

FURTHER READING

- Raymond, Eric S. *The Cathedral and The Bazaar: Musings on Linux and Open Source by an Accidental Revolutionary*. Beijing, and Cambridge, Mass.: O'Reilly, 1999.
- Welsh, Matt. *The Best of Linux Distributions*. Petaluma, Calif.: Linux Press, 1999.
- Young, Robert, and Wendy Goldman Rohm. *Under the Radar: How Red Hat Changed the Software Business—and Took Microsoft by Surprise*. Scottsdale, Ariz.: Coriolis Group, 1999.

—Dan Orzech

Liquid-Crystal Display

A liquid-crystal display (LCD) is a flat screen used in laptop computers and increasingly also as a substitute for **cathode-ray tube** (CRT) monitors. Previously, the main disadvantage of an LCD screen compared with a CRT monitor was its smaller size and lower contrast. The new generation of LCD screens, however, is as large as office CRT screens and offers good luminance factors. LCDs are still more expensive than traditional monitors, but the prices are falling every year.

LCDs work by exploiting a property of light, its *polarization angle*. Think of light as a wave traveling forward and oscillating in a plane perpendicular to the direction of travel. The angle of the plane with respect to the travel direction is the polarization angle. If you look straight at this page, the light reflected from the book can have a vertical polarization angle, a horizontal polarization angle, or any angle in between. Sunlight normally includes waves with all polarization angles, so that the waves reflected from this book are reaching your eyes with all polarization directions.

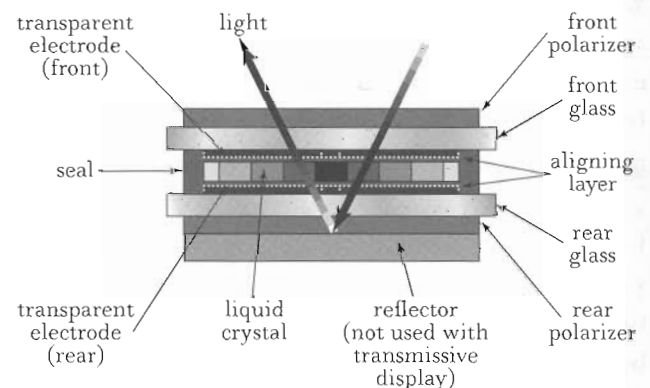
Polarized light can be filtered. A filter can be thought of as a grid that stops all light perpendicular to the grid direction and lets through all light with the same polarization angle as the grid direction. Dark glasses are sometimes built using Polaroid filters that exploit this effect.

An LCD screen is built like a sandwich: a liquid crystal is placed between two glass plates. First discovered in 1888, liquid crystals are transparent solids made of molecules that can rotate in place. These materials are crystals because the arrangement of the molecules is regular, they are “liquid” because the

molecules can be aligned, switching on a small electric field. When no field is applied, the arrangement of the molecules is such that every layer slowly turns the polarization angle of the incident light wave until the final angle has been rotated 90° with respect to the angle of incidence.

The structure of an LCD panel is shown in the figure. A front polarizer lets only light through with a vertical polarization angle. The rear polarizer has the same polarization direction as the front polarizer. The incident light ray goes through the front polarizer, the front glass plate, and the liquid crystal. Remember that the liquid crystal turns the angle of polarization of the light by 90°, so that when it reaches the rear polarizer it is absorbed and no light is reflected back. Applying a small electric field, however, the liquid-crystal molecules align in such a way that the light wave is not twisted, and when it reaches the rear filter it goes through, is reflected back by the reflector layer, and goes back to the eye of the user. The user sees a white point on the screen.

Each pixel on the screen is controlled by a grid of electric connections. Where a white point is needed, a small current is applied. Black pixels are not activated and absorb light. In color LCD screens, there are pixels that look red, blue, and green. A color filter is placed just before the crystal pixel, so that only red, blue, or green reflected light reaches the eye of the user. The pixels are so small and so close together that the user does not realize that there are actually three color grids on the screen, working in conjunction. This is the same technique as that used in television sets.



Structure of a liquid-crystal display.

By providing the screen with a backlight panel instead of reflecting just the incidental light, light can be produced in order to provide more brilliant images. Small LCD displays for watches or personal assistants just reflect incidental light. LCD screens for desktop computers have powerful backlight panels. Obviously, the latter consume more energy.

Thin-film **transistor** LCD (TFT-LCD) screens are arrangements similar to the one described above, in which a transistor is placed in the glass substrate to drive the electric field needed for each pixel. The transistors are so small and thin (“thin film”) that they are not visible for the user. Each transistor can be selected and driven individually using an *active matrix arrangement*. The response time of the transistors is so short that now LCD screens can be used also for video images. Previous generations of LCD screens could not display them, because the time needed to adjust the liquid crystal was too large.

LCD screens usually have a problem with the viewing angle. Since the direction of the crystal molecules is adjusted for users viewing the screen from the front, users viewing the screen from the side are actually looking through several pixel columns, and the polarization angle is not the optimal one. Light will be blocked and the image on the screen is not visible.

FURTHER READING

- Friedman, Peter S., ed. *Advanced Flat Panel Display Technologies*: 7–8 Feb. 1994, San Jose, Calif. Bellingham, Wash.: SPIE, 1994.
- Yeh, Pochi, and Clair Gu. *Optics of Liquid Crystal Displays*. New York: Wiley, 1999.

—Raúl Rojas

LISP

LISP, an acronym for List Processing Language, is a high-level programming language developed by **John McCarthy** (1927–) at the Massachusetts Institute of Technology (MIT) in the late 1950s and early 1960s. LISP is one of the oldest programming languages and is still very popular for **artificial intelligence** (AI) applications.

LISP is a functional language, which means that computations are performed by defining functions and

applying them to data and to other functions. Each function application requires a set of parentheses—extensive programs tend to end in long strings of closing parentheses. The main data structures in LISP are lists, which can contain atomic elements or other lists. Nested lists provide a representation for trees. LISP programs themselves are also lists. Therefore, it is fairly easy to write LISP programs that process other LISP programs. This is LISP’s main difference from languages such as **Fortran** and **Pascal**, which are not geared toward this kind of reflective computing.

At the 1955 Dartmouth Summer Research Project on Artificial Intelligence, a seminal conference in the history of AI, McCarthy formulated his thoughts about a new programming language and the line of research he intended to follow: “It therefore seems to be desirable,” he wrote, “to attempt to construct an artificial language which a computer can be programmed to use on problems and self-reference.... I hope to try to formulate a language having these properties...with the hope that using this language it will be possible to program a machine to learn to play games well and do other tasks.” McCarthy’s first approach was extending Fortran with list processing functions, but very soon he was developing an entirely new language. Looking for a way to describe a universal function capable of evaluating any other function, he finally hit on the idea of using list processing, the functional notation, and list processing instructions. Some of these commands, such as CAR (take the first element of a list) and CDR (take the rest of a list by deleting the first element), took their names from similar assembler instructions in IBM machines. The canonical version of LISP was defined in 1962 by McCarthy in his book about LISP 1.5.

Mac-Lisp, a version of LISP written at MIT in the late 1960s for the PDP-10 computer, became very popular and contributed to the dissemination of the language. However, LISP was still much slower than other, more conventional languages—thus the idea arose to build LISP machines, to lower the semantic gap between the **software** and **hardware**. In the early 1980s, several companies were formed that tried to build these machines; the most successful of them was Symbolics Inc., which stayed in business almost 10