Construction of Electronic Systems

Exercise 9:

USB DAQ project: analog amplifiers design

Things to consider regarding the analog amplifiers design

When designing the amplifier section, you will at one point have to decide where to place the passive components that surround the operation amplifier (see the figures below). Some resistors stand at the *input* of the amplifier; some stand in their *feedback* path. There is also a *low pass filter at the output* of the input signals amplifier. Where to place them?

The input amplifier

Let's first concentrate on the input amplifier. Try to use the basic guidelines for good component placement presented in the previous exercise. Remember how the length of external "cable signals" on the PCB should be as short as possible and should be "terminated" as soon as possible? You can use the input resistors (i.e. R15, R19) to achieve such a termination. And how the current loops should be as short as possible, in general? You could therefore place the feedback resistor (i.e. R12) so, that the feedback loop stays small.

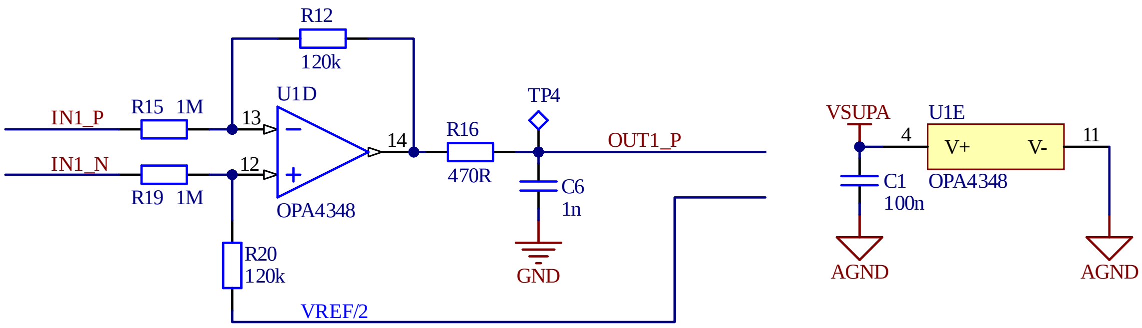

Figure 1 - input amplifier

What about the location of the low pass filter? Which device requires the signal at the output of the filter? The A/D converter in the microprocessor, of course. Therefore, we need to place the components of the filter in such a way that it will do the most to *reduce the noise in the connection leading to the microprocessor ADC pin*. This means that the connection from the filter output to the microprocessor pin must be short. And we can achieve that by placing the filter capacitor near the microprocessor pin.

This will also help stabilize the measured signal voltage during the sample & hold phase of the AD conversion (see the situation in the figure below). The location of the filter resistor is not that critical.

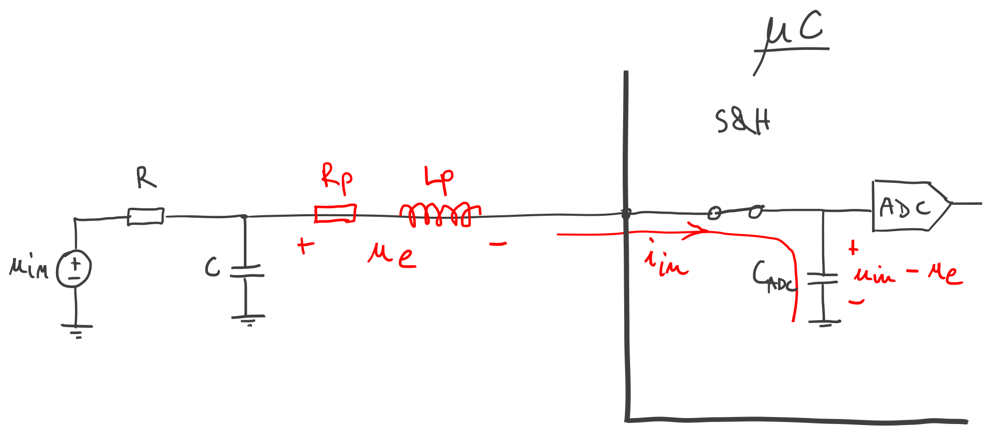

Figure 2 – when the sample and hold switch is closed, a fast current pulse can occur that charges the sampling capacitor C_{ADC}. This current pulse can create a voltage drop along the parasitic impedance on the signal connection leading to the AD converter.

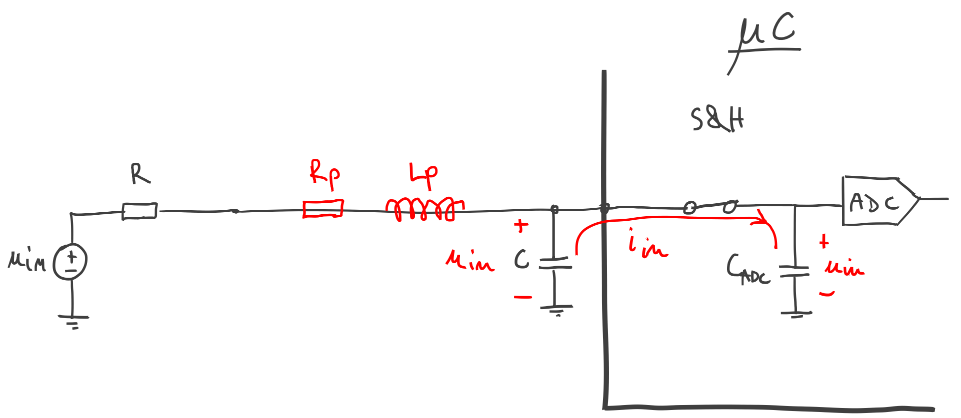

Figure 3 – by placing the filtering capacitor closer to the ADC input pin, the capacitor now provides the current for the sampling capacitor C_{ADC} and the parasitic impedance problem is mitigated.

The output amplifier

What about the output amplifier? Here the input resistors (R11 and R14) are not needed to terminate the external cable signal. So where to place them? It would make sense to place them near the operational amplifier inputs, ensuring that the actual connections to the OP AMP pins inputs stay short. Keep the feedback loop that contains the R8 resistor small. What about the resistor R17? Although it seems that this resistor does not have any important role, it can actually help you minimize the noise that is generated by the so-called "*common impedance coupling*". Let' see how.

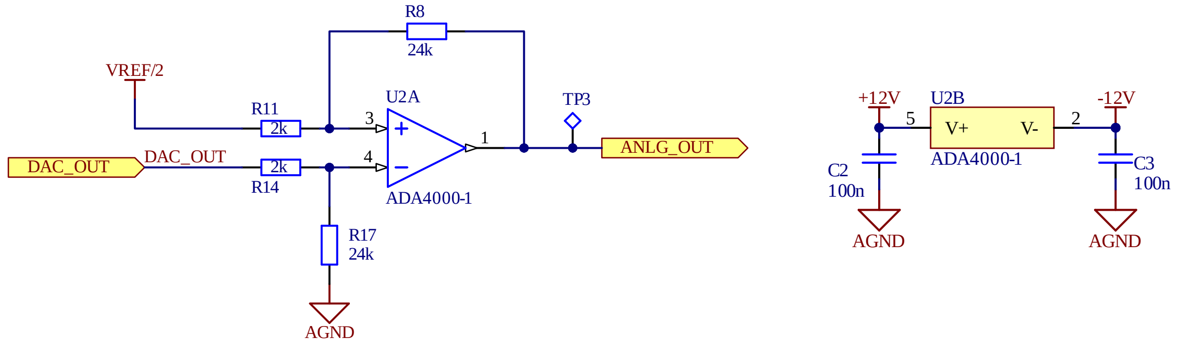

Figure 4 - output amplifier

First we must understand how do we use this amplifier. Below you will find the same amplifier circuit, but the schematic is a bit rearranged in order to better demonstrate the circuit function (Figure 5). The circuit receives the input voltage U_{in} and it provides the amplified output voltage U_{out}, *relative to the AGND reference point*.

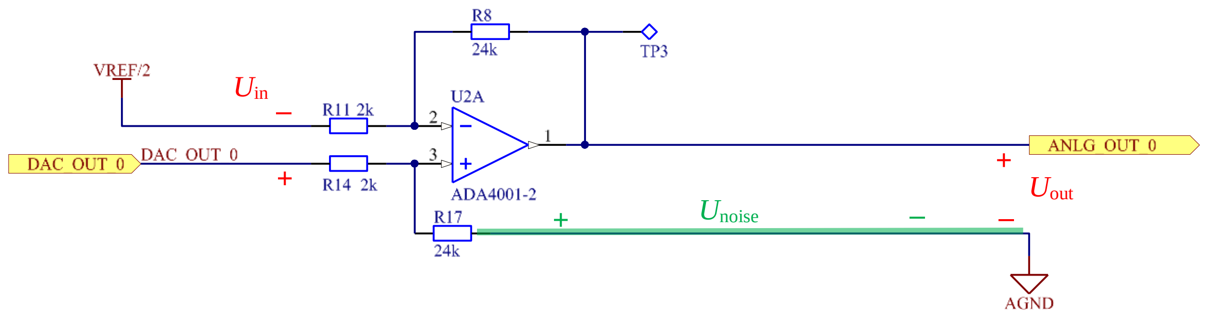

Figure 5 - output amplifier function made more clear:
receiving the input voltage and producing the amplified output voltage ("red voltages")

What we would like to achieve is that at the amplified output signal ANLG_OUT_0 is *transferred to the* <u>*pins of the DAQ I/O connector*</u> *as good as possible*, minimizing the noise-coupling on its way. Which noise-coupling could be problematic here? The noise that is injected by the before mentioned *common impedance coupling* (see lectures). It occurs when other currents also run through the *common connection*. In our case this is the AGND connection (see the "green noise voltage" in Figure 5). How can we minimize this noise? By minimizing the length of the *common* AGND path. And how can we easily achieve that? By simply moving the R17 resistor closer to the AGND pin on the DAQ I/O connector. See the idea below.

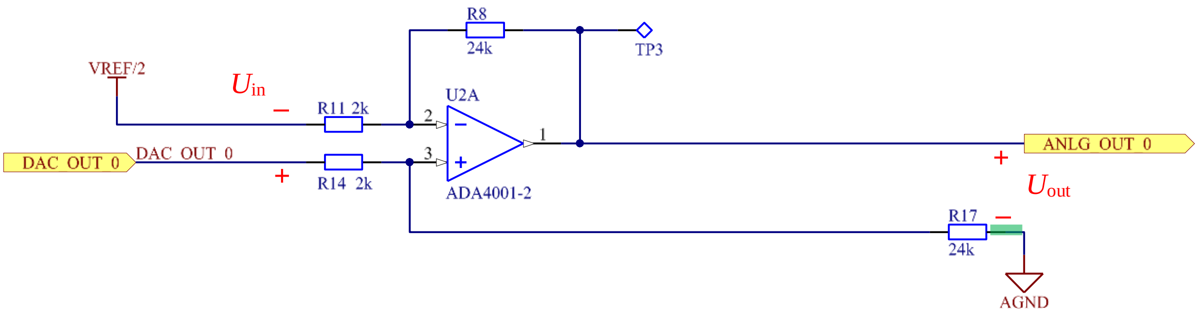

Figure 6 - the length of the common return path AGND is now minimized (green part), minimizing the possible level of the coupled noise

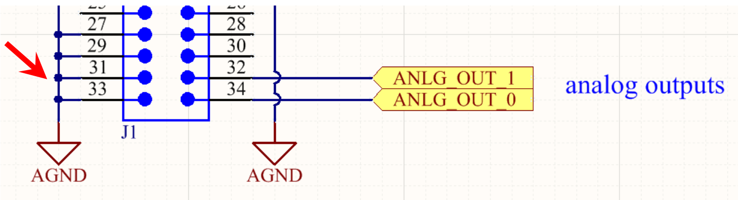

Figure 7 - the output analog signals at the DAQ I/O connector use the AGND connector pins as "the reference" for the output signals

General layout tips

Do not forget about *the* ***good bypass capacitor <u>placement</u> and <u>connection</u>*** for the operational amplifier integrated circuits (see below), that ***ensures a low-impedance path for the power supply current.***

Figure 8 – do not forget about the bypass capacitors for amplifiers

Another ***hint regarding the routing of the tracks leading to the OP AMP integrated circuit***. See the IC footprint below. See how the package of the OP AMP integrated circuit provides a lot of space between the two rows of the IC pins. Try to use this space for connections to the pins as good as possible.

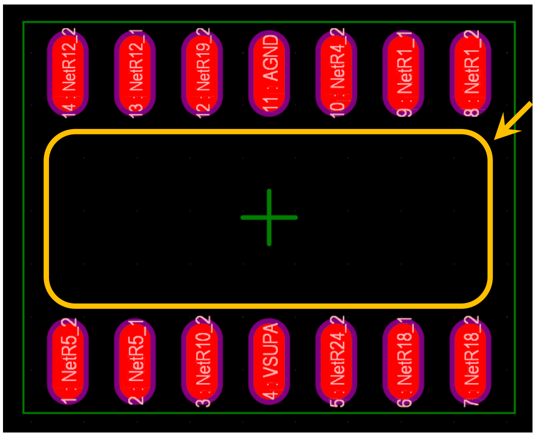

Figure 9 - the package of the OP AMP integrated circuit provides a lot of space between the two rows of the IC pins. Try to use this space for connections.