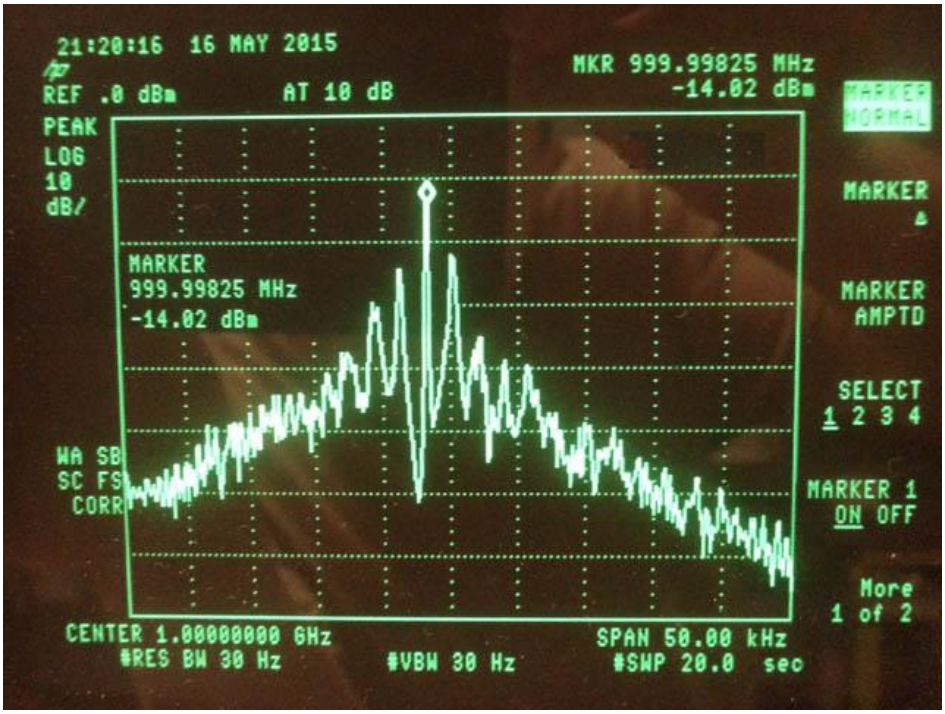
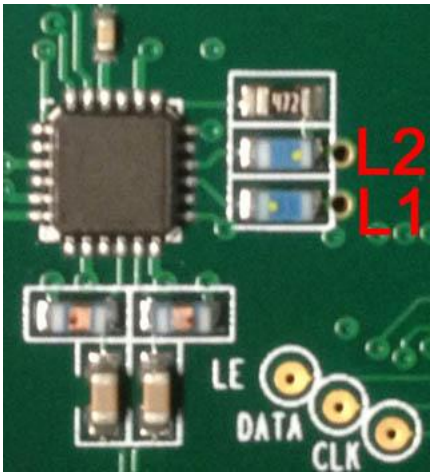
Project Yaigol

Part 2. The PLL (continued)

I went ahead and replaced the loop filter on the PCB. This improved the situation but was not what I expected. The PLL was still wobbling with modulation around the carrier and within the loop filter bandwidth. Modulation was suppressed out of band but the noise level was high.



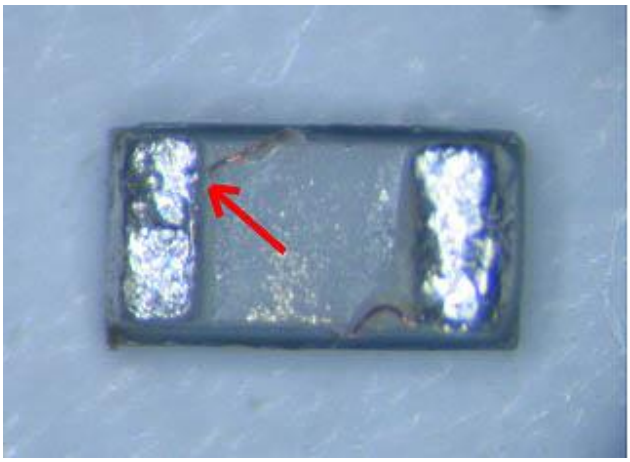
I scratched my head for a while thinking what else may be wrong. I trusted the ADI simulator, I used it many times and it always came up with working circuits. There was not much else to try. I have checked and eliminated the reference oscillator before. I replaced the loop filter. What else left were the output inductors and the VCO inductors. I did not consider the output inductors would give trouble. So, hmmm…, let's take a look at the VCO inductors, here they are again, to the right of the PLL chip:



What can be possibly wrong with them? Well, an RF person would tell right away that they should have been positioned at right angle to reduce coupling. Same says the PLL Datasheet: …"To reduce mutual coupling, the inductors should be placed at right angles to one another." I always place any adjacent inductors at right angle. Any RF designer would. Not Yaigol Yingineers. All they needed to do is to read the Datasheet. They did not. Neither they had a clue about the basics of RF design.

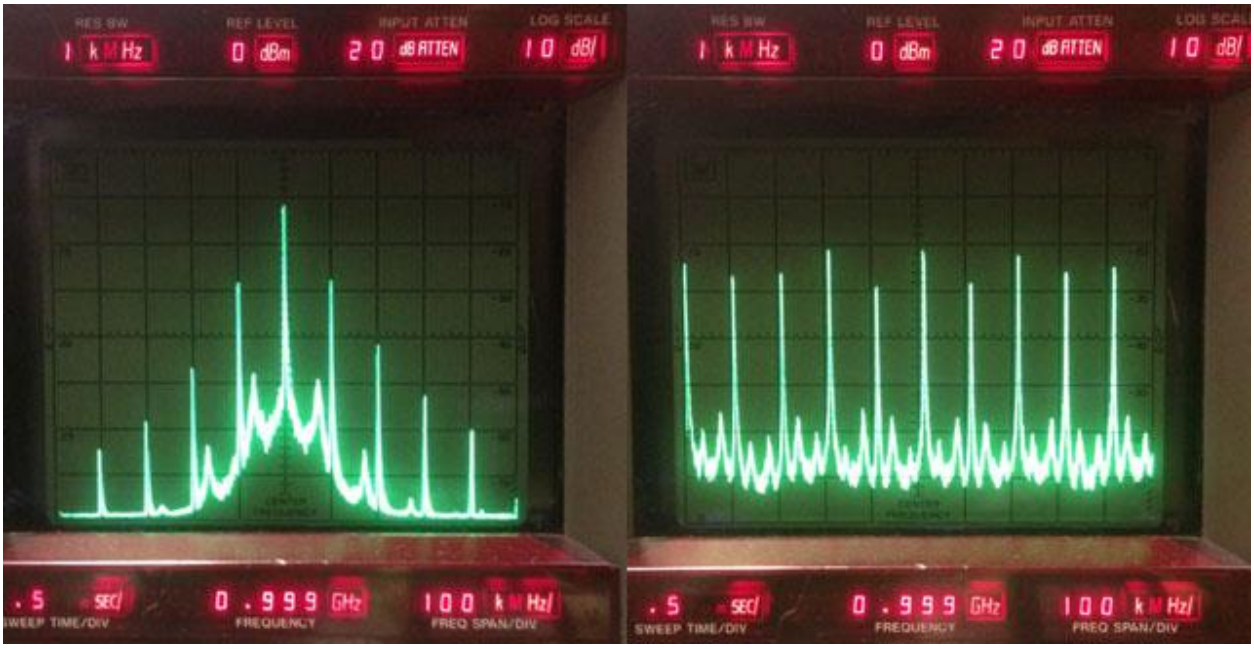
Anyway, before trying to unsolder and reposition the inductors I went with trying to determine their value. It was a bit difficult as the part number and manufacturer was unknown, so I tried to search for 0603 inductors dot marking and a few sources pointed out the Yellow dot could be a mark for 2.2nH inductor. The PLL Datasheet page 22 has a formula for calculating the inductor values, which for 1GHz frequency produced 3.18nH, almost 1nH more. The ADI simulator produced a value of 3.15nH. On the PCB the inductors ground ends connect to the ground with two vias, that could add some inductance but I did not know how much. I decided to unsolder and reposition the inductors at right angle.

I went ahead with unsoldering L1 and added a tiny bit of a wire to one of the pads in order to be able to position L1 at right angle to L2. However the PLL stopped working and no output was observed at all. I measured L1 continuity and there was no continuity, so I thought perhaps I damaged the inductor. I unsoldered it and threw it under the microscope. What I found was a cheap ass wire wound inductor with the wire ends soldered to the terminals and not cold welded, as a reputable manufacturer would do. I also saw one wire end disconnected from its terminal. Apparently when I unsoldered the inductor the first time, I disturbed the winding and the inductor went open circuit because nothing held the winding ends in place, just a blob of solder. What a piece of shit. I tried connecting the loose wire back to its terminal but could not. I then unsoldered L2 and threw them both out to garbage. Here is a picture of the Yaigol shitty inductor on the left with the arrow pointing to the broken end, and a on the right is a picture of a good quality inductor – note the ends are cold welded, so they do not detach from the terminals during solder/desolder.

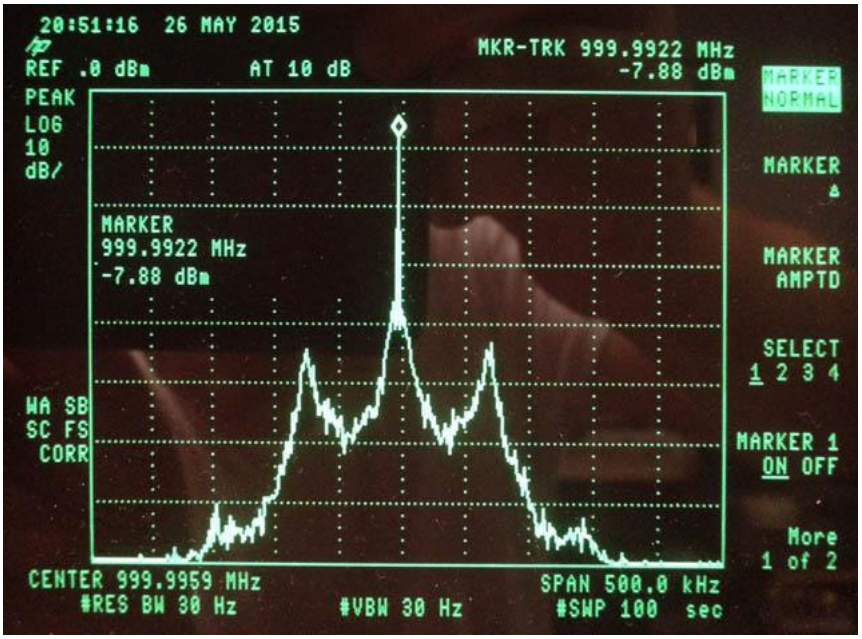


I got a few good quality inductors of 2.2, 2.7 and 3.3 nH. I started with the 2.2nH and soldered them on the PCB pads in parallel same way as the original inductors to just check if the old ones were 2.2nH. Indeed, the PLL came back in exact same wobbliness as with the original inductors. That confirmed they were indeed 2.2nH ones.

I did not bother trying to resolder them at right angle because the PLL Datasheet and ADI simulator were saying you need 3.1…3.2nH. I went ahead and tried a 2.7nH in parallel and at right angle. Here is the result. The left picture is the inductors are in parallel. The right picture is the inductors at right angle.

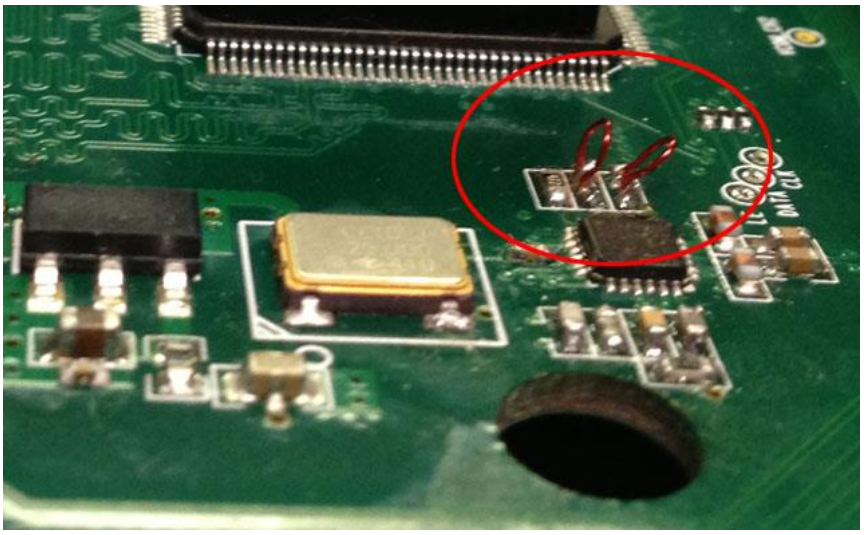


So orientation of the inductors did matter. I figured out from the slope of the VCO control voltage that the VCO was running lower in frequency with the inductors soldered in parallel orientation. Therefore the overall inductance was higher than with inductors at right angle. On the other hand, the left picture with the parallel inductors looked better, and since it was with a higher inductance then perhaps I needed to try even larger inductance. I did not have a 3nH inductors so I tried 3.3nH:

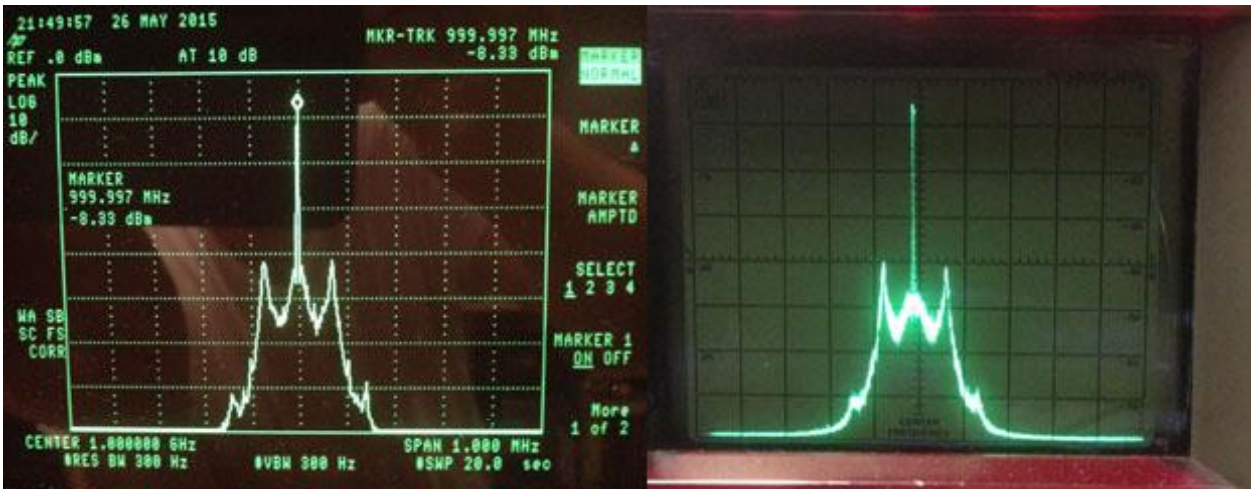


OK baby that drives us closer to home. But … why do those bat wings look familiar… where did I see them? Hmmm… More on this later. For now, I still wanted to try 3.0nH which was in between of 2.7 and 3.3 that I have tried. I searched Digikey for wirewound inductors and found a 3nH 0805 inductor which I not exactly liked because it had black resin coating. I anyways bought a pair but when I tried them the PLL was kind of back to where it originally was, even worse. I unsoldered one inductor and carefully measured with my HP 8753C network analyzer. Sure enough, it was 3nH at low frequencies but its inductance dropped drastically at 1GHz to 2nH. I did not bother taking a PLL screenshot with them.

OK, I ended up with no 3nH inductors so… I made them from a piece of #30 magnet wire. I cut two pieces of 7mm each and removed 1mm of insulation from each end. I then formed them in a single loop and bent the tinned ends so the whole shape looked like the Ohm symbol. I made two of them and soldered onto the the PCB. Because it was just wire, I could easily bend them to bring the inductors closer or separate them; kind of tune the overall inductance. This photo may give you an idea:



The following are screenshots of the PLL output with my home made inductors of about 3nH taken with two different HP spectrum analyzers. Looks about 60dBc/Hz in-band noise if to recalculate to 1Hz bandwidth:



Conclusion

DS2000 oscilloscope PLL is disfunctional on factory oscilloscopes. The two main reasons identified are:

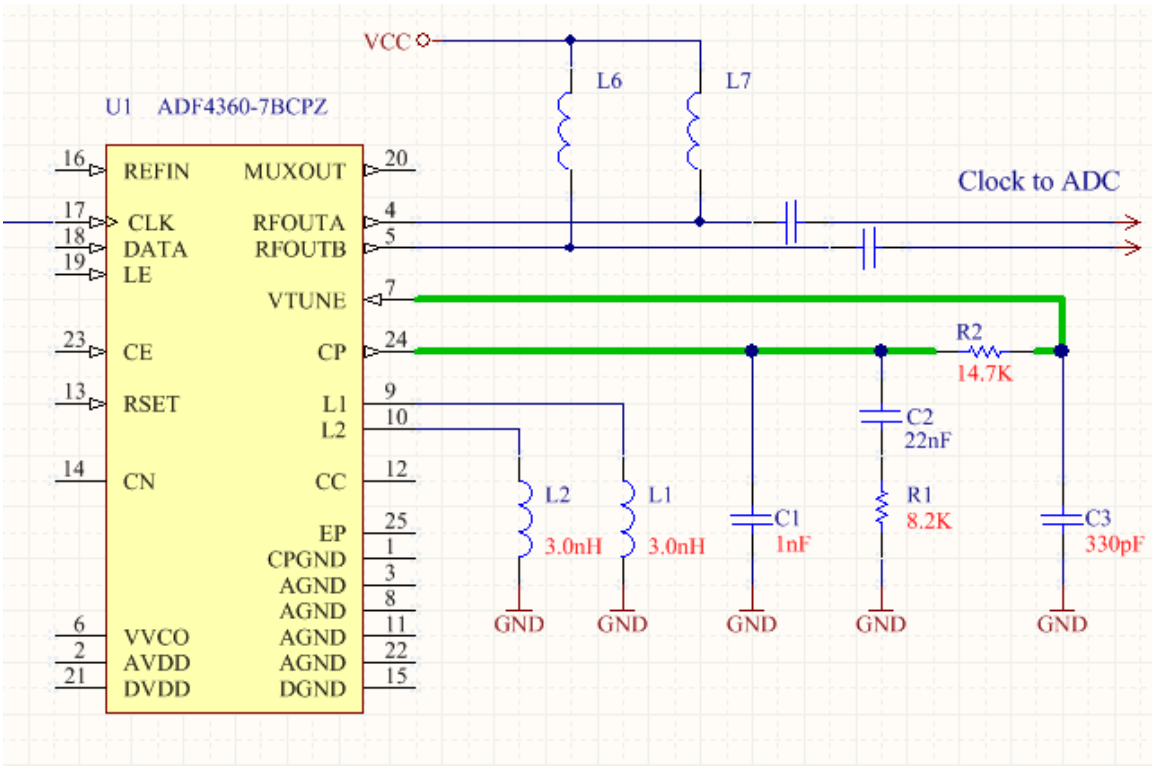
- Incorrect selection of the PLL loop filter component values for the given PFD frequency
- Incorrect selection of the PLL VCO inductor values

It appears the PLL schematic was lifted from some other design and placed in DS2000 without a thought. Also programming of the PLL is incoherent with its hardware. There seems to be a disconnect between them as if it was done by different people who had no clue about what the other person did. On top of that Yaigol Yingineers did not read the PLL Datasheet.

PLL Partial Fix Instructions Summary

This is how to make the change described in this Part 2 to fix Yaigol DS2000 PLL:

- Replace the PLL loop filter components with the values shown in the below schematic
- Replace the two PLL VCO inductors blue-ish color inductors with two 3.0nH inductors. You can either buy or make them from 7mm length of #30 wire as I described above. If you buy them, you must go with wire wound inductors (0603 or 0805) with air core or ceramic core. Do not buy inductors with ferrite or phenolic core. Do not buy multilayer inductors, inductors with resin coating or thin film inductors– they all may change inductance at high frequencies.



Now, if only not those nasty out of band bat wings … Where do they come from? Can we take care of them? I recommend you hold on for now with the above fix and wait for Part 3. There may be something else for you to fix in your Yaigol.