THIS INSTRUMENT consists of an electronic theodolite, an electro-optical distance meter, and a recording unit. These combine to form an electronic tachymeter of pleasing appearance. It was shown for the first time at the 1977 International Congress of Surveyors meeting in Stockholm, Sweden.

An external battery pack supplies power to the tachymeter. One cable connects the battery to the fixed base of the theodolite. All modules are connected electrically, as well as mechanically, of course.

For measuring angles only, the electronic theodolite, the ET2, may be used without the distance meter. Similarly, the E.D.M. may be used with the regular Kern Theodolites.

The Company points out that this modular system can be acquired step by step, each module being put to use immediately, until the total surveying package is available. Separate units also make for easier servicing.

Distance Meter

The DM 502 is a compact E.D.M. that attaches to the telescope of the DKM2-A one-second theodolite, the K1-S "engineers" theodolite, and to the ET2 electronic theodolite. It is so small that it does not disturb the normal manipulation of the theodolite: the telescopes can be plunged in either direction with the 502 attached. It's range varies from about 1000 metres with one reflector, to 2000 metres with three reflectors. Slope distances are read out on a liquid crystal display.

The infra-red carrier wave has a length of 0.9 micrometre. The measuring frequencies are 15 MHz and 150 kHz approximately.

Right-angle sights may be inserted into the tilting axis of the reflectors, to assist in setting up at corners of buildings and faces of walls. In this way, offset corrections are avoided in most cases when points of difficult access are to be tied in.

The Electronic Theodolite

The design of the mechanical components of the electronic theodolite was influenced by two main factors, the modular design of the entire system, and the universality in using the ET2.

The precision inherent in the system of the axes and the circles satisfies the requirements of a one-second instrument. The precision of the vertical angles is provided by the same liquid compensator that has been proved in the DKM2-A. The ET2 features the same telescope and tilting axis as that instrument.

A graduated plane circle is used for measuring a direction or an angle within the instrument. The system is an incremental one, and as with a visual circle reading, the observed value consists of a combined coarse reading and fine reading.

The outer edge of the circle is divided into 20,000 radial lines whose width equals the space between them. Superimposing images of diametrically opposite circle portions eliminates the effects of eccentricity between the circles and the axes of the theodolite. An electro-optical system produces the observation data from the super-imposed circle portions.

The projection, or enlargement, of the opposite circle portions onto a read-out window differs one from the other by a small amount. The ratio between the projections is 100 to 101. This results in a moiré pattern being formed. Figure 1 illustrates such a pattern, but with a projection ratio of only 9 to 10 for clarity.

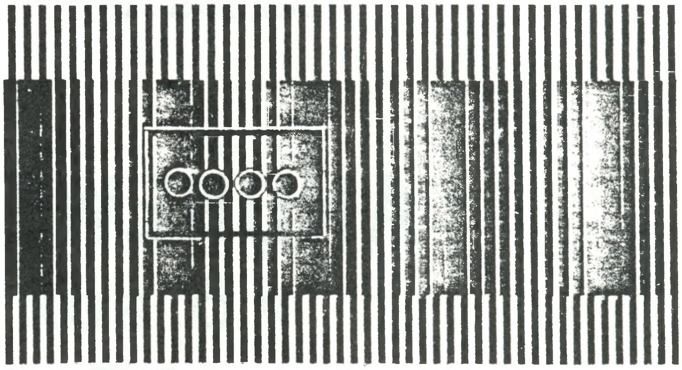


Figure 1

The pattern in this instrument differs from a similar moiré effect in the Geodimeter 710. The Geodimeter pattern is formed from non-radial lines and consists of rows of illuminated diamond shapes separated by bands of darkness. The pattern in the ET2 can perhaps best be described as forming some kind of overlapping vernier.

The coarse reading is obtained dynamically. It is equal to the number of graduation lines or moiré periods which pass a specific spot at the read-out window while either the telescope (vertical circle) or its standard (horizontal circle) are turning. The number of periods which pass the window are counted. This counting mechanism can follow an angular velocity of the alidade or the telescope of up to five revolutions per second.

When the instrument is turned on, the coarse reading will always be zero.

The position of the bright fields and dark fields relative to the read-out window is a measure for a specific graduation line relative to its diametrically opposite graduation line. From this the fine reading is derived.

The distribution of the bright and dark fields in a moiré period follow a sine wave pattern with a good approximation. Four light sensitive diodes are arranged over three-quarters of a period, as indicated in the diagram (Figure 1).

To ensure that the fine reading is obtained to the required precision, the counting interval must be interpolated to within one percent.

As mentioned above, the coarse reading is a dynamic procedure, triggering switching operations. Interpolation is a static procedure which results in the determination of the phase angle associated with the pulsing brightness values of the illumination measured with the four diodes. The electronics appear to be similar to those in the Hewlett-Packard 3820 Total Station outlined in the Winter 1978 issue of the Quarterly.

The difference between the readings of diodes one and three is dephased by ninety degrees relative to the difference between diodes two and four. The two differences are added, and compared to the initial one kiloHertz oscillation of the light source. Both signals are out of phase by the required phase angle.

The value of this angle is determined digitally by a counter which is controlled by the two oscillations when they pass through zero. A 100 kHz oscillator generates the pulses for the counter. A counter chain then adds up one hundred of these phase measurements, and at the same time averages them out. This averaging process reduces the scatter of individual measurements due to signal noise. The two measurement stages are combined to produce a direction or an angle in the display.

The two signals mentioned a moment ago from the readings of diodes one and three and diodes two and four are used to make the forward - backward decision as to the rotation of the circle.

In order to display a '0' after turning the instrument on, even though the phase measurement will occur at 'zero' only by chance, the very first measurement will be stored and subtracted from any subsequent measurement.

This also allows for assigning a predetermined initial value to a given direction, as when it is required to point the telescope along a line of known back-azimuth. The theodolite may be turned until the desired value is in the display. By pressing a key, this value is transmitted to the memory which already contains the initial phase angle. Thus a new zero point is established for the measuring operation. This procedure may be compared with operating the conventional circle clamp screw.

A single switch turns the instrument on (and off), and at the same time starts the measuring process. Due to the principle of the continuous angle measurement, it is not necessary to trigger any angle readings with additional switches. Two seconds after the telescope is pointed to the target, the horizontal direction and vertical angle will be indicated in the display.

If the ET2 is used together with the DM502 as an electronic tachymeter, the distance measurement is carried out as usual by pressing the button on the DM502.

The micro-processor in the theodolite computes the horizontal distance and height difference and moves them to the display, corrects the vertical angle, transfers the two angles into the display, and finally sends the measured values to the recording unit.

The Recording Unit

The recording unit consists of a semi-conductor memory and a keyboard. Its micro-processor is programmed to allow the observer in the field to add as much or as little additional information to the automatically recorded observed data as he requires. Stored data can be recalled to the displays for review in the field. Approximately 750 data blocks can be recorded in the memory.

An internal power supply assures that no data is ever lost.

Data transfer to a computer may be done directly or via telephone lines with suitable interfaces.

Display

The five values, horizontal direction, vertical angle, height difference, and horizontal and slope distances are all shown simultaneously on the liquid crystal displays. So many displays operating at one time is a good indication of the meagre power requirements of this fast evolving technology. A few remarks on liquid crystal displays will serve to close this report.

Up until now, most miniature displays have been constructed with light emitting diodes. These LEDs developed very quickly: in just five years, they moved from laboratory discovery to mass production.

In contrast, liquid crystals have been known for many years. They were discovered in 1888, and their first use in controlling the flow of light was described in a British patent of 1936. The present form of liquid crystal display was demonstrated at Kent State University in 1971.

Liquid crystal displays have certain advantages over other display technologies. They do not 'wash-out' in direct sunlight. In fact, the brighter the sun the better, as they become not less but more legible. Their voltage and current needs are very low. In theory, they can operate on zero current; in practise, their current requirement can be as small as one tenth that required by the integrated chip driving the display.

It is generally known that when two lenses from a pair of polarized sunglasses are placed together, they will transmit light when aligned in similar fashion, and will not transmit light when one of the lenses is turned to be perpendicular to the other. (see Figure 2).

If a material, such as a liquid crystal, were to be placed between two such similarly aligned lenses, and this material was able to twist the light being transmitted through ninety degrees, then no light would pass where such a twist had occurred. This is what a liquid crystal display is able to do.

Liquid crystals, as the name implies, are materials that are neither fully liquid nor fully solid. They have the ability to in some way interact with a beam of light. This interaction can be of many different types; direct scattering of light, modification of polarization, changing the colour of the bulk liquid, colour sensitive reflection from the surface, etc.

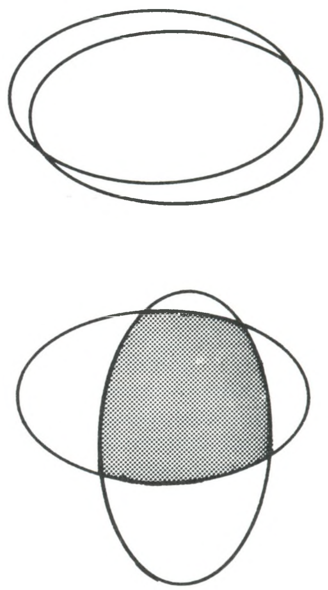


Figure 2

Liquid crystals going into instruments today are twisted-nematic field effect devices.

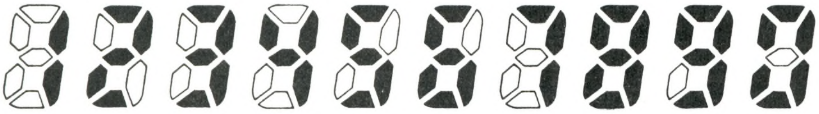
Within a finite temperature range, the nematic phase of a liquid crystal is characterized by the cylinder-like molecules of the liquid crystal all lying with their long axes parallel to each other.

Modern type LCDs have nematic liquid crystals sandwiched between front and back planes of thin glass, which are sealed together with plastic or glass. The two planes of glass are typically about one thousandth of an inch apart.

On the inner sides of both glass planes are transparent conductor patterns that are coated with a special chemical film that aligns the liquid crystal molecules. These patterns generally form the several segments that we are familiar with, and from which collectively and separately are formed the ten digits. Alpha characters, graphics, symbols and designs can be reproduced just as readily.

LCD technology is critically dependent on the ability to pattern elements with as high a resolution as possible.. These conductors are applied by means of screening, or for finer resolution, photolithography.

To the outside of both sides of the glass sandwich are laminated polarizers, each of which passes only those components of light that are parallel to its polar-



The segments forming a box like figure 8

izing axis. In the display under discussion, these polarizers will be similarly aligned, giving eventually dark figures on a light background. If one polarizer was to be perpendicular to the other, light figures on a dark background would result.

Most LCDs have a reflector attached to the rear polarizer. This may be either reflective or transflective in type. Reflective material, of course, simply reflects all light, whereas transflective material is helpful in backlighting LCDs intended for use in low ambient light conditions. A transflective backcoating still permits the display to operate as usual under normal light. The contrast between light and dark figures may not be so great as in a display constructed with reflective material.

To make the conductive patterns visible, the twisted-nematic LCD literally imparts a ninety degree twist to all those molecules in those areas between the conductors. The orientation of the long axes of its liquid crystal molecules varies all the way from parallel with the axes of the front and back polarizers to perpendicular to them, so that these parts of the display cannot pass light.

Causing this twist is an electrical field (hence field effect) brought about by applying an electrical potential to the chemical film of the conductor patterns. This electrical field pulls the molecules into the fully twisted position.

Figure 4 attempts to show this configuration. For clarity, in the diagram the light source is shown to be in the rear of the transflective material (reflector). The twisted polarized light does not pass the front polarizer in this case. If the light source were in front of the front polarizer (for example, daylight from the sun), then any twisted light would not reach the reflector at all - it would be stopped at the rear polarizer. The result is the same though, as a dark area will still occur at the conductive patterns.

Temperature and humidity are the two greatest enemies of LCDs. Some liquid crystal materials remain in a nematic state from -10° to +75°. Above and below these temperatures, the material undergoes a phase change, to either an isotropic liquid or a semi-solid crystal. A display raised to temperatures above its upper limit turns completely dark or completely clear, depending on the orientation of the polarizers. One approaching its lower temperature limit responds more and more sluggishly till it ceases to function at all. Displays usually recover from having exceeded the upper limit when returned to their normal operating range. Similarily, no damage is done if the lower limit is exceeded for only short periods of time.

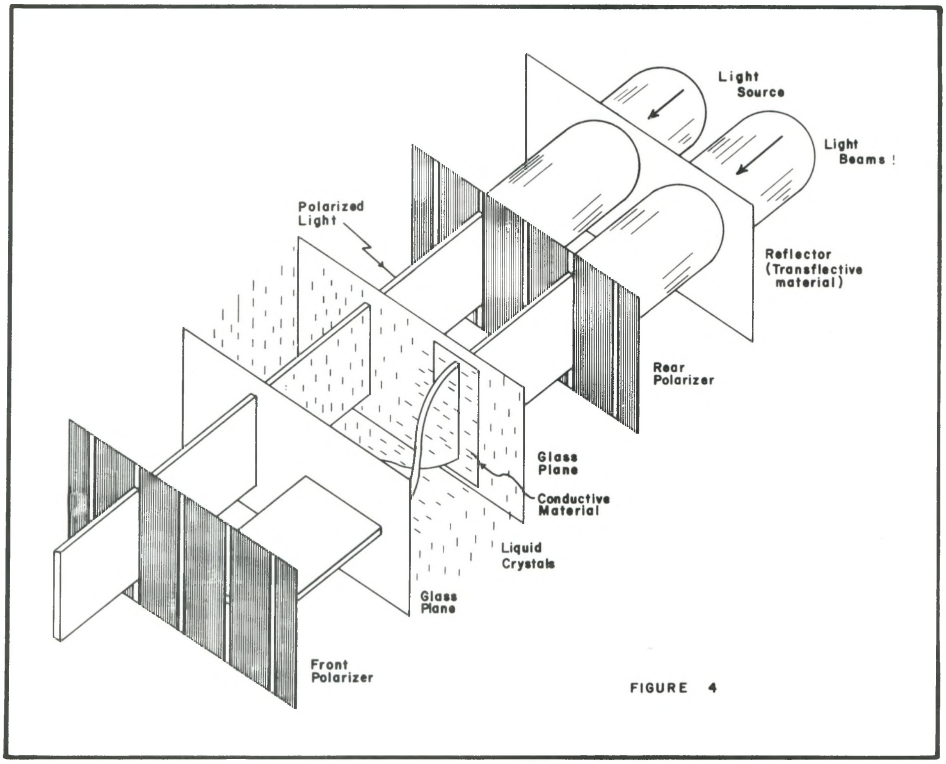


FIGURE 4

The displays in the ET2 and DM 502 are equipped with small heaters, so that they continue to operate in cold weather.

In direct drive LCDs, zero voltage is usually applied to an unselected (off) segment, and an alternating current potential greater than the threshold voltage is applied to selected (on) segments of the display digits. Typically, the threshold voltage is about 1.5 volts and operating voltage is about three volts.

This kind of addressing is usually used in wrist-watch circuits, where no more than four to six seven-segment digits are used.

Large size LCDs are only now coming onto the market. One of the major stumbling blocks to their development has been an inability to properly multiplex, or scan, the various segments and digits comprising the display. One early LCD wrist-watch had no fewer than fifty-one connections between the I.C. and the display. One of the maxims of the industry, up until two or three years ago, appeared to be that 'liquid crystal displays of more than a very few characters cannot be multiplexed in a practical, cost efficient manner'.

In any multiplexed display, the various segments of different symbols are not independent but are interconnected. The method of interconnection commonly used with light-emitting diode displays is to tie together all those segments that have the same location in each symbol (see diagram on page 14 of the Fall, 1979 issue of the Quarterly) and then address the symbols sequentially. The self-isolation of common-anode light-emitting diodes makes simple multiplexing possible. The same circuit fails with a liquid crystal display, because the capacitor-like segments pass alternating current drive signals to a common connection, activating wrong segments.

The problem has been solved in several ways, but generally the solution relies on selectively addressing LCD segments through amplitude selection on a times-synchronized basis. Readers are referred to articles on this subject in technical magazines, which have appeared with some regularity since early 1978.

I wish to acknowledge that the first part of this report is based on a paper entitled "An Instrumental System with Automatic Recording of Measurements" by Dr. H. Aeschlimann, of Kern and Co. Ltd. The diagrams are by Jim Carnegie of Surveys and Mapping, Corp. of the City of Ottawa.