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DESIGN OF TFT SWITCH GRID

GOCE STEFANOV AND BILJANA CITKUSEVA DIMITROVSKA

Abstract. In this paper, an electronic touch screen switch grid is designed and experimentally realized. The realized device is based on a microcontroller and an LCD touch screen. First a theoretical analysis of the LCD touch screen is made, then a design touch screen switch grid, and then the results from experimental work are given.

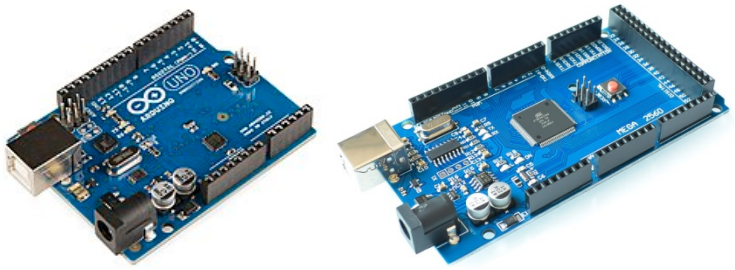
1. Introduction

In electronic's projects, creating an interface between a user and a system is very important. This interface could be created by displaying useful data, a menu, and ease of access. A beautiful design is also very important. There are several components to achieve this: LEDs, 7-segments, character and graphic displays, and full-color TFT LCDs. The right component for design depends on the amount of data to be displayed, type of user interaction, and processor capacity. TFT LCD is a variant of a liquid-crystal display (LCD) that uses thin-film-transistor (TFT) technology, to improve image qualities such as addressability and contrast. A TFT LCD is an active-matrix LCD, in contrast to passive matrix LCDs or simple, direct-driven LCDs with a few segments. In Arduino-based projects, the processor frequency is low. So, it is not possible to display complex, high-definition images and high-speed motions. Therefore, full-color TFT LCDs can only be used to display simple data and commands. The size of displays affects project design parameters. A bigger display is not always better. If a display on high-resolution images and signs is needed, one should choose a big size display with higher resolution. But it decreases the speed of processing, needs more space and also needs more current to run. So, first, the resolution, the speed of motion, the details of color and size of project's images, texts, and numbers should be checked [1], [2]. Practical size of Arduino TFT displays are: 4 inch 520×480, 3.5 inch 480×320, 2.8 inch 400×240, 2.4 inch 320×240 and 1.8 inch 220×176, [3], [4], Figure 1.

Figure 1.4-inch 520×480, 3.5-inch 480×320, 2.8-inch 400×240, 2.4-inch 320×240 and 1.8-inch 220×176

Keywords: TFT display, Microcontroller

After choosing the right display, the next step is the decision about the right controller. If displaying characters, tests, numbers, and static images are needed, the speed of display is not important, the Atmega328 Arduino boards (such as Arduino uno, nano) are adequate. If the size of the code is large, the uno and nano board may not be enough. In this case, Arduino Atmega 2560 should be used, shown in Figure 2. For high resolution images and motions with high speed, the ARM core Arduino boards such as Arduino DUE should be used, [5].



a.) b.)

Figure 2. Board on Microcontroller: a.) Arduino unoR3, b.) Atmega 2560

In electrical industrial plants, especially in older ones, there are mainly mechanical switches. Most of them get broken due to turning them on and off lots of times; either the spring inside the switch gets displaced, or some other problem may appear and the switch board gets broken. These mechanical switches are also going to be outdated and look like old type. Thanks to the development of microcontrollers and TFT displays, there is a possibility of a sophisticated solution for new switching networks or replacing old ones with touch switches. Unlike the old mechanical switch types, these screens use non-moving switches and therefore cannot be damaged. Also, we can add some extra functionality to them such as process parameters (temperature, pressure, flow), monitoring in real time etc. In this paper the emphasis on the use of TFT display and microcontroller is placed on the realization of the application of switches.

2.Theoretical Background of Touch Screen

Touchscreen displays are everywhere. Phones, tablets, self-serve kiosks, bank machines and thousands of other devices we interact with make use of touchscreen displays to provide an intuitive user interface, [1], [2]. In the paper we will learn how touchscreens work, and how to use a common inexpensive touchscreen shield for the Arduino, [3], [4], [5].

2.1 History of the Touch Screen

Although touch screens seem to be everywhere these days, we tend to forget that just a few decades ago these devices were just science fiction for most of us. For many people, the touchscreen concept was introduced 30 years ago in the television series Star Trek: The Next Generation. Eric A. Johnson, a researcher at the Royal Radar Establishment in Malvern UK, is credited for describing and then prototyping the first practical touch screen. His device was a capacitive touchscreen, and its first commercial use was on air traffic control screens. However, the touch screens used then were not transparent, instead, they were mounted on the frame of the CRT display.

In 1972, a group at the University of Illinois filed for a patent on an optical touch screen. This device used a 16×16 array of LEDs and phototransistors, mounted on a frame around a CRT display. Placing your finger, or another solid object, on the screen would break two of the light beams; this was used to determine the position and to respond accordingly.

The first transparent touch screen was developed at CERN in 1973. CERN is also home to the Large Hadron Collider, and this is where Tim Berners-Lee invented the World Wide Web. The first resistive touchscreen was developed by the American inventor George Samuel Hurst in 1975, although the first practical version was not produced until 1982. In 1982, the University of Toronto's Input Research Group developed the first multi-touch touch screen, a screen that could interpret more than one touch at the same time. The original device used a video camera behind a frosted piece of glass. Three years later the same group developed a multi-touch tablet that used a capacitive touchscreen instead.

The first commercial product to use a touchscreen was a point-of-sale terminal developed by Atari and displayed at the 1986 COMDEX expo in Las Vegas. Next year, Casio launched the Casio PB-1000 pocket computer with a touch screen consisting of a simple 4×4 matrix. LG created the world's first capacitive touchscreen phone; the LG Prada used a capacitive touchscreen and was released in early 2007. A few weeks later, Apple released its first iPhone.

2.2 How Touch Screens Work

Although there have been many technologies used to create touchscreens, the two most prevalent are Resistive and Capacitive touch screens. The earliest touch screen devices were resistive, as this technology is generally less expensive than capacitive screens. However, nowadays capacitive screens are more common, being used in the majority of smartphones and tablets. Each technology has its advantages and disadvantages, which will be described below.

2.2.1Resistive Touch Screens

Although they were invented after capacitive touchscreens, resistive touchscreens are probably the most common type used by hobbyists. The reason for that is the price and performance; resistive touchscreens are cheaper than capacitive ones and they are generally more accurate. A resistive touchscreen consists of two thin layers of material, separated by a tiny gap, Figure 3. Spacers are used to maintain the gap and keep the two sheets apart. Both sheets have a conductive side, and they are arranged so that the conductive sides face one another. The top sheet is both flexible and transparent. The bottom one is also transparent; however, it is usually solid. In operation, the resistance between the two sheets is measured at different points. Pressing down upon the tip sheet will change that resistance, and by comparing the measurement points it can be determined where the screen was pressed. Essentially, it creates a pair of voltage dividers.

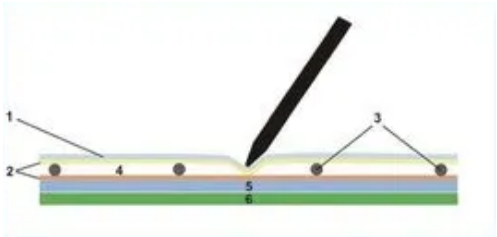


Figure 3. Resistive Touch Screens

There are three types of resistive touch screen: 4 wire analog (where each layer has 2 wires), 5 wire analog (the top layer has 4 wires and the bottom layer has 1 wire) and 8 wire analog (where each layer has 4 wires).

a.) 4-Wire Analog

In a 4-Wire Analog touchscreen, there are two electrodes or "busbars" on each of the conductive layers. On one layer these electrodes are mounted on the two X-axis sides, the other layer has them on the two y-axes. Each layer has wires connected to the busbars. The top ones are the *X*+ and *X*- connections, the bottom ones are labeled *Y*+ and *Y*-. This is the most inexpensive method of designing a resistive touchscreen. The touchscreen display that we will be working with here uses this arrangement.

b.) 5-Wire Analog

In a 5-Wire Analog touchscreen, there are four wires, one connected to a circular electrode on each corner of the bottom layer. A fifth wire is connected to a "sensing wire", which is embedded in the top layer. Touching any point on the screen causes current to flow to each of the bottom electrodes; measuring all four electrode currents determines the position where the screen was touched. With fewer components and a simpler design, the 5-Wire Analog touchscreen is considered to be a bit more durable than other designs.

c.) 8-Wire Analog

This 8-Wire Analog touchscreen uses an arrangement of electrodes identical to the 4-Wire variety. The difference is that there are two wires connected to each electrode, one to each end. While this is the most expensive arrangement, it is considered to be more reliable.

d.) Resistive Touch Screens – Advantages and Disadvantages

- Resistive touchscreens are less expensive than capacitive touchscreens.
- Resistive touchscreens work with a finger or a stylus.
- You can use a resistive touchscreen while wearing gloves
- The display is not as bright as the resistive overlay tends to dull it.
- Resistive displays are more easily scratched or damaged.

2.2.2 Capacitive Touchscreens

Capacitive touch screens are actually older technology than resistive displays. They are commonly used in phones and tablets, so you are probably familiar with them. The capacitive touch screen makes use of the conductivity of the human body. The touch screen itself consists of a glass plate that has been treated with a conductive material, Figure 4.

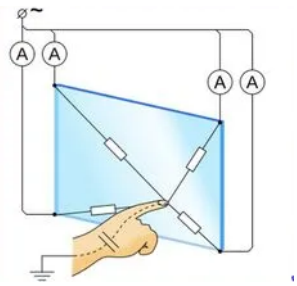


Figure 4. Capacitive Touch Screens

There are two common types of capacitive touchscreens.

2.2.3 Arduino Touch Screen Module

Arduino shield is

a.) Surface Capacitive

The surface capacitive touchscreen is the most inexpensive design, so it is widely used. It consists of four electrodes placed at each corner of the touchscreen, which maintains a level voltage over the entire conductive layer. When your finger comes in contact with any part of the screen, the current flows between those electrodes and your finger. Sensors positioned under the screen sense the change in voltage and the location of that change.

b.) Projected Capacitive

This is a more advanced touchscreen technique. In a projected capacitive touchscreen, transparent electrodes are placed along the protective glass coating and are arranged in a matrix. One line of electrodes (vertical) maintains a constant level of current. Another line (horizontal) is triggered when your finger touches the screen and initiates current flow in that area of the screen. The electrostatic field created where the two lines intersect determines where it was touched. This is a very sensitive screen that can even be triggered by just bringing your finger near the glass, without actually touching it.

c.) Capacitive Touch Screens – Advantages & Disadvantages

- Capacitive touch screens are generally more durable than resistive ones.
- Capacitive touch screens are clearer, as there is no outer membrane.
- Capacitive touch screens allow for multi-touch sensing.
- Capacitive touch screens can be vulnerable to accidental touches
- They are not as precise as their resistive counterparts.

2.2.3 Arduino Touch Screen Module

Arduino Shield is used for the application in the paper, which is widely used for these purposes.

a.) Module Components

The LCD touch screen shield is actually three components in one, so you will actually be coding for more than one interface. You can also just use the shield as an LCD display and ignore the two other components; however, if you intend to do that, it would be cheaper just to buy an LCD display without any touch screen features.

Let us examine the components of the Arduino LCD touch screen shield.

b.) TFT LCD Display

The most obvious component on the shield is the display itself. This is a TFT or *Thin Film Transistor* device that uses liquid crystals to produce a display. These displays can produce a large number of colors with a pretty decent resolution. It must be seen directly at the display for best color accuracy, as most of these inexpensive LCD displays suffer from distortion and “parallax error” when viewed from the side. But, as the most common application for a device like this is as a User Interface (UI), this should not be a problem.

c.) Touch Screen Membrane

The touch screen membrane is a set of resistive elements that sit on top of the display. This shield uses a 4-wire analog resistive touch screen, as described earlier. Two of the wires (one X and one Y) are connected to a couple of the analog inputs on the Arduino. The analog inputs are required as the voltage levels need to be measured to determine the position of the object touching the screen.

d.) Micro SD Card

The display shield also has a microSD card socket. The microSD card socket is a convenience, it is normally used for holding images for the display, but it can also be used for program storage. This can be handy for holding things like calibration settings and favorite selections. We should note that the microSD card uses the SPI interface and is wired for the Arduino Uno. While the rest of the shield will function with an Arduino Mega 2560, the SPI connections on the Mega are different, so the microSD card will not work.

e.) Choosing an Arduino Board – UNO or Mega

The last paragraph regarding the microSD card may make you think that an Arduino Uno is the best choice for the Touch screen Display Shield. And if you require a microSD card, then probably it is a good choice. But using an Arduino Uno with this shield has one big disadvantage – a limited number of free I/O pins. In fact, there are only three pins left over once the card has been plugged in:

- Analog pin A5. This can also be used as a digital pin.
- Digital pins 0 and 1. These pins are used by the USB interface on the Arduino, so using them is a bit tricky.

If the product is self-contained and does not need many (or any) I/O pins, then you will be fine. But if more pins are needed to interface with, then an Arduino Mega 2560 is a much better choice. It has a lot of additional analog and digital pins. So, if the microSD card is not required, or you are willing to hook up a separate microSD card, then the Arduino Mega 2560 is a better choice for most applications.

3. Design and Practical Realization of the TFT Switch Grid

In this part the design and the practical implementation of smart TFT screen switch grid will be explained. On the touch screen 2 switches as start-stop buttons will be pointed, 4 momentary on-off buttons, one input for temperature measurement and one PWM output which is controlling by two momentary buttons. In Figure 5 a block diagram of the design device is shown.

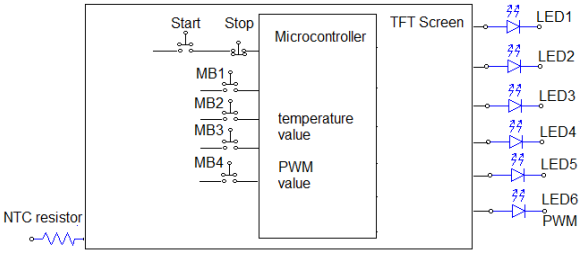


Figure 5. Block diagram of the design device

Description of functionality

LED1 is controled with start-stop buttons. Pressing start will turn on LED1. Pressing stop will turn off LED1. By pressing MB1, MB2, MB3, MB4, LED2, LED3, LED4 and LED5 are currently turned on sequentially. They remain on as long as the MB1, MB2, MB3, MB4 buttons are pressing. LED6 serves to control the generated PWM signal. By pressing MB3 the brightness of LED6 increases, and by pressing MB4 its brightness decreases. Respectively, the width of the generated PWM signal increases and decreases. The DS18B20 sensor was used to measure the temperature.

***a.)* Hardware components**

According to the description of functionality hardware components are used. Arduino uno and 2.4-inch TFT screen 320x240 Shield are used for the realization of the defined task.

TFT Touch Screen

In Figure 6 the investigated touch screen is shown. On the investigated touch screen on0 and off0 are start and stop buttons, on1, on2, on3 and on4 are buttons corresponding to MB1, MB2, MB3, MB4 from Figure 5. The Atmega 328 processor frequency is low. With the Arduino uno full-color TFT, LCDs are suitable to display simple data and commands. The used TFT controller cannot switch internal display RAM, so you cannot use the double buffer technique for animations but still you can re-draw small sections of screen, given the limitations of the Arduino uno - the bigger the display the worse the performance.

Figure 6. 2.4-inch TFT screen 320x240

If you want to take advantage of all its functionality (LCD + touch screen + SD card), only pins 0 and 1 (RX and TX, respectively) and pin 19 (A5) remain unused. If the SD card is not used, pins 10, 11, 12 and 13 are additionally available. With a suitable layout, some SPI devices could be connected even if the SD card is used.

DS18B20 temperature sensor

The DS18B20 digital thermometer provides 9-bit to 12-bit Celsius temperature measurements and has an alarm function with nonvolatile user-programmable upper and lower trigger points. Its functionality is described in [6].

Arduino uno and Arduino Shield

An arduino terminal is used to connect the arduino uno to the TFT display. On Figure 7a an arduino uno terminal shield is shown, and Figure 7b shows a connected arduino uno and terminal shield.

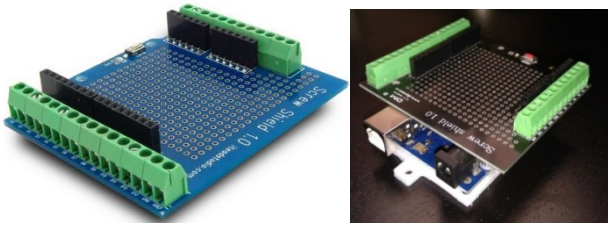


Figure 7.a.) Arduino uno terminal shield, b.) Connected arduino uno and terminal shield

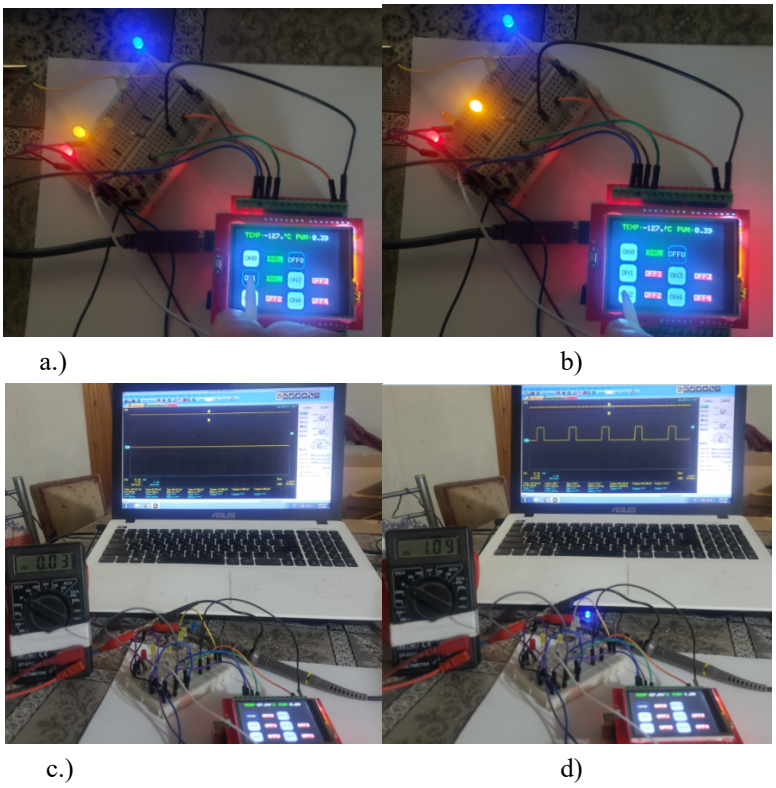
3.1 Results of Experimental Work

In Table I the connections between the arduino uno and the led diode LED1, LED2, LED3, LED4, LED5, LED6 and buttons START-STOP, MB1, MB2, MB3, MB4 are given.

Table I Connections between the arduino uno led diode and buttons

Pin on arduino	Buttons and led diode
12	Start-stop, LED1 (red)
13	MB1, LED2 (yelow)
10	MB2, LED3 (yelow)
0	MB3, LED4 (yelow)
1	MB4, LED5 (yelow)
11	PWMout LED6 (blue)
A5	Temperature sensor DS18B20

In Figure 8 with illustrations the verification of the work of the designed TFT is shown.



a.) b)

c.) d)

Figure 8. Verification of the work of the designed TFT: a.) Start is on, LED1 (red) is on, button MB1 is pressed and LED2 (yelow) is on, b.) Start is on, LED1 (red) is on, button MB2 is pressed and LED3 (yellow) is on, c.) PWM signal is off, (digital meter shows 0 V), LED6 (blue) is off, d.) PWM signal is 22 % (digital meter shows 1.02 V), LED6 (blue) is on to low brightness

From Figure 8a it can be seen that the start is on (red LED1 diode is on), and the pressed MB1 button turns on LED2 (yellow led diode. Also, LED6 is on, which shows that the PWM signal is at some value). From Figure 8b it can be seen that the start is on (red LED1 diode is on), and the pressed MB2 button turns on LED3 (yellow led diode). Also LED6 is on, which shows that the PWM signal is at some value). From Figure 8c it can be seen that the PWM signal is off, (digital meter shows 0 V), LED6 (blue) is off. In Figure 8d it can be seen that the PWM signal is with duty cycle 22 % (digital meter shows 1.02 V), LED6 (blue) is on to low brightness. In Figure 9 illustrations for the verification of the work of the designed TFT when PWM signal is 52 % and 92 % are shown.

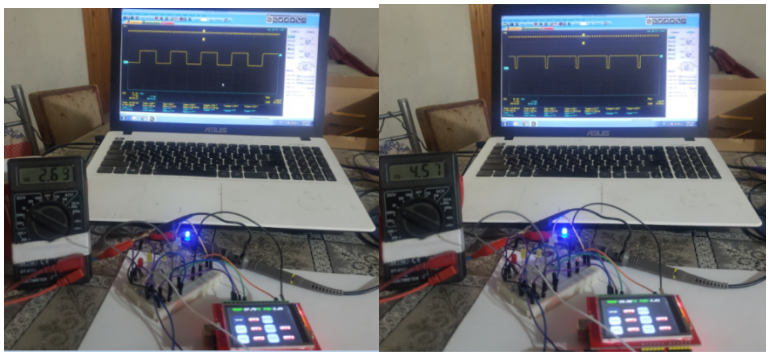


Figure 9. Verification of the work of the designed TFT: a.) when PWM signal is 52 % and b.) when PWM signal is 92 %

From Figure 9a it can be seen that LED6 is on and is at medium brightness, the digital meter shows a value of 2.69 V, the waveform of the oscillogram is with a duty cycle 52 %. From Figure 9b it can be seen that LED6 is on and is at high brightness, the digital meter shows a value of 4.57 V, the waveform of the oscillogram is with a duty cycle 92 %.

4. Conclusion

In this paper, a touch screen switch grid is designed and practically realized with theoretical analysis. The device enables switches placed directly on the screen, through connection with the microcontroller to controlling 6 diodes connected as actuators. In the realized device there is one start-stop and 4 momentary switches, two of which are implemented to generate the PWM signal. The verification of the functionality of the device is made by the illustrations given. The start-stop buttons serve to alternatively activate and deactivate a digital output of the microcomputer. This is illustrated in figures by turning on and off a red LED. Buttons MB1 and MB2 are momentary switches. By pressing them, the appropriate output from the microcomputer is turned on and the LED diodes LED2 and LED3 light up. Buttons MB3 and M4 are also momentary switches and activate LEDs LED4 and LED5. At the same time, with these buttons, a PWM signal is generated at the output of the microcomputer, and this is illustrated by the light intensity of the LED6. The touch screen visualizes the temperature value measured by the temperature sensor DS18B20.

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