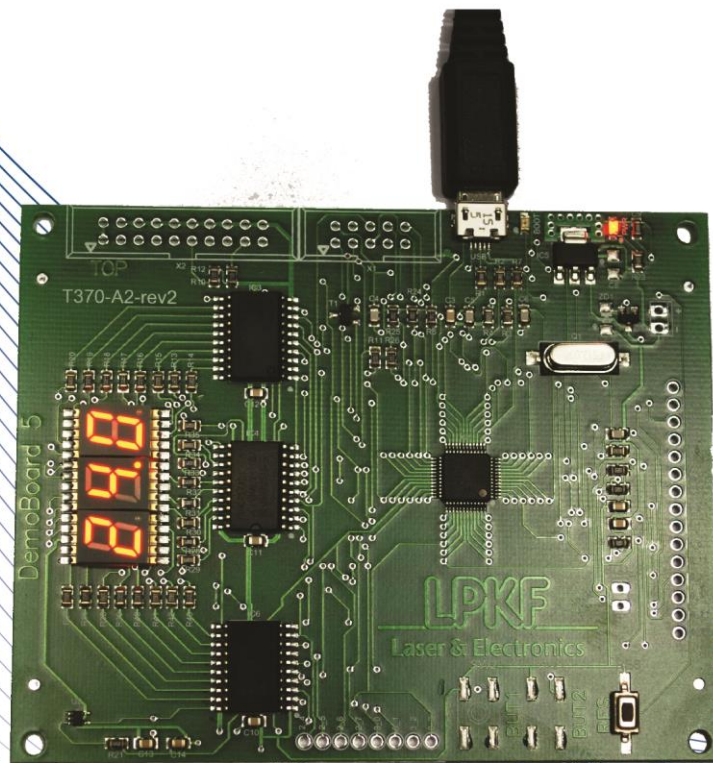


TUTORIAL

New SMT Application 32-bit ARM Cortex-M3 Development Board



BASIC INFORMATION

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Trademark: The logo consists of the word "LPKF" in a stylized, outlined blue font. Below it, the words "Laser & Electronics" are written in a smaller, plain blue font. A horizontal line is positioned between the two text elements.

Symbols, etc. used in this tutorial

Text in *italics* emphasises the importance of the information.

Symbols that you will notice in some chapters have the following meaning:



Danger!
The symbol is used to highlight danger to life or health.



Caution!

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1 INTRODUCTION

The DemoBoard 5 provides a good starting point for the presentation of LPKF products and technology. It offers a good opportunity for your training, as well as the training for your clients. The results are visible very quickly, as its basic function, the ambient temperature indicator, is predefined. Moreover, it is also a good starting point for basic educational purpose, because it offers acquaintance with the complete production process - from making the PCB, assembling, programing to practical functionality.

2 DESCRIPTION

The DemoBoard 5 is a development board that provides a good starting point for novice developers and enough peripheral modules for more demanding ones. The development board is available as a kit version or as the full documentation version only. The complete board could be produced with LPKF™ RP technology. The assembled board could be quickly brought to life with a pre-developed firmware file, which makes use of the on-board temperature sensor and 7-segment display units, to show the current ambient temperature. The DemoBoard 5 built-in functionality could be expanded via multiple extension pins.

The kit version is intended for everyone that would like to make their own PCB with a pre-defined function. This version includes a milled or laser structured PCB, the necessary SMT components, detailed instructions for assembling and a pre-defined firmware.

The board could be optionally produced and assembled in-house. In this case complete technical documentation is available. The documentation includes entire files for PCB production (Gerber and NC Drill), a tutorial with the electrical drawing, layouts, BOM, pre-developed firmware with programing code and links to embedded development tools.

2.1 Hardware requirements

The Demo board can be made using LPKF RP equipment and technology from beginning to the end. For this purpose the followed LPKF equipment could be used:

- ProtoMat and/or ProtoLaser S / ProtoLaser U3
- ProConduct or MiniContac RS / Contac RS
- ProtoPrint S with ZelFlex stretching frame (optionally ProtoPrint E)
- ProtoPlace S
- ProtoFlow S (optionally ProtoFlow E)
- USB microscope (option)

In order for the Demo Board 5 to function, the user has to provide:

- USB A-B Micro cable (required for programming purposes and/or power)
- Universal charger 100-240V, 5.1V, micro USB

3 DEMO BOARD OVERVIEW

The DemoBoard 5 consists of multiple hardware modules. Some of the presented modules have a predefined functionality while some of them are user definable.

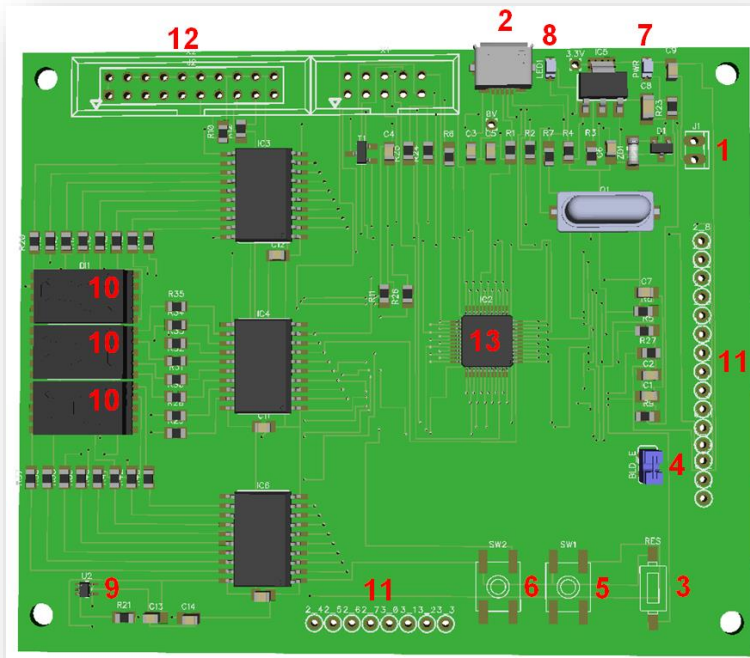
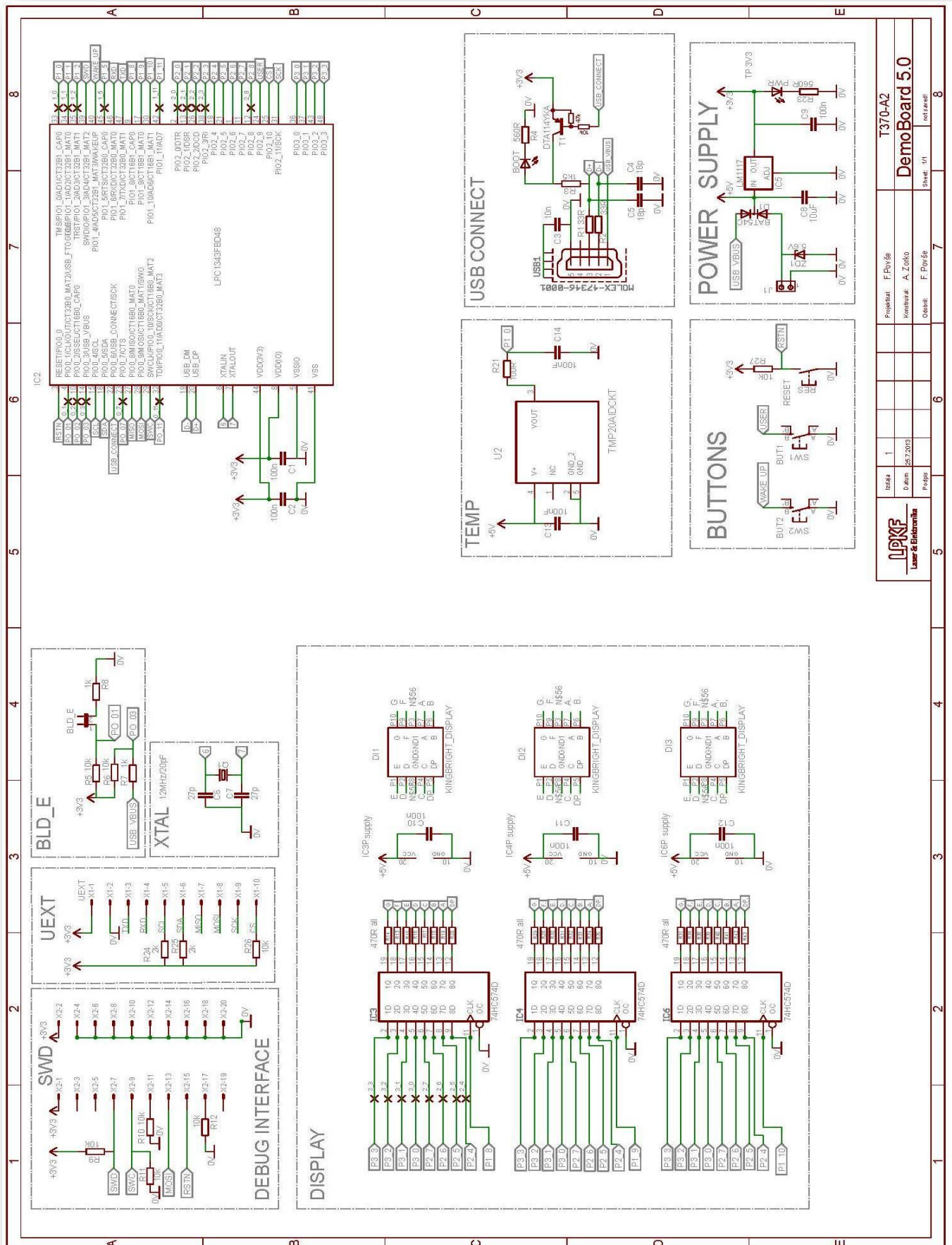


Figure 1: 3D visualization of the Demo Board 5

No.	Name	Description
1	Power Connector	Used for providing a +5 V power supply to the demo board
2	USB Connector	Connectivity and/or power source
3	Reset Button	Used for performing a Hardware reset of the LPC1343 microcontroller
4	BLD_E Jumper	Used for entering the USB Bootloader state
5	Push Button 1	User defined Push Button, connected to LPC1343 pin 40 (PIO1_4)
6	Push Button 2	User defined Push Button, connected to LPC1343 pin 24 (PIO2_9)
7	Power Supply LED	Indicates a +5 V power supply to the Demo Board
8	Boot mode LED	Indicates the device is in a boot mode
9	Temperature Sensor	$\pm 2.5^{\circ}\text{C}$ Low-Power, Analog Out Temperature Sensor (TMP20)
10	7 Segment Display	Three 7-Segment Displays used for showing the ambient temperature (firmware preloaded). See Board Schematic for details.
11	Extension Pins	Provide the possibility to expand the provided Demo Board functionality
12	SWD Header	Connection pins for a Serial Wire Debug interface (connector not included in the kit)
13	LPC1343	LPC1343 microcontroller

3.1 Electrical diagram



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3.2 Bill of materials

1	8	pcs	capacitor 100nF 25V X7R SMD0805	Farnell 1740665RL	C1, C2, C9, C10, C11, C12, C13, C14
2	2	pcs	capacitor MLCC 27pF 50V SMD0805	Farnell 1759196RL	C6, C7
3	2	pcs	capacitor MLCC 18pF 100V COG/NPO SMD0805	Farnell 1740651RL	C4, C5
4	1	pcs	capacitor MLCC 10nF 50V X7R 10% SMD0805	Farnell 2070442RL	C3
5	1	pcs	capacitor MLCC 10uF 16V X7R 10% SMD1206	Farnell 2070502RL	C8
6	1	pcs	crystal 12.0MHz 20pF SMD HC49S	Farnell 2063977	Q1
7	2	pcs	diode LED red 70mcd SMD0805	Farnell 1685059	PWR, BOOT
8	1	pcs	diode schottky BAT54C 200mA 30V SOT23	Farnell 1621834	D1
9	1	pcs	diode zener 5V6 1.5W SMA	Farnell 1431141RL	ZD1
10	3	pcs	display LED KCSC03-105 SMD 0.3" CMN cath red	Farnell 2001753	DI1, DI2, DI3
11	3	pcs	IC 74HCT574D SOIC20	Farnell 1085320	IC3, IC4, IC6
12	1	pcs	IC sensor temperature TMP20AIDCKT analog 5SC70	Farnell 1815752	U2
13	1	pcs	microcontroller LPC1343 32bit CORTEX-M3 LQFP48	Farnell 2072195	IC2
14	1	pcs	PCB_DemoBoard 5.0 rev2	LPKF d.o.o.	
15	1	pcs	pushbutton mini TMG-325N-V-T/R SMD	Diptronics TMG-325N-V-T/R	RES
16	1	pcs	regulator LDO LM1117IMP 3.3V 1% 0.8A 3SOT223	Farnell 1469051	IC5
17	1	pcs	resistor 100R 1% 0.125W metal SMD0805	Farnell 2078948	R21
18	8	pcs	resistor 10k 1% 0.125W metal SMD0805	Farnell 2078962	R5, R6, R9, R10, R11, R12, R26, R27
19	2	pcs	resistor 1k 1% 0.125W metal SMD0805	Farnell 2078954	R7, R8
20	1	pcs	resistor 1k5 1% 0.125W SMD0805	Farnell 2078955	R3
21	2	pcs	resistor 2k 0,1% 0.125W SMD0805	Farnell 1670231RL	R24, R25
22	2	pcs	resistor 33R 1% 0.125W SMD0805	Farnell 2078944	R1, R2

23	2	pcs	resistor 560R 1% 0.125W SMD0805	Farnell 2074483	R4, R23
24	24	pcs	resistor 680R 1% 0.125W SMD0805	Farnell 2074502	R13...R20 , R28...R43
25	1	pcs	transistor PNP DTA114Y KAT146 20V SOT346	Farnell 1680186	T1
26	1	pcs	USB micro type_B receptacle bottom SMD	Farnell 1568026	USB1
No.	Qty.	UM	Description and characteristic	Stand./Item code	Position on board

Farnell codes are written just to help you to find additional information about components their characteristics and datasheets. Some data sheets are also attached as appendix.

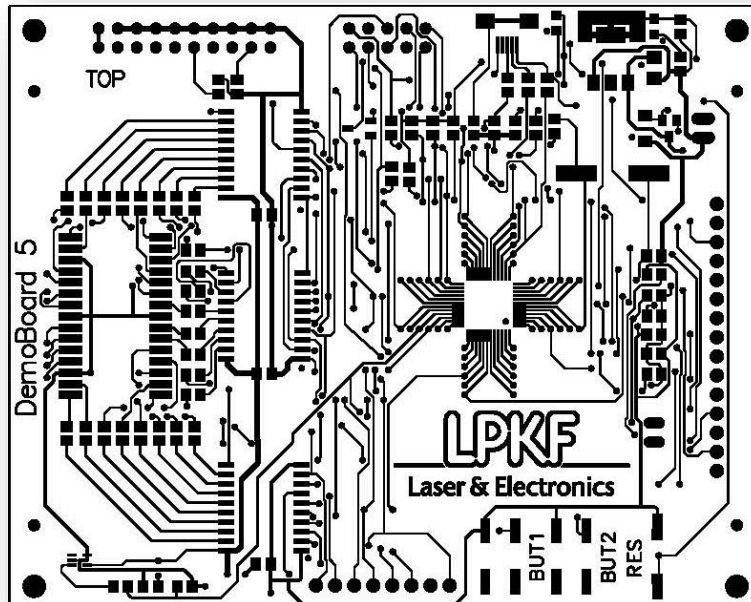
About Farnell (www.farnell.com):

Farnell is one of the worlds leading distributors of electronic, electrical, industrial and maintenance, repair & operations (MRO) products.

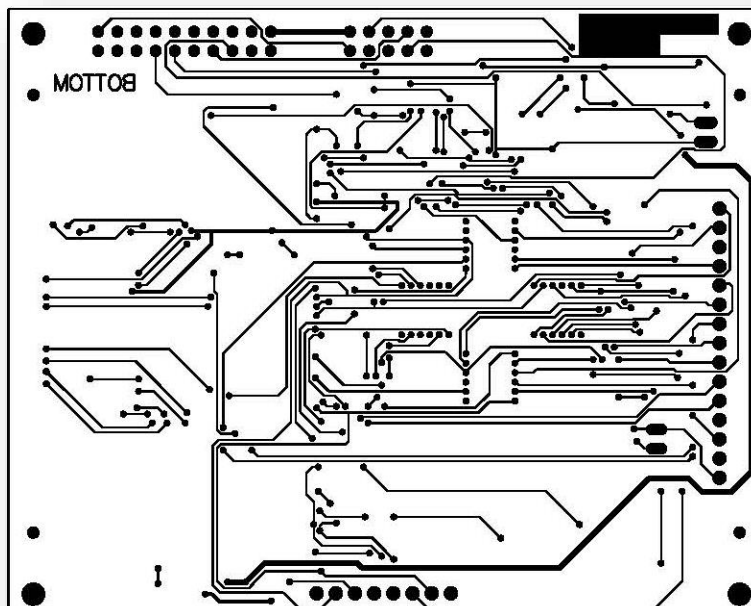
- Employing over 1200 people in more than 20 countries
- Working with over 800 world class suppliers
- Offering over 620,000 stocked products
- With ordering 24 hours a day, 365 days a year

3.3 Layout

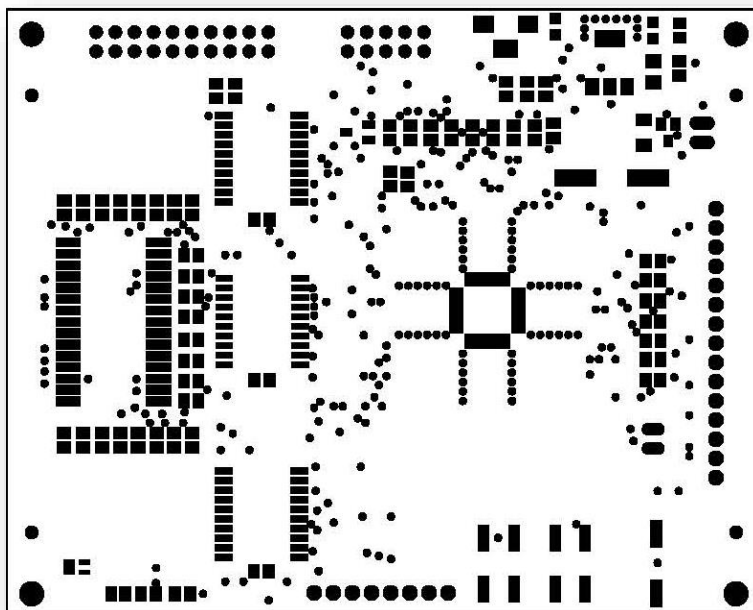
Conductive layer – TOP side; T370-A2.GTL



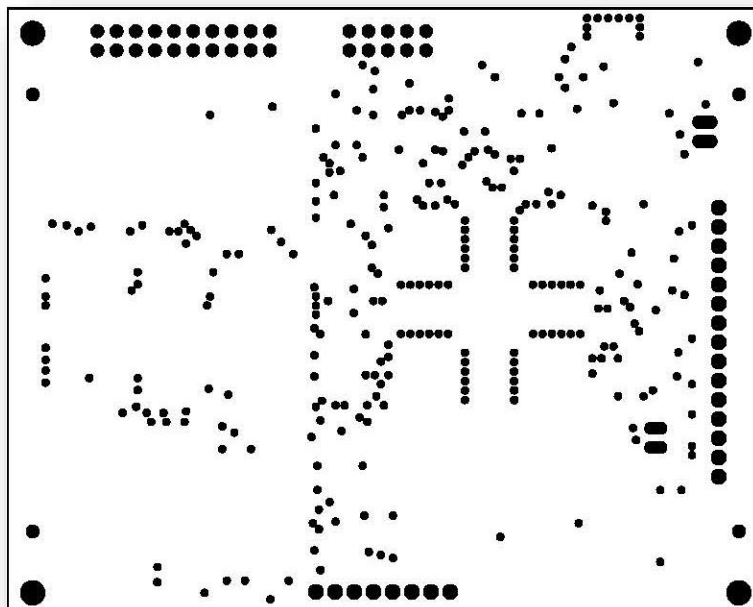
Conductive layer – BOTTOM side; T370-A2.GBL



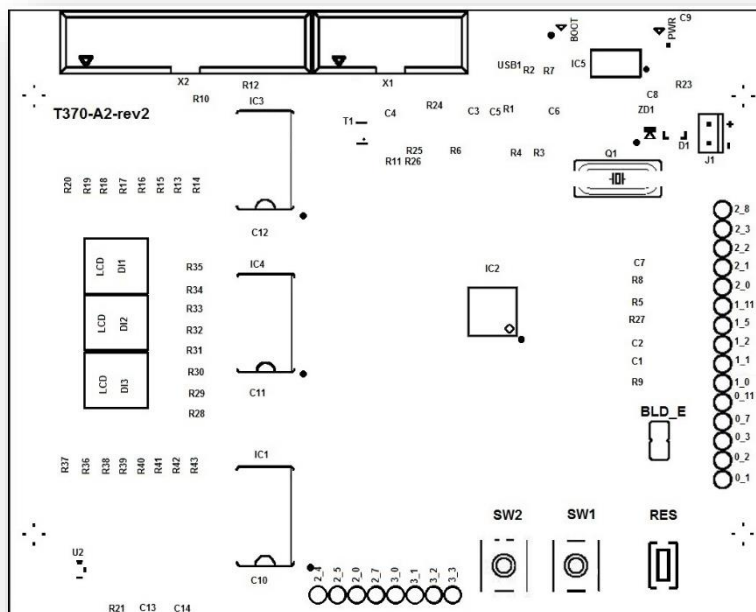
Solder mask – TOP side; T370-A2.GTS



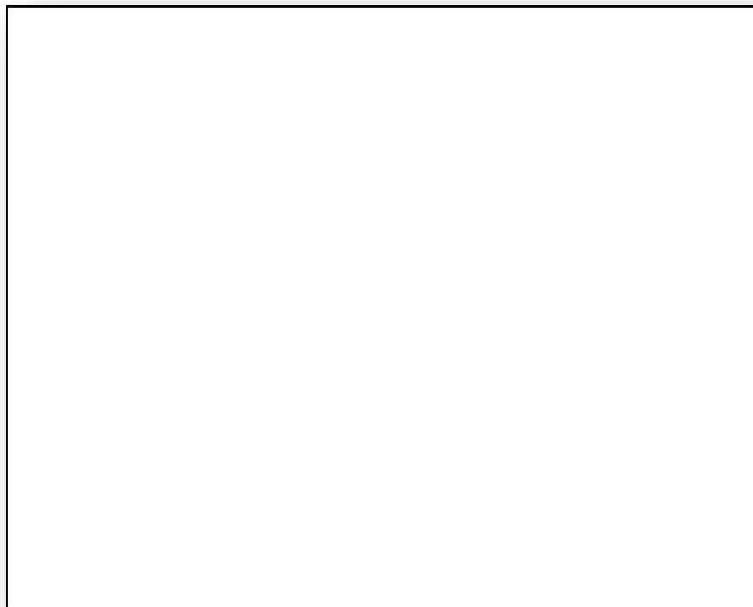
Solder mask – BOTTOM side; T370-A2.GBS



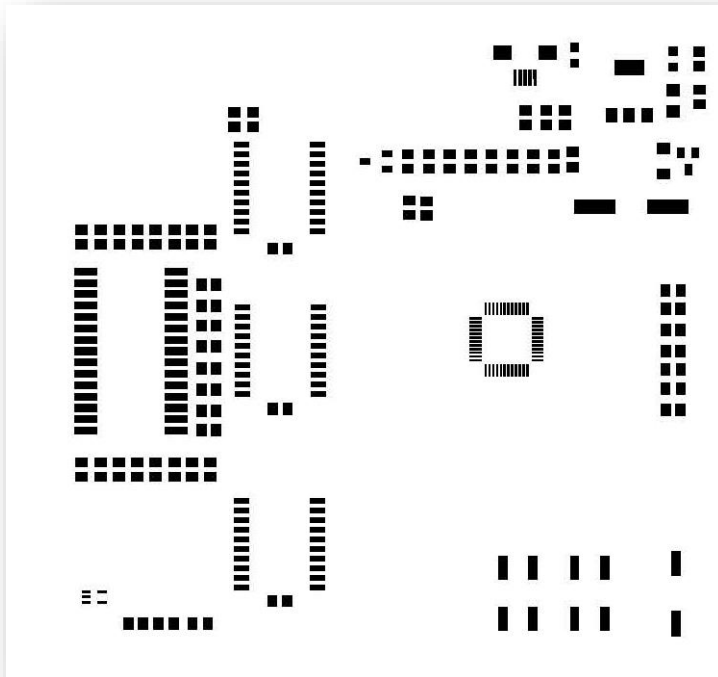
Assembly print – TOP side; T370-A2.GTO



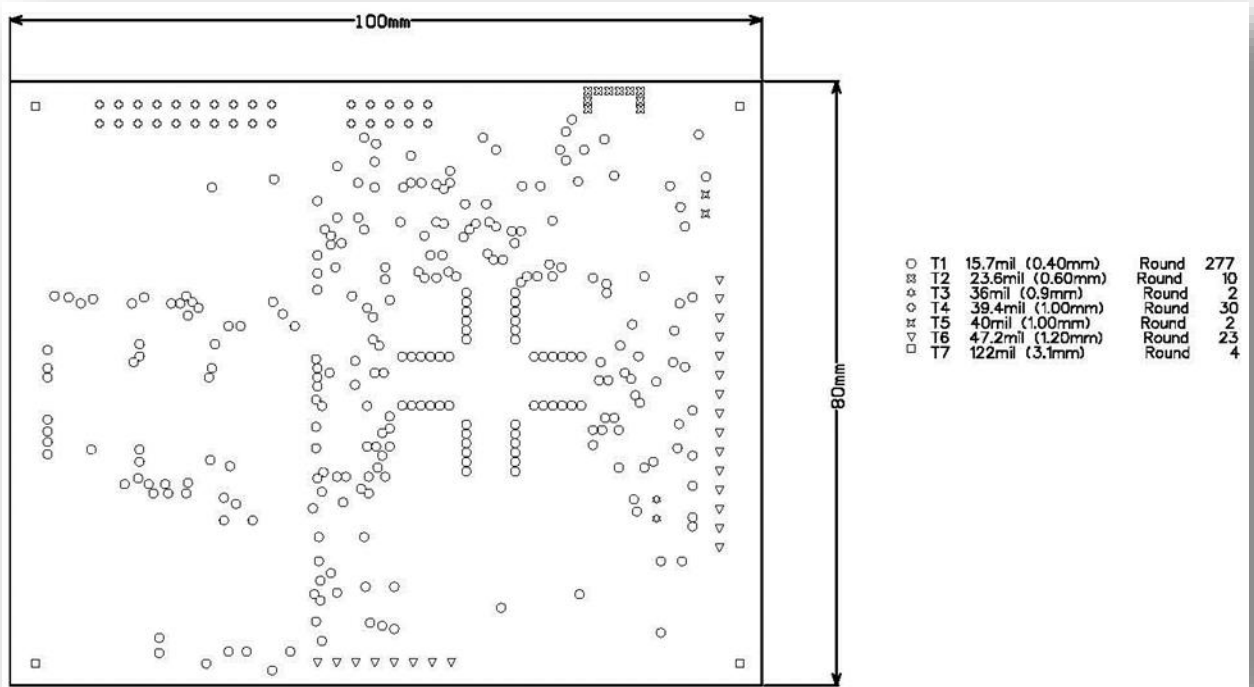
Board outline; T370-A2.GKO



Solder paste mask – stencil SMT – TOP side; T370-A2.GTP



Drill drawing; T370-A2.TXT, T370-A2.DRR



4 PCB PRODUCTION

The complete PCB can be done using standard LPKF RP technology. Structuring of the board can be done either by LPKF Circuit Board Plotters or using LPKF innovative Laser Technology. The PCB can be made from different materials and of different thickness - depending on needs and possibilities. The board is designed as a double-sided board, the through-hole plating is necessary to connect the top and bottom layers together. To get a professional board finishing with solder resist mask and assembly print is also possible.

4.1 Structuring

Structuring of the board can be done either using the ProtoMat or using the ProtoLaser S / ProtoLaser U3.

The complete range of Circuit Board Plotters - from old to the new generation - is suitable. The ProtoMat can handle the complete process - from removing the copper, drilling the holes, cutting out the boards to drilling holes through a plastic foil in the ProConduct process.

Using of ProtoLaser systems is suitable in the combination with the ProtoMat only. When the most common material, FR4, is used, the ProtoLaser S can just remove the copper. For drilling holes and making cut outs, the ProtoMat is absolutely necessary.

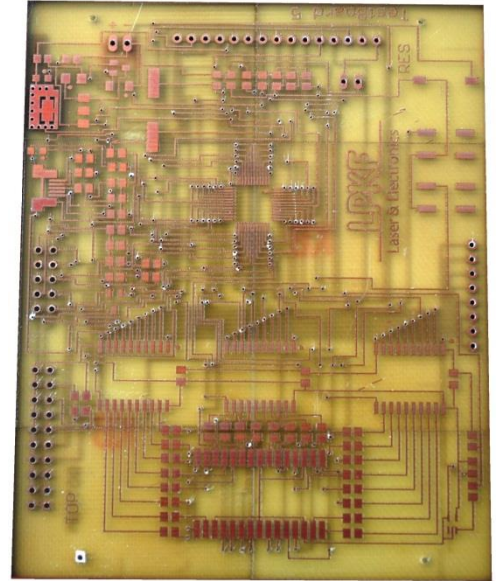


Figure 2: Laser structured PCB

4.2 Through-hole plating

The board is double sided, so the through-hole plating is necessary. The non-chemical ProConduct process or the galvanic MiniContac RS or Contac RS process can be used for through-hole plating.



CAUTION!

The galvanic system is not suitable for ProtoLaser structuring. Use ProConduct system only.

4.3 Finishing

To get a professional look of the PCB, solder resist mask and assembly print can be added after the structuring. This can be done using the LPKF ProMask and ProLegend.

4.4 Stencil making

The stencil can be made with the ProtoLaser systems from polyimide or stainless steel foil with the thickness of 120 µm (125 µm with the polyimide foil). The smallest pitch is 0,5 mm and therefore using the ProtoMat for stencil production is not recommended.



CAUTION!

The ProtoMat is not suitable for producing a stencil in this case. Use ProtoLaser systems only.

5 BOARD ASSEMBLING

Electrical and mechanical connections between the components and the board can be made using the typical three SMT steps. To get perfect assembling result LPKF SMT S line is recommended. Some components on the board are very small (SMD resistors) or they are having 0.5 mm pitch (LPC1343 microcontroller). A lead-free (SAC), low residue, no-clean solder paste is recommended for the same reason. Typically, the choice of the solder paste determines the profile and reflow parameters.

Two levels of populating are available:

- Partially assembled board - temperature indicator - commonly uses for training purpose.
- Full assembled board

The information contained herein is based on the data acquired during assembling with the Alpha[®] OM-338-CSP Ultra Fine Feature Lead-free Solder Paste.



5.1 Applying the solder paste

Paste printing quality is an important factor in producing high-yield assemblies. The solder paste has to be applied using a standard printing method on the ProtoPrint S printer.

Materials and tools

- LPKF ProtoPrint S ¹
- Stretching frame LPKF ZelFlex QR 266 × 380 with adapter ²
- Fine-pitch solder paste ALPHA OM-338 CSP (type 4.5)
- Stencil (120 µm)
- Metal ² squeegee
- Digital USB microscope ³

Note

¹ LPKF ProtoPrint S RP configuration is recommended.

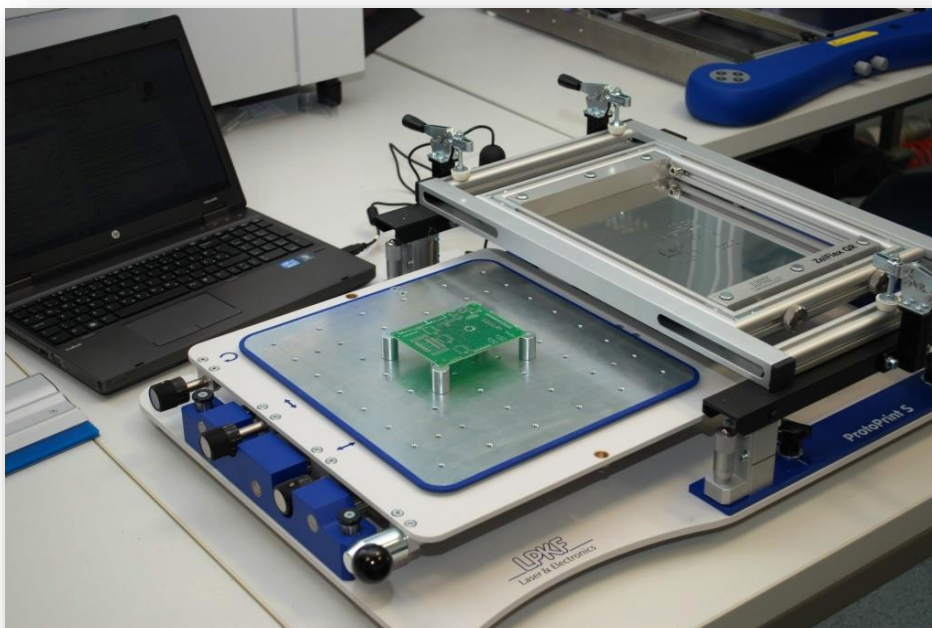
² ZelFlex QR 266x380 with adapter and metal squeegee 180 are part of RP configuration

³ Digital USB microscope is an option only.

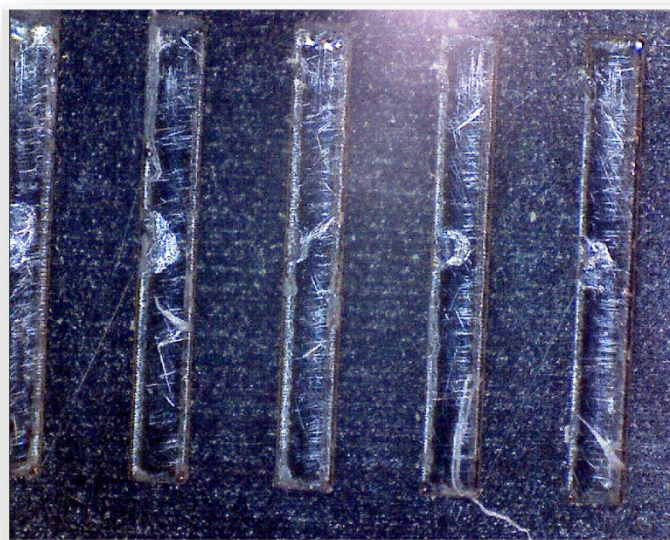
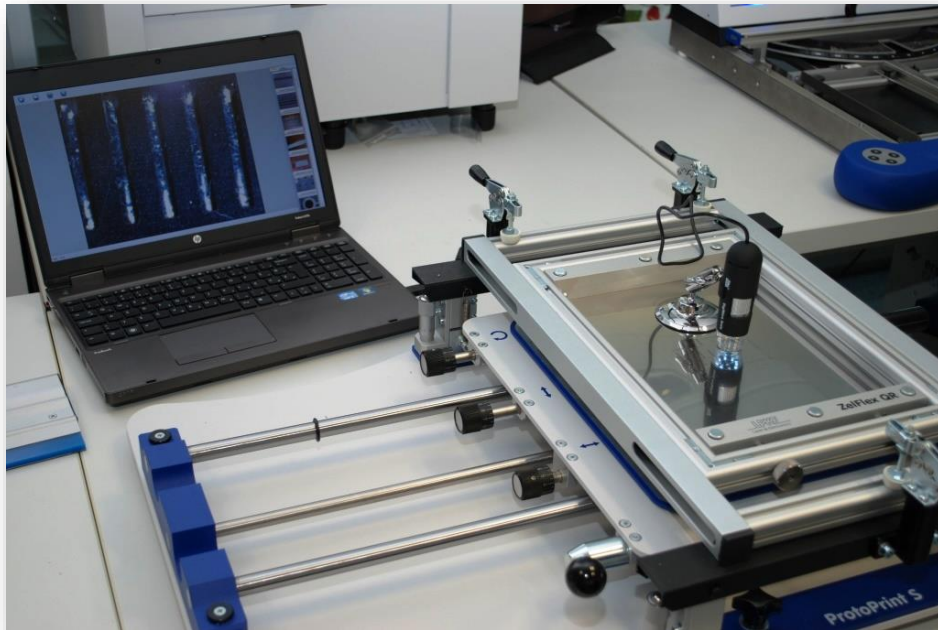
Phases

- PCB fixation (magnetic edge support pins or pin supports)
- Rough frame positioning and its fixation
- Frame height adjustment
- Precise stencil positioning
- Applying solder paste
- Print quality check

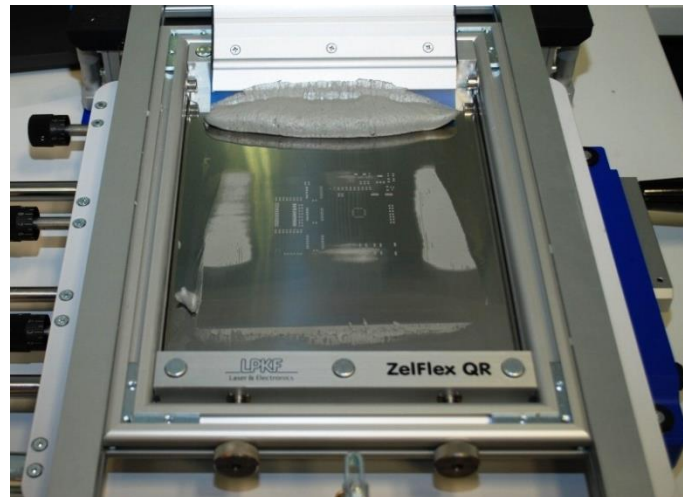
The PCB is fixed with the magnetic edge supports and frame position is roughly adjusted. It is very important to properly adjust the frame height. When the printing table is lifted, the PCB should only touch the stencil without lifting it.



The digital USB microscope is placed on the stencil with the PCB underneath. Adjust its position move the printing table using positioning screws while observing the position on the monitor. It is best to check the position on two opposite corners of the PCB and also on the smallest pitch, in this case on the temperature sensor.

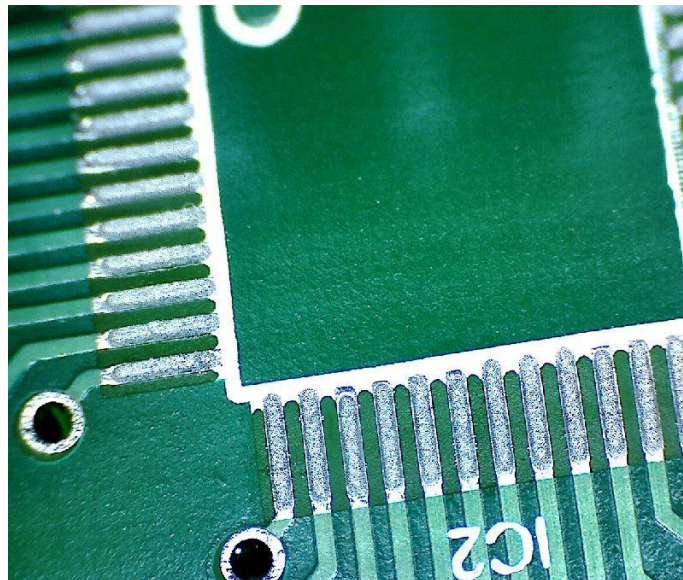
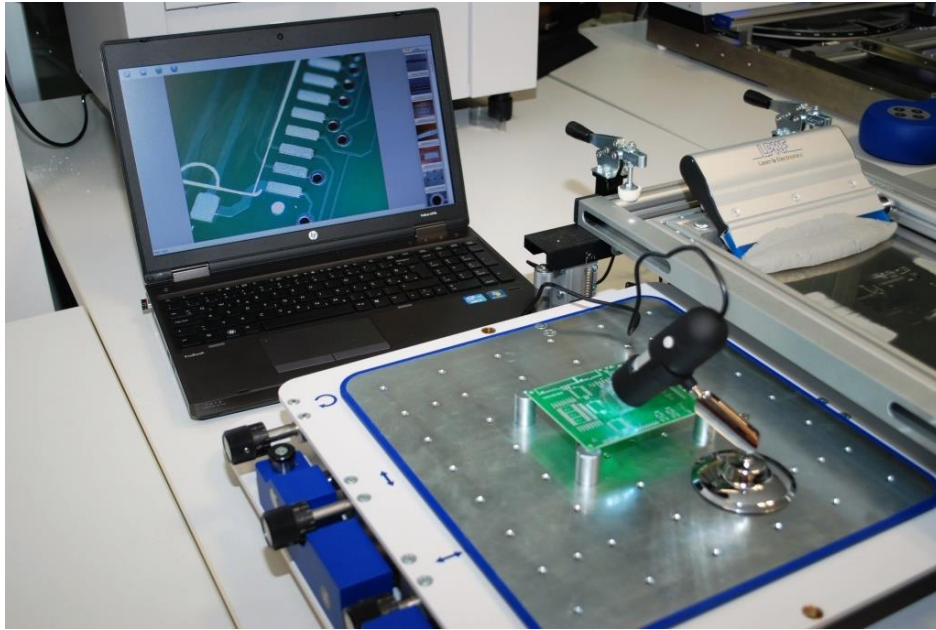


Generously apply the solder paste and make the print with the rubber side of the squeegee. While printing, hold the squeegee with both hands at approximately 45° angle. There should not be too much pressure applied on the stencil. However there should be sufficient pressure applied in order that no (or very little) solder paste remains on the area with the PCB below.



Slowly lower the printing table and pull it out from under the frame.

Check the print using a digital USB microscope.



5.2 Populating the PCB with components

Populating the PCB is the next step in the SMT assembling process. It is a very important part, as the correct orientation and position of components give the board its functionality.

Placing can be done using LPKF ProtoPlace S system. For easier processing, configuration with a camera and motorized turntable is recommended.

CAUTION:



Micro camera is an option on the LPKF ProtoPlace and it is very useful for placing as small as well as fine pitch components.

WARNING:

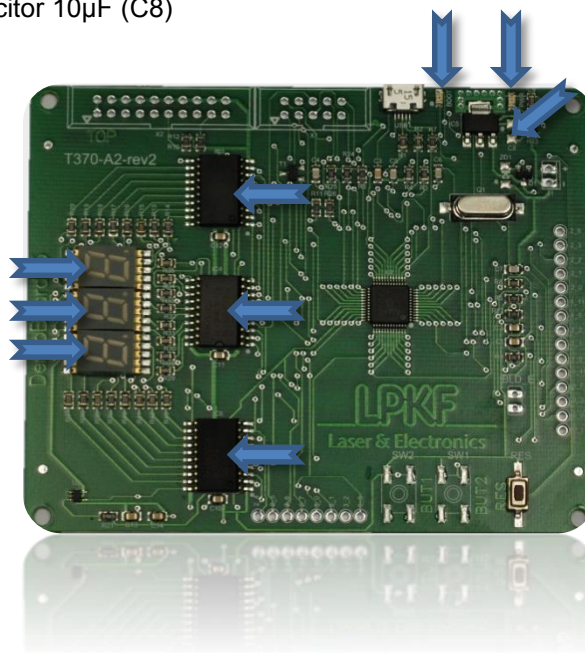


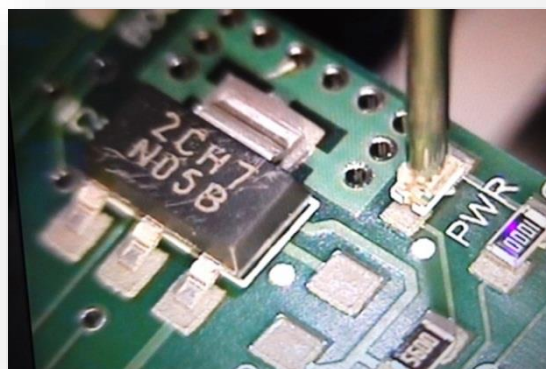
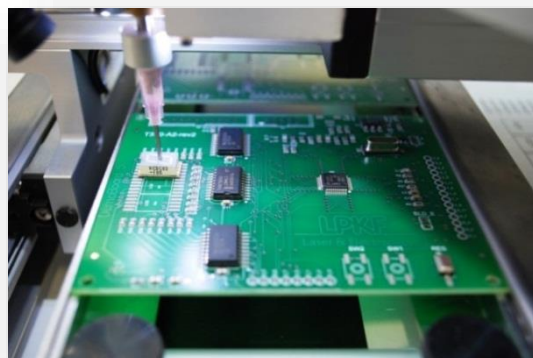
Special attention must be paid to correct orientation of certain components. Where necessary, the orientation is marked on the PCB, usually with a white dot.

Only two needles are required for a complete placement (0,69 mm & 1,53 mm) and there is no need for vacuum caps.

List of components with the possibility of wrong orientation:

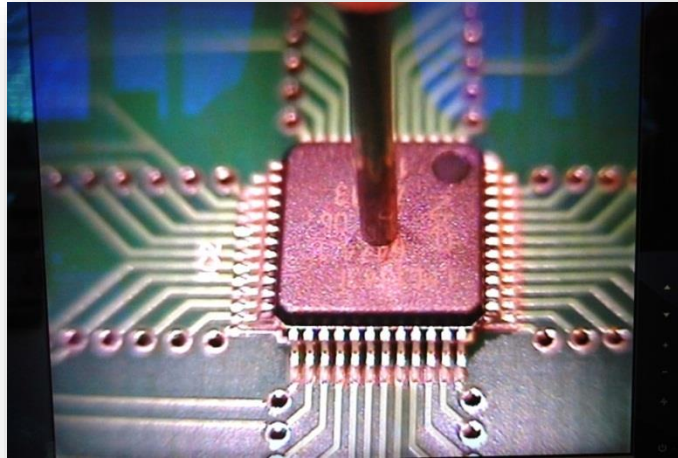
- LED display (DI1, DI2, DI3)
- LED diode (boot & pwr)
- Microcontroller (IC2)
- IC 74HC574D (IC3, IC4, IC6)
- Electrolytic capacitor 10µF (C8)
-



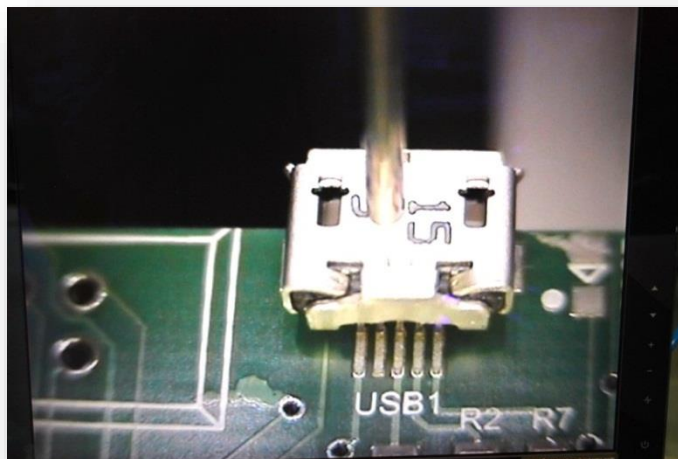


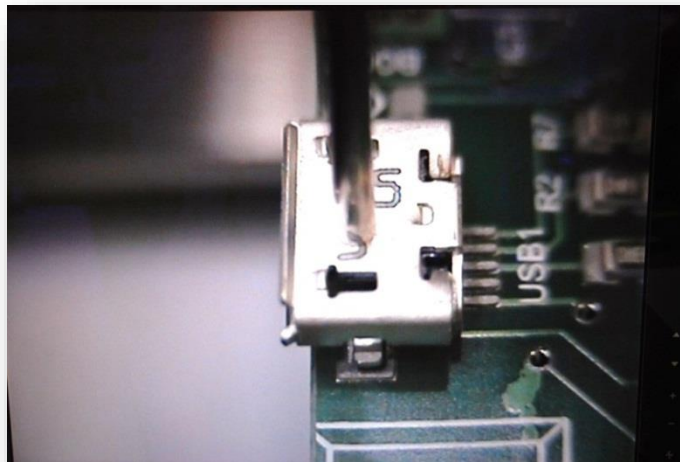
TUTORIAL

The microcontroller must be placed precisely, without solder paste bridges and without misalignment.

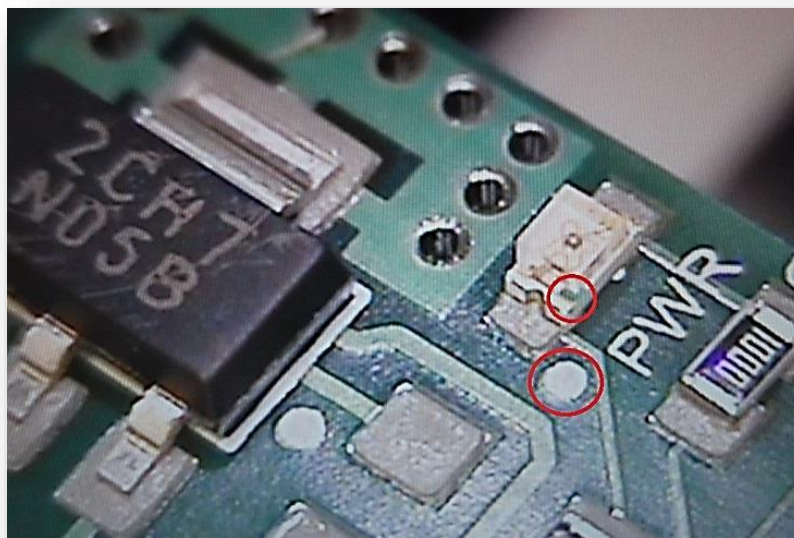


Micro USB connector is the most difficult component to be placed. Its pads are almost not visible, meanwhile its edge must be stretched over the edge of the board.





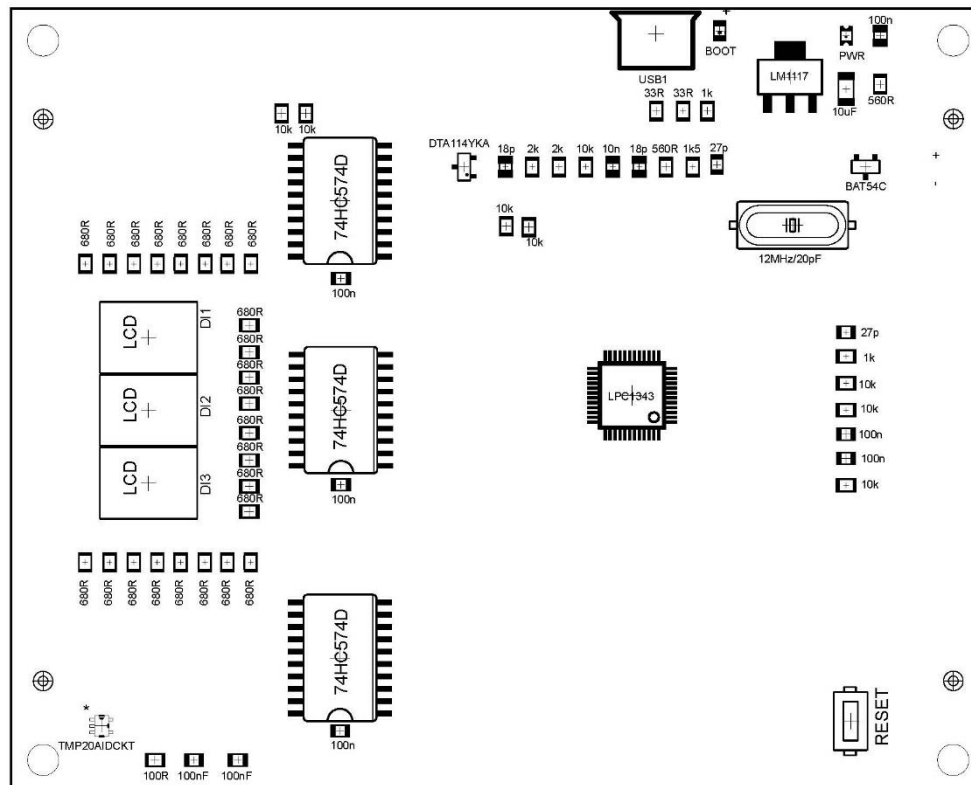
LEDs have a small green dot that indicates orientation.



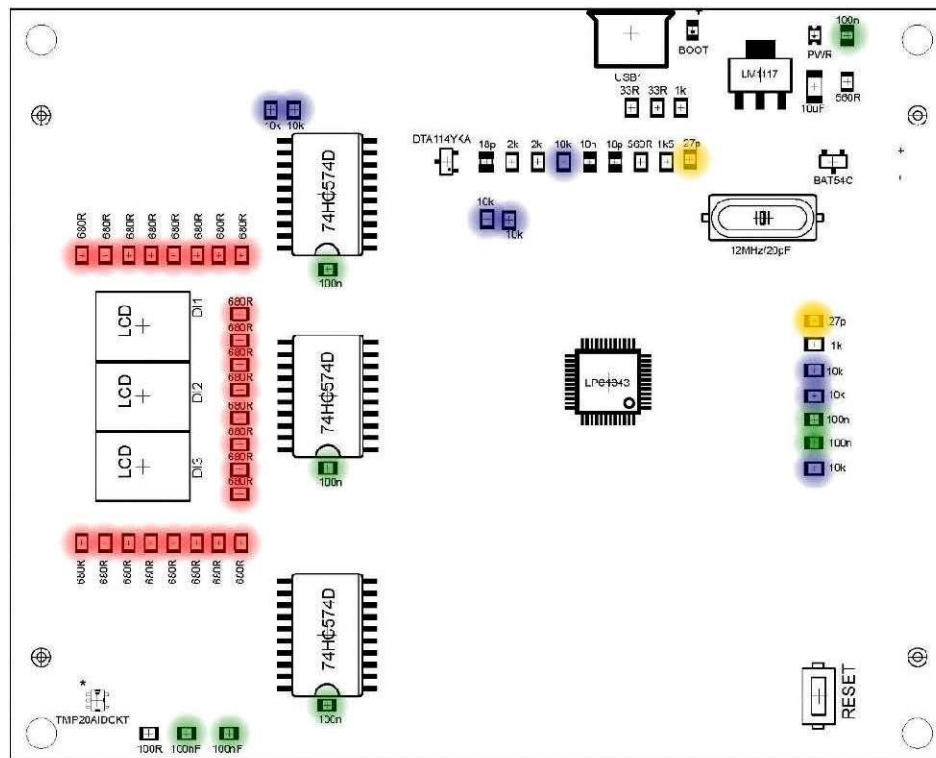
For using this PCB as a temperature indicator, through-hole components are not necessary. They are intended for use of this PCB as a development board.


Besides THT components, zener diode and two switches also remain empty.


The picture below shows only the components that should be populated on this board.





Following picture also shows you which components need to be placed, but on the other way, with colour legend. It might help you.



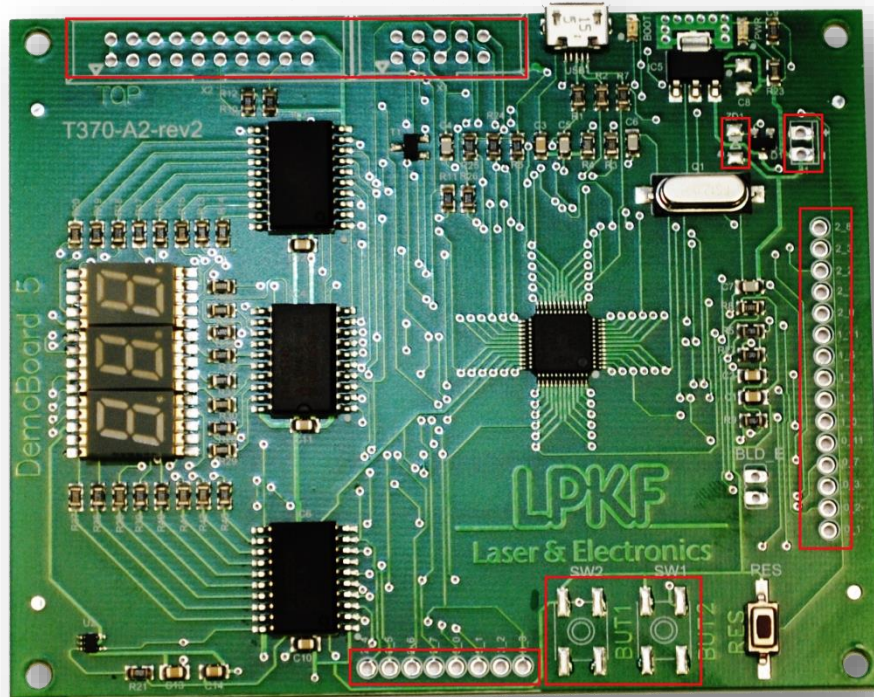
 = 680R

 = 100nF

 = 10k

 = 27pF

In this picture the red marked areas remain empty.



5.3 Soldering

Soldering can be done using LPKF ProtoFlow S or ProtoFlow E reflow ovens.

WARNING!!



Before using the device, carefully read the chapter on health and safety in the LPKF ProtoFlow User manual. Familiarise yourself with potential risks and prescribed safety precautions.



There is a risk of burns, if the PCB securing aluminium laths are touched. Supplied protective gloves enable touching of hot surfaces for short-contact only!

CAUTION!



The oven must be properly warmed up. At least one full cycle must be performed, before a PCB is inserted.

5.3.1 Profiles

<u>PROTOFLOW S</u>	LF SMALL	LF MEDIUM	LF LARGE
	1 board	3 boards	6 boards
PREHEAT	170 °C / 150 s	170 °C / 160 s	170 °C / 170 s
REFLOW*	250 °C / 75 s	255 °C / 85 s	260 °C / 95 s
COOLDOWN	80 % / 90 s	100 % / 90 s	100 % / 100 s
POWER	100 %	100 %	100 %

* These profiles are the default vales from firmware 3.11 onwards.

<u>PROTOFLOW E</u>	LF SMALL	LF MEDIUM	LF LARGE
	1 board	2 boards	4 boards
PREHEAT	170 °C / 150 s	170 °C / 160 s	170 °C / 170 s
REFLOW*	250 °C / 90 s	255 °C / 100 s	260 °C / 115 s
COOLDOWN	110 s	120 s	130 s
POWER	100 %	100 %	100 %

* These profiles are the default vales from firmware 2.11 onwards

* Exact values can vary depending on oven's specific ramp-up rate. Slight modifications (usually +/-5s) to reflow time could be required.

5.3.2 Handling

WARNING!!



During handling with a PCB, pay special attention that USB connector that is stretched over the edge of the board can't be moved!

The side where the USB connector is stretched over the PCB must not lie on the rails. The side with LED displays should be facing towards the window. These are the last components that are soldered, therefore being a good indicator, if the reflow has reached the peak temperature.

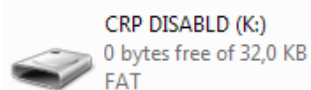


5.4 Uploading the Firmware

The user has to use an appropriate software development environment to generate a *firmware.bin* file. In order to upload the developed firmware, the DemoBoard 5 has to be connected to the host computer via an USB cable. The LPC1343 microcontroller has to enter the USB Bootloader state, where its flash drive is visible as a Removable Disk.

Instructions for uploading the Firmware:

- Connect the DemoBoard 5 to the host computer via USB cable - **micro USB / USB A**
- Wait a moment for the drivers to be installed and the device is shown as a USB memory stick



-
- Delete the current *firmware.bin* file
- Copy a new file to the *Removable Disk*
- Press RESET button

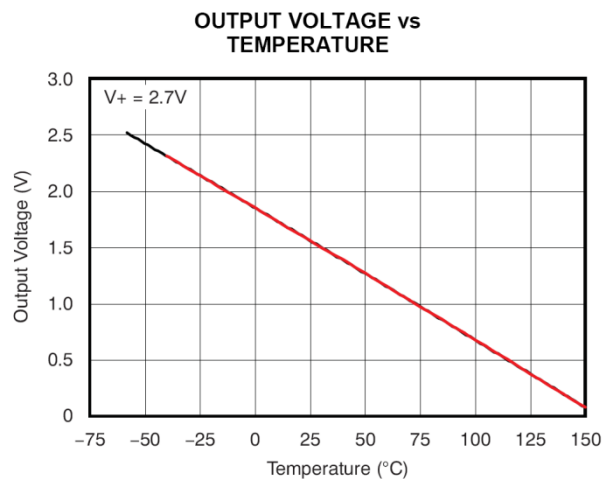
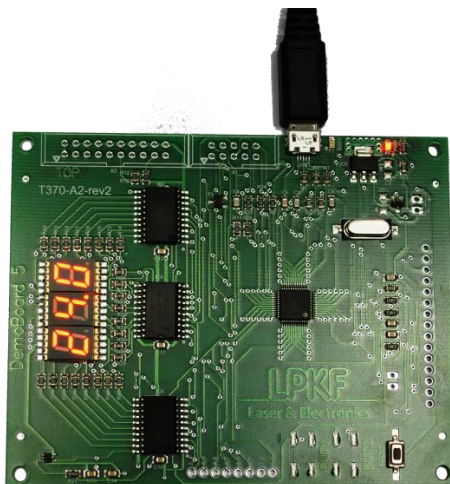
Note

The DemoBoard 5 could be reset manually via a RESET button or in the software via a debug interface (SWD). Both options make use of LPC1343 pin 3 (PIO0_0), driving the signal low, when in reset.

If everything is correctly assembled, LED displays will show the ambient temperature.

5.5 Ambient Temperature indicator

The temperature display circuit consists of a precision analog output temperature sensor ([Texas Instruments TMP20](#)), a LPC1343 built-in 10 bit AD converter, three octal D-type flip-flop ICs ([74HC574](#)) and three common cathode 7-segment displays ([Kingbright Display](#)). A pre-developed firmware is available, which makes use of the presented elements. The temperature sensor is calibrated to operate from -10 °C to 65 °C. All signals from the LPC1343, which are used to drive the flip-flop ICs and consequently the 7-segment displays, are also available via the expansion pins.



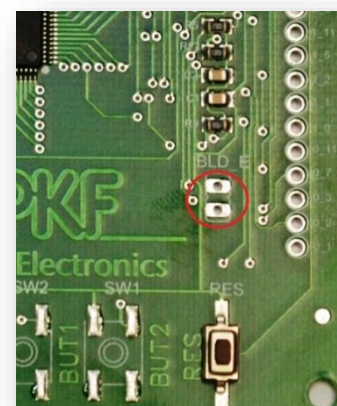
5.6 Debugging

In case of troubles with the connection, display errors or wrong temperature values, a few steps can be followed to try and find an error.

1. Check if all components are properly placed on their designed place and if all orientations are correct.
2. Visually check the solder joints, they should be clean and shiny.
3. Check for any possible bridges between pins.
4. Check if all LED displays solder joints are correctly soldered. Being the last to melt, when properly soldered they ensure, that the rest of the board achieved the correct temperature.
5. Temperature limits range is from -9,5°C to 65°C. If those values are exceeded, the display will show - - -. That is a good indication, that there can be a problem with the temperature sensor or its joints.
6. Firmware reload:

In case of firmware reload, follow next steps:

- Connect the board to the PC using a USB connection
- Connect BLD_E pads together using tweezers or a similar tool
- Press "Reset" button on the PCB while BLD_E pads are connected
- The board will go into "BOOT" mode (LED "BOOT" is turned ON)
- The PC displays the device as a USB memory stick again
- Copy the correct firmware file to the Removable Disk



6 PROGRAM

A pre-defined program, ambient temperature indicator, is written in C programming language and compiled for most popular Cortex-M3 LPC1343 microcontroller.

6.1 Pre-defined firmware source code

For all who are interested in open source code for ambient temperature indicator, it is available on the request only.

7 EMBEDDED DEVELOPMENT TOOLS

For advanced users who want to make their own project using DemoBoard 5 and its microcontroller as a base unit, a lot of information about the embedded development tools, product updates, downloads, application notes, example code, and technical support are available from **Keil** (www.keil.com) website.

Keil™ products from ARM include C/C++ compilers, debuggers, integrated environments, RTOS, simulation models and evaluation boards for ARM®, Cortex™-M, Cortex-R, 8051, C166, and 251 processor families.

The MDK-ARM is a complete software development environment for Cortex™-M, Cortex-R4, ARM7™ and ARM9™ processor-based devices. MDK-ARM is specifically designed for microcontroller applications, it is easy to learn and use, yet powerful enough for the most demanding embedded applications.

Features:

- Complete support for Cortex-M, Cortex-R4, ARM7, and ARM9 devices
- Industry-leading ARM [C/C++ Compilation Toolchain](#)
- [µVision4](#) IDE, debugger, and simulation environment
- Keil [RTX](#) deterministic, small footprint real-time operating system (with source code)
- [TCP/IP Networking Suite](#) offers multiple protocols and various applications
- [USB Device](#) and [USB Host](#) stacks are provided with standard driver classes
- Complete [GUI Library](#) for embedded systems with graphical user interfaces
- [ULINKpro](#) enables on-the-fly analysis of running applications and records every executed Cortex-M instruction
- Complete [Code Coverage](#) information about your program's execution
- [Execution Profiler](#) and [Performance Analyzer](#) enable program optimization
- Numerous example projects help you quickly become familiar with MDK-ARM's powerful, built-in features
- [CMSIS](#) Cortex Microcontroller Software Interface Standard compliant

MDK-ARM is available in four editions: MDK-Lite, MDK-Basic, MDK-Standard, and MDK-Professional. All editions provide a complete C/C++ development environment and MDK-Professional includes extensive middleware libraries.

Note

MDK-Lite (32KB) Edition is available for [download](#). It does not require a serial number or license key.

MDK-Lite can be converted into other MDK-ARM Editions with a valid Product Serial Number.

For all details please visit Keil™ on www.keil.com website.

8 APPENDIX

8.1 Components datasheet

- 8.1.1 SMD chip resistors
- 8.1.2 SMD Multilayer Ceramic Chip Capacitors
 - 8.1.2.1 SMD MLCCs Kemet
 - 8.1.2.2 SMD MLCCs Multicomp
- 8.1.3 SMD C0G (NP0) capacitors
- 8.1.4 SMD Schottky Diode BAT54
- 8.1.5 SMD Zener voltage regulator
- 8.1.6 Octal D-type flip-flop 74HCT574
- 8.1.7 Kingbright Surface mount display KCSC03-105
- 8.1.8 Microcontroller LPC1311_13_42_43
- 8.1.9 SMD Crystal HC49SDF
- 8.1.10 SMD LED 0805
- 8.1.11 Temperature sensor TMP20
- 8.1.12 Transistor DTA114Y
- 8.1.13 USB micro type connector
- 8.1.14 Voltage regulator LM1117

