Embedded Systems

Ch 7.
Display & Keyboard Interface

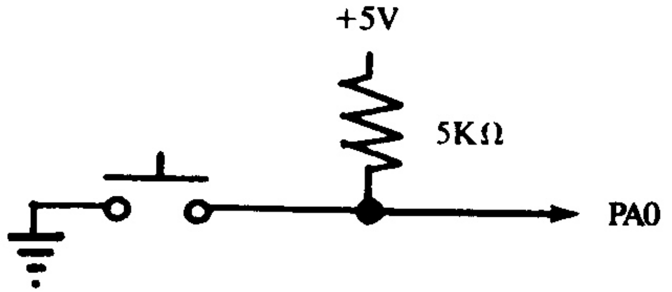
Byung Kook Kim
Dept of EECS
Korea Advanced Institute of Science and Technology

Overview

- *1. Keyboard Interface*
- *2. Display Interface*
- *3. LCD Display*
- *4. Bit Manipulation*

1. Keyboard Interface

- **A. Switch**
  - Two-position switch
    - Common device: Alone, in groups, and keyboards
    - Interfacing with pull-up resistor
      - Switch open: Out = Vcc
      - Switch closed: Out = GND



  - Three-position switch
    - Common, Normally open, Normally closed.
- Switch bounce
  - Just after the contact position is changed, there is a brief period during which the position of the switch is indefinite.
  - If the contacts are coming together, they may contact and then separate several times.

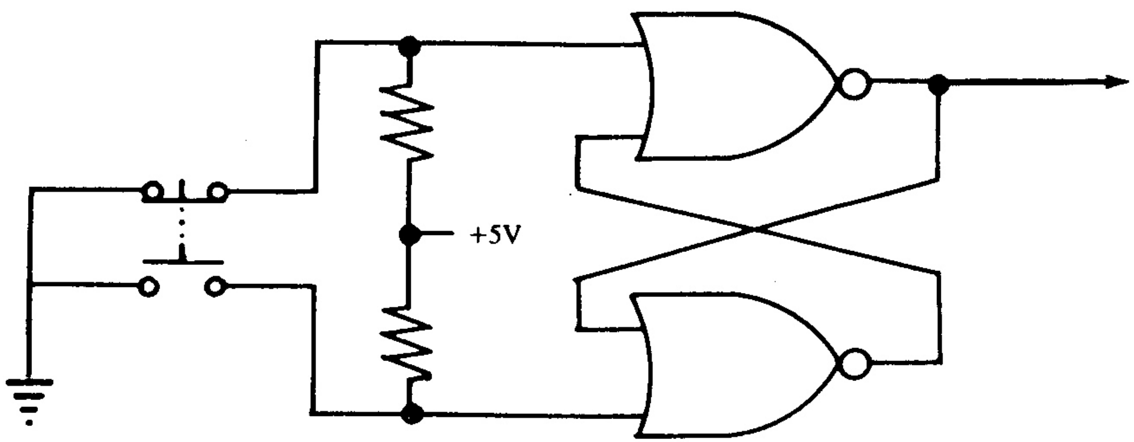
Keyboard Interface (II)

- Debouncing solution (I)
  - Delay
    - Test the switch both before and after the delay.
      - If they disagree, the switch is moving.
      - If they agree, the switch is probably in a stable position.
    - This delay is generally from 1 to about 20 ms.
      - Depending on the switch structure.
    - Delay routine:

```
Delay: sub #1, R7     ; Enter with delay count in R7
       bne delay      ; Keep counting until 0
       rts            ; Return from subroutine
```

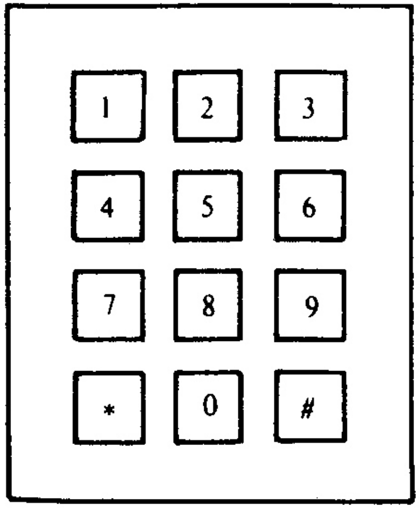
Keyboard Interface (III)

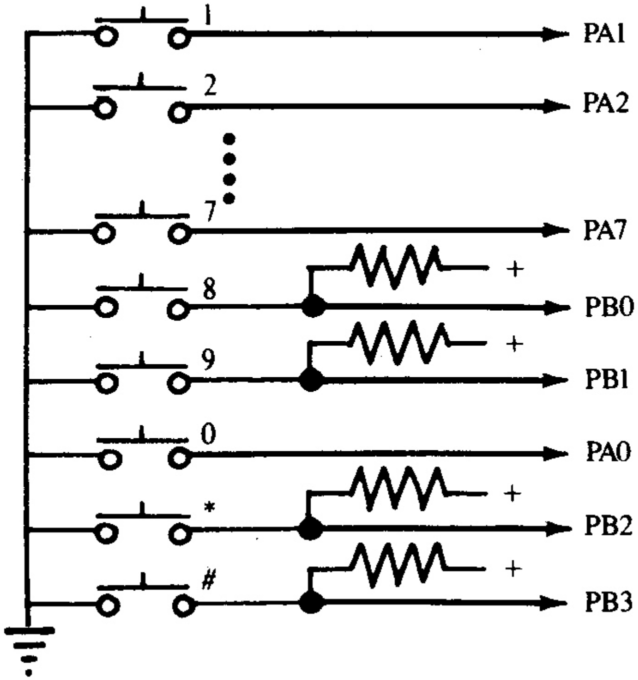
- Debouncing solution (II)
  - Hardware debouncing ->
    - Set-reset flip-flop with two NOR gates
    - Three-position switch
    - Assume that the bounces are not so terrible that the switch recontacts the side it already has left.



Keyboard Interface (IV)

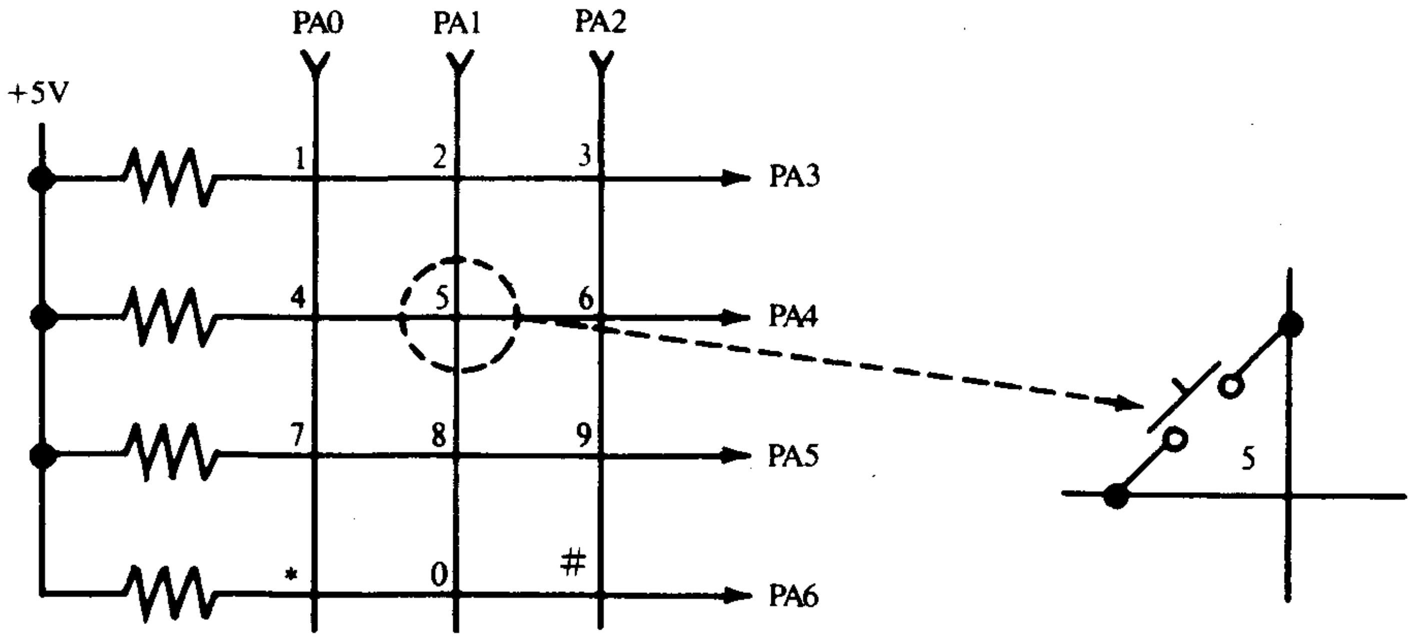
- **B. Telephone keyboard**
  - Standard telephone pushbutton keyboard ->
    - 12 buttons: 0 – 9, *, #
    - 12 parallel input bits are required.





Keyboard Interface (V)

- **C. Telephone keyboard grid**
  - Reduce wires: m*n switches using m+n wires
    - 12 switches with 4+3=7 wires
    - 128 switches with 9+8=17 wires!



Keyboard Interface (VI)

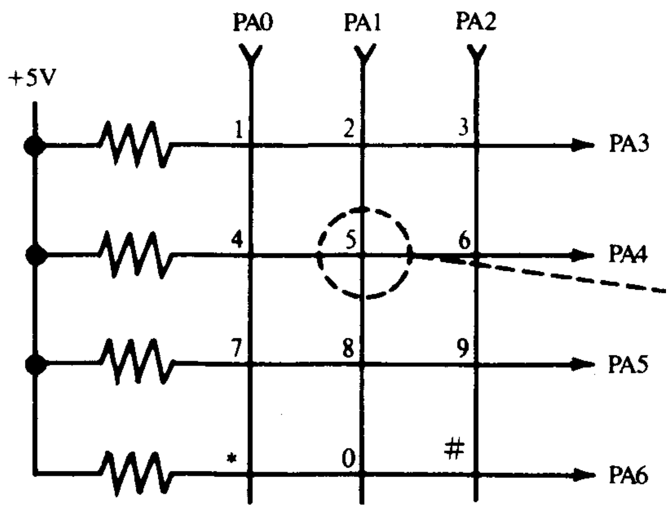
- Program for keyboard grid
  - Read one column at a time
    - Force vertical line to be low
    - Read horizontal lines.
  - Algorithm
    - Make PA2-0 = 011
    - Read horizontal lines. If there is a zero, a key is down in this column.
    - If not, PA2-0 = 101. If there is a zero, a key is down in this column.
    - If not, PA2-0 = 110. If there is a zero, a key is down in this column.
    - *Debouncing*: If a key is found down, save the code, delay, and repeat the reading process.
    - *False Key*: If the newly-read code does not match the old code, save the new code as the old code and go back to Step 1 for another try.
    - If the newly-read code does match the old code, go on to search table for the value of the key.

Keyboard Interface (VII)

- Codes for the keyboard grid

Key	PA6 - 0	Hex
0	0 1 1 1 1 0 1	3D
1	1 1 1 0 1 1 0	76
2	1 1 1 0 1 0 1	75
3	1 1 1 0 0 1 1	73
4	1 1 0 1 1 1 0	6E
5	1 1 0 1 1 0 1	6D
6	1 1 0 1 0 1 1	6B
7	1 0 1 1 1 1 0	5E
8	1 0 1 1 1 0 1	5D
9	1 0 1 1 0 1 1	5B
*	0 1 1 1 1 1 0	3E
#	0 1 1 1 0 1 1	3B

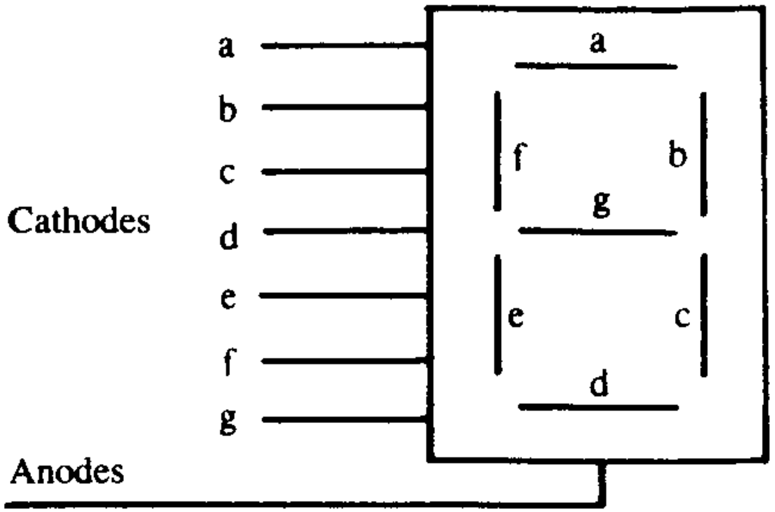
Keyboard Interface (VIII)



- Bidirectional keyboard grid algorithm
  - Advantages
    - Only two read operations without column scanning
  - Algorithm
    - Make PA2-0 output and PA6-3 as input
    - Force PA2-0 low and read to x.
    - Make PA6-3 output and PA2-0 input
    - Force PA6-3 low and read to y.
    - Combine x and y into one byte. The result is the same code as the table in slide 9.

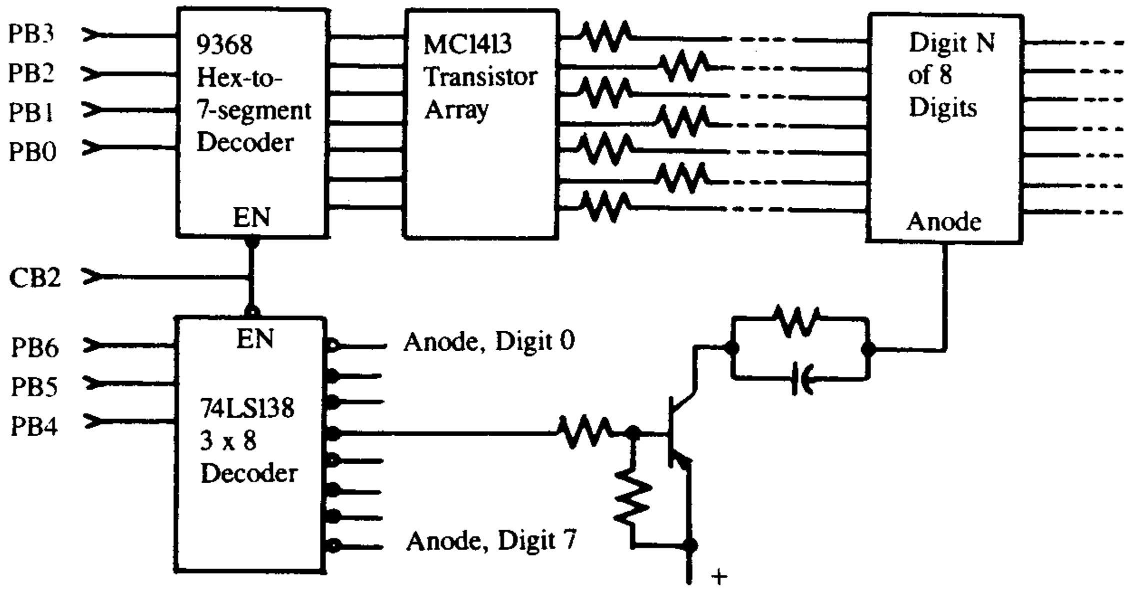
2. Display Interface

- **A. Display of digits**
  - Seven-segment display ->
  - 16-segment display
  - Array of dots
- Types
  - Common anode ->
  - Common cathode



Display Interface (II)

- Multiple-digit seven-segment display
  - Ex: 8 digits ->
    - 7 x 8 = 56 wires
    - 7 + 8 = 15 wires
    - 4 + 3 = 7 wires



Display Interface (III)

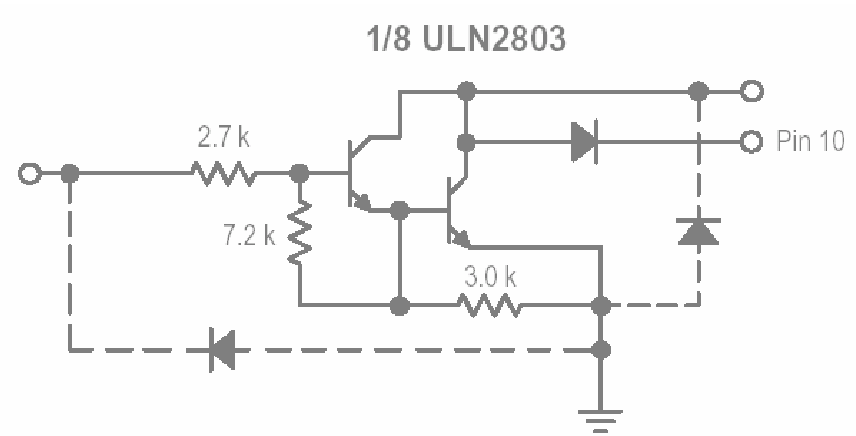
- Algorithm

```
Given c[i], i=0, 1, …, 7
For digit d=0, 1, …, 7
    Output digit selection d
    Output 7-segment display c[d]
    Delay
    Turn off 7-segment display
End of d
```

- Ghost elimination
  - Place turn-on and turn-off side by side after the move
    - (Include red lines as above).

Display Interface (IV)

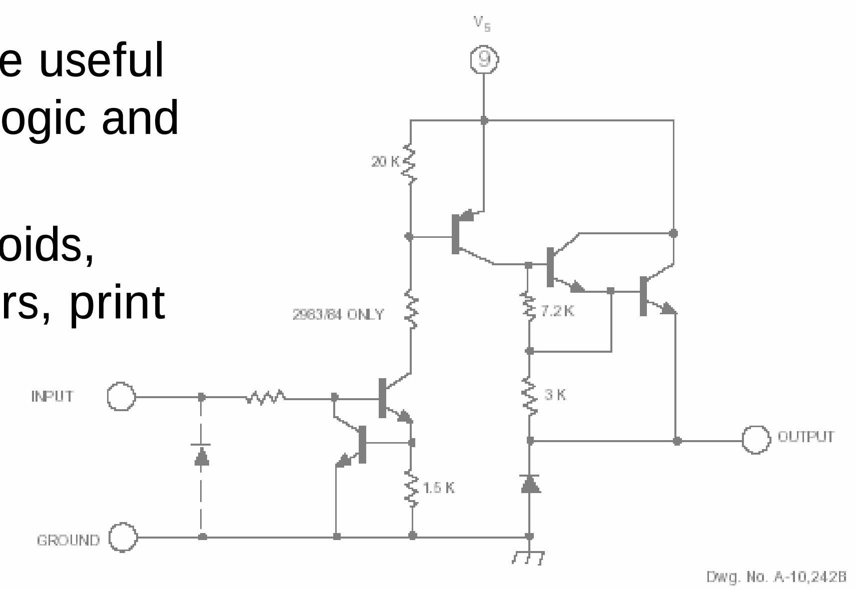
- Driver ICs - **ULN2803**
  - 8-bit 50V 500mA TTL-input NPN darlington driver.
  - The drivers need no power supply; the VDD pin is the common cathode of the eight integrated protection diodes.
  - The eight NPN Darlington connected transistors in this family of arrays are ideally suited for interfacing between low logic level digital circuitry (such as TTL, CMOS or PMOS/NMOS) and the higher current/voltage requirements of lamps, relays, printer hammers or other similar loads for a broad range of computer, industrial, and consumer applications.
  - All devices feature open–collector outputs and free wheeling clamp diodes for transient suppression.



Display Interface (V)

- Driver ICs – uDN2981
  - ***8-CHANNEL SOURCE DRIVERS***
  - Recommended for high-side switching applications that benefit from separate logic and load grounds, these devices encompass load supply voltages to 80 V and output currents to -500 mA.
  - These 8-channel source drivers are useful for interfacing between low-level logic and high-current loads.
  - Typical loads include relays, solenoids, lamps, stepper and/or servo motors, print hammers, and LEDs.

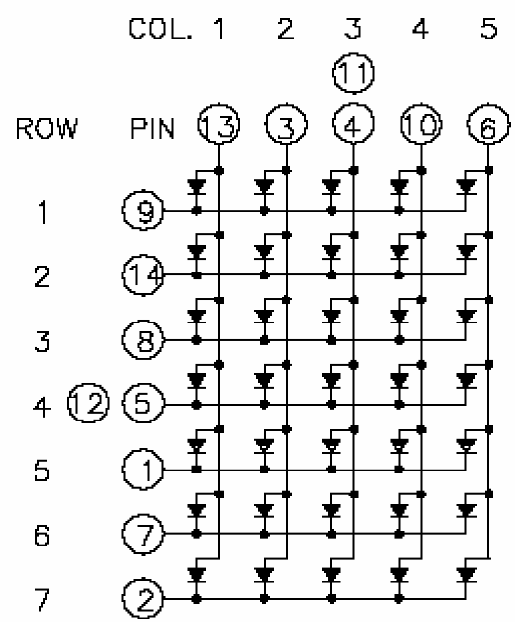
One of Eight Drivers



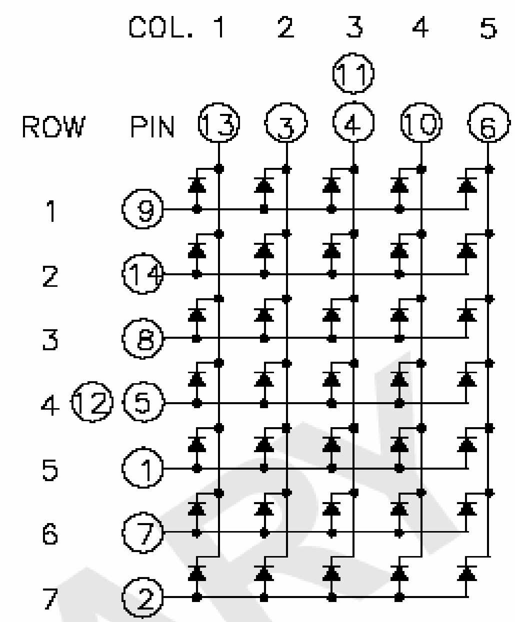
Display Interface (VI)

- **B. Dot matrix display**
  - English 1 x 20 characters
    - 7 x 160 dot matrix display
  - Korean 1 x 20 characters
    - 16 x 320 dot matrix display

A.LTP-2057A



B.LTP-2157A



Display Interface (VII)

- **C. Color display**
  - Red & Green LED: red, green, yellow
  - Color LED: red, green, blue LEDs
  - 1024 x 768 True color
    - 1024 x 768 x 3 bytes for RGB

3. LCD Display

- **LCD (liquid crystal display)**
  - Advantages
    - Thinner and lighter
    - Draw much less power than cathode ray tubes (CRTs)
  - LCD History
    - Liquid crystals were first discovered in 1888, by Austrian botanist **Friedrich Reinitzer**.
    - Reinitzer observed that when he melted a curious cholesterol-like substance (**cholesteryl benzoate**), it first became a cloudy liquid and then cleared up as its temperature rose.
    - Upon cooling, the liquid turned blue before finally crystallizing.
    - Eighty years passed before **RCA** made the first experimental LCD in 1968.
    - Since then, LCD manufacturers have steadily developed ingenious variations and improvements on the technology, taking the LCD to amazing levels of technical complexity.

LCD Display (II)

- Principles on LCD
  - Liquid crystals are closer to a liquid state than a solid.
    - It takes a fair amount of heat to change a suitable substance from a solid into a liquid crystal, and it only takes a little more heat to turn that same liquid crystal into a real liquid.
    - Very sensitive to **temperature:** used to make thermometers and mood rings.
    - A laptop computer display may act funny in cold weather or during a hot day at the beach!
  - Depending on the temperature and particular nature of a substance, liquid crystals can be in one of several distinct phases.
    - **Nematic phase:** Affected by **electric current**.
    - A particular sort of nematic liquid crystal, called **twisted nematics** (TN), is naturally twisted.
    - Applying an electric current to these liquid crystals will untwist them to varying degrees, depending on the current's voltage.
    - LCDs use these liquid crystals because they react predictably to electric current in such a way as to control light passage.

LCD Display (III)

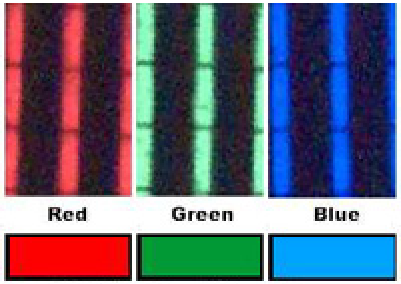
- LCD Systems
  - **Common-plane-based** LCDs
    - Good for simple displays that need to show the same information over and over again.
    - Watches and microwave timers
  - **Passive-matrix** LCDs (TN, STN LCDs)
    - Use a simple grid to supply the charge to a particular pixel on the display.
    - Two glass layers called **substrates**.
      - One substrate is given columns and the other is given rows made from a transparent conductive material. This is usually **indium-tin oxide**.
    - The rows or columns are connected to **integrated circuits** that control when a charge is sent down a particular column or row.
    - The liquid crystal material is sandwiched between the two glass substrates, and a polarizing film is added to the outer side of each substrate.
    - To turn on a pixel, the integrated circuit sends a charge down the correct column of one substrate and a ground activated on the correct row of the other.
    - The row and column **intersect** at the designated pixel, and that delivers the voltage to untwist the liquid crystals at that pixel.

LCD Display (IV)

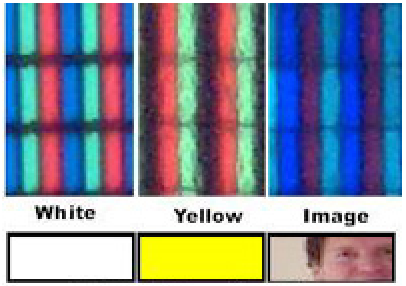
- LCD Systems (II)
  - Drawbacks of the passive-matrix system
    - **Slow response time** and **imprecise voltage control**.
  - **Active-matrix** LCDs
    - Depend on **thin film transistors** (TFT).
    - TFTs are tiny switching transistors and capacitors.
    - They are arranged in a matrix on a glass substrate.
    - To address a particular pixel, the proper row is switched on, and then a charge is sent down the correct column.
    - Since all of the other rows that the column intersects are turned off, only the capacitor at the designated pixel receives a charge.
    - The capacitor is able to hold the charge until the next refresh cycle.
    - And if we carefully control the amount of voltage supplied to a crystal, we can make it untwist only enough to allow some light through.
    - By doing this in very exact, very small increments, LCDs can create a **gray scale**.
    - Most displays today offer 256 levels of brightness per pixel.

LCD Display (V)

- LCD Color
  - Must have **three subpixels** with red, green and blue color filters to create each color pixel.
  - Through the careful control and variation of the voltage applied, the intensity of each subpixel can range over **256 shades**.
  - Combining the subpixels produces a possible palette of **16.8 million colors** (256 shades of red x 256 shades of green x 256 shades of blue).
  - Enormous number of transistors.
    - Ex: A typical laptop computer supports resolutions up to 1,024x768.
    - 1,024 columns by 768 rows by 3 subpixels, we get 2,359,296 transistors etched onto the glass!
    - If there is a problem with any of these transistors, it creates a "bad pixel" on the display.



60 x Magnification



60 x Magnification

4. Bit Manipulation

- Changing i-th bit
  - var = var EOR (1 << i);
- Clear lower half-byte
  - var = var & 0xf0;
- Combine bit groups
  - var = (x & 0xff00) | (y & 0xff);
- Swap half-bytes
  - ROL.B #4, R0
- Binary to BCD (2 digits)
  - Bcd = ((bin/10)<<4) | (bin%10);
- BCD to binary (2 digits)
  - Bin = (bcd>>4)*10 + (bcd&0x0f);

References

- Keyboard interface, display interface, and bit manipulation
  - William Eccles, “Microprocessor systems – A 16-bit approach”, Addison Wesley, 1985.

- Display interface & LCD display
  - Search Internet