case of the feedback signals (input to the Arduino), the first stage makes the gain reduction, and the second stage the correction of offset. As in the previous case, the range of the output signals of the plant is $\pm 5V$, but now the analog input pines of the Arduino have a range of 0 to $3.3V$. With this, the values of the resistance have been recalculated so that the input of the second stage has a range of $\pm 1.65V$ (to be able to make the same change of offset and obtain the desired range in the analog input pins of the control board). In the second stage, the offset voltage will be added to convert the bipolar signal into unipolar centered at $1.65V$.

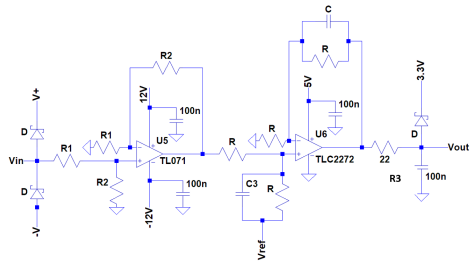

Figura 4: Circuit of the signal conditioner for the output of the A/D converter.

In this case also, the circuit has been equipped with a low pass filter. As it has been done previously, to avoid resistances with different values, some of them have been fixed and the others have been calculated. The chosen values are the following: $R = R_1 = 20k\Omega$, $R_2 = 6k5\Omega$, $R_3 = 22\Omega$ y $C = 0.0265\mu F$.

Finally, the relationship between the output and input voltage is:

$$V_{out} = \frac{R_2}{R_1(1+RCs)(1+R_3 \cdot 100e-9 \cdot s)} V_{in} + \frac{1}{1+R_3 \cdot 100e-9 \cdot s} V_{ref} \quad (3)$$

Being the temporal response:

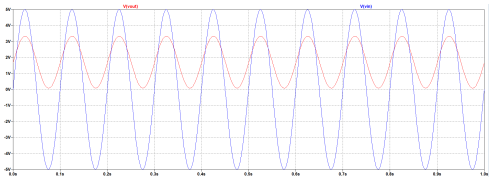

Figura 5: Temporal response of the A/D converter circuit

And the frequency response:

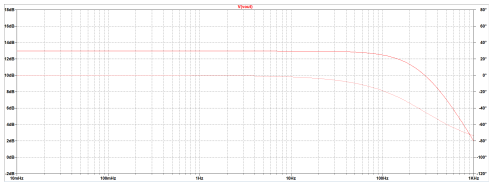

Figura 6: Frequency response of the A/D converter circuit

Generation of the voltage reference

The reference voltage used in the correction steps of the offset is obtained from the voltage reference LM385Z in series with a voltage follower to minimize the effects of load on the reference device.

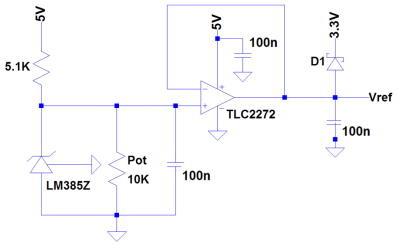

Figura 7: Circuit to obtain the voltage reference

The final result of the board is the one that can be analyzed in the following figure. Where the three circuits have been embedded in it and it fits into the Arduino Due as a shield.

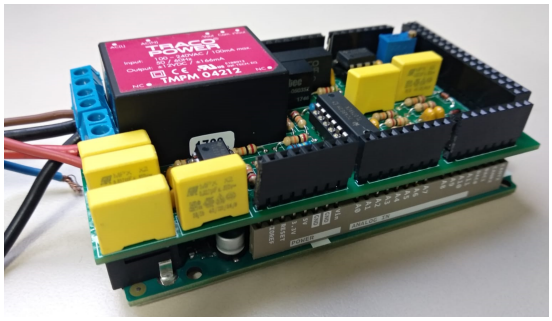

Figura 8: Signal adapter designed for the LJ Technical Systems plant