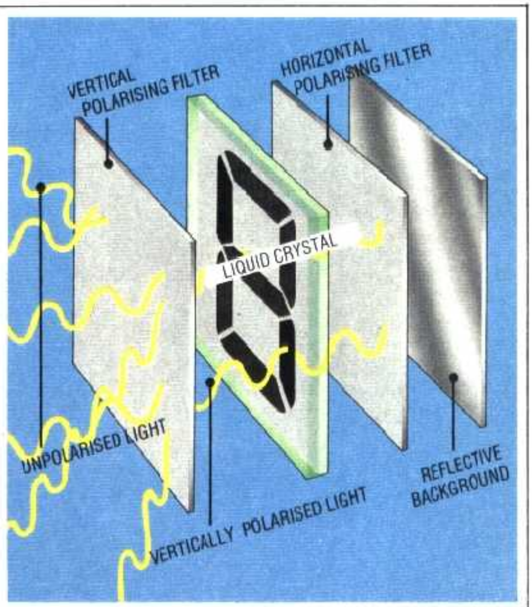
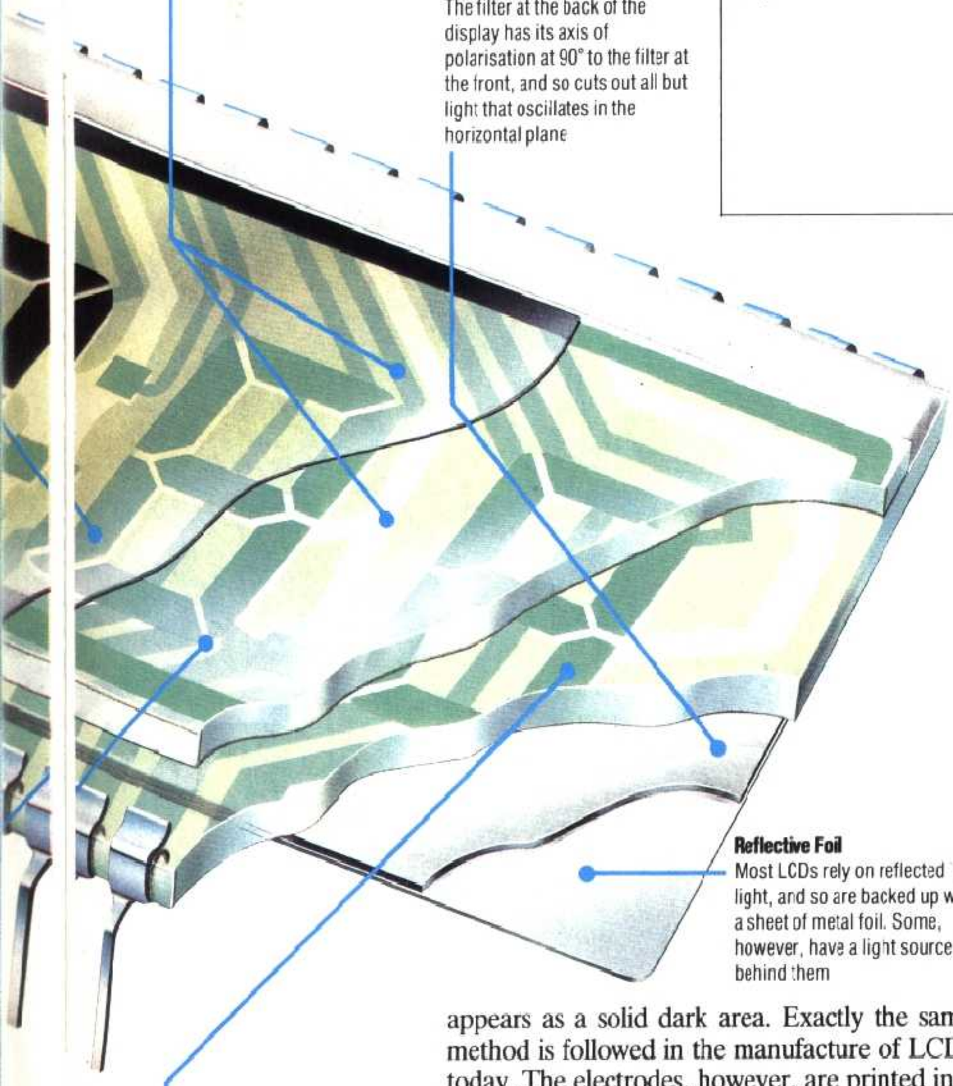
Polarisation
The filter at the front of an LCD only allows rays of light that have the electromagnetic oscillation vertically oriented to pass through it. The liquid crystal then turns the 'polarisation' through 90°, allowing it to pass through the rear (horizontal) filter and be reflected back. When a segment of the LCD is energised, it ceases to rotate the polarisation, resulting in a black image





Connection Paths
Each electrode is connected to its driving circuit by means of an almost invisible deposit of conducting ink on the surface of either the back or the front glass

Horizontal Polarising Filter
The filter at the back of the display has its axis of polarisation at 90° to the filter at the front, and so cuts out all but light that oscillates in the horizontal plane

Reflective Foil
Most LCDs rely on reflected light, and so are backed up with a sheet of metal foil. Some, however, have a light source behind them

Positive Electrodes
In this representation of the characters, each component is separate and individually addressable by the driver circuits

appears as a solid dark area. Exactly the same method is followed in the manufacture of LCDs today. The electrodes, however, are printed in a clear, colourless ink onto the surface of the glass and dry to near-invisibility.

Because of the requirement to produce a variety of characters from the same matrix, the original method — short bars combining to make angular characters — is still used, though dot matrix LCDs are becoming increasingly common. Because each dot in the matrix is individually addressable, the graphics capabilities are quite advanced: both continuous forms and conventional graphics characters can be produced.

It is theoretically possible to use dot matrix-addressed LCDs to act as the screen for broadcast television receivers, as well as monitors for use with computers. The main drawback to this is the lack of variability in the contrast. This was one of the problems explored during the development of the various flat screen televisions now becoming available. The size of the individual elements in the matrix needs to be reduced to something approaching that of a pixel on a cathode ray tube in order to achieve acceptable resolution. Another possibility would require the use of a number of LCDs sandwiched together and operating simultaneously. This method is currently used for the display of complex information where space is limited.

The response time of a high quality LCD at normal operating temperature (20°C/68°F) is about 70 milliseconds for the rise from neutral to black, and a further 80 milliseconds for the fall back to neutrality. This total of 150 milliseconds compares very unfavourably with the cathode ray tube's response of 0.00025 milliseconds. However, the LCD has a number of advantages. We have already discussed its compact size, but its low power consumption is perhaps the most significant advantage. A typical LCD consumes as little as 10 microwatts per square centimetre of the display.

There is one very interesting effect of varying the voltage passed through a liquid crystal. The tilt of the molecules is increased and decreased according to the voltage that is applied. Epson, for example, use this to very good effect in the HX-20 portable computer, by giving the display a viewing angle adjustment.

One further advantage is apparent in conditions of strong sunlight. The contrast of a cathode ray tube display is severely diminished in such circumstances, but because liquid crystals are perceived by the *absence* of light reflected from them, LCDs appear to become more contrasting and thus more readable as external light increases.

Although still only a decade old, LCD technology has already made significant inroads into markets traditionally reserved for cathode ray tubes. As the requirements of micro-miniaturisation become greater, it is expected that this technology will develop still further.