DISPLAYS— the state of the art

Dramatic developments are currently underway in both analogue and digital displays — ETI's special correspondent Associate Professor Peter Sydenham describes the present state of the art.

DURING the past few years digital displays have often been specified for applications where their analogue equivalents would have been more suitable. Now though, common sense is beginning to prevail. Analogue displays are gradually regaining ground as it becomes clear that they are more suitable for trend and other dynamic observations. Nevertheless many of today's analogue displays use digital techniques internally.

Rotating pointers, bar-graphs and similar analogue visual effects are now being developed for use in the automotive industry. Large-scale production prototype systems are already undergoing trials in cars. From this area of development it is logical to expect these new forms of analogue display to find their way into other applications. Now that most of the development has been completed the costs should be low. The consequence is that they will be introduced very rapidly into general use.

CHOICE OF DISPLAY

Choosing a display can be quite a task because many options exist.

Factors of key importance relate to the appearance of the display as seen by the user, reliability, ease of servicing, and power consumption.

Of particular importance is the 'price to use'. This can greatly exceed the cost price because of the costs of power supply, mounting, wiring, and possible connectors. It is also important that at least two sources of supply are available.

Another factor to consider is the special characteristics of a display. Each has some good and some bad characteristics. For example a liquid crystal display is fine where ambient light exists but needs auxilliary illumination in low light conditions. LED's on the other hand are best seen in the dark — they need to be very bright to be seen in full sunlight.

It is also important to assess if the device is really fully developed. Many new products reach the marketplace before they have been fully tested. Today a new solid-state product can be realised and marketed in a matter of a year but it is not possible to test it for the whole of that time. The tens of thousands of hours life that may be postulated by the manufacturer is often merely conjecture. Liquid crystal displays were one example. No user wants to be part of a test programme . . . especially if he's paying for the privilege. New is not necessarily best!

The main display contenders are currently LED's, gas discharge tubes, cathode ray tubes, liquid crystals, and the fast-emerging electroluminescent panels.

The time-honoured filament lamps continue and need no further comment except to say that they are being replaced in small power displays by the more up-to-date devices.

LEDS

LED's emerged first as single element light sources of rather low brightness and in red only. Today they are available in brighter forms and of many different optical styles providing diffusing effects, wider angles of viewing and generally greater utility. Present day technology can provide 50 um square elements of which 300-600 may be integrated into a matrix. Such LEDs are available with light output sufficient for aircraft instrumentation

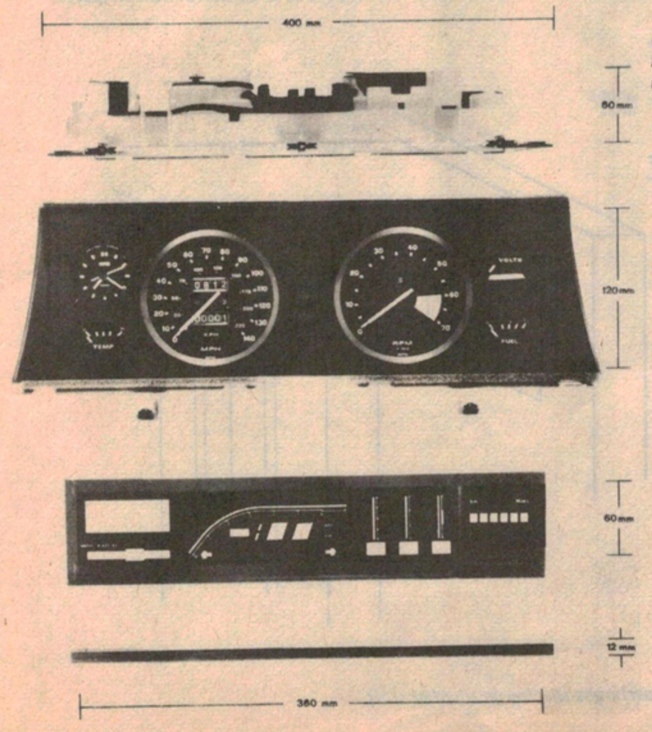


Fig. 1 (left). The conventional mechanical instrument panel (upper) contains 430 parts and is much bigger than the 35-part electroluminescent solid-state display (lower).

Fig. 2. Comparison of the display technologies now in vogue.

		Optimum Number of Bits
Tungsten Filaments		1 - 20
Light Emitting Diodes	LED	1 - 30
Cathode Ray Tubes	CRT	10K - 250K
Gas Discharge (Plasma Panels)		30 - 5K
AC or DC Electroluminescence	DCEL	30 - 3K
Liquid Crystal Display	LCD	5 - 200
Electrochromic (liquid or solid)		5 - 200
Electrophoretic		5 - 200
Vacuum Flourescent	VAC.FL.	10 - 100

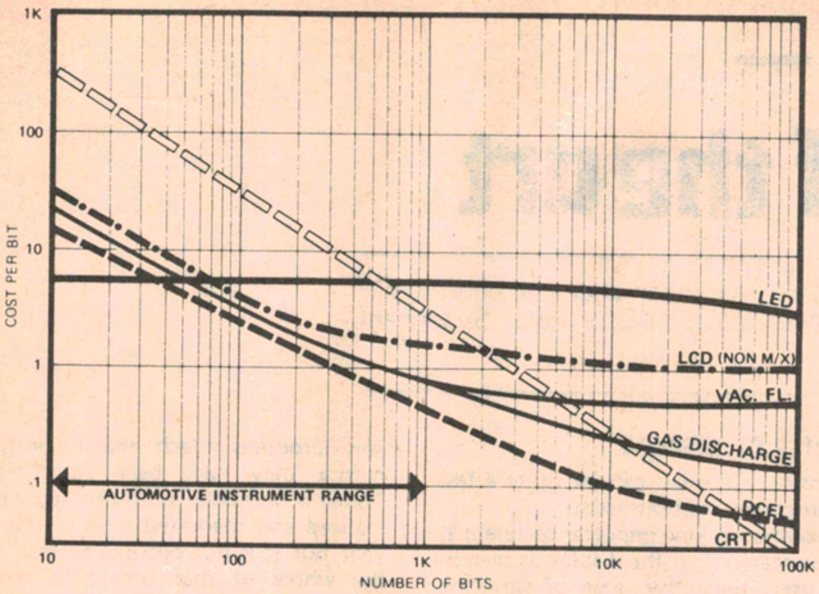


Fig. 3. Comparison of the cost per bit of the various display options.

(10^5 Lux) and can be made to full MIL specifications including operation over a temperature range of $-55°C$ to $125°C$.

They are available in colours ranging from red (the most common and cheapest) through yellow, green, orange and violet. Blue LEDs have been made but appear to lack a large enough market to enable them to be produced at a commerically attractive price.

The reliability of LED's is variously claimed to be from 10^4 to 10^9 hours. There is a suggestion (based on evidence from large-scale users) that price wars have tempted makers to reduce reliability. Reject rates as high as 20% are said to be experienced by some buyers.

LED's are fast operating: typical rise times are 10 - 50 ns. They are offered in pcb packages, in larger metal packages suitable for sealing and in more-expensive-still ceramic packages.

The ready ease with which they can be assembled into lines, circles, matrices and other graphical forms enables them to be used in analogue displays.

LED's are not necessarily the best choice for all displays. Figure 2 compares various displays on the basis of the optimum number of bits for each alternative. It can be seen that LEDs are restricted to applications where the type of display requires only a small number of bits. Electroluminescent panels (discussed below) are more suitable where the application calls for the use of many bits.

Another factor is the cost per bit to manufacture. Figure 3 compares this variable for the various types of displays. The LED does not compare well for applications requiring over 100 bits. On this basis the CRT is way ahead. As yet it is not even remotely matched by any solid-state technique. The CRT's main drawback is that it is bulky and fragile compared with most other types of display.

GAS DISCHARGE TUBES

Gas discharge tubes were the first displays that could reasonably be regarded as versatile. Many older readers will recollect the Dekatron counter tubes of the 1950's in which 'dots' moved circumferentially in a scale of ten. A later development incorporated grids placed behind one another in a single glass envelope in what was generally called the Nixie tube. Their main disadvantage for use with solid-state circuits was their need for a 170 volt supply.

With the introduction of solid-state displays it might be thought that gas discharge tubes would have been supplanted. This has not happened so far. Indeed indications are that they will be used for a considerable time yet. Their brightness and large size are still strong advantages.

Gas discharge tubes are made in many forms. These include low profile, alpha-numeric, bar-graph, special purpose graphical displays, and still in the research and development stage, are phase addressed matrix co-planar units which use thick film manufacturing techniques.

It is possible to construct gas-discharge cells so that a particular cell is set to strike and erase at different discrete voltage levels. Thus, increasing the voltage level to a line of adjacent cells will produce a bar-graph effect. Once struck, the cells latch on exhibiting a bistable storage characteristic.

Cross-bar arrangements of grids (as shown in Fig 4) enable 'dot' discharges to be established at the junction of any two selected bars. Thick-film replication methods are used to manufacture the units.

The colour of discharge tubes can be finely tuned to just about any wavelength. This is done by adding an appropriate phosphor to the cell during manufacture. White and blue remain difficult to produce.

A phase-addressed technique has been developed to reduce the number of leads otherwise needed to connect all matrix positions to external circuits.

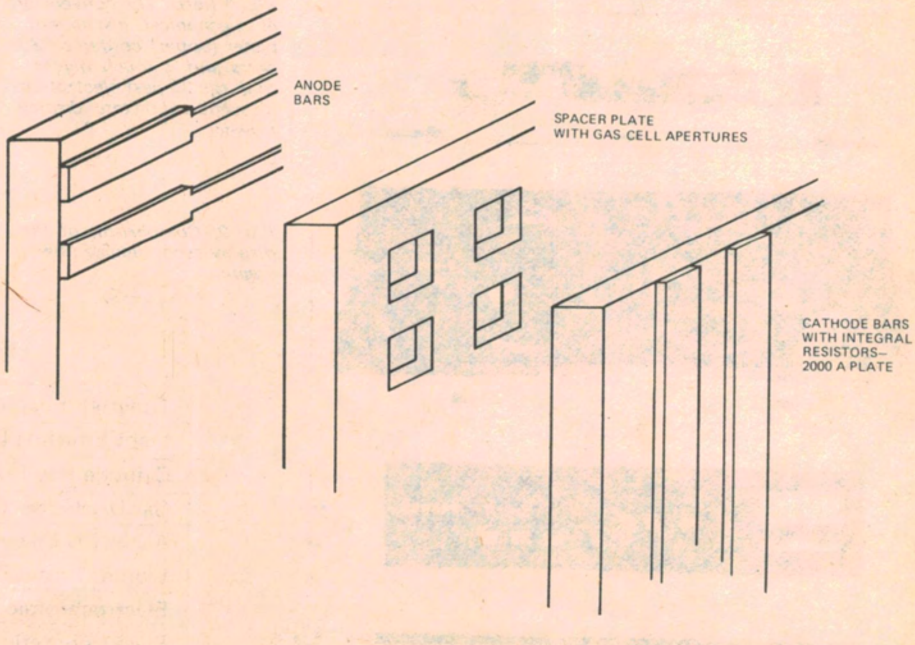


Fig. 4. Construction of dot-matrix gas-discharge display unit.

Gas discharge tubes are still, and will remain, a strong contender in the choice of a display. Figure 2 illustrates this well.

CATHODE RAY TUBES

A CRT screen of good quality and having a good linear scanning system can accomodate a display of 1000 by 1000 elements. The full range of colours is available as well as an intensity scale having perhaps 200 levels. Cost per element is very low but size and fragility go against the CRT in many applications. Eventually, as matrix manufacturing methods become more developed, the CRT's thin flat digital equivalent will become a serious rival. At present (1978) though the CRT has no rivals for displays requiring large numbers of bits.

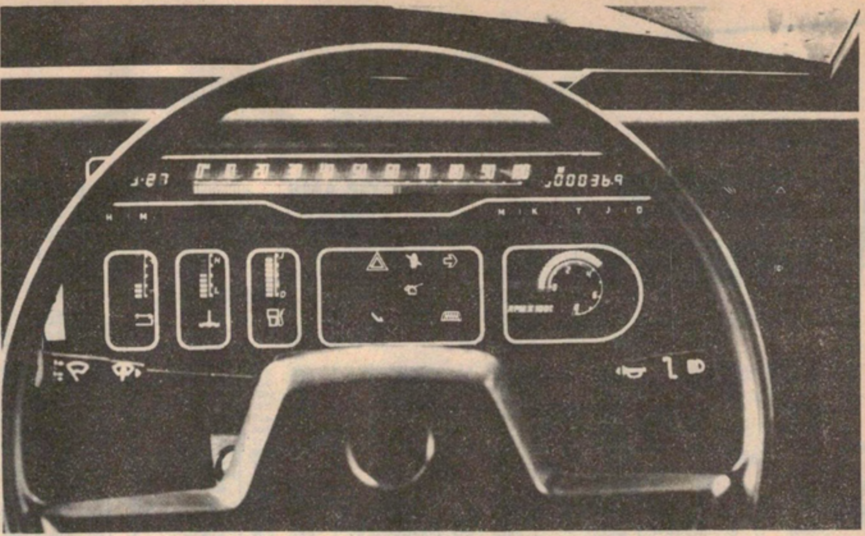


Fig. 6. On-vehicle electroluminescent display dash panel (Smiths Industries).

LIQUID CRYSTAL DISPLAYS

In many ways LCD's got off to a start less worthy than they deserved. Reliability was variable: many failed rapidly whilst others did very well. Failure of an individual display within a batch could vary from almost immediate through to years.

The second generation of LCD's has shown itself to be very much better if made by more controlled procedures and with better materials. Figures such as 90 000 hours to reach a 2% cumulative failure have been claimed for twisted-nematic LCD displays.

A key factor has been the realisation that a non-zero dc cell level rapidly degraded the cell. That restriction was originally controlled by the use of ac bias but now zero level dc working has been devised.

Initial commercial incentive came from watch manufacturers, but now researchers are seeking ways of building much larger panels — 150 mm square for example. Such large sizes pose manufacturing problems for the glass enclosing the LCD material must be flat to within a mere 10 um.

Manufacturing methods are constantly being improved. The glass front seal has been greatly changed . . . that was a cause of many premature failures. Purer LCD material and improved stability with temperature and humidity have also improved.

Matrix units are being investigated but, as with all such units, connecting problems remain. Some LCD's currently being released have shift registers integrated onto the display. This trend may become common practice, for the user does not wish to connect any more than the minimum of leads from the drive circuits to the display.

In general LCD manufacturers suggest that their products are best suited for applications requiring a portable display. The current LCD's are certainly much better than the first generation and their low power consumption gives them a firm place in the display range.

ELECTROLUMINESCENT DISPLAY PANELS

Electroluminescent devices are basically just a layer of special paint between two pieces of glass.

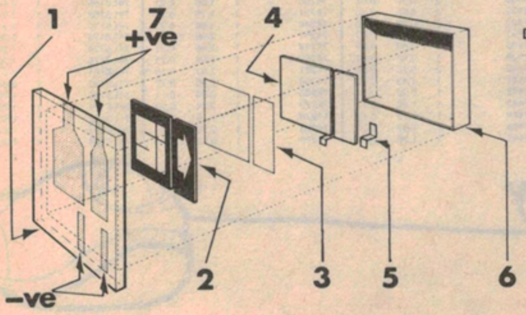
Two basic groups exists . . . ac working (called acel) and dc working (called dcel). Each uses zinc sulphide, manganese-doped phosphors which radiate a yellow-orange light at 585 nm wavelength. The ac cells operate in a capacitive mode, the dc units in a resistive mode. Figure 5 shows the schematic of a dcel unit.

Manufacturing processes are mainly vacuum deposition using photolithographic procedures for masking. This method offers great prospects for the future. The British Post Office for example is considering 1250 character displays for phone call costing. Smiths Industries have vehicle instrument panels in pilot scale production. (Figure 6 shows a recent panel of this type).

As always, addressing the display is a problem. Multiplexing methods have been used to reduce lead counts from 257 (for a 256 unit) down to only 32. The displays can be used in a continuous mode or they can be pulsed. Pulse durations of around 0.5% duty cycle are typical using 5 — 15 microsecond pulses.

Around 120 volts is needed to drive the display present day units require 50 mW per character. A prototype unit using CMOS circuitry consumes only two watts for a 480 character display.

This information was compiled from lectures delivered at an Institution of Electrical Engineers day meeting held in London in January 1978. No full Proceedings were published but the five speakers would be able to provide further information if contacted. Details can be obtained from the Conference Secretary, IEE, Savoy Place, London. Smiths Industries kindly provided most of the illustrations used here.



D.C. ELECTROLUMINESCENCE ASSEMBLY

1. FRONT GLASS
2. INSULATING MASK
3. PHOSPHOR – in contact with 7 through apertures in 2
4. ALUMINIUM REAR ELECTRODE
5. CONDUCTIVE STRIP – joining 4 to 8
6. HERMETICALLY SEALED COVER
7. TRANSPARENT CONDUCTIVE PATTERN

Fig. 5. Schematic of a dcel electroluminescent display panel.