Photoresist exposure via LCD panel

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Abstract—This paper focuses on development and testing of liquid crystal display exposure device using photoresist for PCB manufacturing. The device is controlled wirelessly via dedicated application on various platforms. Most of the device was 3D printed and motif for exposure can be uploaded to the device in Gerber format, which is used all over the world as manufacturing standard format. The paper also contains CAD model, simulation, exposure results and overview of control application.

Keywords—Photoresist, liquid-crystal display, exposure, printed circuit board, ultraviolet rays, diode

1. INTRODUCTION
Nowadays, with the price of circuit boards reaching record lows, especially from Chinese manufacturers, it no longer makes much sense to try to design a home-use device that can compete with the process quality and price of professional boards. However, the big disadvantage of professional production is the delivery time for prototyping, which generally takes weeks to deliver and usually only one sample cannot be ordered. This paper aims to address this shortcoming in particular by designing a device on which it would be possible to create two-layer PCBs to verify the function of the prototype in PCB design.

The way to achieve this is to combine two processes that are divided into two steps in conventional production. The first is the creation of an exposure motif, usually realized on a thin transparent film, and then the exposure of the photoresist through this template. By using an LCD panel on which the desired motif can be displayed, the two processes can be combined into a single step, during which the motif on the display is matched to the substrate and photoresist is exposed.

2. PRINCIPLE OF LIQUID CRYSTAL DISPLAY
In the state where no current flows through the electrodes and no voltage is present, the crystals are arranged in a helix that rotates the polarized light 90°. The light thus has the correct polarization for passing through the output polarization filter at the output, and the subpixel appears to be ON (See Figure 1).

Figure 1: Subpixel structure in TFT LCD technology [1]
The moment we apply an increasing voltage to the electrodes and a current starts to pass between them, the crystals start to rotate and lose their helical shape. Passing light is rotated by an increasingly smaller angle, causing more light to be absorbed by the output polarizing filter. In a situation where the helix is completely rotated, the light is not affected by the crystals and the vast majority is absorbed into the output polarizing filter.

3. DESIGN AND SIMULATION

Body of the device was designed to be 3D printable on basic size 3D printer including the reflector piece. The device uses powerful 30 W COB led diode. The light from this diode is equally concentrated on the LCD layer with custom designed reflector. The LCD layer is driven by cheap Chinese tablet from which was the LCD panel salvaged. The Raspberry Pi Zero inside the device is responsible for power management and communication between user control app and android tablet (See Figure 2).

![Figure 2: 3D CAD model of the device with individual components](image)

4. REFLECTOR

By using only one point source of UV radiation, there was a need to direct the rays towards the LCD layer so that they would fall as perpendicularly as possible and their distribution would be as homogeneous as possible. Professional light simulation software LightningTrace® ZEMAX OpticStudio® was used for simulation of 3D CAD model and based on the results adequately modified.

![Figure 3: Light simulation of reflector with distribution of the incoming radiation in form of heat map and generated correction mask](image)

As can be seen from the simulation (See Figure 3), the distribution of incoming radiation on the LCD layer is far from homogeneous. Therefore, the values of the intensity of radiation passing through the LCD layer were measured and a correction mask was generated based on these values. This mask compensates for the so-called hot center in the middle of the display by darkening the corresponding pixels.
4.1. Power management

The main voltage source was chosen to be a network adapter with a DC Jack connector capable of supplying up to 6 A at 12 V DC to the device. This adapter was chosen based on the consumption of the individual components of the device. A voltage of 12 V is suitable because it is about half the voltage for conversion to 30 V and about twice the voltage for conversion to 5 V. The 12 V can also be used to directly power components such as fans and LED backlights.

4.2. Communication

The communication between the user application and the device is realized via Wi-Fi. The Raspberry Pi microcomputer is hosting a Wi-Fi AP to which the control application and Android tablet are connected. From the application, HTTP requests and files are sent to two HTTP servers that host the Raspberry and the android tablet to allow communication between them (See Figure 4). The optocoupler is used to turn on the Android tablet after successfully turning on the script on the Raspberry Pi.

![Figure 4: Connection diagram between individual components of the device](image)

5. SOFTWARE SOLUTION

In order to control the device using this app (See Figure 5), your computer or phone needs to be connected to the device via Wi-Fi. If this condition is met, it is possible to send requests to both HTTP servers on the device. The control application contains three tabs in the bottom bar that the user can easily switch between. The first tab is used to work with the motif on the display and to send the Gerber file to the device, which will display the motif immediately. The navigation buttons are used to move the image around the display. The user can adjust the step of the movement in pixels and zoom in/out in units of per mil with the movable slider. Rotation or lock of the motif was not implemented in the prototype. The process of exposition is activated by pressing dedicated button on the device.

![Figure 5: Custom Android control app](image)
6. MEASUREMENTS AND TESTING

As you can see in the picture (See Figure 6), the smallest possible conductive path width that can be reliably reproduced is 0.254 mm. The smallest passive component that can be exposed on the device is 0603. As far as active components are concerned, the device managed to expose good quality for footprints SOP, ESOP, SOT, PLCC and DIP. An interesting finding was the resulting quality of the BGA package, which was almost perfect. Unfortunately, due to the limited thickness of the conductive paths, it could not be contacted.

Figure 6: Exposed and developed results for some footprint types

7. CONCLUSION

The result of this work is a working prototype of a device on which it is possible to expose two-layer printed circuit boards after manual alignment of the layers. The quality of the exposed patterns was evaluated in Section 6. At the same time, a software platform has been developed for the device which is modular and can be extended in the future. The platform includes an application, through which the device can be controlled wirelessly from a PC and a mobile device, as well as an application for displaying Gerber files in high resolution on the screen.

ACKNOWLEDGMENT

I would like to thank my bachelor thesis supervisor doc. Ing. Petr Vyroubal, Ph.D. for his professional guidance, consultation, patience and helpful suggestions. I would also like to thank Markus Fußenegger for providing and modifying part of the used software.

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