High Performance Software Defined Radio

Open Source Hardware and Software Project
Project Description: http://hpsdr.org

Hardware Project #2

JANUS Board

Part #2

The Making of JANUS

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Chapter 1: Preliminaries

The HPSDR High Performance Software Defined Radio has become one of the most attended HAM Radio projects worldwide.

Since ATLAS, JANUS and OZYMANDIAS boards are out supporting the FLEXRADIO® SDR-1000 transceiver audio processing an overwhelming amount of people have ordered the whole set of finished boards for their radio.

Surprisingly enough also bare PCBs have been sold in quite good numbers. That's where this documentation kicks in. People should not be left alone with their boards even if they are experienced builders. This whole project is very complex also from the parts point of view and requires exact preparation in order to avoid mistakes. If you make only one it can be kind of difficult to find it.

But enough words, just let's have fun. That's what this is all about.

73
Horst
DL6KBF

1.1 Physical and mental preparation

Before you start building anything please check yourself regarding your personal physical and mental condition. You should ask yourself if you are physically so well that you could start such a project. If you are hyperactive or have problems with tremor in your hands I would recommend that you find another day to start or even stay away from this and buy a finished board.

If you just had a fight with your wife or your boss and you are still very angry or frustrated inside please don't start soldering. You definitely will throw all the tiny parts on the floor and can't find them anymore.

How you should be:
- in a good health condition
- in a gooooooood mood
- calm and cool inside
- have self-confidence

You should be knowing what you are doing!

You also should be familiar with the basic SMT soldering techniques!

1.2 Workbench preparation

1.2.1 Table

The work table should be totally cleaned up and emptied before starting any work on JANUS. This makes it easier to find any part which possibly jumps off the tweezers.

1.2.2 ESD (ElectroStatic Discharge) prevention

Since most of the ICs on JANUS are very sensitive to ESD it is recommended that you use an ESD matt. This should be connected at least to the solder station ESD connector.

Before touching any IC you should place both hands flat on the matt in order to discharge yourself. Alternatively wear an ESD strap around your wrist which is connected either to the matt or to the same potential as the matt.

I use an ESD matt of about 60x50 cm² which is fairly cheap (approx. 15 EUR). It is made from PVC which has the advantage of also having an anti-slip surface. I am usually placing the PCB directly on the matt without using any vise. This makes the PCB handling very easy and convenient.

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1.3 Soldering tools

For this type of project a good quality soldering tool is very essential. Preferably a soldering station with electronic temperature control and a wattage of around 50W to 80W should be used.

- forget about cheap irons. They are too hot. - forget about so-called SMD soldering needles. They usually have around 8 watts which after my experience is useless.

Most important:
Buy the finest solder tip for your iron which you can get. Mine has a tip diameter of 0.2 mm (around .01 inch). This is suitable for soldering even the fine pitch CPLD.

Alternative methods include various kinds of reflow or hot air soldering techniques. You can find many details about reflowing or hot air soldering on the internet in the various microcontroller forums or on some HAM websites.

But be warned:
I tried to reflow OZY with my temperature controlled pizza oven and I had a very bad experience with the board delaminating despite the correct temperature profile.

That's what I am using

1.3.1 Solder wire

With solder wire you have the choice of using wire containing lead or the new lead-free (RoHS compliant) solder wire. Leaded solder wire is still available and you do not need to change your soldering habbits which you most probably have developed over the years.

Lead-free solder wire has the disadvantage of a higher melting temperature which you have to get used to. So, if you decide to use lead-free solder wire please do some test soldering before getting on JANUS.
Very important:
The diameter of the solder wire should be as small as possible. I am using a wire diameter of 0.5 mm. If you can get a smaller wire diameter this should be even better. In Europe the readily availabe minimum diameter is 0.5 mm.

Solder containing lead

Lead-free solder

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1.3.2 Solder Flux

Actually my personal experience with solder flux is twofold:
- it is a fantastic aid for soldering
- depending on the kind of flux it bears some danger of getting bad solder joints and it makes the board look ugly

My experience:
In the beginning I had been using a flux with kind of a jelly texture. It is very sticky and the ICs could be positioned very easily and stayed at their position. But after soldering you could not clearly see the pads anymore in order to check the soldering quality. It also did not disolve with isopropyl alcohol so that the board looked ugly.

My recommendation:
For the JANUS board with its pre-tinned pads you should better use a water-clear no-clean flux and you will only need it to solder the two fine-pitch ICs U11 and U9. The other ICs and components can be soldered fine without using any flux at all.

I am using a solder flux stick as shown in the next picture.

No-clean water-clear solder flux

1.3.3 Solder Wick

This is what you actually need in a good quality and probably a good quantity of it.

It should be of a fine diameter (0.8 mm) for IC pins and about 1.5 mm diameter for other solder joints.

Solder Wick

1.4 Essential tools

Besides the soldering iron this project requires some other specialized tools. You may get along without them but they make life much easier and they are not too ex-pensive. Some of them look like dentist tools and they actually are. So all the HAM dentists out there have an advantage: they can bring home their tools from work. But don't use them for your patients anymore afterwards!

1.4.1 Tweezers

This will be your main tool besides the soldering iron and it should be of excellent quality. The tweezers should be specialized for SMD work and should be stainless steel.

This is what I am using

This model for me is the most convenient one because it has this 30 degree angle and the two little pads at the tips. Others may have other preferences.

Additionally you should have at least one

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extra pair of tweezers with acute tips, either straight or angled.

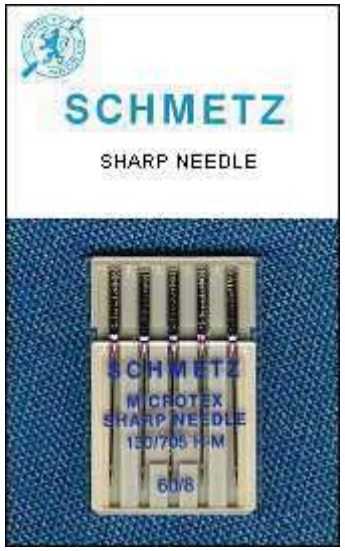
They may look like this

1.4.2 Dentist tools

As mentioned before these tools are very helpful for manipulating parts (especially ICs), cleaning the PCB and probing the quality of solder joints on IC pins. You can get a set of these in acceptable quality for a good price.

1.4.3 What else?

What I am also using are sewing machine needles. You can also use hand sewing needles but household sewing machine needles are more readily available.
So, during your next stop at the convenience store get yourself a pack of sewing machine needles. Microtex needles are to be preferred because they have a sharp tip.



What do I do with them?
The needles have a nice nickel plated surface. So you can solder some wire on them and use them as fantastic probes.
Connected to your multimeter in audible continuity test you are able to touch every single pin of a fine-pitch IC right where they come out of the case and use the second needle probe to touch the pad below the pin or even penetrate through the solder mask lacquer and touch the copper traces in order to verify continuity.

They are a nice and inexpensive tool and I love them (because my company makes them, hi).

Once the tip is worn off just take another set.

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1.5 Last and most important

Vision

Personally I am nearsighted (-6 diopters). So what I am doing is take out my contact lenses, put on **safety glasses** and stick my nose very close to the PCB. Then I have a beautiful and clear view on all the soldering pads.
For the fine-pitch ICs this is still not enough. You should definitely have some kind of magnifying glass with at least a 5x magnification.

A higher magnification is not useful because then you do not have any working distance under the magnifying glass anymore.
The best tool to use is a microscope with 10x and 20x magnification or even a zoom lens.
This is what I am using:

I got a very good bargain on a second-hand one on the internet and this is the best tool I ever bought. It has 10x, 20x and 35x magnification and a work distance of 160 mm with 10x magnification.
The technical data can be viewed at http://www.euromex.nl.

I also have got a USB microscope camera but the disadvantage with this camera is that even with 10x magnification the camera is too close to the board. There is no real workspace under it anymore.

Jason, N8INJ, has reported of having used a cheap webcam:

"...One other idea you may want to share with others is that if a microscope is out of their price range there are some other ways to get more magnification. Possibly the simplest is to use a "webcam" on your computer - most of them are capable of very close focusing out of the box (though some may require minor adjustments to the lens) and can give a good deal of effective magnification cheaply. It's usually also possible to tape a loupe over the lens to get even more magnification. ..."

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1.5 Soldering techniques

On the internet you can find numerous pages with information on soldering fine-pitch ICs

A good information source is

http://www.solder.net

where they have some training videos from time to time which you can download.

Training on old computer boards is also helpful in getting some soldering skills for fine-pitch ICs.

But I am sure that everybody who has ordered the bare JANUS board has understood as well that this is not one of the easiest hobby projects.

And now let's start.

Enough preliminaries.

Let's heat up the soldering station and

DO IT.

Chapter 2: How to start

2.1 Getting organized

According to a little statistic which I calculated you are now sitting in front of 189 parts plus the PCB and you are expected to get ready to do 744 solder joints. This makes it clear that JANUS is not just a little sunday afternoon project.

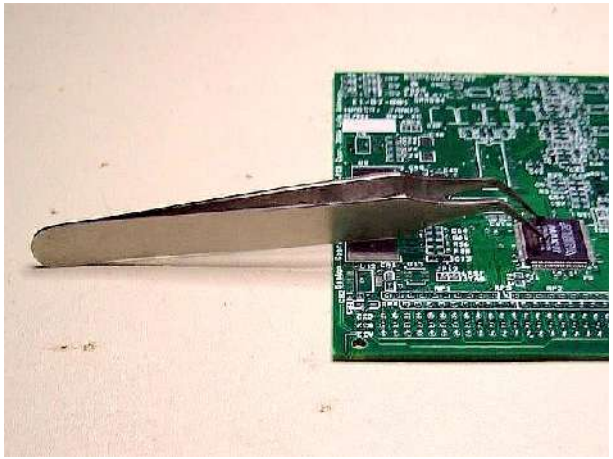
As a little side project I have developed a modified BoM (Bill of Materials) for JANUS which can be downloaded from my website:

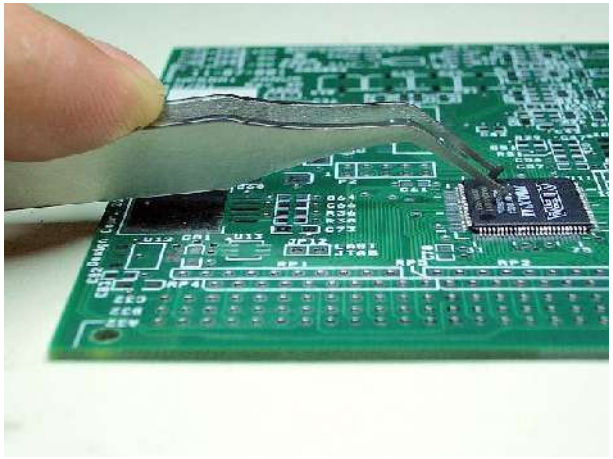
JANUSBOM-Organizer

In this organizer the parts are grouped in the same sequence as they will appear in this document

Chapter 2: How to start

2.2 Don't panic at hundred pins and more





After roughly aligning the chip on the pads (don't be afraid of touching the IC with your fingers if working on an ESD matt) put a pair of tweezers or a similar tool on the chip as a load. Another method which I use very often is to put a thin layer of solder honey on the pads. This makes the pads sticky and the IC can't barely move anymore. In this way it can be aligned properly.

Using the tweezer method I take the soldering iron in one hand, press one finger on the tweezers and with the soldering iron I touch a corner pin of the IC. The tin on the pad (with pre-tinned pads) mostly is enough to tack down that pin on the pad.
Again you should check the correct placement of the chip on the pads and then tack down the corner pin diagonally across the first soldered pin.
If everything fits well I usually solder pin by pin around the IC.
If by accident you use too much solder and make a short between two pins just use the solder wick to remove the excess solder.
Don't be too anxious. In a reflow oven the chip withstands temperatures of 240 °C for minutes.

Chapter 3: Parts Placement

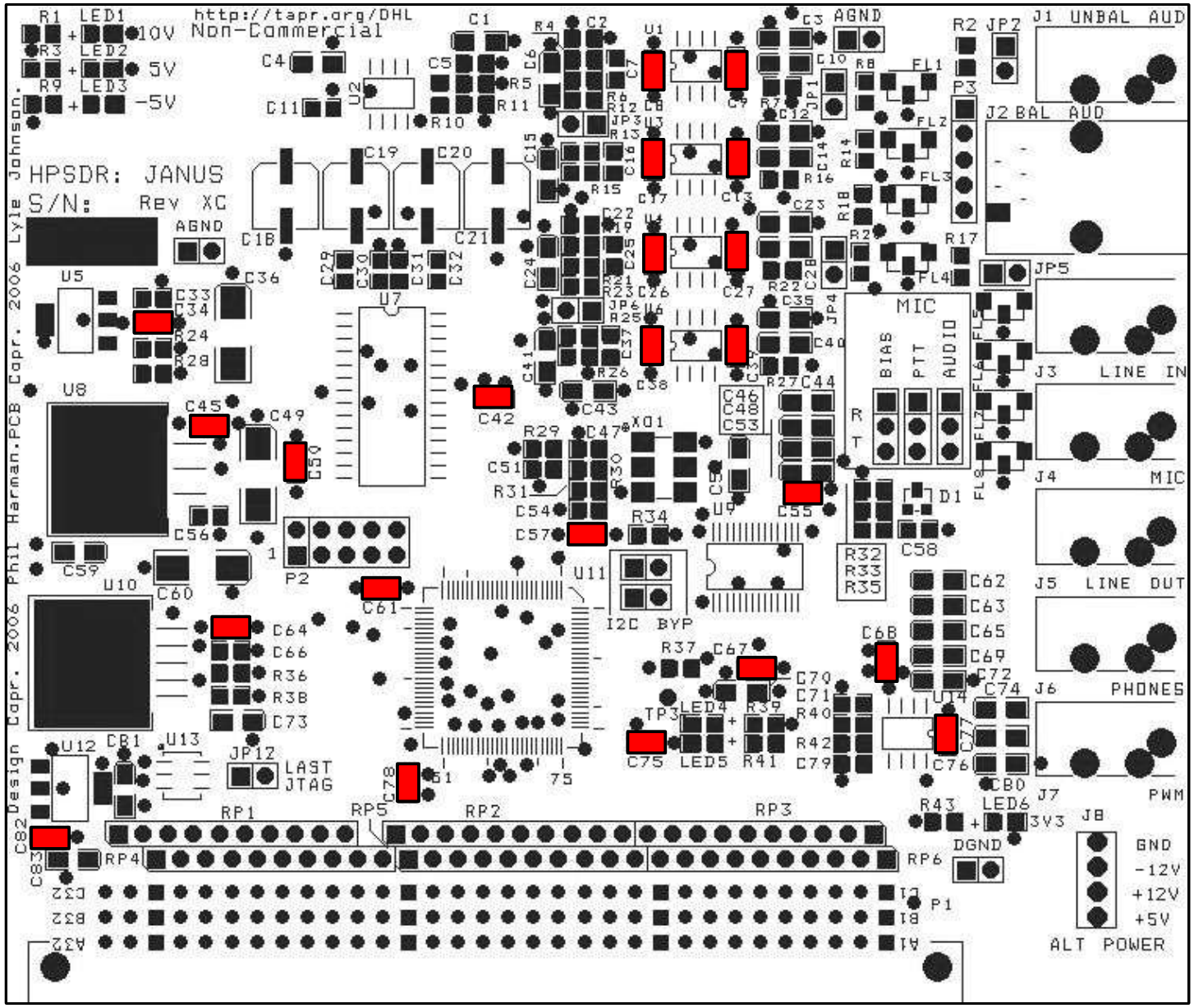
Now we start placing the parts on the board.

The following step-by-step method should make it possible for everyone to populate the board in such a way that it will work immediately. We start with the ICs and then go from 'low' to 'high parts in the order of their values.

So first you should place and solder all the ICs onto the board.
The positions on the board are self-explanatory.
Just make sure
that you always position them the correct way.

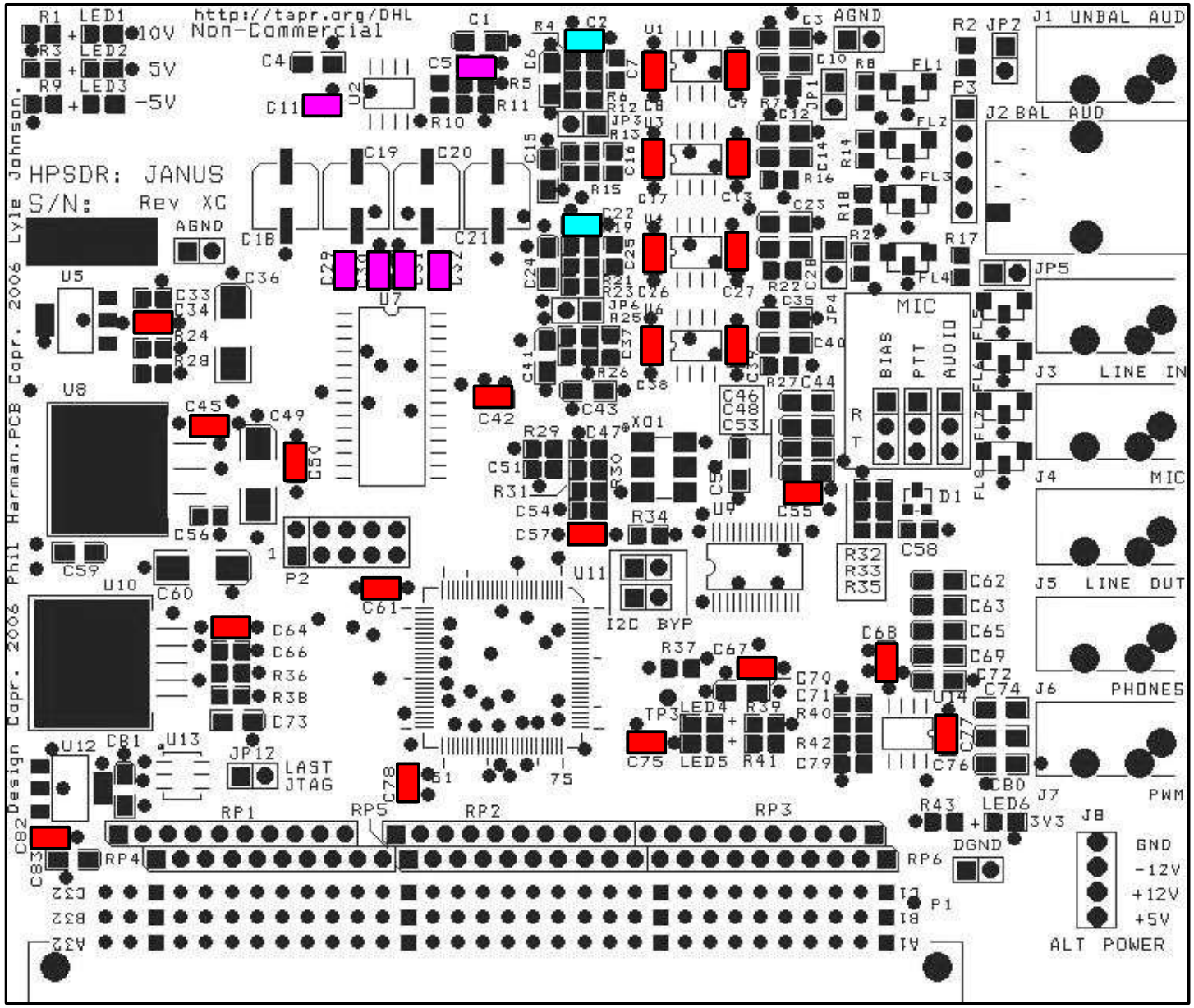
Have fun!!!

Item 1	
CAP 0805; 100n	
Position	**Check**
C8	
C9	
C13	
C17	
C26	
C27	
C34	
C38	
C39	
C42	
C45	
C50	
C55	
C57	
C61	
C64	
C67	
C68	
C75	
C76	
C78	
C82	



Item 2	
CAP 0805; 2n7	
Position	**Check**
C2	
C22	

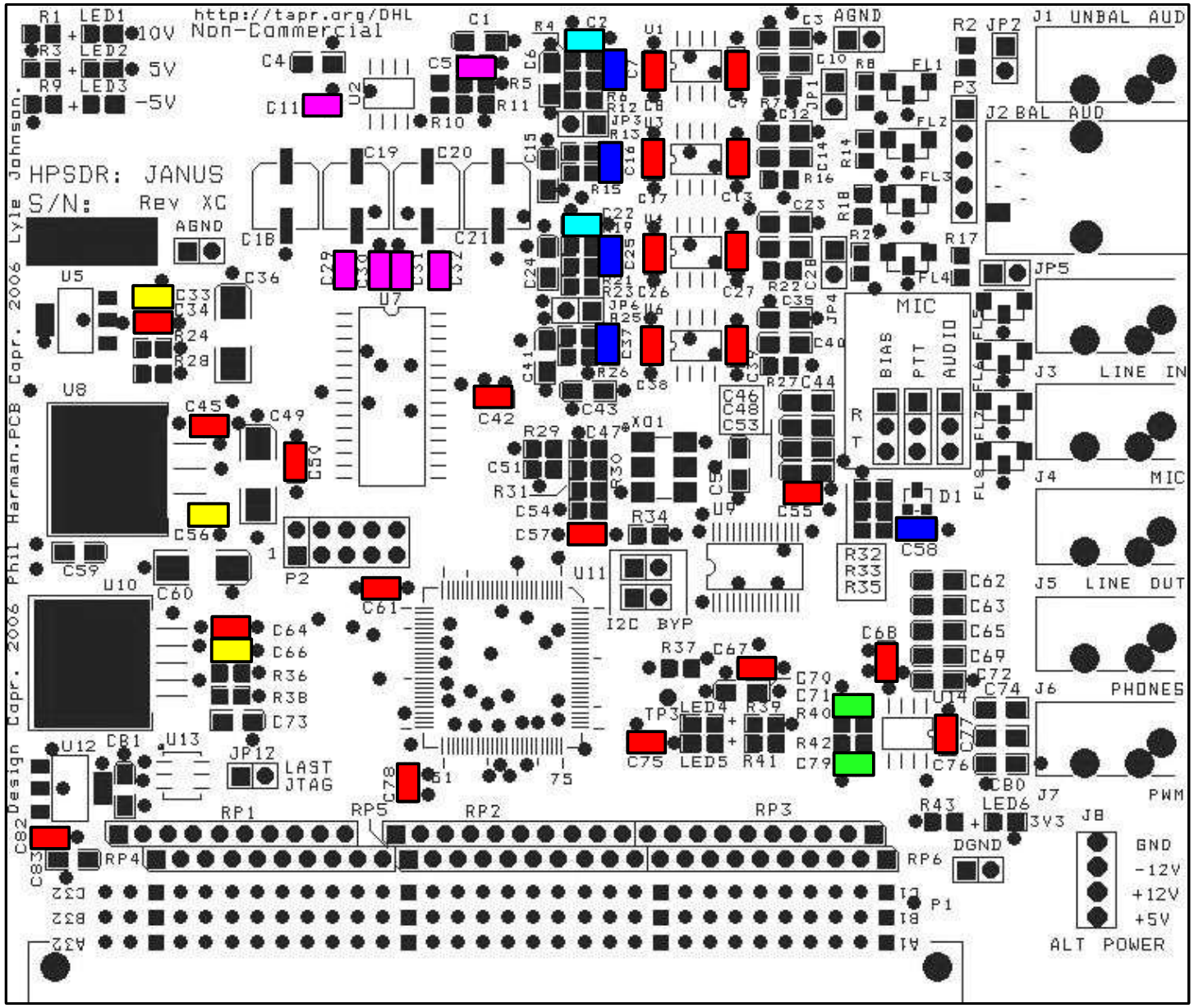
Item 3	
CAP 0805; 220n	
Position	**Check**
C5	
C11	
C29	
C30	
C31	
C32	



Item 4	
CAP 0805; 470p	
Position	**Check**
C7	
C16	
C25	
C37	
C58	

Item 5	
CAP 0805; 10n	
Position	**Check**
C33	
C56	
C66	

Item 6	
CAP 0805: 2n2	
Position	**Check**
C71	
C79	

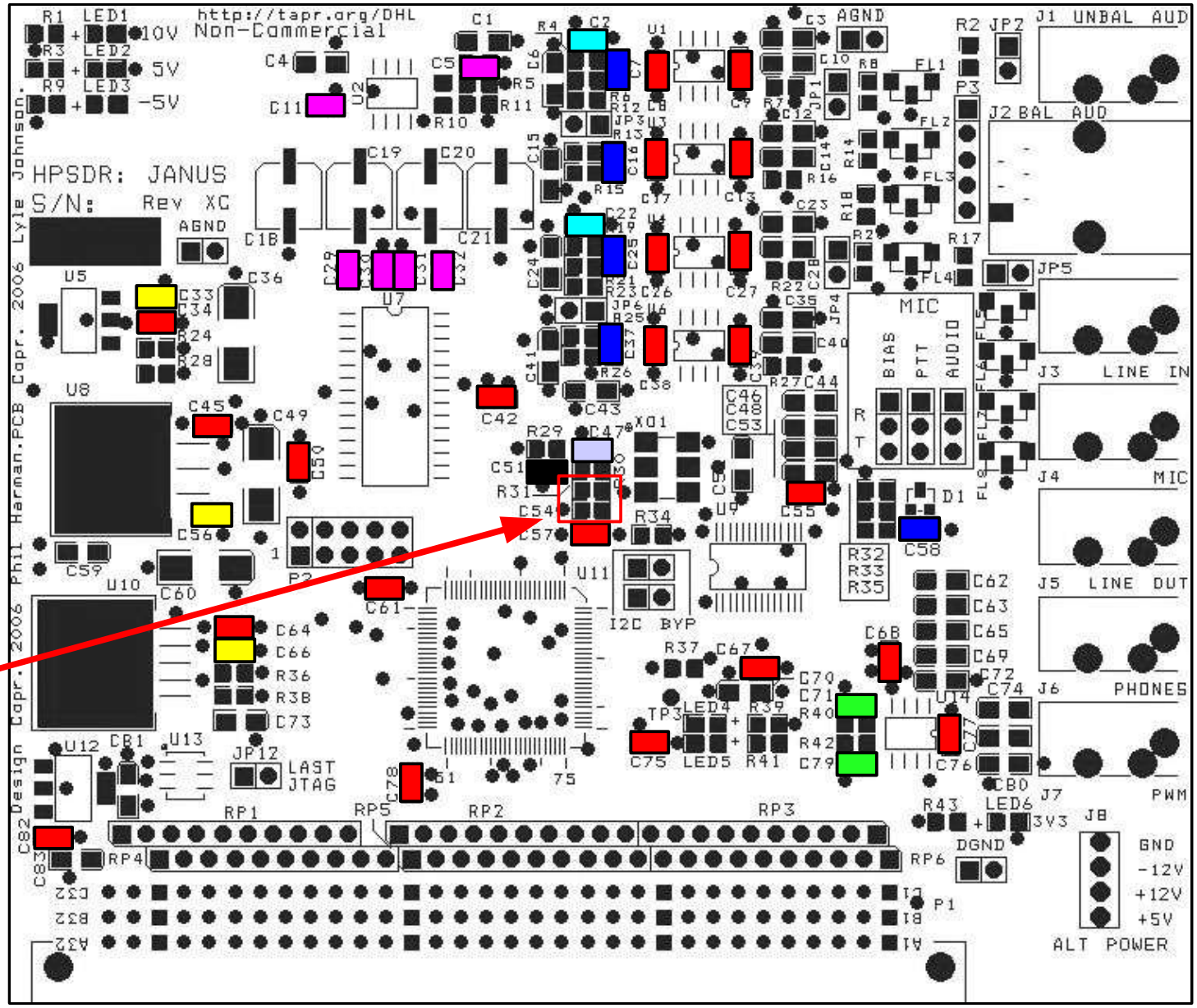


Item 7	
CAP 0805: 1uF	
Position	**Check**
C47	

Item 8	
CAP 0805: 10uF	
Position	**Check**
C51	

Notice:
Positions R31, C54 are not populated. So you should have empty pads there.

All 0805 capacitors are done now. Let's start with the 0805 resistors.

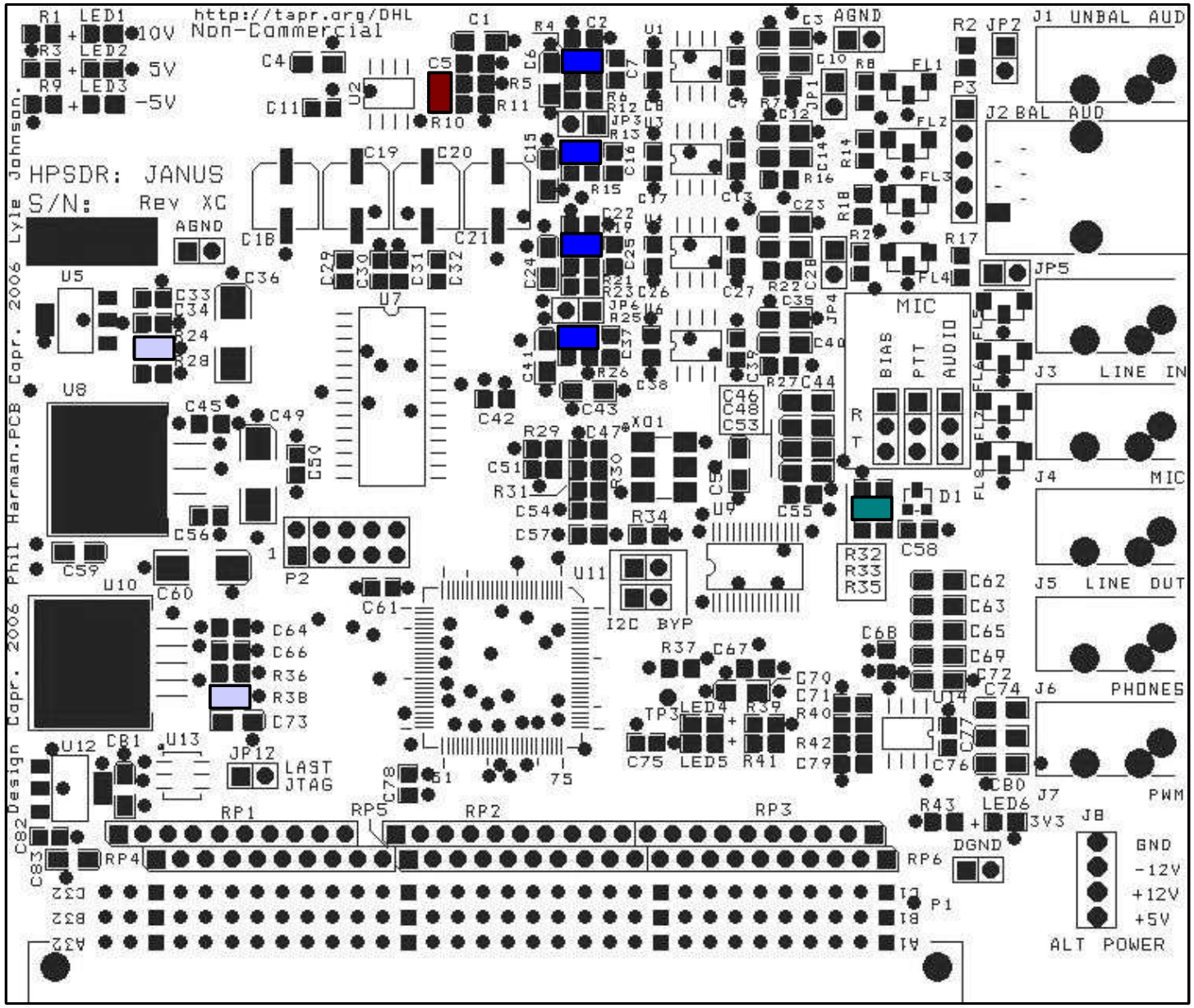


Item 9	
Res 0805; 20R	
Position	**Check**
R10	

Item 10	
Res 0805; 91R	
Position	**Check**
R4	
R13	
R19	
R25	

Item 11	
Res 0805; 120R	
Position	**Check**
R24	
R38	

Item 12	
Res 0805; 220R	
Position	**Check**
R33	

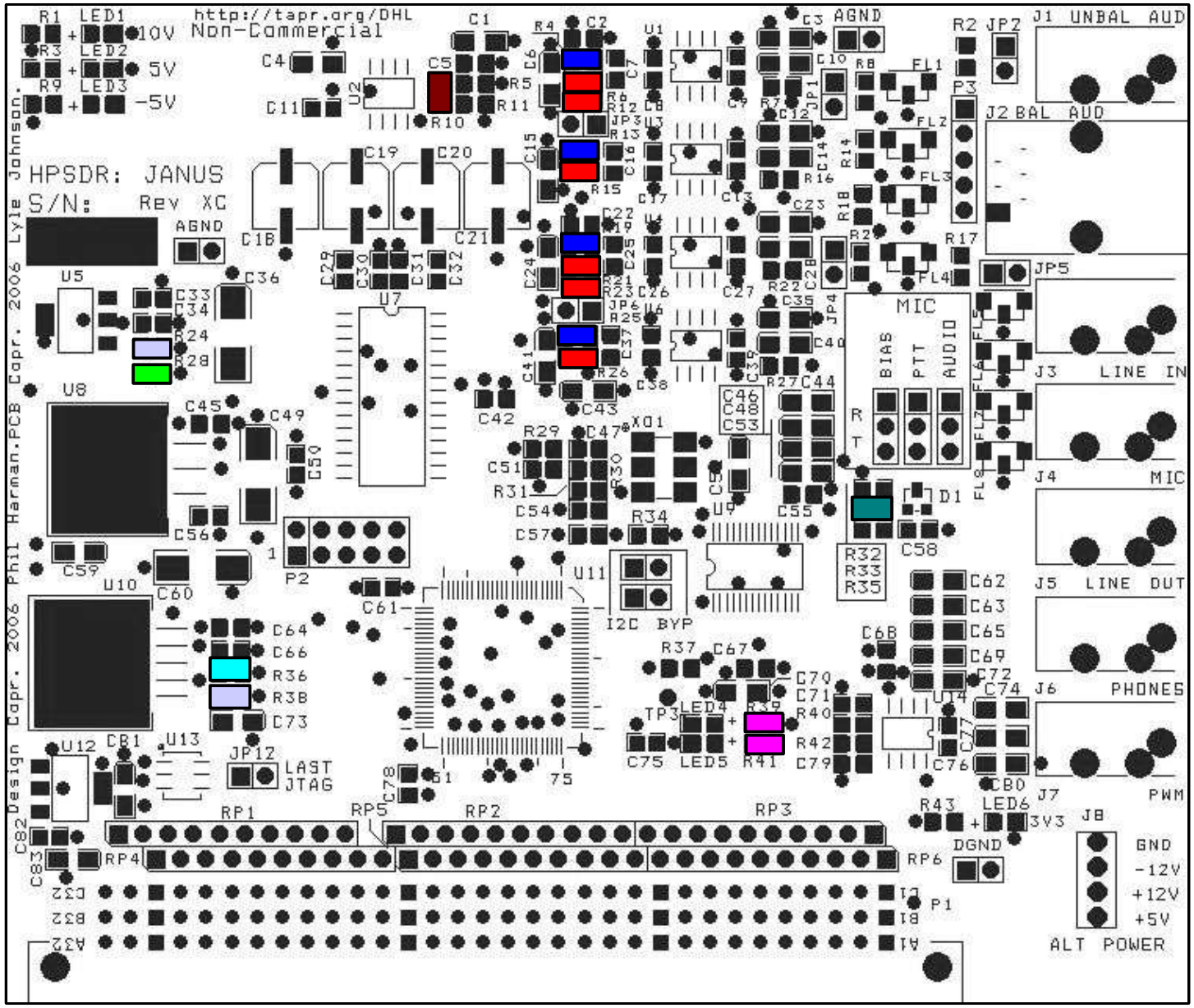


Item 13	
Res 0805; 360R	
Position	**Check**
R36	

Item 14	
Res 0805; 634R	
Position	**Check**
R6	
R12	
R15	
R21	
R23	
R26	

Item 15	
Res 0805; 866R	
Position	**Check**
R28	

Item 16	
Res 0805; 1k0	
Position	**Check**
R39	
R41	

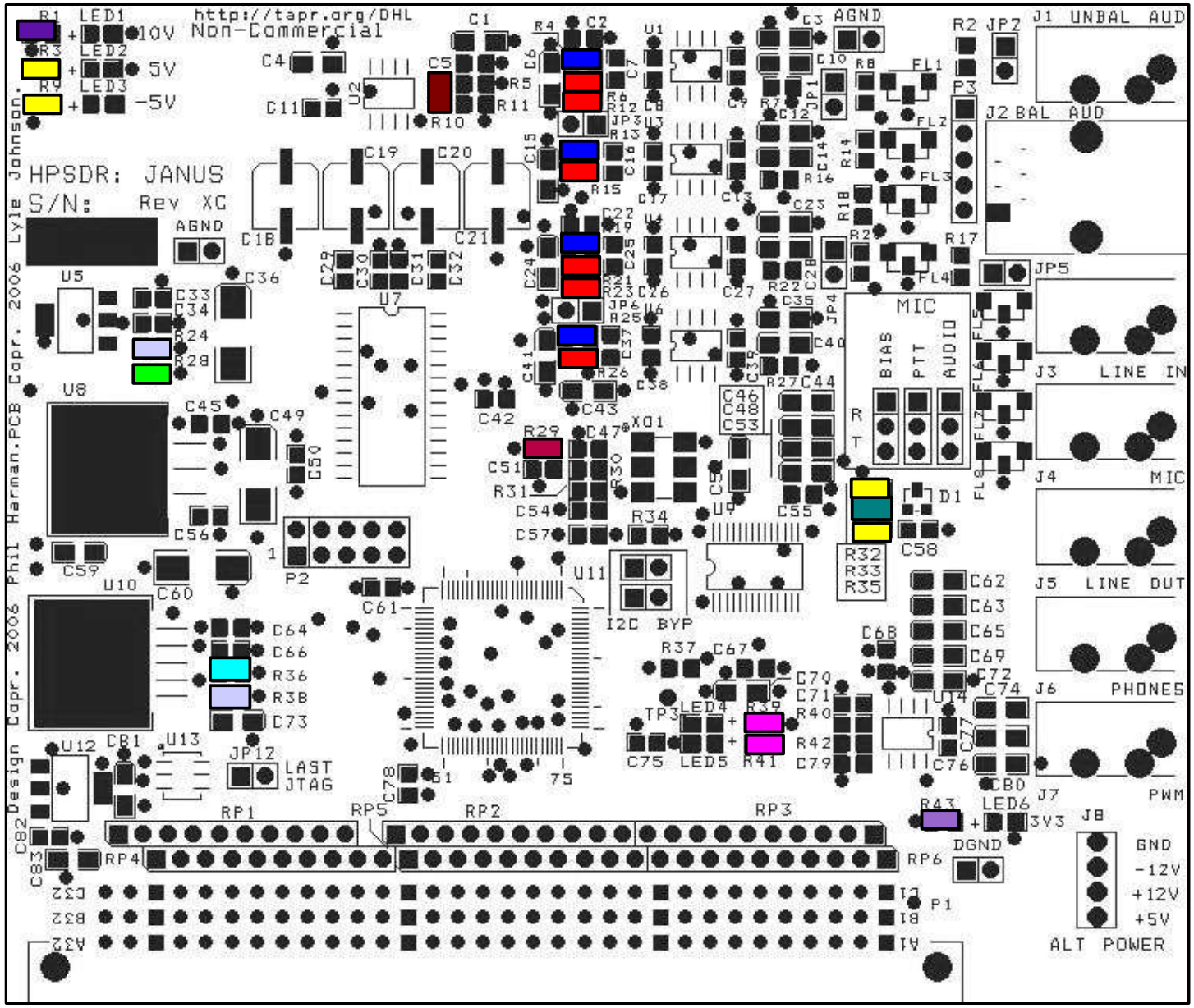


Item 17	
Res 0805; 1k5	
Position	**Check**
R43	

Item 18	
Res 0805; 3k3	
Position	**Check**
R3	
R9	
R32	
R35	

Item 19	
Res 0805; 6k8	
Position	**Check**
R29	

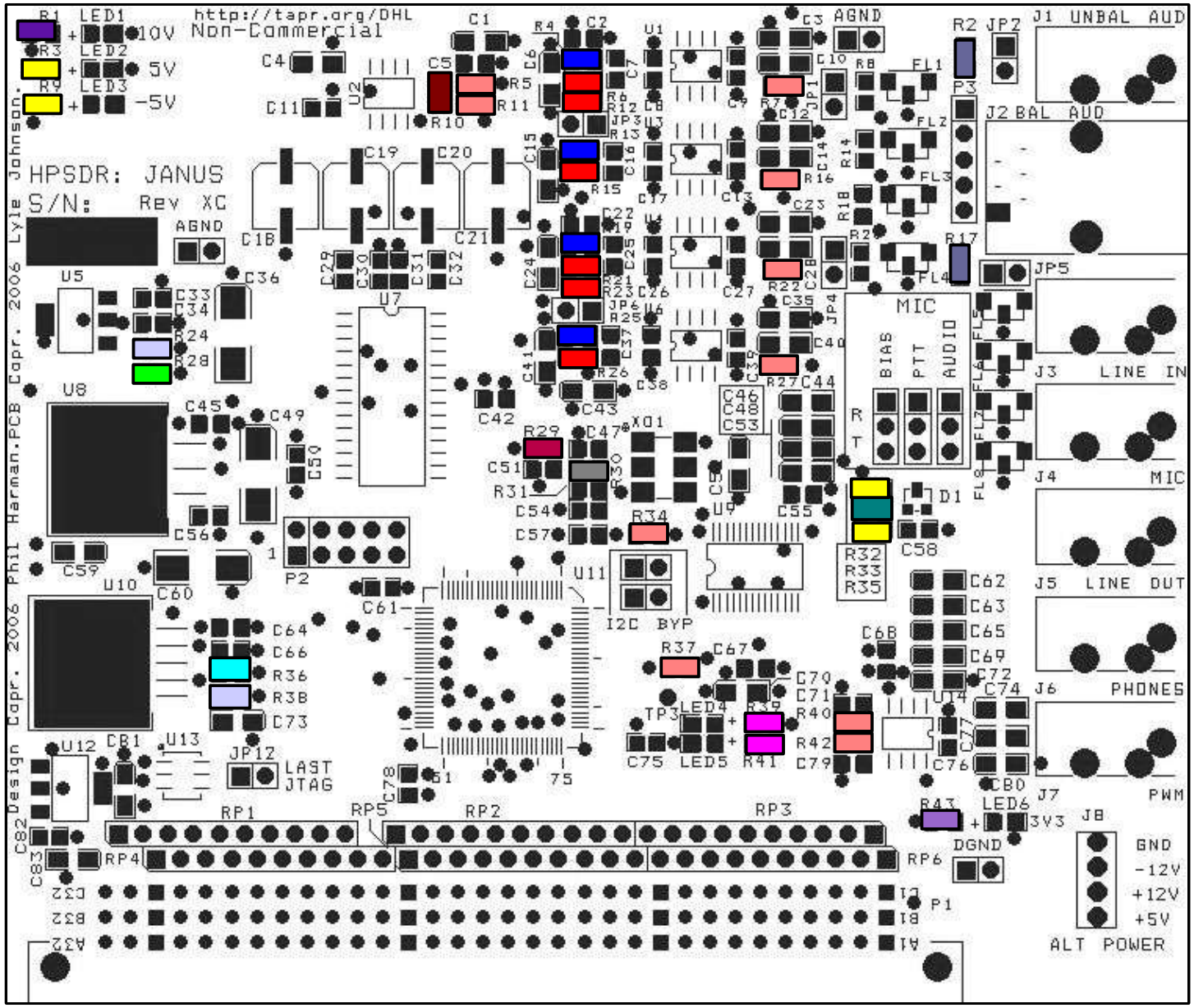
Item 20	
Res 0805: 8k2	
Position	**Check**
R1	



Item 21	
Res 0805; 10k	
Position	**Check**
R5	
R7	
R11	
R16	
R22	
R27	
R34	
R37	
R40	
R42	

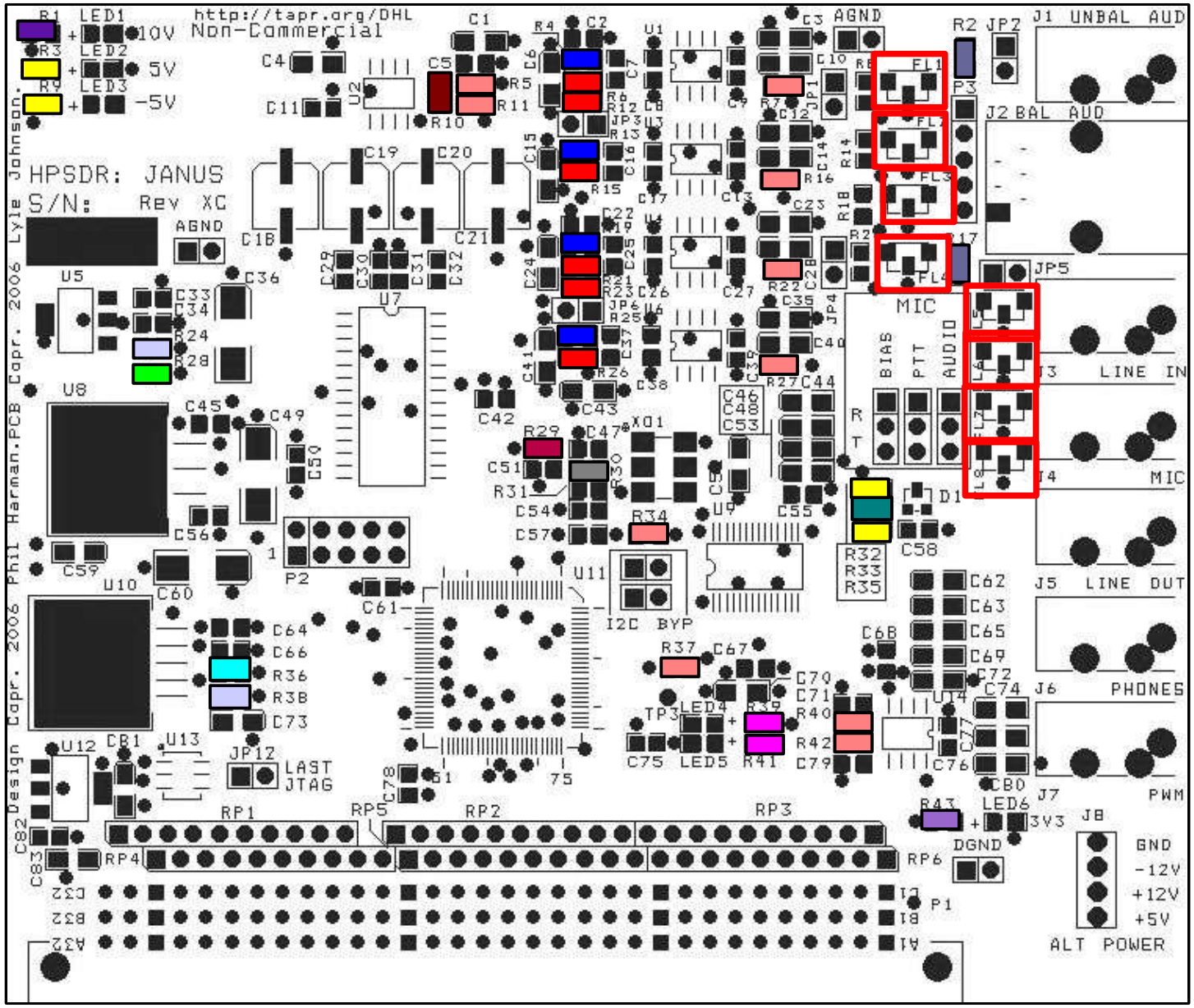
Item 22	
Res 0805; 39k0	
Position	**Check**
R2	
R17	

Item 23	
Res 0805; 68k	
Position	**Check**
R30	



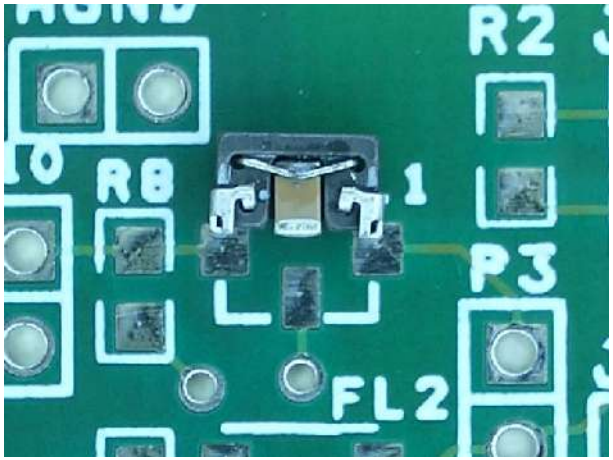
Notice:
Before we can populate the last resistor positions we have to place the filter inductors because partly the pads are very close so that we cannot reach the filter pads for a good solder joint.

Item 24	
Ind. EXC-CET-102U	
Position	**Check**
FL1	
FL2	
FL3	
FL4	
FL5	
FL6	
FL7	
FL8	



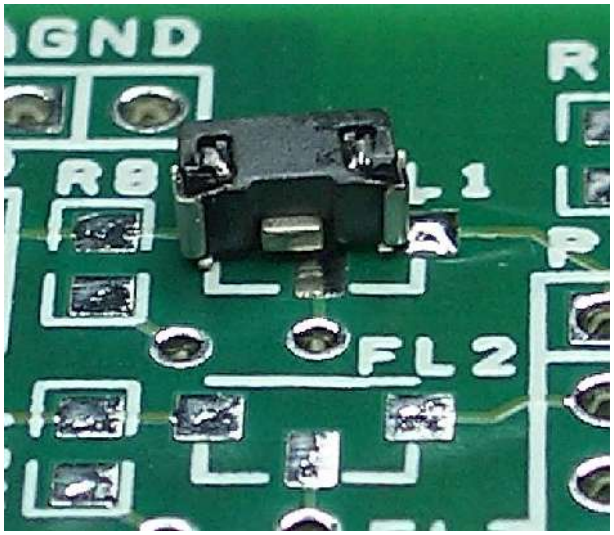
Special Instructions: Placing the Filter Inductors

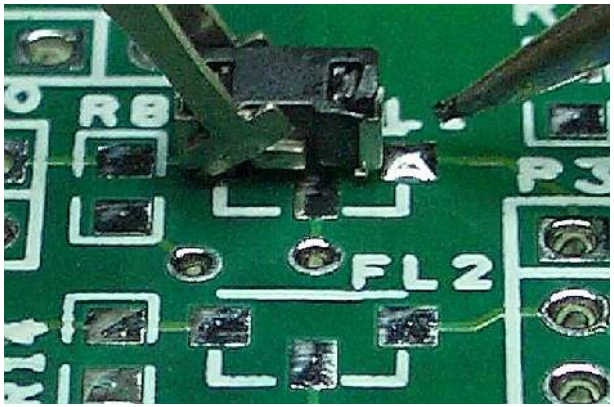
The 3-pad filter inductors FL1 to FL8 need to be specially taken care of. As you can see in the picture below the inductors just fit on the PCB pads only leaving a very small part of the PCB pads visible and touchable.



The picture shows the filter inductor upside down so that you can see how the pads are layed out.

Next you put a little tin on the right pad (just a little heap is enough). You can see this on the next picture.



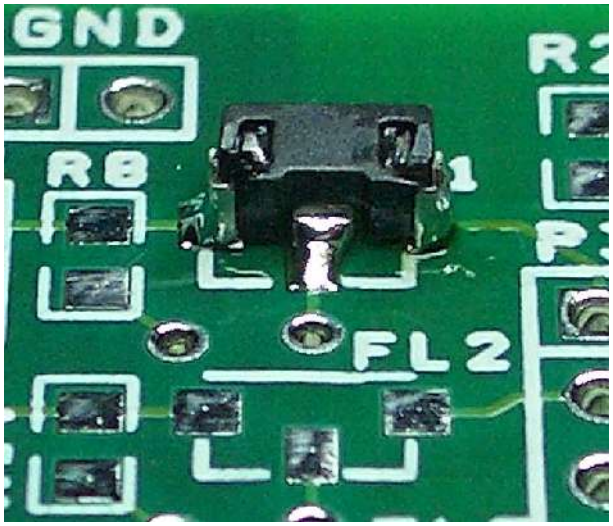


Then you take your solder iron, put the filter inductor between your tweezers, heat up the little pile of tin and push the inductor into the heap of liquid solder.

Push it so far that the center pads line up nicely.

Take away the solder iron, wait 3 seconds and the filter is placed. All of the steps described before should be done in one motion which just takes a few seconds.

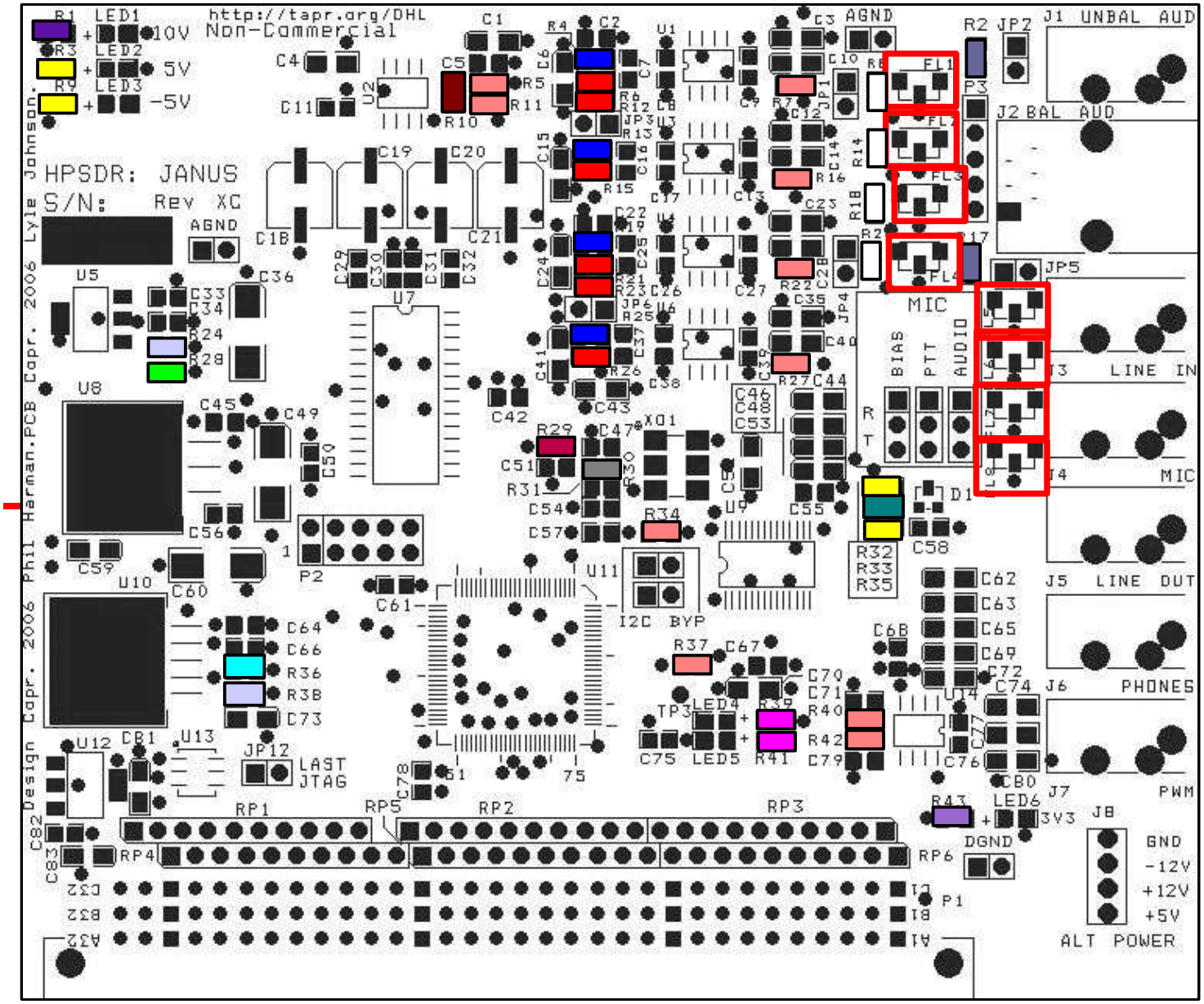
Then you solder the center pad, the left pad and heat up again the right pad with some additional tin. Done.



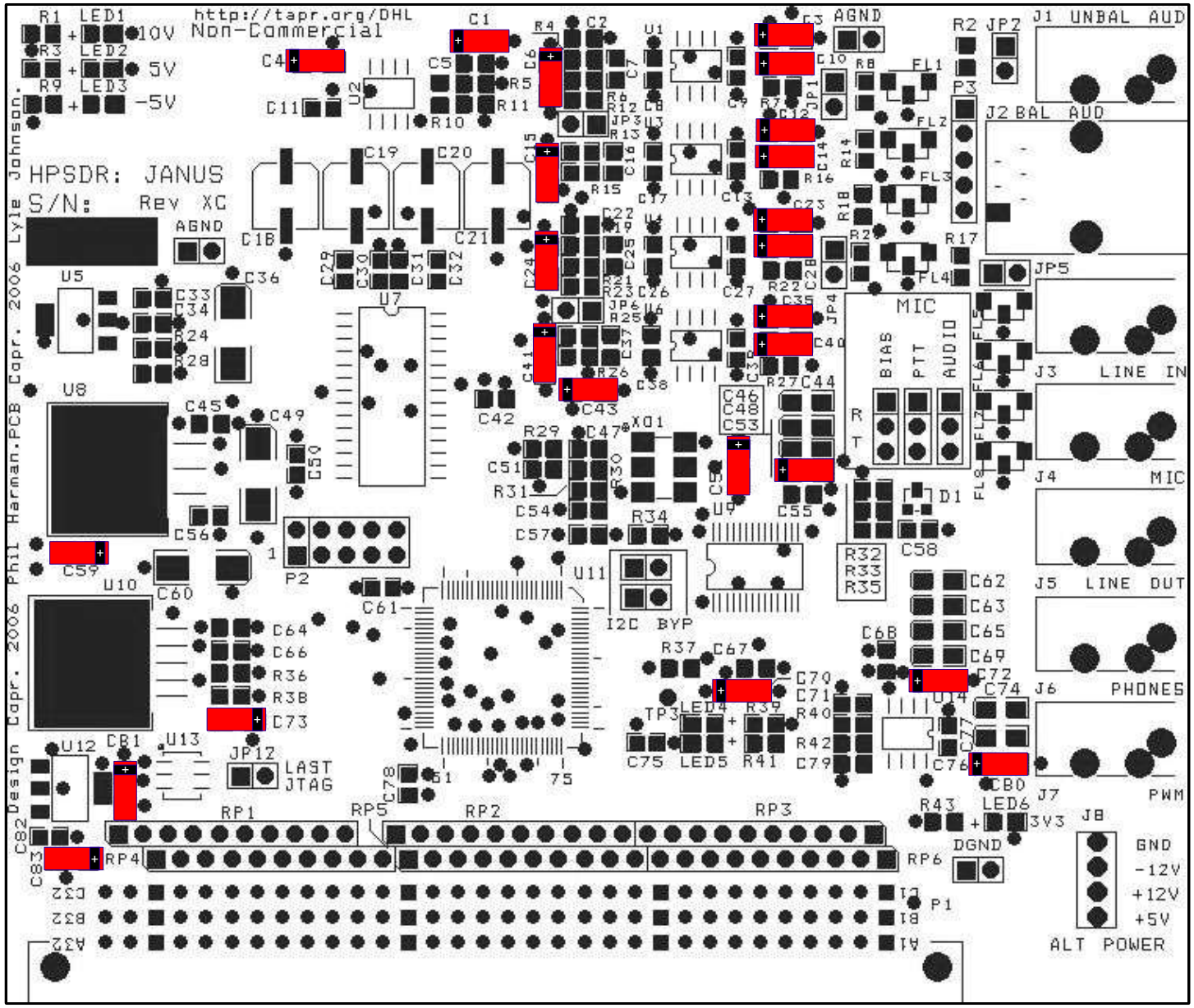
Item 25	
Res 0805; 100k	
Position	**Check**
R8	
R14	
R18	
R20	

Notice:
Positions R31, C54 are not populated. So you should have empty pads there.

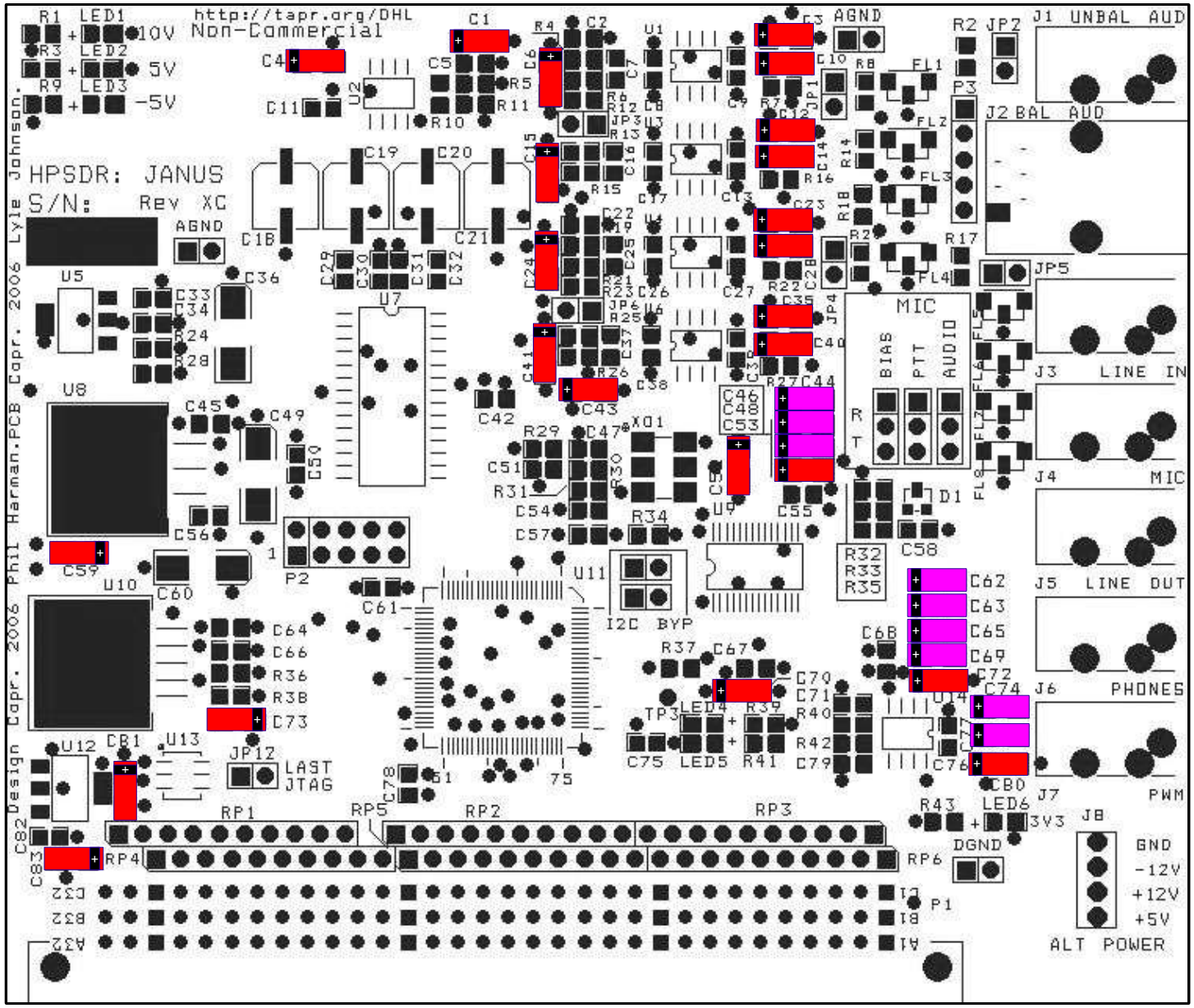
All 0805 resistors are done now. Let's start with the tantalum capacitors.



Item 26	
Tantalum 3216; 10uF/16V	
Position	**Check**
C1	
C3	
C4	
C6	
C10	
C12	
C14	
C15	
C23	
C24	
C28	
C35	
C40	
C41	
C43	
C52	
C53	
C59	
C70	
C72	
C73	
C80	
C81	
C83	



Item 27	
Tantalum 3216; 1uF/25V	
Position	**Check**
C44	
C46	
C48	
C62	
C63	
C65	
C69	
C74	
C77	



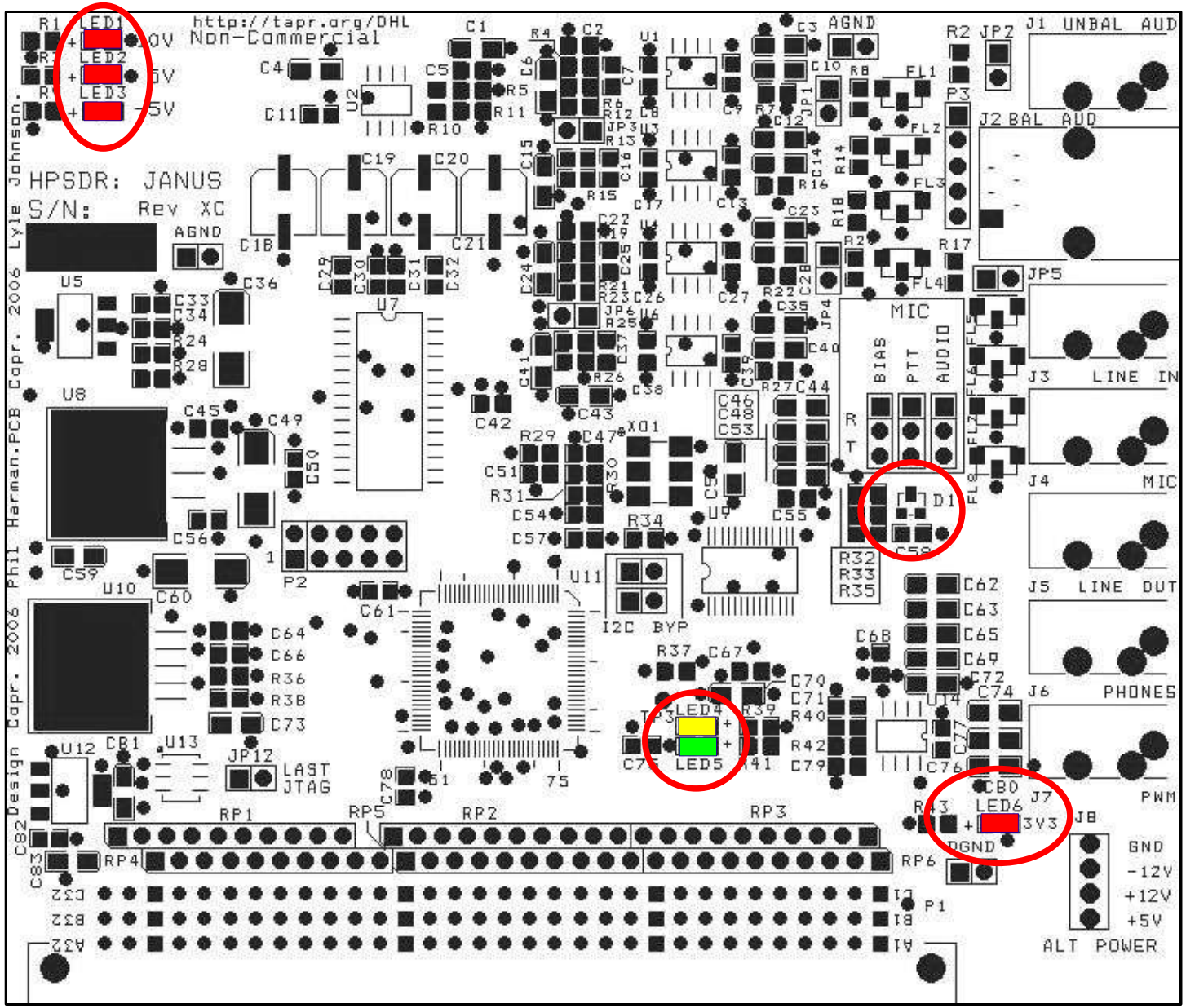
For now we are finished with the 3216 tantalums. The big ones we will leave for later. Next come the LEDs.

Item 28	
LED Red	
Position	**Check**
LED1	
LED2	
LED3	
LED6	

Item 29	
LED Yellow	
Position	**Check**
LED4	

Item 30	
LED Green	
Position	**Check**
LED5	

Item 31	
BAT54	
Position	**Check**
D1	

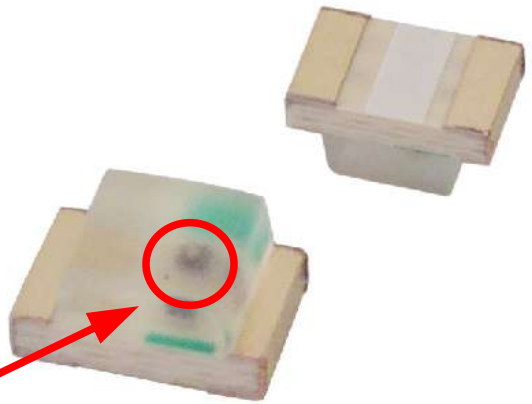


Special Instructions: Placing LEDs 1 to 6 and D1

How to determine the polarity of the 0805 LEDs?

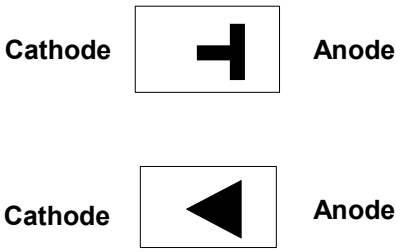
It can be difficult to find out the polarity of the tiny 0805 LEDs if you don't know what to look for.

The Lite-ON® LEDs used in the JANUS BOM are easy to determine the polarity. Looking on them under a magnifying glass you can see that the LED dice (photo) is visible and off-center from the body. This is the anode (+) side which has to match with + on the PCB.



LED Dice

The ones which I am using have a little mark printed on the bottom:

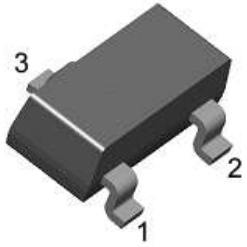


Schottky Diode D1

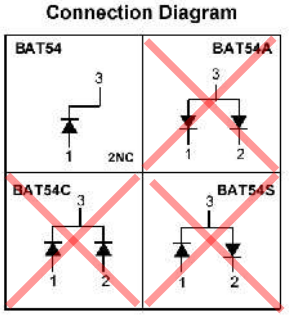
Attention:
The Schottky diode D1 must be of type BAT54 without any supplementary letters. The four available types and their markings are shown in the pictures on the right.
The one marked **L4P** is the correct type.
The MOUSER® part no. is 512-BAT54, not 512-BAT54A, which would be the wrong part.

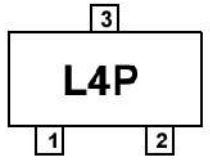
If by accident you have got the A type you can still use it but you have to place it diagonal and reversed. Where normally pin 1 is placed there you have to place pin 3 and on the pin 3 pad you have to place pin 2. Pin 1 remains unconnected.

C type and S type can also be used because pin 2 on the PCB is not connected to anything.



SOT-23

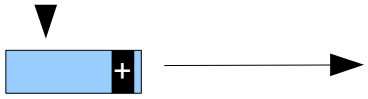




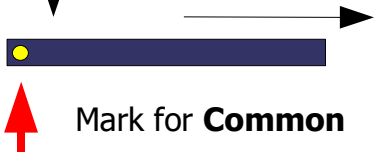
MARKING
BAT54 = L4P BAT54A = L42
BAT54C = L43 BAT54S = L44

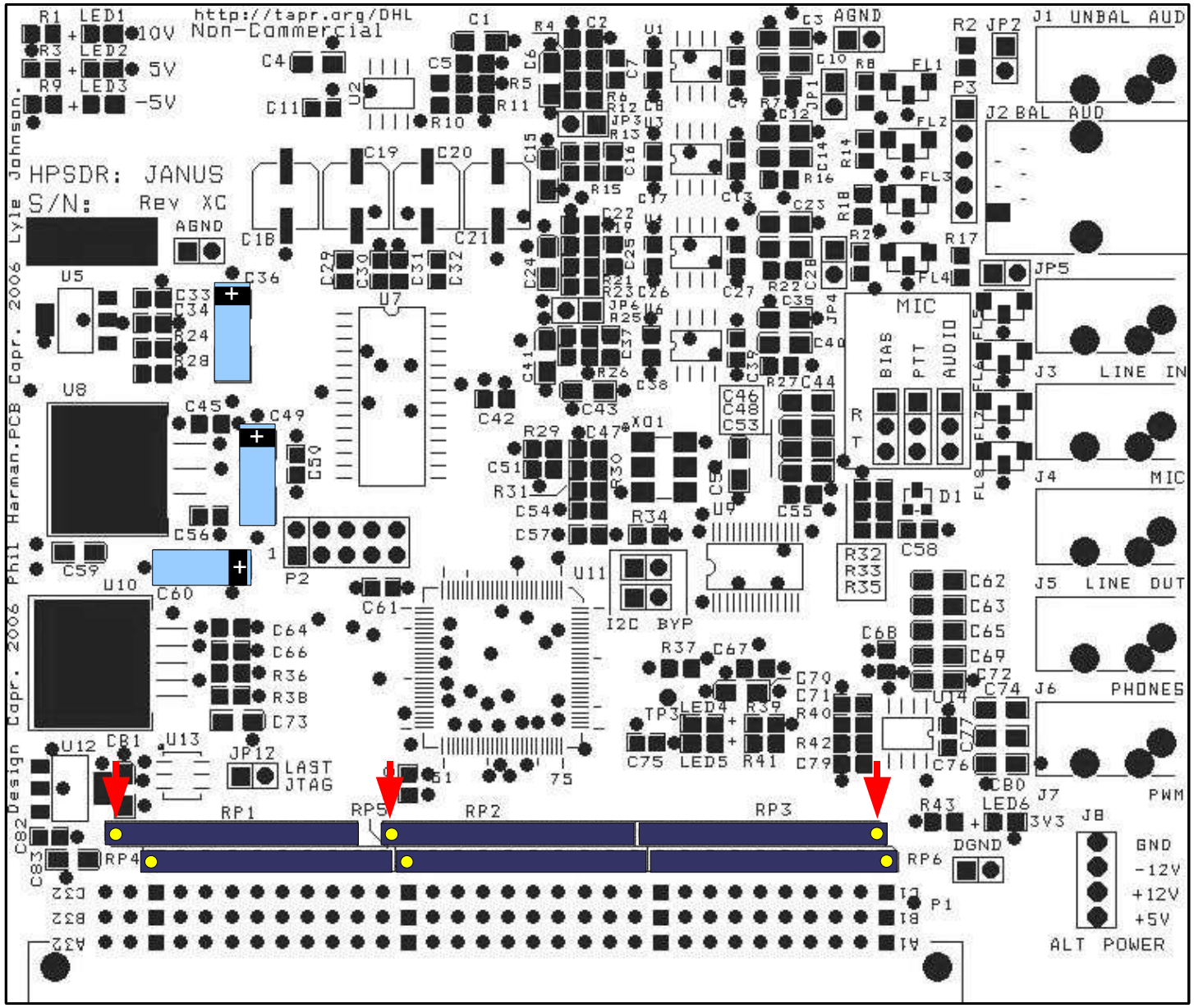
Now after we have finished the 'low profile' parts we will start with the next level of height.

Item 32	
Tantalum 6032; 47u/16V	
Position	**Check**
C36	
C49	
C60	



Item 33	
Res. SIP10P; 100k	
Position	**Check**
RP1	
RP2	
RP3	
RP4	
RP5	
RP6	





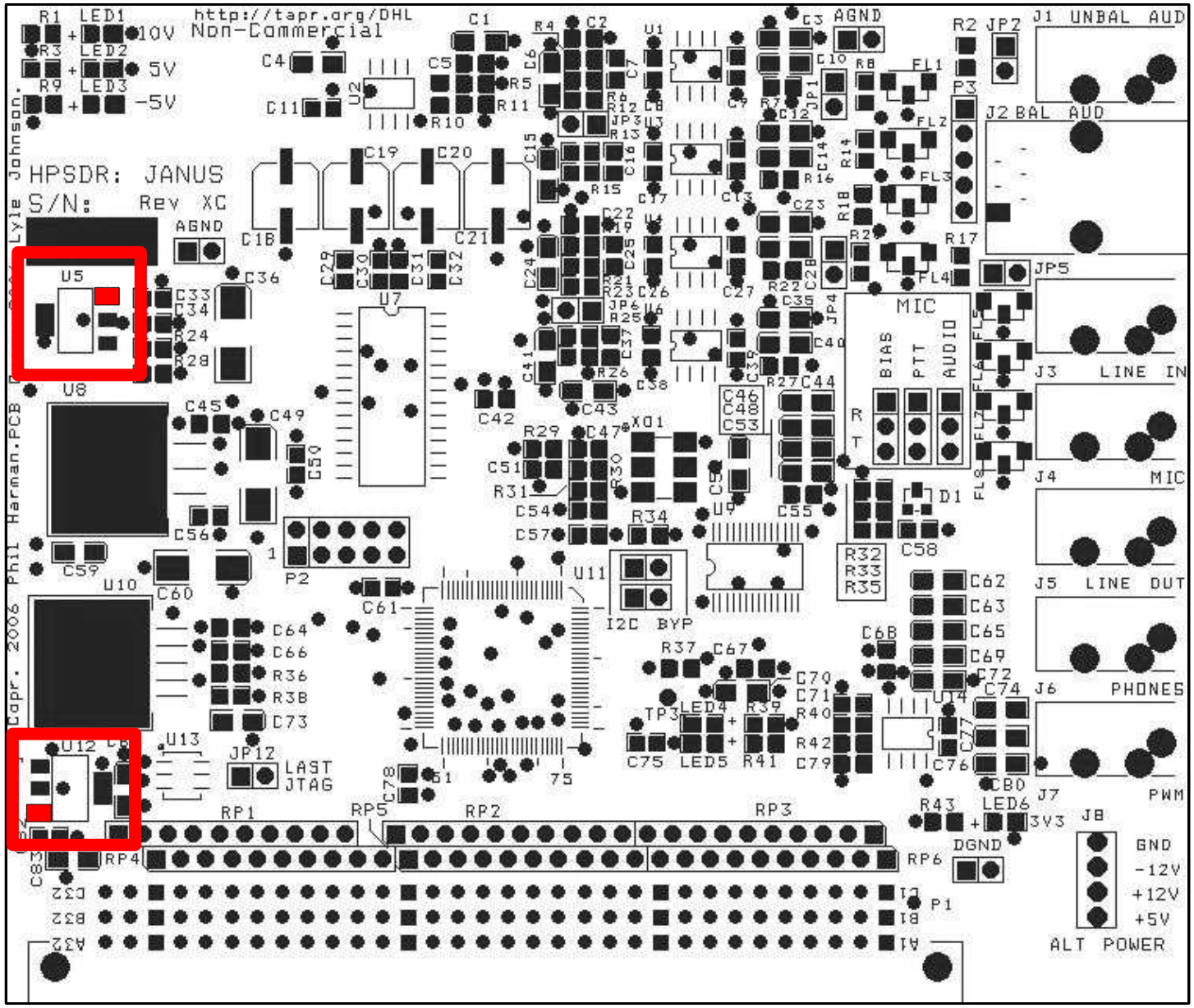
The big E-caps (C18 to C21) we will leave for later and go on with placing the voltage regulators.

Item 34	
LD1117SC-R	
Position	**Check**
U5	

First tack down the leg marked in RED (not the wide leg first). If the regulator is aligned nicely apply solder to the remaining legs. The wide leg requires a little more heat on the soldering iron.

Same procedure for U12:

Item 35	
LD1117S33CTR	
Position	**Check**
U12	



Solder U8 and U10 applying the same technique as before.

Align the regulator in such a way that you still have some solder pad visible at the edge.

Item 36	
LM340S-5.0	
Position	**Check**
U8	

Item 37	
LM2991S	
Position	**Check**
U10	

If possible change to a larger tip on your iron, heat up the pad and the backplate of the regulator and solder along the edge. The regulator will get hot but that's what it usually does during operation.
So don't worry, be happy.