Details of LCD’s and their methods used

The LCD stands for Liquid Crystal Diode are one of the most fascinating material systems in nature, having properties of liquids as well as of a solid crystal. The term liquid crystal refers to the fact that these compounds have a crystalline arrangement of molecules, yet they flow like a liquid. Liquid crystal displays do not emit or generate light, but rather alter externally generated illumination. Their ability to modulate light when electrical signal is applied has made them very useful in flat panel display technology.

There are two types of LCD’s are there

1. without touch LCD
2. with touch LCD
   a. resistive touch & b. capacitive touch.

without touch LCD

There are two types of liquid crystal display (LCD’s) according to the theory of operation
1. Dynamic scattering.
2. Field effect.

Construction of a liquid crystal display. It consists of two glass plates with a liquid crystal fluid in between. The back plate is coated with thin transparent layer of conductive material; whereas front plate has a photo etched conductive coating with seven segment pattern.

In the absence of the electrical signal, orientation order is maintained in the crystal allowing light to transmit. This makes LCD display clear. The current through the liquid crystal causes orientation order to collapse. The random orientation results scattering of light which light displays segment on a dark background.

Dynamic scattering

The first useful displays of this type were developed in the laboratories of Optel, Microma and Texas Instruments in 1967. The first application as display in a wrist watch was achieved by the Swiss 'Société des Garde Temps' in 1972. The construction of such a LCD will briefly be discussed.

The surrounding light goes through the front glass, a liquid crystal layer of 0.025 mm thickness, and is absorbed in the black back plate. On both glass plates, conductive transparent electrodes are attached. When a voltage between 10 and 20 volts is applied on the electrodes, the arrangement of the molecules is destroyed by the collisions of the moving ions, scattering the light and causing this part of the LCD to look darker than the rest of the display.

By replacing the black plate by a mirror it is possible to use the cell in a reflective mode. The segments which are not energized let the light go past, which will cause the mirror to reflect the light and compose the digits. The layer in the electric field between the electrodes scatters the light in all directions and looks dark. When no voltage at all is applied, the display is clear and the parts which are mirrored can be
seen. The latter display has been applied the most. The problems with this display existed in the necessity of a transformer to produce at least 15 to 20 Volts and the fact that the level of power dissipation became so high, that new batteries were needed every eight months.

The first dynamic scattering LCDs had a display produced by Optel or Microma.

**Optel**

The Optel Corporation of Princeton, New Jersey, USA, was founded in 1969 by RCA in pursuit of the development and sale of liquid crystal displays to the general public. The research was so expensive that it required three Swiss companies to participate financially. Therefore, in 1971, S.S.I.H., Landis & Gyr and Gebefina started to work together with Optel. Despite this co-operation, the project defaulted, resulting in Optec's bankruptcy on June 18th 1978.

**Microma**

Microma Universal of Cupertino Mountain View, California, USA, was a subsidiary of the Intel Corporation. The module display was produced by Hamlin of Lake Mills, Wisconsin. Twenty-five percent of the watches were returned to the factory for repair. The first modules contained two batteries, the latter ones only one. Starting in January 1973, Nepro becomes the exclusive distributor for Intel of the Microma LCD line in Europe. As Microma did not fulfill its contractual obligations, Nepro turned to IDS, a joint venture of General Electric and Solid State Scientific.

**Field effect.**

The twisted neumatic effect (*TN-effect*) is the main technology breakthrough that made displays practical. Unlike earlier displays, TN-cells did not require a current to flow for operation and used low operating voltages suitable for use with batteries. The introduction of TN-effect displays led to their rapid expansion in the display field, quickly pushing out other common technologies like light emitting diodes and electroluminescence from most electronics. By the 1990s, TN-effect LCDs were largely universal in portable electronics. This electro-optical effect is also called the Schadt-Helfrich effect.

The twisted neumatic effect is based on the precisely controlled realignment of liquid crystal molecules between different ordered molecular configurations under the action of an applied electric field. This is achieved with little power consumption and at low operating voltages.
Exploded view of a TN liquid crystal cell showing the states in an OFF state (left), and an ON state with voltage applied (right)

The illustrations to the right show both the OFF and the ON-state of a single picture element (pixel) of a twisted neumatic modulator liquid crystal display operating in the "normally white" mode, i.e., a mode in which light is transmitted when no electrical field is applied to the liquid crystal.

In the OFF state, i.e., when no electrical field is applied, a twisted configuration (aka helical structure or helix) of neumatic liquid crystal molecules is formed between two glass plates, G in the figure, which are separated by several spacers and coated with transparent electrodes, E₁ and E₂. The electrodes themselves are coated with alignment layers (not shown) that precisely twist the liquid crystal by 90° when no external field is present (left diagram). If a light source with the proper polarization (about half) shines on the front of the LCD, the light will pass through the first polarizer, P₂ and into the liquid crystal, where it is rotated by the helical structure. The light is then properly polarized to pass through the second polarizer, P₁, set at 90° to the first. The light then passes through the back of the cell and the image, I, appears transparent.

In the ON state, i.e., when a field is applied between the two electrodes, the crystal re-aligns itself with the external field (right diagram). This "breaks" the careful twist in the crystal and fails to re-orient the polarized light passing through the crystal. In this case the light is blocked by the rear polarizer, P₁, and the image, I, appears opaque. The amount of opacity can be controlled by varying the voltage. At voltages near the threshold, only some of the crystals will re-align, and the
display will be partially transparent. As the voltage is increased, more of the crystals will re-align until it becomes completely "switched". A voltage of about 1- V is required to make the crystal align itself with the field, and no current passes through the crystal itself. Thus the electrical power required for that action is very low.

To display information with a twisted neumatic liquid crystal, the transparent electrodes are structured by photo-lithography to form a matrix or other pattern of electrodes. Only one of the electrodes has to be patterned in this way, the other can remain continuous (common electrode). For low information content numerical and alpha-numerical TN-LCDs, like digital watches or calculators, segmented are sufficient. If more complex data or graphics information have to be displayed, a matrix arrangement of electrodes is used. Obviously, the voltage controlled addressing of matrix displays, such as in LCD-screens for computer-monitors or flat, is more complex than with segmented electrodes. These matrix LCDs necessitate integration of additional non-linear electronic elements into each picture element of the display (e.g. thin-film diodes, TFDs, or thin-film transistors, TFTs) in order to allow the addressing of individual picture elements without crosstalk (unintended activation of non-addressed pixels).

**Touch screen LCD's**

*LCD 4-WIRE RESISTIVE TOUCH DATA*

Touch-screen interfaces are effective in many information appliances, in personal digital assistants (PDAs), and as generic pointing devices for instrumentation and control applications. Getting the information from a touch screen into a microprocessor can be challenging. This page introduces the basics of how resistive touch screens work and how to best convert these analog inputs into usable digital data.

4-wire resistive Touch screen

A four-wire resistive touch screen panel consists of two flexible layers uniformly coated with a transparent resistive material and separated by an air gap. Electrodes placed along the edges of the layers provide a means for exciting and monitoring the touch screen.

*Block Diagram of Touch Screen interface.*
**Touch screen Controller/Digitizer**

When a position is measured on a 4-wire touch screen, voltage is applied across the screen in the Y direction; and a touch presses the layers together, where a voltage can be read from one of the X electrodes. The contact made as a result of the touch creates a voltage divider at that point, so the Y coordinate can be determined; the process then repeats with the X direction being driven, and a reading is taken from one of the Y electrodes. A touch-screen controller is simply an ADC that has built-in switches to control which electrodes are driven and which electrodes are used as the input to the ADC.

An Analog Devices AD7843 scans the X and Y axes and determines the unique voltage drop for each axis. The four electrodes for scanning are labeled X+, X-, Y+, and Y-. These electrodes are connected to the AD7843 touch screen controller and the touch sensor is scanned and the analog voltages read.

The four touch electrodes are connected to the inputs X+, X-, Y+, and Y- of the AD7843. A selected axis (X or Y) pair of electrodes is energized with a static voltage and the voltage of the positive electrode of the other pair in the 4 wire touch panel is measured. The sensed voltage is measured and converted to either an 8 bit or 12 bit resolution. A digital word representing the voltage at the contacting point on the touch panel is created and sent out via a high speed SPI serial interface.

Graphic LCD with Touch Screen

**Capacitive touch**

**Introduction**

The 78K0/Kx2-L is a low power 8-Bit MCU series designed to target small battery–powered systems and other applications where low power is needed. 78K0/Kx2-L family has onboard OP_AMP with all I/Os available to the user, which makes it possible to implement capacitive touch solution. There are other devices that have the same OP_AMP configuration like the 78K0/hx2 and 16-Bit 78K0R/Lx3 (-L) which can be found on our [website](#).  

**Principle of Capacitive Touch**
2-1 Theory:
The theory behind capacitive touch can be simply seen from the construction of the two parallel plate capacitor where in free space two conductors separated by a dielectric form a capacitor. Given the fact that the human body is conductive, inspired engineers to use this biological property that uses the effect of body capacitance to alter other conductor’s self capacitance.

2-2 Capacitance Measurement:
When we measure the capacitance in touch system we need to take into consideration the capacitance to ground of the conductive objects. The equivalent circuit can be seen as illustrated in fig-3- where the human finger and the electrode under measurement form a capacitor which lies in parallel to the other capacitors. Therefore the total capacitance is calculated from the following equation:

\[ C_x = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}} \]

Equation -2-

C1: Body capacitance in order of 100pF
C2: Sensor capacitance in order of few pF
C3: Detection system capacitance to ground in the order of 100pF
The main influence on the measured capacitance comes therefore from C2.

Fig-1-
2-3 Renesas Capacitance measurement Solution
There are many techniques to measure capacitance including direct measurement of the RC time constant, relaxation oscillator capacitance based, switched capacitors, charge transfer and many more. Renesas uses the onboard OPAMP to create astable multi-vibrator with the sensing element capacitance as the tuning element for the oscillator.
The circuit above as the name indicates swings between the rails and therefore the OPAMP output is either Vcc or 0V. The resistor network sets the positive input to the OPAMP to either 1/3Vcc or 2/3VCC respectively. The capacitor then charges and discharges between 1/3 and 2/3 of Vcc.

The voltage across a capacitor at any time can be formulated as:

Equation-3-

\[ V_c(t) = V_\infty - (V_\infty - V_{in}) e^{-\frac{t}{RfC}} \]

Let's consider the charging cycle: \( V_\infty = V_{cc} \) and \( V_{in} = \frac{1}{3}V_{cc} \)
Substitute the initial values in Equation-3:-

\[ V_c(t) = V_{cc} - \left( V_{cc} - \frac{1}{3}V_{cc} \right) e^{-\frac{t}{RfC}} \]

At half cycle when \( t = T/2 \)
With some manipulation the oscillation frequency can be obtained as:

\[
f = \frac{1}{2 \ln(2) * R_f * C_s}
\]

Equation-4-

The oscillator frequency obtained using the onboard oscillator can be seen in fig-3 below.

3- Hardware interfacing example:
The 78K0/Kx2-L has a maximum of 2 OPAMPs therefore to interface more than 2 capacitive sensors external multiplexers can be used.
The solution uses 7 I/Os in total to interface up to 8 capacitive switches and then 1 extra I/O for every additional 8 capacitive switches mainly for the enable input of the additional multiplexer. The selection bits and the common pins of the multiplexers are shared between all the multiplexers as it is illustrated in fig-5-:
The effect of a finger approaching the capacitive sensor is to change the oscillation frequency. As the human body adds capacitance, the frequency is reduced, and the software needs to measure this frequency change. There are mainly two methods to measure this frequency either by measuring the number of periods in a fixed amount of time or measure the time it takes for a fixed number of periods. This Renesas solution uses the second approach by measuring the pulses using an 8-Bit Timer as external event counter and the time is measured using 16-Bit Timer. The number of periods is set as the compare register for the 8-Bit Timer and when the interrupt occurs, the measurement is taken.
Capacitive touch sensor circuit using QT100 from siongboon.com

Touch sensor Circuit drawing from piclist.com

Simple Capacitive Touch Sensor Circuit from extremecircuit.net