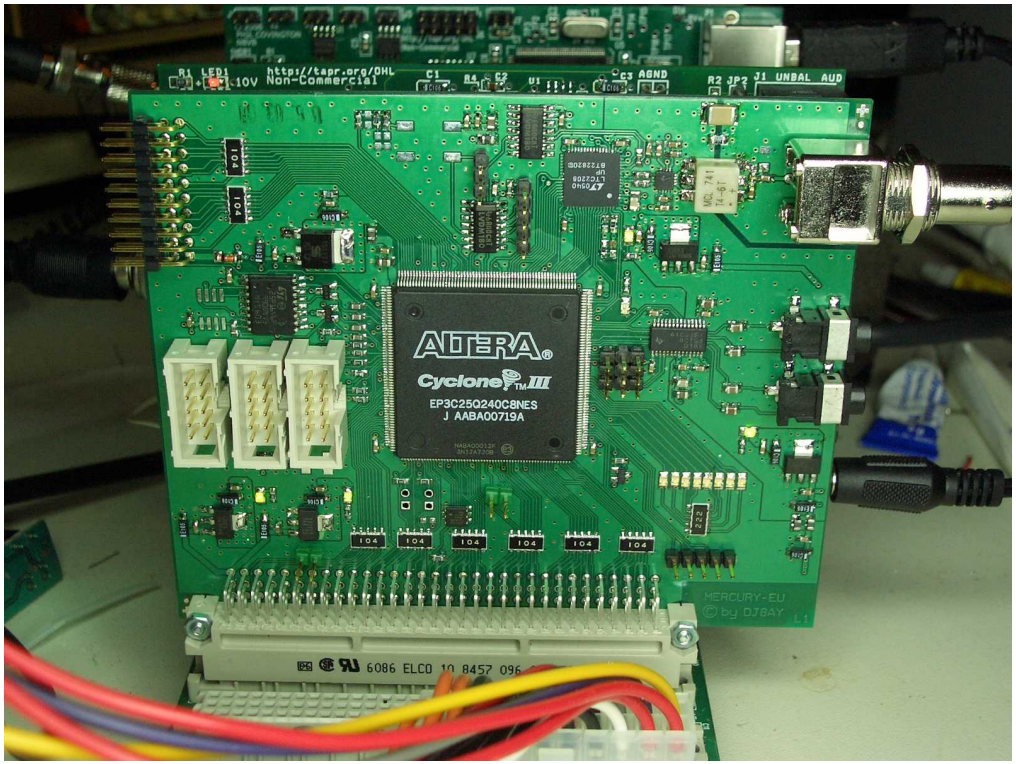
High Performance Software Defined Radio

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



Hardware Project #4

MERCURY-EU Board

Part #2

The Making of MERCURY

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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.

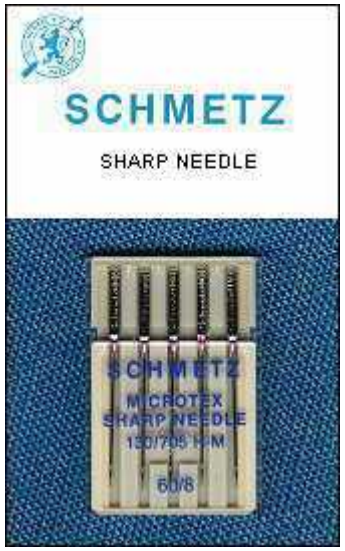
They may look like this

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 around 200 parts plus the PCB and you are expected to get ready to do close to 1000 solder joints. This makes it clear that MERCURY is not just a little sunday afternoon project.

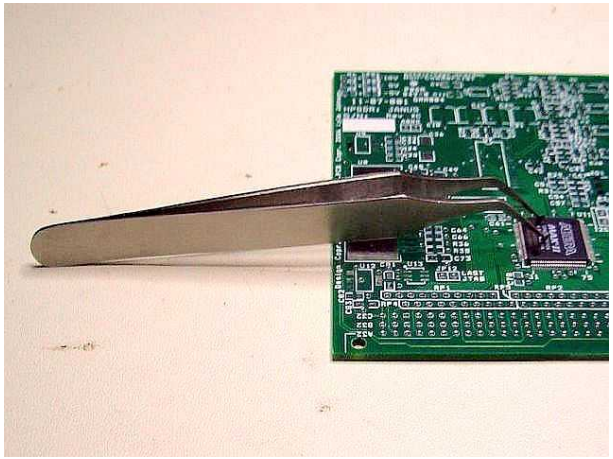
As a little side project I have developed a modified BoM (Bill of Materials) for MERCURY which can be downloaded from my website:

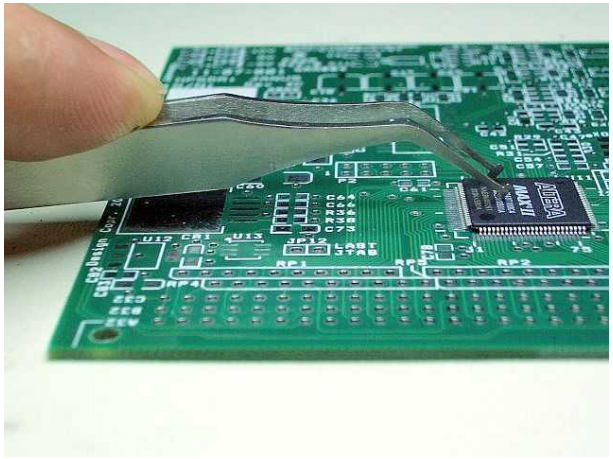
MERCURY BOM Organizer

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

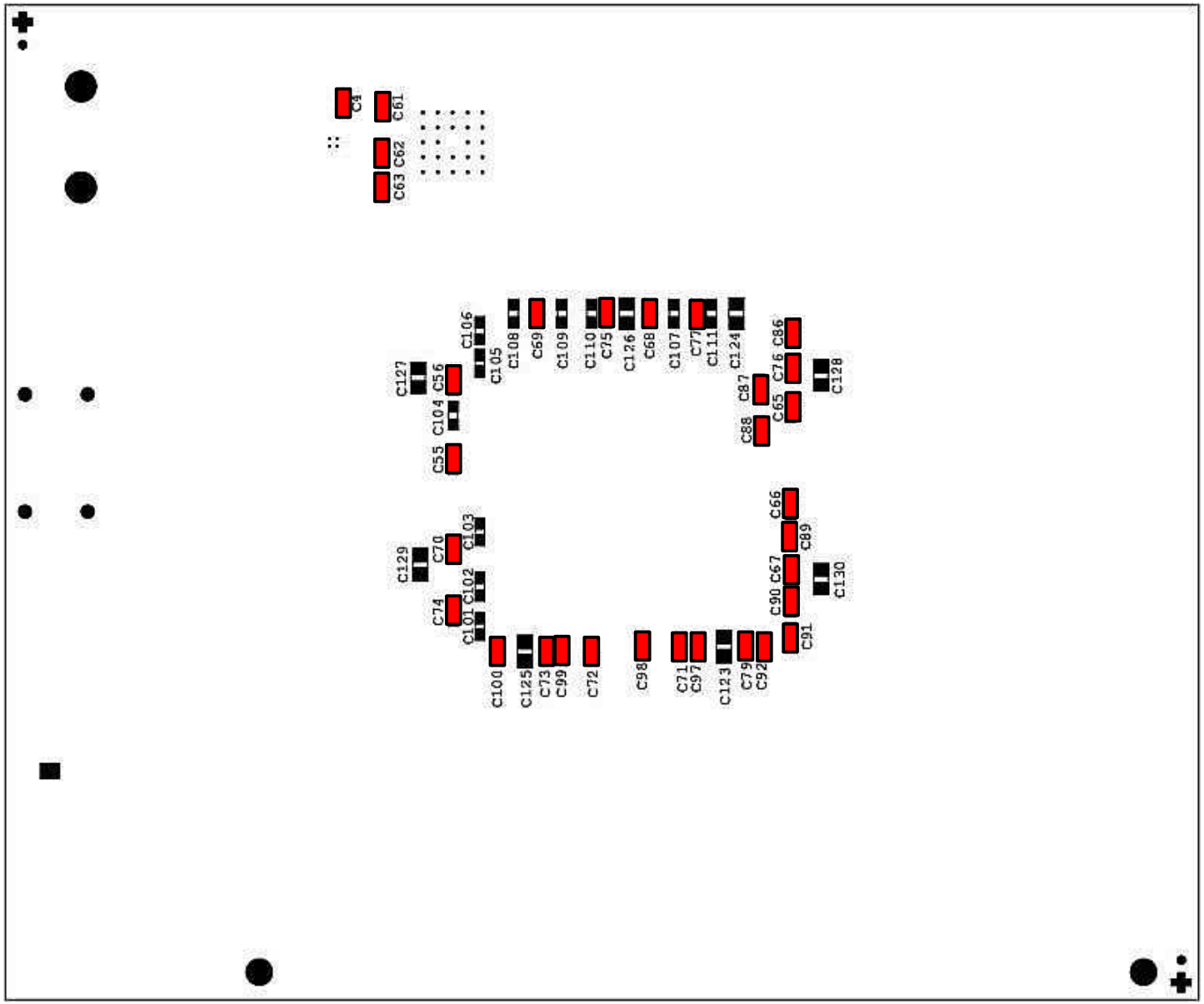
Now we start placing the parts on the board.

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.

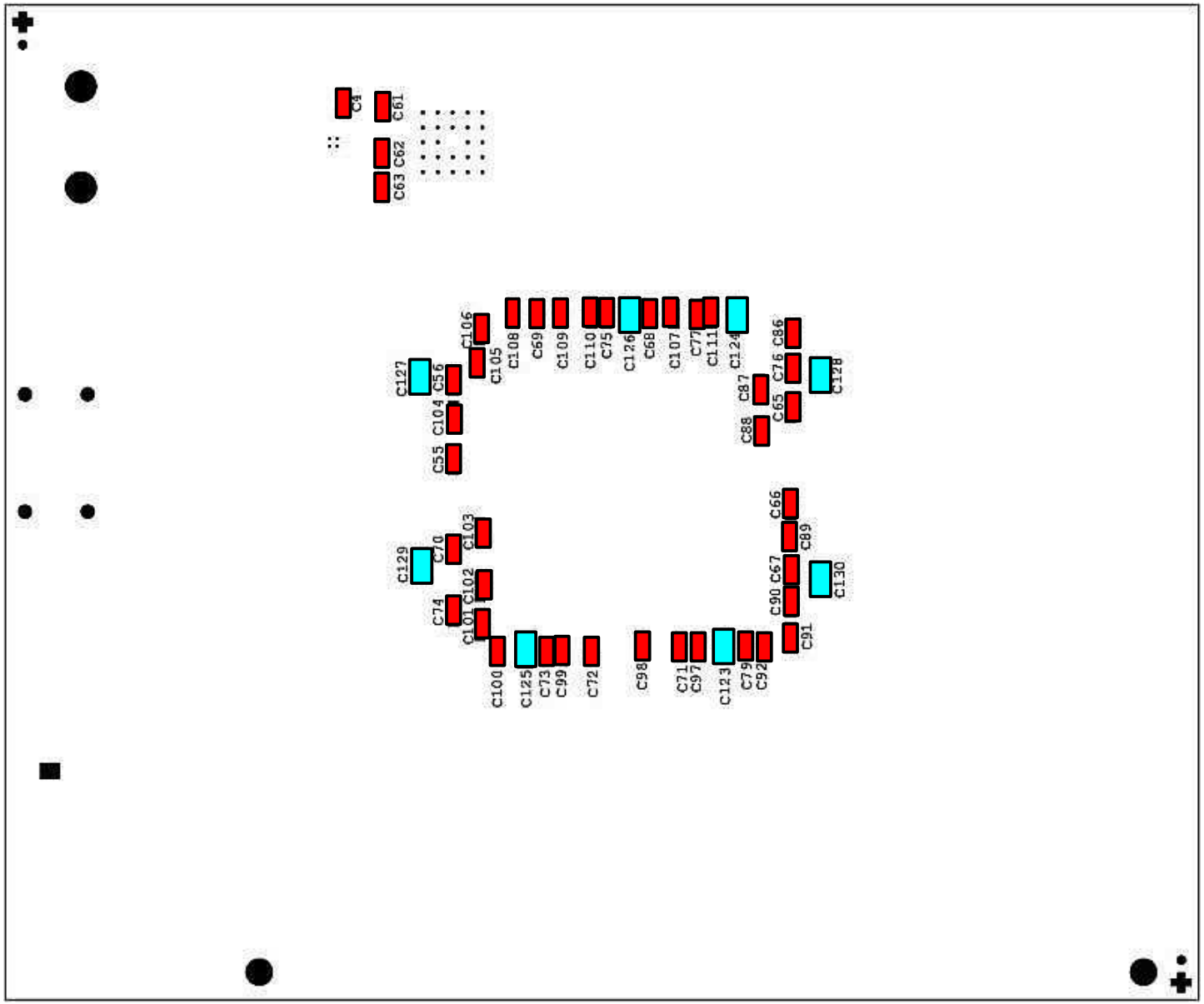
Have fun!!!

CAP 0603; 100n	
Item 1 Bottom	
Position	Reel
C004R	
C055R	
C056R	
C061R	
C062R	
C063R	
C065R	
C066R	
C067R	
C068R	
C069R	
C070R	
C071R	
C072R	
C073R	
C074R	
C075R	
C076R	
C077R	
C079R	
C086R	
C087R	
C088R	
C089R	
C090R	
C091R	
C092R	
C097R	
C098R	
C099R	
C100R	

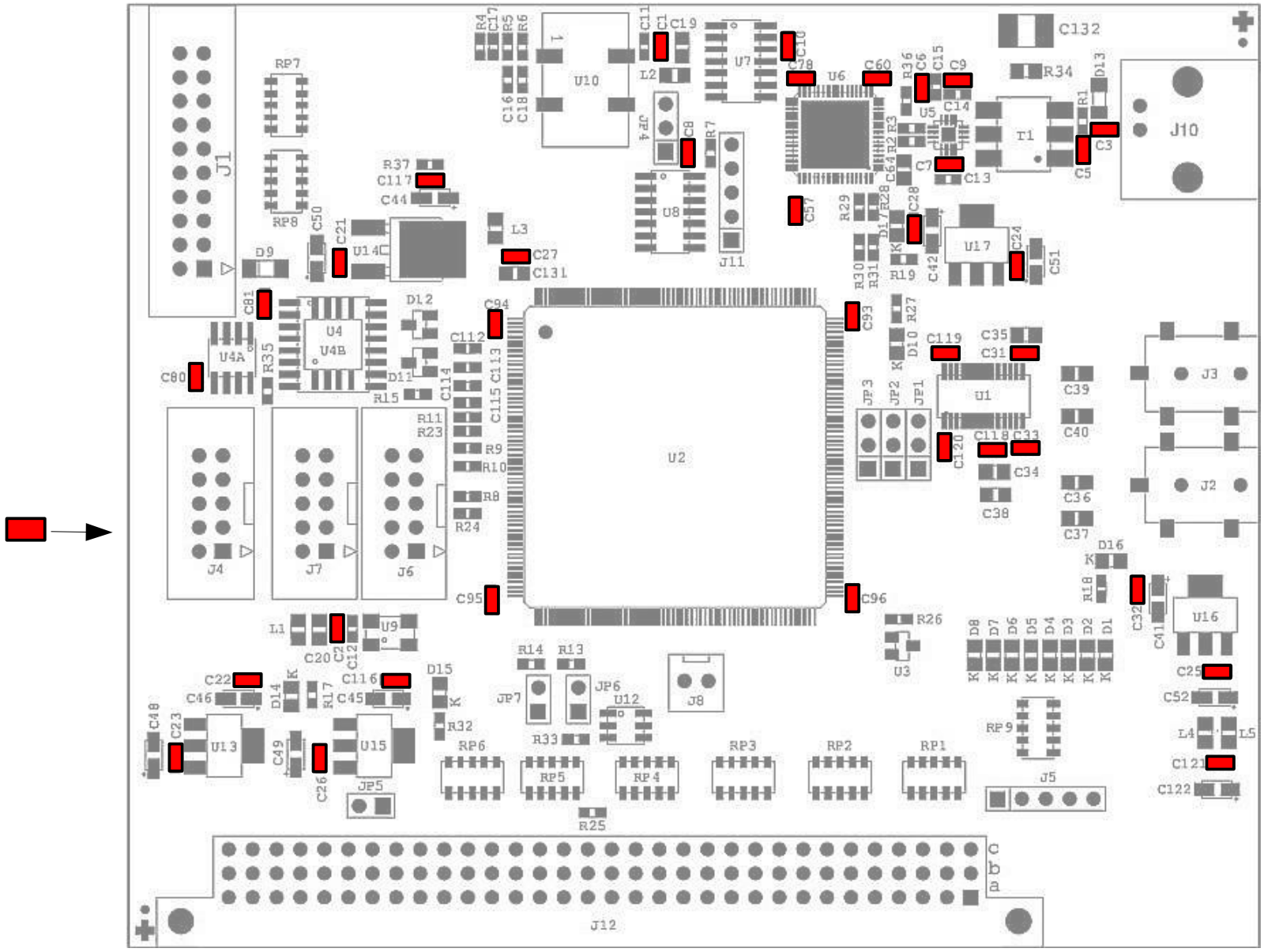


CAP 0603; 100n	
Item 1 Bottom	
Position	Reel
C101R	
C102R	
C103R	
C104R	
C105R	
C106R	
C107R	
C108R	
C109R	
C110R	
C111R	

CAP 0805; 10uF	
Item 2 Bottom	
Position	Reel
C123R	
C124R	
C125R	
C126R	
C127R	
C128R	
C129R	
C130R	



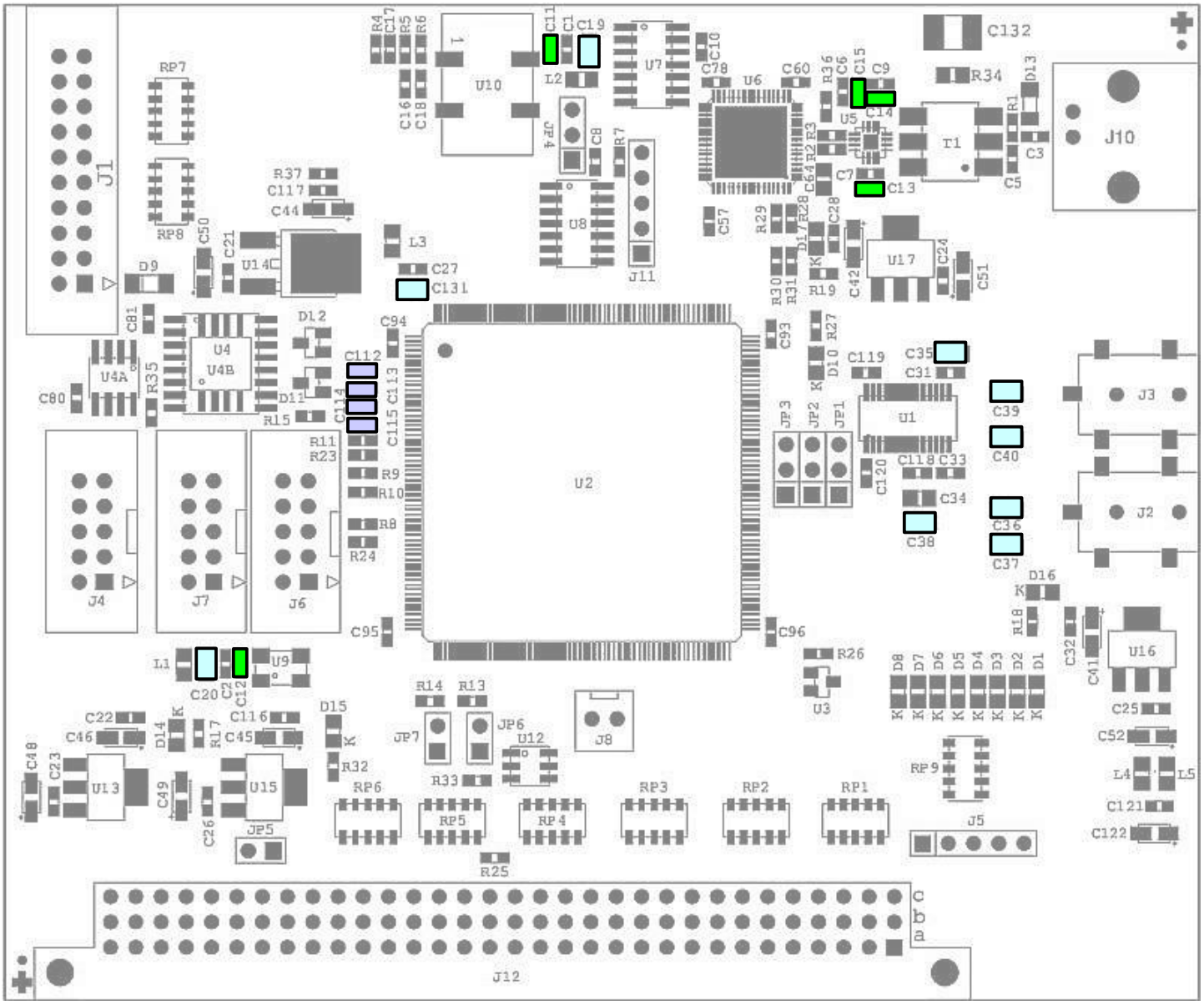
CAP 0603; 100n	
Item 1 Top	
Position	Reel
C001	
C002	
C003	
C005	
C006	
C007	
C008	
C009	
C010	
C021	
C022	
C023	
C024	
C025	
C026	
C027	
C028	
C031	
C032	
C033	
C057	
C060	
C078	
C080	
C081	
C093	
C094	
C095	
C096	
C116	
C117	
C118	
C119	
C120	
C121	



CAP 0603; 10pF	
Item 2 Top	
Position	Reel
C112	
C113	
C114	
C115	

CAP 0805; 10uF	
Item 3 Top	
Position	Reel
C019	
C020	
C035	
C036	
C037	
C038	
C039	
C040	
C131	

CAP 0603; 1nF	
Item 4 Top	
Position	Reel
C011	
C012	
C013	
C014	
C015	



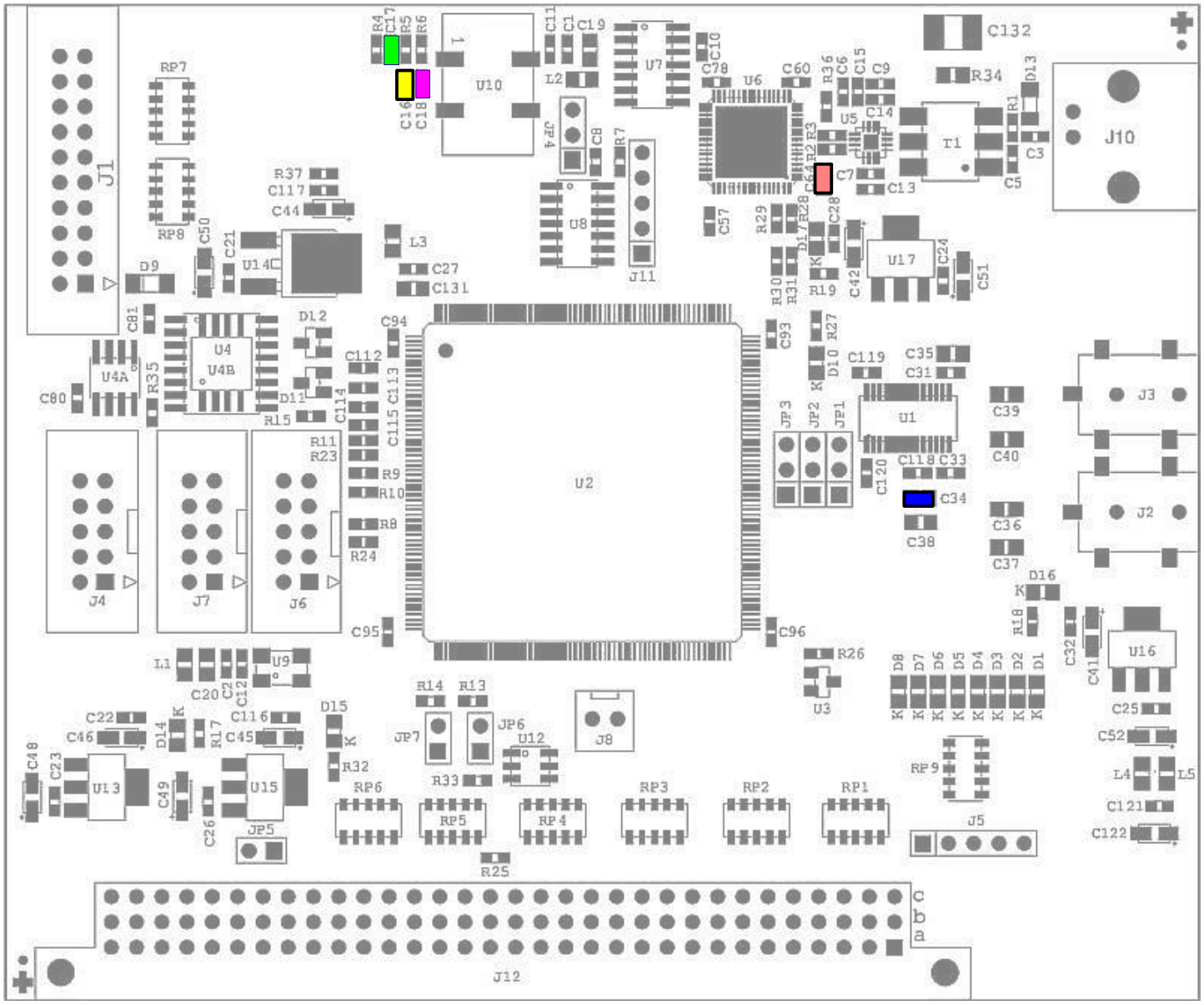
CAP 0805; 1uF/16V	
Item 5 Top	
Position	Reel
C034	

CAP 0805; 2.2uF/10V	
Item 6 Top	
Position	Reel
C064	

CAP 0603; 390nF	
Item 7 Top	
Position	Reel
C016	

CAP 0603; 56nF	
Item 8 Top	
Position	Reel
C017	

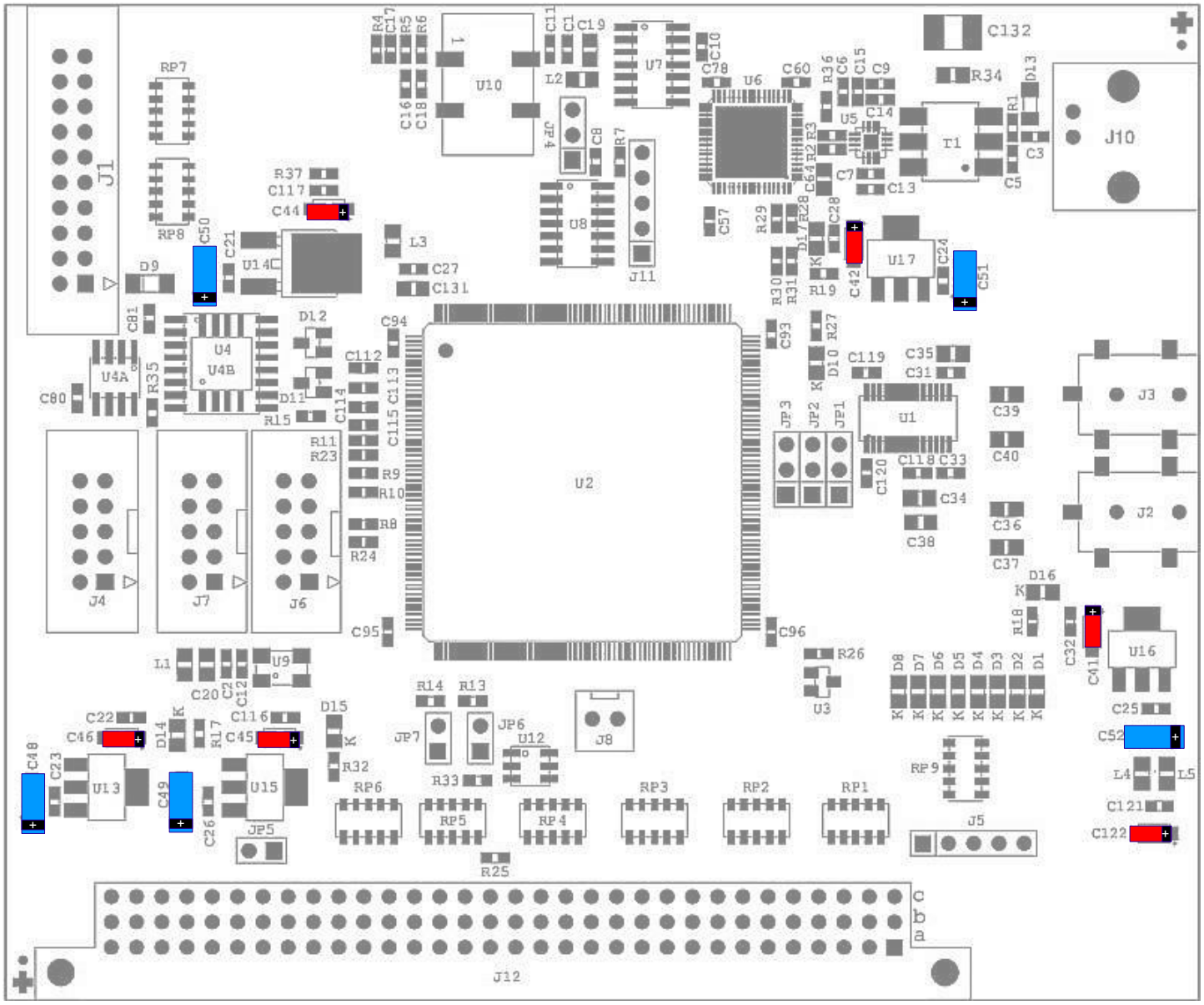
CAP 0603; 9.1nF	
Item 9 Top	
Position	Reel
C018	



CAP 1812; 4.7nF/2kV	
Item 10 Top	
Position	Reel
C132	DNI

Tantal 3216; 10uF/10V	
Item 28 Top	
Position	Reel
C041	
C042	
C044	
C045	
C046	
C122	

Tantal 3216; 1uF/16V	
Item 29 Top	
Position	Reel
C048	
C049	
C050	
C051	
C052	

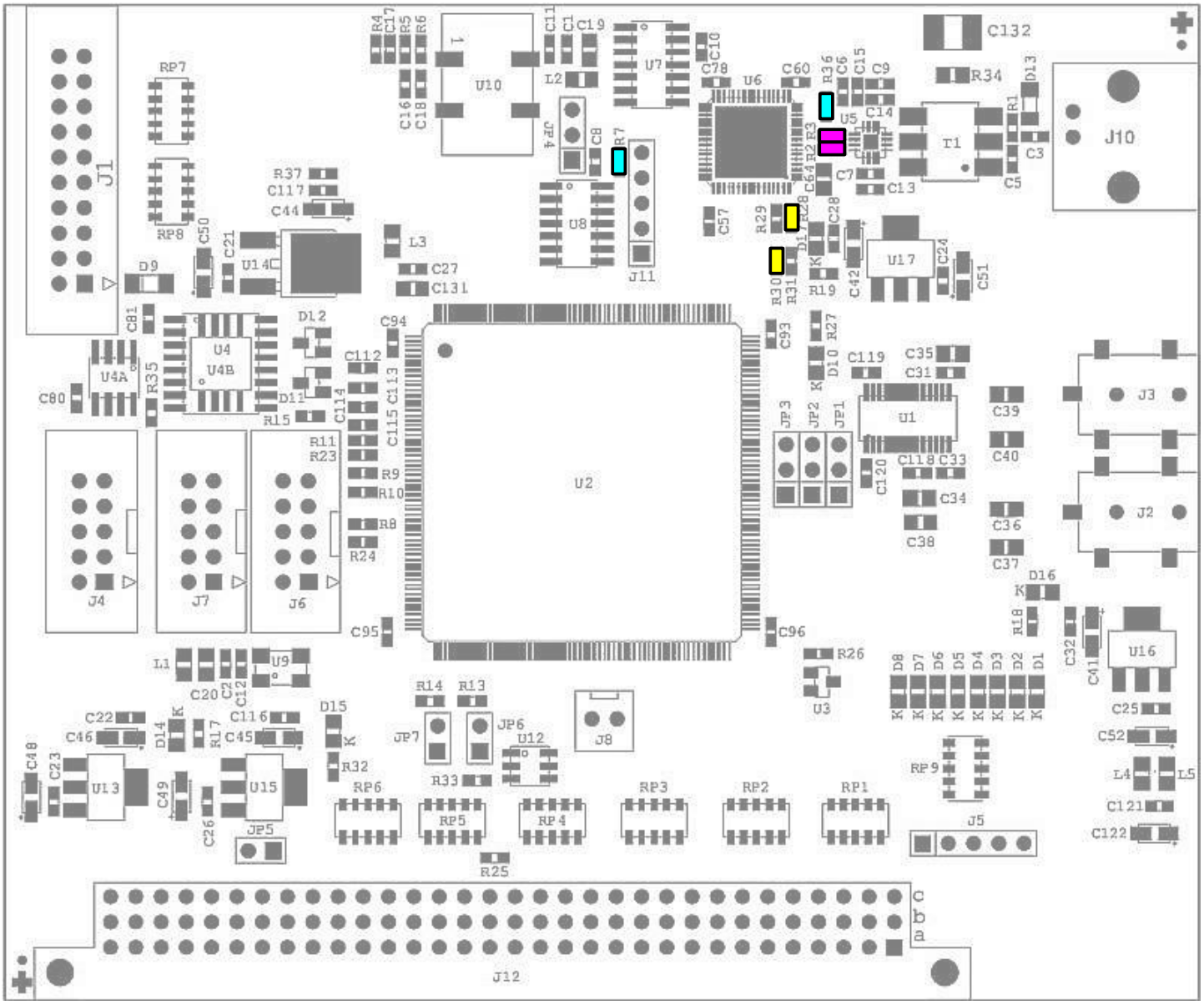


Now we are finished with the capacitors and will start with placing the resistors on the board.

RES 0603; 0R0	
Item 11 Top	
Position	Reel
R28	Pulls MODE High
R29	Not used
R30	Pulls LVDS Low
R31	Not used
R33	Not used ; A19 Reset

RES 0603; 100R	
Item 12 Top	
Position	Reel
R07	
R36	

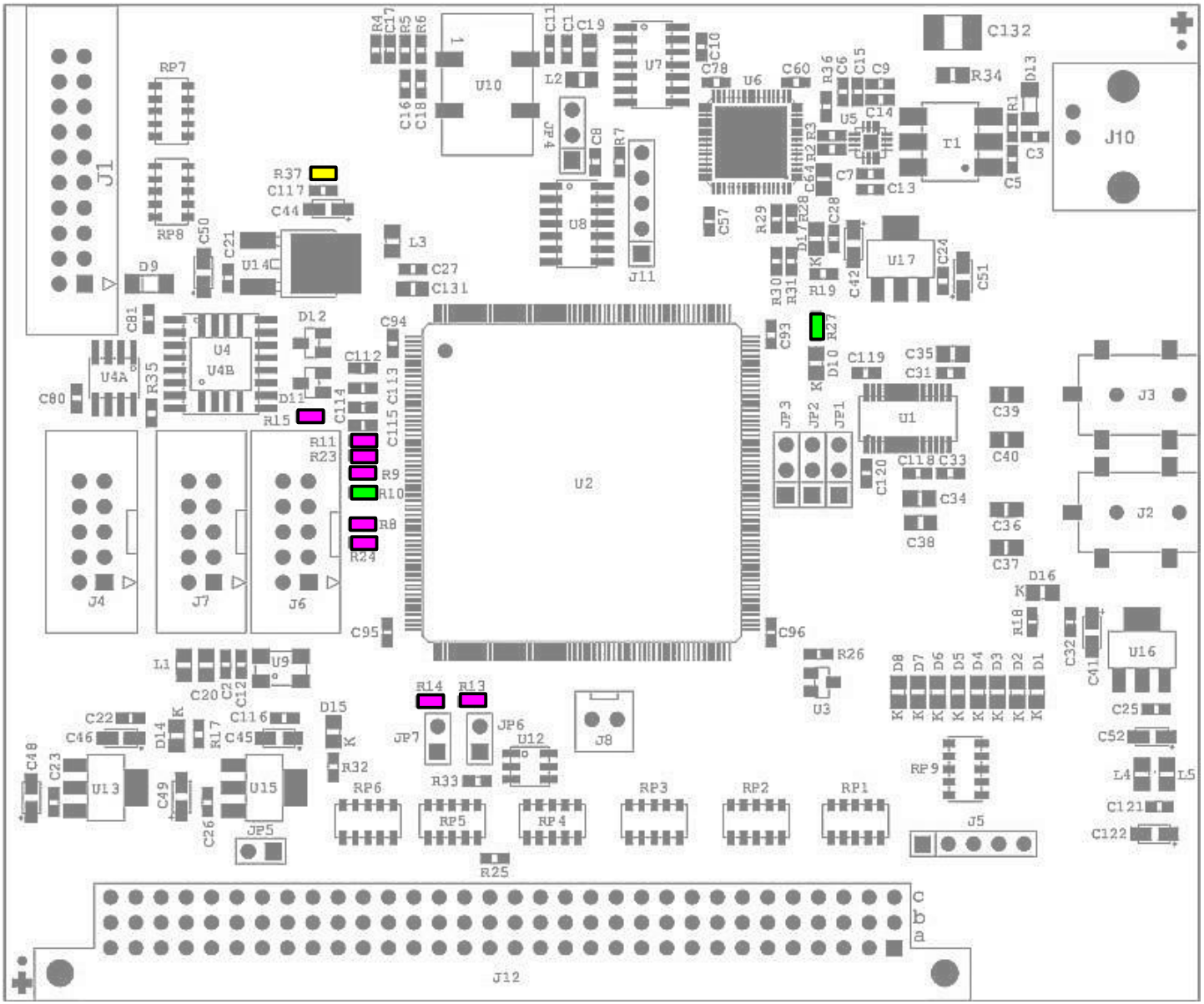
RES 0603; 10R	
Item 13 Top	
Position	Reel
R02	
R03	



RES 0603; 10k	
Item 14 Top	
Position	Reel
R08	
R09	
R11	
R13	
R14	
R15	
R23	
R24	

RES 0603; 120R	
Item 15 Top	
Position	Reel
R37	

RES 0603; 1k	
Item 16 Top	
Position	Reel
R10	
R27	

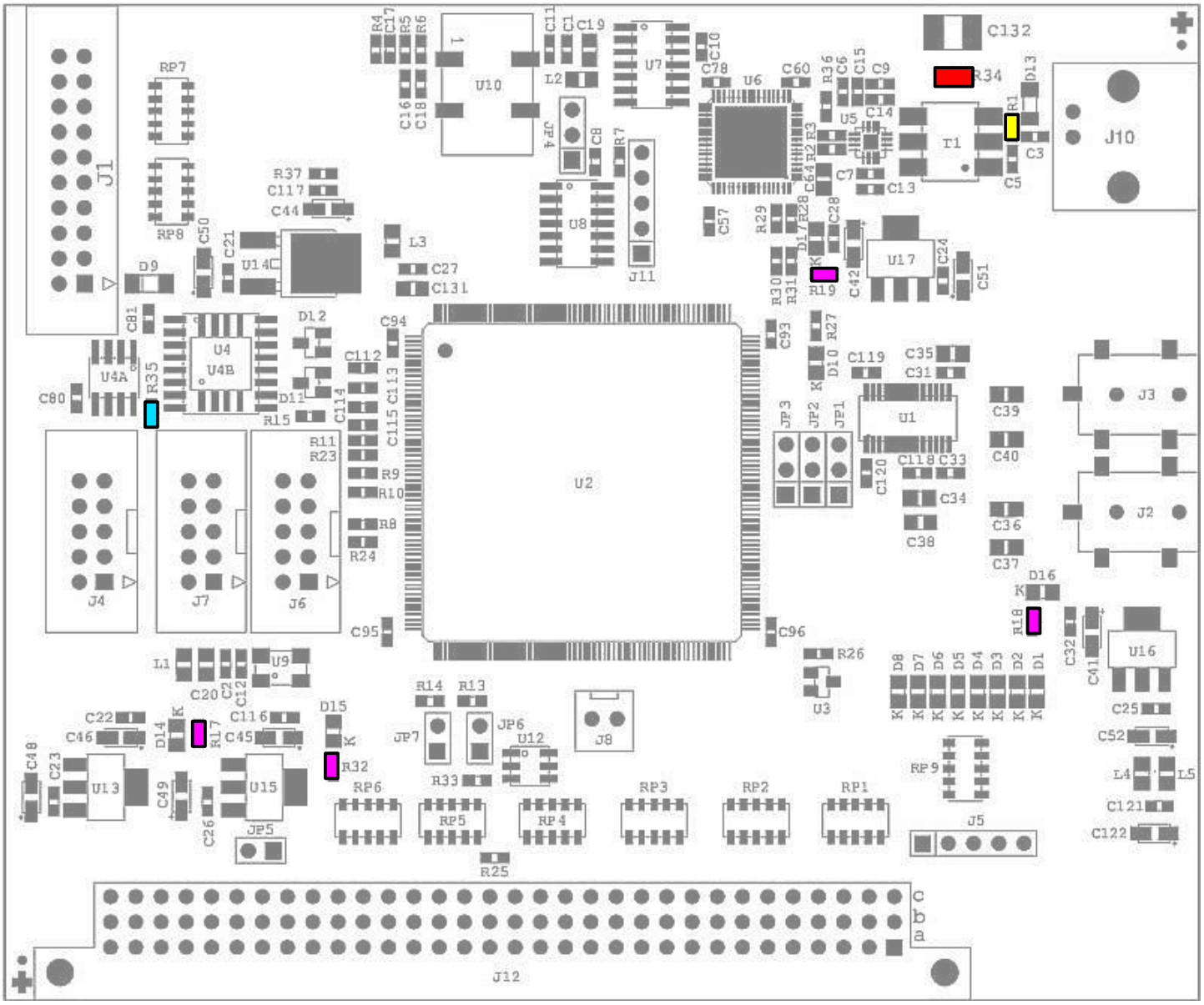


RES 0603; 150R	
Item 17 Top	
Position	Reel
R17	
R18	
R19	
R32	

RES 0603; 1M	
Item 18 Top	
Position	Reel
R01	

RES 0805; 1M	
Item 19 Top	
Position	Reel
R34	

RES 0603; 22R	
Item 20 Top	
Position	Reel
R35	



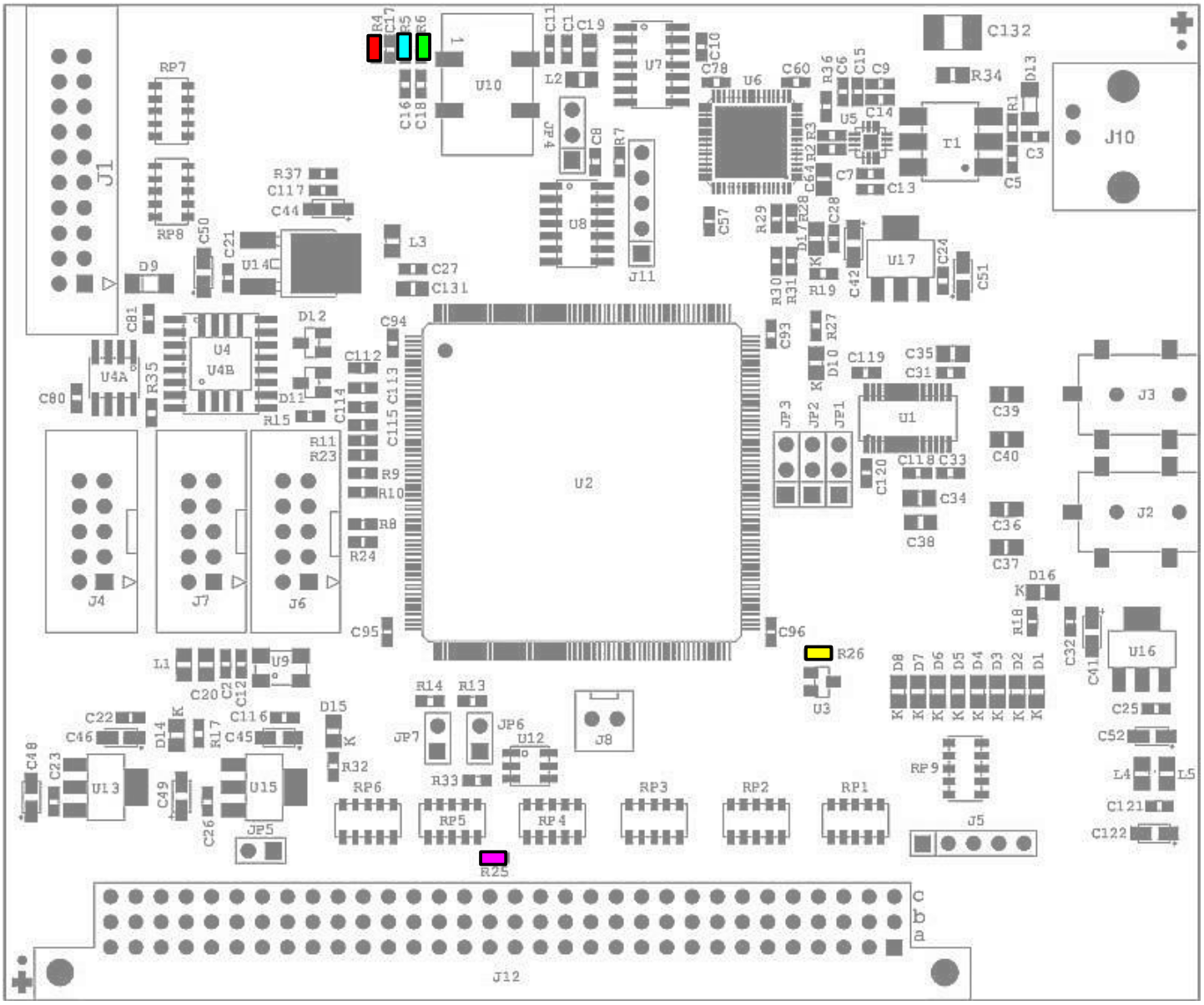
RES 0603; 2k2	
Item 21 Top	
Position	Reel
R25	

RES 0603; 2k7	
Item 22 Top	
Position	Reel
R04	

RES 0603; 4k7	
Item 23 Top	
Position	Reel
R26	

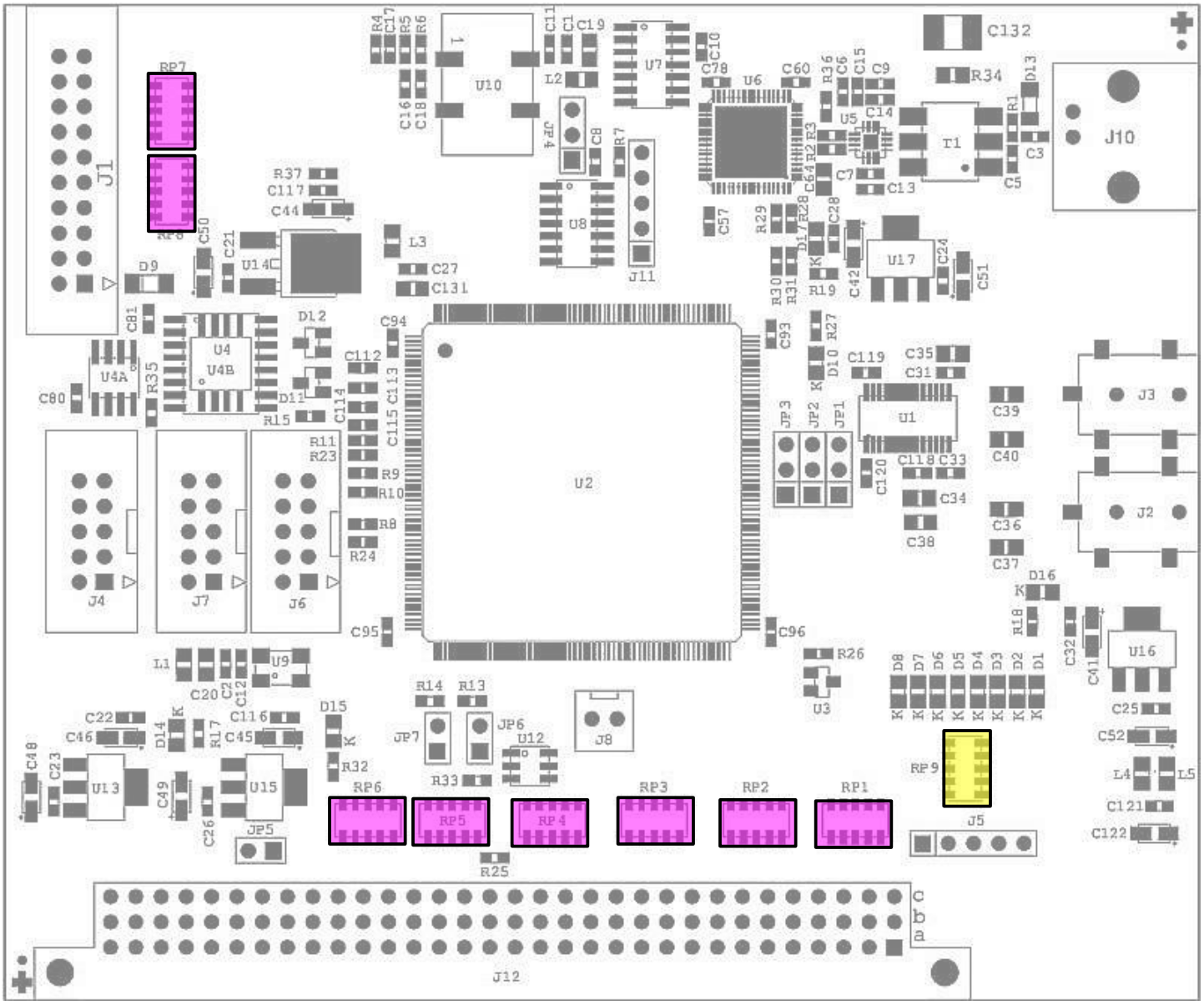
RES 0603; 56k	
Item 24 Top	
Position	Reel
R06	

RES 0603; 9k1	
Item 25 Top	
Position	Reel
R05	



Pana RP-Bus 8x100k EXB-A10P104J	
Item 26 Top	
Position	Reel
RP1	
RP2	
RP3	
RP4	
RP5	
RP6	
RP7	
RP8	

Pana RP-Bus 8x2.2k EXB-A10P222J	
Item 27 Top	
Position	Reel
RP9	

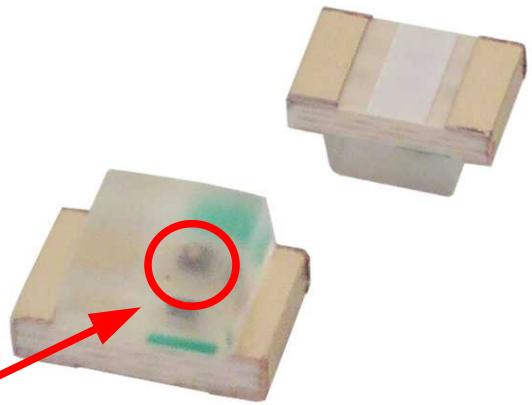


Special Instructions: Placing LEDs 1 to 8

How to determine the polarity of the 0805 LEDs?

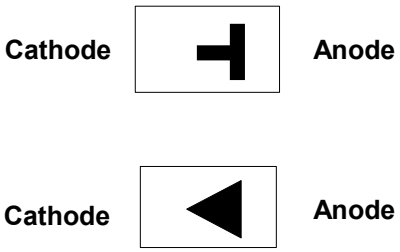
It can be difficult to find out the polarity of the tiny 0805 LEDs if you don't know what to look for.

The Lite-ON® LEDs used in the MERCURY-EU 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.



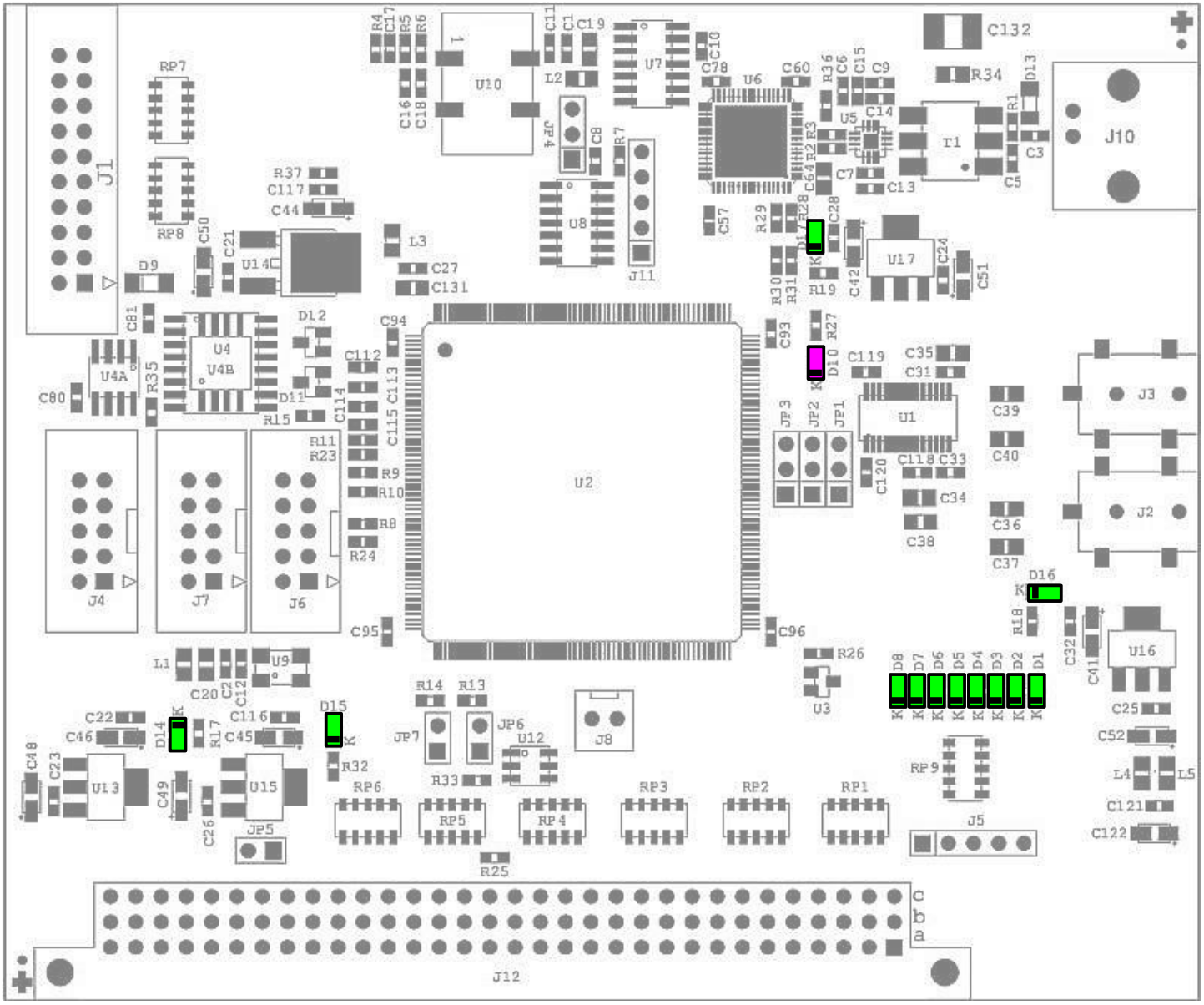
LED Dice

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

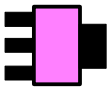


LED green; 0805	
Item 31 Top	
Position	Reel
D01	
D02	
D03	
D04	
D05	
D06	
D07	
D08	
D10	
D14	
D15	
D16	
D17	

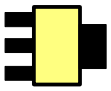
LED red; 0805	
Item 31 Top	
Position	Reel
D10	



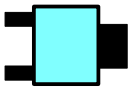
TS1117CW-3.3; SOT223	
Item 32 Top	
Position	Reel
U13	
U16	
U17	

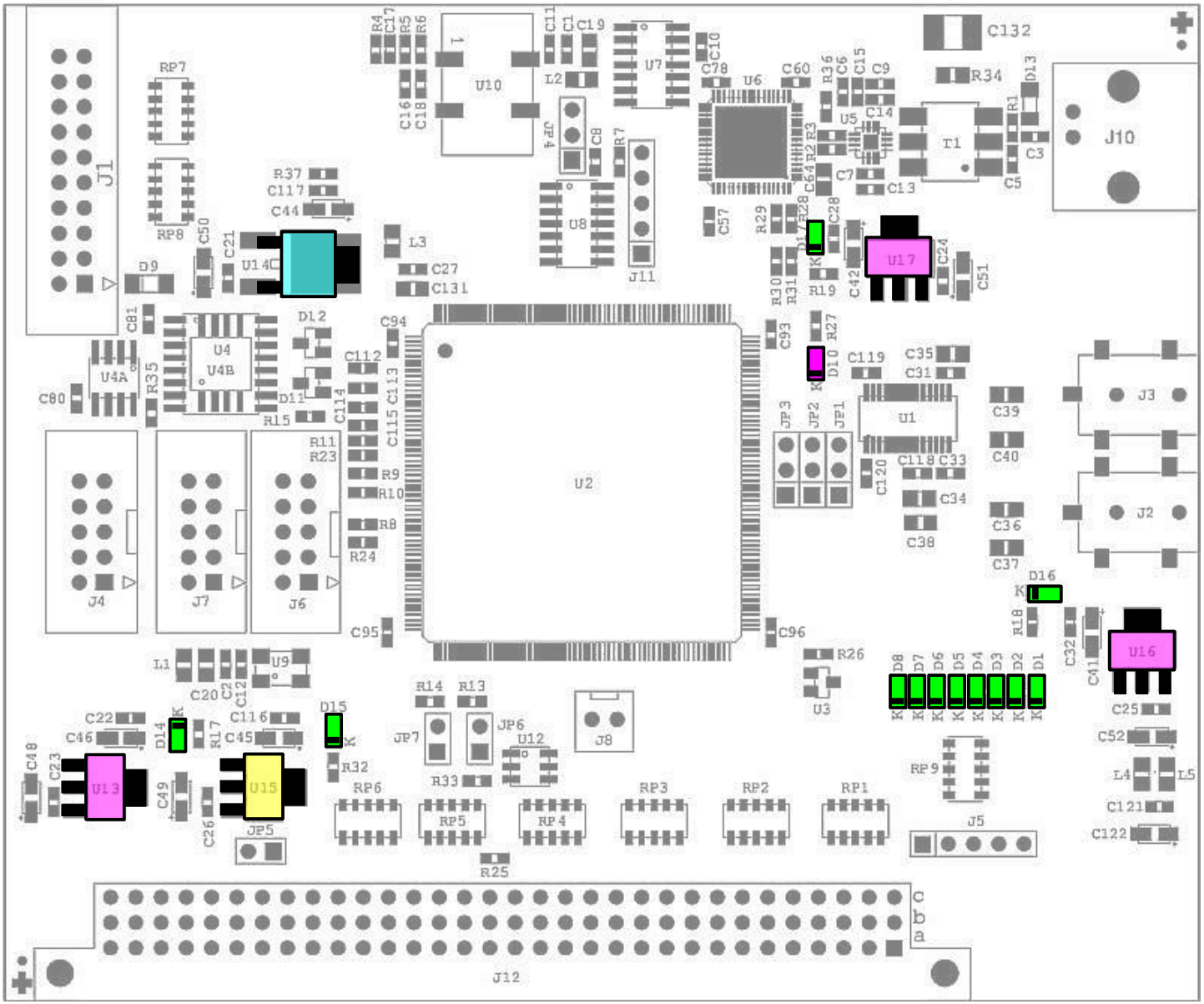


TS1117CW-2.5; SOT223	
Item 32 Top	
Position	Reel
U15	



TS1117CZ; DPAK	
Item 32 Top	
Position	Reel
U14	





Ferrite WE-CBF; 0805	
Item 33 Top	
Position	Reel
L1	
L2	
L3	
L4	
L5	

BAT54C; SOT23	
Item 30 Top	
Position	Reel
D11	
D12	

TVS GBLC03C; SOD323	
Item 32 Top	
Position	Reel
D13