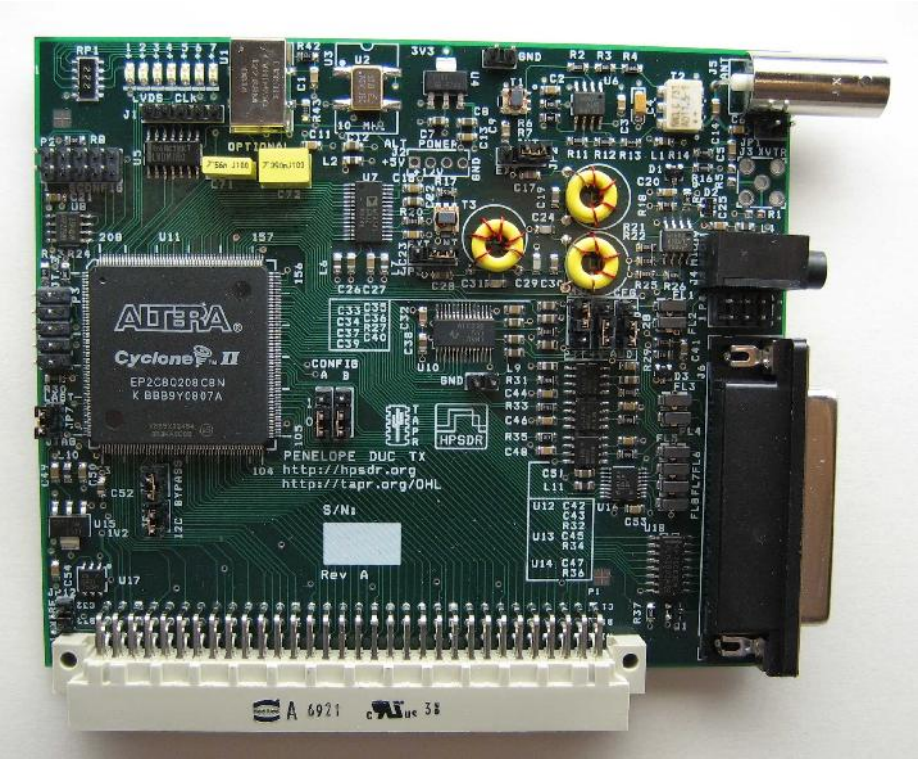
High Performance Software Defined Radio

Open Source Hardware and Software Project

Project Description: http://openhpsdr.org



Hardware Project #5

PENELOPE Board

Part #2

The Making of PENELOPE

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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 PENELOPE. 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 PENELOPE 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.

Chapter 1: Preliminaries

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 FPGA.

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 PENELOPE.
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 PENELOPE 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 fine-pitch ICs. 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

Chapter 1: Preliminaries

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.

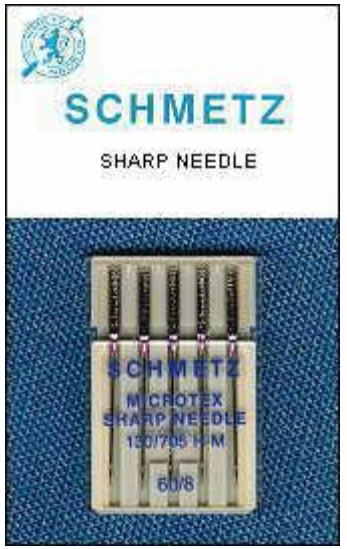
1.4.3 What else?

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 PENELOPE 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 PENELOPE is not just a little sunday afternoon project.

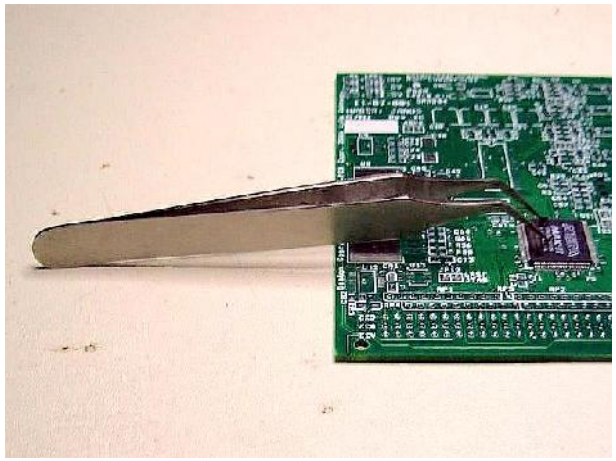
As a little side project I have developed a modified BoM (Bill of Materials) for PENELOPE which can be downloaded from my website:

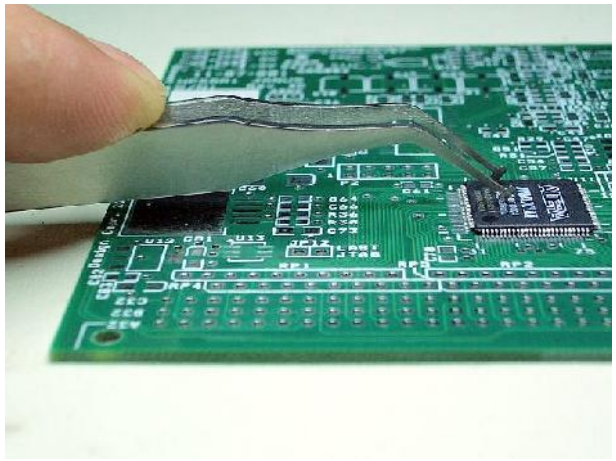
http://www.needles.de/HPSDR/Penelope-BOMOrganizer.pdf

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 bottom parts and then go from 'low' to 'high' parts in the order of their values.

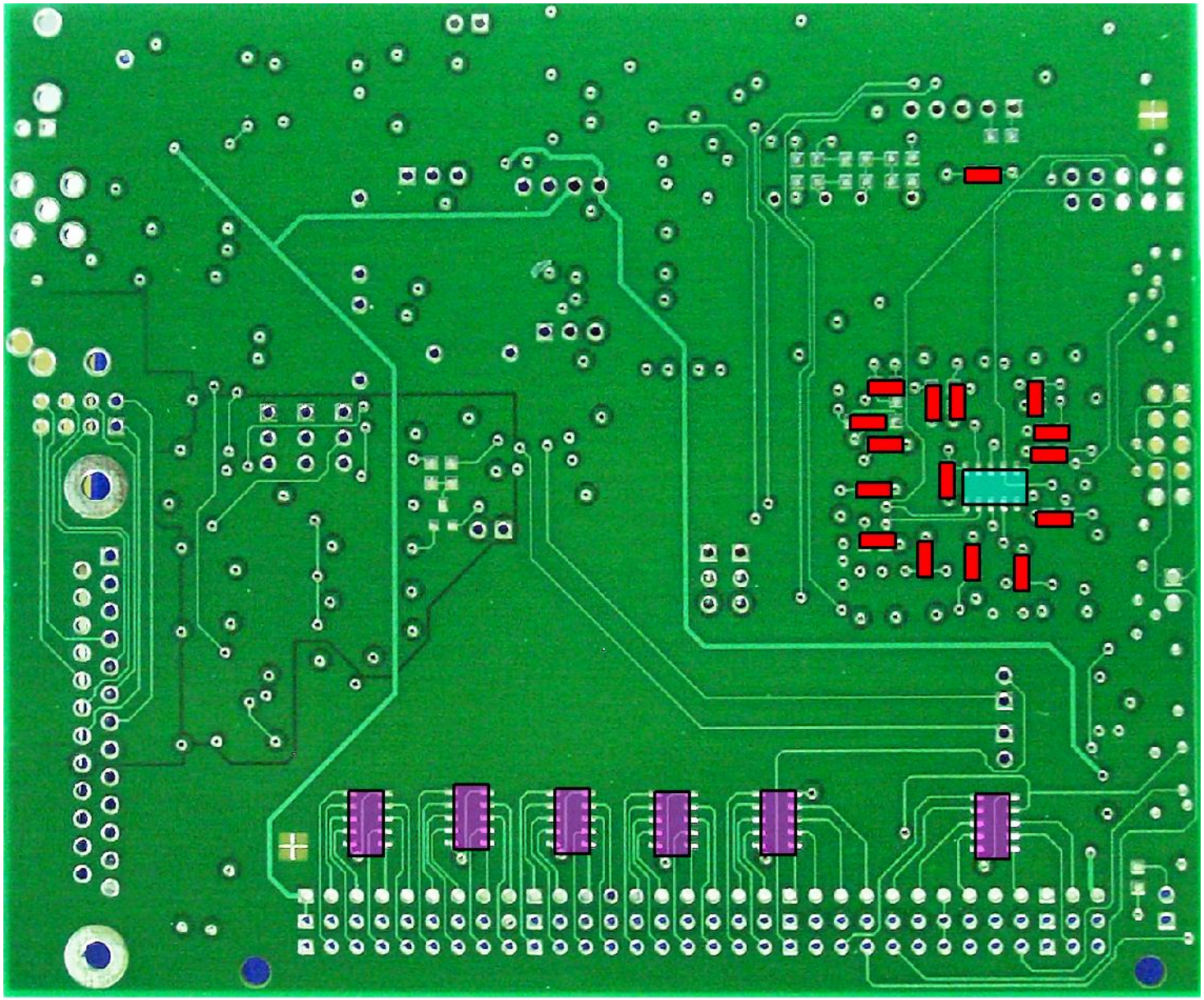
So first you should place and solder all the bottom parts onto the board. The positions on the board are self-explanatory. Just make sure that you always position them the correct way.

Have fun!!!

Item 2	
RES NETWRK 10K OHM 8RES 10PN SMD	
EXB-A10P103J	
Pos	Reel/Tick
RP2-Bot	

Item 3	
RES NETWRK 100K OHM 8RES10PN SMD	
EXB-A10P104J	
Pos	Reel/Tick
RP3-Bot	
RP4-Bot	
RP5-Bot	
RP6-Bot	
RP7-Bot	
RP8-Bot	

Item 4	
CAP CER .1UF 50V Y5V 0805	
Pos	Reel/Tick
C55-Bot	
C56-Bot	
C57-Bot	
C58-Bot	
C59-Bot	
C60-Bot	
C61-Bot	
C62-Bot	
C63-Bot	
C64-Bot	
C65-Bot	
C66-Bot	
C67-Bot	
C68-Bot	
C69-Bot	
C70-Bot	



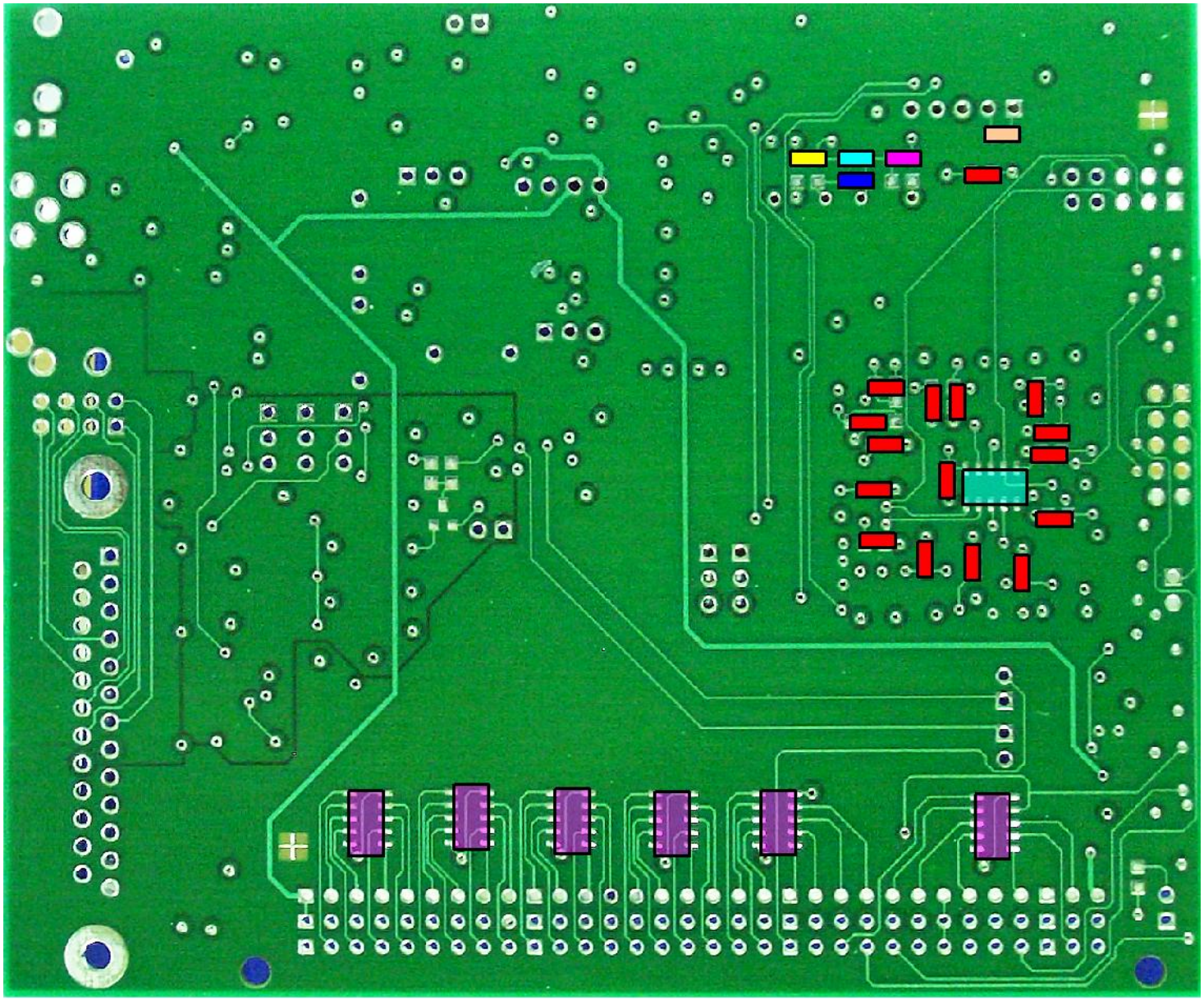
Item 5	
CAP CER 9100PF 50V 5% C0G 0805	
Pos	Reel/Tick
C10-Bot	

Item 21	
RES 2.70K OHM 1/8W 1% 0805 SMD	
Pos	Reel/Tick
R9-Bot	

Item 22	
RES 56.0K OHM 1/8W 1% 0805 SMD	
Pos	Reel/Tick
R10-Bot	

Item 23	
RES 9.10K OHM 1/8W 1% 0805 SMD	
Pos	Reel/Tick
R15-Bot	

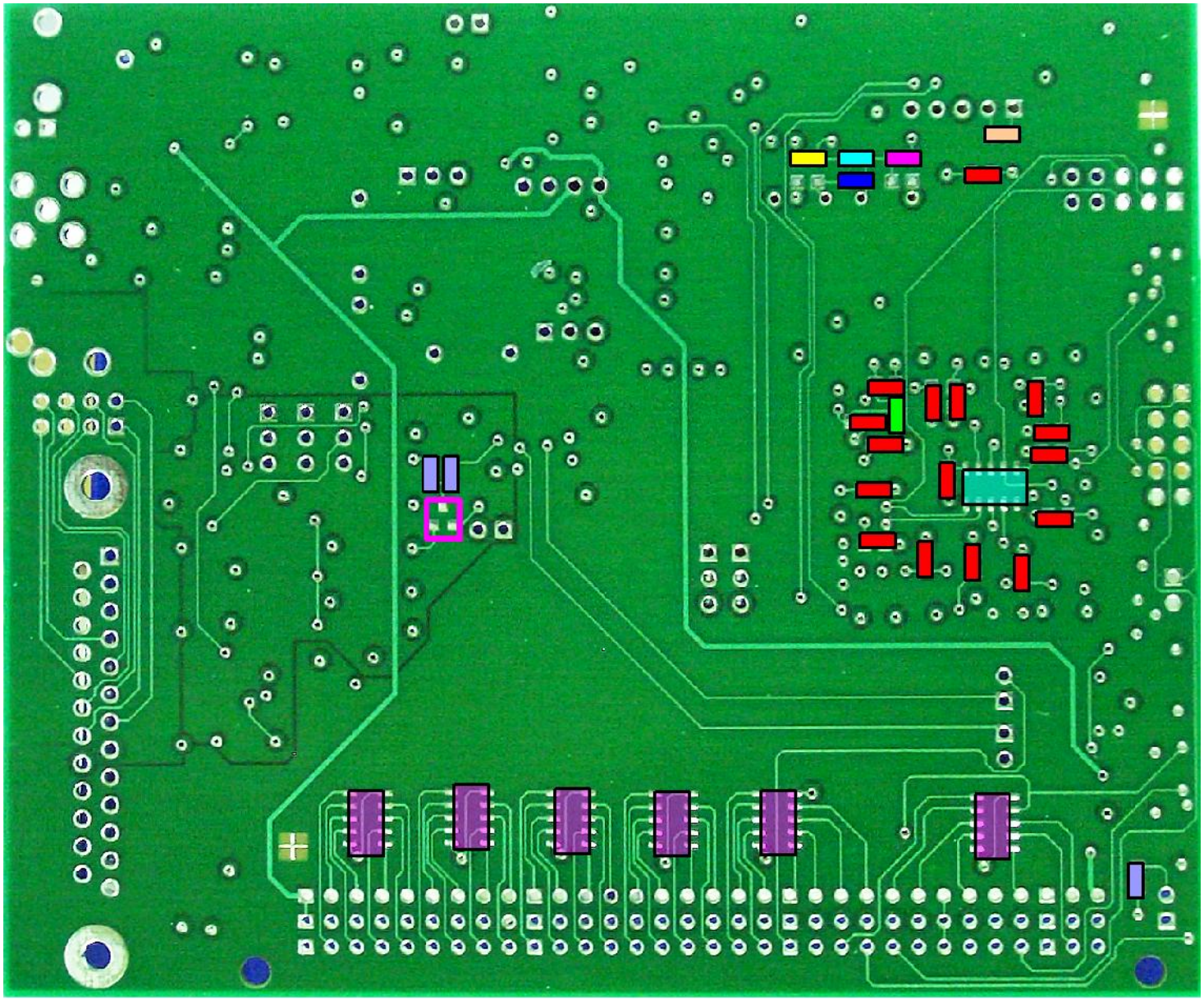
Item 28	
RES 100 OHM 1/8W 1% 0805 SMD	
Pos	Reel/Tick
R38-Bot	



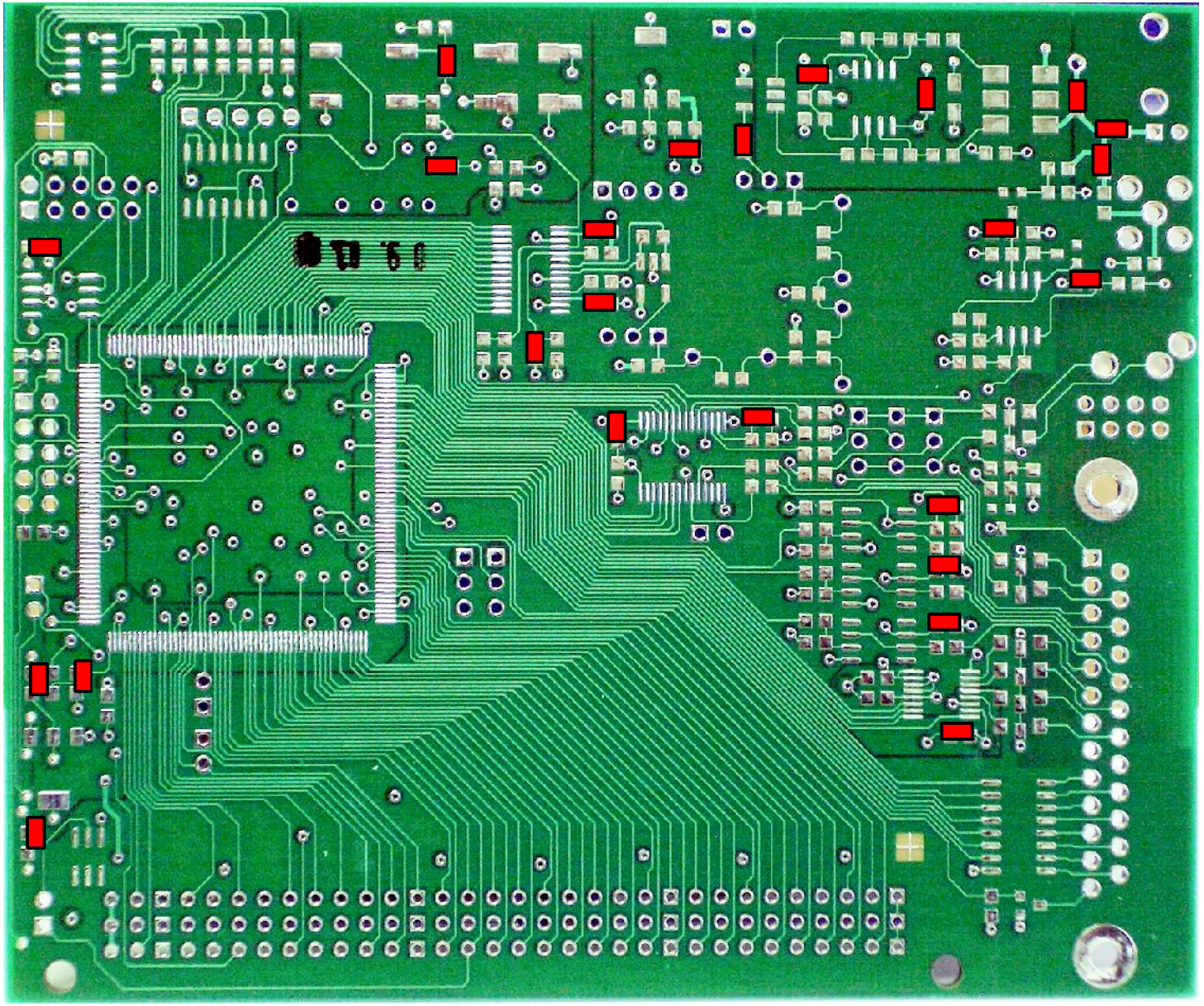
Item 35	
RES 2.20K OHM 1/8W 1% 0805 SMD	
Pos	Reel/Tick
R39-Bot	
R40-Bot	
R41-Bot	

Item 20	
FERRITE CHIP 600 OHM 500MA 0805	
Pos	Reel/Tick
L12	

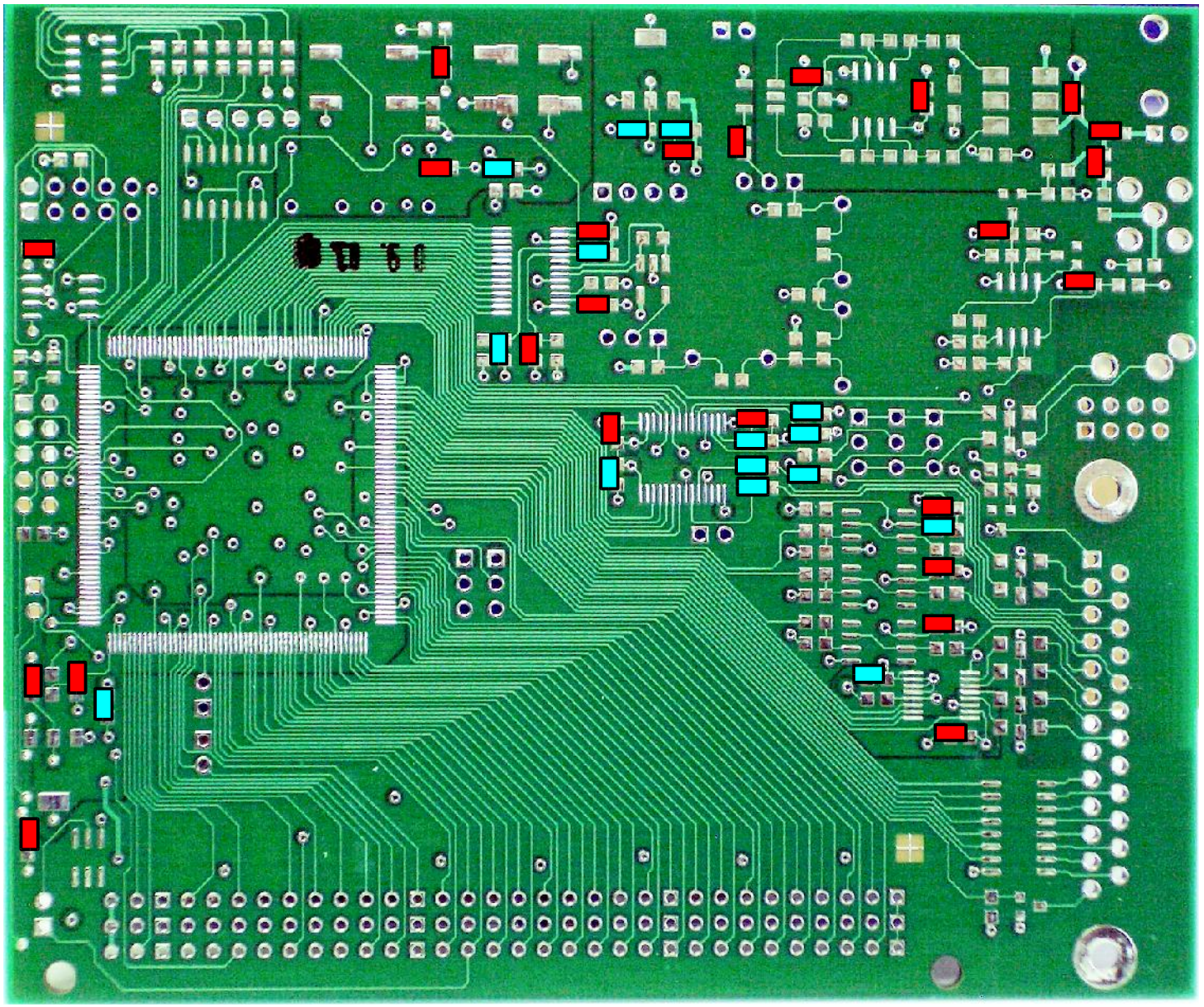
Item 39	
DIODE SCHOTTKY 30V 200MA SOT-23	
BAT 54S	
Pos	Reel/Tick
D4-Bot	



Item 4	
CAP CER .1UF 50V Y5V 0805	
Pos	Reel/Tick
C1	
C2	
C3	
C5	
C6	
C9	
C11	
C13	
C14	
C18	
C20	
C21	
C23	
C25	
C27	
C32	
C33	
C42	
C45	
C47	
C49	
C50	
C53	
C54	



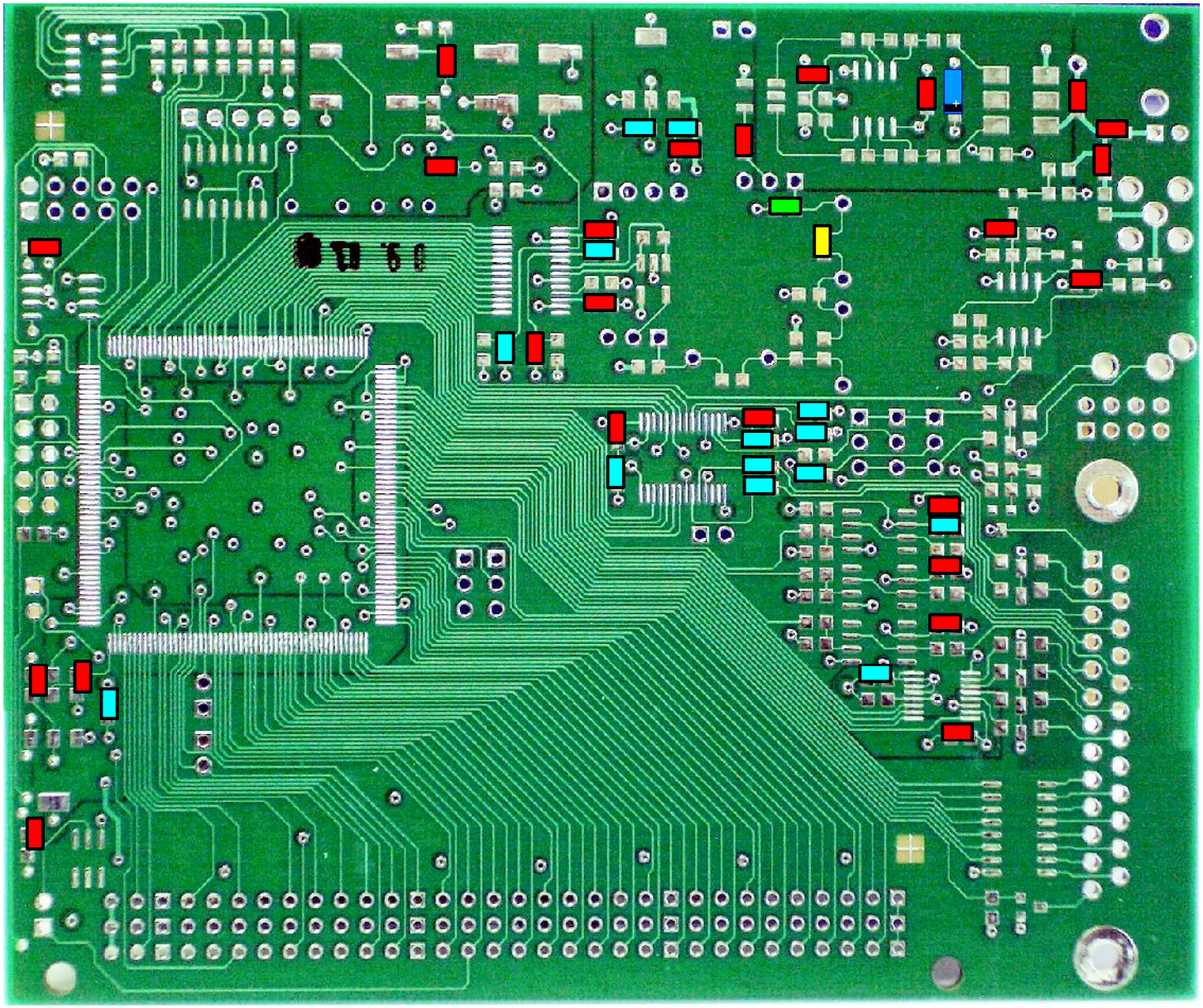
Item 10	
CAP 10UF 6.3V CERAMIC X5R 0805	
Pos	Reel/Tick
C7	
C8	
C12	
C22	
C26	
C34	
C35	
C36	
C37	
C38	
C39	
C40	
C43	
C51	
C52	



Item 8	
CAP CERAMIC 68PF 100V NP0 0805	
Pos	Reel/Tick
C17	

Item 11	
0805 SMD Monolithic Ceramic Chips	
20pF 50volts C0G 1%	
Pos	Reel/Tick
C19	

Item 9	
CAPACITOR TANT 10UF 16V 20% SMD	
Pos	Reel/Tick
C4	

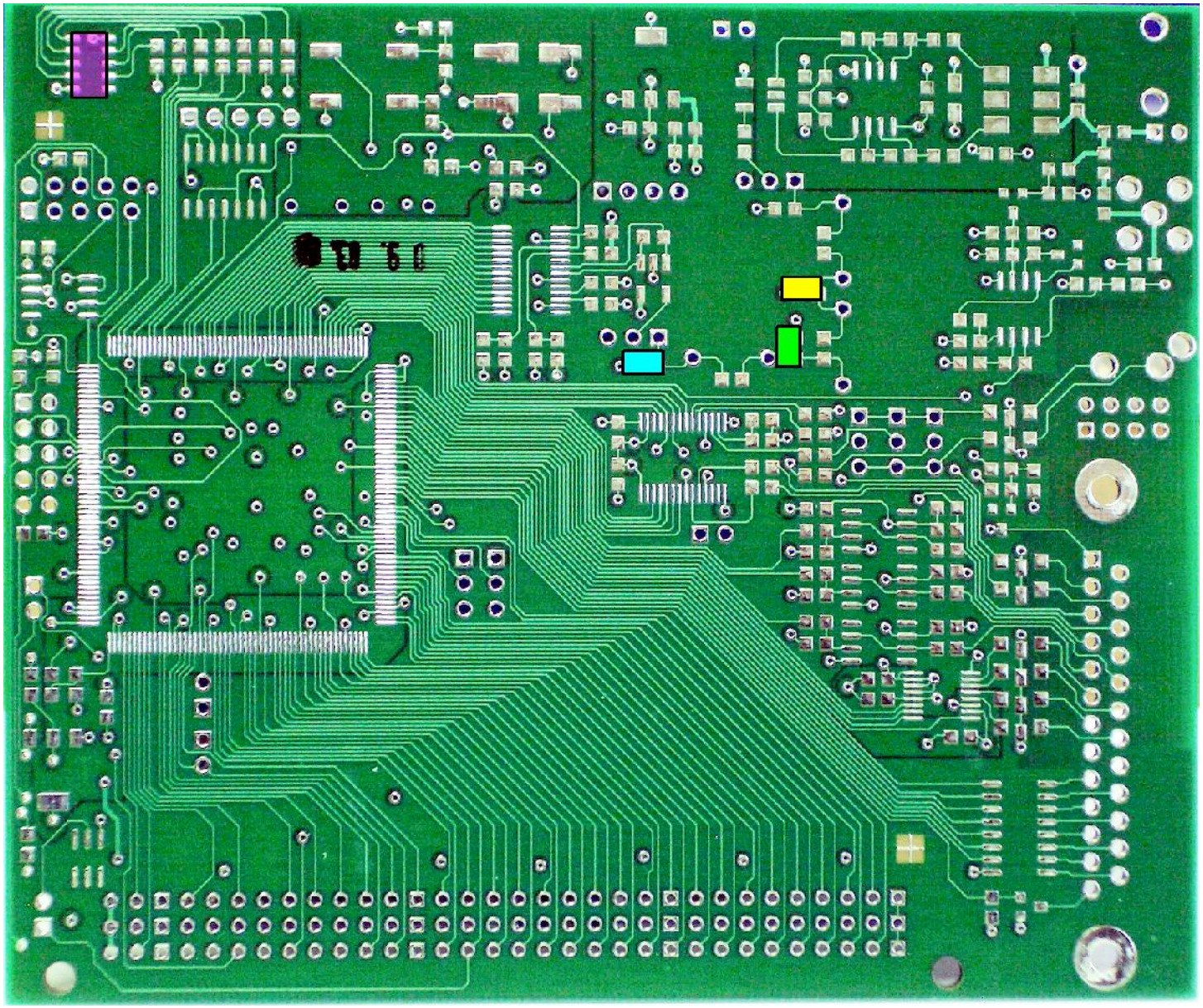


Item 1	
RES NETWRK 2.2K OHM 8RES 10P SMD	
EXB-A10P222J	
Pos	Reel/Tick
RP1	

Item 12	
0805 SMD Monolithic Ceramic Chips	
100pF 50volts C0G 1%	
Pos	Reel/Tick
C24	

Item 13	
0805 SMD Monolithic Ceramic Chips	
82pF 50volts C0G 1%	
Pos	Reel/Tick
C28	

Item 14	
0805 SMD Monolithic Ceramic Chips	
110pF 50volts C0G 1%	
Pos	Reel/Tick
C29	

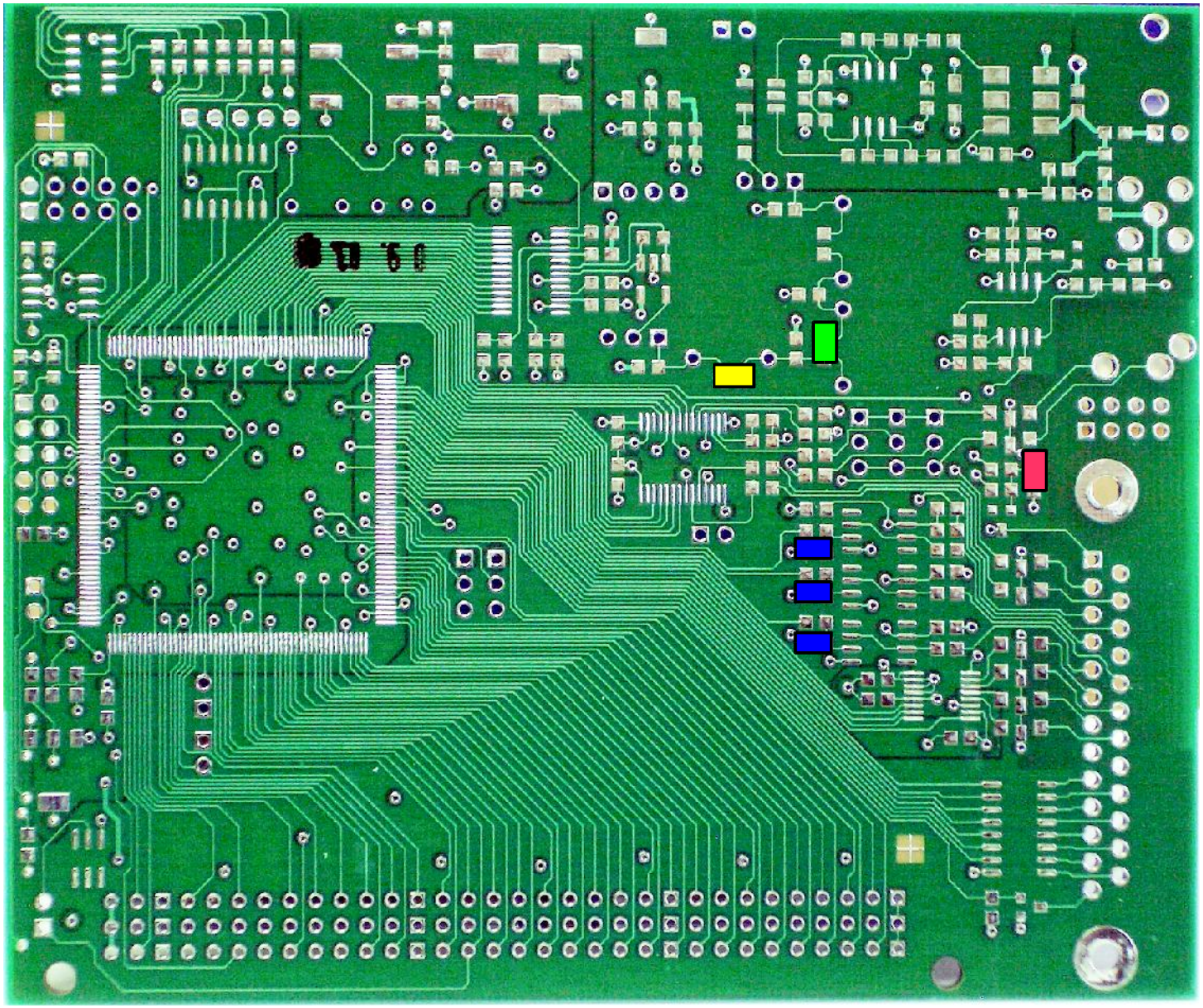


Item 15	
0805 SMD Monolithic Ceramic Chips	
30pF 50volts C0G 1%	
Pos	Reel/Tick
C30	

Item 16	
0805 SMD Monolithic Ceramic Chips	
5.6pF 50volts C0G +/-0.25pF	
Pos	Reel/Tick
C31	

Item 17	
CAP 470PF 50V CERM CHIP 0805 SMD	
Pos	Reel/Tick
C41	

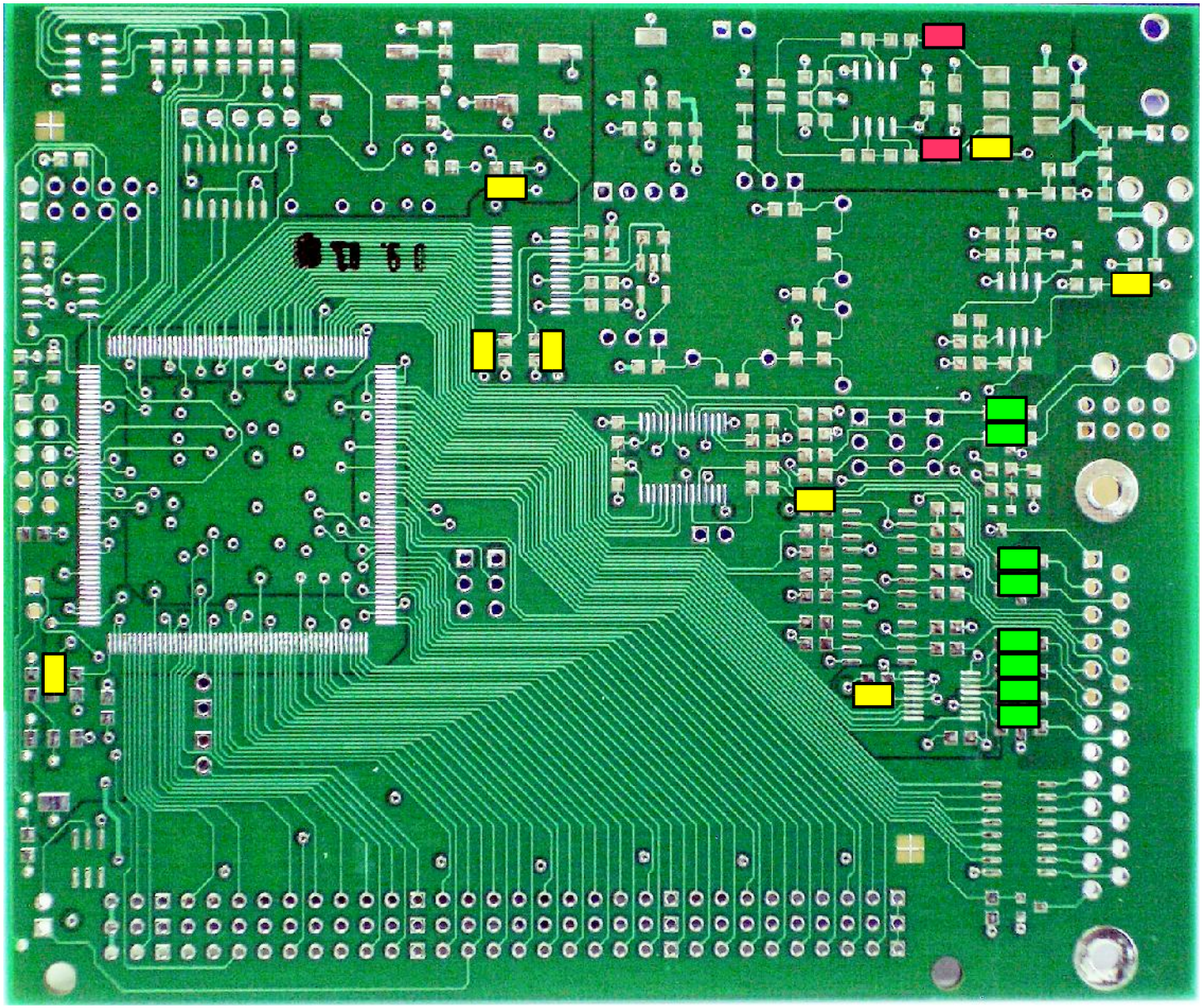
Item 18	
CAP 10000PF 50V CERAMIC X7R 0805	
Pos	Reel/Tick
C44	
C46	
C48	



Item 19	
EMI FILTER 1000PF 50V SMD	
EXC-CET102U	
Pos	Reel/Tick
FL1	
FL2	
FL3	
FL4	
FL5	
FL6	
FL7	
FL8	

Item 20	
FERRITE CHIP 600 OHM 500MA 0805	
Pos	Reel/Tick
L1	
L2	
L4	
L6	
L7	
L9	
L10	
L11	

Item 25	
RES 4.99 OHM 1/8W 1% 0805 SMD	
Pos	Reel/Tick
R13	
R4	

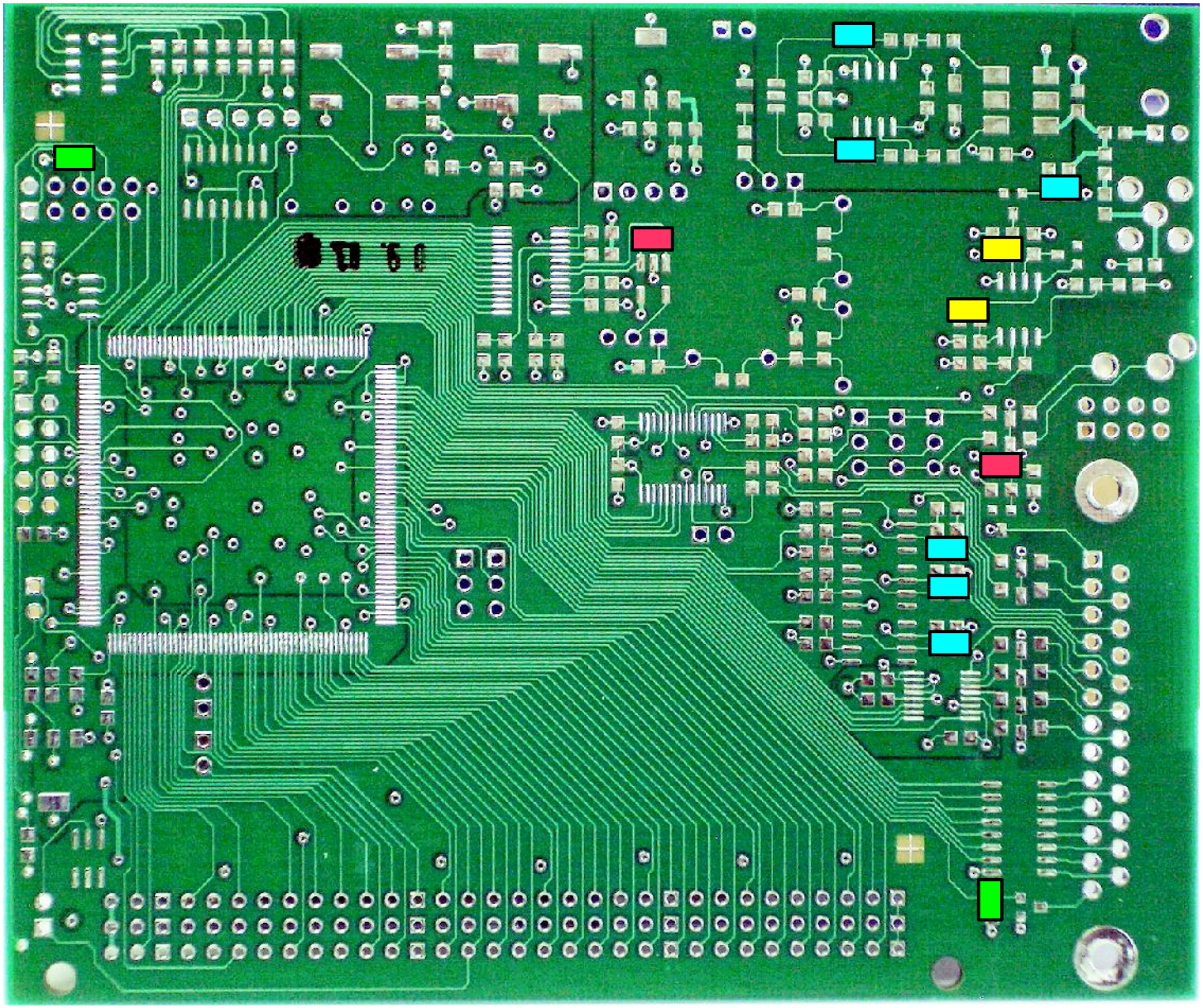


Item 26	
RES 10.0K OHM 1/8W 1% 0805 SMD	
Pos	Reel/Tick
R37	
R8	

Item 27	
RES 100K OHM 1/8W 1% 0805 SMD	
Pos	Reel/Tick
R18	
R21	

Item 28	
RES 100 OHM 1/8W 1% 0805 SMD	
Pos	Reel/Tick
R2	
R11	
R16	
R32	
R34	
R36	

Item 30	
RES 220 OHM 1/8W 1% 0805 SMD	
Pos	Reel/Tick
R17	
R28	

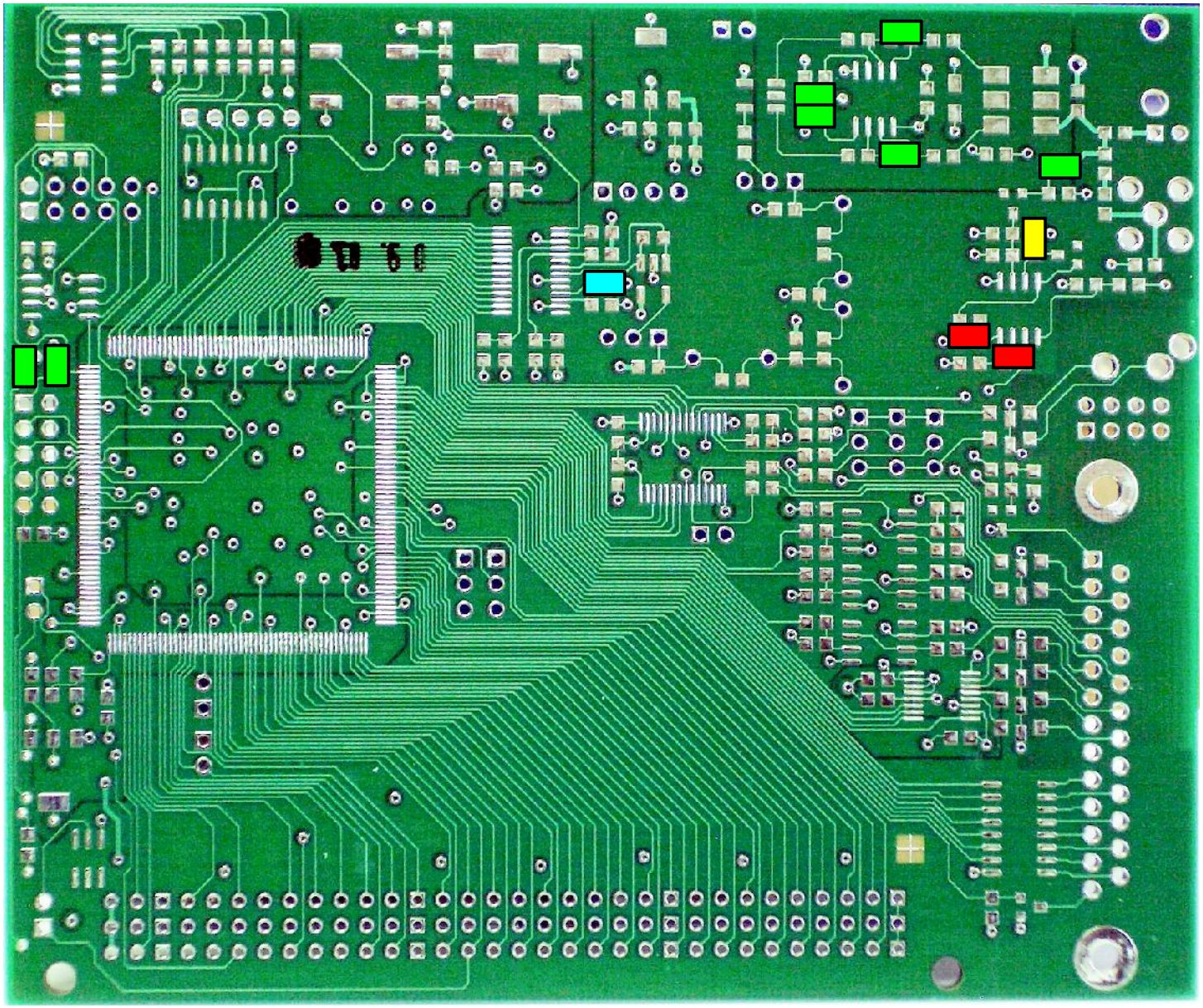


Item 29	
RES 1.00K OHM 1/8W 1% 0805 SMD	
Pos	Reel/Tick
R3	
R6	
R7	
R12	
R14	
R23	
R24	

Item 31	
RES 220K OHM 1/8W 1% 0805 SMD	
Pos	Reel/Tick
R19	

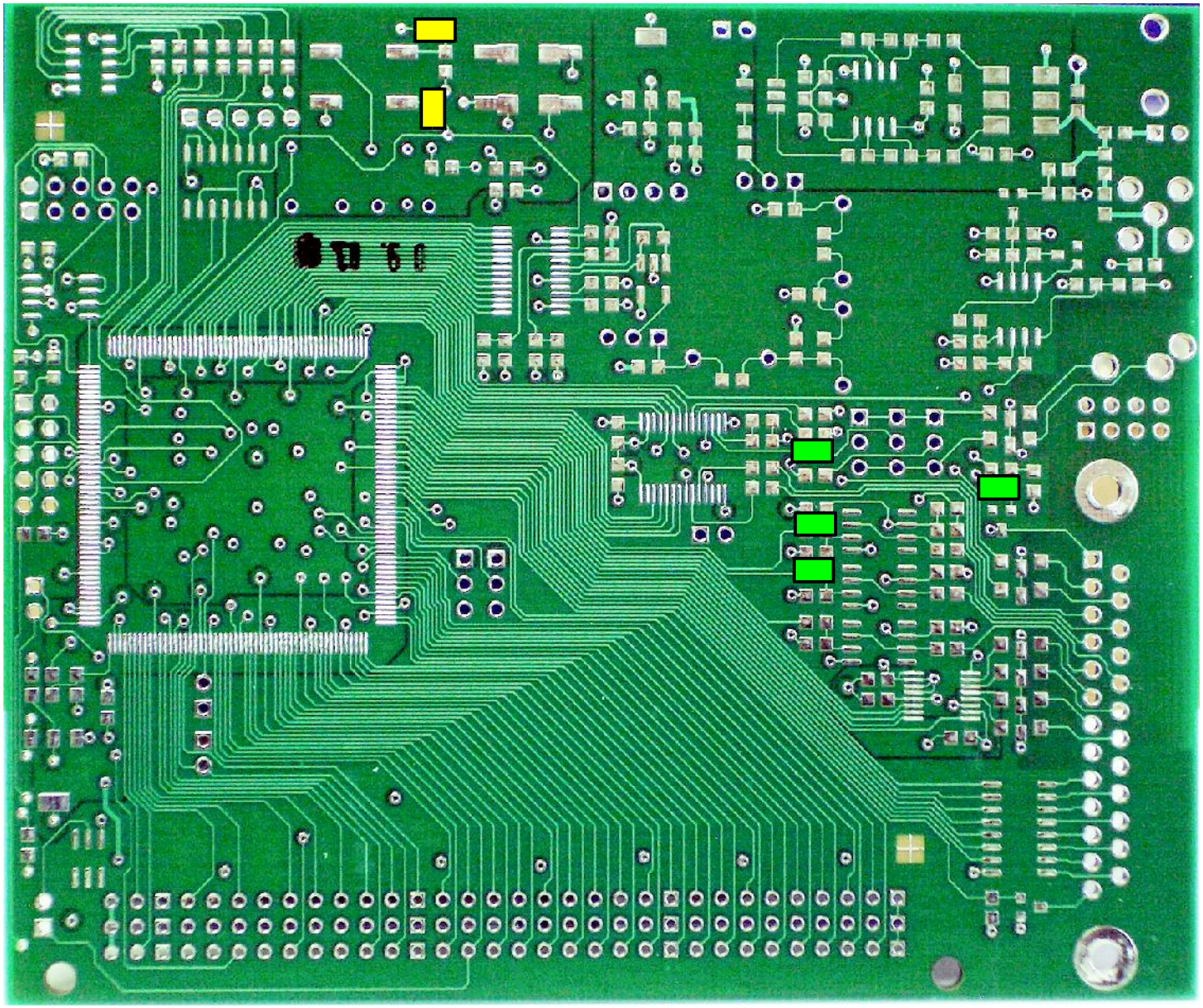
Item 32	
RES 1.8K OHM 1/8W 1% 0805 SMD	
Pos	Reel/Tick
R20	

Item 33	
RES 510K OHM 1/8W 1% 0805 SMD	
Pos	Reel/Tick
R22	
R26	



Item 34	
RES 3.30K OHM 1/8W 1% 0805 SMD	
Pos	Reel/Tick
R27	
R29	
R31	
R33	

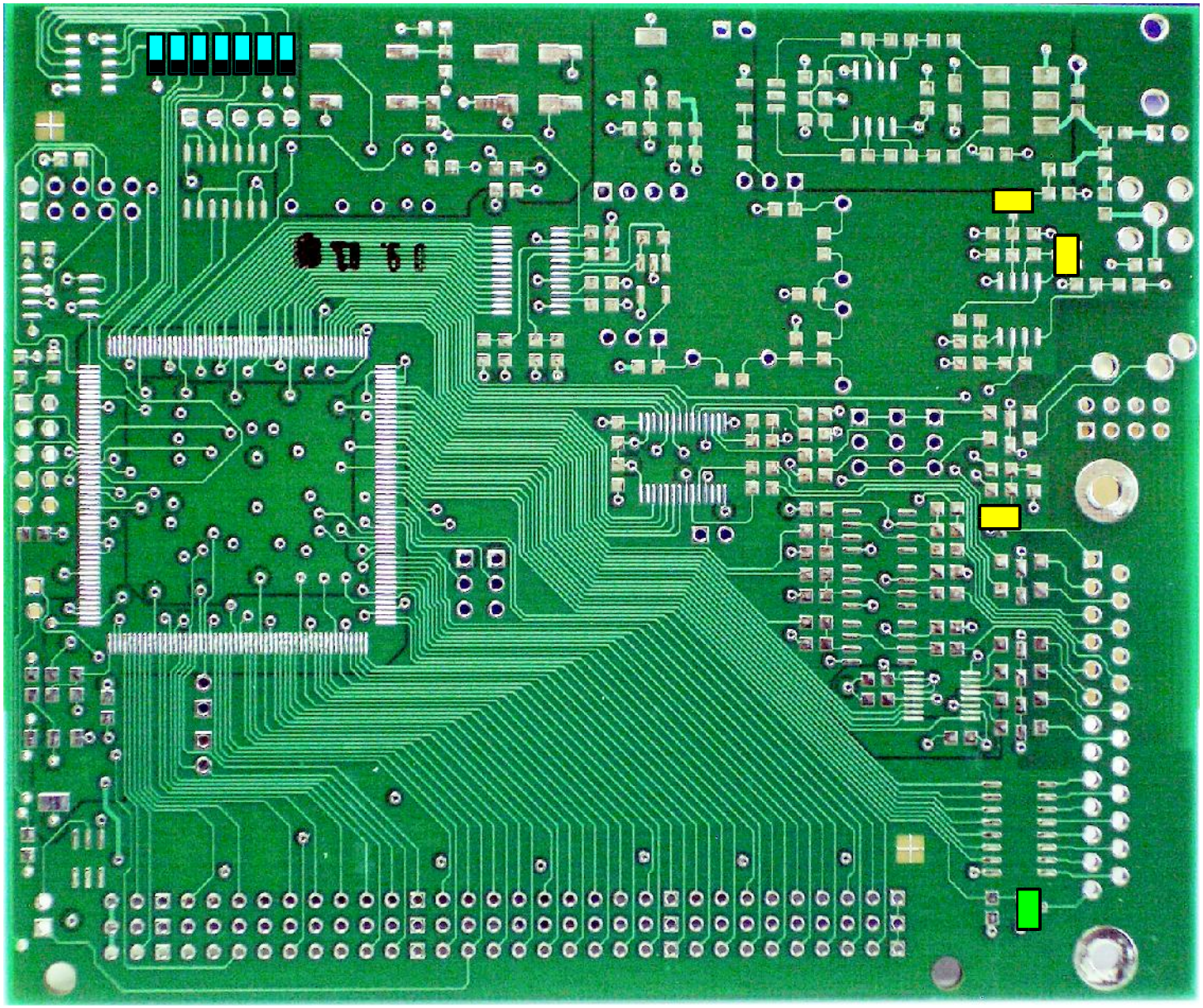
Item 36	
RES 0.0 OHM 1/8W 5% 0805 SMD	
Pos	Reel/Tick
R42	
R43	



Item 37	
MOSFET N-CHAN SS 115MA 60V SOT23	
2N7002LT1G	
Pos	Reel/Tick
Q1	

Item 38	
DIODE SCHOTTKY 30V 200MA SOT-23	
BAT 54	
Pos	Reel/Tick
D1	
D2	
D3	

Item 40	
LED RED CLEAR 0805 SMD	
Pos	Reel/Tick
LED1	
LED2	
LED3	
LED4	
LED5	
LED6	
LED7	

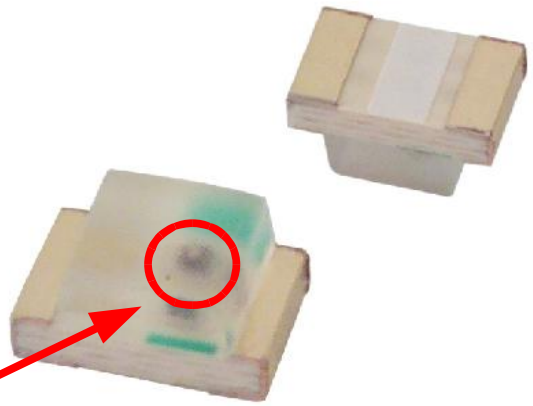


Special Instructions: Placing LEDs 1 to 8

How to determine the polarity of the 0805 LEDs?

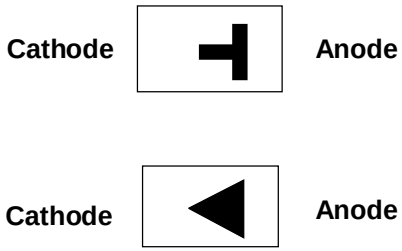
It can be difficult to find out the polarity of the tiny 0805 LEDs if you don't know what to look for.

The Lite-ON® LEDs used in the PENELOPE 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.

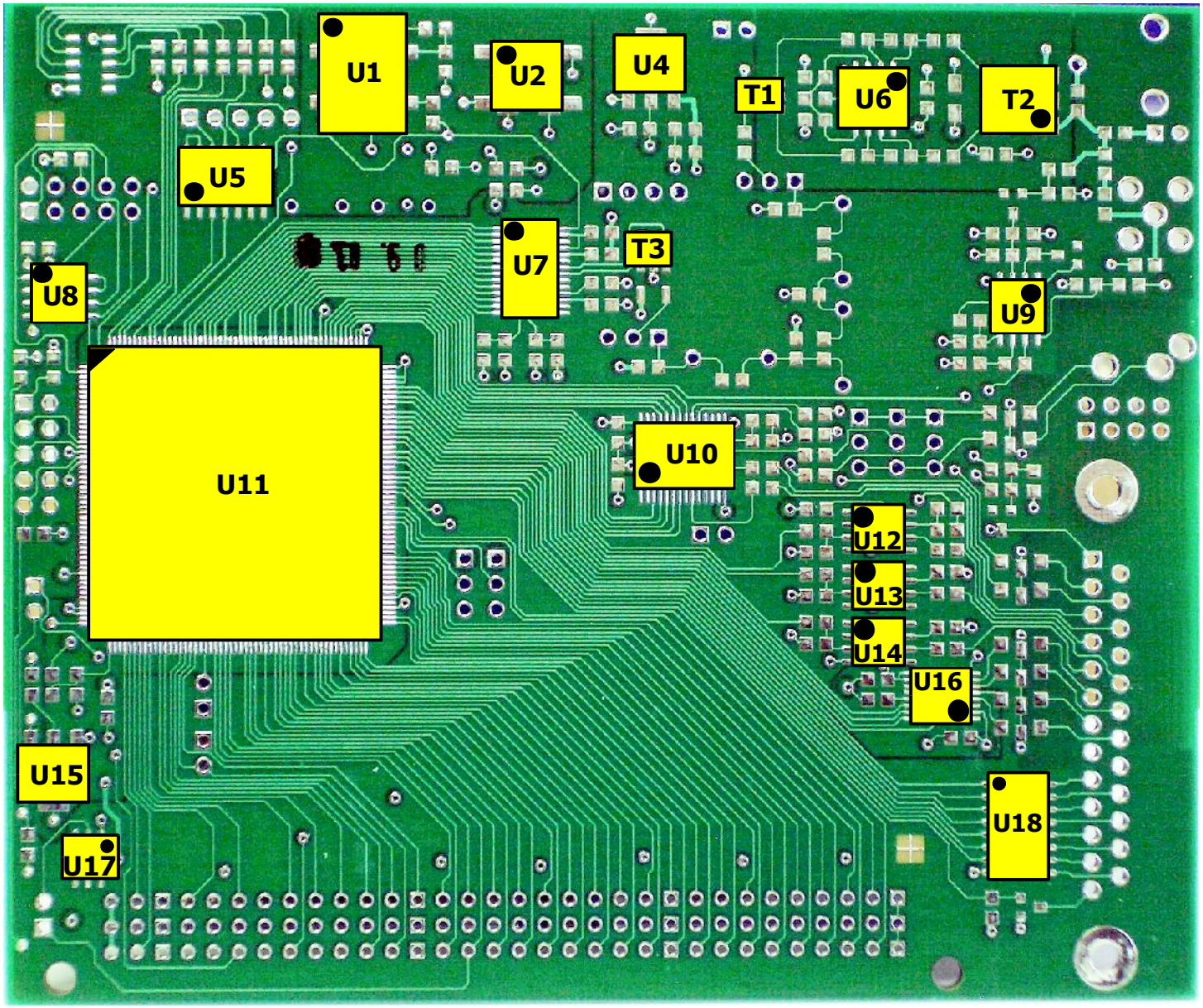


LED Dice

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



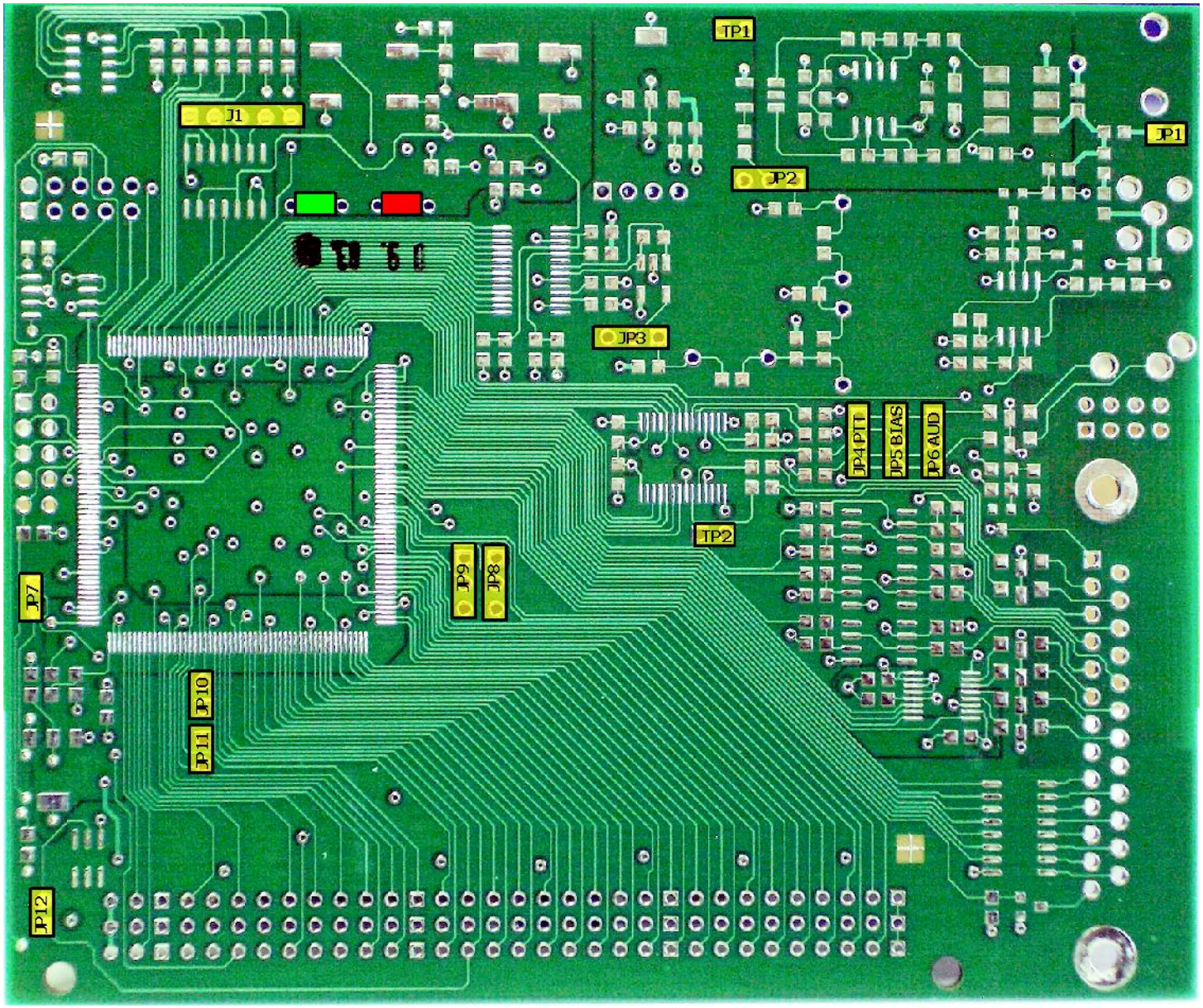
Item 45	
Transformers, Oscillators and ICs	
Pos	Designation
T1	TC4-1T
T2	ADT1.5-1
T3	TC4-1T
U1	CVHD-950-122.88
U2	FOX924B-10
U4	LD1117S33TR
U5	SN65LVDM180D
U6	OPA2674ID
U7	AD9744ARUZ
U8	EPCS4SI8N
U9	LMC6482AIM/NOPB
U10	TLV320AIC23BPW
U11	EP2C8Q208C8N
U12	OPA350UA
U13	OPA350UA
U14	OPA350UA
U15	LD1117S12TR
U16	ADC78H90CIMT
U17	DS2431P+
U18	ULN2003AD



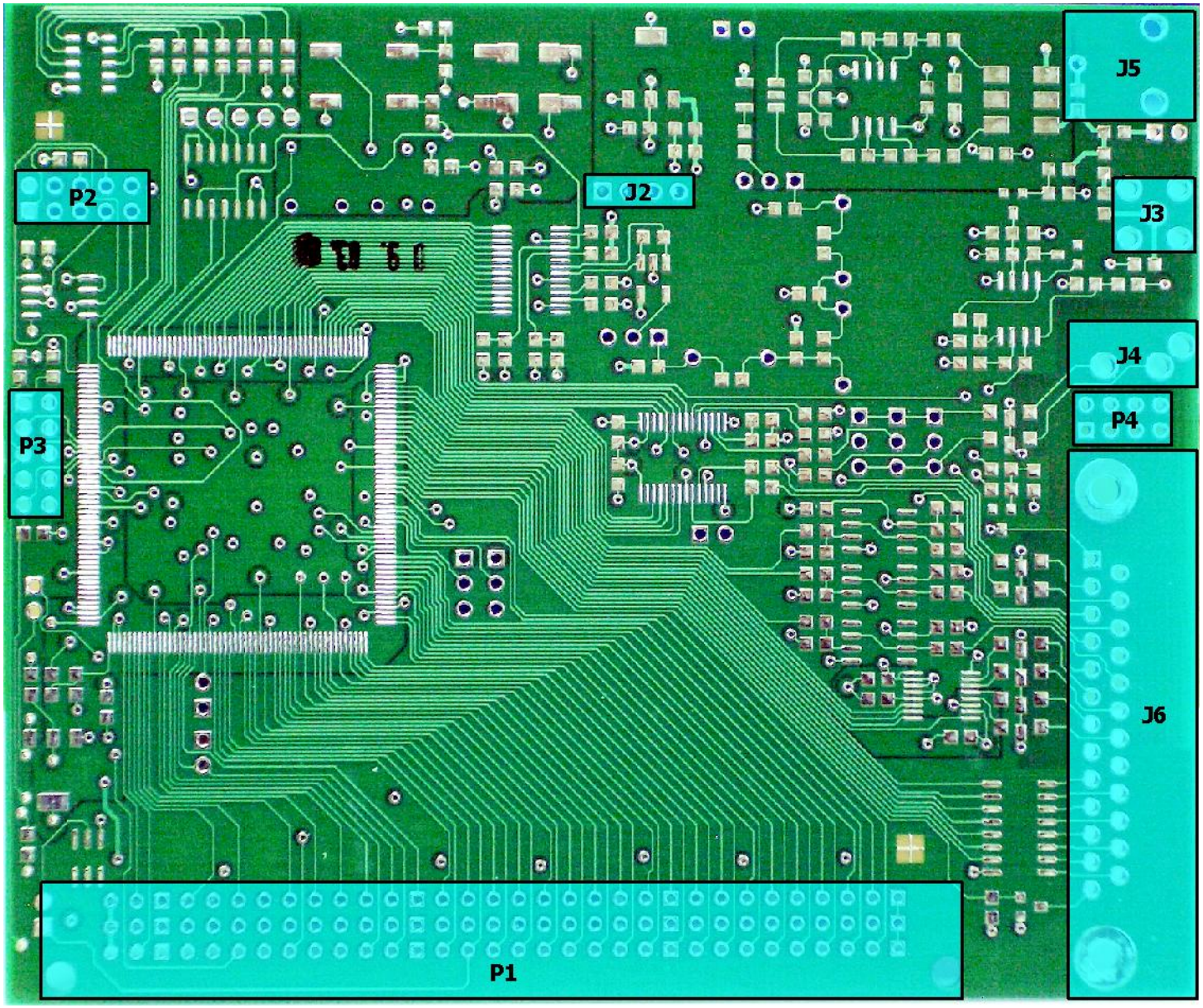
Item 41	
CAP POLYFILM BOX .056UF 63V 5%	
Pos	Reel/Tick
C71	

Item 42	
CAP POLYFILM BOX .39UF 63V 5%	
Pos	Reel/Tick
C72	

Item 43	
Headers	
Pos	Reel/Tick
JP1	2POS .100 VERT TIN
JP3	3POS .100 VERT TIN
JP2	3POS .100 VERT TIN
JP4	3POS .100 VERT TIN
JP5	3POS .100 VERT TIN
JP6	3POS .100 VERT TIN
JP7	2POS .100 VERT TIN
JP8	3POS .100 VERT TIN
JP9	3POS .100 VERT TIN
JP11	2POS .100 VERT TIN
JP10	2POS .100 VERT TIN
JP12	2POS .100 VERT TIN
J1	5POS .100 VERT TIN
TP2	2POS .100 VERT TIN
TP1	2POS .100 VERT TIN



Item 44		
Connectors		
Pos		
J2	CONN TERM BLOCK 2.54MM 4POS	
J3	CONN SMA JACK RT ANG PCB	
J4	CONN JACK STEREO R/A 3PIN 3.5MM	
J5	CONN JACK BNC R/A 50 OHM PCB AU	
J6	CONN DB25 FEMAL .318" R/A NICKEL	
P1	DIN 41612 Signal Connectors 96P 2A MALE R/A SLDR	
P2	CONN HDR DUAL 10POS .100 SRT TIN	
P3	CONN HDR DUAL 10POS .100 SRT TIN	
P4	CONN HDR DUAL 8POS .100 SRT TIN	



Item 45	
AMIDON Toroid T30-6	
Pos	Reel/Tick
L3	5T/0.3mm
L5	6T/0.3mm
L8	5T/0.3mm