Construction of Electronic Systems

Exercise 10:
USB DAQ project:
microcontroller part & USB part design

Some thoughts on designing the microcontroller part

Find a good microcontroller location and orientation

You should try to find a good microcontroller location that will provide *enough room to place all the critical components near the microcontroller*:

1. those components that require *low-impedance connections to the microcontroller*:
   1.1. bypass capacitors,
   1.2. decoupling capacitors,
   1.3. "signal stabilizing capacitors" for the analog-to-digital conversion;
2. those components or connections that might produce the EMI with the connections to the microcontroller
   (e.g. fast oscillators, fast communication signals etc.);
3. bulk capacitors etc.

Start the design with the most critical parts

Always start the design of the circuit part with the most critical section and then gradually progress towards the less critical sections. This ensures that you always have the most available space for the design of the critical parts, which means that you can do them as best as you can. And then all of the less critical sections have to be designed around the more critical sections.

In the case of the microcontroller part, the most critical components are already listed above in the previous section in the correct order: from the bypass capacitors to the fast oscillators.

By the way, why are the fast oscillators less critical? Because although these fast oscillators work at a high frequency, their signals typically have the *sinusoidal shape* and are not digital *square* signals. This means that they do not have the problematic high order harmonics. See the example of the 16 MHz oscillator signal from the Arduino ATmega microcontroller below. And usually, these oscillator signals have much smaller amplitude that the digital signals. Nevertheless, you should still be careful with the oscillator design and try to do it as best as you can. The oscillator is still a source of constantly present high frequency signal.

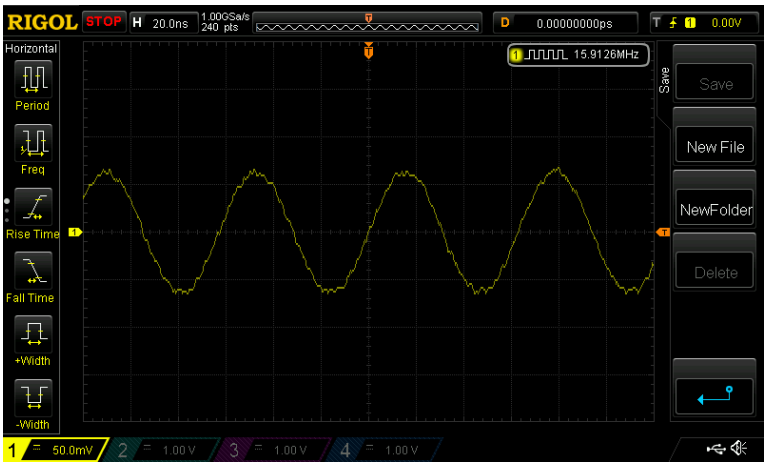

Figure 1 – the 16 MHz quartz oscillator signal on Arduino. It has a sinusoidal shape, which means that it does not contain fast voltage transients as do the fast digital signals of square shape.

Bypass capacitors – good placement is not enough

In order for the bypass capacitor to really be *efficient*, you must, of course, place it near the chip power supply pin. If you *want to make the entire current loop of the bypass capacitor small*, this is obviously the way to start. But the good placement alone is not enough! You must also ensure that the *return current path over the ground is as short as possible.* And this is something that we can easily overlook if we are not careful, because we are relying on the "almighty ground polygon pour on the bottom side". See the example below.

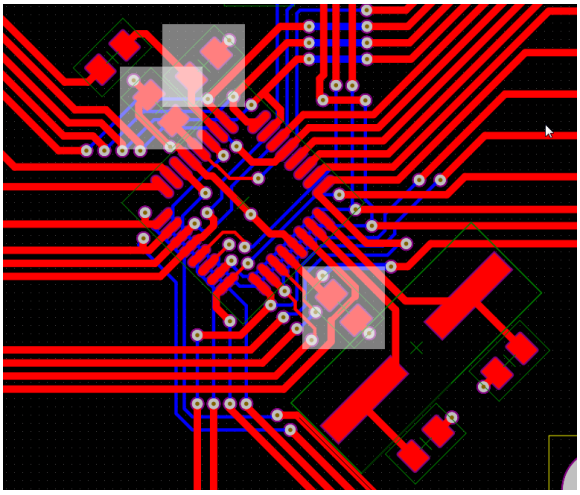

Figure 2 - the bypass capacitors for this ATmega microcontroller are placed very well. But…

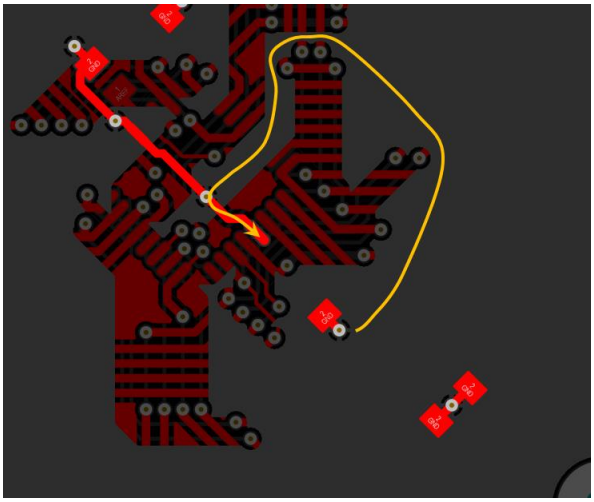

Figure 3 - but when inspected in more detail we notice that the bypass capacitor ground return path is really very long! This happened because the bottom ground polygon is cut right underneath the microconroller, preventing the short return path.

Ensuring a good ground return path by placing connections on the bottom

One way to really ensure the good ground return path for the bypass capacitors, for instance, is to *actually place a ground track on the bottom side of the PCB*. See the example below. At the end of the PCB design these ground tracks will be poured over by the GND bottom copper pour.

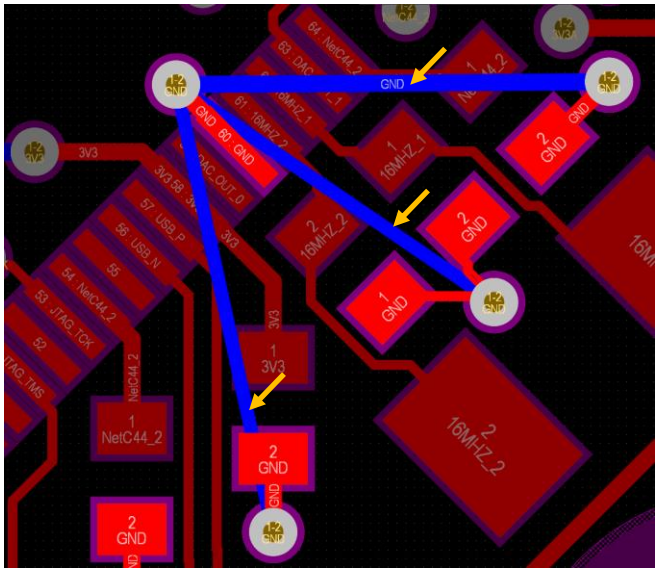

Figure 4 - reserving the room for the good ground return paths where this is critical by actually placing the ground tracks

If you decide to use the approach above, then you must first ensure that the Altium does not remove connection loops for the ground net. You can do this in the

PCB panel : Nets : All Nets : GND -> [right mouse click] -> Loop Removal -> Set selected OFF

See below.

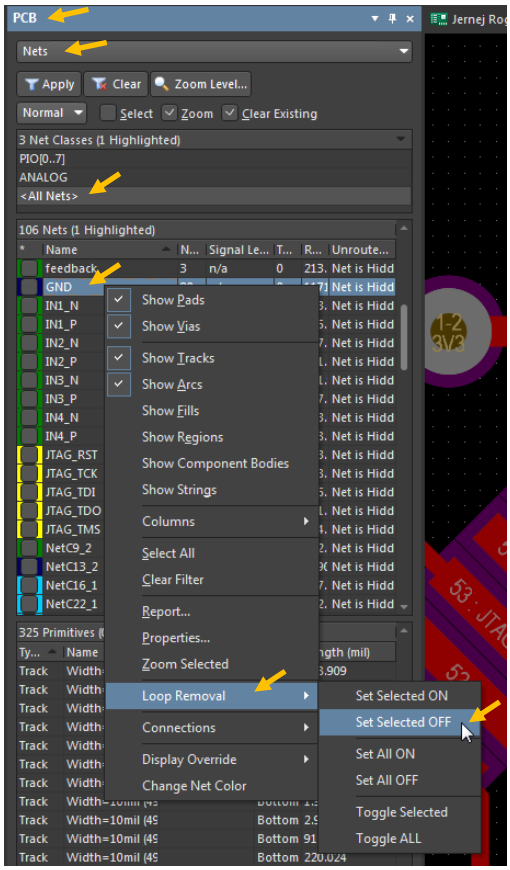

Figure 5 - preventing the Altium to remove connection loops for the ground net