Construction of Electronic Systems

Exercise 9:

USB DAQ project: analog amplifiers design

In this exercise you will *design the amplifier part of the analog section*, namely the input amplifiers and the output amplifiers. The analog amplifiers section is *considered a sensitive part of the system*, which should be designed for *low EMI susceptibility*. Therefore, you will first make sure that the sensitive analog section is *adequately separated from the noisy digital section*. Then you will analyze the amplifier circuits and *come up with good design decisions* that will help you design a good amplifier section.

Exercise tasks:

1. ***If necessary, revisit the initial component placement try to improve it with a special focus on the good separation between the digital and analog sections.***

   Consider the "signal flow" between the modules, which will eventually lead you to good analog-digital separation.

2. ***Analyze the input differential amplifier circuit (Figure 1) and try to identify the critical parts. Also, consider how the individual circuit components can be used in the most beneficial way to make a better circuit design.***

   a. Which circuit loops are critical in light of *inductive* interference coupling to the analog input signal?

   b. What can be done to decrease this inductive coupling of interferences?

   c. How can the amplifier input resistors (R15 and R19 below) be used to decrease the coupling of the EMI from the PCB onto the cable connected to the DAQ IO connector J1?

   d. Which components are used to filter out the high frequency interferences (noise)?

   e. How can the filtering capacitor be used to stabilize the measured signal during the sample & hold phase of the analog-to-digital conversion?

   f. How should the power supply bypass capacitor be connected to the operation amplifier chip?

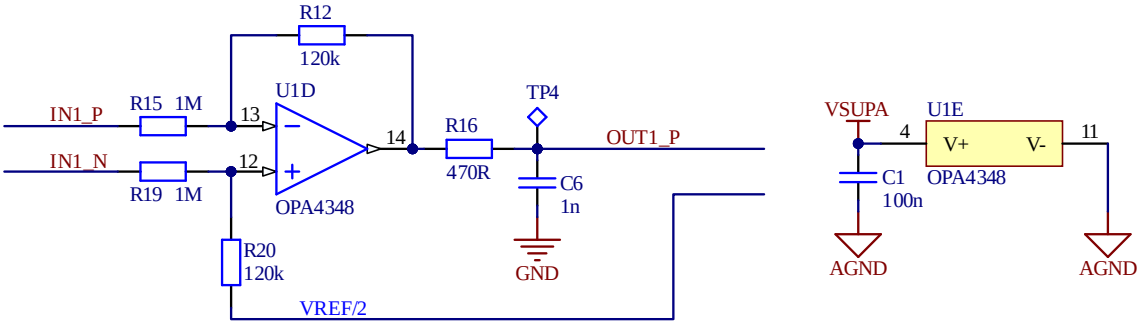

Figure 1 – input differential amplifier circuit

3. ***In a similar fashion, analyze the output differential amplifier circuit.***
    a. Which circuit loops are critical in light of *inductive* interference coupling to the output analog signal? What can be done to decrease this inductive coupling of interferences?
    b. How should the power supply bypass capacitor be connected to the operation amplifier chip?
    c. The output signal ANLG_OUT is referred to the analog ground ANGD. In the analog ground AGND interferences can get coupled to the output signal via the *common impedance mechanism*.
        i. How can the resistor R17 be used in such a way that it minimizes such interferences to the output signal at the DAQ IO connector J1? Where should this resistor be placed?

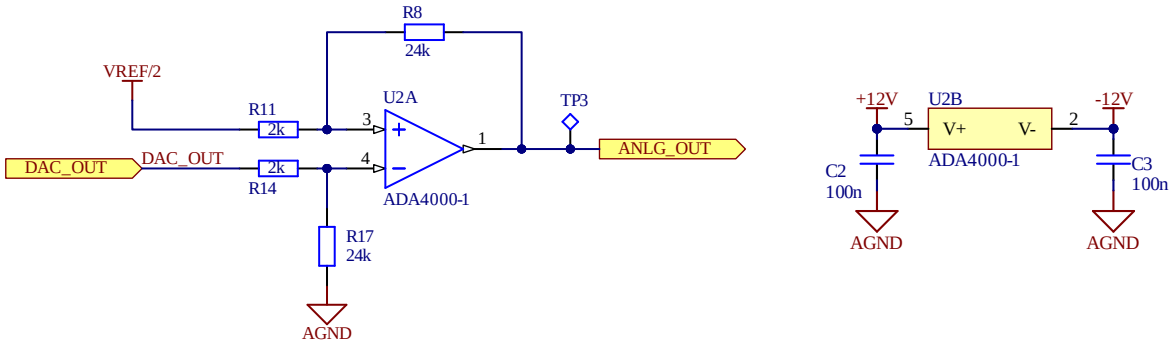

Figure 2 - output differential amplifier circuit

4. ***Design the analog input amplifiers part and the output amplifiers part on the PCB. Also, connect these amplifiers to the DAQ I/O connector.***

    Advice: start with the detailed individual component placement. Start placing the more critical components first and proceed to the less critical. Only when you are satisfied with the component placement, start routing the connections. Do not forget to prepare the GND and AGND vias that will be connected to copper polygons in the last phase of the PCB design.

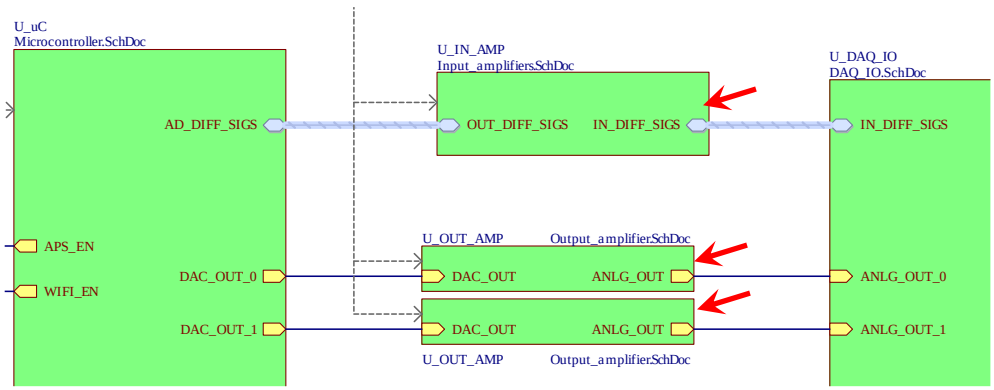

Figure 3 – you will design the analog amplifier parts and connect them to the DAQ I/O connector.

Explanation of the exercise

In the first part of this exercise you return back to the work that you have already done – and try to improve it. Keep in mind, the PCB design is really an iterative process, where you often return to the design that you already made and try to fine-tune it. In this way your PCB design keeps getting better and better. In your case, you will first revisit your initial component placement with the special attention to good separation between the analog and the digital sections. Why is this separation desired? Because it separates the typical fast-changing digital signals away from sensitive analog signals, preventing the digital section to inject noise into the analog section.

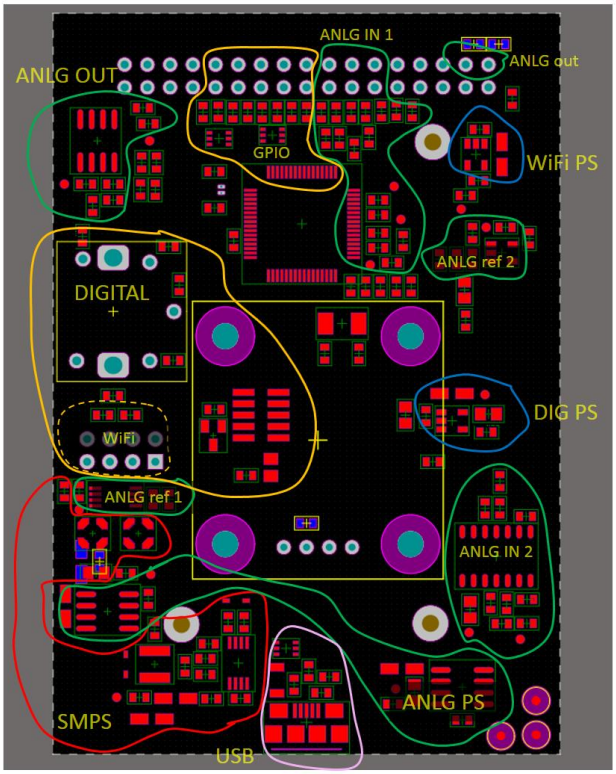

Figure 4 – an example of a bad initial component placement. Such a placement leads to awkward and long connections between modules, where the digital and analog sections often mix and overlap. This will most probably cause problems with digital noise being coupled to the analog section.

In the second part of the exercise you will design the analog amplifiers for the input and output signals. Here the design challenge is reversed from the previous exercise: your design will not be focused on minimizing the EMI generation, since the analog section is not problematic in this way. This time you will be designing a circuit that should be designed for *good EMI immunity* and *low EMI susceptibility* so that the analog signals are not that easily affected by the possible surrounding interferences.