Ultraviolet radiation device for prototype production printed circuit boards

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***Abstract*—** For the production of high quality PCB in small quantities is the photo etching method the most favorable. For the needs of our university and its students, when creating their diploma theses, device for generating ultraviolet radiation was created.

***Keywords*—** LED, Ultraviolet radiation, Freescale, exposition, printed circuit board (PCB)

I. INTRODUCTION

On the present, the technology of printed circuit boards (PCB) has been well sophisticated. Professional manufacturers have reached a standard that is unattainable for home-made products. The problem occurs when we need to create only one specimen, for example when producing a functional sample or a single unit for diploma thesis. Preparing an industrial production of one specimen is rather luxurious and very often impracticable. On the other hand, in the recent age of microcontrollers, buses and other devices having a high density of pins per an area unit it is impossible to create PCBs by real amateur methods like manual drawing the conductor pattern with a varnish etc. This is why the methods using photosensitive materials are widely spread[1]

II. THE PHOTO ETCHING METHOD

The steps of producing a PCB by the photo etching method are as follows: Firstly, the copper layer of the board is provided with a photosensitive varnish. Then a mask pattern is applied and this pattern is then transmitted to the photosensitive layer by means of the ultraviolet rays. Consequently, the pattern is chemically developed and in the end it is etched with the perchloride of iron. The transmitting of the pattern is quite critical while we have no feedback concerning the real exposition. As lately as the pattern is developed, we can see whether the exposition was correct or not and if not, we can only throw the PCB out. This is why it is convenient to make the ultra violet flux stable and set the exposure time properly. Both these requirements are matched with the light source which, when properly set, enables us to reach a good reproducibility..

III. LIGHT SOURCE CONSTRUCTION

The light source is designed in order to get the uniform flux over an area accordant to A4 sheet size. The intensity of the flux is constant during the time thanks to stabilised current through the LEDs. The exposure time can be set from 1 to 60 minutes with a step of 1 second. When exposed, the PCB is covered with a lid so no UV light gets out of the source. When the lid is removed, magnetic sensor immediately stops the exposing and do not allow to start it again until the lid is moved back. The ultra violet flux is generated by 252 LEDs evenly displaced at the bottom of the box of the source. The current through the LEDs is restricted to approx. 8 mA in order to assure their working life. When driven moderately, the LEDs tend to be more stable during their lifetime, producing more stable flux. The exposition is controlled via a microcontroller, which can moreover detect if any LED is opened due to its failure, which would break the uniformity of the flux.

In light of the circuitry the unit can be divided into three main parts: power supply, controller board end LED board. Connection between this parts is displayed in the Fig. 1.

Manuscript received June 29, 2011: Revised version received XXXXXXX. This work was supported by by the European Regional Development Fund under the project CEBIA-Tech No. CZ.1.05/2.1.00/03.0089 and by the Internal Grant Agency at TBU in Zlin, project No. IGA/46/FAI/11/D.

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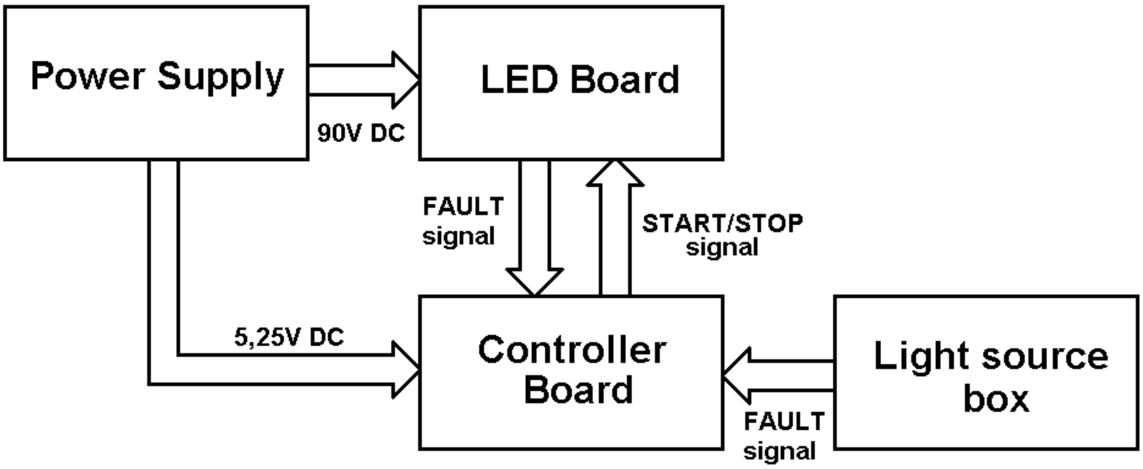

Fig 1. Block diagram

The power supply board delivers 5.25 V for feeding the microcontroller and subsidiary circuits and approx. 90V to feed the exposition board. The controller board uses employs a Freescale microcontroller, display, voltage reference and three buttons. It checks whether the lid is closed, counts down the time, sets the reference voltage for the exposition board and checks the exposition board for failures. The exposition board holds 252 UV LEDs connected in series of 18 items. This makes 14 columns and 18 rows. The threshold voltage of each LED is approximately 3.6 V, so 18 LEDs connected in series need at least 65 V. Considering the current stabilisation, the supply voltage was set to 90 V. Each column of LEDs has its own current stabiliser. The reference voltage for all 14 stabilisers is shared and is driven by the microcontroller.

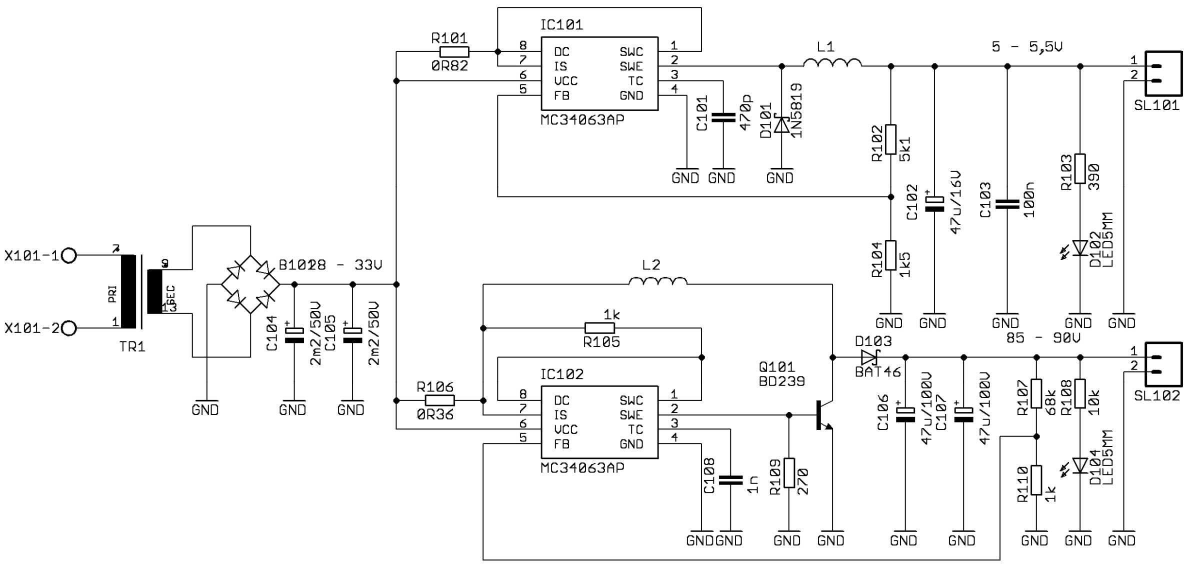

Fig 2. Circuit diagram of the power supply

In the Fig.2 the circuit diagram of the power supply board is displayed. As can be seen, conventional transformer is used to separate the unit off the mains. The main switch and fuse are not plotted as these are mounted separately on the box of the unit. The transformed and rectified voltage is then converted by two switching converters, employing simple circuits MC34063. IC101 is connected as a step-down converter, producing approximately 5.25 V, while IC102 is connected as a step-up converter. In order the voltage of 90 V could be achieved, the integrated circuit must be reinforced with a power transistor T101. Both converters oscillate randomly at frequencies around 30 kHz and can deliver up to 125 mA. The total output power of the power supply is approx. 12.5 W, which is rather advantageous, considering the power consumption of conventional mercury lamp is at least 10 times higher. PCB based on the power supply circuit diagram is displayed on Fig. 3. All connections between components are realized in the bottom side of PCB. Components placement is displayed in Fig.4. Pattern in Fig. 3 of power supply PCB is of real size which was used for creating the fully functional system.

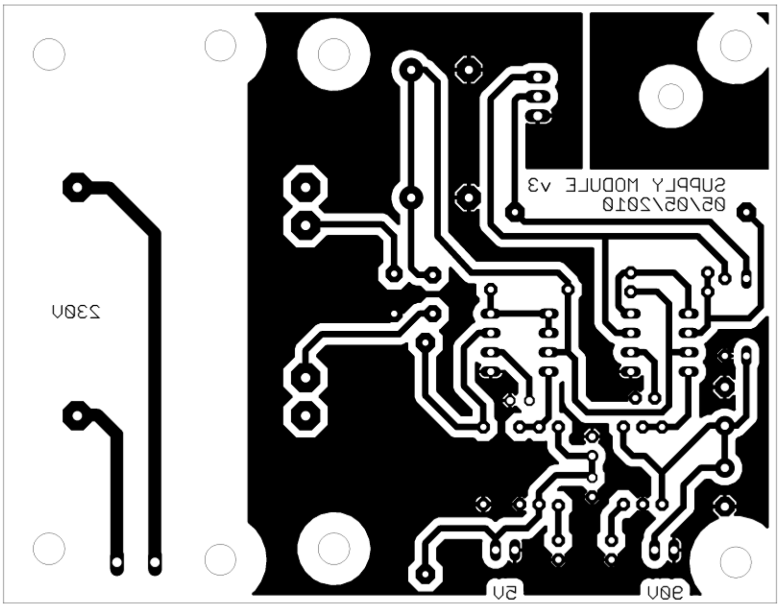

Fig 3. Power supply printed circuit board (top view)

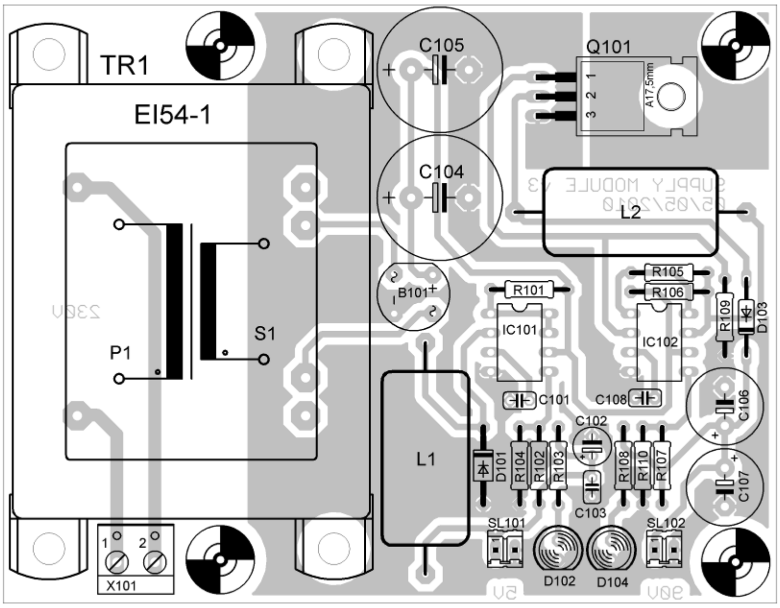

Fig 4. Power supply placement (top view)

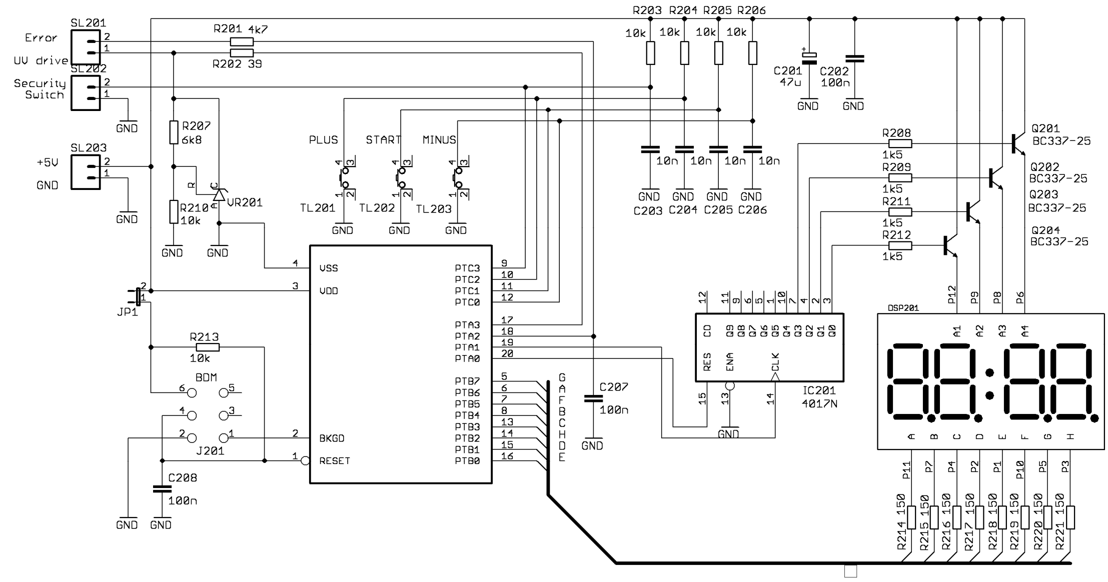

Fig. 5 Circuit diagram of control unit

In the Fig. 5 there is a circuitry of the controller board displayed. The heart of the board is the microcontroller IC201. Together with Johnson´s counter IC202 it drives the display DSP201, acquires data from the buttons TL201 to TL203, checks the safety switch connected to SL202 and drives the exposing board connected to SL201. The voltage reference VR201 sets the output voltage to 4.25 V in case the UV LEDs are switched on. To switch the UV LEDs off, the output voltage is set to zero. The Error pin of SL201 connector is then connected to the A/D converter of the microcontroller, assuring checking the proper function of the exposing board. The microcontroller can be programmed on board by means of BDM interface, connected to J201 connector. PCB based on the control unit circuit diagram is displayed on Fig. 6. All connections between components are realized in the bottom side of PCB. Components placement is displayed in Fig.7. Pattern in Fig. 6 of control unit PCB is of real size which was used for creating the fully functional system.

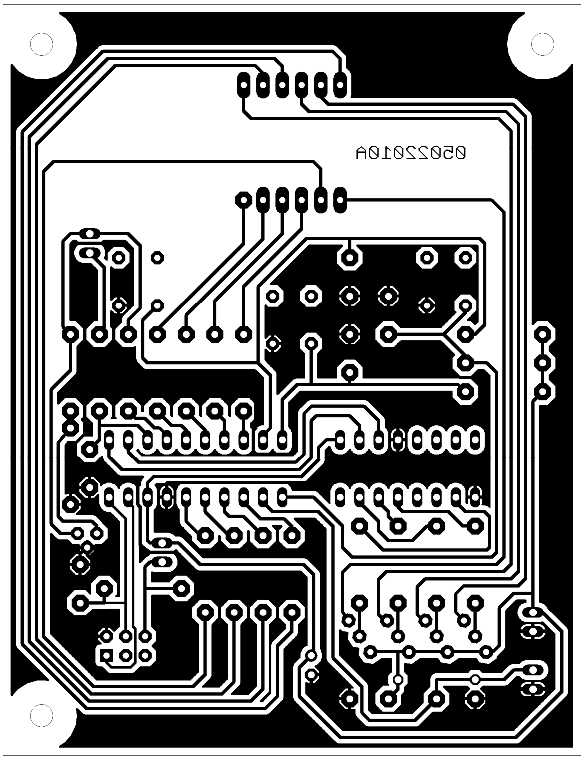

Fig.6 Control unit printed circuit board

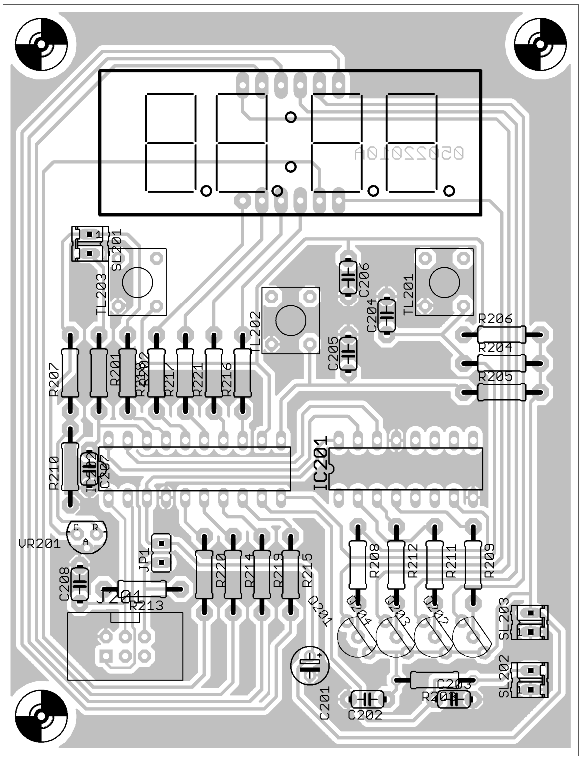

Fig. 7 Control unit placement

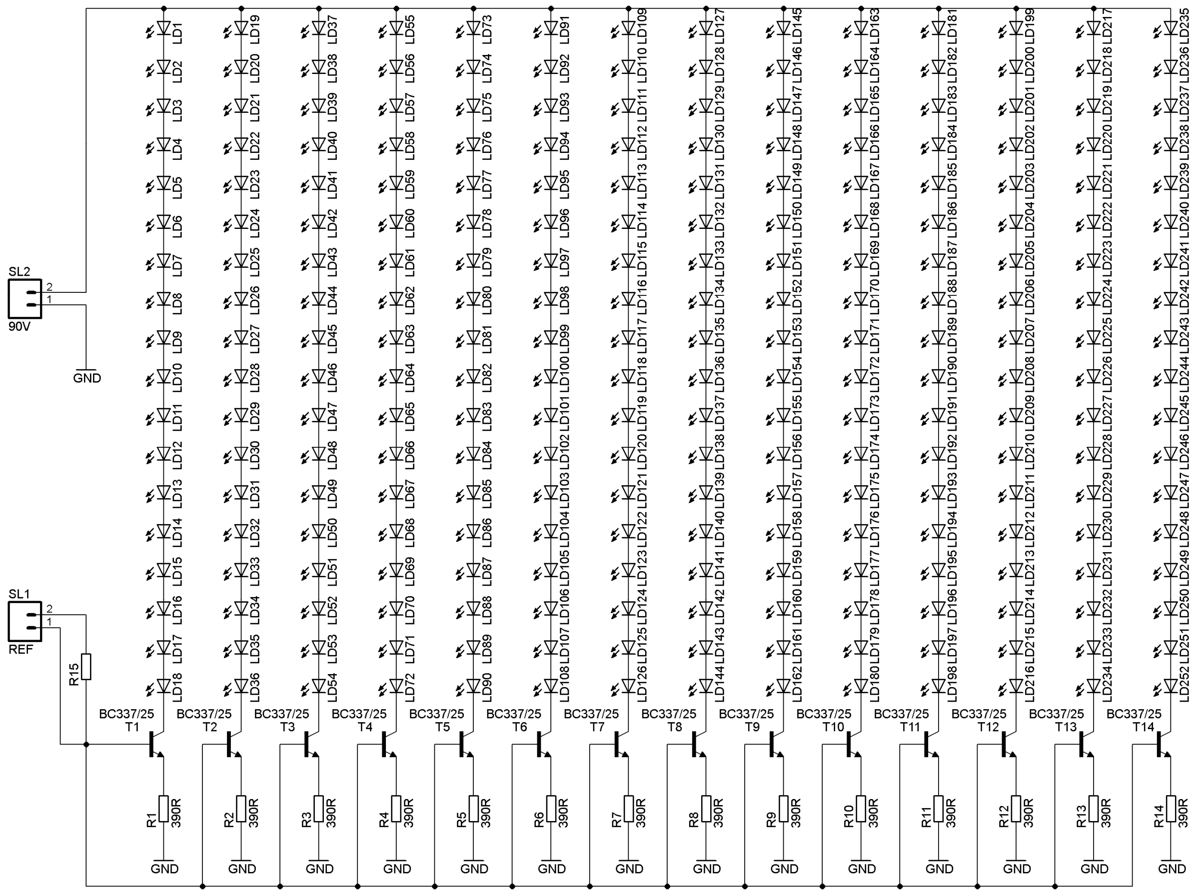

Fig. 8 Circuit diagram of LED board

In the Fig. 8 there is a circuitry of the LED board displayed. The LED board is standard A4 sheet sized in order to get uniform light flux. The UV LEDs LD301 to LD552 are evenly displaced on it. The 90 V supply voltage is connected to SL301, the driving is processed by means of SL302. The transistors T301 to T314 serve as current stabilizers. If the UV LEDs are required to lit, the reference voltage of 4.25 V is distributed to the bases of the transistors through the resistor R301. The current through the branches of the LEDs then come to stay at the level which is equal to the voltage drop on emitter resistors, voltage drop on the base-emitor junctions and voltage drop on the R301. For the reference of 4.25 V and the emitter resistors of 390 Ω the current is approximately 8 mA. If any UV LED fails and the branch gets opened consequently, no current flows between the collector and the emitter of the appropriate transistor. As a result of this, higher current starts to flow between the base and the emitter of this transistor, because there is no voltage drop at the emitter resistor. This increased current leads to increasing the voltage drop at R301 which can be detected by the A/D converter of the microcontroller. Problem of power supply delivery can be detected by this method as well. If there is a problem with wiring or the voltage reference gets lower or higher for any reason, the failure is also detectable.

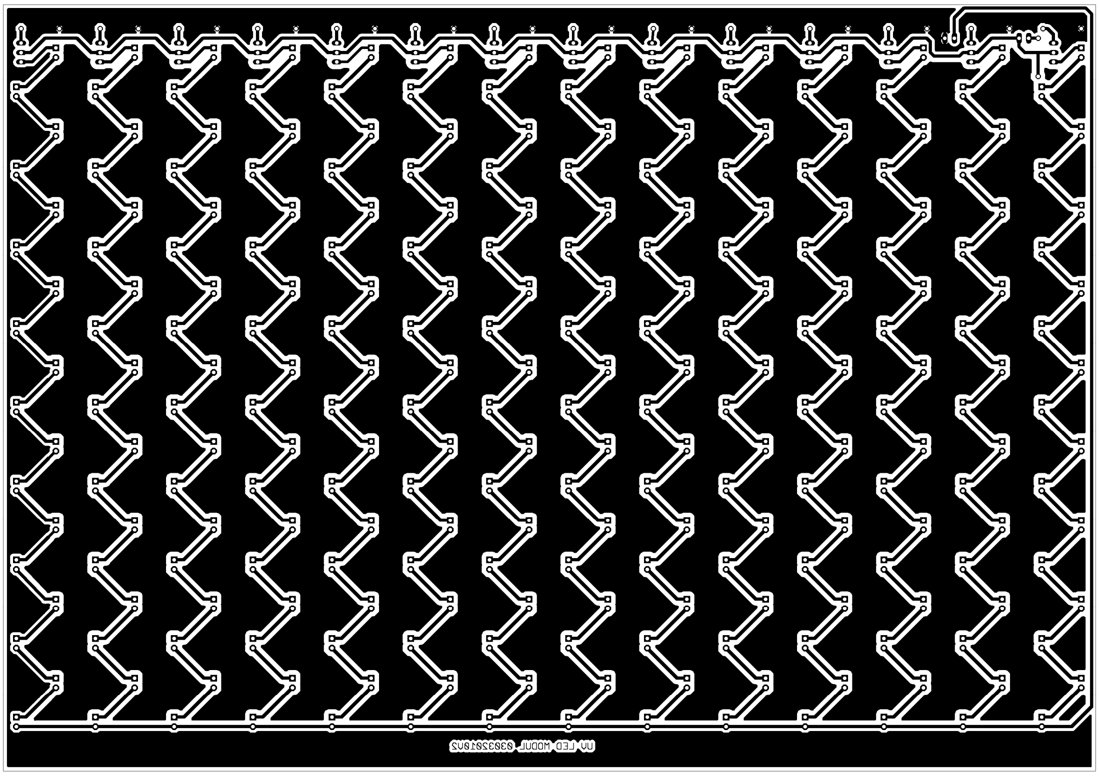

Fig. 9 LED board PCB

PCB based on the LED board circuit diagram is displayed on Fig. 9. All connections between components are realized in the bottom side of PCB. Components placement is displayed in Fig.10. Pattern in Fig. 9 of LED PCB is shown in a half scale compared to the one which was used for creating the fully functional system.

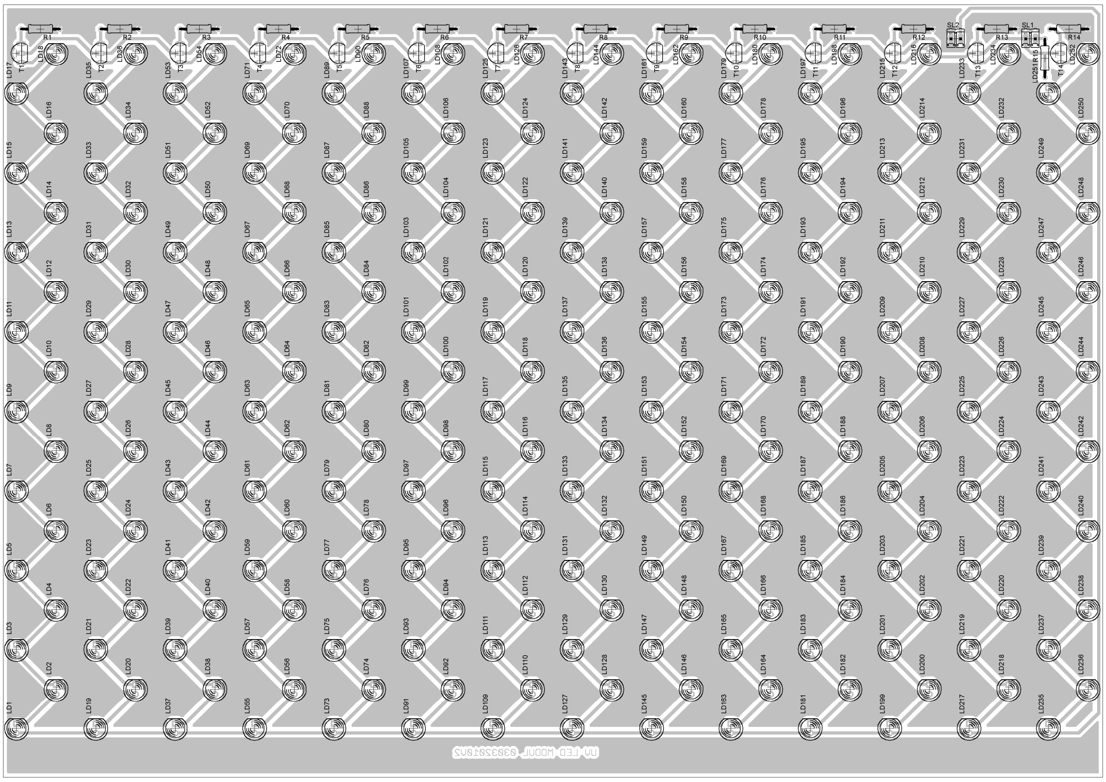

Fig. 10 LED board placement

IV. MICROCONTROLLER

The heart of the Light source is a microcontroller by Freescale, model MC9S08SH4. It uses freescale HCS08 core and instruction set. The application uses the internal oscillator of the chip running at 20 MHz. This frequency should stay stable during the life time of the device. The deviation of the frequency is lower than 2 % [1].

From the extra peripherals, an A/D converter was used as a failure detector and two internal timers were used as accurate clock generator and Johnson´s counter driver. Other I/O pins are occupied only with logical signals.

The program for the microcontroller has been created in Assembler, according to the proper instruction set. When the power supply is connected, the microcontroller suggests a predefined amount of exposing time and lets the user to set the time with buttons "UP" and "DOWN". When the time is modified, the user can start the exposition by pressing the button "START/STOP". Box lid closure is detected by a magnetic contact. When the lid is not present, exposition process will not run and display of control board shows sign "Er 1". The microcontroller also controls the correct function of the LED board. In case of failure of some of parallel branches LED light source will not start. This is indicated by "Err 2" sign on the display of control board. If the lid of the box is closed the exposition starts and is processed until the time expires. After that the exposition cycle is finished. If needed, the exposing can be interrupted by pressing the "START/STOP" button anytime.

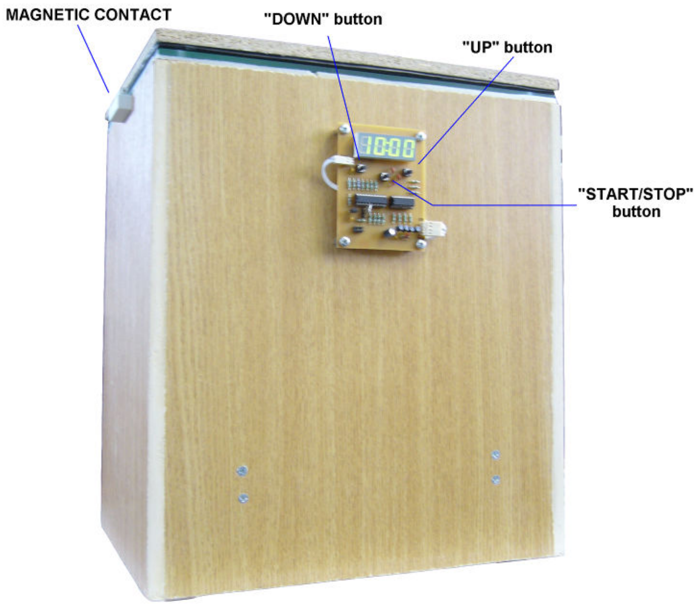

Fig. 11. Box for light source

V. CONCLUSION

The Light source has been designed and made and is a subject to process several tests at the present. Compared to a conventional mercury lamp the power consumption of this source is considerably lower and the flux of the UV light is more uniform. This enables the users to produce PCBs with high density patterns, using for example a grid of 250 μm. Recently, testing the proper exposure time is processed, but at first sight, the total power needed to expose one printed circuit board is lower than in case of employing the mercury lamp. Exposing the PCB by a 150W mercury lamp is processed for approx. 4 to 5 minutes, while the estimated time for exposing the PCB by the LED UV light source is approximately 12 minutes. This brings roughly 70% saving.

ACKNOWLEDGMENT

This paper is supported by the Internal Grant Agency at TBU in Zlin, project No. IGA/46/FAI/11/D and by the European Regional Development Fund under the project CEBIA-Tech No. CZ.1.05/2.1.00/03.0089.

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