An Introduction to Digital Electronics—12

Basic readout devices

The output information from digital systems must often be displayed visually in numerical form. This chapter looks at the variety of basic readout devices used for output displays of this type. Those described are gas-discharge tubes, light-emitting diodes, fluorescent displays, incandescent filament tubes and liquid-crystal panels.

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In many applications of digital electronics, the output from a system is interpreted as a number which must be displayed directly to the operator in visual form. A good example of this is provided by digital instruments such as frequency counters and digital voltmeters (DVMs), where the number displayed corresponds directly to Hertz or volts, respectively.

Over the years many different types of display device have been used to provide this sort of readout, some with more success than others. To cover all of them here would take a great deal of space, and in many cases the effort spent would be largely wasted as the devices concerned have long since faded into obscurity. We will therefore look only at the devices and techniques which have survived the test of time, and are still in current use.

Probably the first really successful digital display device to be developed was the shaped-cathode gas discharge tube, shown in Fig. 1. These are often given the generic name of "Nixie" tubes, although this name is strictly a trademark of the Burroughs Corporation in the USA who first developed tubes of this type.

Basically these tubes are a development from the simple neon lamp, which has two metal electrodes sealed inside a glass tube containing neon gas and a trace of mercury vapour. When a potential of about 75 volts DC is applied between the electrodes, the gas inside the tube ionises and a glow discharge is produced in the immediate vicinity of the cathode (more negative electrode).

It is this confinement of the glow discharge to the immediate vicinity of the cathode which is exploited in the shaped-cathode display tube. Here there is not one cathode but ten, and each is shaped in the form of one of the ten decimal numerals 0-9. The ten cathodes are stacked one behind the other, as shown, with the anode in the form of a fine wire mesh in the front. The tube may thus be arranged to display any of the numerals at will, simply by activating the appropriate cathode.

Typically this is done using a circuit of the type shown. The anode of the tube is connected to a source of around 150V DC, via a resistor R. Each of the cathodes is connected to ground (negative) via a high-voltage switching transistor, with the transistors controlled by the outputs of a BCD-to-decimal decoder. The decoder thus causes the tube to display the decimal numeral corresponding to the BCD code presented to its input.

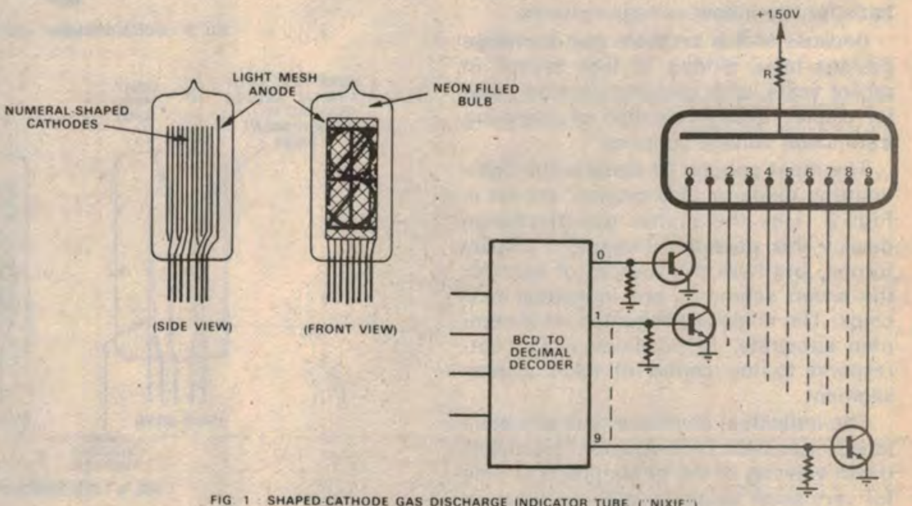

FIG 1 : SHAPED-CATHODE GAS DISCHARGE INDICATOR TUBE ("NIXIE")

The anode series resistor R is required because although the tube has a voltage drop of around 70V when ionised, it requires at least 120V for ionisation to take place. The resistor absorbs the difference in voltage, and also tends to maintain the tube current relatively constant despite differences between the various cathodes. Typically the resistor value is between 50k and 100k.

While the shaped-cathode display was used in a great many digital readouts, it had one main disadvantage. This was that the discharge produced by the cathodes near the rear of the tube tended to be obscured by the cathodes in front, making them difficult to read.

In order to obviate this problem, designers came up with the planar type of gas

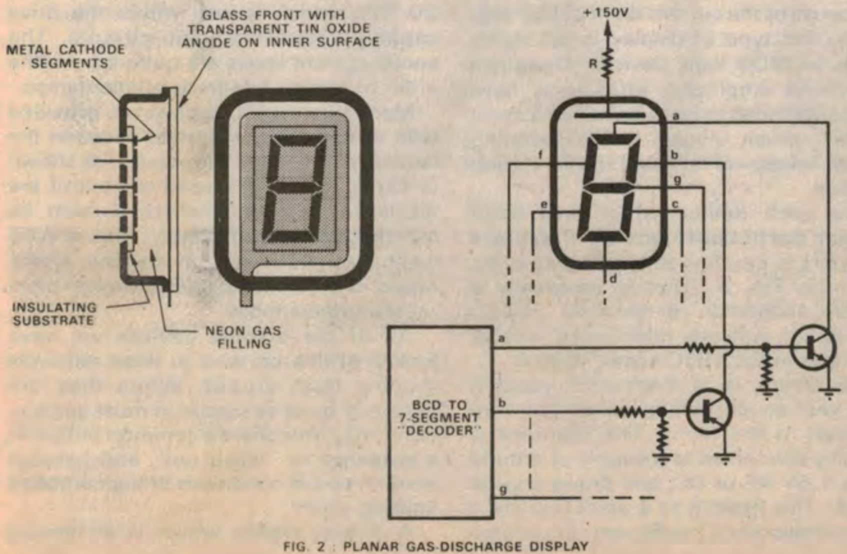

FIG. 2 : PLANAR GAS-DISCHARGE DISPLAY

discharge display shown in Fig. 2. This uses a somewhat flatter construction, with the multiple cathodes all in the same plane. But in this case there are only seven cathodes, arranged in the now-familiar squared-8 or "seven segment" format, so that the various decimal numerals may be displayed by activating combinations of segments simultaneously.

Thus a "1" is displayed by activating cathodes b and c, for example, or a "6" by activating cathodes c, d, e, f and g. The cathodes are again controlled by high-voltage switching transistors, as shown, but in this case the transistors are driven by a BCD-to-7-segment code translator rather than a decoder.

Note that the anode of a planar gas-discharge display is not usually a wire mesh, but rather a transparent electrode of tin oxide deposited on the inside of the glass front plate. This tends to give improved visibility also, over and above that provided by the single-plane type of display.

Of course the planar gas discharge display shares with the original shaped-cathode type the need for a high-voltage power supply, and for switching transistors capable of withstanding up to 120V or so. This makes both types rather unsuitable for use in low voltage systems.

Because of this problem gas discharge devices have tended to lose favour in recent years, with designers opting more for display devices capable of operating from lower voltage supplies.

The most popular of these is the light-emitting diode or LED display, shown in Fig. 3. Like the planar gas-discharge display this uses the 7-segment display format, but here the sources of light for the seven segments are individual LED chips. The chips are mounted on a common substrate, in positions which correspond to the centre of each display segment.

The individual chips are typically quite small—less than 1mm square. This makes direct viewing of the chips practical only for very small displays, such as those on digital watches and pocket calculators. Even for these applications, moulded plastic lenses are usually fitted in front of the chips to provide optical magnification.

For larger displays, the technique shown in Fig. 3 is generally used. Here a moulded plastic block which mounts in front of the chips on the substrate is provided with tapered slots, the inside of which are metallised to form mirrored "light pipes". In front of these again is a red tinted diffusing filter, and together the mirror pipes and filter effectively spread the light from the LED chips out to form uniformly lit segments.

Electrically the LED chips are usually connected either with their cathodes commoned, as shown, or with their anodes commoned. Devices with both arrangements are made and used, as each has advantages in certain applications. The advantages of having one side or the other of the chips commoned are twofold: the number of device connections is reduced, lowering package cost, and the common connection allows convenient electrical control of the display digit as a whole.

LED displays tend to have high reliability and a long operational life, as a result of the solid state construction. And conducting LED chips have a voltage drop of around 1.7V, making them quite compatible with most digital system power supplies. These features have made them very popular as digital displays in a wide variety of applications, although as a LED chip typically requires an average current drain of around 15-20mA for a reasonably bright output, a full 7-segment digit display tends to have a current consumption of around 140 milliamps.

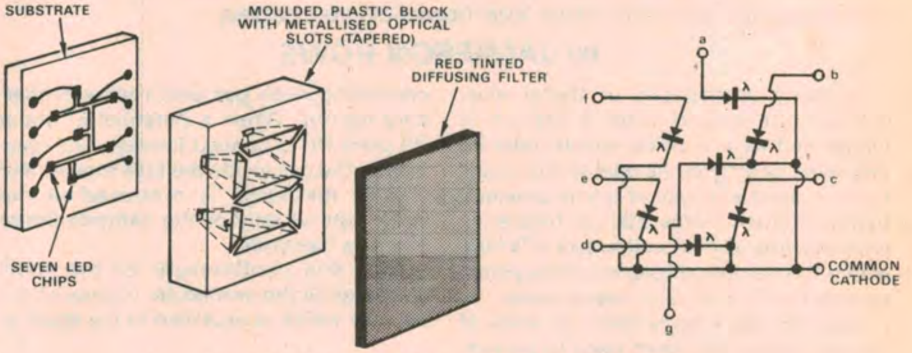

FIG. 3 : SEVEN-SEGMENT LED DISPLAY (COMMON CATHODE)

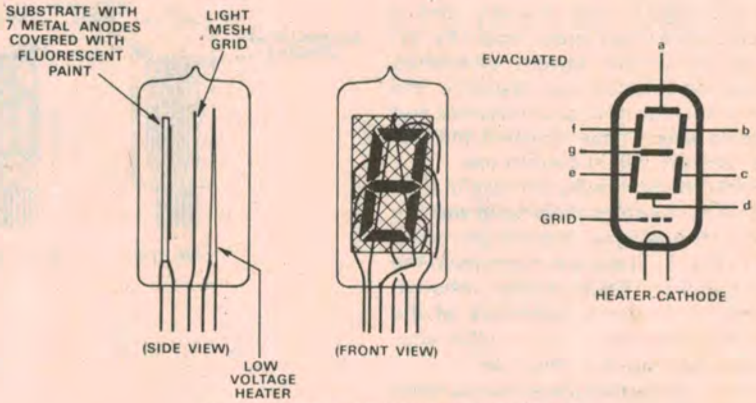

FIG. 4 : FLUORESCENT 7-SEGMENT DISPLAY TUBE

Because of the current drain of LED segments, this type of display is not easily driven by MOS logic devices. Designers of systems employing MOS logic have therefore tended to use alternative display devices, which involve lower operating current levels—or at least lower control currents.

One such device which has been popular particularly among Japanese designers is the fluorescent display tube, shown in Fig. 4. This is essentially a modern adaptation of the early "magic eye" tuning indicator tubes, used in valve radio sets in the 1930's and 1940's.

The device is a thermionic vacuum tube, with an electrically heated fine wire filament in the front. The filament is typically connected to a supply of around 1V to 1.5V AC or DC, and draws around 40mA. This heats it to a point just short of incandescence, sufficient to release free electrons from the surface of the wire, but not sufficient to make the wire visible.

At the rear of the tube is a substrate with seven metal anodes, shaped and laid out in the familiar 7-segment format. The anodes are covered with fluorescent paint, which glows with a greenish-blue light when struck by electrons. Any anode segment may thus be caused to glow by making it positive with respect to the heater filament, so that some of the free electrons released by the filament are attracted to the anode and made to impinge upon the fluorescent paint coating.

The positive anode voltage required to produce this action need only be around 20-25V, which is well within the drive capability of MOS logic circuits. The anode current levels are quite low, in the order of tens to hundreds of microamps.

Many fluorescent displays are provided with a mesh grid electrode between the heated filament and the anodes, as shown in Fig.4. The grid is used to control the display as a whole, where it must be switched on and off rapidly. This is done using a negative bias on the grid, which repels the electrons and prevents them reaching the anodes.

All of the display devices we have looked at this far tend to have relatively modest light output. While they are generally quite adequate in most applications, they thus share a common problem: a tendency to "wash out" and become hard to read in conditions of high ambient lighting levels.

A display device which is somewhat

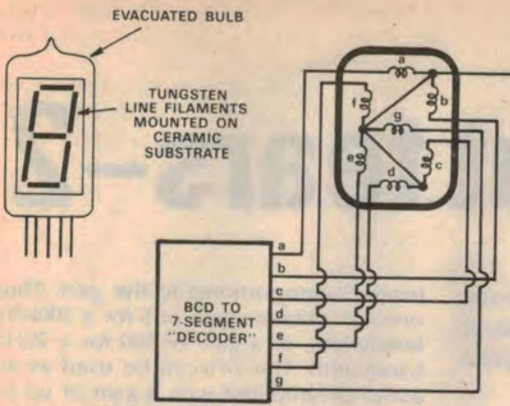

FIG. 5 : FILAMENT 7-SEGMENT DISPLAY

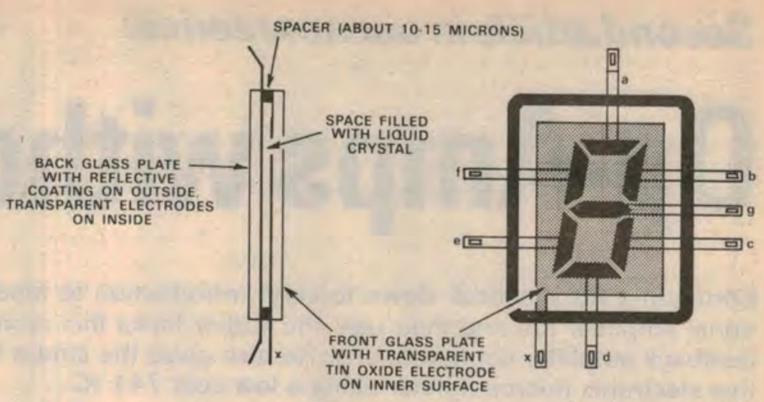

FIG. 6 : LIQUID-CRYSTAL DISPLAY

better in this respect is the directly-viewed filament display, shown in Fig. 5. This is basically a development of the conventional incandescent lamp, with seven tungsten wire filaments arranged in the standard 7-segment format. However, the filaments are here operated at a bright red heat—around 1400 degrees K (Kelvin)—compared with the white-hot 2500 degrees K temperature used with normal household lamps. This gives a very significant improvement in reliability, together with an average life expectancy of over 100,000 hours.

And despite the apparent fragility of the fine filaments, the displays turn out to be surprisingly rugged. So much so that in view of their high visibility in bright conditions they are widely used in high-shock applications such as aircraft cockpit displays

The ability to provide a highly visible display in conditions of high ambience is also possessed by the most recent type of readout device, the liquid-crystal panel. This competes with ambient lighting not by attempting to out-shine it, but by using it, ie, the liquid-crystal panel is basically an optical filter or modifier of existing light rather than a source.

Actually there are a number of different types of liquid-crystal display rather than a single type. All depend upon the rather unique properties of liquid-crystal materials, and the way these properties can change when the materials are subjected to an electric field. But different displays make use of different properties, or put the same property to different use.

One type of display make use of the property whereby a liquid crystal may be optically transparent when its molecules are at rest, but becomes cloudy due to molecular turbulence when an electric field is applied.

This type of display is known as the "dynamic-scattering" type of liquid-crystal panel, and is the type most widely used.

The other main type makes use of the fact that some liquid-crystal materials may be made to exhibit a light-polarising ability, which is again affected by an applied electric field. This type of liquid-crystal display is known as the "field-effect" type.

Both dynamic-scattering and field-effect displays may be made in either of two forms: transmissive and reflective. With transmissive displays the panel acts as a selective filter, modifying light which passes through it from behind. Reflective displays act instead as selective mirrors, modifying light incident on them from the front.

The construction of a dynamic-scattering reflective type of display is shown in Fig. 6. As you can see it is basically two sheets of glass sandwiching a very thin layer of liquid crystal. The inside of the front glass sheet is covered by a transparent electrode, usually of tin oxide, while the inside of the rear sheet has seven similar electrodes laid out in the familiar 7-segment format. The outside of the rear glass sheet also has a reflective mirror coating.

With the rear segment electrodes at the same potential as the front electrode, the molecules of the liquid crystal are at rest and the display appears bright due to the clear optical path to and from the rear mirror. However, if an external voltage is applied between any of the rear electrodes and the front electrode, the liquid crystal molecules immediately in front of the active segments become turbid, clouding the optical path. This makes the desired display evident, as a dark digit displayed against a light background.

Liquid-crystal displays are the most efficient of all in terms of electrical power consumption—typical power consumption is in the order of microwatts. They are also relatively low in cost, and these two features make them attractive for battery-operated consumer applications such as pocket calculators and digital watches.

It seems likely that liquid-crystal displays will be used much more widely in the future, although there are still some problems to be solved. One is response speed, as at present they are very much slower than other types of display in terms of turn-on and turn-off times. Another problem is display appeal—at present liquid-crystal displays tend to look drab and grey, compared with the other types. Until recently they also had a rather limited operational life, although this problem now appears to have been largely solved.

Before closing this introductory look at digital display devices, there is one point which should be noted. Although all of the examples shown in the diagrams have been single-digit displays, many of the different types of display device are also made in multi-digit form—providing 2, 3, 4, 5 or more digit displays in the one package.

The actual operation of such multi-digit displays is exactly the same as for single-digit displays, although the method of driving them from the associated logic often differs. A technique often used with multi-digit displays is multiplexing, which both reduces the number of connections required for the displays themselves, and also simplifies the driving circuitry.

We will look at multiplexing and demultiplexing techniques in the next chapter.