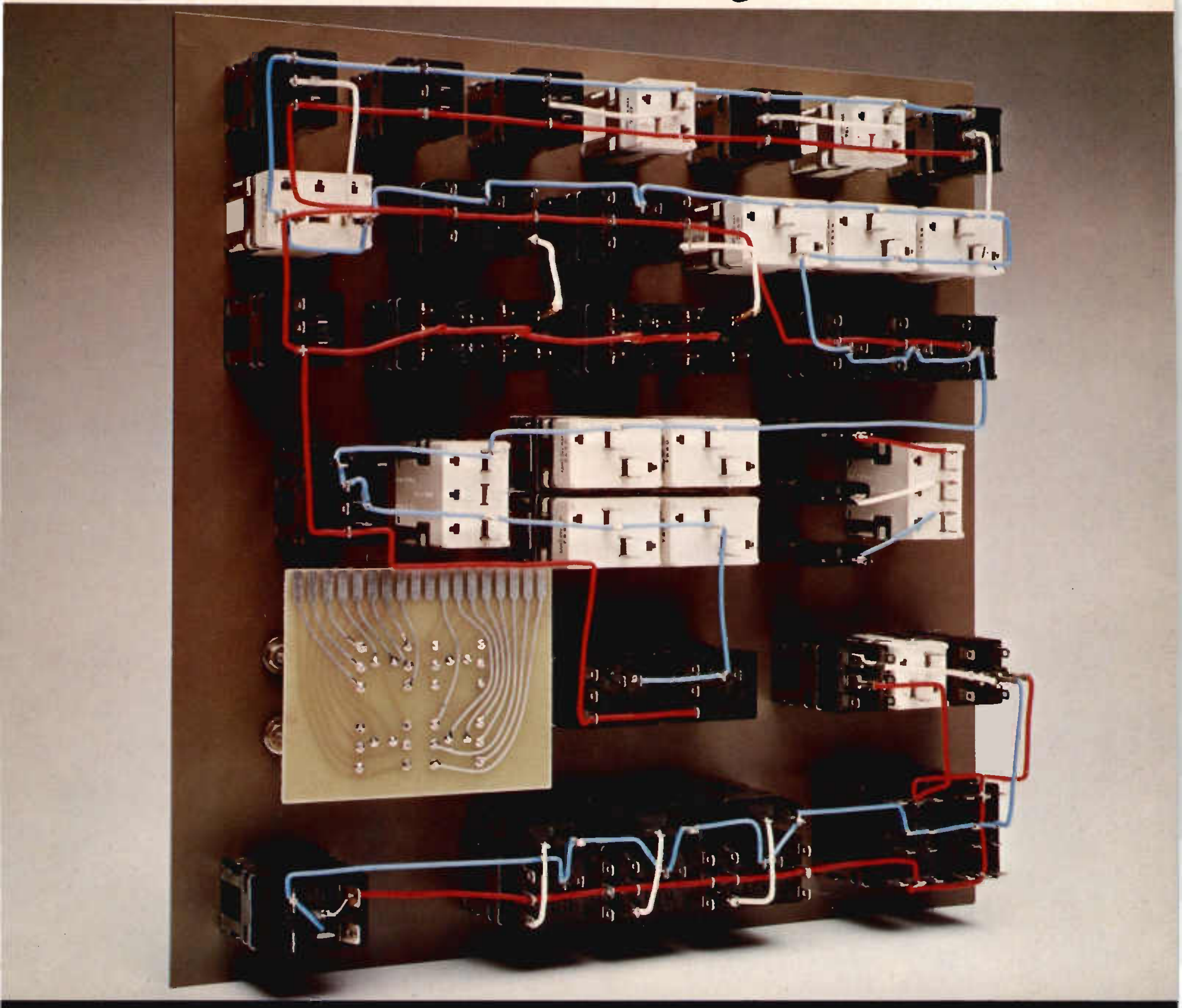
electronic engineering

February 1977

Simplifying communications in instrumentation systems

Switches you'll like to see the back of!

1 on enquiry card



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Write for our AML data sheet or call your nearest Honeywell Branch Office. Either way you'll end up with one thing – a push-button that works as well as it looks.

Honeywell MICRO SWITCH DIVISION

Honeywell Ltd. Honeywell House, Charles Square, Bracknell, Berkshire. RG12 1EB Tel: 0344-24555

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ABC

This month's cover depicts a Telequipment oscilloscope, illustrating how versatile modern oscilloscopes can be greatly extended by the incorporation of plug-in modules.

electronic engineering

Vol 49, no 588 **February 1977**

4 on enquiry card

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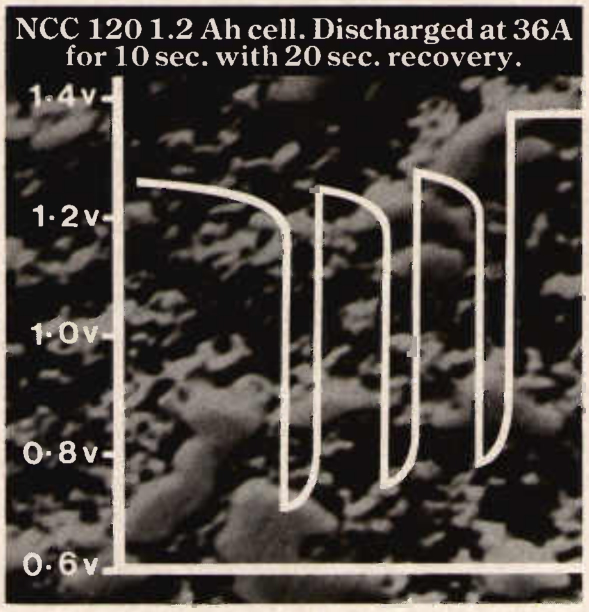

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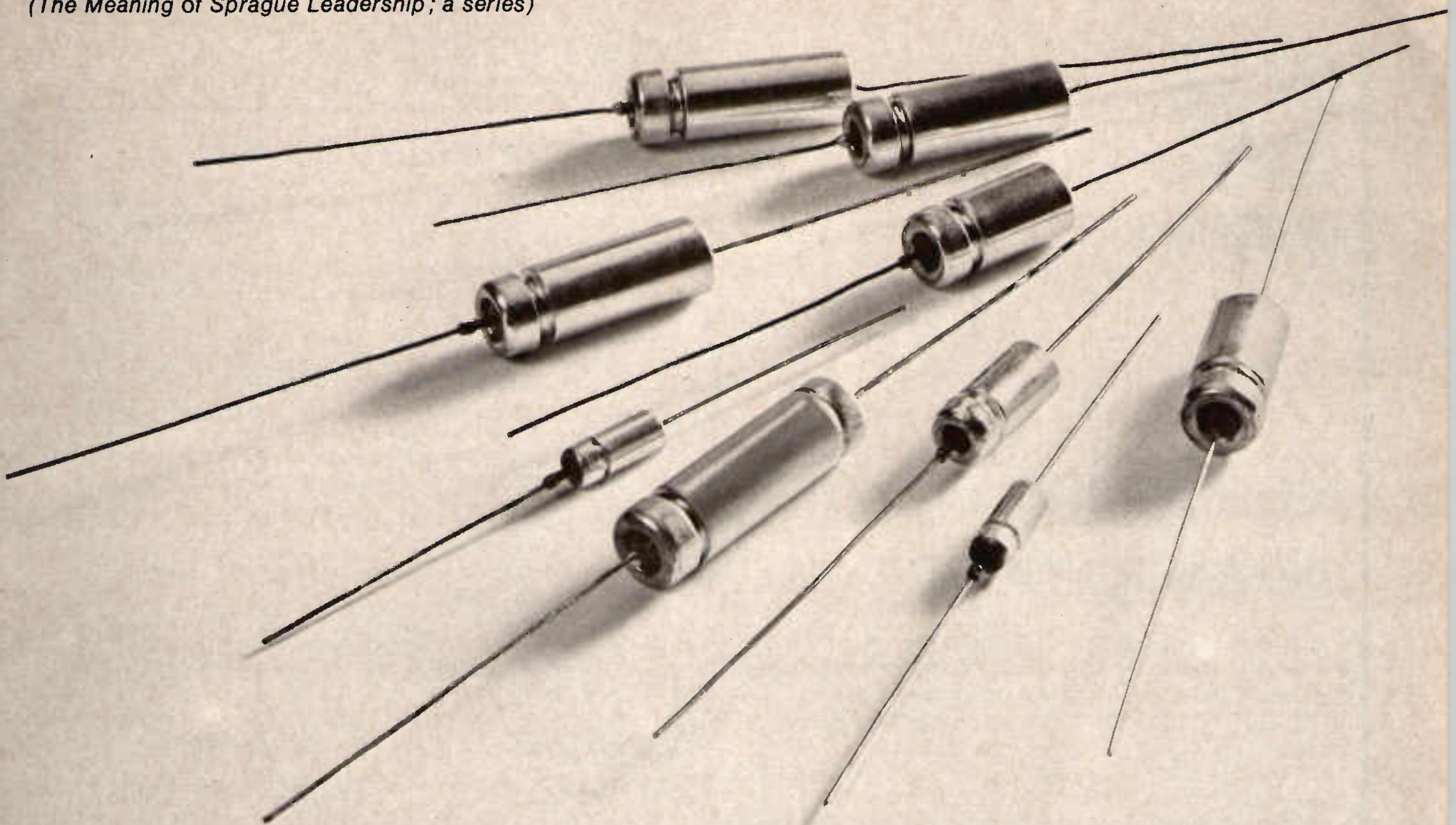
(The Meaning of Sprague Leadership; a series)



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All inquiries, on any aspect of this advertisement, should be addressed to: Mike Jones, Sales Manager, Sprague Electric (UK) Limited, 159 High Street, Yiewsley West Drayton, Middlesex. Telephone W. Drayton 44627, telex 261524.

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Stimulating development

According to a government pamphlet on the electronics industry, large scale capital expenditure is needed in the industry to provide new plant and machinery for the production of sophisticated and rapidly developing goods and equipment.

The paper also maintains that much of the industry's resources should be injected into advanced technology research on which the industry relies for so much of its future growth and wealth.

However it has always been the case that the R&D research in electronics has been high. In fact it is higher than the industry's fixed capital expenditure and accounted for 12 per cent of the total expenditure in 1968 for example. If we compare this with manufacturing industry as a whole we see that the amount of turnover taken up by R&D was only 1,75 per cent.

Despite the relatively high percentage of capital poured into the R&D activities of the electronics industry we still seem to be falling short of our requirement. The government itself finances 40 per cent of the research and development either directly or through various bodies such as the Computers, Systems and Electronic Requirements Board (CSERB).

In the Central Office of Information paper on the industry, it states that the government plays an important role in its support for the electronics industry. However convinced it may seem that an indigenous electronics industry will be important for the progression of the economy as a whole, it must be prepared to create an economic climate where individuals as well as companies can flourish.

Government funding of research, while not to be discouraged, is not enough to gain the success we need. One of the purposes of research is to provide more and better marketable products but, these products have to be conceived, marketed and supported by motivated, enthusiastic staff.

The government must ensure that the money it provides is being put to good use in injecting the correct stimulus that will give our industry the impetus it so badly needs. The expertise and the quality of products we already have. But, it is the present claustrophobic environment which stifles the motivation we need to drive us into foreign markets.

READOUT

Cheaper solar cells

The cost of silicon solar cells could be greatly reduced if polysilicon rods are used as the starting material, according to a research team at Madrid University.

Solar cells made from monocrystalline silicon can have efficiencies above 15%, but extreme care in processing the silicon is essential.

The polysilicon rods that are used to obtain electronic grade silicon consist of an almost monocrystalline doped core surrounded by fine grains of intrinsic silicon. The rods can be converted into homogeneously doped silicon with a relatively large grain size ($10^4 \mu m^2$) by a single-pass melting zone.

Diffusing n^+ and p^+ regions on opposite sides of the silicon and adding evaporated aluminium contacts produced solar cells with efficiencies of about 5%.

However, the Madrid team states that this figure would be doubled if a more efficient contact design were used and that the addition of antireflective coatings would lead to a further increase in efficiency of about 50%.

The maximum efficiency obtainable will therefore be about 15% so that the cells will have a performance comparable to that of the monocrystalline silicon types but the production costs will be significantly lower.

Nuclear monitor

For once the British have beaten the Japanese on their own ground. The British company TCS Ltd which is based in Worthing has gained a contract worth £100 000 to supply an electronic system to the Japanese Atomic Energy Research Institute (JAERI).

Despite fierce competition with major Japanese electronics companies TSC which is a member of the Eurotherm International Group won the contract which is to control and monitor experiments to establish the behaviour of fuel rod casings in simulated nuclear reactor cores.

The fuel safety laboratory at JAERI is working on the safety of fuel cells which use a special alloy cladding containing radio active fission material. The tests are being carried out under conditions known as loss of coolant conditions. In the experiments the radio active fission material is not used but, its heat output is simulated by electric furnace elements which are designed to operate at very high temperatures.

The equipment from TCS controls the power output to the heaters while monitoring the temperature variations which occur throughout the test cycle which lasts for 30 minutes. Information is fed into a computer which analyses the effects of temperature on the structure of the fuel rod cladding.

Receiver muting unit

A Wales based company, Callbuoy Marine Electronics, has produced a device for duplex radio installations which is intended to eliminate receiver breakthrough which can arise during transmitted speech syllables.

The unit has been patented and its major application is seen to be in single sideband marine radio systems. It has been designated the dmu- the duplex muting unit—and is inserted between the receiver and its antennae.

It monitors the rf and attenuates for the length of time that receiver breakthrough is likely to occur.

Instrument symposium

Electronic measuring instrument technology will be the subject of a symposium to be held at the university of Keele by the Society of Electronic and Radio technicians. The symposium will take place from the 5th to the 7th of July and will be broken down into five sessions as follows: computing techniques in instrumentation, signal generation, measurement displays and a miscellaneous section which is intended to cover such areas as new techniques in calibration, continuous process measurement and various applications such as the brain scanner.

READOUT

Portable cartridge

A portable cartridge instrumentation recorder the Ana-log 714 has been introduced by Philips which is capable of operating in a wide variety of applications. There are two basic versions of the recorder; the first version has positions for a voice track (vt) and seven frequency modulated (FM) or direct recording (DR) channels, the second has fourteen positions which can be arranged in various combinations of voice, FM or DR recording.

The instrument can operate on a set of four standard tape speeds 60, 15, $3\frac{3}{4}$ and $\frac{15}{16}$ in/sec. Although, other tape speeds are available on request.

There are also several extra facilities which can be added to the basic instrument. These are a repeat facility, a computer interface (which allows the analog 714 to operate under the control of a computer programme), an absolute tape counter, a combined remote control/audio unit and a long term speed stability unit.

The remote control unit has a built in microphone and loudspeaker to allow recordings to be made and played back via the voice track channel of the recorder. To initiate remote recording, the record button together with either the forward or reverse button has to be depressed.

The long term speed stability unit is used when playback is required to exactly follow the time sequence of recording. The special unit provides a constant frequency signal derived from a crystal oscillator, which is recorded onto one of the available data tracks. During reproduction the signal from this track is compared with the crystal oscillator signal on the servo system and the signal difference is used to correct any capstan speed anomalies.

The instrument has a wide variety of applications in medicine, science and mechanics.

Bubble memories take off

Texas Instruments is taking the first tentative steps towards full production of bubble memory systems. The first device intended for marketing is the TBM 0101, which is a 92 kbit bubble memory chip which is assembled in a 14 pin dual in line package with its drive coils, permanent magnet and magnetic shield assembly. The device occupies less than 0,5 in^3 weighing less than 25 gms and dissipating a power of 0,7 W during continuous operation.

The storage of data in a bubble memory device relies on the presence or absence of a magnetised domain in magnetic garnet material. The magnetic domain, which is the termed the bubble, is moved around the device by a rotating magnetic field and follows a path determined by a permalloy pattern which is deposited on the garnet.

The bubbles themselves are formed by external control circuitry and are detected by a special circuit gate. This gate has the ability of either destroying or replicating the bubble. Any bubble which is fed into the gate is stretched and cut by a timed current pulse. One half of the bubble is diverted into the detector while the other half is fed into the major loop. To destroy the bubble the timing is changed.

In the production version of the memory the chip has a major/minor loop architecture containing 157 active loops of which only 144 are functional. This loop redundancy is eliminated due to production defects. Each functional loop has 641 active bubble positions which gives a total capacity of 92 304 bits of nonvolatile storage.

Data is accessed serially and since the data is transferred from a minor to a major loop the access time for the first bit is 4 msec. However data will normally be stored as a 144 bit page, one bit from each minor loop and accessed as a full page in 9,6 msec. On speed performance it is comparable with disc type stores but is almost four times slower than dynamic semiconductor ram but, it does have the advantage of being a nonvolatile memory.

The company will also be marketing the special support components required to provide the complete system. These include the TMS 5502 bubble memory controller which interfaces with the bubble memory with a microprocessor and converts the data into eight parallel bits.

Also there is the SN74LS362 which is the timer which generates the timing pulses to generate, replicate and annihilate bubbles.

Lcd watch production

A second British company is preparing to manufacture digital watches. The firm, Trafalgar Watch has most of its company directors in the US visiting semiconductor manufacturers to obtain supplies of integrated circuits.

Production of the watches (which are of the lcd type) is expected to begin early this month. They will be constructed in the company's North London factory probably using a majority of components brought in from the US.

Until now Trafalgar has been importing ready built circuit modules and assembling them into their own brand of cases. These pre-assembled modules have been of the led type.

Trafalgar intends to market its new range at a price lower than other lcd watches.

International exhibition

In May the first international microcomputer, minicomputer and microprocessor exhibition will be held in Europe. The venue for the exhibition will be the Palais des Expositions in Geneva in May.

The organisers of the exhibition hope that it will serve as an international forum where the latest developments from many manufacturers can be presented. Many companies will be present including Plessey, Data General, General Automation and Wang.

A technical programme which supports the exhibition will focus on the practical applications of small computing systems and include topics such as testing of microprocessors high level language considerations in microcomputer applications and, the application and integration of memories and memory systems.

Pocket TV market hopes

The long awaited announcement of the launching of Sinclair's miniature television has finally been made. The television has taken twelve years to develop at an estimated cost of £500 000. The set, which has a two inch screen and has overall external measurements of 4 by 7 by 1,5 inches, is claimed to operate on all vhf/uhf bands and is capable of receiving transmissions throughout the world.

It can either be powered by internal rechargeable batteries or directly from the mains. The battery cells are nominal 5 V dc working from four 1,2 nickel cadmium cells. According to the company four hours viewing is typically available from fully charged cells.

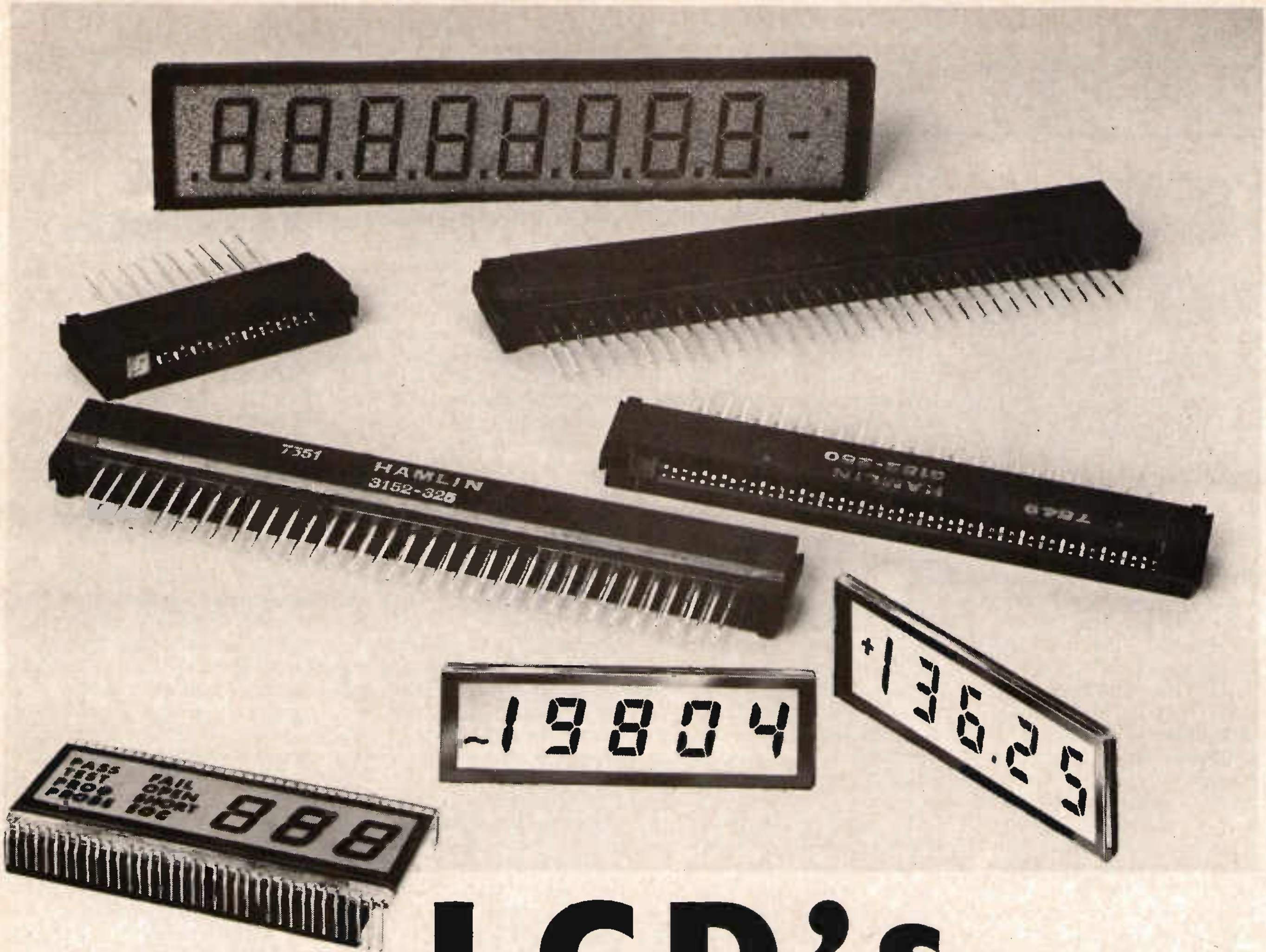
The picture tube uses electrostatic deflection of the electron beam rather than the conventional magnectic deflection method. The set also has a very low power heater which only takes 15 seconds to warm up and the eht is 2 kV.

Much of the internal circuitry is integrated most of the functions being performed by five bipolar ics.

Both the vhf and uhf tuners are bipolar devices and band changing is performed by pin diodes. Tuning is achieved by varactor tuning which have both automatic frequency control and automatic gain control to try and compensate for the effects of drift and variations in signal strength.

The television which is aptly named microvision will be marketed at a price of £175 and will be given its first public debut in Chicago.

Sinclair hopes that the product will be an export winner and will be needed not only to boost the British export drive but to fill the Sinclair's coffers which are sadly depleted from the losses sustained by the black watch project.



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Filter as vibration tester

A new filter introduced by Kemo functions not only as a narrow-band filter but also as a vibration analyser. In addition, it enables direct readout of acceleration, velocity and displacement.

Known as the VBF-18, the instrument is essentially a wide-band selective voltmeter, combining a relatively wide narrow-band (7%) with high rejection outside of the passband. This, says Kemo, allows accurate measurements of vibration to be carried out even when frequency jitter is present. The width of the broadband is one-third of an octave, the broadband response approximating to ISO 51.11 1966 Class 2. In the all-pass mode, a weighting of −6dB/octave or −12dB/octave is switched into the circuit to provide direct measurement of velocity or displacement in conjunction with a suitable accelerometer.

The meter circuit enables both true rms and true peak-to-peak measurements to be made, at frequencies up to 10 kHz. The peak-to-peak circuit has a hold and reset capability.

The rms/peak-to-peak facility enables the instrument to be adjusted according to the type of measurement to be made. RMS measurements are used when the energy content of a signal needs to be known whereas peak-to-peak measurements are more suited to shock and displacement - vibration tests. The hold circuit retains the maximum vibration level if, for example, a resonance occurs.

Telecine for Nigeria

Another British company which has won an export order is Marconi Communications Systems. This is for the supply of £1 million worth of B3404s telecine equipment to Nigerian Broadcasting Corporation. Nigeria now has twenty of these systems in operation.

The contract involves the supply of 15 colour telecines as well as a number of ancillary add-on equipments. The B3404 equipment won a 1976 Queen's award to industry for technological achievement and was designed specifically for the television industry unlike most telecine equipment which is derived from the cinema projection equipment.

It has had an excellent export record with 98 per cent of all such equipment finding a home overseas. Its export sales have exceeded £5 million since full production began in 1973.

Among its features are instant start and variable speed, fast wind and rewind on 16 mm projectors. It can accept either positive or negative film, and has a controlled spool tension to prevent film clinching.

Damage test made simple

A company claims that possible damage to electronic equipment, magnetic recording media and optical instruments can be very simply detected by an inexpensive device. The company, Standard Listing which is based in Croydon, has recently introduced the device.

It has been designated Shockwatch and comprises a length of precision bore capillary tubing containing a reservoir of red liquid. Any shock or acceleration exceeding a pre-determined level forces the liquid from the reservoir and floods into a thin channel running the length of the tubing. The device immediately turns from clear to a vivid red.

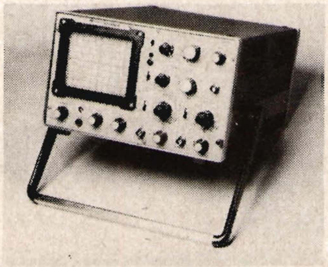
Thick and thin conference

An International Conference on Thick and Thin Film Technology will be held in Augsburg, Germany, in September 1977.

The subject areas to be covered include substrate materials, techniques for the deposition of films (including methods for small and large-scale manufacture); the properties of film components such as active components and transducers, pattern generation techniques including the generation of very fine patterns, interconnection methods, testing etc.

The conference language will be English and prospective authors are invited to tender their prospective papers.

Dual trace oscilloscope



Recently, Gould Advance announced the introduction of a dual trace 15 MHz oscilloscope. The new instrument incorporates a 10 kV high brightness-split beam tube. Its sensitivity is between 5 mV/cm and 20 V/cm which is controlled in a 1:2:5 sequence.

The speed rating of the oscilloscope is 50 ns/cm which has been achieved by using the ten times expansion on the 0,5 µs/cm−0,2/cm timebase.

The market of the OS260 is intended for people who do not require a large bandwidth but who need a bright display and comprehensive trigger facilities, the company claims. The sensitivity of the oscilloscope means that it can be used with transducer inputs and should be suitable for a wide range of electronics mechanical and medical measurements including medium speed logic testing.

Use of tungsten improves mnos

A new method of fabricating thick-oxide mnos transistors and capacitors could lead to the production of nonvolatile memories with data retention times of about 200 years.

One of the major problems with mnos structures is choosing the thickness of the SiO_2 layer. In thin-oxide (20-30Å) transistors, the nonvolatility is limited by charge leakage through the SiO_2 layer.

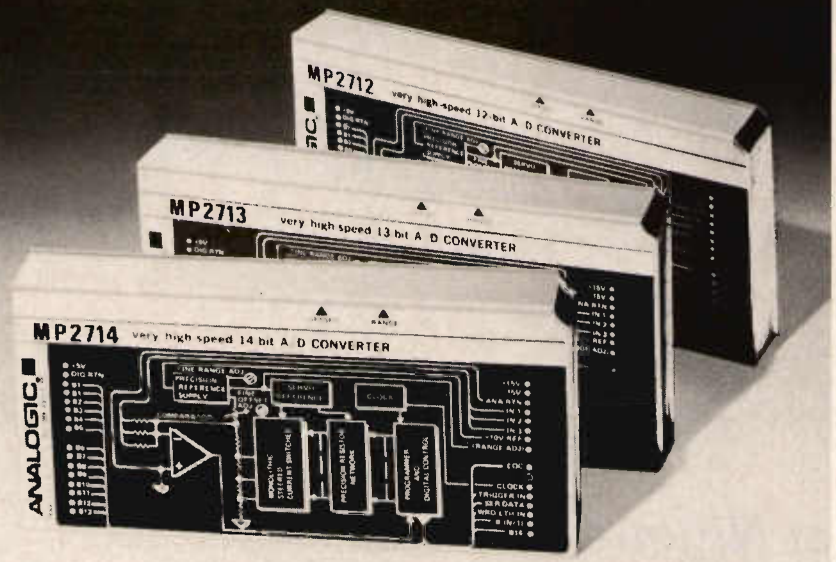
The charge retention can be improved by the use of thicker oxide layers (greater than 45Å), but the charge-storage capability tends to zero at reasonable gate pulses, as a result of the large decrease in the SiO_2 conductance.

The new method, developed at the Institute of Microelectronics, Sofia, Bulgaria, consists essentially of treating the oxide layer with tungsten to increase the conductance without degrading the dielectric properties. After the oxide layer is formed, a layer of tungsten, 2000Å thick, is deposited by sputtering. The metal is then entirely etched away and a layer of Si_3N_4 deposited. Currently, write pulses lasting 50 milliseconds are required but it is thought that this could be reduced to 1 millisecond.

£20 million in radio orders

The latest export orders for Clansmen military radio equipment has pushed the company's overseas sales to over £20 million. The Company supplying the equipment is the MEL Equipment Company. The system supplied under the contract is for VRC 321 and VRC 322 hf mobile vehicular stations and spares.

Analogic A/D Converters give you a bit more for less



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Four full scale ranges, providing a 4 to 1 range sensitivity, enable the designer to choose the range best matched to the balance of his system. Built-in gain and offset adjustments eliminate external pots and assure that every unit shipped is calibrated to within a guaranteed accuracy specification traceable to the NBS.

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ANALOGIC
. . . The Digitizers

The All-Electronics Show. 19~21 April 1977

Already The All-Electronics Show invites you to put your stamp on the event.

With The All Electronics Show opening its doors for the second time on Tuesday 19th April, the organisers report that they are most gratified with the number of ticket requests received so far. The response from overseas is already greatly increased on 1976 numbers.

If you would like a free ticket for the exhibition just complete the coupon at the bottom of this page and return it to the organisers. (If a ticket is not obtained in advance, admission is 50p "on the door".)

First time exhibitors

Due to a high level of success in its first year, The All Electronics Show has attracted for 1977, many of the newer—and, in some cases, less prominent—companies in the industry. With its uniform stand style and cost effectiveness it is an ideal event for companies new to the exhibition world. And from many new ideas may be culled.

One company exhibiting its products for the first time ever is Cambridge based Powertron, manufacturers of power supplies. Director, Miles Rackowe, who visited last year's show said —"we reckon that our switch mode power supplies are too good to be hidden from the electronics industry any longer, and that The All Electronics Show is the best place to give them an airing".

Narrow band filter doubles as vibration analyser

The All Electronics Show will be the first public showing for the Kemo VBF-18, tunable narrowband filter. It is a portable, battery operated unit with a built-in meter, offering the facility of direct readout of acceleration, velocity or displacement and doubles as a vibration analyser. The meter circuit functions in the range 1 Hz to 10 kHz when measuring true root-mean-square values and in the range 0,1 Hz to 10 kHz for true peak-to-peak measurements. The peak-to-peak circuit has a hold and reset capability, together with two preset internal time constants of one and 10 seconds. The width of the broadband is one-third of an octave and in this mode the response characteristic approximates to ISO 51.11 1966 Class 2. When the all-pass mode is selected, a weighting of −60 dB/octave or −12 dB/octave is switched into the circuit to provide direct measurement of velocity or displacement in conjunction with a suitable accelerometer.

STOP PRESS: The most recent companies to take stands are: Wessex Electronics, Celdis Ltd and Elex Electronics.

This year's exhibition catalogue, which is being compiled by the sponsoring journal, *Electronic Engineering*, will be given to all visitors free of charge. Preview information will also appear as part of the April issue of *Electronic Engineering*, so that all readers will receive information in advance of the exhibition. Incorporated in the catalogue will be a "Product Locator" giving details of all products manufactured or distributed by each exhibiting company, which will prove to be a useful reference guide throughout the year.

Organisation

Every effort is being made to ensure that visitors enjoy the exhibition and find it of value. An information desk will be set up in the Foyer of the exhibition area and will be staffed throughout the show to deal with any queries or problems.

Although part of the exhibition takes place below street level, access is possible for wheelchairs, etc.

The exhibition venue, Grosvenor House in London's Park Lane is easily accessible by public transport and for car drivers a large underground car park is situated right opposite the Hotel.

If you have any queries regarding visiting the exhibition, please contact *Samantha Clarke* at Saffron Walden (0799) 22612 or Telex 81653.

I enclose a 6½p stamp to cover second class postage and I look forward to receiving my ticket to The All-Electronics Show.

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Components ITT

Field lab!

The new SE 7000 is the most advanced instrumentation recording system of its kind. It takes the highest recording technology out of the laboratory into the field. It does so in a complete 43 Kg package that is easier to use, far more versatile and at the same time less expensive than alternative equipment.

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You save time on setting up and calibration too, because a unique calibration module is also a built-in feature – eliminating the need for external cross-patching of modules.

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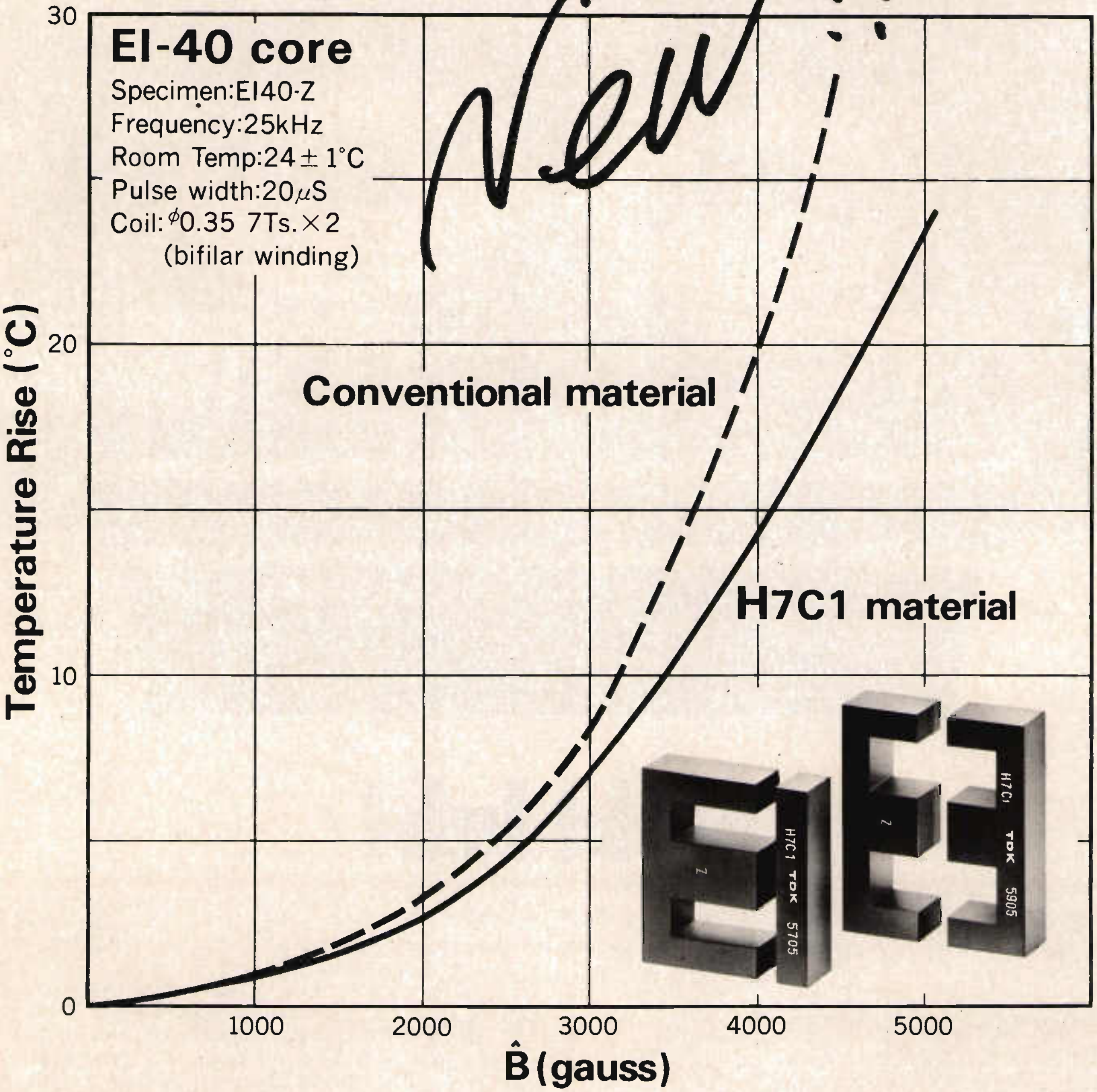

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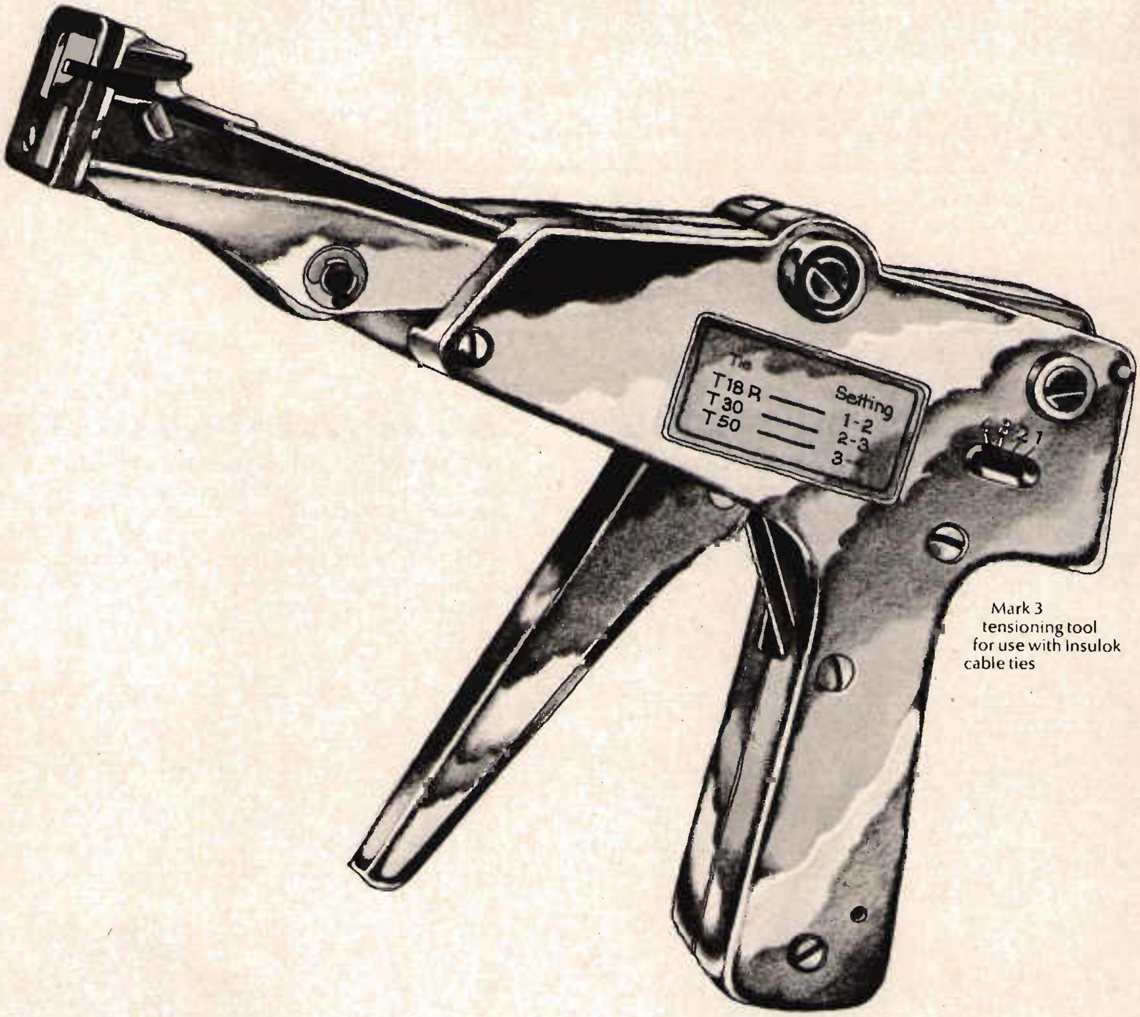

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TYPE	Output Voltage	Imax 50°C	Transient Load 2mS	Dimensions (mm)		
				H	L	W
SU8/5	5v fixed	1.5A	-	40	140	76
SU8/12	12 ± 5% adjustment	0.5A	0.75A	40	140	76
SU8/24	24 ± 5% adjustment	0.25A	0.375A	40	140	76
SU16/5	5v fixed	3.0A	-	55	160	100
SU16/12	12 ± 5% adjustment	1.0A	1.5A	55	160	100
SU16/24	24 ± 5% adjustment	0.5A	0.75A	55	160	100
Overvoltage protection is standard fitting on 5 volt output units						
Voltage adjust potentiometer standard on all but 5v models.						

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				H	L	W
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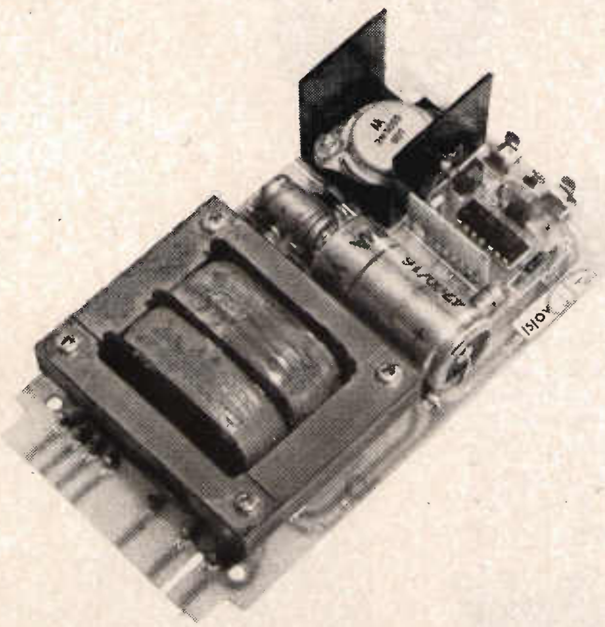
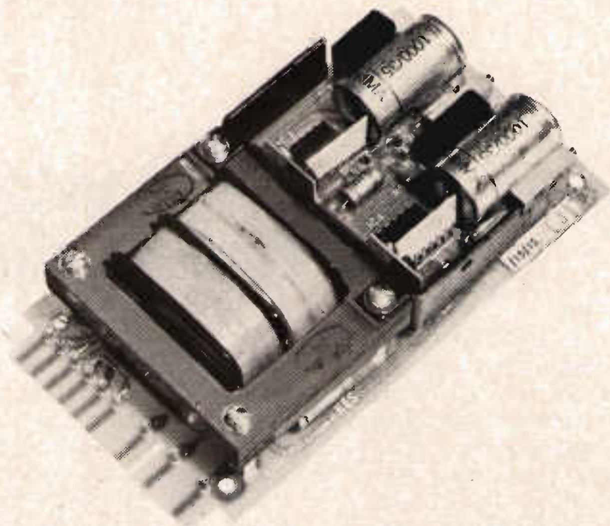
SU16/T	5–15v & 12–15v	0.5A	0.75A	55	160	100
1. Multiway 0.1" pitch edge connector, used on 0.2" spacing, designated "/EC".						
2. 0.2" pitch screw terminal connector, designed "/TB".						





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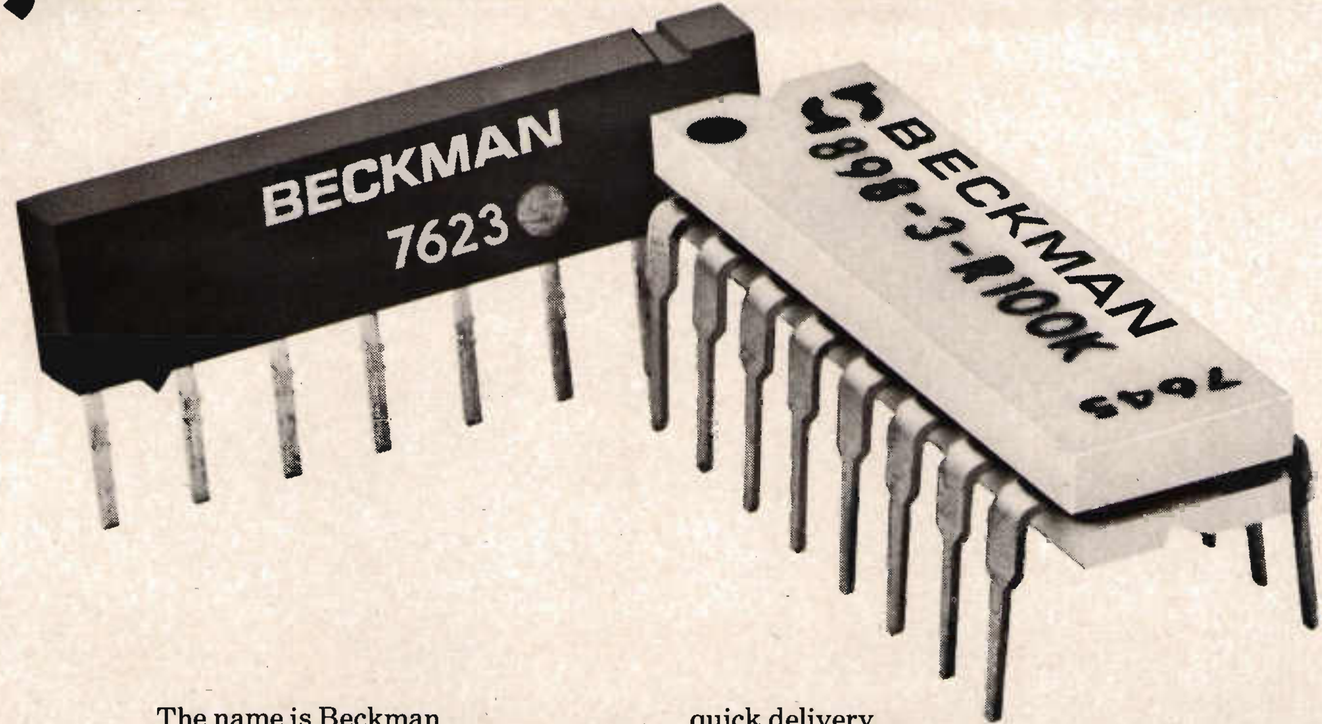

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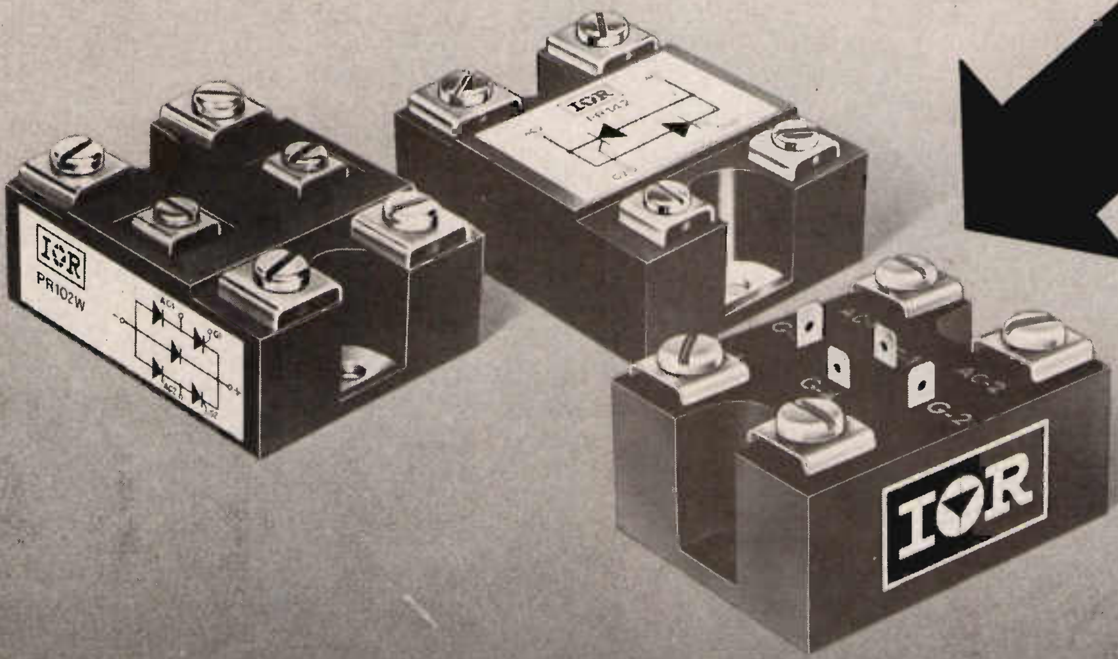

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Applied Ideas Competition 1977

This year Electronic Engineering will be giving £1,000 worth of prizes

Once again *Electronic Engineering* will be running the Applied Ideas competition and will be giving away prizes which have a total value of £1000. Jubilee Year marks the fourth appearance of the competition and the co-sponsors this year will be Siliconix, the Swansea based semiconductor manufacturer.

Prizes will again be awarded for the best Applied Ideas published in *Electronic Engineering* during the year, Originality, suitability, elegance, adaptability and general usefulness are some of the factors which will be taken into account.

Contributions should give a concise account of the application of the submitted Applied Idea along with design criteria and an indication of performance of the design.

electronic engineering

Siliconix

Entries must be from named individuals and must not have appeared previously outside the originating establishment. A contributor's fee of £10 will be paid on publication.

Applied Ideas must be typed, using only one side of the paper, with double spacing and wide margins. Illustrations must be drawn clearly on separate sheets. They should be captioned, show component values and type numbers, and indicate test voltages and waveforms where appropriate. Entries should conform to the usual style of the journal.

Please send entries to the Applied Ideas Editor, *Electronic Engineering*, Morgan Grampian House, 30 Calderwood Street, London SE18 6QH.

The Editor's decision in all matters is final.

Cash award of £150 for the best Vmos circuit

Siliconix are running an associated competition in 1977. A cash prize of £150, plus a runner's up consolation prize of a Siliconix digital stop watch will be awarded to the best practical applications of circuits using vmos devices.

Design ideas incorporating these power mosfets will be judged by Siliconix, and any of these ideas which are published in *Electronic Engineering* will not only receive the normal contributor's fee of £10, but will also automatically qualify for the £1000 annual Applied Ideas competition.

The standards and format required for the vmos circuit ideas should be the same as these specified in the rules of the Applied Ideas specified above.

Entries must be accompanied by an application form which can either be obtained through *Electronic Engineering* by circling the reply card number 544 or by writing directly to EE/Siliconix design contest Siliconix Ltd, Morriston, Swansea, SA6 6NE. All entries for this competition must be post marked no later than April 29th, 1977.

Accumulating adder works with reversible counter

The computation of the sum of a large amount of positive and negative binary numbers is required n certain realizations of digital circuits. Fig. 1 shows how this can be implemented. It consists of a very well known accumulating adder constructed from two 7483 MSI adders and two 74195 registers[1]. The signal of the *carry* C4 passes through several *nand* gates and enters the 74193 reversible counter. We can assume that the added number *A* has an 8-bit form for positive numbers: A = sgn/A/+magnitude of A sgn/A/ = zero.

for negative numbers: A = sgn/A/+2's complement of A sgn/A/ = one

The carry signals C4 is added to the reversible counter in such a way that the register outputs Y1, . . ., Y7 together with outputs of the counter Y8, . . ., Y11 shows the result of the addition. It is easy to prove that during adding of a negative number to the previous result of summing, we must change the state of the reversible counter only if C4 equals the logical *zero.* Then one pulse is given to the input C−. If we add a positive number, the state of the reversible counter is changed when the signal C4 equals the logical *one.* Then the pulse to the input C+ is applied. After summing, the circuit can be cleared and the operation repeated. A very short signal *t* which is the clock signal for registers and reversible counter can appear after at least doubled propagation time of the 7483 adder, calculating from the moment of feeding of the number A to the adder inputs.

The maximum of summed numbers can be increased by a cascade connection of another 74193 counter. The result of the addition can be truncated to the necessary number of bits. The choice of a sign bit of the result depends on the expected maximum value of the sum. For example if the magnitude of the sum is not bigger than 1111111111, Y11 can be taken as a sign bit.

The circuit shown on Fig. 1 can be applied for example for the binary output signal evaluation in binary hardware implementation of FIR digital filters.

Reference

1. P. Misiurewicz, M. Grzybek, "Pół-przewodnikowe uklady logiczne", Wydawnictwa Naukowo-Techniczne, Warszawa 1975.

Krzysztob Westowski, Poland

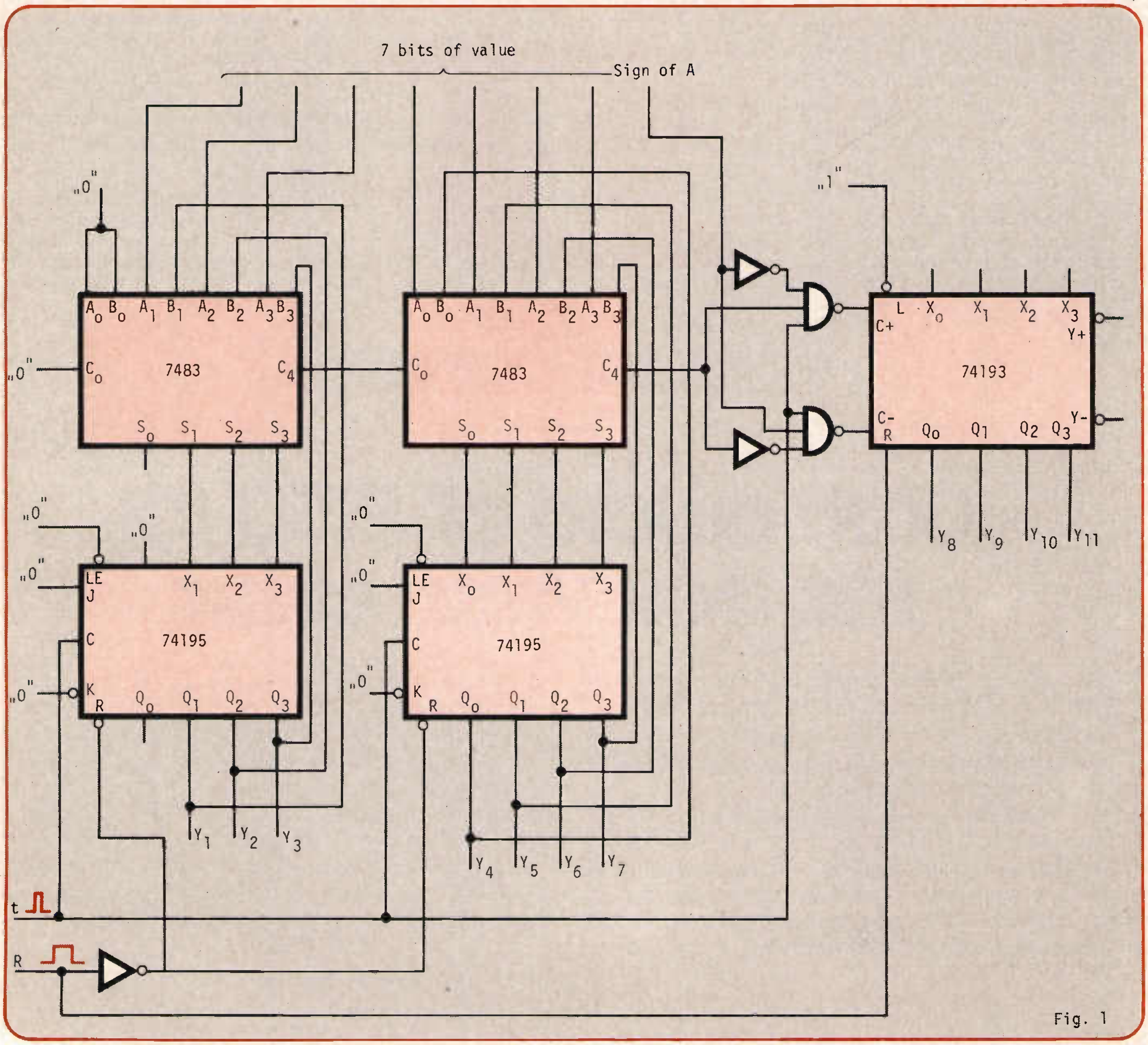

Fig. 1

Beat frequency indicator uses light emitting diodes

This circuit indicates the relationship between two input frequencies by using four leds. The direction of rotation of the spot of light shows which frequency is the greater, and the rate of rotation is a quarter of the difference frequency between the inputs. The spot of light fades smoothly from one led to the next, providing a highly sensitive and intelligible display.

The circuit is ideally suited to such applications where a small difference frequency needs to be clearly shown. The circuit is suitable for use with input frequencies from about 50 Hz to well above the audio region.

The transistor stages boost the signal to a level sufficient to drive the Schmitt gates and may be dispensed with if the signals are already ttl compatible. Almost any n-p-n transistor is suitable, maximum sensitivity being achieved with the collector biased between the threshold levels of the Schmitt.

The Schmitt gates produce rectangular pulse trains of arbitrary mark-space ratio from arbitrary input waveforms. The J-K flip-flops divide these pulse trains down to produce waveforms A, B, C, and D which are then gated together to produce the lamp excitations L1, L2, L3, and L4 such that:

$L1 = AB\bar{C}\bar{D} + \bar{A}\bar{B}C\bar{D} + A\bar{B}\bar{C}D + \bar{A}BCD$

$L2 = A\bar{B}CD + \bar{A}B\bar{C}\bar{D} + ABC\bar{D} + \bar{A}\bar{B}\bar{C}D$

$L3 = \bar{A}\bar{B}CD + A\bar{B}\bar{C}\bar{D} + \bar{A}BC\bar{D} + AB\bar{C}D$

$L4 = ABCD + \bar{A}\bar{B}\bar{C}\bar{D} + A\bar{B}C\bar{D} + \bar{A}B\bar{C}D$

These equations may be more implemented in the form:

$L1 = (A\bar{C}(B \oplus D)).(\bar{A}C(\bar{B} \oplus D))$

$L2 = (B \oplus D).(\bar{A} \oplus C)$

$L3 = (\bar{A}C(B \oplus D)).(A\bar{C}(\bar{B} \oplus D))$

$L4 = (\bar{B} \oplus D).(\bar{A} \oplus C)$

The diagrams show how the mark-space ratio of the lamp wave forms vary with the phase difference between the inputs, which the eye sees as a continuously changing brightness.

For f1<f2 the spot of light rotates anticlockwise, and vice-versa. If the rate of rotation is too great it may be reduced by placing dividers between the Schmitt gates and flip-flops.

C S K Clapp, London.

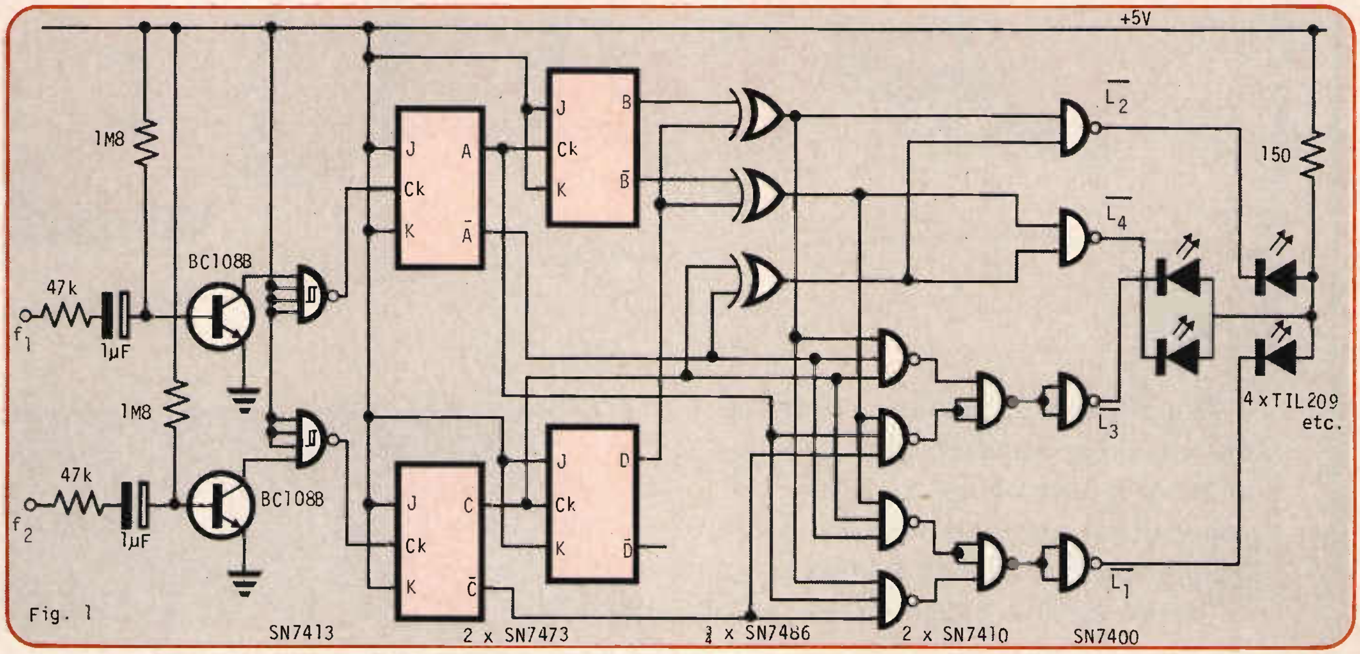

Fig. 1

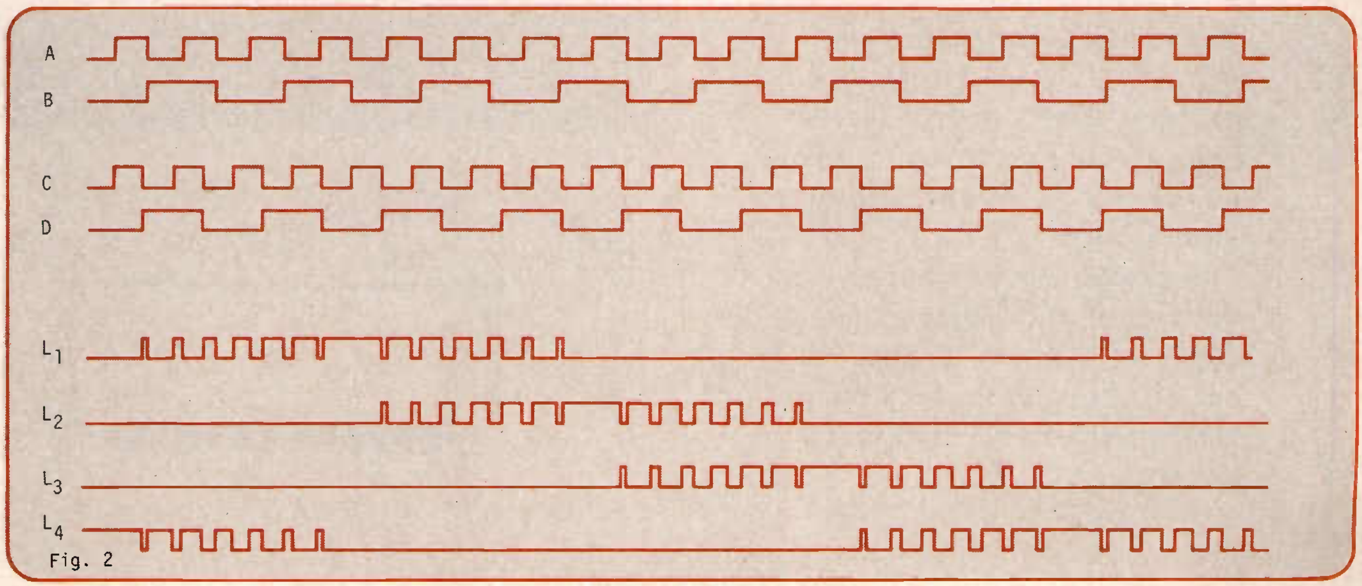

Fig. 2

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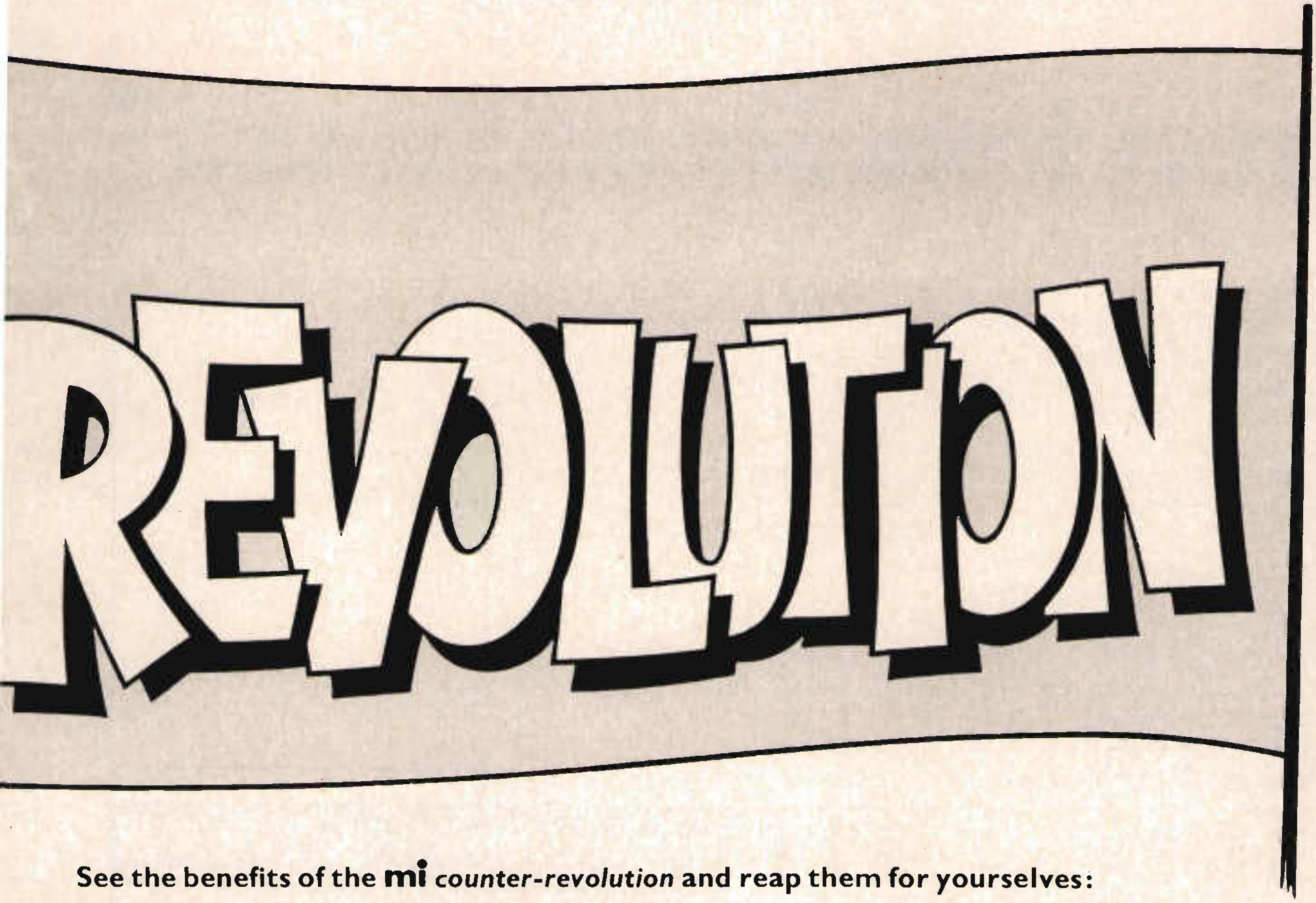

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Building a sferics counter with two ics

The general requirement for sferics counters is for indicating the total number of lightning flashes within a known radius. The Fig. 1 shows a simple scheme which achieves this using just two popular ics and a few discrete components. Input to this circuit is fed from a vertical wire antenna of suitable length, with a pre-amplifier stage for impedance matching.

A_1 is a low-pass filter that fixes the frequency band of interest. In this case it is 0-20 kHz. The 3 dB cut-off point is at 20 kHz and the attenuation beyond the pass band is 12 dB/octave.

The full wave rectifier A_2 which follows the filter produces a unidirectional voltage, irrespective of the waveform of the initiating atmospherics. This stage ensures detection of strokes of either polarity in the 0-20 kHz range.

A_3 is a comparator with an adjustable reference voltage V_t. Whenever the input signal exceeds this reference voltage, the comparator output changes state. Adjustment of V_t determines the level at which the counter operates and hence the overall sensitivity. The actual voltage level is a function of the antenna used and the average intensity of strokes in a given locality.

The change of state that occurs at the comparator output is used to trigger a monostable multivibrator built around A_4. This triggered circuit is included since the duration of the lightning strokes is relatively short. Use of this multivibrator minimises dependance of operation on the duration of the atmospherics.

The monostable multivibrator's output can be used to initiate a direct read-out electromechanical counter, which would indicate the total number of counts. A continuous record of the counts can also be obtained over long periods, if required, using a chart paper recorder.

J Raja and M Ramanamurthy, Vikram Sarabhai Space Centre, Trivandrum, India.

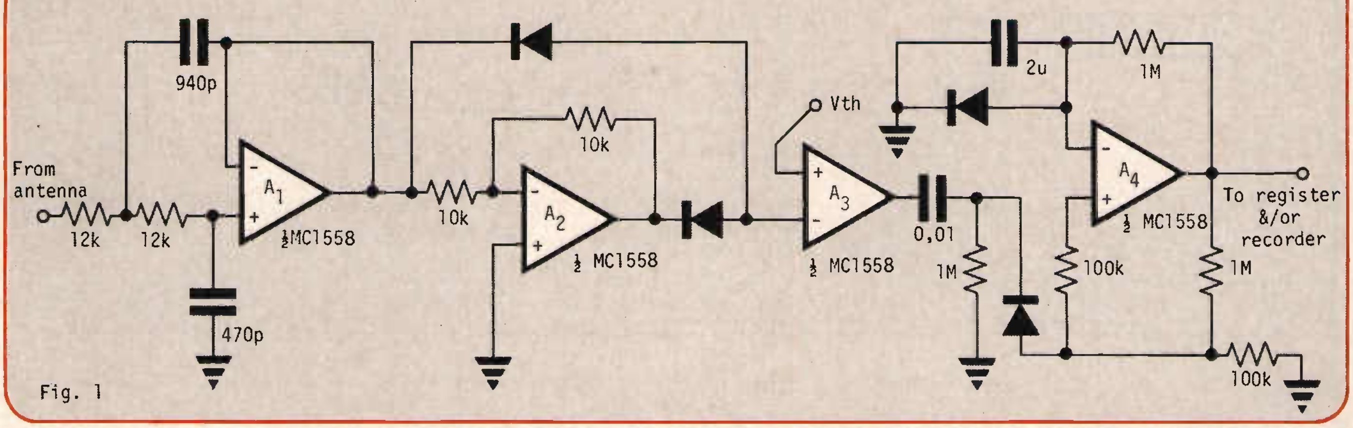


Fig. 1

Filter exhibits no phase shift with the fundamental

It is not often realised that to construct a low pass filter exhibiting no phase shift at the fundamental, all one needs is a cheap 748 or 301 OPA.

The solution is merely to use a 748 and provide a capacitor across pins one and eight which is selected for the frequency of operation. In the circuit shown, the 748 has a 0,22 µF capacitor which provides a cut off of 100 Hz at 1 V pk-pk sine wave and effectively removes all traces of spikes generated from thyristors etc.

Using a standard low pass filter a considerable number of components are required to provide zero phase shift with the incoming signal.

Vernon Boyd, The Welding Institute, Cambridge.

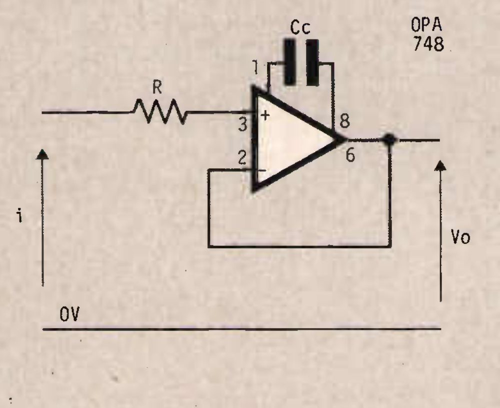


Fig. 1

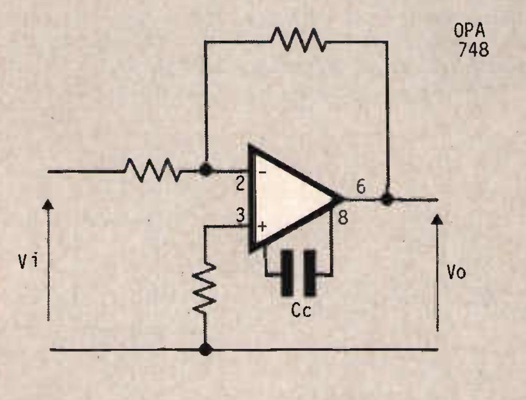


Fig. 2

APPLIED IDEAS

Programmable frequency selector

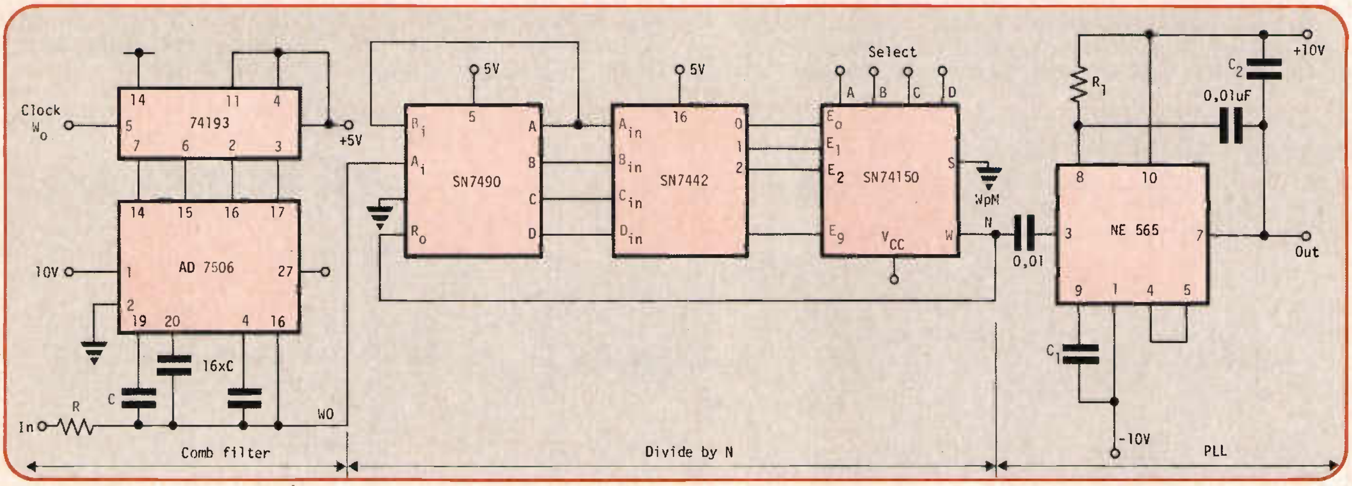
The circuit designed for frequency analysis of input signals consists of a filter, a programmable divide by *N* circuit and a pll.

If the clock generator is set at frequency ω_0, the filter will let through frequencies $\omega_2 = n\omega_0$, where $n = 0, 1, 2, \ldots$ The frequency divider is built up with a decade counter, SN 7490, which provides a bcd input to four-to-ten-line decoders, SN 7442. Any of nine possible divisors can be selected by the inputs *A, B, C, D,* to the data selector, SN 74150, the selected output of which is fed back to reset the counter at the end of each count cycle.

The output of the data selector is fed to the pll, the vco of which is tuned by choosing the proper values of R1 and C1 at the frequency of the clock generator. Since the output of the filter is $\omega_2 = n\omega_0$, the output of the SN 74150 is given by $\omega_2^1 = \omega_2/N = n\omega_0/N$. Since the pll locks at frequency $\omega_2^1 = \omega_0$, it then follows $n = N$.

This yields the following result: by setting the data selector at a given value of *N*, the component of the input signal of frequency $N\omega_0$ can be detected by the pll. Using the pll, type NE 565, the frequency selector may operate at the frequency range up to 500 kHz, for a frequency range above 500 kHz, the NE 562 is to be applied.

Kamil Kraus, Ejpovice 96 337 01 Rokycany, Czechoslovakia.



Simple sequence delay for digital data

This is a simple but accurate method of delaying digital sequences or any data stream for less than their clock periods.

Each edge of the incoming sequence produces a zero pulse (about 50 ns) at the output of the exclusive *or* gate (4), the length of the pulse being determined by gates 1, 2, 3. Any other convenient method of generating this delay can be used. However if this delay is also not inverting then gate (4) output should be fed into the B input of the monostable. This pulse must be over 40 ns to trigger the 74121.

The monostable produces positive pulses of adjustable length and provides the sequence delay. The delay between A and E is adjustable from about 150 ns, to the clock period plus about 100 ns, for standard ttl.

The J-K flip flop must be initialised before the incoming sequence arrives. Pre-setting the flip flop will invert the delayed sequence.

P M O'Leary, Dublin.

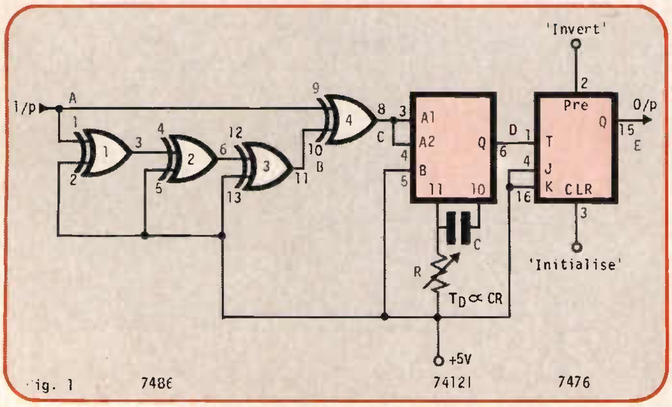


Fig. 1

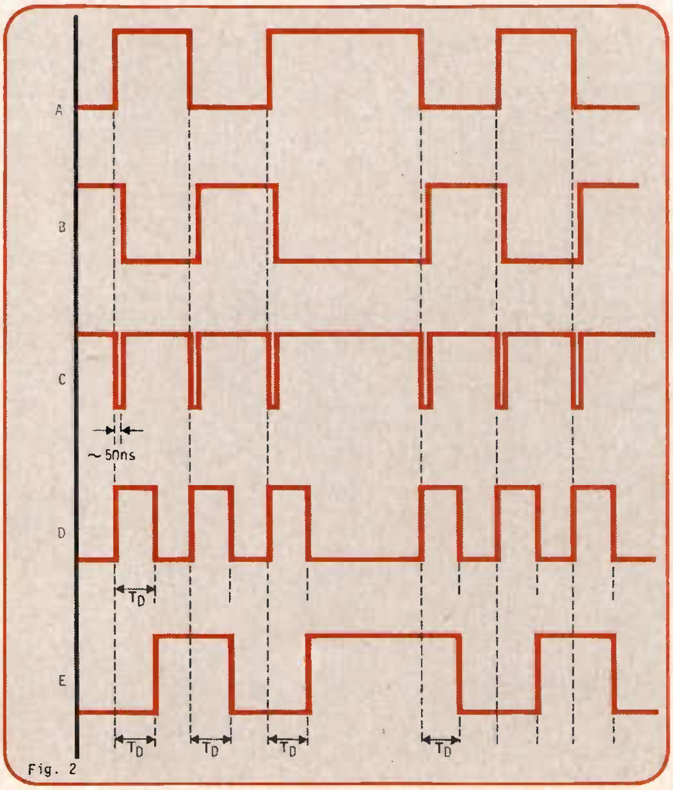


Fig. 2

Integrated univibrator permits linearity of ±2 per cent.

In many applications, for instance in pulse generators, linear change of the pulse width and/or repetition rate is needed. Such a demand can be accomplished when the capacitance C of the integrated univibrator type 74121 is charged from a constant current source built on a pair of complementary transistors as shown in Figure 1.

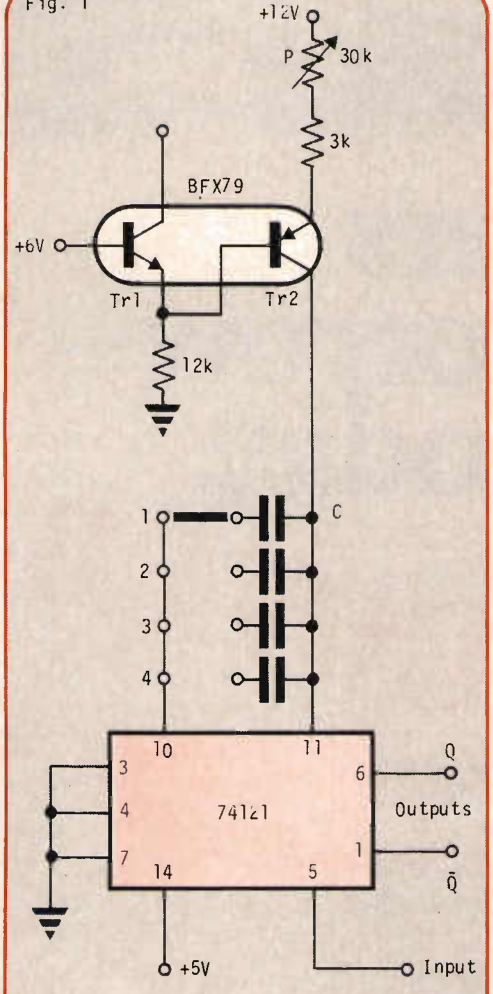
The width of the pulse depends linearly either on the value of the voltage applied to the base of the first transistor Tr1 or on the value of the current of the second transistor Tr2 which is regulated by means of the potentiometer P inserted in the emitter of the second transistor.

The circuit shown in Fig. 1 generates pulses the width of which can be changeable in four steps. The helipot P gives the continuous linear change of the width whereas the change of the value of the capacitance C allows this change in steps.

To build a multivibrator two univibrators ought to be connected together as shown in Fig. 2. Mechanically coupled potentiometers P allow continuous linear change of the frequency of the multivibrator and the change of the value of the capacitances C allows this change in steps.

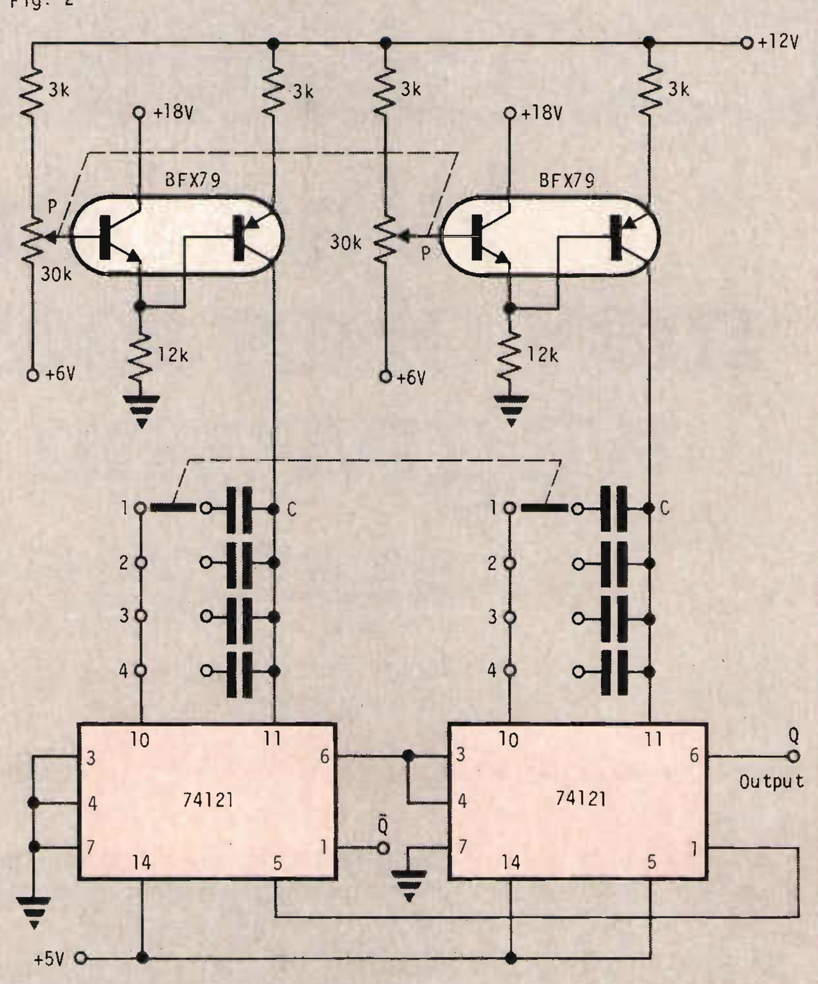
Ryszard Bayer, Swierk, Poland.

Fig. 1



Step	C	T
1	47p	0,1 - 1μs
2	470p	1 - 10μs
3	4,7n	10 - 100μs
4	47n	100 - 1000μs

Fig. 2



Step	C	f
1	1μ	25 - 250 Hz
2	0,1μ	0,25 - 2,5kHz
3	10n	2,5 - 25kHz
4	1n	25 - 250kHz

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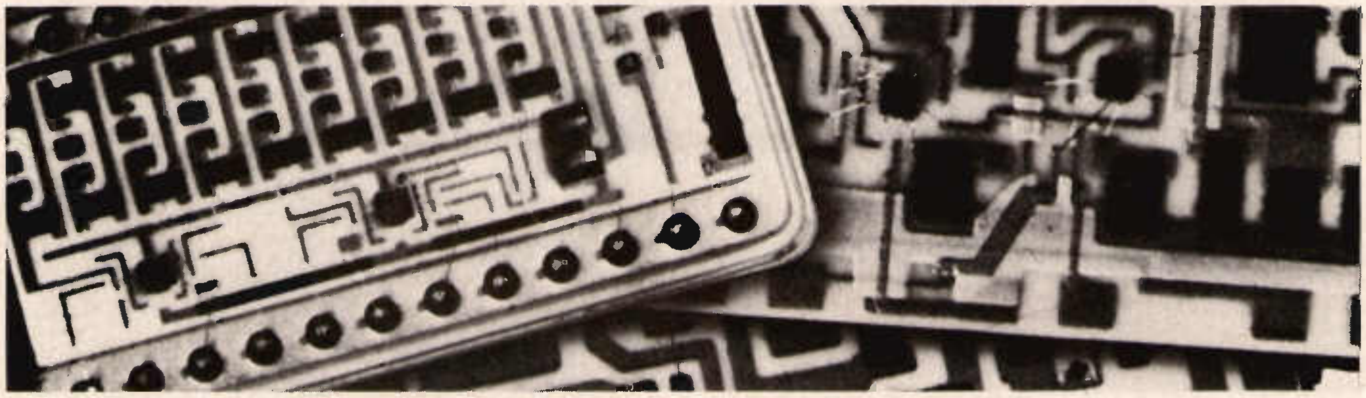

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Oscillograph reading by pages for long signal periods.

A process is described here for the best exploration of the *crt* screen, in the study of signals of very long periods. The work was carried out specifically for the visualisation of electrocardiograms affected by the anomaly named the period of Luciani-Wenckebach, obtained from a ECG generator previously designed and constructed in the laboratory of the authors.

When very slow signals are being explored it proves difficult and, at times, impossible to include a complete period in only one sweep of the *crt*. This is the case of the so-called periods of Luciani-Wenckebach which because they take place throughout a few cardiac cycles have lesser frequency than that of the ECG itself. The exploration of the complete period in successive sweeps presents difficulties:

a) An inevitable loss of information in the period contained between the end of one sweep and the next.
b) As the traces corresponding to different fractions of the period are superimposed, neither direct observation on a storage *crt* nor using a photograph from a general purpose *crt* would be easy.

For this reason the use of a register is indispensible. In the method we have developed the information appears on the screen in successive horizontal lines in the same way as normal writing without noticeable loss of information between the end of one line and the the next.

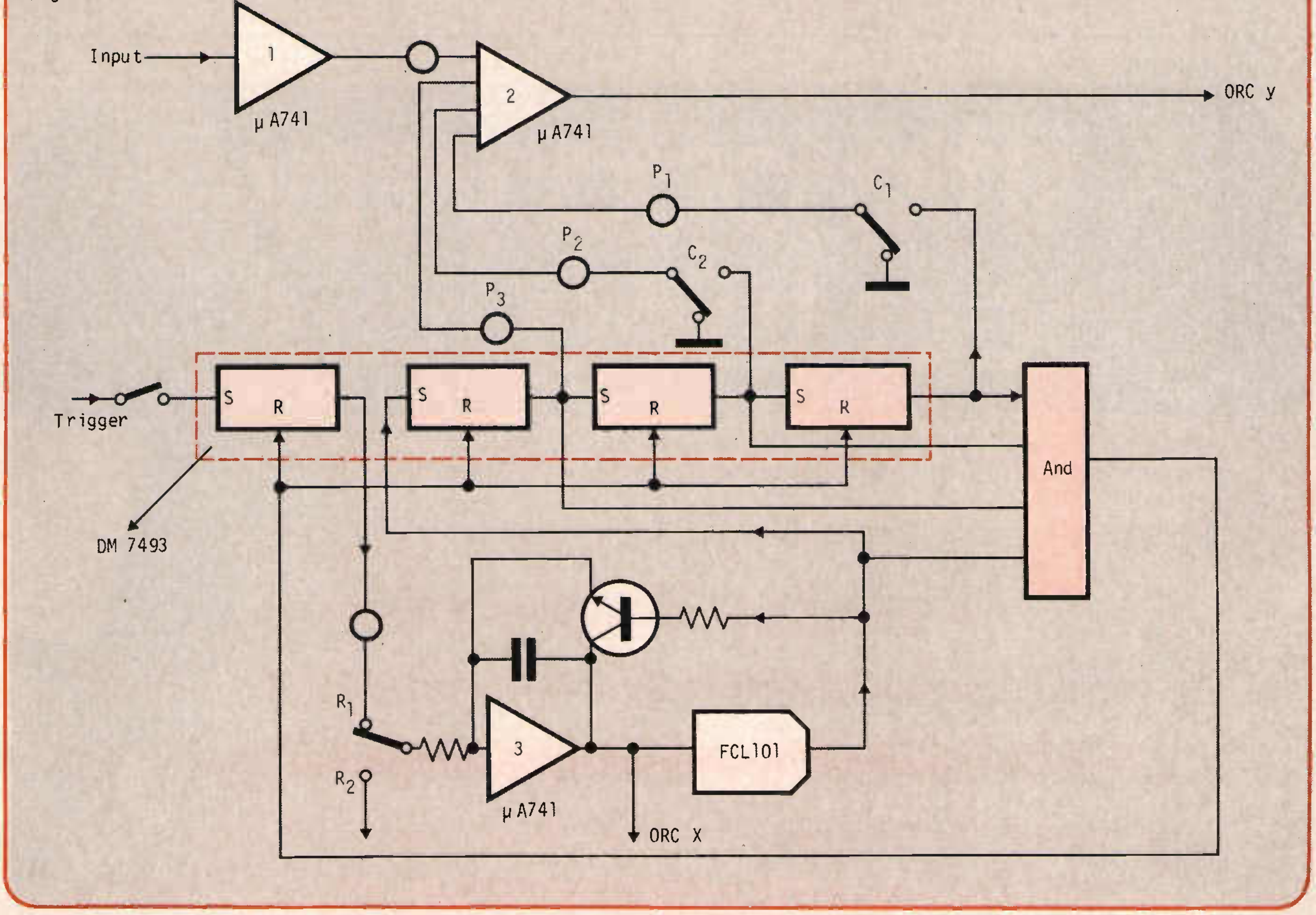
Figure 1 corresponds to the logical scheme of the disposition used. The integrator 3 which supplies the X voltage of the *crt* is permanently compared with an arbitrary reference. This allows the adjustment of the sweep for more comfortable observation. The level detector circuit performs two functions simultaneously: on the one hand it serves as a control element for setting the output of the integrator at zero and on the other hand it supplies the impulses destined to change the inner state of the counter, consisting of the bistables *A, B* and *C* whose outputs constitute the inputs of a d-a converter, on this is superimposed the signal we are going to explore, conveniently attenuated. The output of the circuit 2 supplies the Y voltage of the *crt*.

The eight counter consists of the three last bistables of a 16 bit integrated counter which, following a widely used technique has the first bistable independent. This last bistable allows us two kinds of sweep.

The switch in the position R2 permanently supplies to the integrator an input tension which previously adjusted determines the speed of the sweep. In this type of operation the *crt* allows the reading by pages in a continuous form, ie, it begins a new page immediately after having finished the previous one. In the position R1 the *crt* once triggered explores only one page, because of this gate Y is used for the detection of the state **111** of the counter and supplies via the terminals *reset* the impulse necessary to set this at zero when the sweep of the eight lines is completed. The potentiometers Pi allows us to adjust the separation between the lines and the switches Ci, which connect two inputs of the gate to the outputs of the bistables of the counter or to the fixed tension corresponding to the state *one* of the chosen logic, allows the fixing at 2, 4 or 8 the number of lines per page.

R Luengo G, B Mahedero B, J J Peña B, and M Gálvez D

Fig. 1



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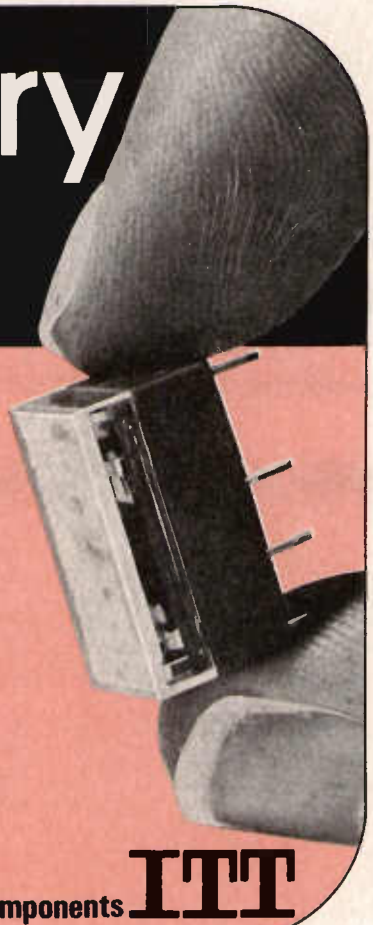
19 on enquiry card

A little of a very good thing



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APPLIED IDEAS

Space packets of pulses to desired time

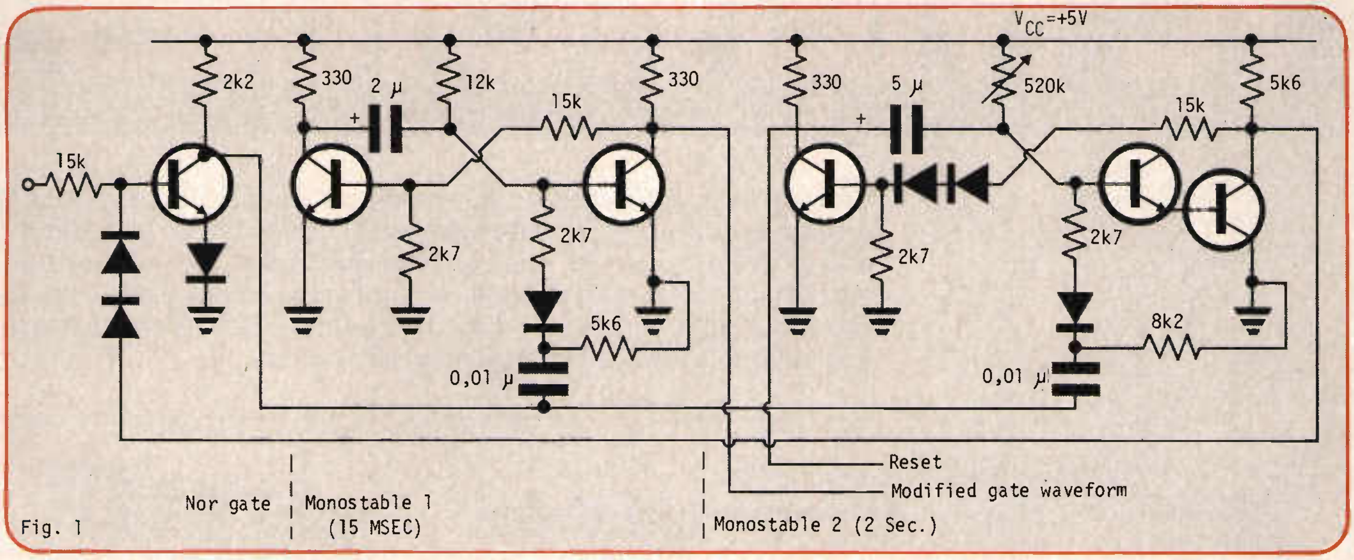

Fig. 1

Some applications involve the automatic counting displaying and resetting of the counter. The circuit shown in Fig. 1 does the same function. It spaces two packets by a time determined by monostable 2. The monostable 1 is adjusted to the time such that $T/2 \leqslant T_1 < T$. Monostable 2 can be constructed by using 74121 chip to get improved time spacing greater than 2 seconds. The given circuit spaces packets only by two seconds.

The feedback is given to the *nor* gate from *Q* output of the monostable of period 1 to 2 seconds to avoid the fractioning of the gate waveform. The complete packets of pulses occur after a few seconds. The period between two packets is varied from one to two seconds. This is also called as display time. The positive edges of gate waveform and the output of 15 msec. monostable are obtained in synchronism by above circuit.

To obtain the packets of pulses, the waveform shown in Fig. (1-5), gate waveform and clock oscillator waveforms are given to *and* gate. The output obtained is given to the counter. The counter counts the number of pulses in the packet, which are proportional to the phase difference. The reading is displayed on the display for a time decided by 2 seconds monostable. The counter is reset in a few msecs. before counting the next packet, which has again the same number of pulses as counted before.

Patil Vinayak, India.

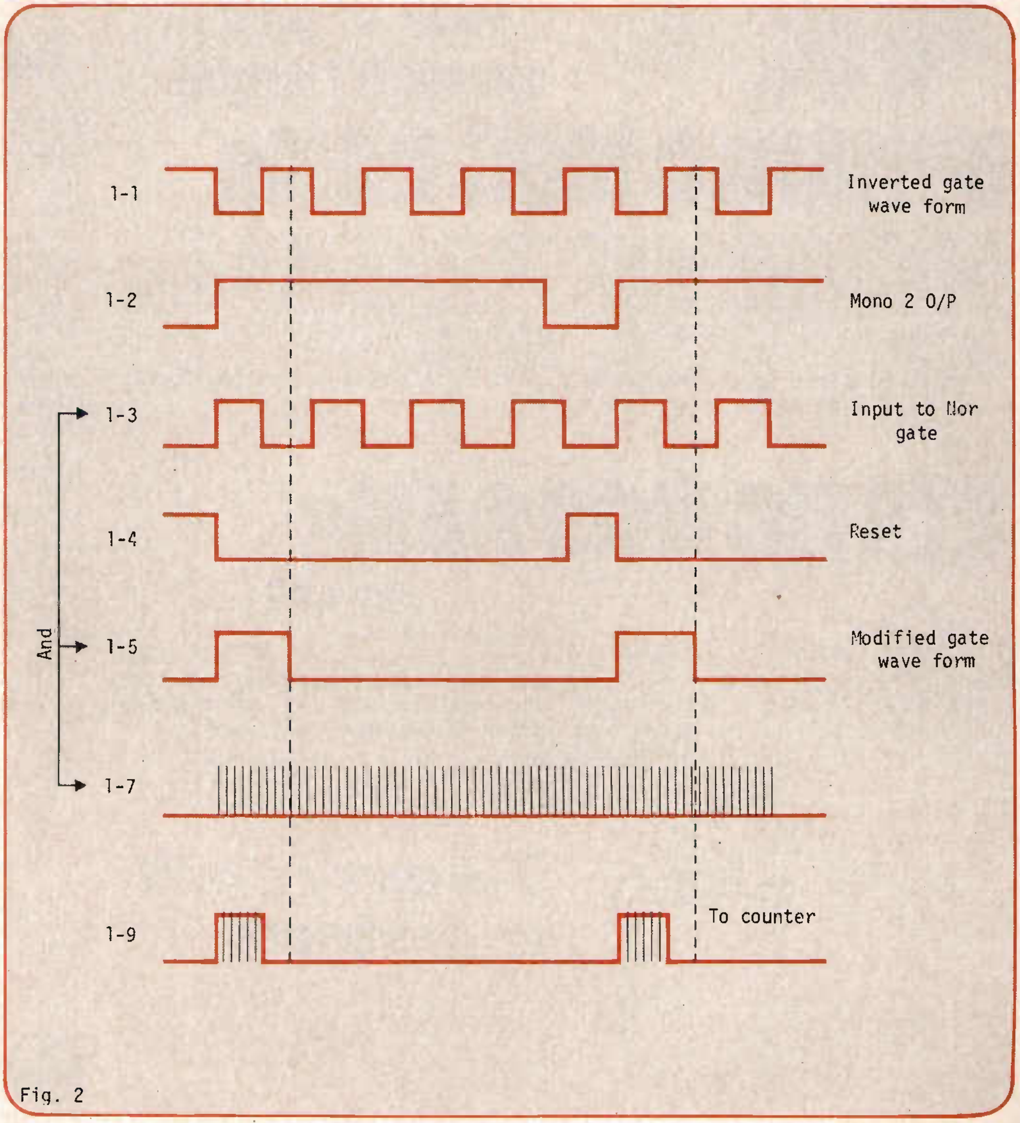

Fig. 2

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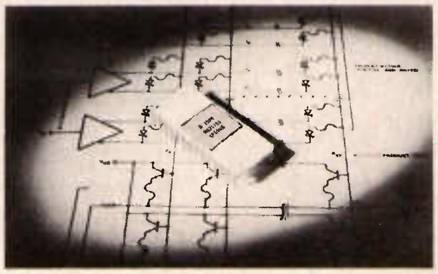

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Circuit generates 256 functions sequentially

The circuit shown in Fig. 1 generates all the 256 functions of 3 variables sequentially. The three variables X1, X2 and X3 directly control the eight-line-to-one-line multiplexer. If all the multiplexer inputs D0, D1 . . . D7 are *zero* then the trivial function *zero* is realized. On the other hand if the inputs D2 and D3 are *one* and the other inputs are *zero*, the function X1 X2 X3+X1 X2 X3 (i.e. $\Sigma(2, 3)$) is realized. The 8 bit counter outputs are connected to the multiplexer inputs and as the counter cycles through its 256 states all the 256 are realized.

A Mageswaran, Tamil Nadu, India.

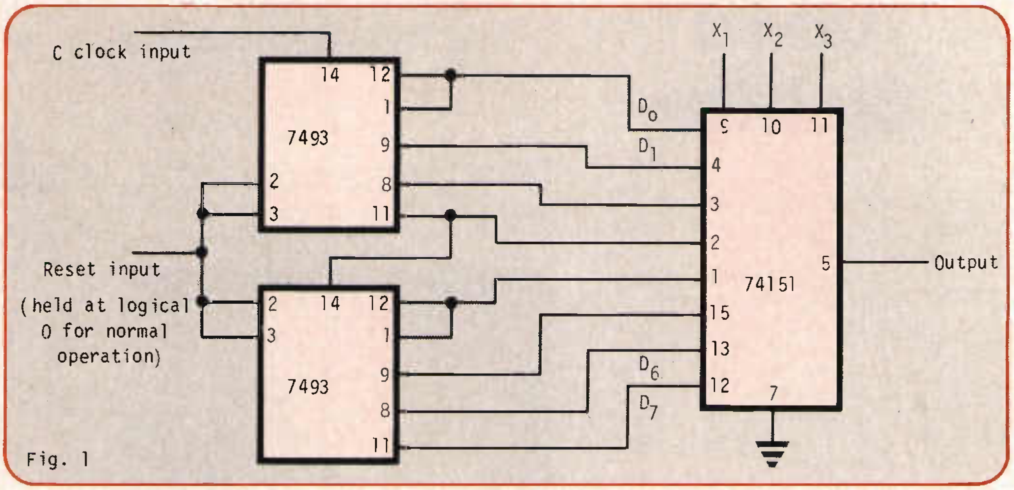

Fig. 1

Voltage to frequency converter with linear regulator

In voltage to frequency converters the integral element capacitor (see Fig. 1) defines the output frequency by the charging time and discharging time.

The charging time is always completed at a pre-determined V_0 voltage. Its speed is dependant on the charging voltage which is proportional to the input voltage. Its discharge is well defined, starting after reaching V_0—usually very near 0V.

So the time period T consists of two parts, T1 the charging time and T2 the discharging time.

During the charging time T1, the capacitor voltage is evenly increased. At the beginning of discharging period T2 the current is at its peak and is gradually decreased. The discharge period T2 is proportional to C.

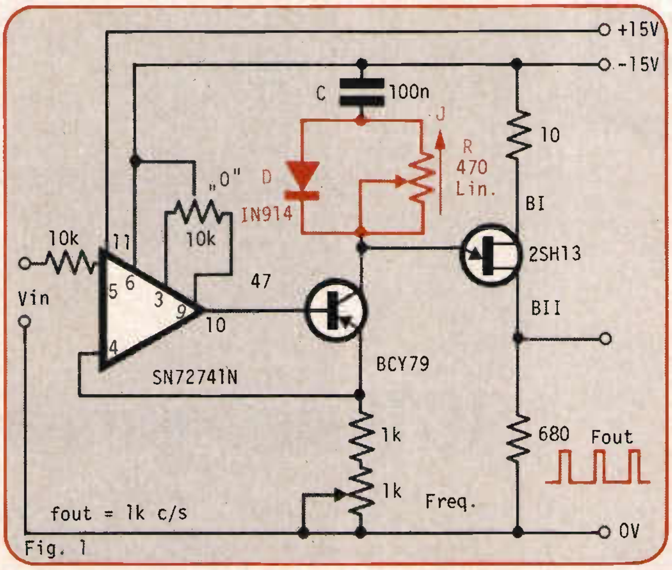

Fig. 1

$$f = \frac{1}{T} = \frac{1}{T_1+T_2} = \frac{I}{C(V_0+kI)}$$

Because the charging current appears in the denominator the relationship is non-linear. But if we place a resistor in the path of the charging current then the sum of a reduced current through R and the current of the condensator will produce the currents start discharge.

Now we have the following voltage frequency relationship:

$$f = \frac{I}{C.V_0+C.I(k-R)}$$

Regulate k to equal R:

$$k-R = 0 \text{ and } f = \frac{1}{C.V_0} I$$

As the I is no longer in the denominator, the frequency is a linear function of voltage.

J Ormay, Wilmington, Kent.

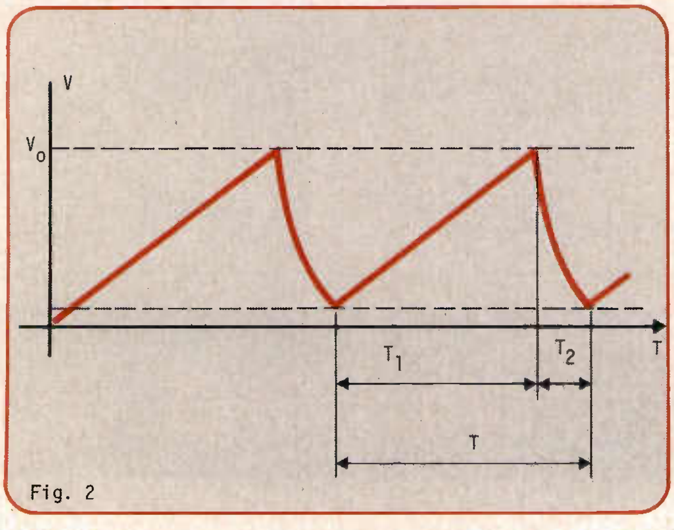

Fig. 2

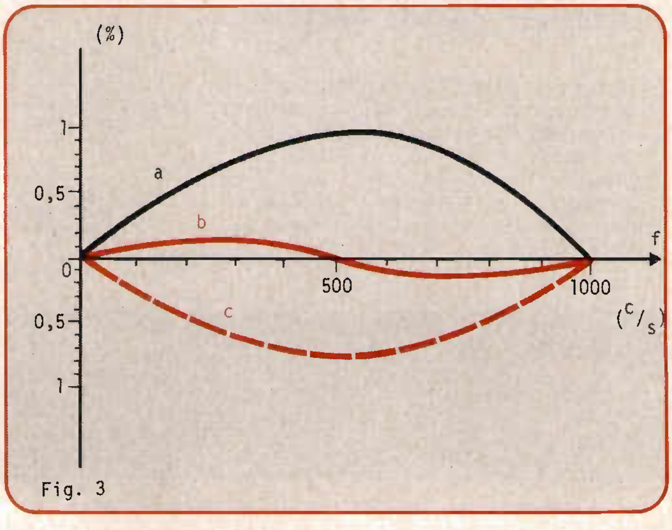

Fig. 3

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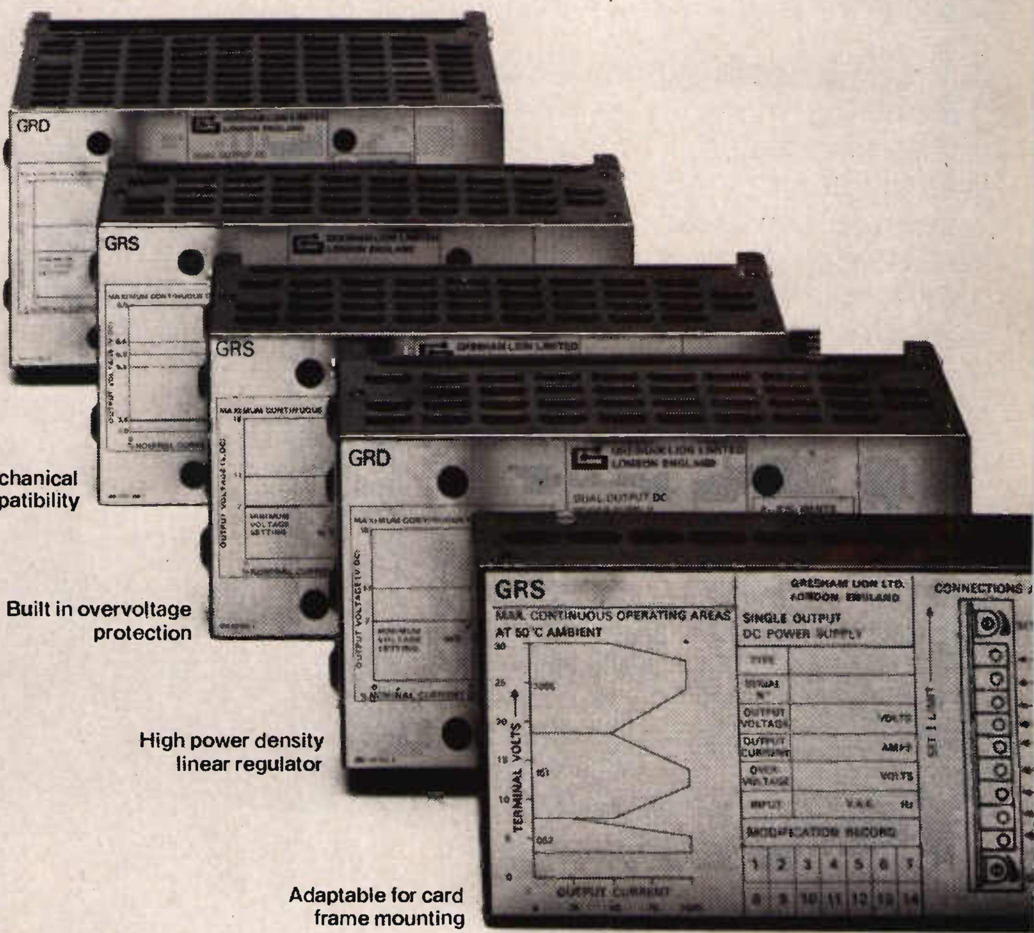

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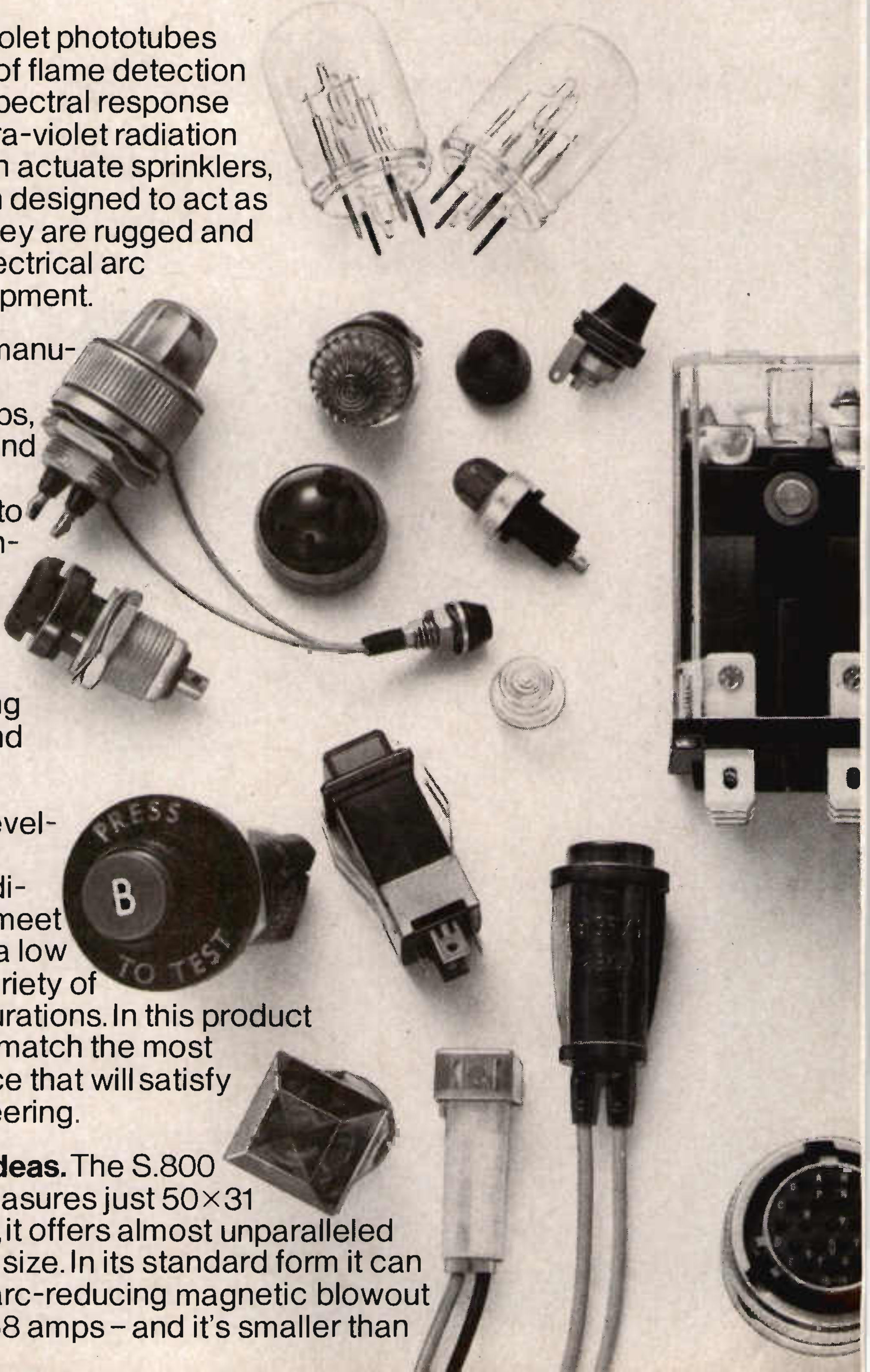

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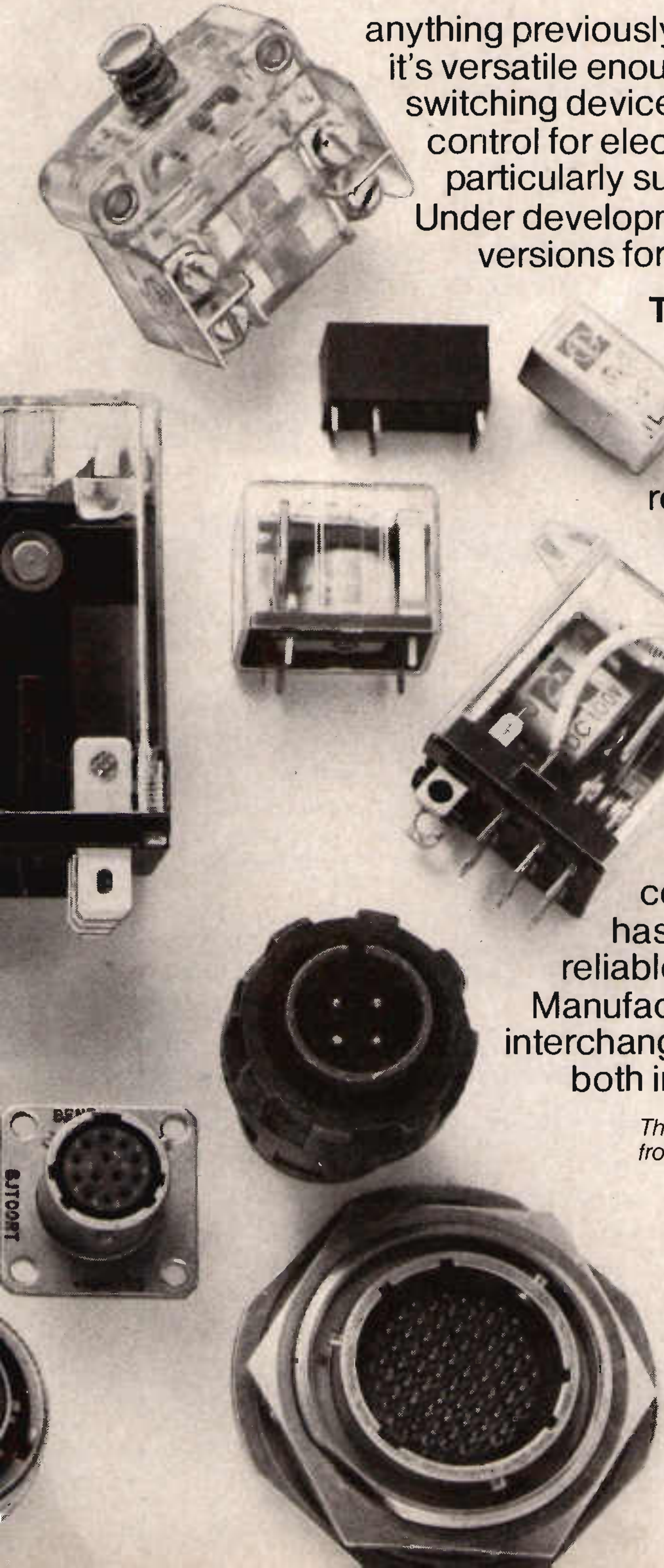

anything previously available. Not only is the S.800 tough, but it's versatile enough to operate at the heart of a wide range of switching devices. Already used in a cam operated speed control for electric trains, its robustness and long life make it particularly suitable for 'fit and forget' applications. Under development are pushbutton, lever and cam operated versions for wide industrial applications.

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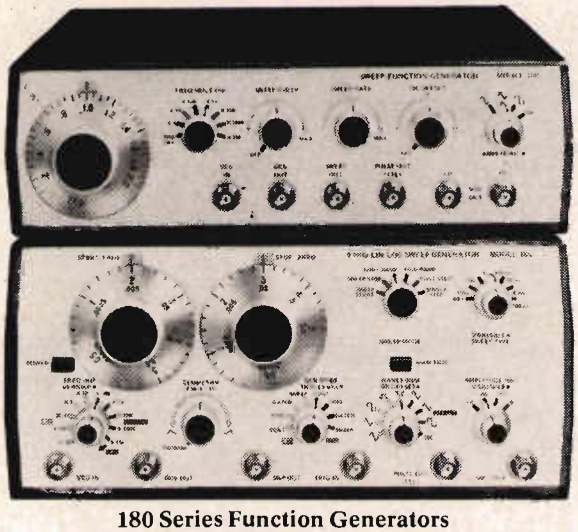

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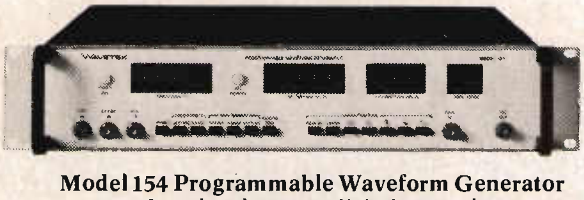

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Instrument interfaces to ease system design

In this article *David Metcalfe* explains the principles behind interface buses and how they can be used to link-up instrumentation and associated equipment of various manufacture.

With an increasing level of complexity in all types of electronic equipment, and a shortage of skilled technicians, manufacturers and large users are having to implement automated test systems. International agreement on a standard instrument interface removes many of the difficulties of handling incompatible inputs and outputs in systems using instruments of different manufacture.

The traditional approach to interface in the area of general bench-top instrumentation has been to provide access to a number of specialised control, data and status lines in individual instruments. Although this makes it relatively easy to interface with the outside world at an individual level, problems arise when a number of instruments are required to communicate with one another in a systems configuration. Then, many different interface adaptors are needed to cope with the wide variety of signal levels, logic conventions, protocols, codes, formats and so on that are in use throughout the world.

If anything, the situation has worsened with the introduction of sophisticated programmable instruments. Some of these require more than fifty signal lines and a few demand over a hundred. In these situations, interfacing can become a nightmare in systems involving only a few instruments.

David Metcalfe is with Hewlett-Packard Ltd.

A review of instrumentation system components and requirements highlights a very wide range of needs. While some systems use fifty or more instruments, detailed analysis reveals that it is rare for more than twenty to have a need to communicate with each other at any one time. Also it shows that most instrumentation systems remain intact for long periods, whereas other systems are changed on an almost daily basis. No doubt this is due to the rigidity of traditional instrumentation systems design. Other observations reveal that it is customary to locate the majority of instruments around a central control and provide remote terminals and displays. Data rates within traditional systems may vary by as much as three orders in magnitude.

It is, therefore, almost impossible to establish an interface system which will meet the needs of every user. Cost and complexity of an all-embracing interface would be prohibitive for general use. The Hewlett-Packard Interface Bus (Hewlett-Packard's implementation of IEEE Standard 488-1975) fulfills many of the basic requirements.

No single interface method is a panacea for all the world's interface requirements and the HP instrumentation bus is no exception. It has, however, undergone exhaustive field trials and fulfills the major needs for a range of calculator and computer controlled instrumentation systems.

Simplicity is a keynote of the HP interface design. The bus itself is entirely passive, with drivers, receivers, message coding and other active circuitry contained within the individual instruments. This arrangement is very cost effective, since the interface circuitry can be tailored to meet the specific needs of individual system components. A printer, for example, is basically a receiver of information and requires less interface circuitry than say a digital multimeter which has to be instructed to perform specific tasks.

Up to 15 units can be connected to the HP interface bus, which is shown schematically in Fig. 1. Here, for purpose of explanation, four typical units are connected to the 16-line bus. The arrangement is quite arbitrary, but does

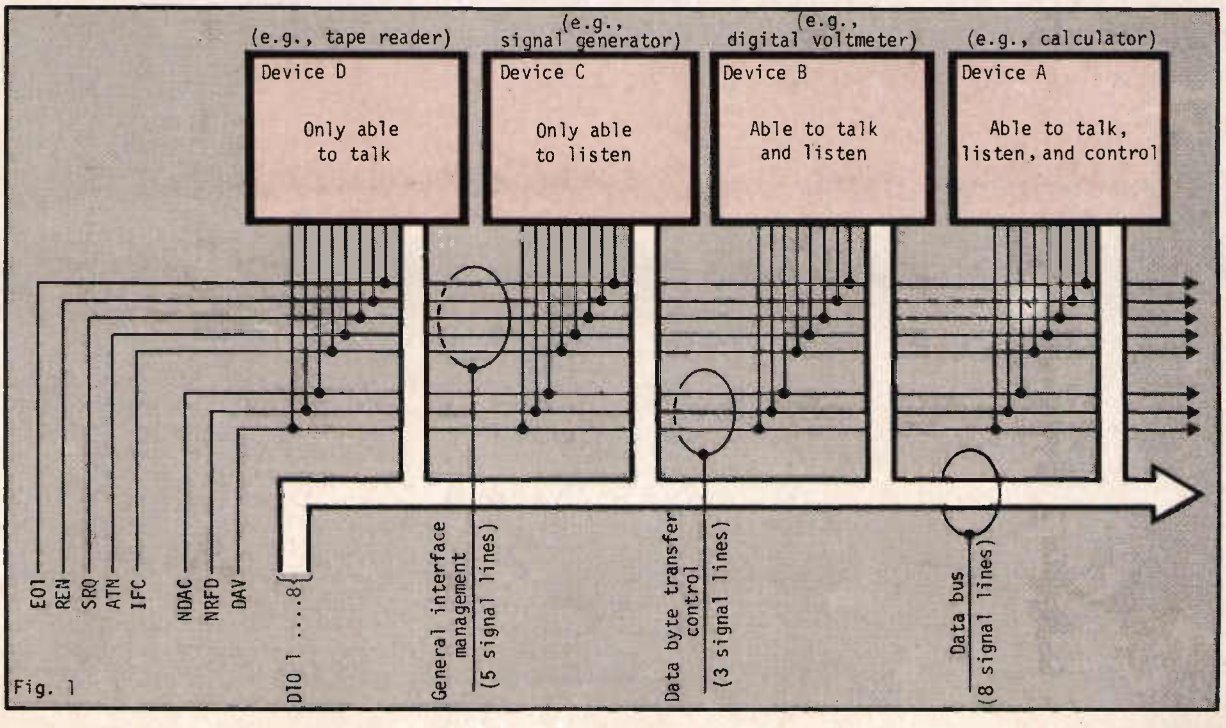


Fig. 1. Interface capabilities and bus structure.

illustrate the type of inputs and outputs that have to be carried on the bus and also the general interface management.

Bus structure

Functionally, the interface is split into three sectors. The largest of these, occupying eight lines, is used to convey data in bit-parallel, byte-serial form asynchronously and also to issue principal instructions. In conjunction with the data-byte transfer control bus, which occupies three lines, comprehensive handshake facilities are established between 'talkers' and 'listeners'. The remaining five lines are used for general interface management.

As indicated in Fig. 1, devices connected to the bus may be talkers, listeners or controllers, or a combination of all three. The main controller dictates the role of each of the other devices by setting the ATTENTION LINE (ATN) *true* and sending talk or listen addresses over the data lines DIO-1 to DIO-8. Each instrument and peripheral in the system is coded during the commissioning phase to accept specific send and receive addresses (a simple operation involving the setting up of codes on either switches or pcb jumpers on the back of each component in the system). When the ATTENTION LINE is *true* (digital *low*) all devices in the system are made to listen to the controller. Then when the ATTENTION LINE goes *High*, only those devices that have been addressed will actively send or receive data: all other units are isolated from the data bus.

More than one listener can be activated simultaneously, but, for obvious reasons, on a bi-directional bus only one talker can be active at any one time. A common address can be allocated to listeners that always need to be on at the same time. Addresses are usually formulated in standard seven-bit ASCII code and communicated to the system components over seven of the data bus lines. This enables almost any controller to be used on the HP bus and offers the user considerable flexibility. Using five bits for addresses, 31 talk and listen discrete addresses can be included in a single byte. Secondary commands, occupying two bytes, extend the capability to 961 talk and listen addresses.

A talk address selects one instrument to send data and automatically disables all other interface circuits with data transmission facilities. A listen address, on the other hand, does not effect the status quo—it merely links an individual instrument (or instruments) to the data highway. By sequentially addressing a number of listeners, several instruments can be connected to the data highway at the same time.

Information is transmitted sequentially under the control of the data-byte transfer bus. No step in the sequence can be initiated until the previous step is completed. Thus data can be transmitted at speeds compatible with the addressed instruments. The handshake routine, included in Fig. 2, is repeated at the byte level to ensure that fresh data is not transmitted until every listener is cleared down. Interface circuitry at the receivers can of course include memory to store data and allow data generation and data settling times to overlap with the listener's ready-for-data time. With this arrangement speeds up to about 1 Mbyte/s can be achieved on a burst basis.

For convenience, ttl logic levels are used on all signal lines of the bus. *High* is held at or above 2,4 V, while *low* is kept at or below 0,8 V. The driver circuits are usually open collector types capable of sinking around 50 mA. Where speed is critical, three-state drivers can be used to advantage. Again, the receiver circuitry is conventional and often integrated with other circuitry in individual instruments.

To simplify the transmission paths, each line is terminated in each device by a 3 kΩ resistor up to the positive logic rail and a 6,2 kΩ to logic common. This is an engineering compromise which avoids the usual termination problems during commissioning at the expense of transmission path length. If connector lengths of more than 20 m are required, then traditional extender and terminal techniques have to be employed.

The remaining control lines of the bus are self-explanatory. Providing overall management functions, they are interface clear (IFC), service request (SRQ) and end of identify (EOI).

Building up an automated system of instruments already fitted with standard interface circuitry is fairly straight forward. Individual instruments are linked together by cables with special 'piggyback' connectors. These have male and female terminations at either end and a simple lock-screw mechanism enabling cables to be stacked on top of each other. This gives the user complete freedom in cable routing. He may set up a line of star configurations or any combination that is convenient in terms of space available. Theoretically there is no limit to the number of connectors that may be stacked, but practical considerations

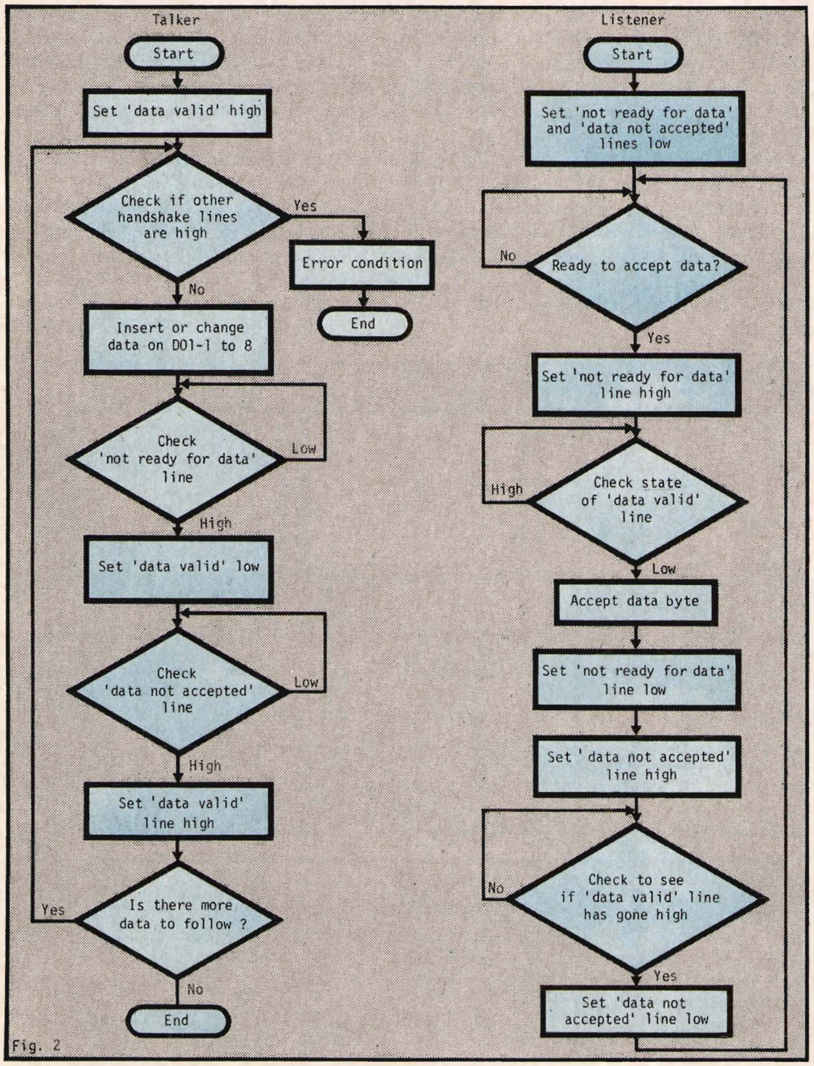


Fig. 2. This handshake routine ensures that data is transferred correctly and at a speed compatible with the addressed listeners.

suggest four is about maximum; otherwise front panel damage may occur from the resultant cantilevered structure. Normally there is no reason to have more than two or three, since one can parallel up all system components. Electrical considerations limit the lengths of cable to 20 m in the basic system.

From the foregoing it is clear that once a common interface is established universally, instrumentation systems involving items of different manufacture will be easier to assemble. It will not, however, alter the fundamental process of designing and building systems. The systems engineer will still have to define the problem, select basic instruments, controllers and other peripheral apparatus, integrate the system, write utility and applications software and document the system.

Although the common interface solves the mechanical, electrical and functional compatibility problems of communication between instruments in a systems configuration, it does not get over the various operational differences. Generally speaking instruments tend to have unique programming commands and/or data output formats. Failing to understand the syntax needs for each instrument can cause readings to be taken at the wrong time, cause a controller to interpret data incorrectly, prevent instruments from triggering when they should and so on.

Then there are problems of equipment selection. At some point the systems designer may be faced with a choice between using a bench instrument either already designed for system use or adaptable to it through various bus-compatible accessories such as dacs and code converters, and using a system component that may not be the best solution for solving a particular problem. Often the lab-bench instrument has higher performance capabilities and the price difference can be off-set by the fact that, being capable of manual control, it could be useful in debugging a new system and also for diagnosing problems in a unit under test that is found to be faulty. Problems of this nature will of course reduce as the systems designer gains experience and more system evaluation equipment becomes available.

Producing the accompanying software should be easier with a common interface system. The utility software is certainly easier, since the addressing structure allows all bus instruments to share a common driver routines. Also, since the bus is basically a communications structure, information can be treated as discrete packages. There is no need to specify the characteristics of particular devices: the handshake routines ensure packages of data at byte level are accepted by all addressed listeners.

The simplest form of utility software for an HP interface bus system is a card reader. Binary code for each data line on the bus and for the attention line could be marked on individual cards for each byte of information. This kind of detail could, of course, be handled by rom in a calculator or computer, enabling an operator to control the system through the higher-level language of the keyboard.

The availability of desk-top calculators with their readily grasped programme generation, editing and debugging techniques aid the systems designer produce applications software. Helping with routine work they give the user a little elbow room in one of the most critical areas of system design. Defining how measurements are to be taken and how the raw measurement data is to be processed is of paramount importance.

All too often, a systems builder underestimates the extent of effort needed to establish good working solutions.

The systems designers should keep in mind who will use the software. In many cases, the systems user is able to contribute valuable software improvements even though he may not have had previous programming experience. If software-user interactions are planned carefully, then the programme can allow a test-technician to decide what course of action should be taken when a failure occurs in a device under test. It should also take into account human fallibility. Mistakes do occur, especially when priming a system, and a facility to correct a wrong entry in isolation is much better than requiring an operator to repeat a lengthy input procedure.

This air of cautiousness in no way detracts from the advances made in systems engineering in the last five years. A common interface for instrumentation is a great step forward. Facilities to interconnect instruments of different manufacture in a systems configuration benefit every one.

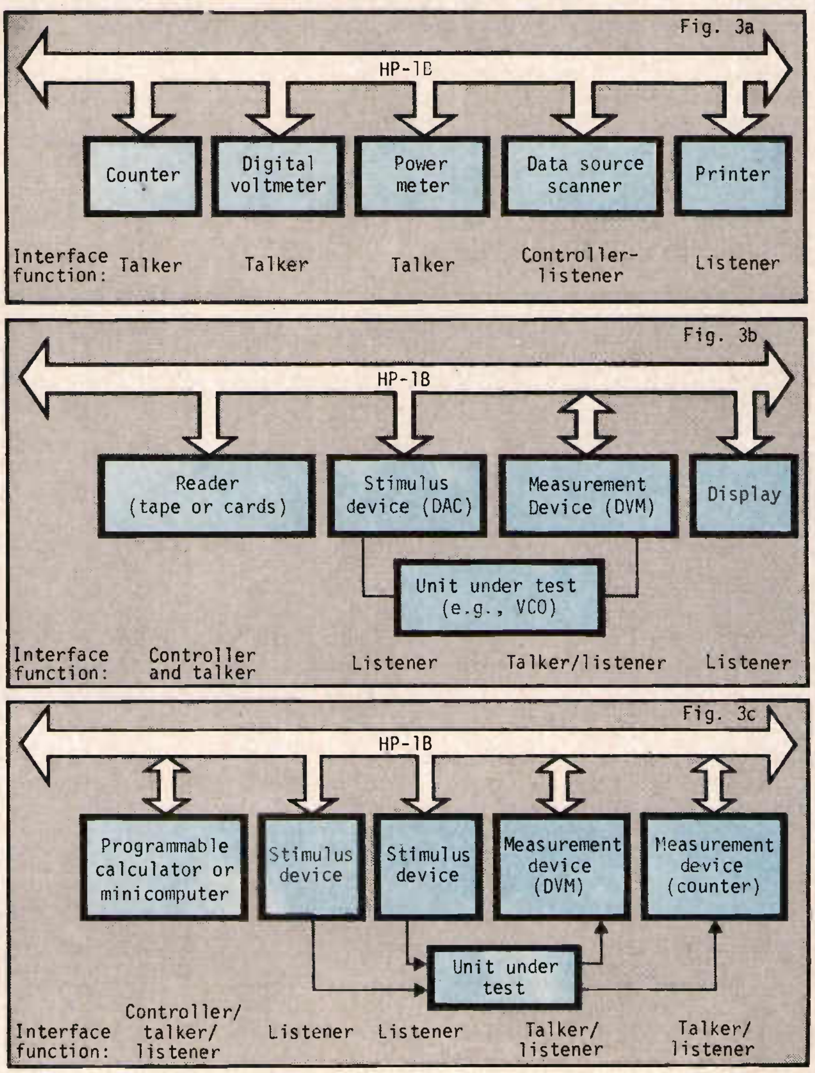


Fig. 3. Typical bus configurations, (a) shows how a scanner can be used to allow several measurement devices to take turns in supplying data to a recording device; (b) illustrates a card or tape reader controlling the functions and ranges of other instruments; (c) depicts a programmable calculator or minicomputer arrangement where extensive data manipulation and decision making can be written into a test programme.

New vmos technology threatens bipolar supremacy

Although mos technology is widely used where high density is required, high power applications have favoured bipolar techniques. The development of vmos devices, writes *Philip Regan*, means that bipolar devices are no longer the automatic choice where power handling capability is required

Until 1976, whenever an application required a high voltage, high current, active device, the automatic choice was a bipolar device. Where high current gain was another requirement, a power Darlington would be employed. Recently, however, a new processing technology has resulted in the development of vertically structured, field effect power devices in which the main current flow occurs in a vertical direction. These new devices are expected to become a serious rival to bipolar devices in many applications from dc to uhf. Vertically structured junction fets (vfets) have been available for some time as a result of development by Japanese companies such as Sony, NEC, and Yamaha. These devices are, in the main, limited to applications below 1 MHz due to excessively high capacitances. Furthermore, drive and bias arrangements for these devices tend to be complicated. Notwithstanding, the power handling performances of vfets such as the Sony 2SK60 (n-channel, 63 W), the Sony 2SJ18 (p-channel, 63 W) and the Yamaha 2SK77 (n-channel, 200 W) are very good.

Philip Regan is with Siliconix.

More recent investigations have been made into vertical mos (vmos) technologies and show greater promise than present vfet technology. Several power mos structures are under development but so far only one such structure is commercially available — the MOSPOWER range. This range includes devices that can handle up to 25 W dissipation in a TO-3 package and switch currents up to 2 A. These devices are available with typical ON resistances between 1,4 and 3,4 Ω and breakdown voltage ratings between 35 and 90 V.

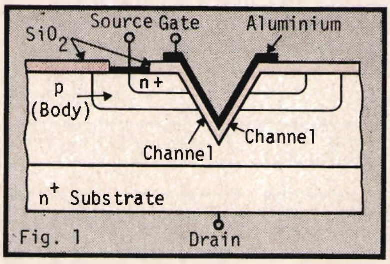


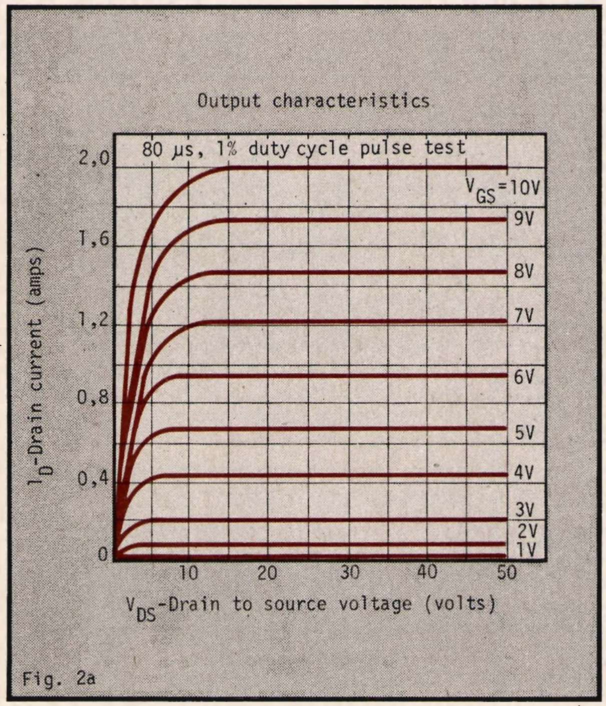
Fig. 1 Simplified vmos structure
Fig. 2a VMP-1 output characteristics
Fig. 2b Transconductance vs drain current for the VMP-1.

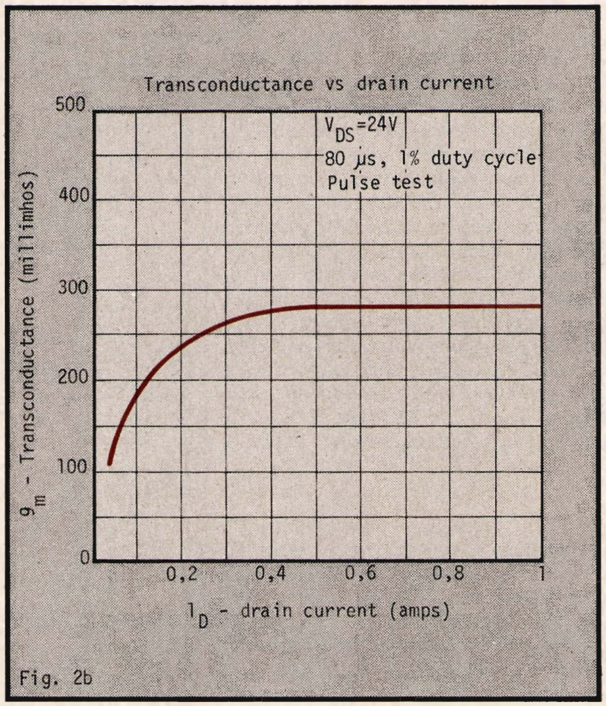
Lower power versions are available in TO-39 packages, capable of handling currents up to 1,5 A with a dissipation of 4 watts.

VMOS technology

Fig. 1 shows a cross-sectional view of a simplified vmos structure. The substrate, which also forms the drain, is heavily doped n+ type material and provides a low resistance current path to the back surface of the chip. The more lightly doped n− type epitaxial layer above the substrate increases the structure's breakdown voltage capability by virtue of having a much wider depletion region than n+ material. In addition, this lightly doped epitaxial layer acts as a buffer to reduce the all important gate-drain capacitance.

The p type body and n+ type source regions are diffused into the epitaxial layer in a fashion similar to the base and emitter diffusions in bipolar technology. Subsequent selective etching produces a V groove through the source and body regions into the n− layer. The accuracy of the dimensions is determined mainly by the crystallographic orientation of the silicon. All that remains is to produce the





usual silicon dioxide coating and contact metallisations by standard masking and deposition techniques. The resulting device is one whose most critical dimensions (in particular the channel length) have been controlled by diffusion techniques which are more accurate than the masking techniques used to control the same critical dimensions in conventional lateral mos devices. In operation, the Siliconix vmos device is an n-channel enhancement mosfet whose gate is controlled by voltages which are positive with respect to the source. As the gate is taken positive, an n-type channel is induced at the p-type oxide interface. Consequently, a conducting path is established between the source and drain. Conversely, as the gate voltage is taken towards zero the device is gradually turned off.

VMOS vs lateral mos

There are a number of important differences between vmos and conventional lateral mos devices. Because the channel length can be more accurately controlled, it can be made much shorter than that of a lateral mosfet. Thus, by virtue of its lower width/length ratio, a lower channel resistance is possible. A typical length for the VMP-1 channel is approximately 1,5 μm, whereas for a conventional mos device it must be at least 5 μm to account for mask alignment tolerances. Each V groove produces two channels, thereby inherently doubling the current carrying capability. Since the substrate forms the drain region, the need for top surface drain contacts is eliminated; therefore, the surface area of the chip is reduced. Furthermore, the saturation resistance is reduced and heat conduction efficiency between the drain and the package is greatly improved. Feedback capacitance is especially low for such a device since the process allows minimal gate-drain overlap.

Typical output and forward transfer curves (Figs. 2a and 2b) show clearly that, for drain currents above approximately 400 mA, the transconductance (g_m) is constant. This is a direct result of the reduced channel length. Drift velocity saturation of the majority carriers in the channel occurs above a certain threshold of field intensity produced by the gate bias. Below this level the device exhibits the conventional mos square law characteristic with g_m proportional to V_{GS} and I_D proportional to V_{GS}^2, and above this threshold level I_D is very nearly proportional to V_{GS}.

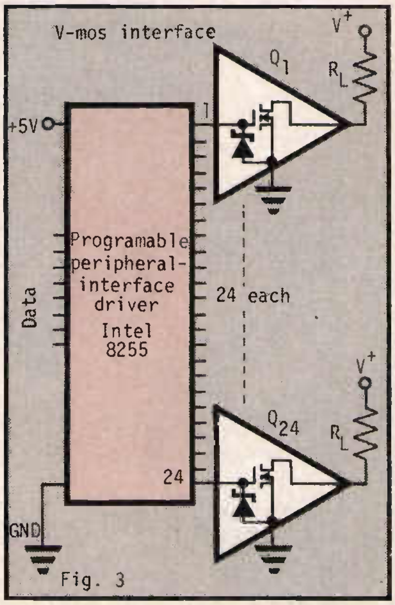


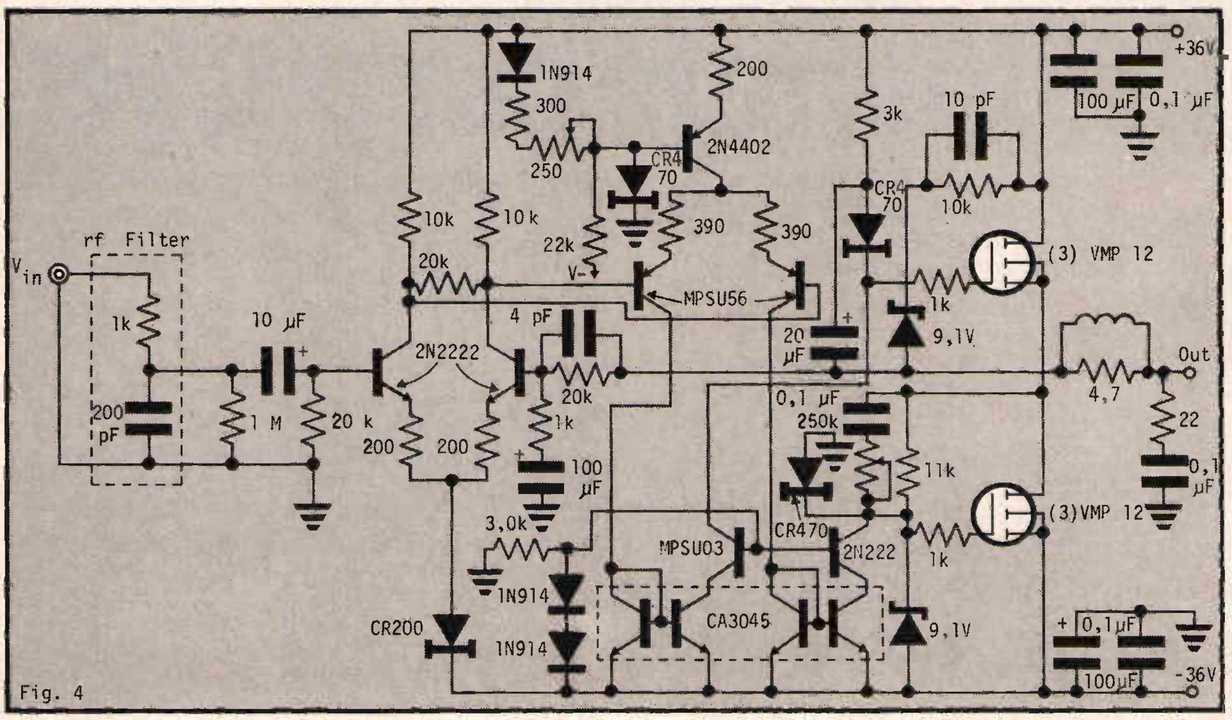
Fig. 3 VMOS uscd as peripheral control device with low power driving logio.

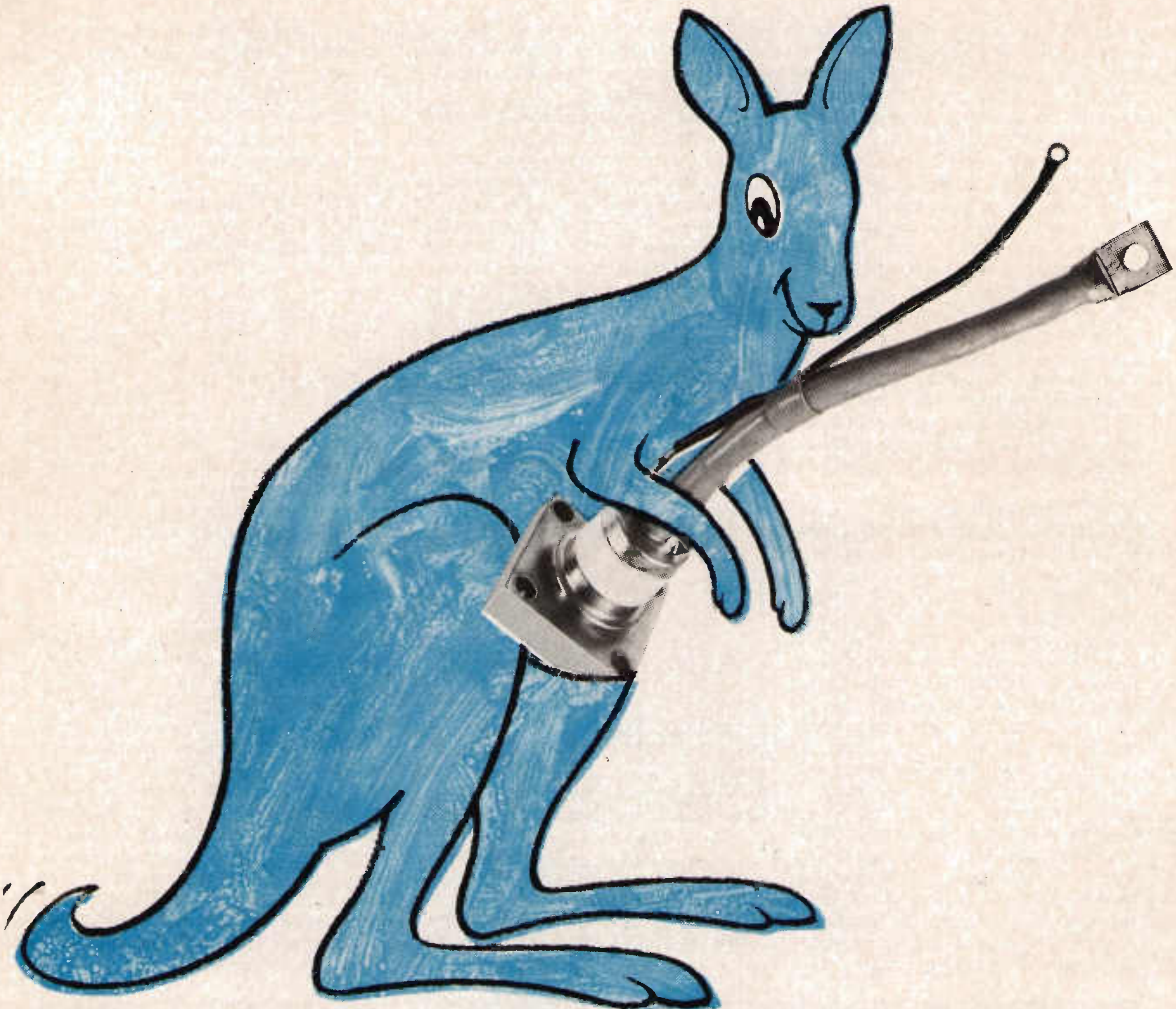
Fig. 4 High quarterly 40W amplifier using six fets in a quasi-complementary push-pull arrangement.

VMOS vs bipolars

VMOS fets are voltage-controlled majority-carrier devices and have many advantages over bipolar transistors, which are current-controlled minority-carrier devices. Input impedances are higher over the entire operating frequency range. Impedance values range from greater than $10^9\ \Omega$ at dc to a few tens of ohms at vhf. VMOS fets will interface directly with high output impedance drivers, such as cmos logic, with very small drive power requirements. In contrast, bipolar input impedances at dc are in the region of a few hundred ohms reducing to fractions of an ohm at vhf. Further, drive currents of some hundreds of milliamps may be required to switch collector currents of the order of amps.

Bipolar transistors exhibit slow switching speeds because of minority-carrier storage effects. VMOS, on the other hand, is unhampered in this respect. The only switching limitation is the ability of the drive circuit to charge and discharge associated circuit capacitance. The VMP-1 can typically switch 1 A in 4 ns into a 50 Ω load. This is many times faster than can be achieved by bipolar devices and also indicates a potentially good amplification performance at frequencies up to uhf. VMOS does not suffer from thermal runaway since the drain current has a negative temperature coefficient (as for all fets).





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VMOS is also free from secondary breakdown. This is also a result of the negative temperature coefficient of drain current. This is another way of saying that vmos has a positive temperature coefficient of channel resistance. If localised high current regions arise in the channel, the associated temperature rise will cause the channel resistance to increase locally. This will cause the local current to be reduced and thereby stabilised. VMOS devices may be run in parallel without current hogging, for the same reasons that no thermal runaway or secondary breakdown will occur. Base and emitter ballast resistors would be required to prevent current hogging in bipolar circuits. VMOS devices having such high input impedances will draw only leakage currents under quiescent dc conditions. They can therefore be considered as having very large values of current gain (typically 10^9 for present devices). This is several orders better than can be achieved by power Darlington bipolar devices.

VMOS disadvantages

VMOS devices do have some inherent disadvantages. Saturation voltage is higher than for bipolar devices. This is a function of drain-source resistance $r_{DS,on}$, which is, at present, in the low ohms region, although resistances of the order of fractions of an ohm will be possible with future vmos devices. Input drive voltage is fairly high. About 10 V is required at the gate for maximum drain currents. This drive requirement can be reduced but will not of course reach the low levels needed by bipolars, which require only that the base-emitter junction be forward biased. However, the low current drive requirements of vmos more than offset this disadvantage. The VMP-1 and VMP-2 exhibit capacitances of approximately 65 pF at their gates, due to input and Miller capacitances. When used for switching, this capacitance must be charged or discharged before the device is turned on or off, respectively. It is this capacitance which effectively limits the switching speed of the mosfet. For example, to switch a VMP-1 in 10 ns with a gate control voltage of 15 V a peak gate current of 98 mA would be required.[1]

An excellent application for vmos devices is as peripheral drivers interfacing between cmos control units and devices such as printers, solenoids and actuators. A simple example is given in Fig. 4 where devices such as the S75V01, 11 and 12 may be used to advantage. Each vmos device performs the function which would conventionally employ a power Darlington transistor with three resistors.[2]

Amplifier applications

Two factors point to the suitability of vmos devices for amplifiers. Firstly, the high, constant transconductance exhibited for drain currents above approximately 400 mA indicates a potentially more linear performance than can be achieved by a bipolar transistor which has an exponential characteristic. Secondly, the fast switching speed capability indicates an excellent high frequency characteristic. A high quality vmos audio amplifier has been designed,[3,4] which is capable of 40 W continuous operation into 8 Ω, with 1 Hz to 800 kHz frequency response. Typical distortion at 40 W and 1 kHz is 0,04% and the amplifier is capable of a slew rate greater than 100 V/μs. The output can be short circuited without damage because of the inherent safety features of fet devices. The circuit design shown in Fig. 5, is based on a quasi-complementary, push-pull, arrangement with three parallel VMP-12 devices in each complementary section. Only 22 dB of negative feedback was required to obtain the desired performance. Where high efficiency is a design requirement, Class D (pulse width modulation) amplifiers can be designed to take advantage of the excellent switching performance of vmos devices.

A number of rf amplifier designs using vmos devices have been published.[1,2,5,6,7,8] One notable circuit which emphasises the simplicity of rf design, using a VMP-4, is that of a broadband driver,[5] shown in Fig. 6. Two features are immediately apparent. Firstly, broadband input matching is achieved with a simple 4:1 impedance balun. Secondly, there is effectively no matching circuit at the output. The drain load impedance is designed to be approximately 50 Ω. The operational frequency range of the circuit is from 40 MHz (limited by the core properties of T1) to 265 MHz. For driving purposes, with output powers of 10 to 12 W into a 50 Ω load (depending upon input and bias conditions), this circuit shows a power gain of 12 to 15 dB, flat to within ±0,5 dB over its entire operating frequency range. The two-tone, third-order intercept point is typically 48 dBm, referenced to a single tone. The amplifier is able to withstand infinite vswr at the output, without damage. When used as a receiver front end, a typical small signal noise figure for this circuit was 2,4 dB at 146 MHz. Other class A designs have also been published,[6] but where higher efficiencies are desired then class C, D, E or F designs can be employed by virtue of the excellent capabilities of vmos devices to operate in pulsed modes.

1. Siliconix App. Note AN76-3, May 1976.
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3. Shaeffer, Lee, "Vertical mosfets (vmos) in high quality audio power amplifiers". Audio Eng. Soc. 54th Convention Preprint No. 1106.
4. Siliconix Design Aid DA76-1, May 1976.
5. Siliconix Technical Article TA76-1, August 1976.
6. Leighton, Larry, "Two-metre transverter using power fets". Ham Radio Magazine, September 1976.
7. Oxner, Ed, "MOSPOWER fet as a broadband amplifier". Ham Radio Magazine, December 1976.
8. Oxner, Ed, "A new technology takes on HF power bipolars". Microwave Systems News, October/November 1976.

A simple broadbandvhf amplifier design

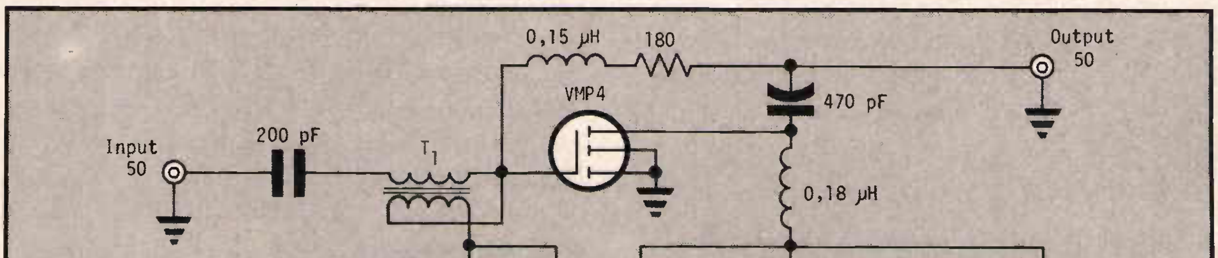

Fig. 5

T_1 = 4T 22 AWG twisted pair on indiana general core F625902

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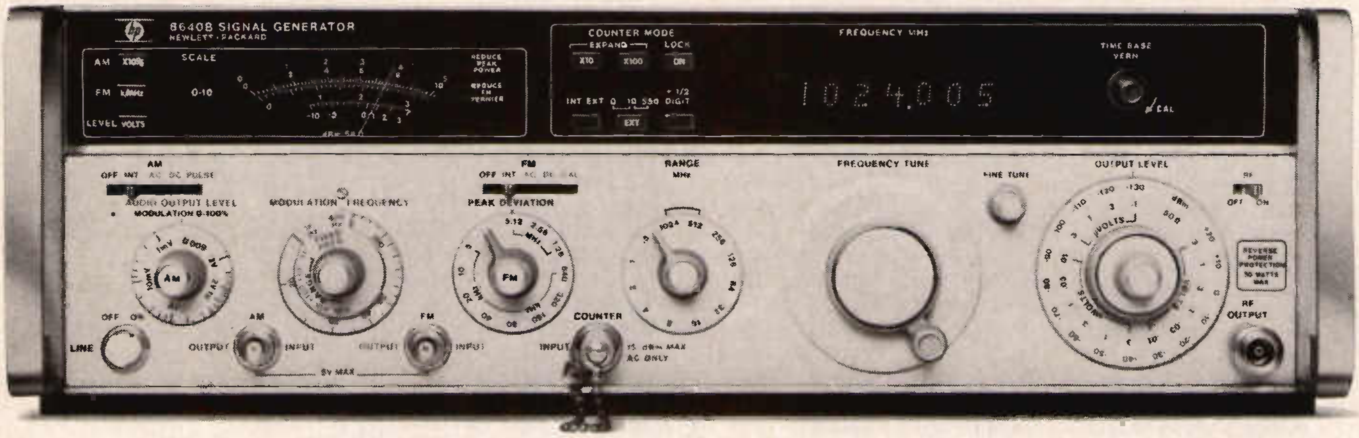

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Design of programmable sequential logic circuits

In this article, *Chris Heath* discusses a formal design approach for sequential logic systems that is particularly suitable to applications of msi and lsi components

There is a considerable body of literature that describes the design of sequential circuits by means of Switching Theory. A formalised design technique of this nature creates a structured design which is susceptible to formal diagnostic techniques and test sequence generation. Further, techniques exist, although not well developed, for designing into the circuit a degree of testability, and for incorporating self checking and fail safe properties into the basic logic structure.

Although there are significant advantages in formally designed circuits they are not often amenable to the inclusion of msi components. As most simple sequential circuits, such as counters, shift registers, and comparators, are available in msi the formal design, is costly in terms of the number of packages and area.

Chris Heath is with Cambridge Consultants Ltd.

However, by using prom and simple programmable control some of the advantages of the formalised approach may be realised, whilst avoiding the worst excesses of both random and formalised circuits. In a simple programmable controller the number of branches allowable from each state is limited—usually to one or two—whereas in a formal switching theory design, branching from the current machine state to the next state is limited only by the number of inputs. By reducing this multiple branch capability to a single branch per state a simple, more universal sequential controller can be designed.

Fig. 1: Flow diagram of sequence detector.
Fig. 2: State-table of sequence detector.
Fig. 3(a). Is state table exhibiting state redundancy removed to produce table shown in Fig. 3b.
Fig. 4: Transition and output table of sequence detector.
Fig. 5(a,b,c). Boolean expressions for the output Z, Y1, and Y2 are obtained by Karnaugh map.

Sequential circuits are defined as logic networks that contain memory in the form of feedback signals. The feedback vectors, which depend upon previous input values, determine the state of the circuit. There are two classes of sequential circuits: Mealy and Moore. In the former, the output at any time is determined by the current input and the current internal state of the circuit,

Fig. 1

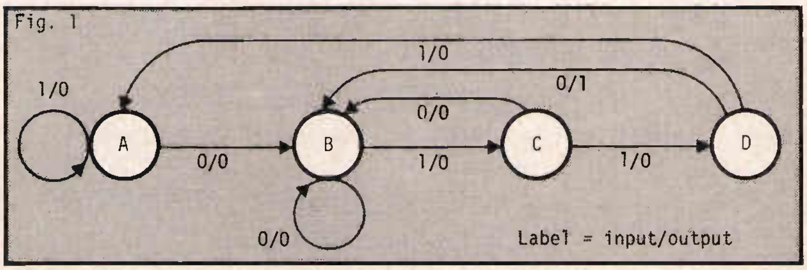


Fig. 2

PS	NS/z x = 0	NS/z x = 1
A	B/0	A/0
B	B/0	C/0
C	B/0	D/0
D	B/1	A/0

PS = present state, NS = next state, x = input, z = output

Fig. 3A

PS	NS/Z x = 0	NS/Z x = 1
A	A/0	B/0
B	A/0	C/0
C	D/1	C/0
D	A/0	B/0

Fig. 3(b)

PS	NS/Z x = 0	NS/Z x = 1
A	A/0	B/0
B	A/0	C/0
C	D/1	C/0

Fig. 4.

y_1y_2	Y_1Y_2/z x = 0	Y_1Y_2/z x = 1
A = 00	01/0	00/0
B = 01	01/0	11/0
C = 11	01/0	10/0
D = 10	01/1	00/0

Fig. 5(a)

y_1y_2 \ x	0	1
0 0		
0 1		
1 1		
1 0	1	

z map $z = \bar{x}y_1\bar{y}_2$

Fig. 5(b)

y_1y_2 \ x	0	1
0 0		
0 1		1
1 1		1
1 0		

Y_1 map $Y_1 = xy_2$

Fig. 5(c)

y_1y_2 \ x	0	1
0 0	1	
0 1	1	1
1 1	1	
1 0	1	

Y_2 map $Y_2 = \bar{x} + \bar{x}y_1y_2 = \bar{x} + \bar{y}_1Y_1$

while in the latter, the output depends only on the internal state of the circuit.

Sequential circuits (sometimes called sequential machines) may be synchronous or asynchronous, depending upon whether the circuit is operating under clock control or not. In synchronous circuits the clock is normally used for timing the data transfer through a memory element incorporated in the feedback line. The memory element can be one of a variety of bistables.

An alternative use of the clock is to strobe in the inputs, via *and* gates, for example. Asynchronous circuits are not controlled by a clock and hence the inputs and outputs are represented by levels rather than by pulses.

It is useful at this point to introduce the terminology of the subject.

The *internal state* (or simply *state*) of a circuit refers to the internal condition of the circuit which is determined by the history of its inputs. The *present state* of a circuit is defined by the logic values on the feedback lines, and this, in conjunction with the next input defines both the *next state* of the circuit and its response to the input. A circuit containing n feedback lines can have 2^n unique states. The *initial state* of a circuit refers to the state of the circuit prior to the application of any inputs. It is normal practice to reset sequential circuits to a known state when power is switched on.

The specification of the behaviour of a sequential circuit in terms of its inputs, present states, outputs and next states is described by either a *state-table* (or *flow-table*) or a *state-diagram* (or *state-graph*, or *flow-diagram*). A state-table has p columns, one for each input combination, and n rows, one for each state; an example is given in Fig. 2.

A state-diagram is composed of vertices, indicated by circles, and directed arcs between the vertices. The vertices correspond to individual states of the circuit which are identified within the circle. The directed graphs represent the transitions of the circuit from one state to another caused by the inputs. If an input does not cause a state transition then the arc of the vertex is directed to itself and is shown as a loop starting from and ending on the same vertex. The directed graphs are labelled to indicate the input combination and the output.

In order to implement a sequential machine it is necessary to use some device capable of storing information regarding the previous inputs. Such a device is composed of logic elements, each of which can have two states. Logic values have to be assigned to these elements to represent the various states of the machine. The device itself can be a delay line, or a monostable, or a bistable. The present state of the delay element is specified by its output y while its present input Y represents its next state. That is, $Y(t) = y(t+1)$ where t represents time. The states of the delay element are the states of the machine. The process of assigning the states of the physical delay element to the states of the machine is known as *state assignment* (or *secondary state* assignment). The output value y is referred to as the state variable (or *secondary variable*, to distinguish it from the primary input variables.

The main steps involved in synthesising synchronous sequential circuits.

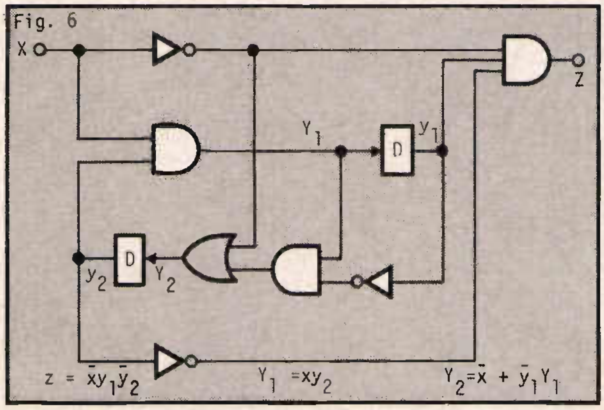
(i) Form a state-table (or a state-diagram) which specifies the circuit performance in terms of present output and next state.

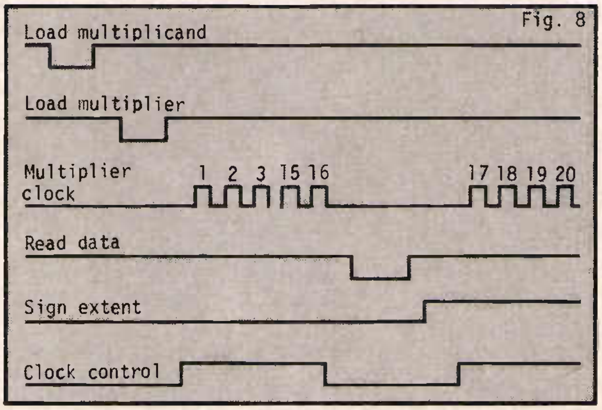
(ii) Check the table to see if it contains any redundant states. If so, reduce the state-table.

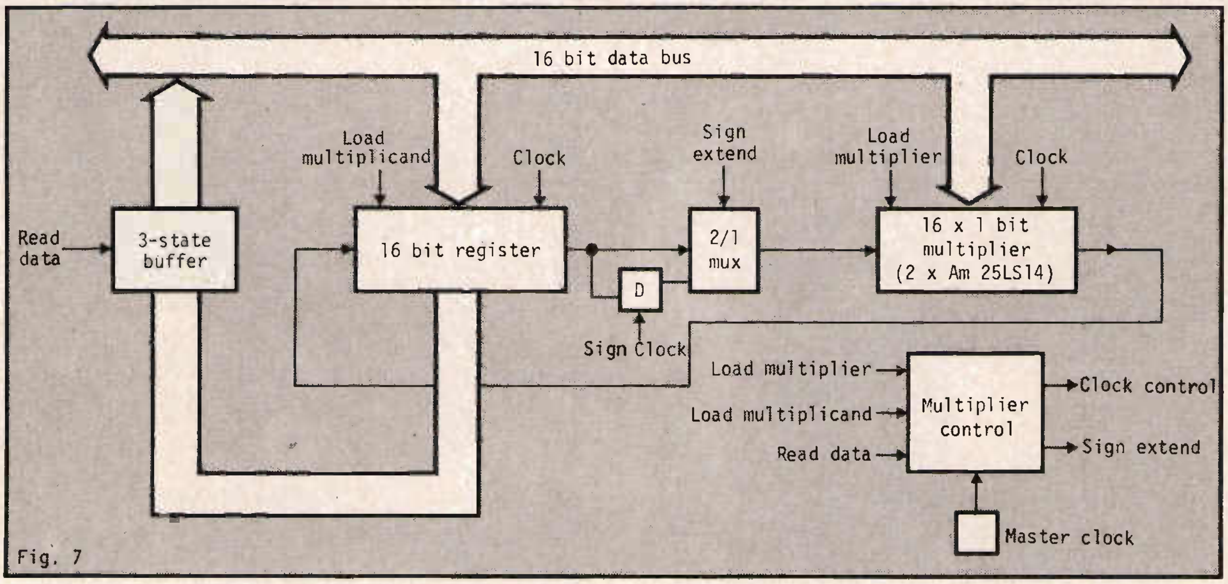
(iii) Select a state assignment and the memory elements to be used.

(iv) Derive transition and output tables from the state-tables. (A transition-table specifies the next state of the

Fig. 6: Circuit diagram of detector.
Fig. 7: Multiplier System.
Fig. 8: Timing Diagram.







memory elements. The output-table describes the current network output in terms of the current inputs and current circuit states.)

(v) Derive an excitation-table and the excitation and output functions from their respective tables. (An excitation table has as its inputs the value of the memory-element inputs required to produce the next states.)

(vi) Synthesise network using combinational logic synthesis procedures.

In step (v) the problem of sequential circuit synthesis has in effect been converted into the more familiar form of combinational circuit synthesis since the excitation and output functions are both combinational switching functions representing one time-frame of the sequential machine operation.

This design procedure will now be demonstrated by way of a simple example. A synchronous sequence detector is required which produces an output 1 every time the sequence 0110 is detected, and at 0 at all other times. For example, if the input sequence is 00110110110 then the output sequence is 00001001001.

The first step is to express the verbal specification in a state-diagram. At time t_1 the circuit is assumed to be in the initial state, designated (arbitrarily) A in Fig. 1. While in this state the circuit can receive an input of either 0 or 1. If it receives a 0 it must move to some other state B to signify that it has received the first bit of the sequence. If a 1 is received then the circuit remains in state A. This is indicated by the self-loop. The output remains 0 for either input.

If the circuit has moved to state B and it receives a 0 it remains in this state to indicate that this second input 0 might be the start of the sequ nc . If a 1 is received then the sequence to date has progressed correctly and this is acknowledged by the circuit by its moving to state C. The output remains at 0 since the sequence has not yet been completed.

Continuing, an input 0 returns the circuit from state C to state B, while a 1 moves it to state D. The output is still at 0.

With the circuit in state D an input 0 would complete the desired sequence 0110 and the circuit would acknowledge this by producing a 1 at its output. The circuit would also move to state B to indicate that the 0 might also be the start of another sequence. If a 1 is received then the sequence to date is 0111 which is incorrect and the circuit is reset to state A until a 0 is received.

Fig. 9: Flow-chart.
Fig. 10: Sequential Controller.

The next step is to draw the state-table Fig. 2 from the flow-diagram. The entries under the input columns x = 0, 1 indicate next state/present output. The state-table is examined for redundant states, and if there are any, they are removed. Fig. 2 has no redundancy.

As an example of state redundancy, in the state-table in Fig. 3(a), states A and D are equivalent since they respond identically to x, and so one of them is removed to produce a reduced state-table, Fig. 3(b).

The next step is to select the state assignment and also the type of memory element to be used which in this case is the D-type flip-flop. Since there are four states A, B, C, D a minimum of two state-variables are required to represent them.

Fig. 4, the transition- and output-tables, is derived from this state assignment and from the state-table of Fig. 2. The entries in the transition-table specify for each combination of present state and input the values that the outputs of the delay elements should assume next. But since the *next* values of the delays are the same as their present *excitation*, the transition-table entries in effect specify the required excitation of the delay elements.

The Boolean expressions for the out-

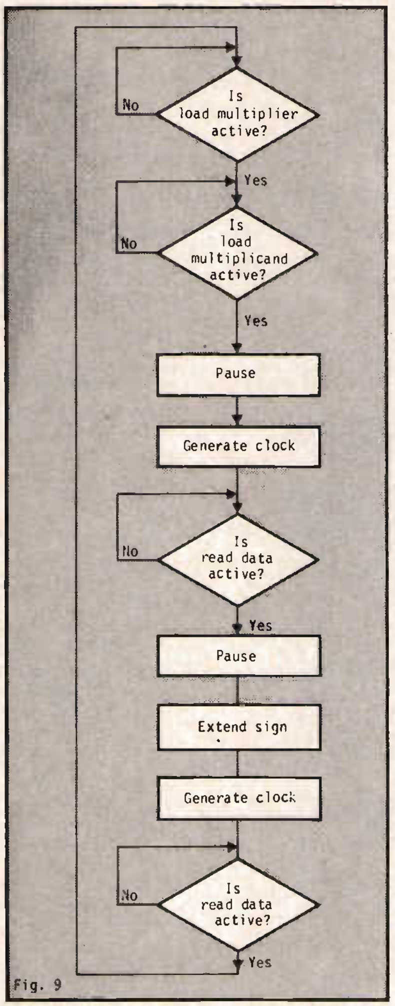


Fig. 9

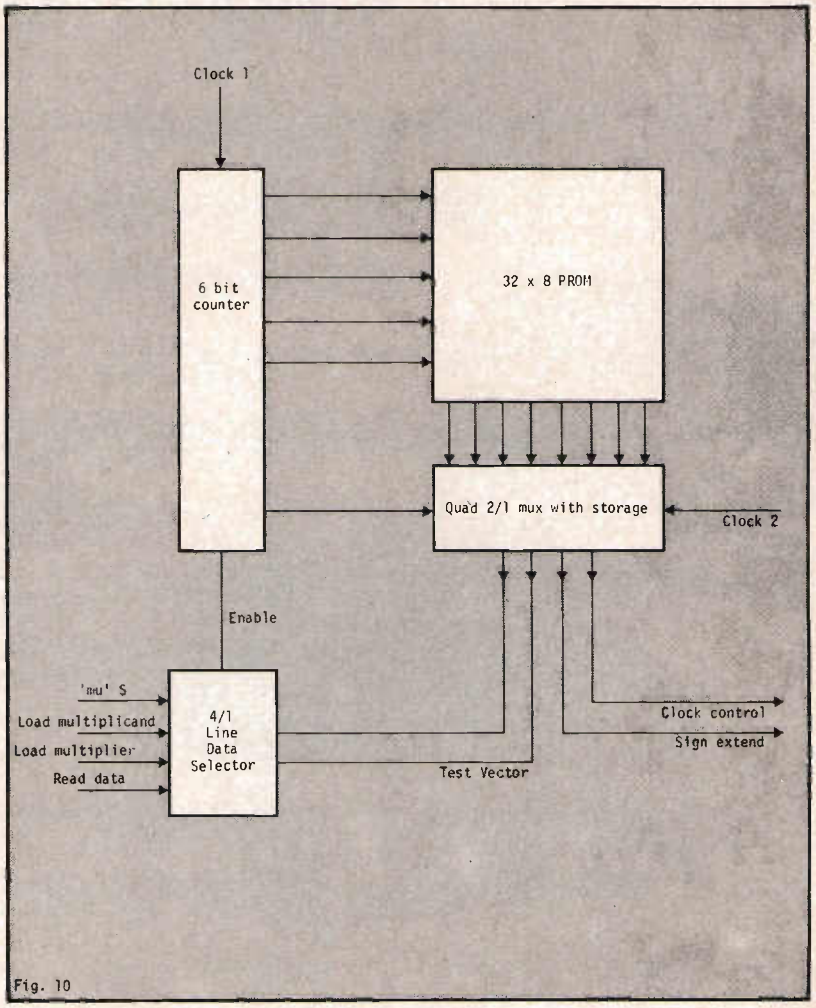


Fig. 10

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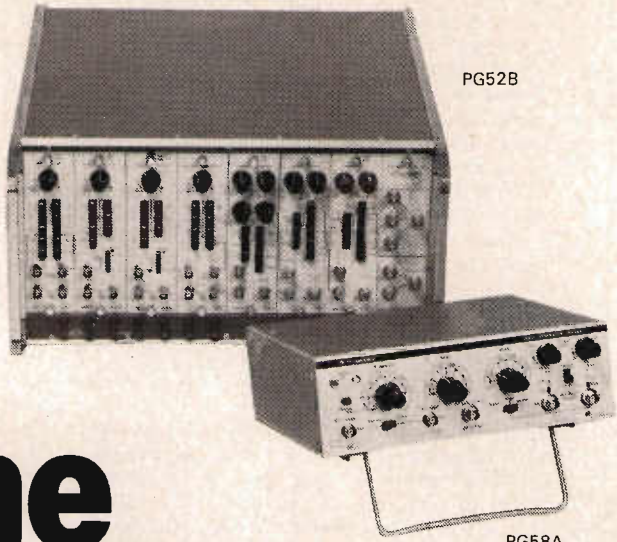

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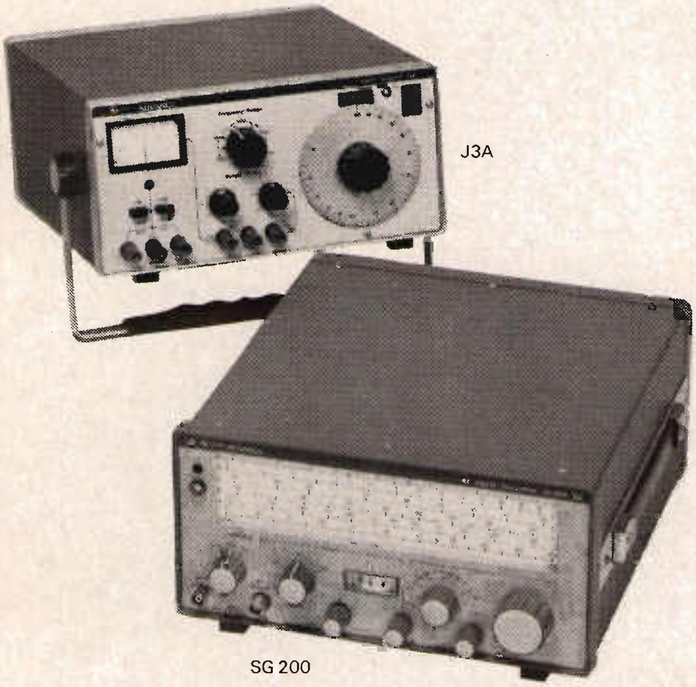

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put z (Fig. 5(a)) and for the excitation functions of Y_1 and Y_2 (Figs. 5(b) and 5(c)) are conveniently obtained from the Karnaugh map representation of the transition- and output-tables and are shown below and implemented in the sequence detector of Fig. 6.

$$z = xy_1y_2$$
$$Y_1 = xy_2$$
$$Y_2 = x+y_1Y_1$$

Table 2

In the above example each state has the possibility of branching to a number of other states, for example, state D branches to A or B. In fact, in a fully sequential circuit branching is limited only by the 2^n input vectors (for n inputs). Thus a sequential circuit once designed is not capable of modification to perform a different function. If however branching at each state is limited to a single true/false test of a *selected* input—a more universal circuit can be created.

The example given below, a programmable controller for a 16 × 16 bit multiplier, shows how the principle of programmable control can be applied at a relatively low level in the digital system —without loss of generality—to produce a flexible but structured system that is economical in terms of package count (or pcb area occupied). The design process has distinct similarities with switching theory, in waiting loop (or self-loop) memory aspects.

The recently introduced Am 25LS14 is an 8-bit by 1-bit sequential logic element that performs two's complement digital multiplication using Booth's algorithm internally. The chip is particularly useful when applied in higher performance microprocessor systems.

The distinctive characteristic of the Am 25LS14 is its serial/parallel mode of operation. The device accepts an 8-bit multiplicand in parallel and stores it in eight internal latches. The multiplier used is accepted as a serial bit stream—least significant bit first. The product is clocked out serially with the least significant bit first. As the multiplication of an m-bit multiplicand by an n-bit multiplier results in an m+n bit product, the Am 25LS14 must be clocked for m+n clock cycles to produce this.

Whilst this serial/parallel mode of operation allows the complete flexibility of the chip as an lsi element, it is inconvenient in fully parallel systems such as microcomputers. Fig. 7 shows the complete multiplier system including the parallel to serial conversion.

The 16-bit multiplier is loaded into the 16-bit register, under processor control, from the microprocessor data bus and, similarily, the 16-bit multiplicand is loaded into the two Am 25LS14 chips which form the multiplier. Multiplication is carried out in two cycles. In the first cycle, the multiplier is shifted, least significant bit first, into the 16 × 1-bit multiplier, and, simultaneously, the result is shifted into the 16-bit register. After 16 clock pulses, the register holds the least significant 16 bits of the result, and the D-type flip-flop holds the sign (most significant bit) of the multiplier word. The processor can now read the contents of the register by enabling the 3-state buffer. In the second multiplication cycle, the 2- to 1-line multiplexer is set so that the multiplier sign bit is fed to the multiplier, and the clock to the D-type flip-flop is disabled. The sign of the multiplier word is therefore extended for the remainder of the multiplication—a necessary condition of Booth's algorithm. After a further 16 clock pulses, the register holds the most significant 16 bits of the 32 bit result.

Fig. 8 is the logic timing diagram for the multiplication sequence showing the three control inputs—load multiplicand, load multiplier and read data—which are derived from the read/write strobes associated with the register and multiplier address locations. The multiplier must generate two control signals—a 'clock control' to gate 16 pulses to the multiplier and register, and a signal to control the 2 to 1-line multiplexer.

The multiplication sequence translates into the flow-chart shown in Fig. 9. This flow-chart should require little explanation; the controller waits until both the multiplier and multiplicand have been loaded—pauses to allow completion of the write pulse and then enables 16 clock pulses. When the least significant word has been read, the 'sign extend' is set, and another 16 clock pulses are enabled. Only when the most significant word has been read can the sequence continue.

From the flow-chart we can derive an outline of the controller, for example:

(i) The controller need only wait until a tested condition is true, i.e., at any branch, one of the two next states is always the current state.

(ii) only three inputs are tested, but a fourth test is needed to always increment the machine state.

(iii) only two outputs are required.

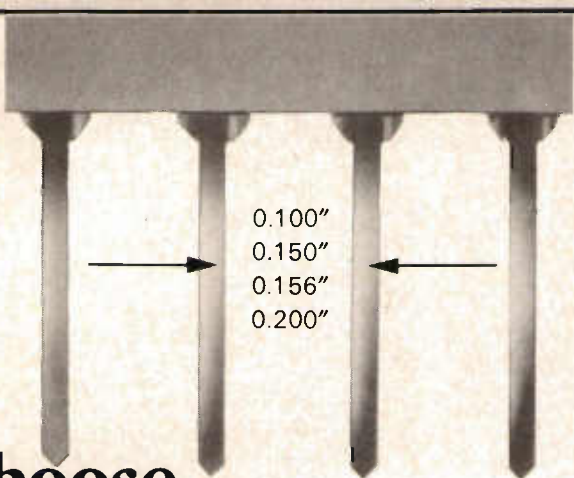
In fact, without any further investigation of the detailed sequence, it is clear that the circuit shown in Fig. 10 is sufficient for this application. The 32×8 prom is configured as a 64 × 4-bit control memory. Each 6-bit address word in the counter selects a 4-bit control word—2 bits of which are called the test vector, the remaining 2 bits being the clock control and sign extend outputs. The test vector selects one of four inputs to be tested—a "true" test causing the counter to increment thereby selecting the next control word. Note that one of the four inputs is hard-wired to the "true" state allowing an unconditioned increment of the counter. The table shows the complete programme for the controller—the programming is a very simple task and it is only necessary to ensure that sufficient "pause" states are inserted to ensure that critical race hazards are avoided.

The major weakness of this type of controller is the 'latency' at the end of the programme cycle. In this example states 41 through 63 are "pause" states, and some 24 machine cycles are required before the controller is ready for the next multiplier cycle. In this example, the "latency" is not critical, but in more general controllers it can be an embarrassment. Of course, latency can be overcome simply by providing a reset bit in the control word giving a much more powerful and flexible controller.

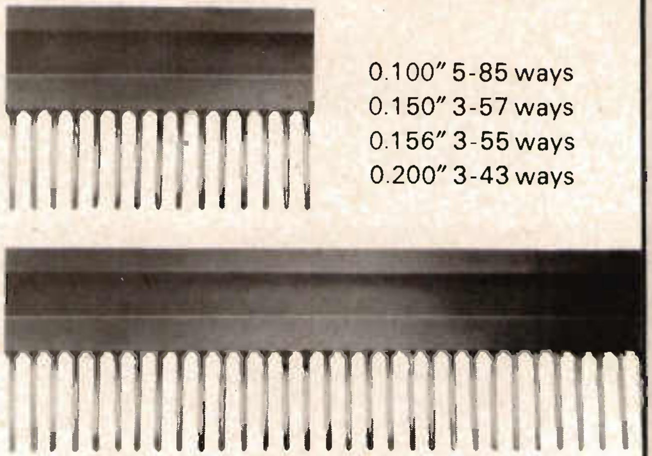
Machine state	*Function*	*Test Vector*	*Outputs* clock	sign
φ	Test load multiplicand	φ1	φ	φ
1	Test load multiplier	1φ	φ	φ
2	Pause	φφ	φ	φ
3	Pause	φφ	φ	φ
4	Generate clock 1	φφ	1	φ
5	Generate clock 2	φφ	1	φ
:	:	:	:	:
19	Generate clock 16	φφ	1	φ
20	Test read data	11	φ	φ
21	Pause	φφ	φ	φ
22	Set sign extend	φφ	φ	1
23	Generate clock 17	φφ	1	1
24	Generate clock 18	φφ	1	1
:	:	:	:	:
38	Generate clock 32	φφ	1	1
39	Test read data	11	φ	φ
40	Pause	φφ	φ	φ
41	Pause	φφ	φ	φ
:	:	:	:	:
:	:	:	:	:
63	Pause	φφ	φ	φ

Left: Complete program for multiplier control. below: Key to test vector

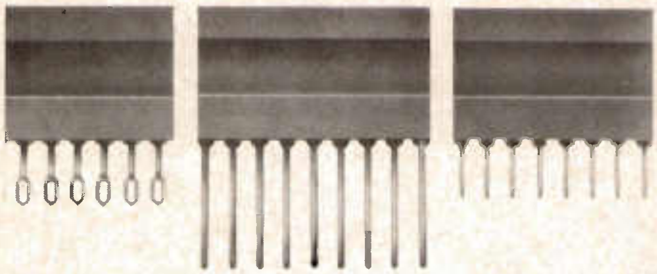
φφ	Unconditioned increment
φ1	Increment if multiplicand true
1φ	Increment if load multiplier true
11	Increment if read data true



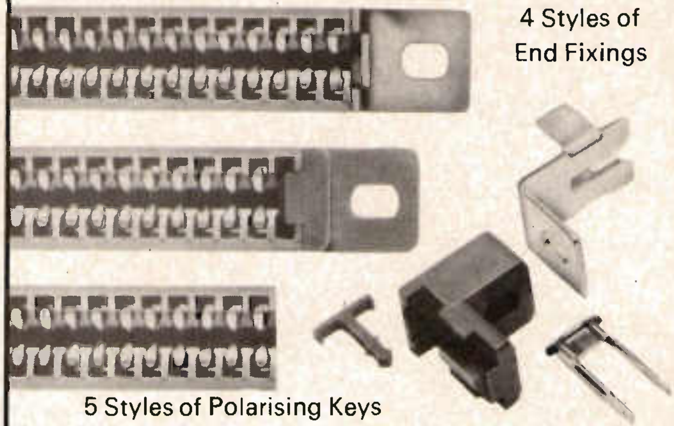
choose contact spacing...



choose length...



choose wiring method...



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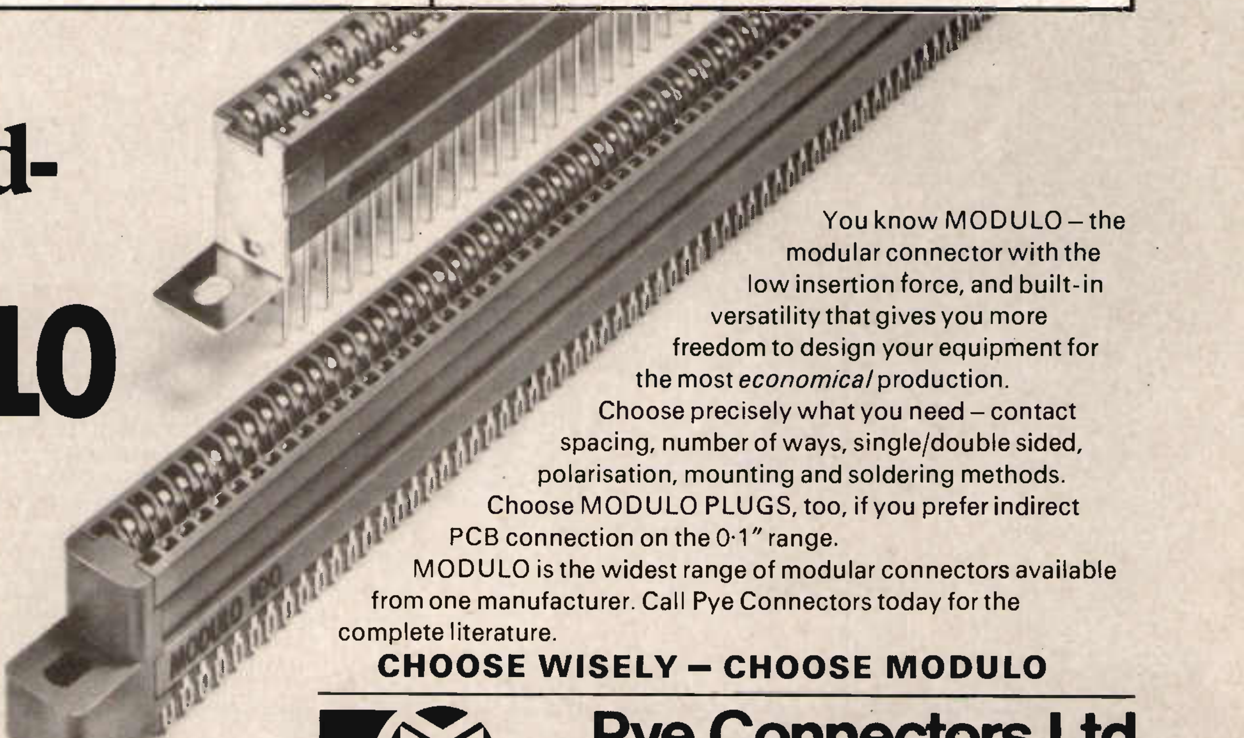

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Implementation of cyclic redundancy check circuits

Cyclic redundancy checks can be more efficient than traditional parity checks, writes *Peter Cavell*. This article examines the theoretical basis and the implementation of cyclic checks.

Error detection schemes using parity checks are well known. A parity check on a character is called "vertical" parity and a check on corresponding bits of every character in a message (data block) is called "longitudinal" parity. Used together, they provide a satisfactory checking scheme; the measure of protection provided is better than using vertical or longitudinal parity alone. However, the level of redundancy to achieve this protection is relatively high. For example, if there are x bytes in a message each consisting of 7 data bits and 1 parity bit, the ratio of number of check bits to data bits is $(x+8)/7x$. As x increases, the ratio tends towards a limit of 1/7.

Another checking scheme exists (called polynomial or cyclic coding) that can be designed to perform with higher efficiencies than traditional parities. The level of protection achieved with a 16-bit cyclic check is probably satisfactory for most practical purposes; when used with a data block consisting of 7x data bits, ratio of check to data bits is only $16/7x$. The ratio reaches a limit of zero as x increases. This high efficiency is inducing designers to incorporate cyclic check schemes in modern data communication and peripheral equipment such as tapes and discs. Theoretical knowledge necessary for cyclic check implementation existed for several years. However, widespread use is only in recent designs using integrated circuits. Because it is relatively new, many designers do not have the needed exposure to cyclic schemes and tend to shy away from using them.

The algebraic concepts required to design circuits for implementing cyclic check schemes are of value not only to the hardware designer but also to the diagnostic programmer who must generate the code to check the implemented logic for validity and failures.

Polynomial methods

A very convenient way of expressing a bit stream (message) consisting of K bits is to think of it as polynomial in a dummy variable x with K terms. The bits of the message are the coefficients in the polynomial. Thus, if 100100011011 is the message, it may be written as:

$$M(x) = 1.x^{11}+0.x^{10}+0.x^{9}+1.x^{8}+0.x^{7}+0.x^{6}+0.x^{5}+1.x^{4}+1.x^{3}+0.x^{2}+1.x^{1}+1.x^{0}$$

or, $M(x) = x^{11}+x^{8}+x^{4}+x^{3}+x+1$.

To compute the cyclic check on a message, another polynomial P(x) called a generating polynomial is chosen. The degree "r" of the P(x) is such that it is greater than zero but less than the degree of M(x). Moreover, P(x) has a non-zero coefficient in the x^0 term. It is clear then that for a given message length, more than one generating polynomial of desired length can be specified. Fortunately, several accepted standard generating polynomials exist; most common are CRC-16 and CRC-12 which were originally proposed for the IBM binary synchronous communications.

CRC-16 is a 16-bit check resulting from a generating polynomial $x^{16}+x^{15}+x^{2}+1$ and CRC-12 is a 12-bit check resulting from $x^{12}+x^{11}+x^{3}+x^{2}+x+1$. Theory suggests that use of CRC-16 and CRC-12 will catch all messages with an odd number of errors, all with a single burst of less than 16 or 12 bits respectively and most of the few messages with larger bursts.

Algebraic operations

Cyclic check computation involves manipulating M(x) and P(x) using laws of ordinary algebra, except that modulo 2 arithmetic is used. Because modulo arithmetic yields the same result for addition and subtraction, it is necessary only to consider three operations involving polynomials—addition, multiplication and division.

Addition of two polynomials $x^{6}+x^{5}+x^{2}+x^{1}$ and $x^{5}+x^{4}+x^{3}+x^{2}$ yields $x^{6}+x^{4}+x^{3}+1$ as shown below:

$$\begin{array}{rcr} x^{6}+x^{5}+0+0+x^{2}+0+1 & & 1\,1\,0\,0\,1\,0\,1 \\ x^{5}+x^{4}+x^{3}+x^{2}+0+0 & \text{or,} & 1\,1\,1\,1\,0\,0 \\ \hline x^{6}+0+x^{4}+x^{3}+0+0+1 & & 1\,0\,1\,1\,0\,0\,1 \end{array}$$

Multiplication of two polynomials $x^{7}+x^{6}+x^{5}+x^{2}+1$ and $x+1$ results in $x^{8}+x^{5}+x^{3}+x^{2}+x+1$.

$$\begin{array}{r} (x^{7}+x^{6}+x^{5}+x^{2}+1)(x+1) \\ x^{8}+x^{7}+x^{6}+0+0+x^{3}+0+x+0 \\ x^{7}+x^{6}+x^{5}+0+0+x^{2}+0+1 \\ \hline x^{8}+0+0+x^{5}+0+x^{3}+x^{2}+x+1 \end{array}$$

It is interesting to note that multiplication of a polynomial by x^m results in a shifted bit pattern which is identical to the original except for zeros in the lower m positions. Dividing $x^{13}+x^{11}+x^{10}+x^{7}+x^{4}+x^{3}+x+1$ by $x^{6}+x^{5}+x^{4}+x^{3}+1$ results in a quotient of $(x^{7}+x^{6}+x^{5}+x^{2}+x+1)$ and a remainder of $(x^{4}+x^{2})$. Practically, it might be easier to divide by longhand if the bit pattern is used rather than the polynomial.

To compute a check on M(x), a generating polynomial P(x) is chosen as mentioned earlier. The message polynomial M(x) is first multiplied by a power of x equal to the degree of P(x). As noted earlier, this process yields zeros in the lower r positions of the result. These vacated positions are in preparation for the r check bits that will be appended to the message. Also note that this process does not alter the message bit pattern.

The result obtained from the previous step is divided by P(x). This gives a quotient Q(x) and a remainder R(x). The remainder will be r bits or less. The quotient is discarded and the remainder is added to the result of the first step. The remainder is the check. The message with this remainder at the tail end constitutes the transmitted polynomial T(x).

The following example illustrates the computation procedure. Let $M(x) = x^{11}+x^{10}+x^{8}+x^{4}+x^{3}+x+1$ (= 110100011011) and $P(x) = x^{5}+x^{4}+x^{2}+1$ (= 110101). Thus r = 5 and $x^5M(x) = x^{16}+x^{15}+x^{13}+x^{9}+x^{8}+x^{6}+x^{5}$ = 11010001101100000.

$$\frac{x^5M(x)}{P(x)} = \frac{11010001101100000}{110101}$$

Carrying out this division, Q(x) = 100001100111 and R(x) = 1011. Transmitted message T(x) is obtained by adding R(x) to $x^5M(x)$:-

$$\begin{array}{rr} x^5M(x) = & 11010001101100000 \\ R(x) = & 01011 \\ T(x) = & 11010001101101011 \end{array}$$

Note that transmission occurs from left to right; data thus is unmodified and check bits follow at the end.

Data validation

The transmitted polynomial arrives at the receiver modified or unmodified depending on whether transmission has encountered errors or not. Clearly, one of the ways by which the receiver can ensure data validity is to recompute the check bits on the message using the same generator polynomial and compare them with the received check bits. If they agree, it is assumed that received data is good.

Instead, the received can divide the complete received polynomial by the same generator polynomial P(x). If there are no errors, it can be shown that this division results in zero remainder. This property can be easily verified by long division of T(x) = 11010001101101011 by P(x) = 110101. If the division results

Peter Cavell is with Fairchild Semiconductors

in a non-zero remainder, it can be assumed that T(x) has been modified by errors. This may be verified by introduring error and performing the division. The process of dropping and picking bits can be viewed as adding another polynomial E(x) (error polynomial) to T(x).

For example, if T(x) = 10010001101101011 is received, instead of T(x), T'(x) = T(x).E(x) can be written where E(x) = 01010001101101011. It follows then that if T(x) is exactly divisable by P(x), the receiver is blind and indicates no errors. This only happens if E(x) is exactly divisible by P(x). Knowing the characteristics of the transmission medium, it is advisable to choose such a generating polynomial that the probability of error patterns occurring that are divisible by P(x) is extremely low. The process of not detecting such errors is somewhat analogous to the erroneous validity indication in normal parity schemes where multiple bit errors may cancel each other's contribution to the check.

Circuit implementation

Consider long hand division of the polynomial $x^{16}+x^{15}+x^{13}+x^9+x^8+x^6+x^5$, i.e. 11010001101100000, by another polynomial $x^5+x^4+x^2+1$, i.e. 110101.

From this example, long hand division procedure can be summarised as follows; align the most significant bits of the partial remainder and divisor borrowing from the dividend as required. (This implies aligning the divisor and dividend to start the division process.) Then, subtract the divisor from the partial product using modulo 2 arithmetic. When all bits in the dividend are processed, the result is the remainder.

Subtraction in modulo 2 of two bits is the same as performing an *exclusive-or* operation and alignment of bits suggests a shift operation. Consider two registers as shown in Fig. 1.

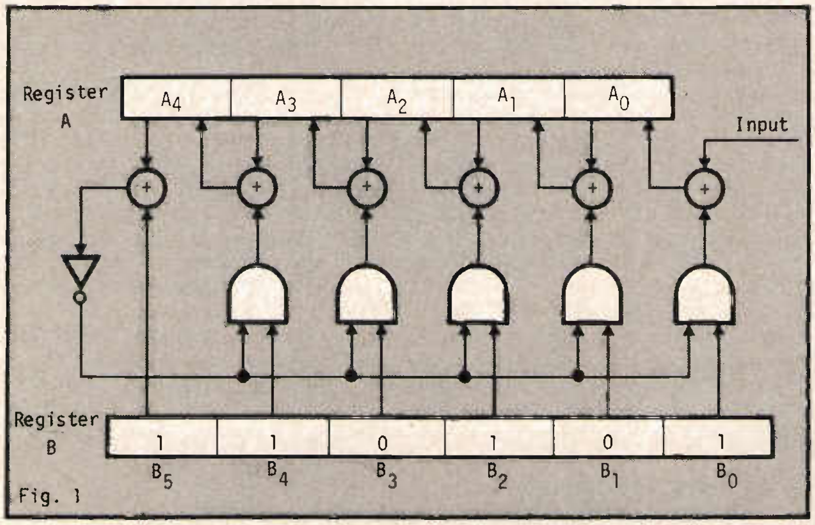
Assume that register A is initially clear and register B contains 110101, which is the divisor bit pattern. Also, imagine that the dividend serially enters the network as input (most significant bit first) in response to a clock signal that operates register A. As long as A_4 is cleared and B_5 is set, the *and* gates are inhibited. This establishes a connection between A_4 input and A_3 output. A_3 input and A_2 output etc. Thus, register A serves as a "shift left" register. When clocked with the dividend as serial input, the most significant bit eventually appears in A_4. At this point A_4 and B_4 are both set, i.e. the most significant bits of divisor and dividend are aligned. This alignment enables the *and* gates. However, this has no effect on the *exclusive-or* gates with inputs derived from Zero bit positions of register B. The "shiftleft" nature of register A at bit locations fed by these *exclusive-or* gates is therefore preserved.

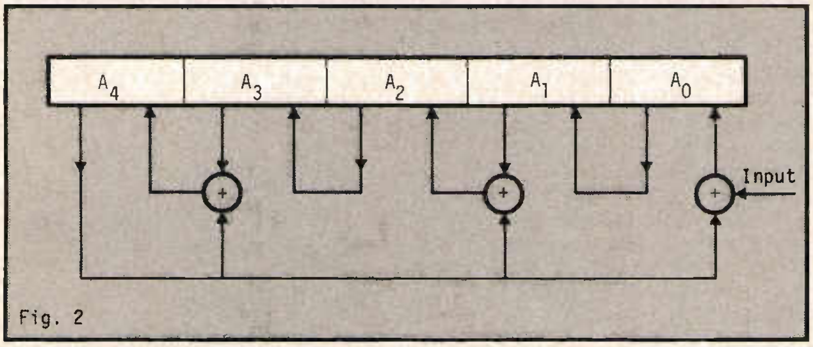
Thus in Fig. 1, the A_1 input comes from A_0 and A_3 input from A_2. On the other hand, the remaining bit positions receive the result of modulo 2 subtraction between appropriate bits. In summary, when register A is clocked after bit alignment, the partial remainder is loaded into it. If clocking is continued until all dividend bits are processed, the content of register A is the required remainder. Closer examination of Fig. 1 suggests that it can be greatly simplified. Fig. 2 shows a functionally identical scheme similar to that used for cyclic checking purposes.

Discussion on basic polynomial division circuits can now be concluded with these observations—the division algorithm can be implemented by suitable interconnection of shift registers and *exclusive-or* gates. The total number of register positions equals the degree of the divisor polynomial. The total number of *exclusive-or* gates is equal to one less than the number of non-zero terms in the divisor.

Polynomial divider

But for one drawback, the polynomial divider could be used as a cyclic check generator. Imagine that the dividend polynomial $x^{16}+x^{15}+x^{13}+x^9+x^8+x^6+x^5$ is the result of multiplying $(x^{11}+x^{10}$





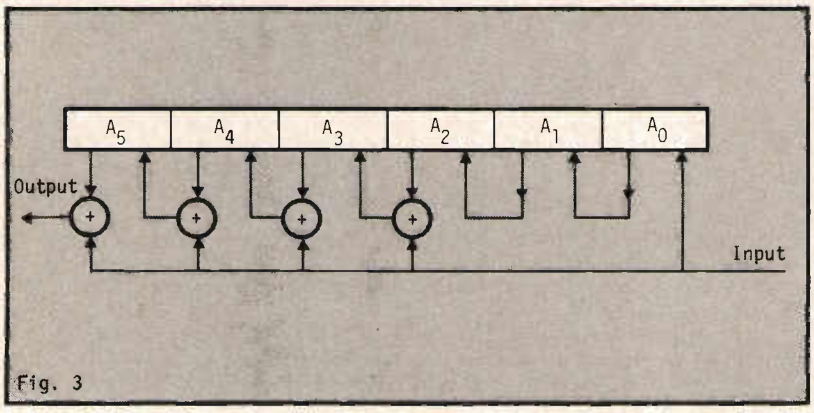


Fig. 1: Diagram of a conceptual polynomial divider.

Fig. 2: Polynomial divider for $x^5+X^6+x^2+1$

Fig. 3. Circuit multiplying by $(x^6+x^5+x^3+1)$.

$+x^8+x^4+x^3+x+1$) by x^5 and the divisor $x^5+x^4+x^2+x+1$ is the generating polynomial. From the cyclic check coding scheme, remember that $x^{11}+x^{10}+x^8+x^4+x^3+x+1$ is the actual data stream. The divider circuit discussed so far does not provide the remainder until the trailing zeros have been processed. Thus, if the remainder is to be appended as a check to the data stream, there is a delay before it is available for transmission. In almost all applications, such a gap between data and check bits is undesirable. This deficiency could easily be rectified if a circuit were possible which could multiply two polynomials together while dividing by a third simultaneously.

Polynomial multiplication circuits can be derived using analogous arguments that result in the division circuit. For example, the arrangement shown in Fig. 3 multiplies an incoming polynomial by $x^6+x^5+x^4+x^3+1$. Fortunately, for cyclic check applications, multiplication by a single term (the rth power of x, where r is the degree of the generator polynomial) is sufficient. To implement a "multiply by x^5" circuit, only a 5-bit shift register and one *exclusive-or* gate are needed as shown in Fig. 4.

Combined multiply/divide

It is possible to combine the multiplier shown in Fig. 4 and the divider in Fig. 1 to implement a simultaneous "multiply by x^5 and divide by $x^5+x^4+x^2+1$" circuit as shown in Fig. 5. As before, Fig. 5 may be simplified to arrive at Fig. 6 which can be used as a cyclic check generator for the generating polynomial $P(x) = x^5+x^4+x^2+1$.

It is clear that the remainder is available as soon as the last data bit is processed. Also, note that the quotient bit pattern appears in A_0. If it is desired to transmit the remainder from the register of Fig. 6 in a serial fashion, the connections must be established to make the register a straight shift from right to left by disabling the feedback through the *exclusive-or* gates.

CRC-16 is a widely used cyclic checking scheme using $x^{16}+x^{15}+x^2+1$ as the generator polynomial. From the preceeding discussions, it is apparent that a 16-bit register (degree of polynomial) and three *exclusive-or* gates (one less then the number of non-zero terms) are required. Fig. 7 shows one possible implementation using shift registers of the 9300 type.

To compute the check bits:

a) Clear register by pulsing CLEAR L signal.
b) Assert CRC COMPUTE L signal by making it *low*. This signal remains *low* for the duration of computing.
c) Data to be encoded is presented serially on the DATA IN L line. A *low* level represents a logic *one*.
d) Each bit is processed on the *low* to *high* transition of CLOCK H signal.
e) After the last bit has been entered, the CRH COMPUTE L signal goes inactive and the check bits appear on CRC OUT H and CRC OUT L lines (true and complement respectively) in response to the proper clock transitions.

Note that in Fig. 7, the CRC COMPUTE L signal, when inactive, disconnects the feedback and establishes a simple shift mode of operation. Also, *zeros* are entered into the register as the check bits are shifted out. Thus, the register remains in the cleared state after shifting out the 16 check bits.

Validation circuits

Data validation requires examining the received data and check information to determine if any detectable errors have occurred. If the received polynomial, i.e. data and check bits, were divided by the same generator polynomial as used for generating the check bits, a zero remainder indicates that no detectable errors have occurred. Because of this property, a similar circuit that generates the check bits during transmission can be used for error checking during reception. The only additional logic is that needed to monitor the register for all zeros.

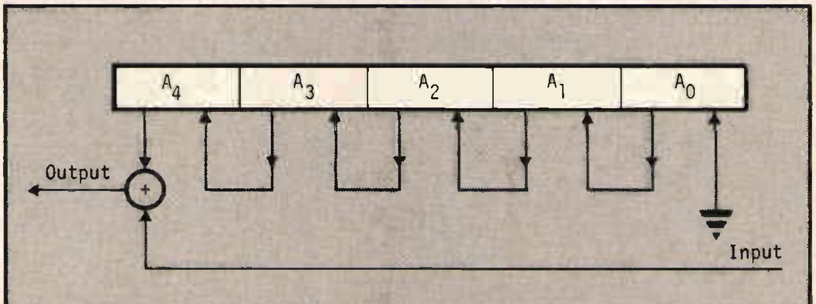


Fig. 4

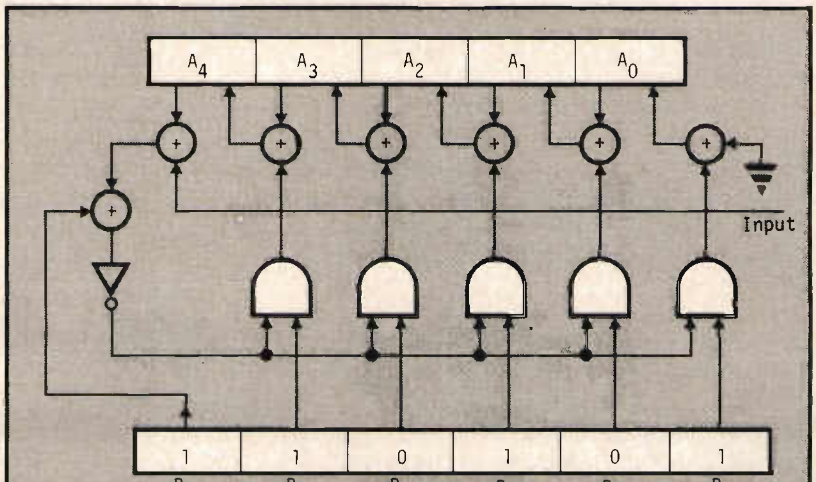


Fig. 5

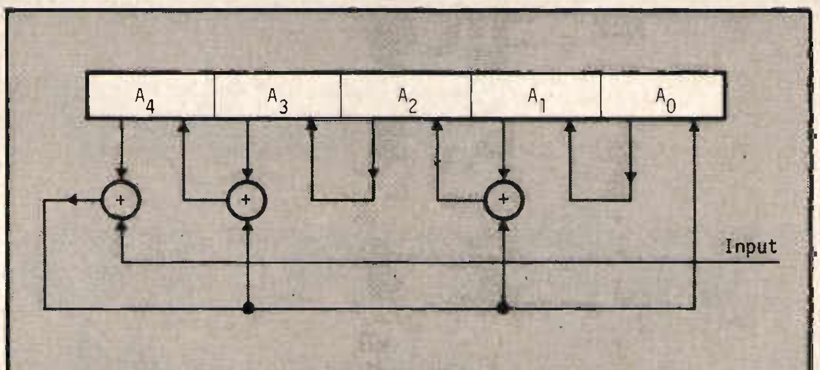


Fig. 6

Fig. 4: Circuit for multiplying by x^5.
Fig. 5: Conceptual cyclic check generator.
Fig. 6. Basic cyclic check circuit for $P(x) = x^5+x^4+x^2+1$.

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It is quite feasible to compute the check bits just as was done at the transmitter and compare the computed check bits with the receiving check bits for equality. Such a comparison can easily be accomplished in a serial fashion. The choice of using zero monitoring or serial check bit comparison rests with the designer.

The reason for shifting zeros into the register in Fig. 7 is not entirely incidental. Many systems where cyclic checks are used may be half duplex in nature, i.e. they transmit or receive but not both at the same time. In such cases, the same circuit can be used as a check generator during transmit and error detector during receive. Shifting zeros while transmitting check bits gives identical register content after transmitting or receiving a good data block. Thus, some error has occurred if the register is non-zero after a data block regardless of whether transmitting or receiving. This eliminates the need for inhibiting error detection circuitry in the transmission mode.

Reverse polynomials

Cyclic checks are often used in magnetic tape systems. Many of these have capabilities to read data in both forward and reverse directions. One of the reasons for this capability is to combat the overload required to position the tape in front of the data block for a re-read operation in the event of an error. When "data followed by check bits" format is used to write on the tape, the check character is encountered first while reading in the opposite direction and the bit order for the whole block is reversed. Clearly, if the same check circuitry is used for error detection in both directions, erroneous indications are inevitable when reading in the opposite direction. This situation can be avoided by utilising a reverse polynomial for checking in the opposite direction. The reverse polynomial is obtained by writing a polynomial bit pattern backwards. For example, the bit pattern for CRC-16 (forward) is 11000000000000101, i.e. $x^{16}+x^{15}+x^2+1$. The reverse polynomial for this pattern is 10100000000000011, or $x^{15}+x^{14}+x+1$.

Monolithic crc circuit

Circuit implementation aspects of cyclic error checking schemes are quite straightforward and polynomial division circuits can be realised by suitable interconnections of shift registers and *exclusive-or* gates. A one-chip crc generator/checker, the 9401, is a more recent arrival. The 9401 has provisions to use any one of eight generator polynomials, selected by appropriate logic levels on three select lines S_0, S_1 and S_2 (Fig. 8).

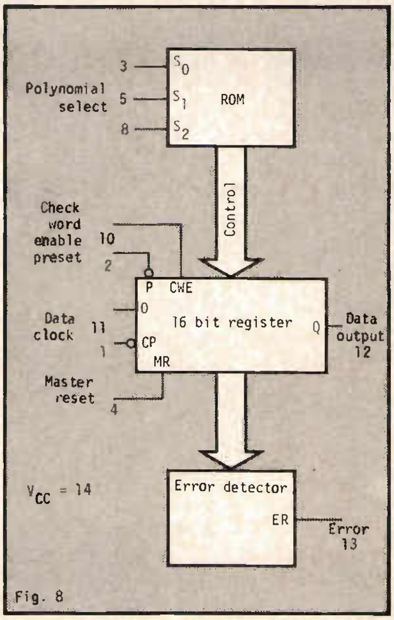


Fig. 7: Cyclic redundancy check implementation for 16 bits.

Fig. 8: Block diagram of redundancy check circuit on one chip.

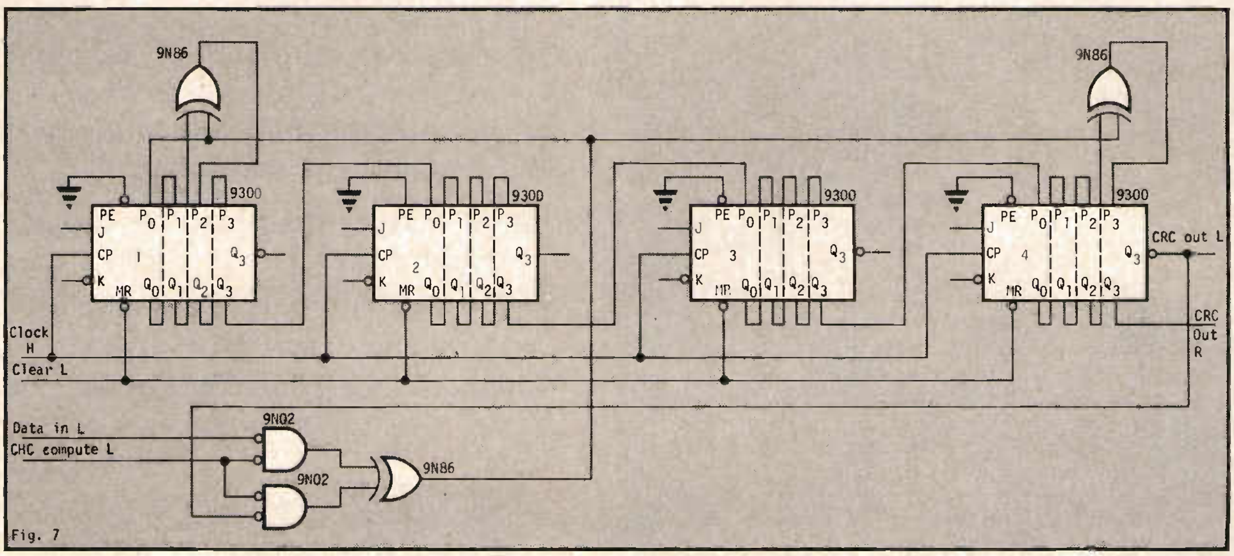
The 9401 consists of a 16-bit register, a rom and associated circuits as shown in Fig. 8. The polynomial select code presented to S_0, S_1 and S_2 inputs is decoded by the internal rom. The rom outputs establish shift mode operation on the register with *exclusive-or* gates at appropriate inputs. The rom also performs right justification, i.e. the exponents of those polynomials which are of degree less than 16 are appropriately scaled up.

It is possible to clear the crc register prior to the beginning of check character accumulation. However, this practice results in all *zero* check bits when all data bits are *zero*. To avoid this situation, the register must be initialised to a pattern other than *zeros*. For example, the register is preset to all *ones* in floppy disk systems. The 9401 therefore has both Reset and Preset control lines to simplify the initialisation procedures.

To generate the check bits, data is entered via the D input using the *high* to *low* transition of the clock (CP). The Check Word Enable (CWE) input controls the feedback path; it is held *high* while data is entered. After entering the last data bit, CWE is brought *low* and check bits are shifted out of the register on the Q output.

To check an incoming message for errors, both the data and check bits are entered through the D input while CWE is held *high*. If there are no detectable errors after receiving the last check bit, the Error (ER) output will be *low*. A *high* level on ER indicates an error.

A *high* level on the Master Reset (MR) asynchronously clears the register. A *low* level on the Preset (P) input asynchronously sets the register. Automatic right justification control from the rom allows the entire register to be set if a 16-bit polynomial is specified by the select inputs. In case of 12 or 8-bit polynomials, only the most significant 12 or 8 bits will be set while the remaining bit positions are cleared.



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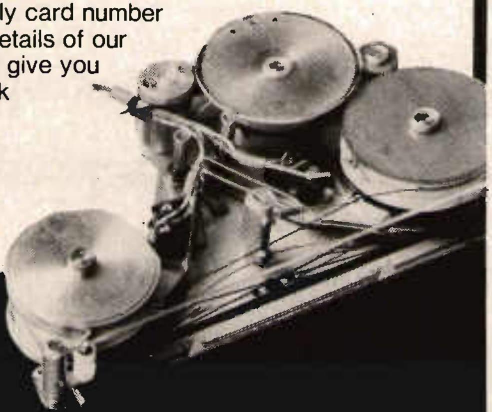

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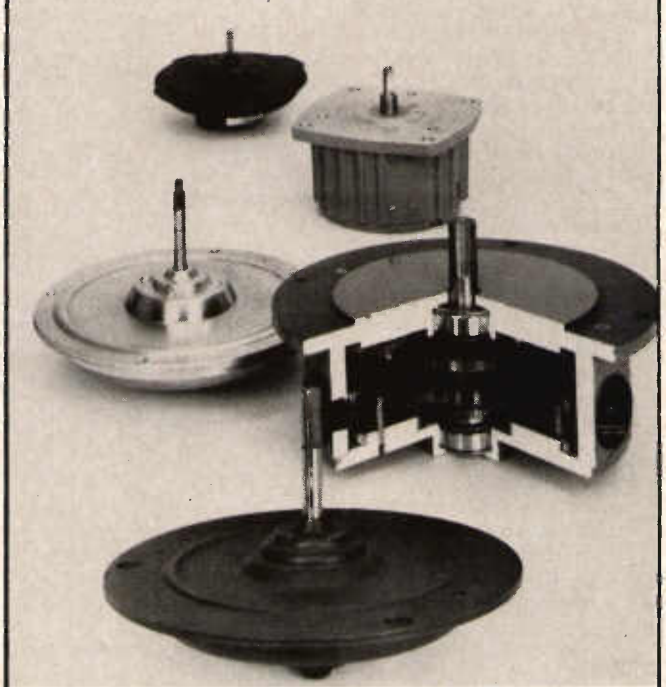

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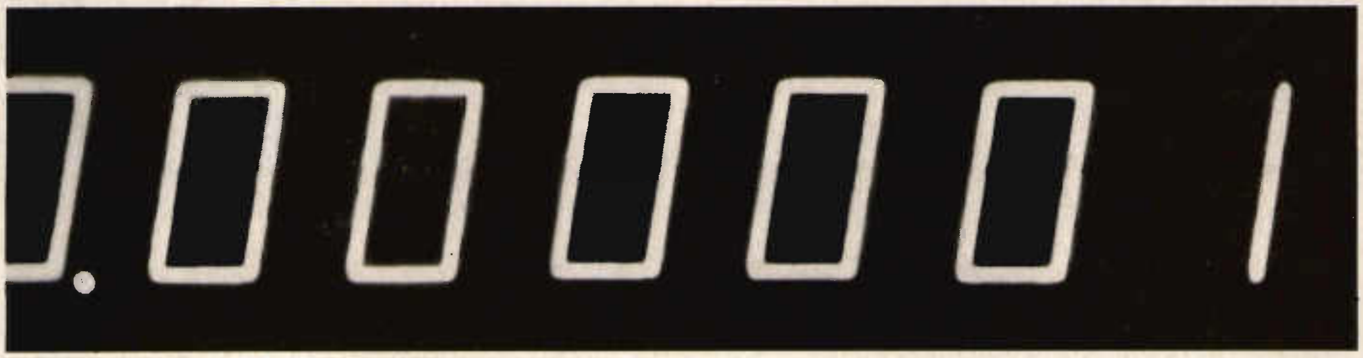

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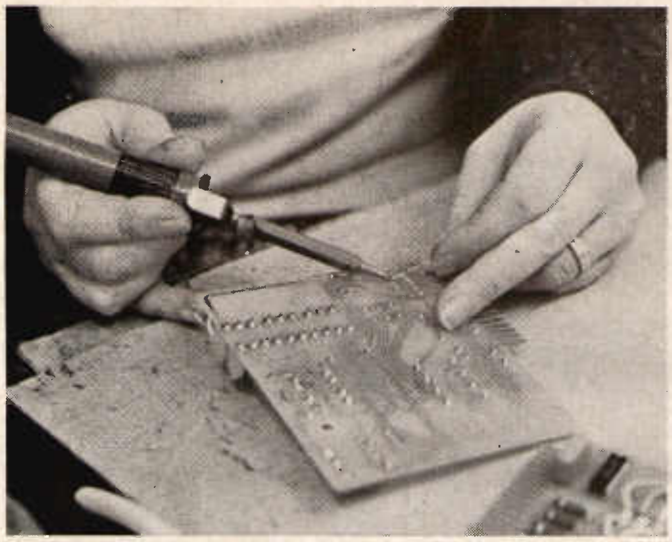

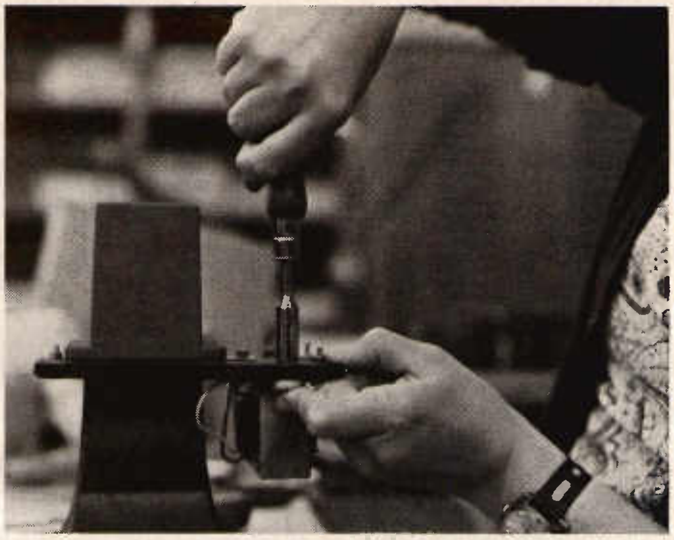

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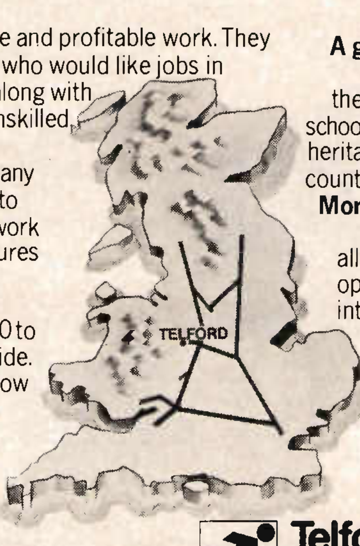

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The new generation of single-chip microcomputers

The first single-chip microcomputers were of relatively low performance. A new generation of devices is emerging with performances approaching those of the multichip microprocessors, writes *Peter Gebler*.

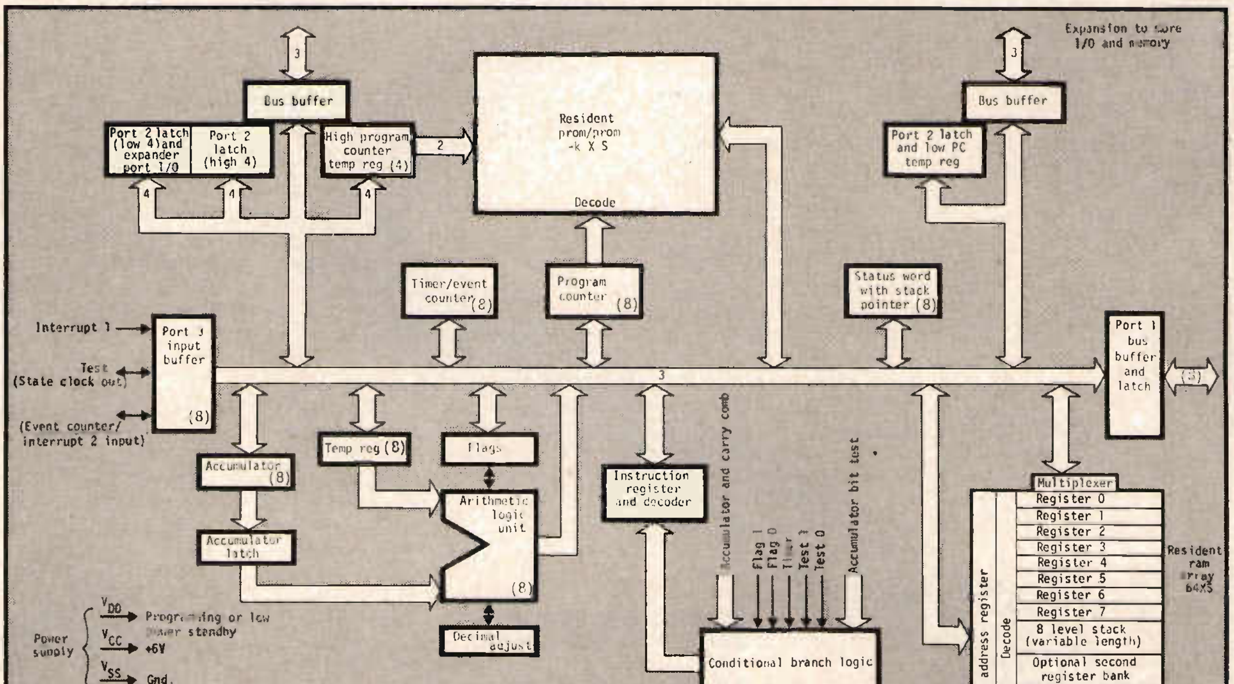
The laser was once described as a solution in search of problems and the same might be said, in some respects, of the microprocessor. All of the semiconductor manufacturers and most users realise that the microprocessor will be used in an increasingly wider range of applications. The term, however, is a very general one, encompassing many different kinds of architecture and performance, so that determining exactly which problems a particular microprocessor will solve has not turned out to be so easy.

Part of the difficulty is that the manufacturers have, on the whole, developed their products in a haphazard fashion. Some devices evolved from the requirements of a single customer and are therefore optimised for a specific application. There are also some good general purpose devices which can be used in a wide range of applications but are optimised for none.

The single-chip microcomputer is now emerging as one of the solutions to this problem. These devices contain in a single package the four essential parts of any microprocessor system—cpu, ram, rom and I/O circuitry. The importance of the single-chip systems is that the devices are optimised, not for any particular application, but for well-defined sectors of the market, principally medium- to high-volume, cost sensitive applications and as local intelligence in distributed systems. Designers can decide, with little difficulty, whether their applications falls within the scope of the one-chip microcomputers. Thereafter, it is much easier to choose a particular microcomputer. Because there are not usually any extra system costs to calculate, the selection can often be made on the basis of simpler considerations.

The currently available devices can all be described as first generation devices, a loose classification which includes the TMS 1000 and its derivatives, the PPS-4/1 devices and GIM's CP 1650. Although the devices have a wide range of architectures and the group includes both four- and eight-bit devices, all of the first generation microcomputers are aimed at the same kinds of application and offer approximately equal performance in that they will all carry out the required functions without additional circuitry. It is true, of course, that some devices are faster than others or have instruction sets which make more efficient use of the internal registers. In most applications however, this will be irrelevant. This is not always the case with microprocessors, where the correct choice of microprocessor might save several ic packages and result in a lower system cost. In a single-chip system, it is of no importance whether the internal rom is fully utilised or only half used, nor does it matter if some of the I/O lines are not used. While a microprocessor user

Fig. 1 shows the internal structure of the 8048/8748 devices.



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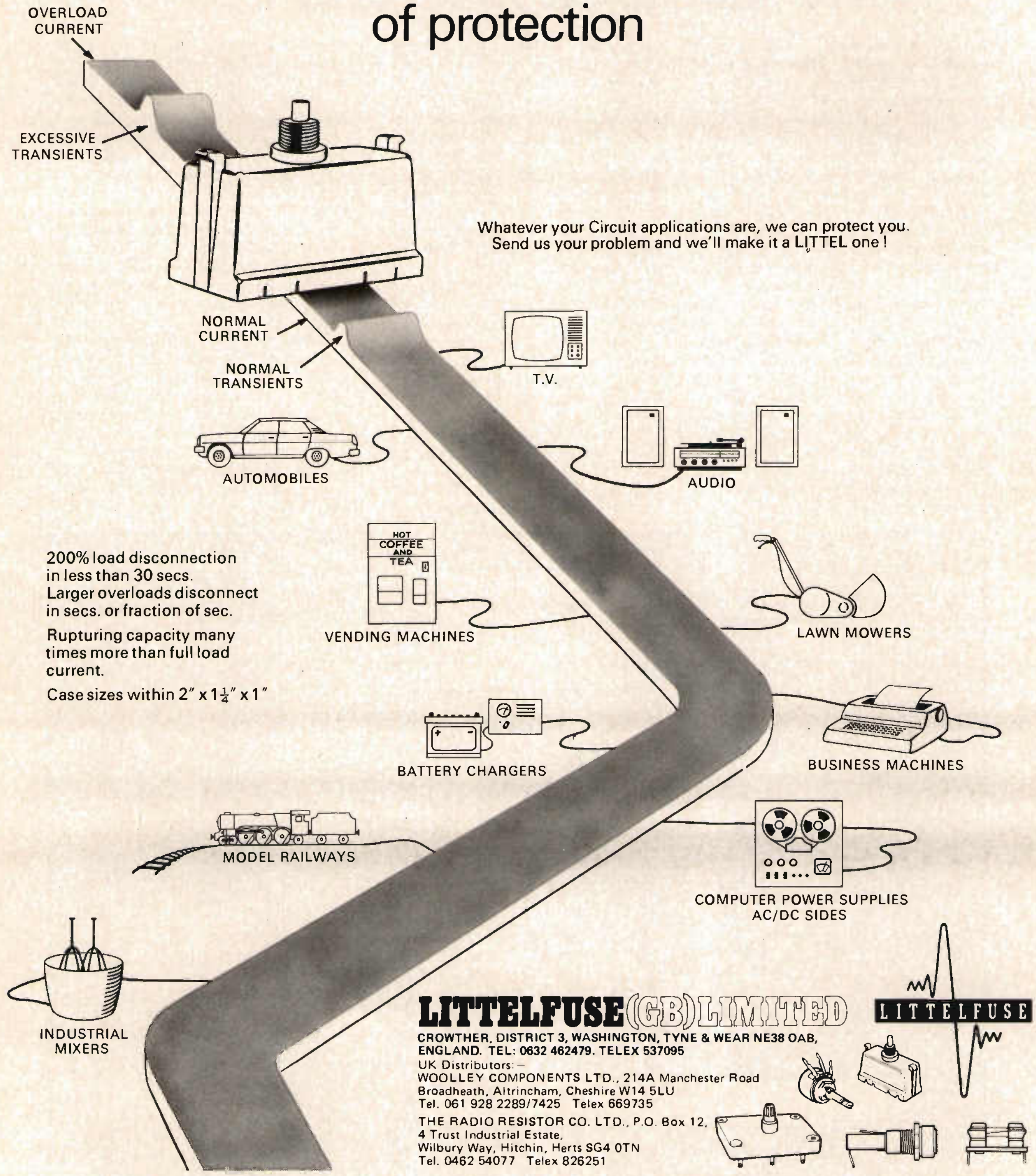

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must ask how efficiently a particular microprocessor works in his application, the microcomputer user only needs to know that his chosen microcomputer is powerful enough.

The ready acceptance of the first generation devices and the rate at which their market is increasing has spurred the development of a second generation of devices offering a much higher performance within the single-chip framework. These will predominantly be n-channel, 8-bit devices, some of which will be available with eprom storage instead of mask-programmed rom. Intel's 8748, for example, contains a 1k×8 eprom and TI's 9900 family will include a single-chip device with eprom storage. It is worth taking a closer look at the 8748/8048 devices because not only will they be the first of the new generation of microcomputers to become generally available but also because they illustrate the direction in which the single-chip microcomputer is evolving.

The basic 8048 system (Fig. 1) comprises a 1k×8 programme store, 27 I/O lines, an interval timer/event counter, an 8-bit alu, an interrupt system, power-on reset circuitry, clock generator and and 64×8 ram. All these features are available in a single package which requires only two external components —a 6 MHz crystal (which can be replaced by an RC network) and a capacitor to set the time-constant of the power-on reset circuitry.

There are two important constraints to the design of single-chip microcomputers—the size of the programme store and the assignment of package pins. The programme store must have sufficient capacity to allow a large enough number of applications to need no external memory. At the same time, it must be small enough to allow economical chip sizes, so that poor yields do not force up the price. Intel, like most other manufacturers, has settled for 1k bytes of rom/eprom.

This would be a little on the low side by microprocessor standards so the 8048 has been provided with some instructions designed to reduce the number of instruction bytes required to write a programme. For example, one of the most frequently used instruction sequences in many programmes consists of a "register decrement" instruction followed by a "jump if not zero' instruction. This is used either to count the number of times a particular sequence of instructions is executed or simply to generate delays for synchronisation or pulse generation purposes. The 8048 can perform this function with one "DJNZ" instruction (decrement and jump if not zero) which decrements one of eight registers, testing the result for zero and jumping to a user-supplied address if a non-zero result is found.

A common feature of most microprocessors is that the address and data busses are brought out to package pins. A microcomputer needs a large proportion of its pins for I/O lines, so it is not possible, within the confines of the standard 40-pin package, to provide complete address and data busses for system expansion. Nonetheless, it is desirable to make provisions for system expansion since the devices can then be used "intelligent" peripherals for other microprocessors or as components of a distributed processing system.

The 8048 has three 8-bit I/O ports and one of these, port 0, is used for memory and I/O expansion in conjunction with control signals supplied by the 8048 and one or more external circuits. Fig. 2 shows how an additional 256 bytes of ram can be added to the system using a pair of 256×4 rams and the 8212 I/O port from the 8080 family.

The new generation of single-chip microprocessors will be capable of a performance which comes close to that of multichip configurations, within the limitations of memory size. The 8048, for example, has a repertoire of more than 70 instructions, 16 general-purpose registers (bank switched in two groups of eight) and an eight-level stack.

The availability of powerful single-chip microcomputers will accelerate the spread of microprocessor technology. Used alone, they will allow production and engineering costs to be reduced and reliability to be increased, because fewer soldered joints will be required and printed circuit boards can be very simple. As peripheral circuits for other microprocessors, they will reduce the amount of external hardware needed and also relieve the microprocessor of much of its peripheral servicing tasks. Fig. 3 shows how a single microcomputer package and buffers for the hammer drivers can form an interface between a microprocessor and a drum printer. When the microprocessor is required to print a message, it loads the micro- computer with the appropriate string of characters and is then free to perform other tasks.

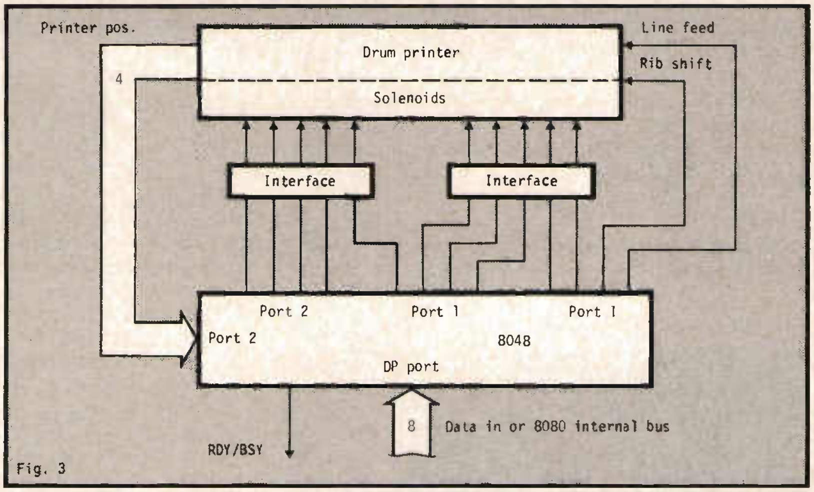

Fig. 3

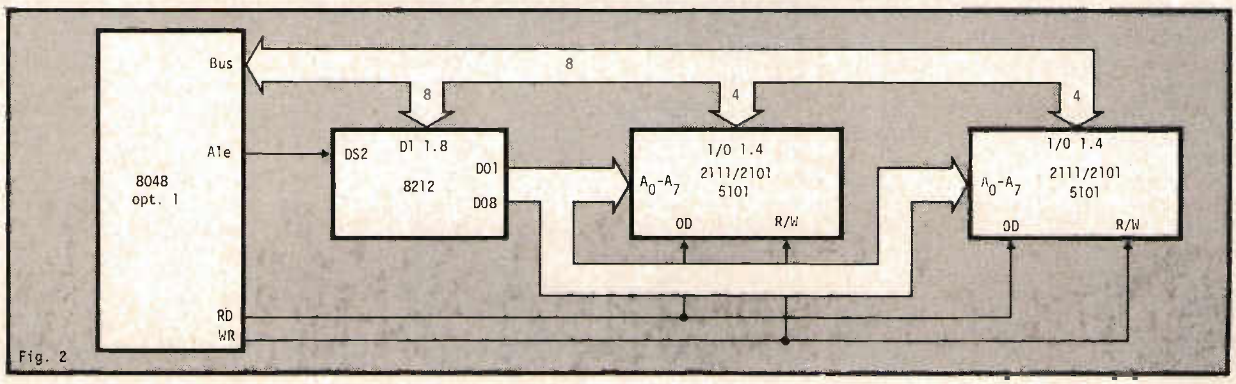

Fig. 2

Fig. 2 shows how additional ram can be added to the 8048 while Fig. 3 shows a typical single-chip application.

The impact of electronics on modern aircraft systems

In this article *Elaine Williams* looks at the highly sophisticated world of electronics in aircraft systems and explains some of the methods used in avionics.

Avionics has grown out of the marriage of two young technologies, whose rapid advances have out-stripped the growth of any other field. Avionics itself now accounts in value (on board the aircraft) for almost a third of the total aircraft cost, along with the engine. Avionics is really split into two major areas: communications and control. The communications areas consist of a large number of systems for speech as well as radar guidance systems and navigation both on board the aircraft and external systems which use beacons such as the Omega system. The control section covers such fields as instrumentation, head up displays, monitoring and automatic flight control.

With modern airways becoming more and more congested, the need for good communications becomes a necessity and the ground crew who are providing information and guidance on landing need to be in constant contact with the aircraft being monitored. Long range voice communications with the ground is normally achieved by using the high frequency band (2 MHz to 30 MHz). Modern aircraft aerials take the form of notches cut into the skin of the aeroplane, usually near the tail fin. A tuning unit is fitted into the notch to match impedances. Once the transmitter is in operation, phase and amplitude detectors fitted into the tuner monitor the mismatch between aerial and transmitter and, activate servomechanisms to adjust the equipment to give optimum performance and hence maximum power transmission.

The normal method of hf transmission uses single sideband amplitude modulation. The single sideband mode allows twice as many communication channels with a reduced power requirement. Also the speech quality is better than double sideband transmission since this is subject to selective fading and distortion caused by differential phase changes between the upper and lower sidebands. The transmitter and receiver are accurately tuned to the desired frequency by a digital controller. This controller operates a frequency synthesiser in the transceiver and the oscillator (which is also the local oscillator for the receiver or the drive oscillator for the transmitter) is tuned over the required range by varactor diodes. When the controller has selected a frequency, control lines provide a voltage to tune the oscillator to select the desired frequency and a programmable divider is set to a specified division ratio.

The divide down output of the crystal oscillator feeds a phase comparator which is also fed by the output of the programmable divider. The phase detector output varies until these two inputs are equal. The tuning increments of the variable oscillator are determined by the frequency of the crystal oscillator.

The speech input to the transmitter is achieved from the headset of one of the flight deck crew connected through the intercom system. This means that communications is not only possible between crew members but also between the ground and other aircraft. Often the hf transmitter has a selective calling unit to allow messages from the ground intended for one particular aircraft to be received by that aircraft only. This unit may be activated by a series of coded audio tones which alerts the flight crew by a light or a bell that their aircraft is being called.

Unfortunately hf transmission is not really suitable for short range communication and it is usual that at ranges of 320 km or less vhf transmission (118-136 MHz) are more effective. The aerial commonly used for this type of communication (which uses double sideband amplitude modulation) takes the form of a blade projecting from the airframe.

However with the ever increasing volume of air traffic the hf communications band is becoming highly congested and there has been serious consideration of using higher frequencies for long range communications. It has been estimated that by 1980 there will be over 200 aircraft in transit between Europe and America during peaks, all needing to have communication with ground bases. Unfortunately all higher frequency transmission are restricted to line of sight and it is possible that satellite repeaters could provide a solution. A single geosynchronous satellite repeater could service up to one third of the earths surface and, its relatively low power equipment could give satisfactory communications.

An automatic map reader

Unfortunately there are two main factors which have prevented the immediate and wide use of satellite repeaters to provide long range communications. The first consideration is cost. The launching of the satellite as well as its construction is expensive and for some applications is prohibitively so. The design life of a satellite may be seven years and a working life in reality of only five.

Also the frequency spectrum space is being consumed at a very rapid rate and satellites are already being used to transmit large quantities of data on a point to point basis. The allocation of frequency is an international problem due to the coverage of the satellite and it is seen that satellite communications will supplement rather than replace present communications mediums.

It has been estimated that at the earliest it would be 1985 before an operational system but feasibility studies have already been made.

There are several systems by which an aircraft may navigate or be navigated. Navigation aids can be of three types, those which rely on ground based beacons, those which are self contained within the aircraft and finally short range systems. Medium range navigation uses ground beacons. The most versatile of these is the automatic direction finder (adf). Other systems which use information radiated from ground beacons are the VOR systems (very high frequency omnidirectional range). This comprises special ground beacons which radiate a carrier with two modulations at 30 Hz in the 112 MHz to 118 MHz band. The phase difference between the two modulations is proportional to the direction of

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the point of reception relative to magnetic north. A vhf receiver is used which is fed from either a blade or notch aerial. The phase difference between the two modulations can be resolved to an accuracy of 4° although improved equipment now increases the accuracy to within about 2°.

Most VOR units can work with distance measuring equipment (dme). The dme can determine the distance of the aircraft from the beacon by transmitting a series of coded pulses to the beacon. These are then retransmitted on a different frequency 50 ms later. The time between transmission and reception gives the measure of distance from the beacon. In general this dme is used with VOR and can be meaningful up to a height of 12 000 m in a range of 132 km.

Military systems such as Tacan (tactical air navigation) are based on VOR & dme but only use one beacon. For long range navigation there are systems like the Decca Navigator and the Loran (Long range navigation) which rely on a series of ground stations to transmit coded signals. An aircraft receiver measures the phase difference or the time lapse between signals arriving from the stations.

Another of these hyperbolic navigation systems is the Omega system which operates in the 10-14 kHz vhf band. The system was developed to make use of the long range, low attenuation rate and stable phase velocity of very low frequency signals. Omega only requires eight ground transmitters to give world wide coverage and has a positional accuracy of 2/3 m. Airborne equipment measures phase differences between Omega signals from various transmitters. In a typical receiver there are three channels tuned to 10,2, 11,33 and 13,6 kHz. From the phase difference calculations a positional fix can be determined by a small special purpose computer.

Before the advent of ground beacons the pilot had to make use of on board navigation aids. One of the first commercially available of these types were based on the Doppler principle. A narrow beam is radiated from the aircraft and is partially reflected. Due to the relative motion of the aircraft and the point of reflection the returned signal undergoes reflection proportional to the velocity vector of the aircraft resolved in the direction of the transmitted beam.

About the same time as the Doppler system was developed another navigation aid known as inertial navigation was born. Although this system is simple in concept, its realisation is fairly difficult and expensive but it gives a better solution to the problem of navigation. An inertial navigation system measures the acceleration of an aircraft and integrates this twice to find positional data relative to the starting point. This means that measurements have to be made relative to a fixed point in space. The accelerometers are mounted on a platform stabilised by gyroscopes and this demands that the equipment is very precisely made. Two similar channels placed at right angles to measure two components of acceleration should be sufficient. However there are several obstacles to be overcome. A record is needed of the angular relationship between the axes of the measuring system and the axes chosen for navigation. A horizontal accelerometer used on the earth's surface is unable to distinguish between a legitimate acceleration and a component of 'g' resulting from tilt. Also a perfect gyroscope has the property that its axis will point continuously at a point in space. This is why the accelerometers are mounted on a platform stabilised by gimbols against a set of axes derived by gyroscopes. Although the platform appears to drift in azimuth or topple from the vertical; this effect can be calculated and allowed for. The accuracy of an inertial system is illustrated by the fact that at the end of a three hour flight an error rate corresponding to a positional error of less than 16 km is typical.

With the increased sophistication of communications system has also come about an equally startling advance in onboard systems such as flight control management. Basically there are three functions to be fulfilled by the flight controller. The ailerons, rudder and elevators are all driven (in a modern aircraft) by servo mechanisms. One of the first purposes of flight control is to enhance the flying characteristics of the aircraft ie to make it easier to fly and also make the ride as smooth as possible for passengers. In this enhancement mode the flight controller can only make slight controls to the rudder etc. The next stage is that the aeroplane can be made to fly along a pre-selected route and this based on a series of comparison circuits.

Total automatic flying is effected by a small special purpose computer. By using sensors such as Omega or VOR, the computer can keep on the route initially set up. Once the ability to fly automatically has been established automatic landing systems is the next step. There has been a great interest in microwave landing systems with the limitation of instrument landing system in unhealthy weather conditions. MADGE (microwave aircraft digital guidance equipment) is one such system. All weather operations are becoming increasingly important for helicopter flying in both military and commercial applications. The decision on an international microwave landing system to replace ILS is already near final agreement. Large scale integrated logic and microwave subsystems have enabled this development to establish itself.

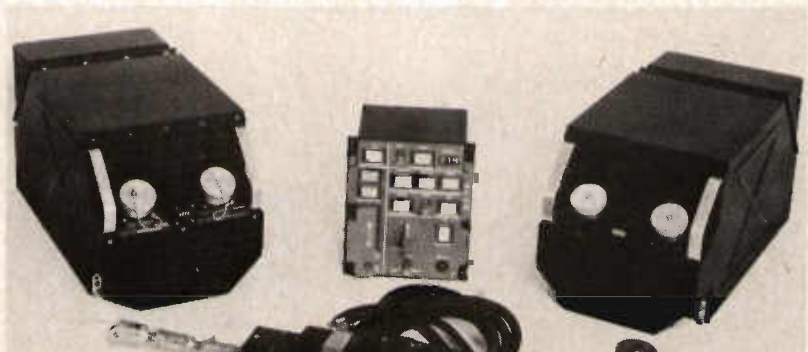
The principle behind the microwave system is interferometry, which is the technique of finding as much information as possible about the direction of an incident wave by measurements of phase within an aperture. Consider a plane radio wave incident on a pair of receiving aerials, the aerials feed a phase descriminator. The measured phase is given by

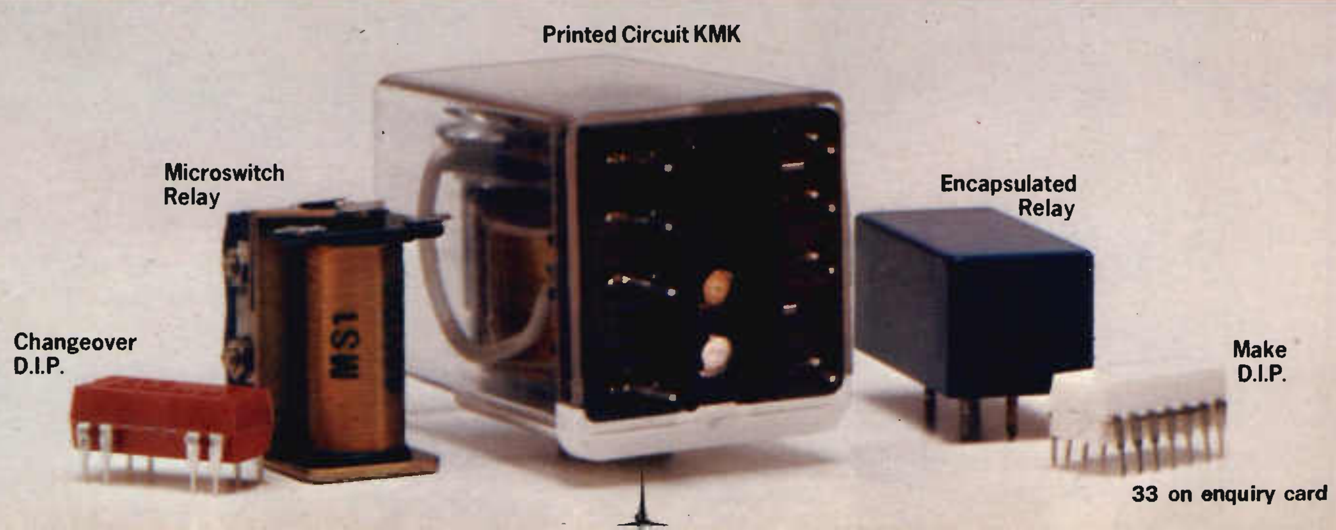
$$\phi = \frac{2\pi d \sin \theta}{\lambda} \qquad (1)$$

where d is the aerial spacing, the signal wavelength and θ is the bearing angle with respect to the axis of the aerial array. The bearing-measuring accuracy of the interferometer increases with its spacing d. This can be seen by differentiating eq. (1).

$$\frac{\delta\phi}{\delta\theta} = \frac{2\pi d \cos \theta}{\lambda} \text{ or } d\theta = \frac{\lambda}{2\pi d \cos \theta} \delta\phi$$

However when the aerial spacing d exceeds λ/2, ambiguity results because the phase difference ϕ contains unknown integral multiples of 2π. Often more than one interferometer is used to remove ambiguity.





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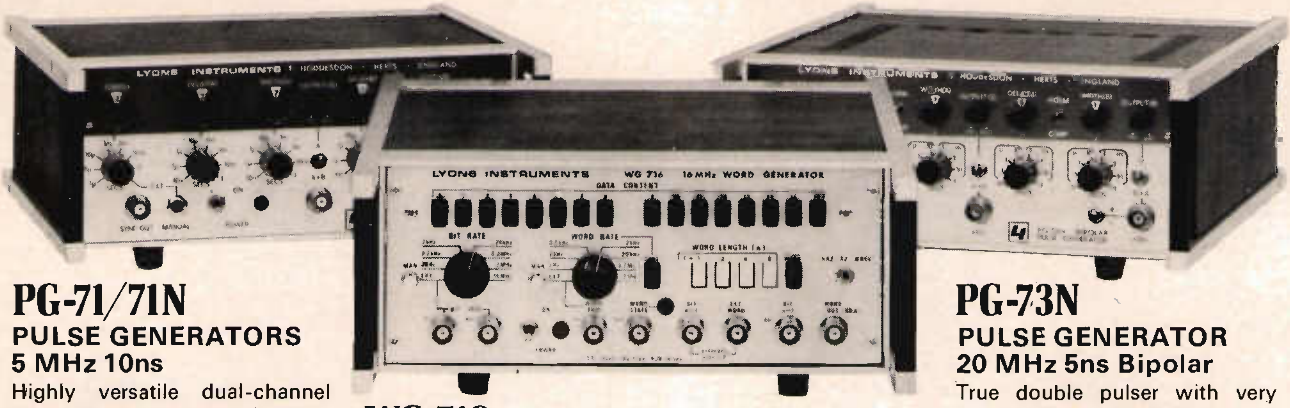

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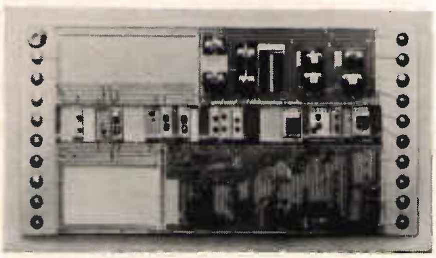

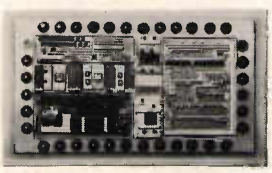

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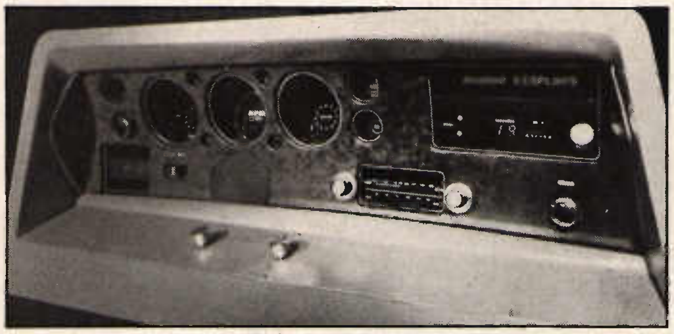
DISPLAYS

The modern display device is frequently the aesthetic focal point of any equipment, certainly the aspect that initially catches the eye. Improvements in intensity, luminescence etc., are freely claimed by most manufacturers. It is *Brian Jennings* intention, through this article to make the designer aware of developments and present day limitations.



This conceptual car dashboard by Bowmar, illustrates the way future car dash panels may look. Incorporating both circular and linear bargraphs, digital and alpha numeric displays.

Of all the variations available in displays currently in use, light emitting diodes (leds) are still the most widely adopted in our industry. They have become a standard 'tool' to all engineers and designers through the pocket calculator and latterly the digital electronic watch.

Leds came to prominence in the mid '60s with companys, such as Monsanto offering 111-V compounds showing great promise as light emitting material. Infra-red devices based on GaAs were subsequently introduced and, after a further 'refining' period and the addition of an epitaxial layer containing phosphorus, a red light emitting material resulted.

Red is still the most commonly used colour and therefore the cheapest. It is questionable as to whether it is the best colour. Red, amongst other things, means danger; but not all equipments emitting a red legend signify a dangerous situation. Hence, non standard forms of warning have had to be developed. Another inherent problem with red, is that the eye is not very sensitive to light at that end of the spectrum.

Subsequent developments resulted in further colours becoming available. With 80% GaP in the GaAsP 'mix', the resulting emission becomes yellow, but with a marked trade-off in efficiency. Processes using 100% GaP deposited onto the GaAs substrate varies the colour. This being achieved by doping the GaP with suitable materials, such as nitrogen or zinc oxide. An n-doped led affords a green emission at about 565 nm; a zinc oxide doped device gives a red emission at about 700 nm. Nitrogen doping also brought about a fourth colour—orange—which offers an efficiency some four times that of red.

Selection procedure

Most leds are used either as discrete indicator lamps or as elements of a segmented or dot matrix display. As such, they are viewed directly by the human eye, therefore the primary criteria for determining their performance lies ultimately with the viewer. Equipment for measuring red light output should therefore simulate human vision. Such judgement should take into account factors appertaining to physical size, anticipated viewing distance and angle, character height and font, viewing background and filtering, on-to-off contrast ratio and anticipated ambient light conditions. Whilst human vision and judgement of led performance is sufficient, it is grossly inadequate for the measurement of product performance; ie the relative amplitude response of the eye tends to be logarithmic, so that the 'normal' eye barely notices differences, say as great as a factor of two. In low light small leds can cause spot saturation of the retinal response.

Life expectancy of leds varies between manufacturer but published figures indicate that accelerated life testing shows that the first 2000 hours of use, the light intensity falls to 90% of the initial brightness. Thereafter, a gradual decline takes place in a linear fashion to be projected 50% of initial brightness after 19 years.

The attraction of leds has of course interested designers and manufacturers of a wide range of products beyond the domestic and consumer markets. However, the visibility problem has remained for outdoor use and until recently has completely ruled out their use in aircraft applications. Other difficulties, as stated previously, have been that most displays have been in red, which is a requirement for warning and alarm indication, whilst construction techniques using reflector packages are unacceptable in sunlit.

Plessey have developed, with MoD support, an led display specifically for avionics use.

The display, type GPD 420, is a yellow four digit numeric with a character height of 4 mm. At the heart of the display is a specially designed bar chip, 0,25 × 0,75 mm in size. This chip has small diffused active areas, so that in operation at 20 mA mean current, a spot brightness of 3000 ftL. is achieved; in addition the whole bar chip lights up to give a wide field of view. In the GPD 420 display each segment of the 7-bar numerics is formed from two bar chips driven in series. The substrate used is a thick film ceramic, designed to minimise wire bond lengths and areas of metallisation from which light can be reflected. The substrate and back plate provide a good heat-sink for the display.

Prototypes have been tested at RAE Farnborough at illumination levels of 10^5 Lux. Further developments using the same technology are under way, with applications in analogue and matrix displays as well as in digital and alpha-numeric arrays. A green variant of the GPD 420 is currently under test.

Many companies looking to the future of fibre-optic telecommunications systems are opting for developing complex gallium, aluminium — arsenide double hetero-junction lasers for illuminating systems.

Plessey have opted for a high radiance led to emit a greater brightness in optical communications systems. They are to introduce a plug-in transmitter, receiver module containing a long life led for short-to-medium haul optical fibre links. Data rates are expected to be as high as 30 Megabits per second, finding use in military, computer and industrial arenas. The high radiance zinc diffused GaAs led in the OML 40D module will be the prelude to a new 'link'.

Light pipes

For the past seven years Fairchild have been developing their patented air-gap light pipe principle to produce larger and brighter digits. This technique they claim is commercially more viable than the filled pipe technique, obviously a debatable issue! The company, with its capacity for in-house production, claim to be supplying in excess of 50% of the world's requirement of GaAsP material. Pioneering the air-gap principle, has led to their development of stick array displays consisting of one, two, three and four digits mounted on a pcb. At present Fairchild displays are available in red GaAsP with the individual digits available in high brightness red versions. Technologies used are liquid EPI-GaAsP to give a pure emerald green and a 'super' GaAsP for amber.

The trend today is towards larger and larger leds, the IEE 'king size', 26 mm high, for example, has a typical luminous intensity of 500 µcd at 20 mA/3,3 VF and a wide viewing angle in excess of 160°. The slightly smaller height, 15,24 mm display from Xciton available from Distronic, includes red, green and yellow numeric and overflow digits. A development by Xciton, the XC 1209 is an ir-emitting diode produced in GaAs by a liquid epitaxial process. Typical output is 1,5 mW at a $I_f = 20$ mA, with ir-radiation

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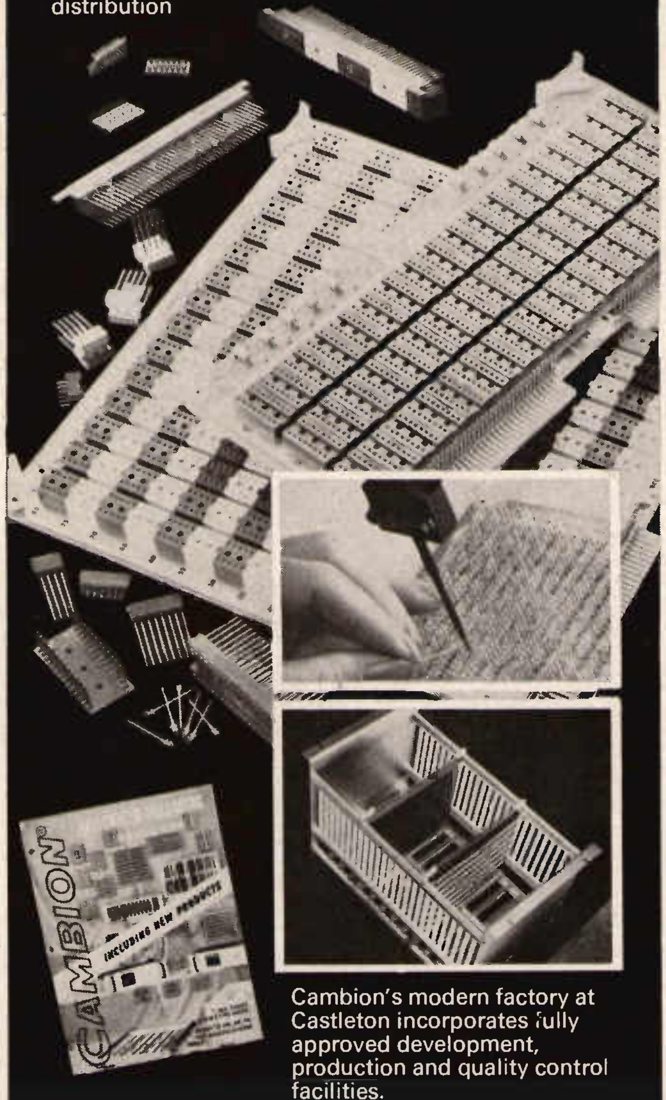

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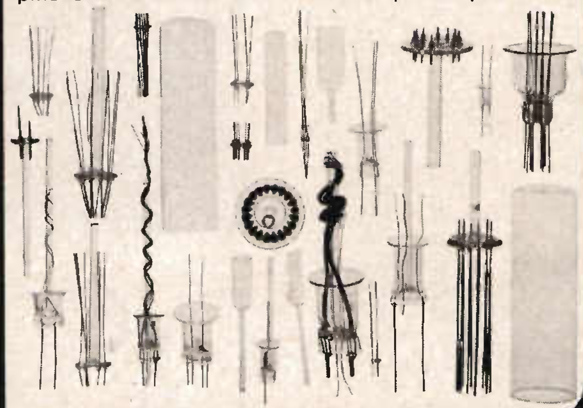

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peaking at 940 nm.

Monsanto, on the other hand, have introduced a new 15,24 mm orange led produced by GaAsP on GaP substrate technology and is a high speed device for multiplexing and logic control. The new display is compatible with the MAN 6600 series of double digit displays and is itself designated MAN 6660 (common anode) or MAN 6680 (common cathode). Both units emit orange light at a radiated wavelength of 630 nm and feature 510 μcd/segment digit at a forward current of 10 mA. Risetimes for these displays is 10 ns.

Hewlett-Packard's HDSP-2000, is a four character alphanumeric with a 3,8 mm, 5 × 7 array, packaged in a 12-pin dil. This novel device features an on-board serial-in-parallel-out, 7-bit shift register associated with each digit controlling constant current led row drivers. Full character display is achieved by external column strobing and they are externally programmable and typically capable of sinking 13,5 mA pk/diode.

Every type of read-out, display or for that matter print-out device requires appropriate drivers to activate the output medium. Modern lsi techniques have produced at least two 4-digit display drivers which greatly simplify the displaying of numerical data via leds or fluorescent displays. One device the AY-5-4007 is manufactured by GIM; the other, type ZN 1040E, is fabricated by Ferranti. The following comparison table is shown purely as a guide in assisting the design engineer.

Parameter	GIM.AV-5-4007A	Ferranti ZN1040E
Supply requirement (driving leds)	+5; −12 or −7 V	+5 V (TTL)
Current	15 or 30 mA	80 mA
Power consumption (driving leds)	0,75 W (average)	0,75 W (average)
Speed	600 kHz	600 kHz
Led current drive (max)	25 mA (1 V drop)	80 mA (max)
Internal oscillator	Yes	Yes
Lamp test/intensity control	No	Yes
Up/down counting with look ahead	Yes	Yes
TTL compatibility on i/p & o/p	Yes	Yes
Schmitt trigger on i/p	No	Yes
Decade carry o/p	Yes	No
Direct cascading for 8-digits	No	Yes
Minimum system component count	4 transistors, 7 resistors	4 transistors, 7 resistors
Cost (100) up	£5,50p.	£5,20p.
Package	40-pin dil	40-pin dil

These figures in the table were correct at the time of going to press and were furnished by SDS Components, Portsmouth.

Liquid crystals are organic compounds which in their liquid phase exhibit two distinctly different states, the anisotropic and isotropic state. Immediately above the melting point the anisotropic phase occurs. This is denoted the 'mesophase', in which the liquid shows certain crystalline properties, one such property is double refraction. As the temperature is increased further beyond the 'clearing point', the crystalline liquid becomes isotropic.

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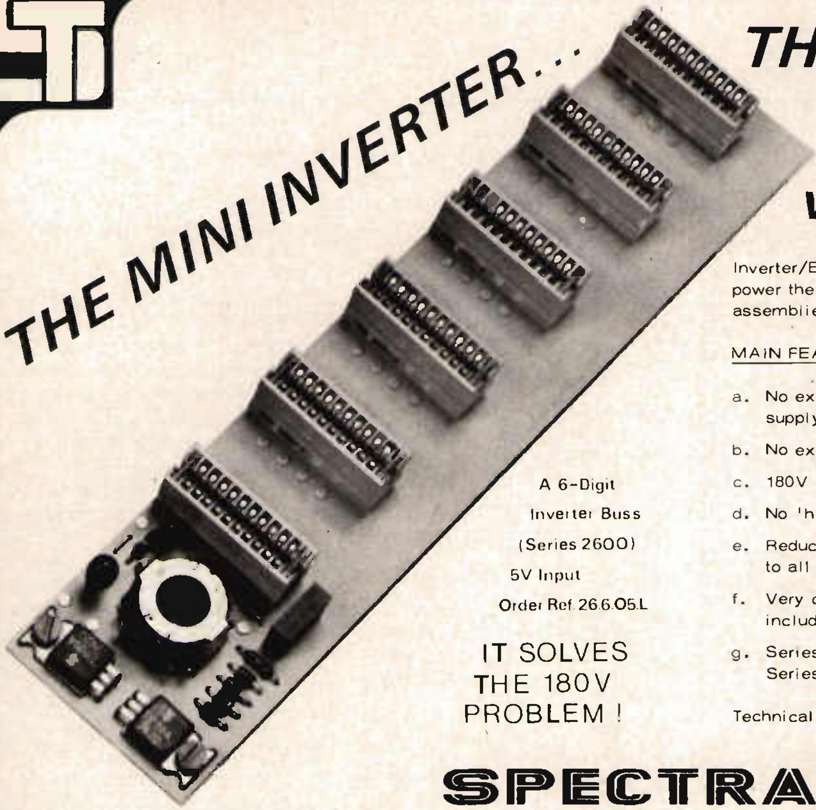

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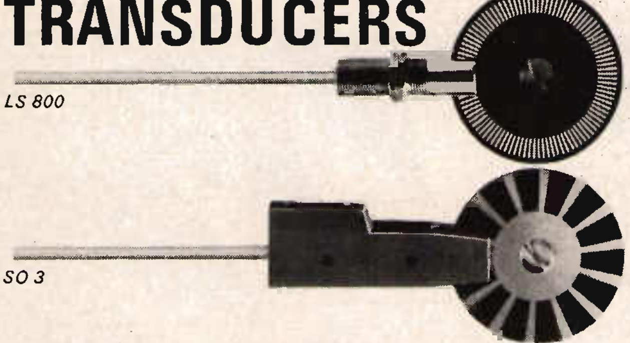

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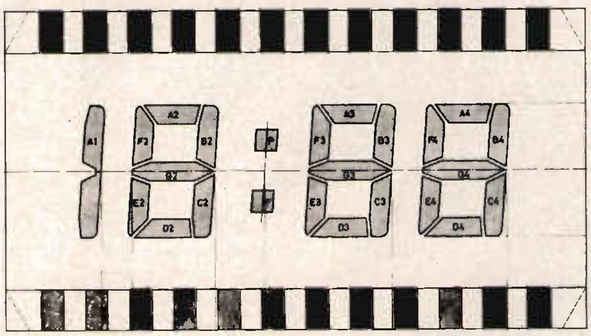

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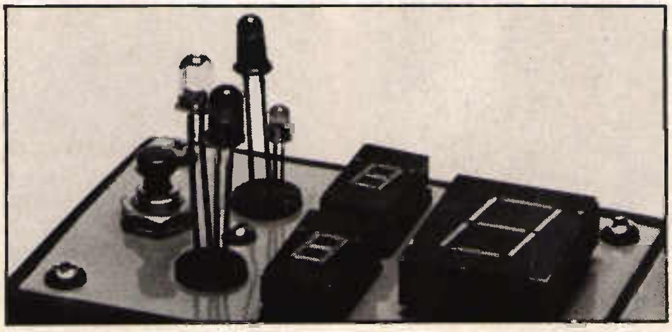
PRODUCT FOCUS

There are three general types of liquid crystal (lc); those exhibiting nematic, smectic and cholesteric mesophases. Today two sorts of lcd's are being produced, dynamic scattering mode (dsm) and field effect mode (fem) types. Both are available in several forms, operating either by the reflection of incident light, by the transmission of light from an artificial source or, by a combination of transmission and reflection.


A typical range of sizes and shapes in led's.

If a nematic lc-film is located between two parallel glass plates, application of an electric field causes the previously clear lc to become 'milky'. The electric field is produced by applying a voltage to a conductive, transparent coating on the inside of the glass plates. The preferred plate spacing is about 10 μm. A threshold field strength of 0,5 V/μm is required to start the effect.

Field effect mode (fem) lcds, based upon the principle of the twisted cell, have electrode surfaces, which have specially been treated in order to align the adjacent lc-molecules in a particular direction. The alignment directions of the molecules on the two opposite electrode surfaces are perpendicular to each other. If the twisted nematic cell is sandwiched in between two crossed polarisers, the light, which enters the cell polarized, will also be twisted by 90° on its way through. Thus, without electrical power applied to the cell, the display passes light. When a certain threshold voltage is applied, however, to the cell, the molecules align in the direction of the electric field and the twist is destroyed and the display becomes opaque to light. With crossed polarisers, therefore, black symbols may be produced on a light background and by using parallel polarisers, light symbols on a black background.

Looking ahead

Marconi Research Labs., who, since 1968 have pioneered research in lc materials, have devices ranging from shutters to alpha-numerics.

The chief features of lcs are the low-power requirements, typically three to 30 V at a few $\mu A/cm^2$ and their good visibility under high ambient lighting conditions. Dsm displays were among the first type of devices produced. These devices operate at 15 to 30 V rms and 25 to 200 Hz, with a current density of 3 $\mu A/cm^2$. Transmissive displays produced include a large area clock display with an active area of 180 × 70 mm backed by a louvred plastic film and illuminated by a 4 W fluorescent tube. The problems in accessing a matrix were partly solved by producing a vertically scanned 112 × 20 matrix 15 mm high, with numeric and graphic capabilities. Later displays have been constructed as twisted nematic devices using a nematic lc with dielectric re-orientation. The advantage of such field effect devices is the lower power requirements, typically one to 10 V at 50 to 1 kHz and good contrast ratios (100:1).

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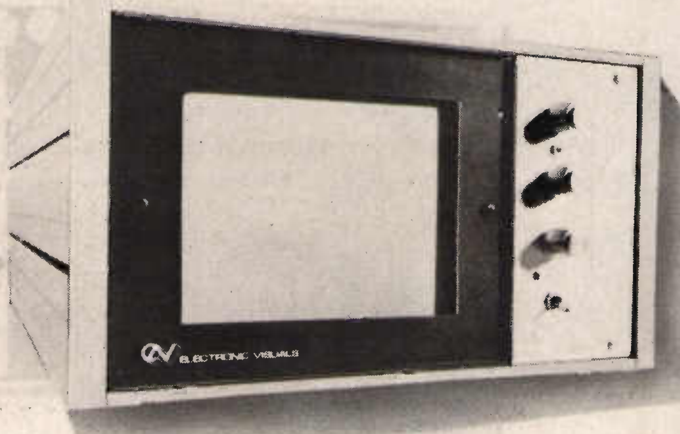

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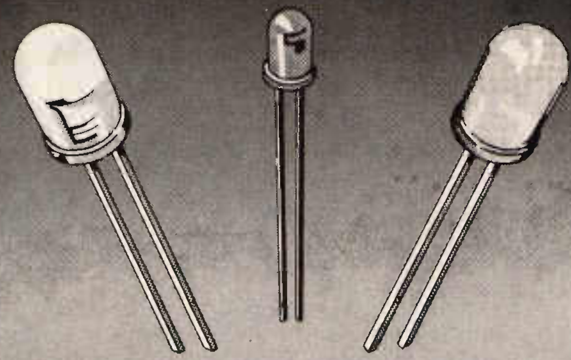

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The most recent development has been a graticule with 150 × 400 electrodes and a resolution of 10 lines/mm and stackable four numeric displays with 8 mm high characters. Both displays have chip circuitry integrated on the substrates. By selecting suitable lc materials and using an integral heater the temperature range of operation may be −35 to +80°C.

The proliferation of lcds is only too apparent with the quantity of calculators, watches and more recently their incorporation into instrumentation. Sharp Corp., represented by Hakuto, produce a reflective, dsm display for 8-digit calculators. They are multiplexed and have a 1:4 duty ration, thus permitting vast reductions in the complexity of driving circuitry. But certain precuations must be observed, since the life of lc-devices will be seriously impaired if the energising signal has a dc component. Precautions are also necessary owing to the extreme high resistance of the devices, such that mos on/off type devices may have sufficient leakage to energise the cells.

An economical and convenient driving method would be a direct cmos drive. The display frequency source should be a square wave sufficiently symmetrical with respect to both time and output impedance (high-to-low-state) to meet the dc offset constraints (500 mV). Low source impedance (1 kΩ) is desirable to minimise external voltage drop. CMOS is preferred over n-mos or p-mos, because of lower symmetrical output impedance. Adequate contrast is achieved with V_{DD} = 15V (voltage applied to display = 30 Vpp); however a 16,5 to 17 V source is recommended to achieve faster on-times.

Reverse square wave drive can be achieved by means of an exclusive-OR gate or by the adoption of bilateral switch connections. Any drive circuit not having a suitably symmetrical 'high' and 'low' output impedance, such as the wide variety of lcd watch drivers available on the market, may be interfaced with an inexpensive cmos inverter or buffer.

It is now accepted that fem displays have taken over the watch, clock and instrument markets, because of their better all round performance. Never-the-less, according to TCI, not one manufacturer has succeeded in producing one piece large area fem displays. This is because in the twisted nematic mode, the lc-layer must be of a very tightly controlled thickness (between eight and 12 µm). Thinner displays show multi-coloured fringes, making legibility difficult and thicker displays lose out on viewing angle and switching time.

Joseph Electronics, agents for Electrovac of Austria, are now supplying lcds in different colours, with coloured backgrounds. Watch displays can be assembled with an arrangement of two colours, eg black hours and minutes with red seconds, in the same display.

Magnetic displays

Research engineers at the Magnavox Corp., have developed a 2 × 3 cm flat display that reflects light from magnetic particles suspended in a transparent panel. The non-volatile display consumes minimal power but at this stage it is purely experimental. Unlike lcds these magnetic displays appear not to be affected by extremes of pressure or temperature and may offer an alternative, albeit long-term, for aircraft usage.

The engineer who developed the display, Laurence L. Lee, maintains that by careful design of the matrix addressing system and the correct choice of memory material, the display could be sequentially addressed to provide a variable grey-scale that registers brightness in proportion to the amount of video-scanning current applied to the grid. Resolution and contrast, in theory, have been estimated at a span of 100 and 200 µm, limited not by particle size, but by the spacing between the con-

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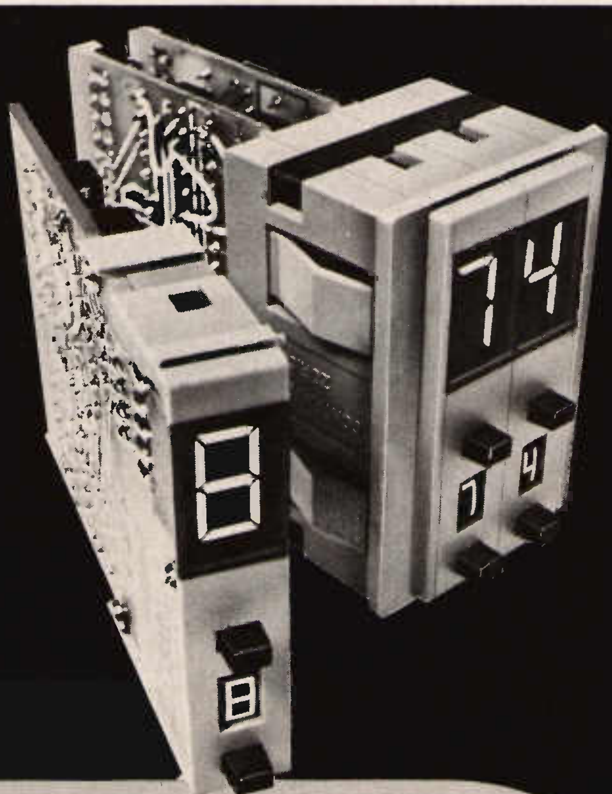

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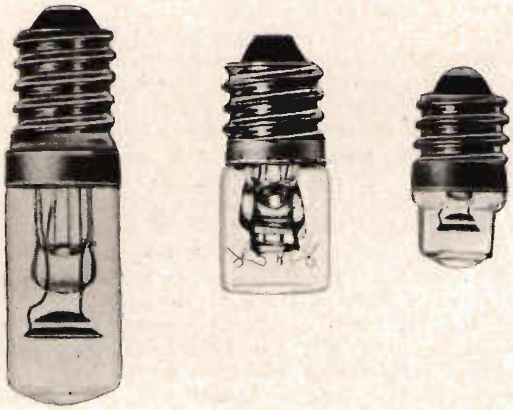

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ductors of the addressing grid. The particles are of ferrite powder held in a binding of wax or plastics made in sizes as small as 20 μm in diameter.

A simple variation by Philips Research of standard silicongate technology has produced extremely versatile arrays that make adc's, analogue type displays and light pattern scaners. The arrays consist of devices similar to standard mos elements, except that a resistive electrode replaces the normal metal insulated gate. One type of array, for example, allows an analogue voltage to regulate the length of a column of leds. Developments of these arrays have been used to produce sophisticated types of adc's offering 5-bit resolutions, as well as light-pattern scanners up to 100 elements in length, requiring simple clocking systems.

A recent introduction is that of a novel, low cost, transparent electrode system for use in solid-state electronics, developed by the ERA. Several of the newer types of display, including lcds, depend for their operation on the use of glass with a special coating, which is both electrically conducting and transparent to visible light. The coating is patterned into electrodes having the form of the characters of the display.

This new alternative method of producing patterned transparent electrodes requires that an organic paste containing metal compounds is screen printed in the required pattern onto plain glass sheets which are subsequently heated in suitable furnaces. During firing, the paste completely decomposes, leaving a thin metal oxide film firmly adhered to the glass. Thus the conducting film is deposited, formed and patterned in two operations. Ordinary window glass may be used as the substrate material and a high optical transmission is obtained. Sheet resistivity is normally around 800Ω/square with higher conductivities obtainable by modified processing.

Although this method was originally developed for lcds it should be suitable for use with plasma panels and electroluminescent displays.

Electrophoretic displays

The electrophoretic display, being a comparative newcomer to the display scene, offers the designer a combination of high contrast low power operation on pure dc colour, without polarizers, memory and multiplex ability. The electrophoretic display consists essentially of a sandwich cell formed between two electrodes, at least one of which is transparent, with a working fluid composed of a suspension of small (submicron) pigment particles in a densely coloured liquid. If the two phases are suitably selected, the pigment forms a lyophobic (ie solvent repellent) sol or suspension in which the particles are electrically charged, probably as a result of the adsorption of impurity ions from the liquid phase. Applications of an electric field causes migration of the particles to one electrode, which therefore assumes the colour of the pigment; reversal of the field causes the particles to move in the opposite direction and the electrode colour changes to that of the liquid phase. The use of shaped or segmented electrodes, together with pigment particles and dye solution of contrasting colours, enables on-off, digital and alpha numeric displays to be made.

An important feature of the display is its memory, the particles remaining on the electrode for periods varying from a few seconds to many months after the removal of the field.

Electrochromic displays

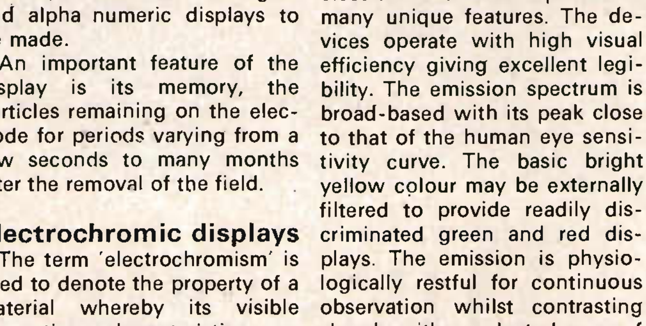
The term 'electrochromism' is used to denote the property of a material whereby its visible absorption characteristics are reversibly altered under the application of an electric field. Such spectral changes may result from field effects, charge injection or electrolytic reduction and oxidation. The materials under investigation are based on tungsten oxide and related compounds in the form of transparent thin films which are deposited by evaporation or chemical methods. These materials change from colourless to deep blue under the application of fields in excess of 400 V/cm. Upon removal of the field, the colour persists for many months. Sandwich cell structures can be fabricated which can be reversibly cycled from colourless to blue with switching speeds in the order of 0,1 to 1 second. Methods of obtaining hydrogen ion concentrations are being devised to improve the speed and performance of these solid-state devices, which can be fabricated with 90% transmission in the off-state.

Dc electroluminescent displays are based on polycrystalline copper and manganese doped zinc sulhide powder phosphors. The devices are fabricated on transparent conductively coated glass substrates, which are photo-lithographically etched to provide delineation of the required light emission pattern.

As a display technology dc electroluminescence possesses many unique features. The devices operate with high visual efficiency giving excellent legibility. The emission spectrum is broad-based with its peak close to that of the human eye sensitivity curve. The basic bright yellow colour may be externally filtered to provide readily discriminated green and red displays. The emission is physiologically restful for continuous observation whilst contrasting sharply with unselected areas of the display and the surround.

Displays can be made secret until lit. This display technique lends itself readily to the production of X-Y matrix addressable multi-character alphanumeric display panels. Alphanumeric devices ranging from a single 7 × 5 matrix to a 60 000 dot matrix of 25 rows of 50 characters have been produced. Typical element sizes are 0,64 and 1,8 mm square. Matrix panels with resolutions up to four lines/mm are under development.

Large size ac electroluminescent displays.



Phosphor Products, who produce this type of display, explained that matrix displays are driven by short unidirectional pulses at low repetition frequencies. The pulse voltage is usually 30-40% in excess of the dc forming voltage. Brightness of between 25 and 40 ftL are achieved with 100-130 V pulses of 10 μs duration at a 1 ms refresh rate. A recent innovation from Phosphor Products is a 256 character system, organized as eight rows of 32 characters, the display is available with drive and character generation boards, the requisite power source module and V24 data interface will be available shortly.

A recent introduction by SRDL is the use of ac electroluminescence for large numeric and alpha numeric displays. The logic for the drive unit uses t²l circuitry which accepts a bcd input and converts it, for example, to a seven-segment numeric display. The hv capabilities of scr's are combined with its usefulness as a transistor, in this case as a symmetrical transistor to control the full-wave ac drive of hv, medium frequency and low current drive. At 400 V and 400 Hz a maximum of 10 mA is taken through the gate. Brightness is 25 ftL and digits are available in sizes ranging from 25 to 300 mm. The predominant phosphor colour is light blue, other colours, dark blue, orange and white are available, but with subsequent trade-offs in light output.

Message panels

Dot matrix message panels of the type produced by IEE of USA and available from Perdix are ideally suited for alphanumeric *on* and *off*-line terminal and console displays (input, output, editings, query, remote, slaved or multiplexed, et al). This particular range is available in 14 different configurations and conform to either ASC11 & EBCDIC-compatible, 5 × 7 dot matrix formats.

Furthering the appeal for array type modules, again from IEE, is a high density fibre optic display, available in a choice of seven numeric or 16-segment

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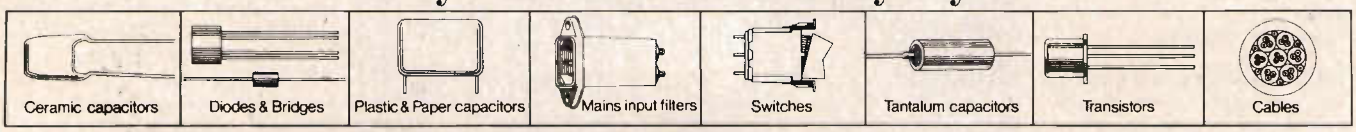

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alphanumeric with 6,4 mm high characters. Packaging density is high, namely 2,54 or 4,1 mm³ affording a high intensity 1500 ftL display. On the power side 0,2 mA/segment at 5 V dc is required. Initial tests have shown these displays to be well suited for avionics and in particular cock-pit usage being easily readable in high ambient light conditions.!

There are two main types at plasma panel: the capacitance coupled ac and the resistance coupled dc types. A typical ac plasma panel of the type produced by ITT may have a 215 mm square display area, with 512 × 512 x/y addressing lines. The 1024 inputs address 26 2144 light points on the panel with a resolution in both directions at about 2,5 points to the millimeter. Such a panel will display up to 4000 upper and lower characters.

Basically each section consists of thick plate glass having parallel conductors brought out to the edges. A thin glass frit is put down over the conductors to form the dielectric layer. The plates are then placed at ninety degrees to each other and sealed except for the filling tube.

The complete panel is then fitted with a gas mixture and sealed. By applying an alternating voltage of 50 kHz with an amplitude of just less than the gas ionisation the potential between the x/y lines, the panel will function. The further addition of a writing pulse to the maintaining voltage, when seen by a particular pair at x/y lines, will ionise the gas in a column where the lines cross and produce a light output.

Self-powered sources

Betalights, a development by SRDL, are sealed glass capsules, internally coated with phosphor and filled with tirtium gas. The tritium, an isotope of hydroten, emits low energy beta-particles (electrons) which strike the phosphor causing it to emit the light characteristic of the phosphor used. The brightness is determined by the quantity of tritium used, but are known to range up to 4000 µL.

The advantages of a self contained, self powered light source are manifest, for instance the lack of wires, batteries etc., panels can be lit without considering heat and servicing.

A recent new application is in illuminating the digital display of lcd time pieces; eliminating the need for a bulb and the consequent drain on battery life, let alone the need for pressing a button to read the time!

There is no shortage of filament tube display manufacturers and the techniques of construction have been adequately covered over the years.

Recent developments have included a high brightness filamentary seven segment indicator, manufactured by Okaya and available from KGM Electronics. Minimum brightness is 8500 ftL and applications are foreseen in areas demanding a rugged unit, such as taximeters, weighing machines, petrol pumps etc. Another form of filament display from ISE Int. and obtainable from Hakuto is a single envelope answer to multiple display requirements. These devices have individual grids for each legend and common internal connections minimising external leads. Minimum brightness for the larger display is 100 ftL,

Cathode ray tubes

In the field of miniature crt's, Ferranti have led in the development of the 25,4 mm crt package, the original tubes being produced in 1968 for the American Helmet Mounted Display project. Since that time the basic tube has undergone considerable development and is now in use in many commercial military applications including phototypesetting, battle tank gun sight and missile simulators. This tube was considered too heavy for its original application of helmet mounting and a smaller size tube has been developed to fit into the second generation contoured helmets.

The latest addition to the 25,4 mm range is a rectangular version, with an anticipated market in viewfinders for hand held tv cameras and spot injection systems requiring a rectangular format.

Shadow mask tubes are not suitable for high resolution colour displays and to meet this requirement penetron phosphor tubes are used. Developments in this field hinge on higher brightness particularly at the red emission which is normally obtained at low kV.

High control displays

To provide the high contrast necessary for a Head Down Display in an airborne cockpit where very high ambient illuminations can exist, special techniques are necessary. The latest displays make use of rare earth phosphors which have a narrow band spectral emission characteristic. In front of the crt is mounted a filter with a narrow transmission band matched to the phosphor and with an antireflective coating.

To simplify the crt system design, crt's providing high resolution from an electrostatic focus gun have been designed. These provide a simple economical package for applications such as computer output of microfilm.

RCA Solid-State and Centronic produce a range of flying-spot scanners and photo recording applied devices. They are available in a range of shapes and a selection of diameters spanning 25,4 to 203,2 mm with operating voltages from 0,9 to >6 kV.

Bistable storage

Bistable storage crt's are claimed to offer long storage time, resistance to burning, high resolution and high contrast. A 127 mm tube developed by Matsushita Electronics has a writing capability of 10 mm/s. Known as the model 140BFB1' it has been designed to compete with devices that write between one fifth to a half as fast.

The Ferranti 25,4 mm crt ideal for hand-held equipments.

The device includes a fine-spot electron gun for writing and two flood guns for reading and erase. The writing gun's dynamic deflection/defocussing correction capability enables the device to maintain a spot diameter of 0,2 mm over the total screen area. This correction is obtained by applying a negative triangular voltage proportional to the horizontal deflection from the centre of the screen to the grid between the vertical and horizontal deflection plates.

Polarizing msterials

A full range of linear polarizing materials for use in the manufacture of lcds can be supplied by Polarizers Ltd. These materials may be with or without adhesive and are available in three versions—transmissive, reflective and transflective for back lighting.

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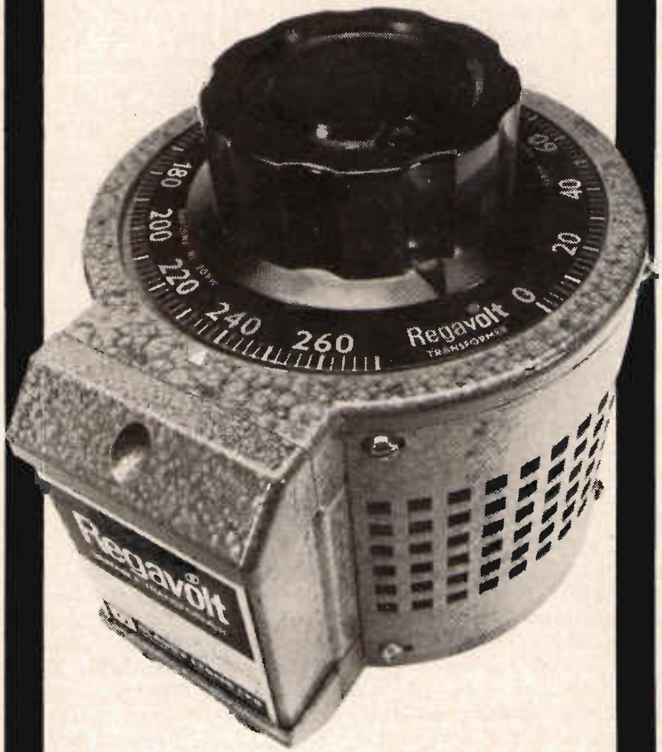

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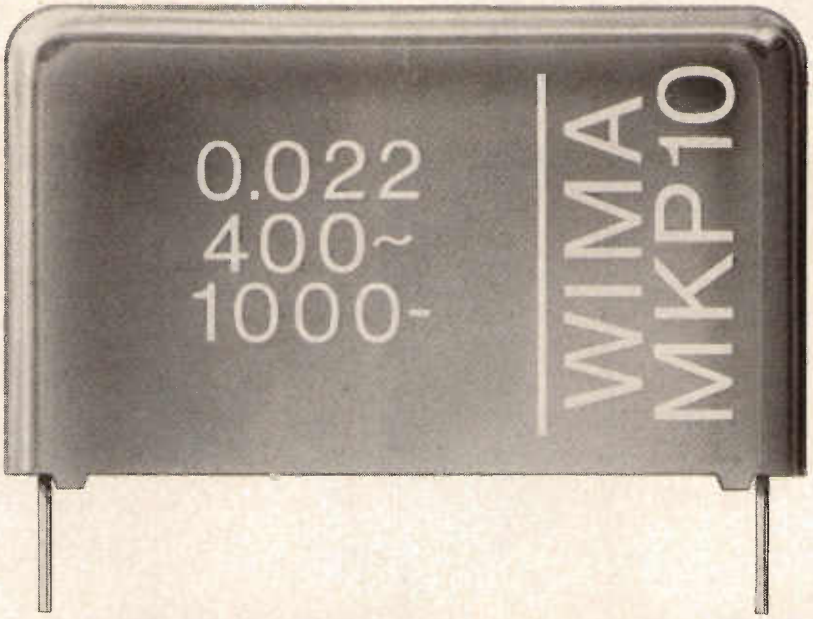
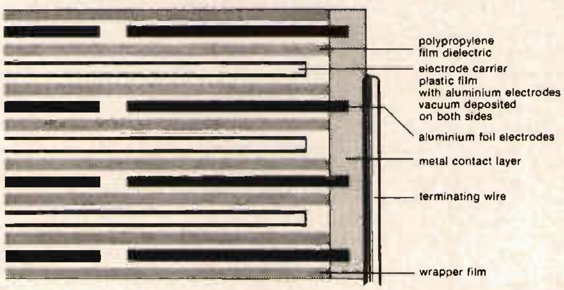
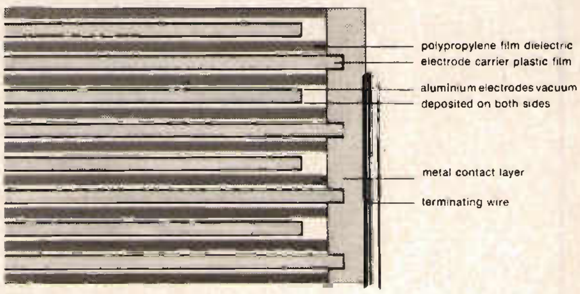


Wima® FKP-1 & MKP-10 polypropylene dielectric capacitors

Designed for stringent pulse duties, these low-loss Wima capacitors represent a major technical breakthrough. The electrode system employs an electrically passive carrier film of polyester which is metallised on both sides. This Wima design avoids the disadvantages of polypropylene dielectric film with directly vacuum deposited metal electrodens, namely, poor adhesion of the metallisation, unreliable end contacts and the hazard of corrosion with consequential loss of capacitance. Wima capacitors are manufactured by Wilhelm Westermann, West Germany, and comprehensive data sheets covering 24 Wima ranges are included in the Waycom Handbook. Contact Waycom for the latest Wima information.





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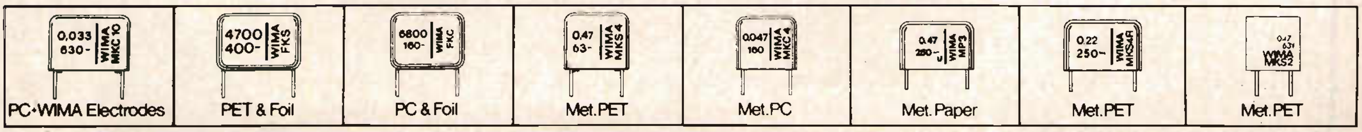

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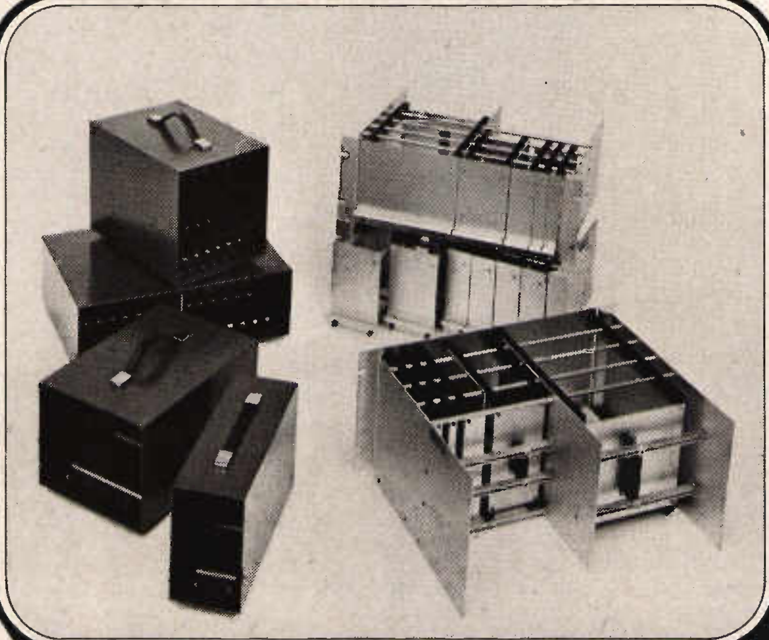

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New from ESI

New micro processor controlled LRC digital meter from ESI

Tranchant bring you ESI's latest auto LRC Meter - Model 296. It measures R, L, C, G and calculates D and Q. Because it's microprocessor controlled, the cost of optional features is reduced making them plug-in accessories.

Model 296 is the perfect answer to your manual or automatic testing of components. A 24 button keyboard enables easy selection of function ranges, test voltages and frequencies, or these can be programmed via the optional IEEE 488-1975 interface bus.

Here are the features that make the 296 a money-saver for anyone with QA on his mind:

* dual 4½-digit displays.
* 1 kHz and 120 Hz freq.
* wide ranges (C to 200,000µF).
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* autoranging.
* selectable test voltages.
* 100-300 ms measurement speed.
* low cost options including:
  IEEE 488-1975 interface bus.
  limits comparators.
  higher measurement speed.
  D.C. resistance measurement.

		Capacitance	Inductance	Resistance
Full	1 kHz	0 to 20,000µF	0 to 2000 H	20 m Ω to 2 M Ω
Scale	120 Hz	0 to 200,000µF	0to 20,000 H	20 m Ω to 2 M Ω
Ranges	D range is 0.0001 to 1.9999. Q range is 0.5 to 10,000. Gp 200 S to 2000 nS.			

Send for your copy of the 296 data sheet giving full specifications today.

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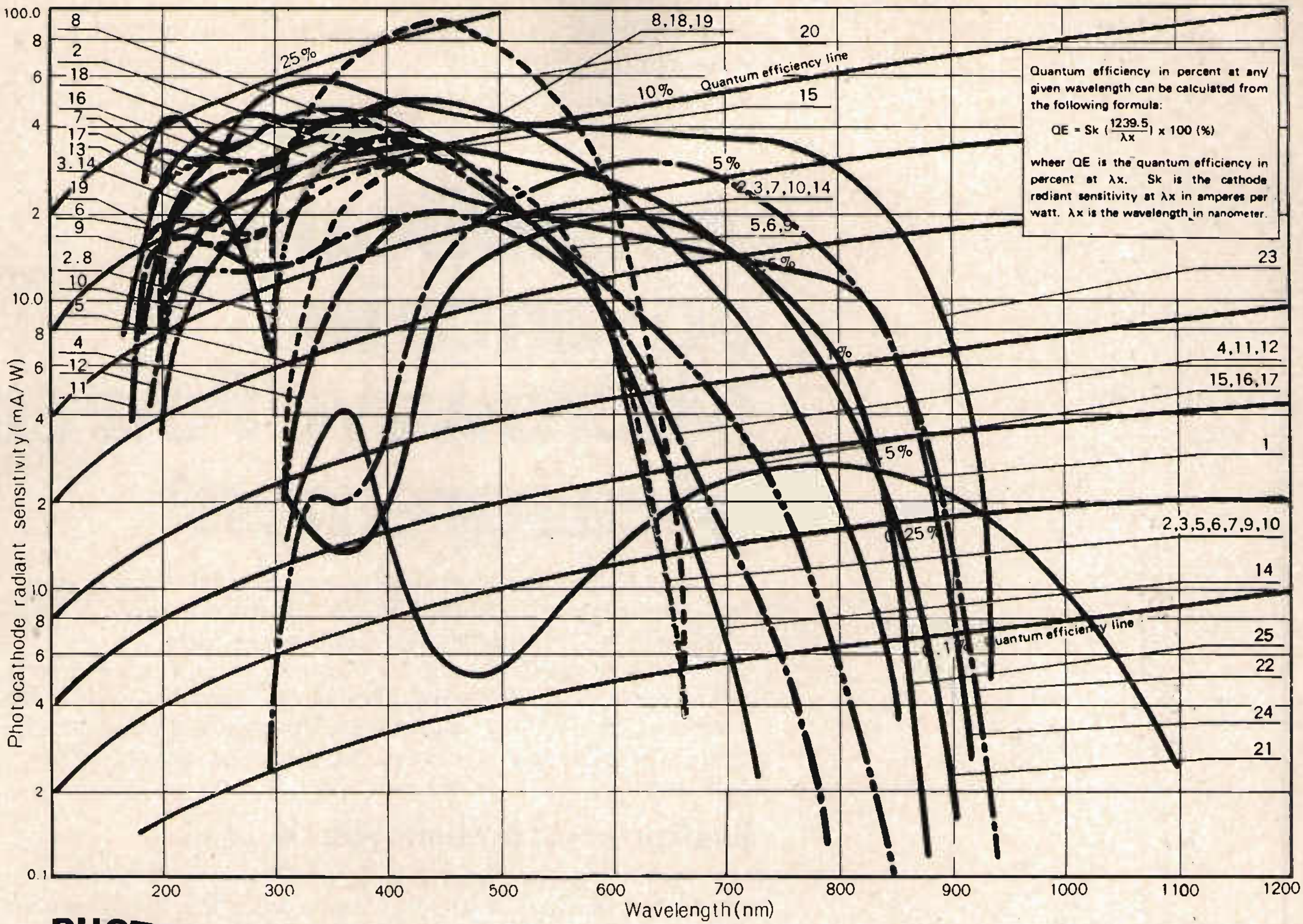

PHOTOMULTIPLIER TUBES, PHOTOTUBES BY HAMAMATSU

The black and white reproduction above shows a spectral response chart for the enormous range of photocathode types available in the HTV range of photosensitive devices. The original is printed in 6 colours on stiff plastic and is readily available from our address below. HTV are well known internationally for the technical quality of their products which are exclusively available in the UK from Hakuto. In addition to the spectral response chart above, we also have available a 46 page catalogue, send now for your copy.

Hakuto

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Hewlett-Packard's new Model 436A combines three important advantages: low VSWR thermocouple sensors; high instrumentation accuracy; and simplicity of operation.

A significant advance in Microwave Power Measurement

Model 436A is a general purpose power meter with a frequency range of 100kHz to 18GHz, and a power range of -70dBm to +35dBm depending on the sensor used.

The low VSWR of the HP8480 family of sensors with which this meter works (8481A - less than 1.1 from 50MHz to 2GHz, and less than 1.28 to 18GHz), and its 0.5% instrumentation accuracy, lead to RF and microwave power measurements of very high precision.

Read power in the units you choose

Push-button operation and digital display make the 436A easy to interpret and easy to use in any application. Mode switches allow you to read absolute power in either watts or dBm, and relative power in dB. Its auto-ranging capability allows for hands-off operation.

Automatic sensor recognition

The 436A automatically recognises which sensor is connected to it, displays the correct power units, directly and accurately.

Remote programming

Two programming interfaces are available as options on the 436A: the Hewlett-Packard Interface Bus (HP-IB) and a BCD interface, both of which allow full remote control of the meter's functions.

With the new 436A mismatch uncertainty is minimised while accuracy and simplicity are greatly increased - a significant advance in microwave power measurement.

You ought to get the details

Just write to Hewlett-Packard Ltd., Enquiry Department, Winnersh, Wokingham, Berks. RG11 5AR.

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NEW PRODUCTS

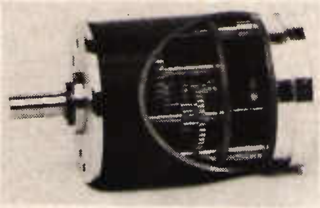
Indicators
This solid state neon-plasma display strip indicator is available either as a dual channel or a single indicator with "hi" or "lo" settable alarms. The indicator called Striplite, when in the dual format accepts and displays on each channel any normally used electrical i/p signal. Both versions provide integral signal conditioning to give an analogue o/p of 2 V. *Penny & Giles, Mudeford, Dorset.* **300**

Digital tachometer
This full 4-digit solid state fibre optic tachometer enables information on the speed of gears and spindles and the flow of liquids, gases and powders to be displayed. Small in size and very compact, the unit can be fitted into control cubicles or used as a portable or free standing instrument. It can also be supplied with either a magnetic or capacitive probe. *Forward Electronics, Leicester.* **301**

Expander modules
The models MDXP-32 and 32-1 data acquisition expander modules are designed to increase the i/p capacity of 16- and 8-channel systems. Both modules contain 32 analogue multiplex channels permitting the expansion of the MDAS-16, to 48 single-ended channels and the MDAS-8D up to 24 differential channels using single-level multiplexing. Turn *ON* time is 500 ns and turn *OFF* time 300 ns and the operating temperature range covers zero to +70°C. *Datel, Basingstoke, Hants.* **302**

Low pass filter
Designed for applications where the removal of spurious radiation is a requirement, these Conhex rf connectors incorporate low pass filter functions. Representative of the family is a 50 Ω screw-on jack receptacle designed for bulkhead mounting. It features a minimum attenuation of 45 dB from 0,2 to 2 GHz. *Sealectro, Portsmouth, Hants.* **303**

Miniature gearbox
The Maxon 2926 gearhead for small electric motors is available in 16 different ratios from 1 :2,5 to 1 :1976. These cylindrical



gearboxes offer continuous o/p torque capability of ten or 15 ncm with a factor of three overload capability for short term operation. Gearbox efficiency is >92% reduction step and the gear trains range from two to eight steps. Maximum recommended i/p speed is 5000 rpm. *Trident Engineering, Winnersh, Berks.* **304**

Timers
For elapsed time control from four to 30 mins the type ET is offered with comparatively simple basic sp/st and dp/st switching. With an eddy current brake mechanism, the switch rating is 16 A at 240 V ac. *NSF Controls, Tyne & Wear.* **305**

Low power registers
Two new low-power Schottky shift registers with gated serial i/p types Am25LS164 and AM-54/74LS164 are 8-bit serial-in/parallel-out shift registers offering maximum clock frequencies of 35 and 25 MHz respectively. The gated i/p provides enable/disable control over incoming data. Additionally these devices offer an asynchronous clear i/p to simultaneously clear the devices' eight flip-flops. *AMD, London.* **306**

Transducers
This reliable, low cost reflective transducer combines a high efficiency led with a silicon phototransistor. The OPB704 is packaged in a hermetically sealed glass-metal ceramic case and has a usable continuous operating life of more than five years when operated at 20 mA. With an led i/p current of 50 mA, the o/p of the phototransistor is typically 0,5 mA. *Norbain Opto-Electronics, Reading, Berks.* **307**

Power supply
This range of low cost pcb mounted power sources includes a ±15 V, 100 mA for op-amps etc. It features current and thermal shut-down protection and is o/p short circuit protected. Load regulation is 0,6%; line regulation 0,13% and o/p noise voltage 0,06 mV. *Lascar Electronics, Billericay, Essex.* **308**

Development system
This single board computer, QMS 80-1180 utilises the industry standard 8080. The board has been designed for use in the development of hardware and software or in production equipment and, for this reason the addresses of the 2k ram and 1,5k of prom can be selected by the user. Thus a programme developed in ram can be transferred to proms without modifying memory referenced instructions. The QBUG programme, operable in either hexadecimal or octal, is expandable to full mnemonic working on the direct assembler principle. *Quarndon Electronics, Derby.* **309**

Avalanche diode
Two new silicon planar epitaxial controlled-avalanche diodes, types BAW21A and /21B, are fast switching devices intended for use in general applications where transients occur, or where a very steep forward characteristic is required. The 21A has a defined avalanche breakdown voltage at $I_R = 100\ \mu A$ of 90 to 150 V, whilst the value for type 21B is 120 to 175 V. Rectified forward current averaged over any 20 ms period for both types is 0,4 A maximum and the repetitive peak reverse energy is 5 mJ max. *Mullard, London.* **310**

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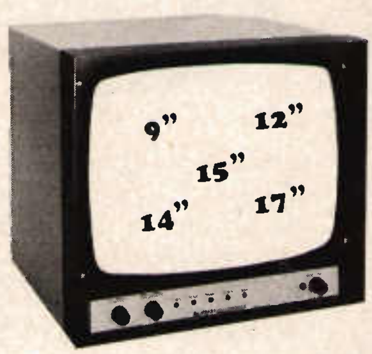

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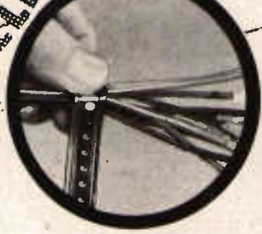
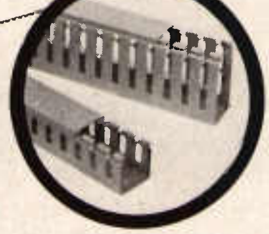

CABLE STRAPPING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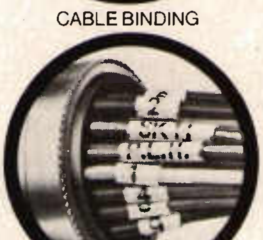
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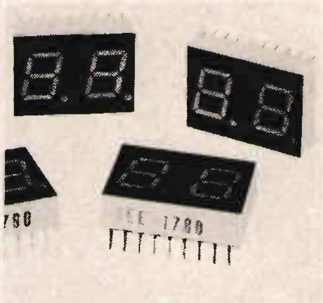
NEW PRODUCTS

Impulse voltmeter
A newly developed precision impulse voltmeter is available for use in hv test systems. It measures and stores peak values of impulse voltages, currents and periodic events to an accuracy of ±1%. A built-in analogue computer multiplies the i/p voltage with the transformation ratio of the hv divider providing direct reading in kV or MV. Designated type 64M, the unit is highly resistant to electromagnetic interference and overvoltages. *High Voltage Test Systems, Switzerland.* **311**

Microcomputer
The TI990/4 microcomputer on a board has been designed to provide a reliable low cost solution to a wide range of data processing and manufacturing automation problems. Based around the TMS9900 mos n-channel 16-bit μP, this microcomputer provides up to 10k-bytes of on-board memory, 8k-bytes of dynamic ram and 2k-bytes of pin compatible ram or prom and, in addition direct access to a total expanded memory of up to 64k-bytes. *Mogul Electronics, Epping, Essex.* **312**

Distortion meter
The model E-2001 automatic distortion meter, offers automatic fine frequency tuning and balance to the measurement of af total harmonic distortion. The unit provides 0,1% fs high sensitivity over a range from 20 Hz to 20 kHz as a distortion meter and is also usable as a 10 Hz to 200 kHz, 100 μV fs sensitivity ac voltmeter. *Lyons Insts., Hoddesdon, Herts.* **313**

Sweep generator
This compact sweep generator test assembly, Polyskop IV SWOB, is a two channel generator with linear and logarithmic display in the frequency range



0,1 to 1000 MHz. It permits the frequency response of two test parameters to be displayed simultaneously on a 21×16 cm screen, the resulting test curves define gain, attenuation, linearity or matching. The sweep range is continuously and linearly adjustable from approximately 0,5 MHz over the entire range. The logarithmic display range is 60 dB. *Aveley Electric, Chessington, Surrey.* **314**

Electronic pliers
Two versions of these electronic pliers are available, type 2131 features a bevel on the outer face of the jaws; whilst the type 2132, without outer bevel, is for flush cutting. Precision grinding of the cutting edges and careful heat treatment has resulted in an excellent cutting performance. *Bacho Tools, Banbury, Oxon.* **315**

Alarm buzzer
Measuring approximately 25,4 ×19 mm this buzzer uses a silicon transistor-oscillator with 15 mA drain, generating negligible interference in the form of rf voltages. The device requires no setting-up or maintenance and delivers up to 80 dB of sound o/p at around 450 Hz. The DM-01 series is ideally suited for portable alarm systems and is available in a choice of operating voltages spanning three to 24 V. *Hakuto Int., Rayleigh, Essex.* **316**

Pressure transducer
The type XT33 pressure transducer offers a small sampling cavity and fast response time, enabling accurate measurements to be made of injection pressure and its relevant transient response. The pressure ranges available extend from 300 up to 750 bar (4350 to 10 875 psi). *Intersonde, Watford, Herts.* **317**

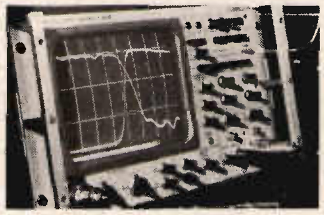
Transistors
The BFW92 npn silicon planar transistor is designed for use in broadband amplifiers for telecommunications applications. It offers low noise, 4 dB at 500 MHz and low cross modulation with high f_T 1,6 GHz. The configuration of common-emitter affords optimum performance in broadband uhf applications. *SGS-Ates, Aylesbury, Bucks.* **318**

Operational amplifiers
Series 833-21 power operational amplifiers deliver an o/p current of >1 A. Hermetically sealed in an 8-pin TO-3 can, the power rating is >20 W with an adequate heat sink. Features include wide full power bandwidth (15 kHz); low quiescent power (100 mW at ±15 V); low i/p offset voltage (1 mV); low i/p offset current (20 nA); high slew rate (3 V/μs) and high open loop gain (100 dB). *Beckman Insts., Fife, Scotland.* **320**

PCB kit
This low cost pcb artwork kit contains sufficient symbols, tape, pads, etc to produce up to three artworks at scales of 1:1 or 2:1. *Lormay Electronics, Towcester, Northants.* **322**

Float switch
The RSF33 is a horizontal float switch, that can be reliably used in fluids with specific gravities down to 0,785. The device utilises reed switches giving excellent reliability and prolonged life. Two versions are available, 100 W, 240 V ac or 50 W, 440 V ac. *FR Electronics, Wimborne, Dorset.* **323**

Two digit led's
Series 1780 and 1790 comprise of two 10,16 mm high digits (0-9) with individual right hand decimal points integrally packaged in a single, compact unit.

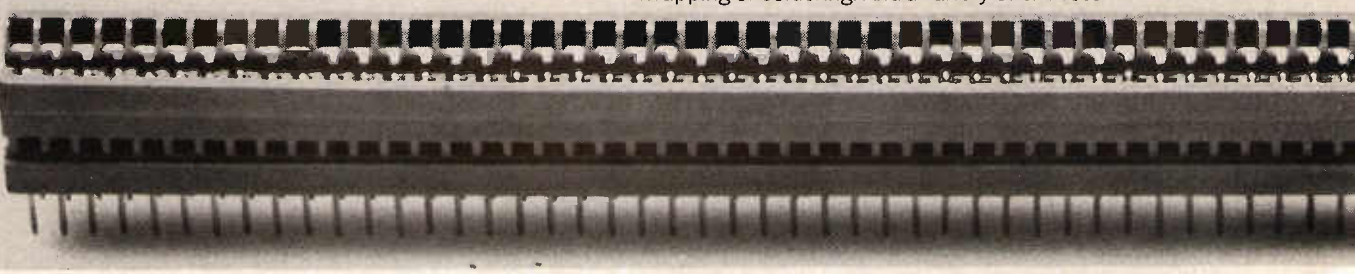


These led's are available in common cathode or anode design with typical 250 μcd/segment luminous intensity at 20 mA/1,6 V. *IEE, Van Nuys, California, U.S.A.* **319**

Connector Capability

Keep to the connectors you know. At Ferranti we're keeping to the high standards we set ourselves right at the start. That's why so many people choose Ferranti connectors.

Pitches of .100" (2.54mm) (modular connector), .150" (3.81mm), .156" (3.96mm) and .200" (5.08mm). Non-porous gold plating on the contacts—or gold flash if you wish. Terminals for wire wrapping or soldering. And a variety of end feet.



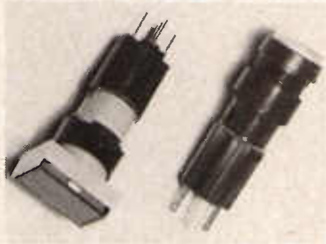
NEW PRODUCTS

Analyser
Signal frequency error in communications, navigation or laboratory rf systems can now be determined directly using the model FE47B frequency error analyser. Covering a range of 100 kHz to 5 MHz the unit measures the error between a reference signal i/p and an i/p of unknown stability. Five ranges give readings from parts in 10^7 to a minimum error reading of one part in 10^{11}. *Euro Electronics Insts., London.* **321**

Power transistors
Three npn silicon power transistors, continuously rated at five, eight and 15 A, can sustain V_{CEO} of either 300 or 400 V dc at a case temperature of 25°C and power dissipation figures of 100, 125 and 175 W. With dc current gains >60 these 2N6542/-7 devices are ideal for high speed power switching in inductive circuits where fall times of <800 ns are imperative. They are operable over a temperature range of −65 to +200°C. *Jermyn Distribution, Sevenoaks, Kent.* **325**

Power source
The model 1200 dc/dc converter features all the necessary o/p to power an 8080 µP, plus four 2107A ram's or four 1702A rom's It is designed for local circuit board transformation of 5 V dc logic power into clean, regulated and isolated triple o/p voltages of +12, −5 and −9 V dc. Other features include line and load regulations of 0,05%; a maximum o/p ripple of 1 mV rms and a maximum transient recovery time of 50 µs. *Datel (UK), Basingstoke, Hants.* **326**

Pushbutton switches
This series of illuminated pushbuttons, incorporates a Hall-effect chip from which a switch o/p via two open collector transistors, operating either in phase or in antiphase is derived.



Capable of operation between 4,5 and 27 V and with rise and fall switching times of <0,5 µs, the o/p from these switches enables them to be directly interfaced with all data logic systems. *Electronic Engineering Services, London.* **324**

Op amps
The OP-04 series of dual matched high performance general purpose operational amplifiers, provides significant improvements over the industry standard 747 types, whilst maintaining pin-for-pin compatibility, etc. Key specifications are guaranteed over the full operating temperature range. *Bourns (Trimpot), Hounslow, Middx.* **327**

Isolation amplifiers
These multi-channel isolation amps feature an open board construction to maintain low cost/channel. Designated model 282J (two channel) and 283J (three channel), the units are ideally suited for use in medical applications. The devices facilitate the measurement and control of off-ground mV signals in the presence of ±350 V of cmv. Both models feature dual isolated regulated power o/p; adjustable gains from one to 1 kV/V; low i/p noise 1,5 µV rms (1 kHz bandwidth) and a high cmrr off 160 dB. *Analog Devices, E. Molesey, Surrey.* **328**

Data modules
Phase lock loop fsk data modules type 1100, are available either as plug-in units or for mounting as a component sub-assembly. These versions consist of standard assemblies for the transmitter and receiver units, with separate plug-in filter assemblies to determine the frequency and baud rate. They are available to cover standard CCITT channels from 50 to 1200 baud, although the use of cad allows further extensions to be gained. *ATS Telemetry, Haywards Heath, Sussex.* **329**

Digital thermometer
Details are available of the type DTM-10 digital thermometer, for the measurement of temperature from −40 to +180°C with direct reading; or measuring thermocouple voltages of zero to 200 mV, convertable to give a temperature range of −200 to +1200°C. Accuracy is quoted at ±0,5% of displayed value, ±0,2 can be obtained with a resolution of 0,1°C. *Wallac Controls, Newbury, Berks.* **330**

Solid state relays
There are seven devices in the range, all of which have an i/p (control) circuit which is ttl/dtl compatible. The GB12000 s/s relay series is a completely solid-state heavy duty power controller, comprising a triac ac power switch controlled by a photo-coupler providing isolation of up to 3,75 kV rms. The light source is energised by an external control i/p of three to 32 V dc, which is current-limited to 12 mA. *Gentech Int., Girvan, Scotland.* **331**

Pressure transducer
The sensing diaphragm of the G218 pressure transducer is machined in one piece with the stainless steel body and equipped with a bridge of piezo-resistive strain gauges. The electronic system in the body converts the bridge o/p to the industrial standard four to 20 mA. Specifications include an i/p from 15 to 30 V dc; a linearity of ±0,25% maximum and isolation ranges from infinity to 100 MΩ under 20 V. *Shape Insts., Woodley, Berks.* **332**

Linear potentiometer
The model 8FLP10 linear motion potentiometer is designed for the measurement of small displacements up to 11 mm at low cost. The device has a conductive plastics resistance element pro-

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As well as edge connectors Ferranti offer multi-pole low orce connectors with a choice of 35, 50, 70 or 91 contacts. All with ow spring rate for easy insertion and withdrawal.

Contact Connector Sales, Ferranti Limited,
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Dundee DD2 3PN, Scotland. Telephone: 0382 89321 Telex: 76166.

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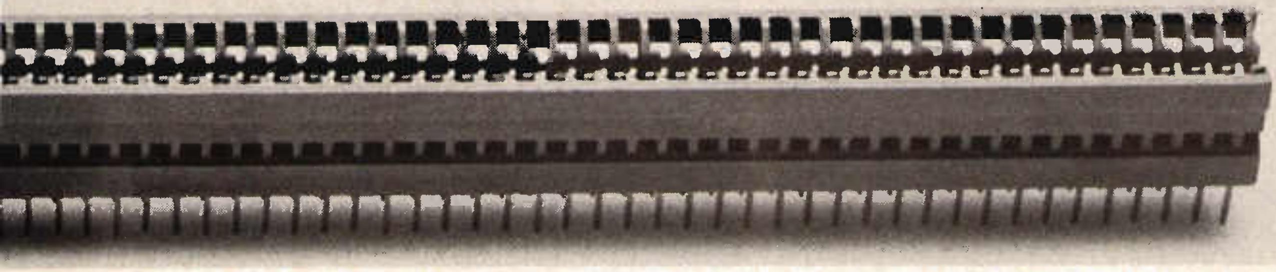

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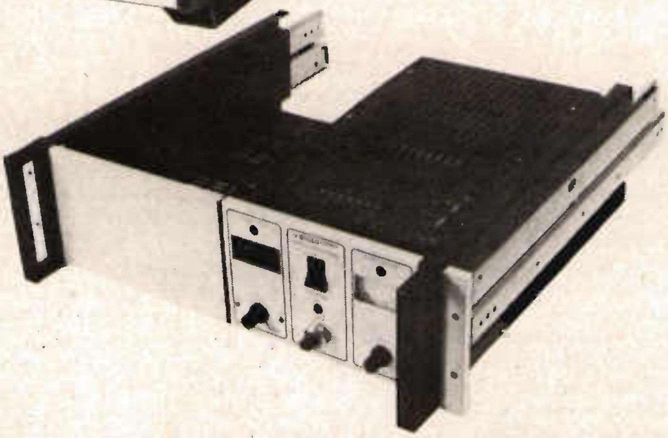
BRM Power Supplies.

All the power you need in a tight spot.



Gould Advance BRM Power Supplies are designed to pack the most power into the smallest possible space.

Using the latest techniques in transformer design and thyristor control, they are so compact that some models can deliver as much as 1 Watt for every cubic inch – without the need for cooling fans.

All units have the facility for varying output voltage, output current limit and overvoltage setting.

These functions are remotely programmable making the BRM range ideal for laboratory use or for incorporating into complex electronic systems and automatic test facilities.

There are five models in the range: three half rack sizes, 0 to 60V 1A, 0 to 40V 5A and 0 to 40V 10A output, and two full rack sizes in 0 to 40V 30A, and 0 to 40V 50A ratings.

All units are covered by a full 5 year guarantee.

Contact us for further details.
Gould Advance Limited,
Raynham Road, Bishop's Stortford,
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GOULD ADVANCE

NEW PRODUCTS

viding infinite resolution and prolonged life. The operating temperature range is −30 to +105°C. *Techni Measure, High Wycombe, Bucks.* **333**

Keyboards
The KL series "minikey" low profile keyboard is now available with several encoding capabilities. These include two of seven and two of eight tone multifrequency switching for communications applications and row and column for µP use. Contact rating is 50 mA at 28 V dc resistive. *Digitran Endevco, Royston, Herts.* **334**

Speed controller
The AM-H controller automatically adjusts the voltage to the terminals of single and three phase induction motors to control the speed of variable and constant torque loads within 1% of maximum, over a range of 100:1. Ratings range up to 3 kW with speed settings by potentiometer or by remote dc signal, with the option of a speed indication signal for zero to 100 µA. *Arclid Control & Eng., Thornby, Northampton.* **335**

Data converter
These 12-bit hybrid data converters, designated HX and HZ series, are composed of 12 different dac models and six different adc models. There are two basic 12-bit adc lines, with three models in each: ADC-HX series has a conversion time of 20 µs; ADC-Hz has a faster conversion time 8 µs and the DAC–HZ range are 12-bit devices with o/p settling times of 3 µs. These dac's all feature dtl/ttl compatible i/p five programmable voltage o/p, 20 ppm/°C maximum tempco and 0,5 lsb maximum linearity. *Datel UK, Basingstoke, Hants.* **336**

Gunn oscillator
This solid state substitute for Klystron oscillators in the industrial, scientific and medical band at 10,5 GHz type 917, Gunn oscillator and the 821 power supply modulator serves as a general purpose signal source. The 917 provides a minimum o/p of 50 mW at a centre frequency of 10,5 GHz with a mechanical tuning range of ±200 MHz. The 821 operates at 50 or 60 Hz line frequencies and supplies an adjustable nine to 11 V dc at 900 mA plus an adjustable square wave modulation signal of 1000±100 Hz. *REL Equip. & Comps., Hitchin, Herts.* **337**

Counting circuits
Two extender counting circuits for use in conjunction with two-modulus dividers, types SP8790 divide-by-four and the SP8794 divide-by-eight circuits, are designed to increase the minimum division ratio of prescalers, whilst retaining the existing difference in division ratios. Thus a divide by 10/11 combined with the SP8790, produces a divide by 40/41. The clock i/p of the -/90 and -/94 are ac coupled and have a dynamic range of 300 to 1000 mV pk-pk. *Plessey Semis., Swindon, Wilts.* **338**

Transceivers
A new 700 W pep single sideband transceiver, designated the 700CX, features up to 10 channels for MARS operation with operational SWAN 510-X plug-in crystal controlled oscillator. Top and bottom frequency ranges are: 80 m (3,5 to 4 MHz) to 10 m (28 to 29,7 MHz). Modes of operation are selectable and the built-in calibrator is selectable at 25 or 100 kHz. The receiver features <0,5 µV at 50 Ω for 10 dB signal plus noise-to-noise ratio. Audio o/p is 4 W to 3,2 Ω load. *Cubic Corp., San Diego, U.S.A.* **339**

HV regulators
This family of three terminal positive voltage regulators, designated the 78HV00 series, provides o/p voltages in the range five to 24 V. In addition to the standard electrical parameters of the 7800 the new devices offer 60 V minimum guaranteed i/p voltage breakdown. If adequate heat-sinking is provided, they can deliver in excess of 1 A o/p current. *Mullard, London* **340**

Soldering iron
The SRB iron operates at 220/240 V, 16/18 W. A new bit securing method provides high efficiency heat flow and permits rapid interchange from standard 3 mm bits to alternative 1,5, 4,5 and 6 mm bits. *S & R Brewster, Plymouth.* **341**

Connectors
New to the "Blue-Macs" cable/connector system, comes the D plug and socket connector which utilises a unique insulation displacing contact in a spread-pitch configuration. This design feature enables the connector to be mass terminated to standard 1,27 mm pitch flat cable, whilst at the same time maintaining intermateability with existing standard D type connectors. Electrical properties include a current rating of 3 A; an insulation resistance of $>1\times10^9\ \Omega$ and a dielectric strength of >500 dc. *Thomas & Betts, Beds.* **342**

Analogue µP
With the introduction of the MP10 and 11 analogue µP, this

manufacturer claims to be the first company to offer dedicated analogue o/p circuits for most popular µP. These 32-pin triple-wide dip units are completely compatible with 8008, 8080A, 6800 and over half a dozen other µP from a voltage level, loading, timing, logic and software point-of-view. Each provides two channels with ±10 V o/p. Throughput accuracy is >±0,4% fs range. *Burr-Brown, Watford, Herts.* **343**

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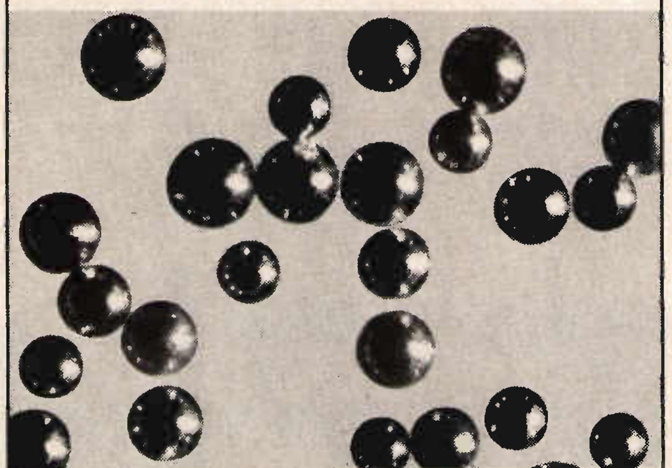

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NEW PRODUCTS

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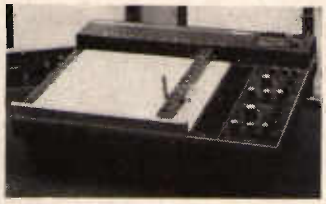

PM8041, /8141 and /8132, the former offers nine i/p ranges from 2 mV/cm to 1 V/cm, variable span and full zero positioning control. The 8141 extends this flexibility with 14 i/p ranges and increased sensitivity. The A3 chart sized recorder, is a two pen version simultaneously plotting two independent variables (Y_1 and Y_2) with respect to time or to a third variable in the X axis. *Pye Unicam, Cambridge.* **344**

Trimmers
A single turn cermet trimmer, type CT170 offers a wide resistance range, from 10 Ω to 1 MΩ ±20% in a small package. Resolution is essentially infinite and the tempco is 250 ppm/°C over an operating temperature range of −55 to +150°C. Rated at 0,5 W at 85°C the device meets the requirement of MIL-R-22097. *Ritro Electronics, Maidenhead, Berks.* **345**

Crystal oscillators
A new range of low cost ttl compatible crystal controlled oscillators are designated XA-TT-1. They are available from four to 15 MHz, requiring only 5 V at 10 mA allowing a fan-out of ten standard ttl loads. Coefficients of 0,2 ppm/°C and 1 ppm/V are specified. *ECM Electronics, Pangbourne, Berks.* **346**

Linear thermistors
These linear thermistor networks offer a greater sensitivity than comparable thermocouples. Three temperature ranges, −5 to +45°C, −30 to +50°C and zero to 100°C are covered in three body styles in each range. *Electrautom, Maidstone, Kent.* **347**

Capacitors
This series of micro-miniature solid tantalum capacitors finds use in high density circuits. The series, designated MT, has a capacitance range of 0,001 to 150 µF at four to 50 V and are available either polarised or non-polarised. *Tekelec Airtronic, Leigh-on-Sea, Essex.* **348**

Prom eraser
The SE15 is one of a family of memory programming aids. The Eraser is simple to load and will accept 15 prom's on a sliding tray, accessible from the front of the equipment. Safety features include the prevention of spurious uv radiation. A preset timer facilitates the repeating of erasure durations. *Stag Electronic Designs, Potters Bar, Herts.* **349**

Pulse generator
The model 100A is a versatile 10 MHz pulse generator with a 5 ns rise time and ±10 V o/p capability. Repetitive rates from 0,1 Hz to 10 MHz are available with single or double pulse operation. Variable width and delay controls give spans up to 10 s and the device has a ±250 mV trigger sensitivity with both asynchronous and synchronous gatings available. *Electroplan, Royston, Herts.* **350**

Accelerometer
This miniature accelerometer, known as the EGAL125-5 measures acceleration, vibration and shock from 0,001 to 5 g. Weighing <0,5 gms and occupying <0,15 mm³, it is a semiconductor strain gauge device capable of measuring static dc and dynamic acceleration with a sensitivity of 15 mV/g un-amplified. *SE Labs (EMI), Feltham, Middx.* **351**

Display counter
A flexible and easy to use general purpose 4-digit display counter, the ZN1040E, produces high segment drives (80 mA typical or 50 mA minimum) ideally suited for larger size numeric led displays. Features include automatic zero suppression; direct cascading; suitability for six or eight digits; bcd o/p; Schmitt i/p, to counteract noise; an 8 MHz count rate; blanking and segment test. *Ferranti, Oldham, Lancs.* **352**

Electrometers
This range of electrometers have the standard i/p impedances of 10^{14}Ω and i/p bias currents of 0,1 pA, whilst offering a slew rate of 10 V/µs. A full zero to 10 V i/p voltage range, fully variable by push button switches, together with a fs offset voltage potentiometer allows full use of the large mirror scale meter. *Hermes Controls, Newcastle-upon-Tyne,* **353**

HF linear amplifier
Claimed to be the first third-generation 100 W solid state broadband linear amplifier, the HFA125, gives continuous operation on both voice and cw negating the use of liquid coolants or fans. It is light weight, sealed and achieves full 100 W c/w on 24 V over the frequency range, 1,5 to 20 MHz. *Redifon Telecomms., London.* **354**

SCR's
Three series of sensitive-gate silicon controlled rectifiers with gate sensitivity measured in µA have been designed for switching ac/dc currents. The S106,/107 and /108 series have rms on-state currents rated at 4 A. The µA gate-current characteristic offers a degree of noise immunity. A controlled minimum gate current of 100 µA is specified. *RCA Solid State, Sunbury-on-Thames, Middx.* **355**

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NEW PRODUCTS

Monitoring system
The 747 series laser monitoring system is intended for accurate measurements of pulsed laser power and energy. The system has been designed for maximum flexibility and can be used over a range 0,33 to 1,1 microns from 300 μJ to 300 Joules. A fast o/p socket gives directly calibrated signals such as 1 V/MW of 1 ns rise and 3 ns fall times into a fast CRO. *Rofin, Egham, Surrey.* **356**

UHF attenuators
Now available is the 67DR range of constant impedance variable attenuators, suitable for use in broadband amplifiers. One use is in tv and radio distribution systems, for frequencies of 40 to 860 MHz. Fifty, 60 and 75 Ω versions are available with attenuations of zero to 10 at zero to 20 dB. *AEG-Telefunken, Slough, Berks.* **357**

RF transistors
The BFT96, silicon pnp rf transistor, is a driver or medium power amplifier for ultra-linear o/p up to 0,5 V across 75 Ω at 1 GHz. In a wide band amplifier the use of a BFT95 as a first stage, allows a typical nf of 2 dB to be obtained between 40 and 1000 MHz. *SGS-Ates, Aylesbury, Bucks.* **358**

RF generator
This swept, pulsed rf generator, type MAL1083, for RACON applications, represents one of a range of vco sources designed for use in radar. The o/p frequency sweeps across the radar band in approximately two minutes and then returns in <1 s. Output frequency sweep range is <9,315 to >9,485 GHz under all conditions. Sweep linearilty is such that it takes six ±1 s to cross any 10 MHz band. The signal is pulsed by 2,5 μs pulses as part of a self test function and by 20 μs pulses when interrogated by a radar. *Microwave Ass., Dunstable, Beds.* **359**

Counter/timer
The TC314 is a sophisticated counter/timer, featuring a large six digit gas discharge display and a 10 MHz reference crystal held in a tco. The unit has frequency measurement capability on three channels (A, B and C). Channel A covers the range dc to 50 MHz in eight decades with a 10 mV sensitivity up to 20 MHz. Channels B and C cover the range dc to 10 MHz, also in eight decades with a basic sensitivity of 100 mV. *Electroplan, Royston, Herts.* **360**

DIL capacitors
Layer-built ceramic capacitors in low profile 4-pin bantam dil packages have been designed for use in hf data and signal processing applications. Type 935C monolithic ceramics feature low inductance and low impedance with a high self-resonant frequency and offer an inductance of <4 nH when used in a four terminal mode. *Sprague Electric, W Drayton, Middx.* **361**

15,24 mm displays
This new range of led displays, includes green, red and yellow numeric overflow digits. The red devices are available as conventional GaAsP displays for pulse-drive use, or with GaP for dc drive. Typical luminous intensity/segment varies from 500 μcd for the GaP, up to 1500 μcd for the green display. All devices are rated at a forward current of 20 mA, except the red, which is rated at 10 mA. *Distronic, Harlow, Essex.* **362**

μP crystals
This range of standard quartz crystals is ideal for μP, timepieces, baud-rate generators and other related ic's, covering the frequency range 32 kHz to 50 MHz. *Pulsar Debelopments, Marlow, Bucks.* **363**

Ceramic capacitors
These dipped monolithic ceramic capacitors are offered in three tempcos: and seven radial case sizes. The Skycap range meets the requirements of MIL spec. Capacitance values from 4,7 pF to 4,7 μF are available depending on voltage rating (50 or 100 V) and temperature coefficient. *Waycom, Bracknell, Berks.* **364**

Distortion system
The model 1700B is a distortion analyzer and oscillator simultaneously tuned in one system. Its facilities include the use of a 0,001% distortion oscillator for testing from 10 Hz to 110 kHz; measuring distortion down to 0,002% in <5 s; measuring ac voltage to 30 μV fs to 300 V fs with 2% accuracy and measuring voltage or signal-to-noise ratios with 100 dB dynamic range. *CE Hammond, Byfleet, Surrey.* **367**

Rectifiers
This range of fast switching rectifiers, designated the RGP series, is available in one, 1,5, two and 3 A versions, with several piv ratings between 50V and 1 kV. Recovery times varying from 150 ns for 50 V types, to 500 ns for 1 kV types. Typical reverse leakage currents are <1 μA. *GI (UK), High Wycombe, Bucks.* **366**

S/H amplifier
The new SH703 high performance sample/hold is packaged in a 14-din dip and meets the requirements of speed and accuracy of practically all 12-bit data acquisition systems. The unit consists of an op-amp with its o/p in series with a low-leakage analogue switch and a mos/fet unity gain amplifier. Key specifications include an acquisition time of 4 μs; a settling time to 4 μs; a droop rate of 50 mV/s and an aperture time of 50 ns. *Hybrid Systems, Camberley, Surrey.* **368**

Development system
This low cost development system (LCDS) has been introduced as a powerful tool for developing and de-bugging programmes on SC/MP and is capable of being expanded to provide additional memory and programming capabilities. The system incorporates a cpu card, plugged into one of four prewired sockets, thus providing cpu interface for execution of user generated application programmes and development system resident firmware. *Jermyn Dist., Sevenoaks, Kent.* **369**

Capacitors
This range of metallised polyester resin moulded capacitors, type PMC2R, are available in one to 10 μF (63 V dc); 0,068 to 4,7 μF (100 V dc); 0,033 to 2,2 μF (250 V dc) and 0,01 to 1 μF (400 V dc) capacitances. Standard tolerance is ±10%. *ITT Comps., Harlow, Essex.* **370**

Frequency source
The simple packaged crystal oscillator (SPXO) provides a stable frequency source interfacing directly with cmos circuits. The small plastics encapsulated units provide a high stability of ±0,002% over the frequency range four to 10 MHz. Standard frequencies in the range five, 6,4, eight, 8,192 and 10 MHz. Operating temperature range is −20 to +70°C. *Cathodeon Crystals, Cambs.* **371**

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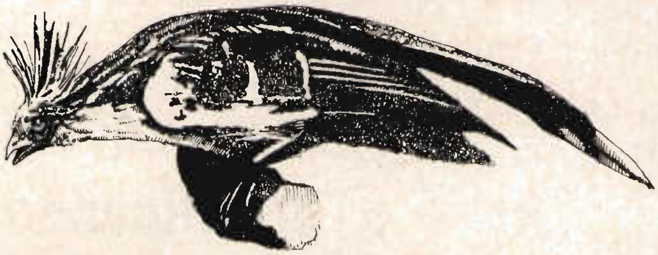
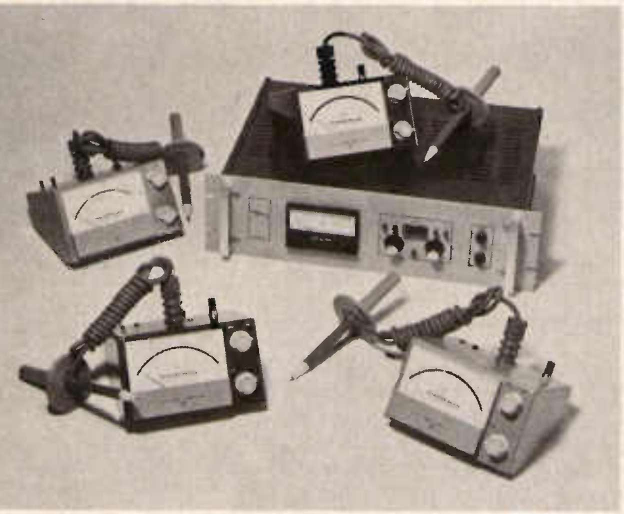


The hoatzin, it's been suggested, could be the missing link between reptile and bird. Certainly it has evolved a long way since the age of reptiles; yet the young still have claws on their wings.



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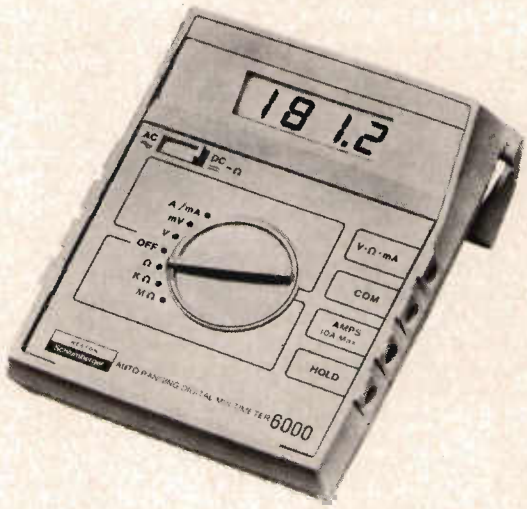

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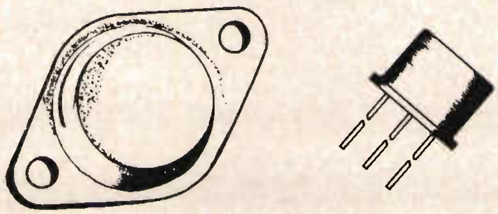
VMP 1	60V	2A	2·2 Ω	4ns
VMP 12	90V	2A	3·4 Ω	4ns



4 watts (max) in package TO-39

VMP 21	35V	1·5A	1·4 Ω	4ns
VMP 2	60V	1·5A	2·2 Ω	4ns
VMP 22	90V	1·5A	3·8 Ω	4ns

$^*V_{GS} = 10V, I_D = 1A$

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NEW DATA

A leaflet is available on the 5000 digital **panel meter** made by Data Tech and is available on request from *Telonic Altair, Maidenhead, Berks.* **421**

The 1977 Booth Electronics General catalogue contains information on variable frequency **inverter drives**, dc thyristor drives, and ac power controllers. *REL, Hitchin, Herts.* **422**

A technical note available on the MP51 **pulse generator** has been produced by *Lyons Instruments, Hoddesdon, Herts.* **423**

A data conversion products catalogue has been released by Hybrid Systems and covers components such as **multiplexers**, peak detectors, encoders and power supplies. *Hybrid Systems, Camberley, Surrey.* **424**

A four colour brochure is available from Sensor Technology which explains how solar **energy modules** can be used to power recreation and survival equipment. *Sensor Technology, California, U.S.A.* **425**

Quartz crystal **oscillators** are the subject of a leaflet C276 which has been produced by *ECM Electronics, Pangbourne, Berks.* **426**

Available from Sealectro is a reprint of an article entitled "Discussion of phase errors in coaxial transmission lines", which gives recommendation on suitable **cable** types for use under a wide range of conditions. *Sealectro, Portsmouth, Hants.* **427**

Intel has published the first report on the reliability of large **erasable proms**, the 2708 prom to be exact, *Intel, Cowley, Oxford.* **428**

A data sheet is available from Data I/O on its **rom** simulation emulation system which is known as the romulator. *Data I/O, High Wycombe, Bucks.* **429**

A brochure of disposable wiping **materials** and accessories has been published by *J. Mullett and Co, Bath.* **430**

An international quarterly **journal** has been launched to cover the assessment, control and management of developments in telecommunications and information systems, *IPC, Guildford, Surrey.* **431**

A four page publication from U.K Solenoid describes a range of **contactors** and overload relays. There are thirteen standard types ranging from 6 A to 500 A 660 Vac. *U.K. Solenoid, Newbury, Berks.* **432**

Electronic transition **lasers** edited by J. I. Stenfield, £11,25, contains a set of papers on this type of **lasers** which were presented at a colloquium in the U.S.A. *MIT Press, London.* **433**

The latest six page shortform catalogue from Solid State Controls describes and illustrates the company's wide range of industrial **timers** and temperature controllers. *Solid State Controls, London.* **434**

BXL has prepared a new leaflet on the **Parylene** conformal coatings which can be obtained on request from *BXL, London.* **435**

A range of single phase, three phase and dc **solenoids** marketed by Radiatron Instruments are described in a 40 page catalogue. *Radiatron Instruments, Twickenham.* **436**

The book, EMP radiation and protective techniques, £21,20, covers every aspect of electromagnetic **pulse radiation.** *John Wiley and Sons, Chichester, Sussex.* **437**

A user **manual** for the RCA cosmac microprocessor is specifically written for electronics engineers having only a limited familiarity with computers. The manuals cost £3 and can be obtained from *RCA Solid State, Sunbury on Thames, Middx.* **438**

The **book** Electric and Magnetic fields by Charles Oatley, £3,50 paperback, provides an introduction to electromagnetic theory. *Cambridge University Press, London.* **439**

Literature is now available from Computer Engineering which describes the company's intelligent remote printing **terminal**—the diplomat. *Computer Engineering, Hitchin, Herts.* **440**

National has produced its 1977 catalogue on electronic **measuring instruments** and includes technical specifications on all its equipment such as oscilloscopes and signal generators. National catalogues can be obtained from *Telonic Altair, Maidenhead, Berks.* **441**

An illustrated fifty two page catalogue covering the two piece metal to metal **pc connector** product line has been issued by the *Elco Corporation, California, U.S.A.* **442**

A new edition of the **microwave tube** data book is now published and may be obtained from London Information at £32,65 for a year's subscription. *London Information, Ascot, Berks.* **443**

Computer Instrumentation has published a revised leaflet, entitled "Digital plotting with the Economists" giving performance information on the Economist series of incremental **plotters.** *Computer instrumentation, Eastleigh, Hants.* **444**

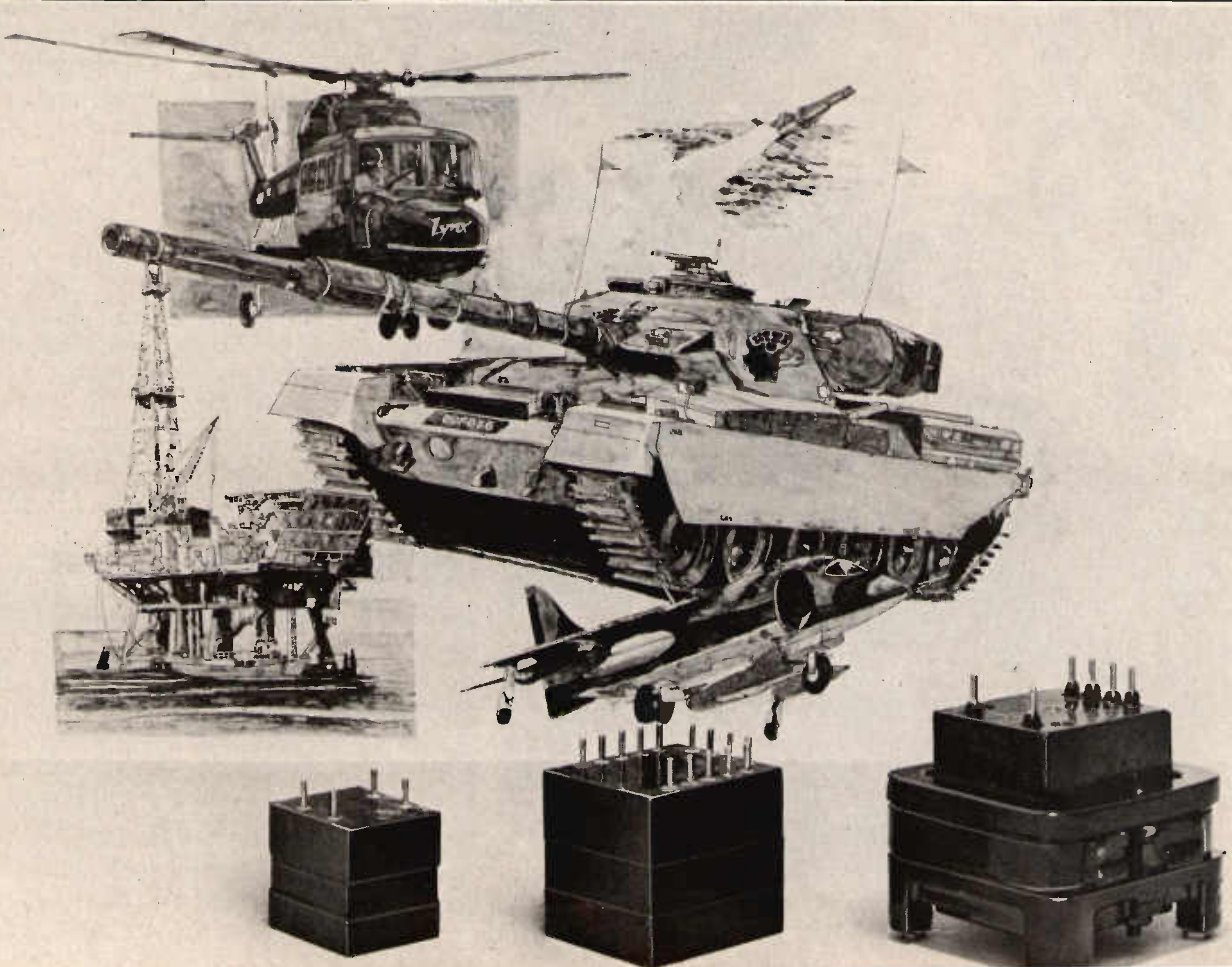
Communication System Principles, $22,50, by Peyton Z. Peebles, is intended as an introduction to the subject but also contains advanced topic and problems for the graduate. *Addison Wesley, U.S.A.* **445**

A brochure is available on Tufnol phenolic paper **laminates** for electrical insulation and introduces the low cost grade 1P/13. *Tufnol, Birmingham, West Midlands.* **446**

The Mackintosh **Yearbook** of West European Electronics Data 1977 is the fourth publication and contains statistical information on the electronics industry, *Mackintosh, Luton, Beds.* **447**

Membrain has produced a brochure giving details of its products and services in the field of **fault isolation** on digital circuit modules for example. *Membrain, Wimborne, Dorset.* **448**

The first of three **publications** on rules of competition in the EEC—covering agreement on industrial property rights—has been produced by the CBI, £2. *CBI, London.* **449**



NEW DATA

A guide to the major properties and uses of more than 50 specially formulated **epoxy** and related compounds used extensively in the electronics and aerospace industries has been prepared by *Techform, California, U.S.A.* 450

Connectors are the subject of a handbook on the K grip range of **connectors** which are marketed in Europe through *AWP, Horley, Surrey.* 451

Information is available in a leaflet on the EF 50 active filter module, which has been designed to operate as a preset 50 Hz band **stop filter** with facilities to allow the notch to be set in the range 10 Hz to 500 Hz. *Barr & Stroud Ltd, London.* 452

A six page leaflet has been published by Computer Automation which describes the company's general purpose input output **interfacing system** for its minicomputer. *Computer Automation, Rickmansworth, Herts.* 453

A colourful **wallchart** is available free showing world wide annual solar radiation in kj/cm² from *Sensor Technology, California, U.S.A.* 454

The Electrical Research Association is producing a **control gear** digest which will provide short abstracts of papers and notification of conferences and meetings. Information can be obtained from *ERA, Leatherhead, Surrey.* 455

Digital Signal Analysis by Samuel Sterns is intended as a reference for signal processing procedures and systems. *Hayden, U.S.A.* 456

Principles of active network synthesis and design, £13,45, contains the fundamental principles of active and **passive network** synthesis. *John Wiley & Sons, Chichester, Sussex.* 457

A four page data sheet is available from Belling Lee on each of the following products—L1996 **attenuator**, L2270 three pole moulded plug and lead, L2222 ten way open fuseholder and the L2216 high temperature terminal coupler *Belling Lee, Enfield, Middx.* 458

The 1977 Rifa catalogue of **capacitors** and semiconductors is now available from Rifa and contains information on interference suppressors, diodes, and monolithic driver circuits. *Rifa, Sweden.* 459

Components for tv **receivers** and analogue integrated circuits are the subjects covered in two books from *Siemens, Brentford, Middx.* 460

Hellerman Insuloid has published a catalogue covering its range of **cable fixings** and accessories as well as two new leaflets. The catalogue contains information on cable ties, module boards, mounting cradles, adjustable cable saddles, clips and strappings. *Hellerman, Manchester.* 461

Vector Analysis by N. Kremmer, £3,95 paperback, is a physicist's guide to the mathematics of fields in three dimensions, *Cambridge University Press, London.* 462

An eight page booklet giving details of its Fibretran **fibre optic** components and systems has been published by *Belling Lee, Enfield, Middx.* 463

Information is given on the 4662 **digital plotter** from Tektronix in the tekscope journal Vol. 8 no. 3. *Tektronix, Harpenden.* 464

An illustrated technical brochure describing the Panduit din **connector range** of accessories is available on request to *Panduit, Sittingbourne, Kent.* 465

A winter catalogue containing 136 pages of specification, diagrams and illustrations of over 4,000 **components** is available from *RS Components, London.* 466

BSI has issued the **BS 5404** code of practice for the maintenance of electrical switchgear for voltages up to and including 145 kV. *BSI, London.* 467

Radio Resistor has a short form catalogue available on **electrolytics**, switches and relays. *Radio Resistor, Hitchin, Herts.* 468

The **World of Learning** contains 2000 pages of information on over 24 000 academic institutions. *Europa Publications, London.* 469

Allen Bradley now has a **shortform** catalogue available which covers all the company's product range. *Allen Bradley, Jarrow.* 470

Infrared application No. 2 is the latest in a series of publications by Perkin Elmer and investigates the application potential of the model 580, a computer compatible ratio recording infrared **spectrophotometer**. *Perkin Elmer, Beaconsfield, Bucks.* 471

Data I/O has published a leaflet which describes the company's model VIII portable **prom** programmer. *Data I/O, High Wycombe, Bucks.* 472

More than 3500 standard **power supply** modules are listed in the new catalogue from *Abbott Transistor Laboratories, Los Angeles, California.* 473

A booklet describing the operation of **touch-controlled switches** has been produced by *AMI Microsystems, Swindon, Wilts.* 474

Nevin has produced a brochure describing the range of **printed circuit board** design and manufacturing services offered by the company. *Nevin Electric, Colnbrook, Bucks.* 475

Two new financial surveys from Jordan Dataquest cover **manufacturers** and **distributors** of electrical and electronic consumer products. *–ordan Dataquest, London.* 476

Bonnella Switches has published a brochure which gives details of the

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company's recently-introduced **ex-stock service.** *Bonnella Switches, Cheltenham, Glos.* 477

Data sheets available from Bell & Howell describe four new series of **pressure transducers.** *Bell & Howell, Basingstoke, Hants.* 478

Daturr has published a **100-page** catalogue of the company's range of **enclosures and accessories.** *Daturr, Richmond, Surrey.* 479

Also available from Daturr is a 40-page catalogue on **telescopic slides.** *Daturr, Richmond, Surrey.* 480

Optoelectronics is the main subject of the latest edition of Philips Technical Review (Volume 36, No. 7) *Philips Research Laboratories, Eindhoven, The Netherlands.* 481

A leaflet describing **uv oscillograph system amplifiers** and accessories has been published by *Bryans Southern Instruments, Mitcham, Surrey.* 482

Micro Consultants has published a short form catalogue of its **computer** and **video equipment.** *Micro Consultants, Caterham, Surrey.* 483

A data sheet produced by Wallis Electronics describes the "S" series of 30 W, high voltage **power supply** units. *Wallis Electronics, Worthing, Sussex.* 484

A new short form catalogue describing the Souriau range of **connectors** and other components has been published. *Souriau, Windsor, Berks.* 485

Data sheets are available describing a new range of subminiature **coaxial relays** and a range of edge connectors which incorporate coaxial sockets. *Radiall Microwave Components, Staines, Middx.* 486

An updated catalogue from Dawe contains details of **ultrasonic equipment** for cleaning, welding and other applications. *Dawe, London.* 487

The Veeco range of thin-film **deposition systems** is described in an 8-page brochure. *Veeco Instruments, Plainview, N.Y.* 488

A series of seven data sheets describing the Elma range of **rotary switches** is available from *Radiatron Components, Twickenham, Middx.* 489

The BDH range of **liquid crystals** is described in a new brochure which also includes information on the measurement of lcd parameters. *BDH Chemicals Poole, Dorset.* 490

DTV Group has published its 1977 catalogue containing **information** about products from Mullard, National, IR, Dow-Corning, Weller, Belling & Lee, TRW/IRC, Lambda and Bulgin. *DTV, London.* 491

The range of EMI **cctv products** and systems is described in an 8-page brochure available from *EMI Sound and Vision Equipment, Hayes, Middx.* 492

Data I/O Europe has published the third issue of its newsletter **Prombits.** *Data I/O Europe, Amsterdam.* 493

The latest edition of **Update** contains stock information on the range of components and instruments handled by REL. *REL, Hitchin, Herts.* 494

Hybrid Systems has produced a catalogue of its **data conversion** products. *Hybrid Systems, Camberley, Surrey.* 495

Number 20 of the technical scientific journal Disa information contains a number of papers on **flow measuring** problems. *Disa Electronik A/S, Copenhagen, Denmark.* 496

Details of the range of engineering **plastics** available from Ciba Geigy is described in a brochure available from the company, *Ciba Geigy, Cambridge.* 497

Some of the many applications possible with Marconi Instruments TF2008 am/fm **signal generator** are described in a booklet produced by *Marconi Instruments, Chelmsford, Essex.* 498

An application note is available on the use of Measurement Technology's **safety barrier** for use in hazardous areas. *Measurement Technology, Luton, Beds.* 499

Another IBA review No 8 deals with **service planning** and propagation. *Engineering Information Service, IBA, Winchester, Hants.* 500

Reprints of an article "New digital techniques applied to rate measurement" describing recipromatic computation principle and basic operation of time interval **conversion counters** and their application are available from *Orbit Controls, Cheltenham, Glos.* 501

Frequency Synthesizers: *theory and design* is the title of a 523 page hardback by Vadim Manassewitsch, engineering consultant, General Instrument Corp. According to the preface, the objective of this book is to provide training and reference material for engineers working in comms, radar and other areas where frequency synthesizers are used. £19,50; *John Wiley and Sons, Chichester, Sussex.* 502

Krohn-Hite **filters,** oscillators, phasemeters, power amplifiers, function generators and ancillary equipment is included in a shortform catalogue available from *Keithley Instruments, Reading, Berks.* 503

Magnetic tape recording equipment is described in a 24 page brochure available from *SE Labs (EMI) Ltd, Feltham, Middx.* 504

A 4 page guide explaining the Escap miniature permanent-magnet dc **tachogenerators** is available from *Portescap (UK), Reading.* 505

A leaflet on **DataLook** which monitors up to eight lines of logic information and stores the last 256 bytes clocked into the system is available from *Brensal Electronics, Bristol.* 506

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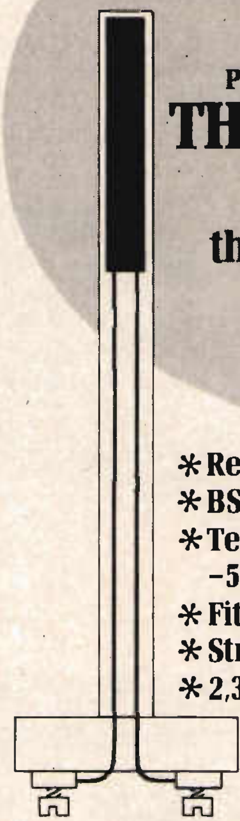

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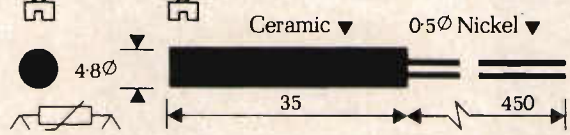

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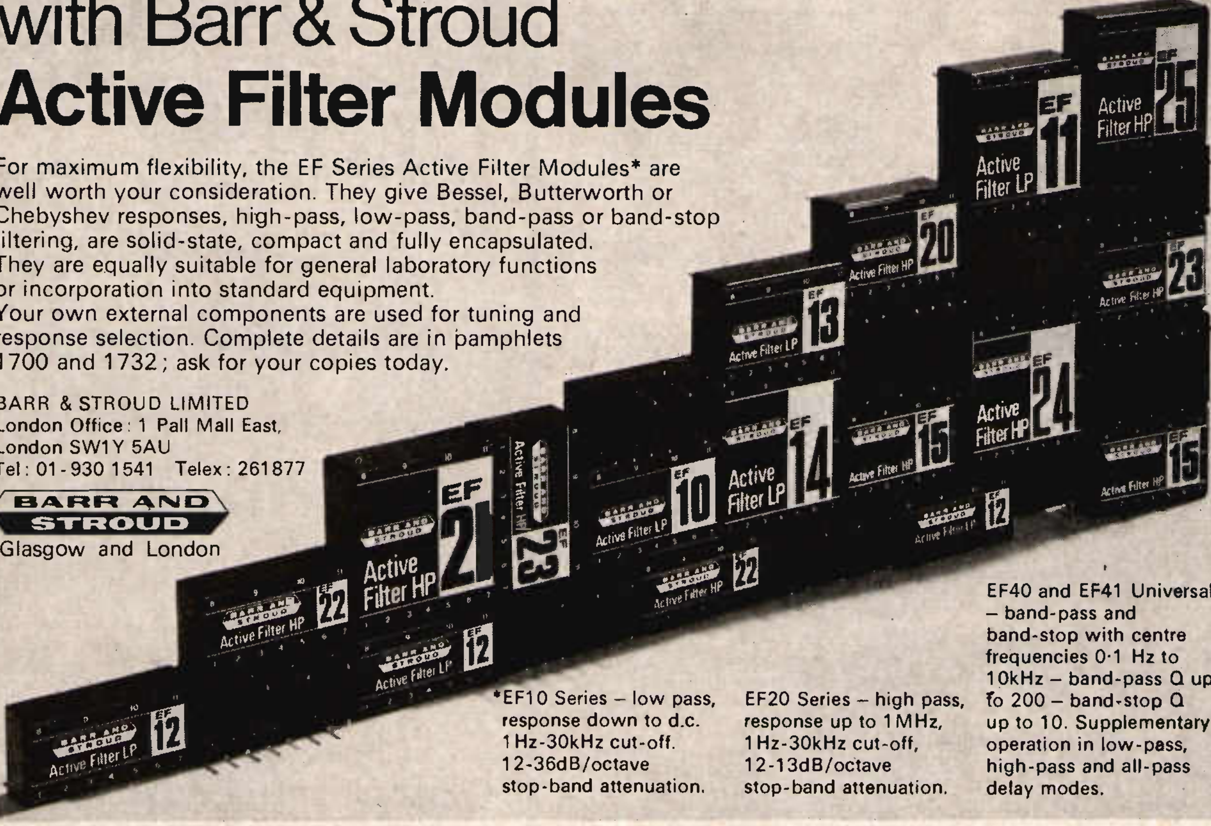

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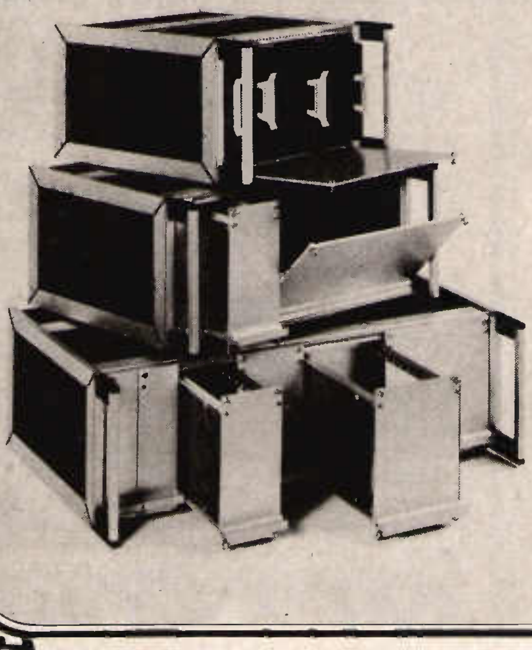

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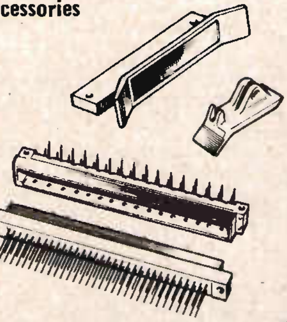

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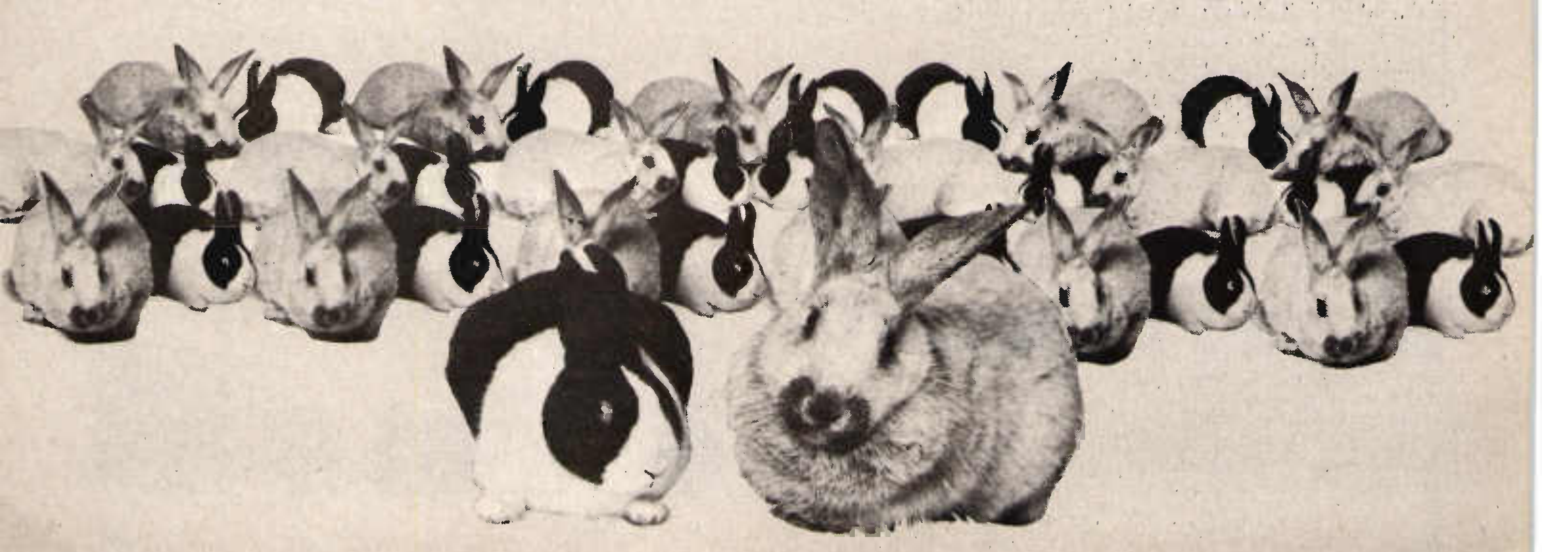

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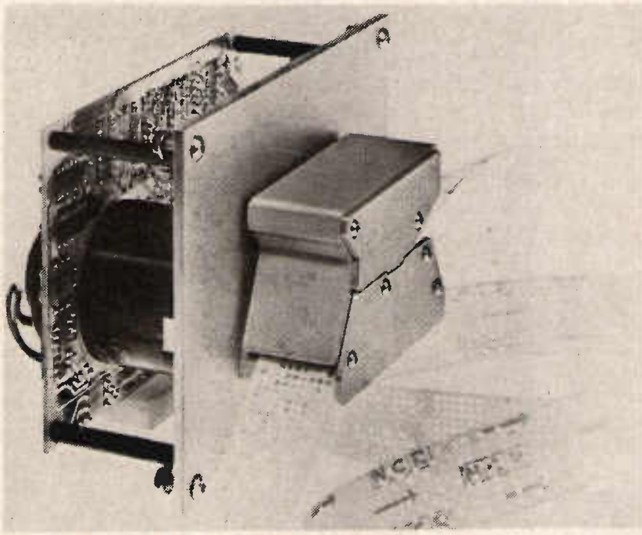

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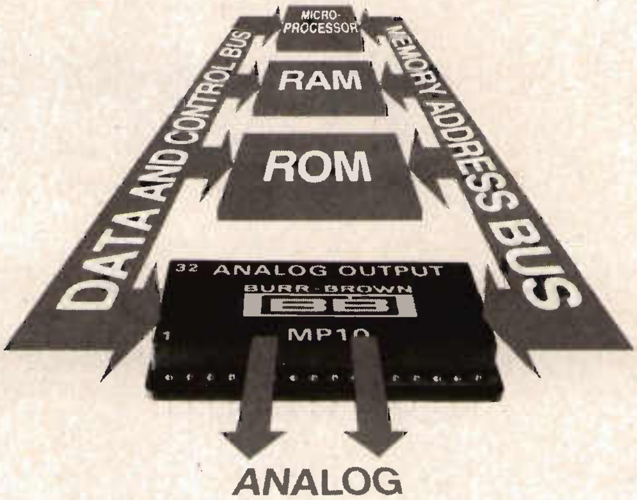

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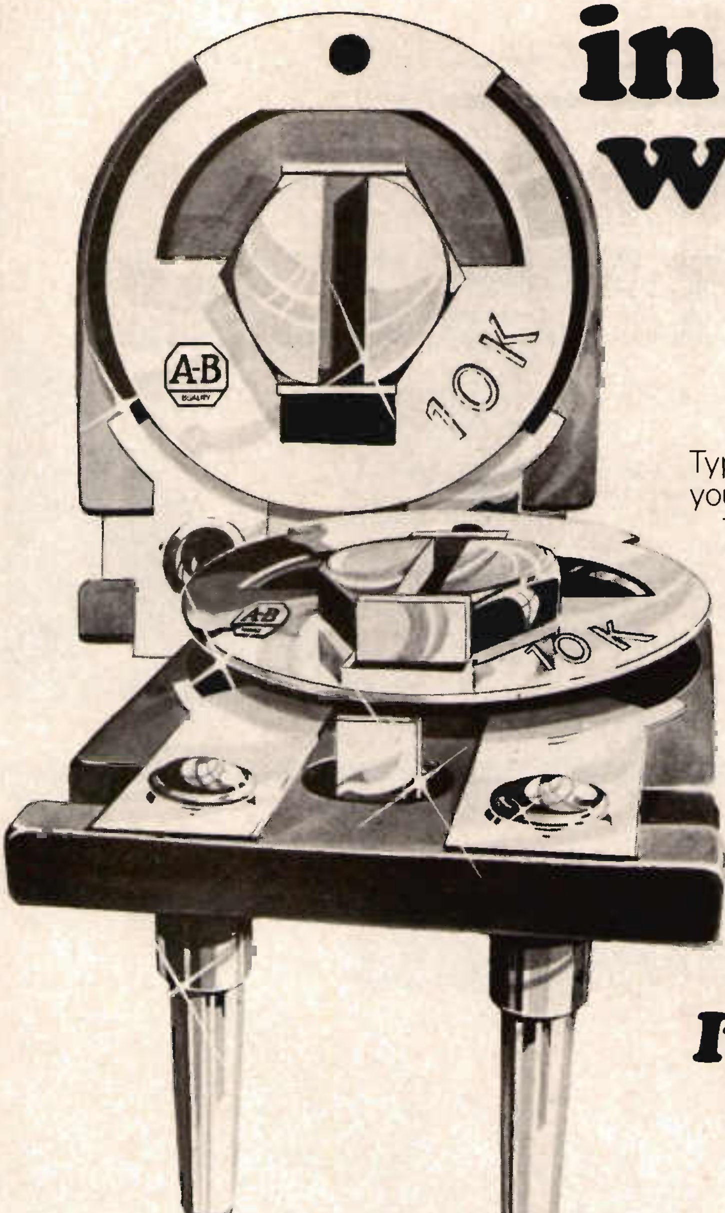

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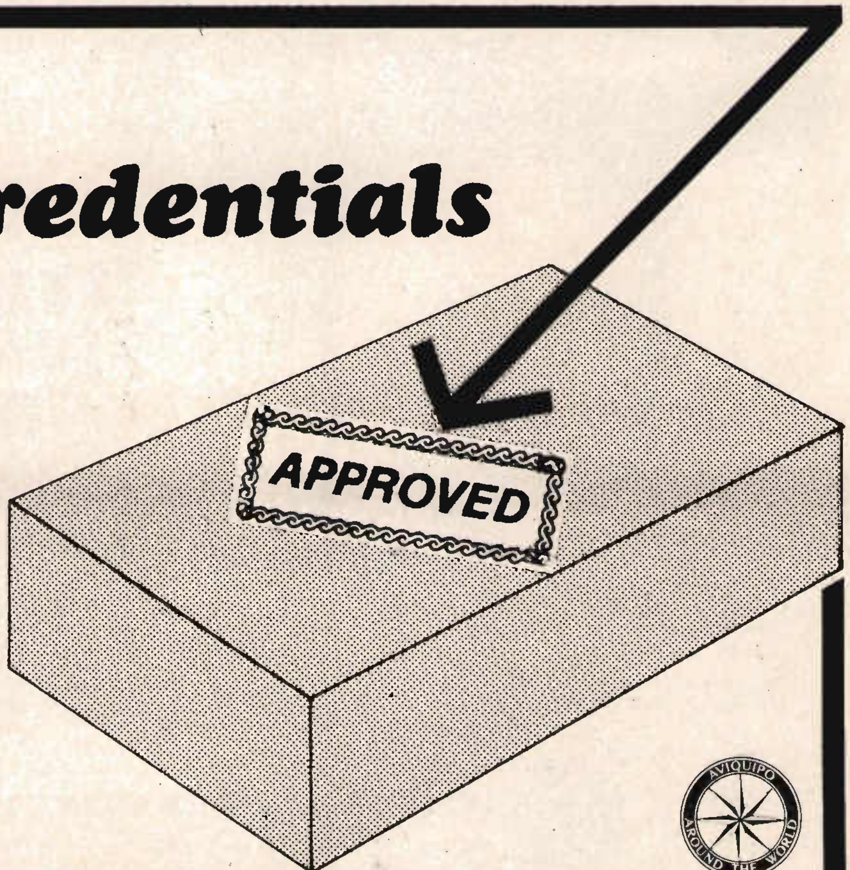

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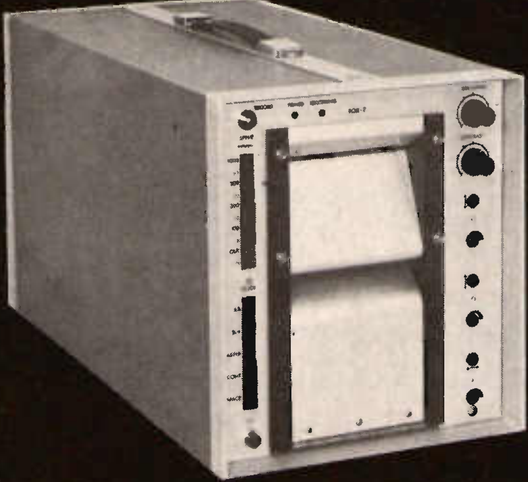

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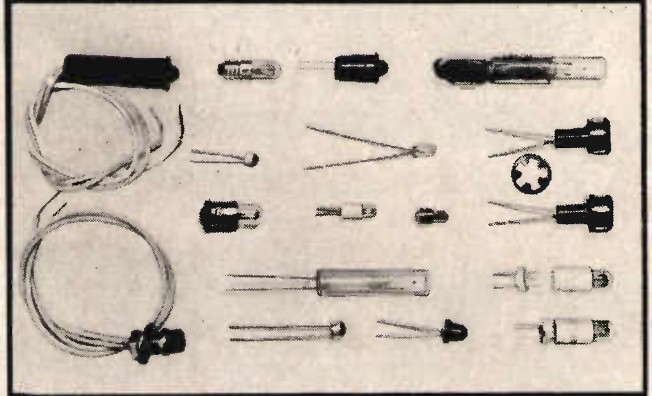

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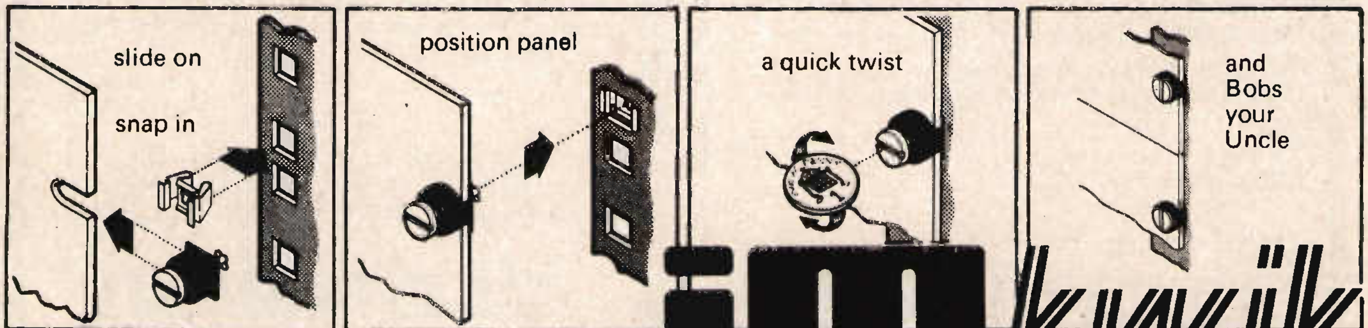

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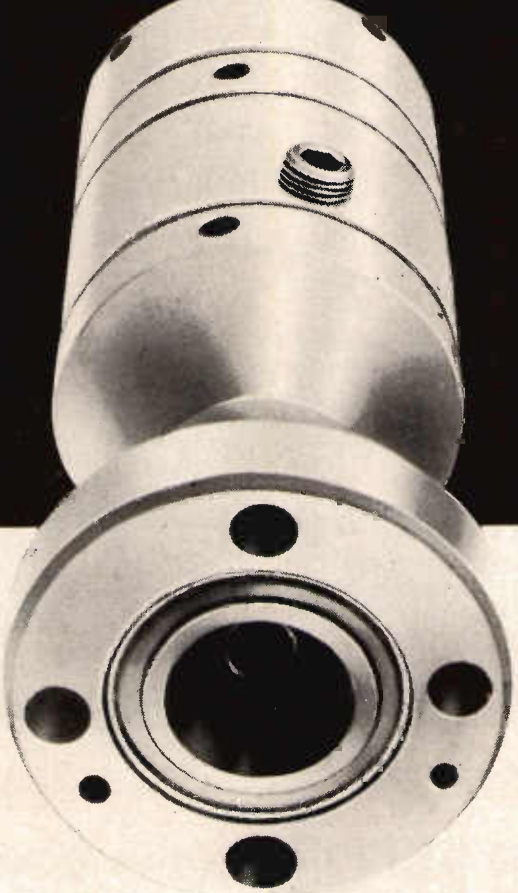

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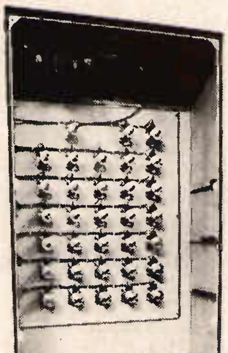

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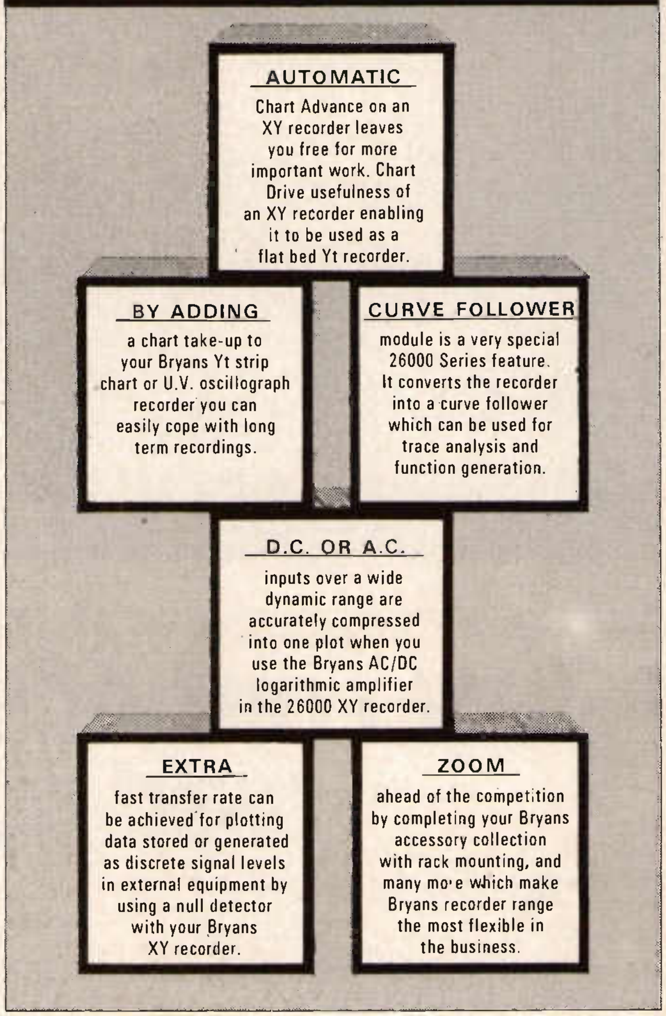

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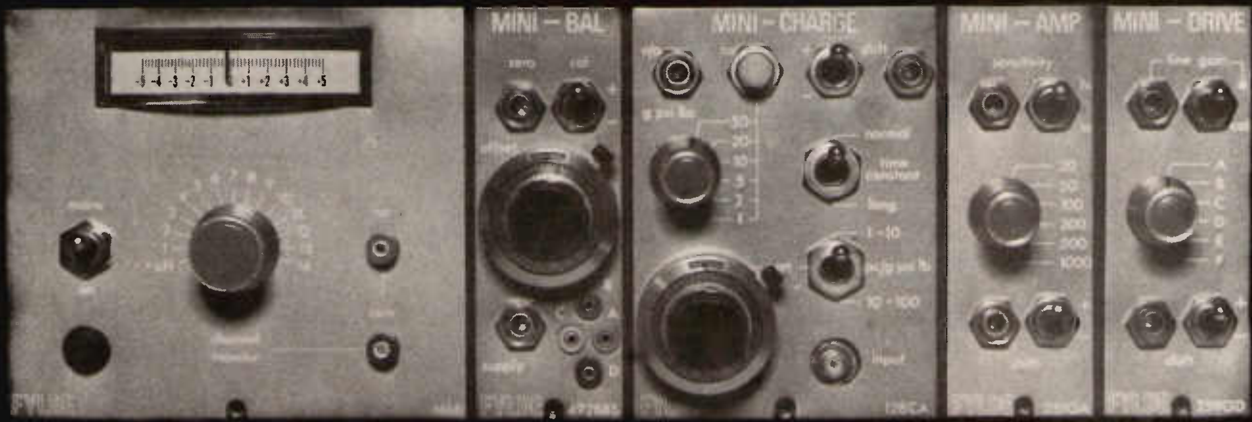

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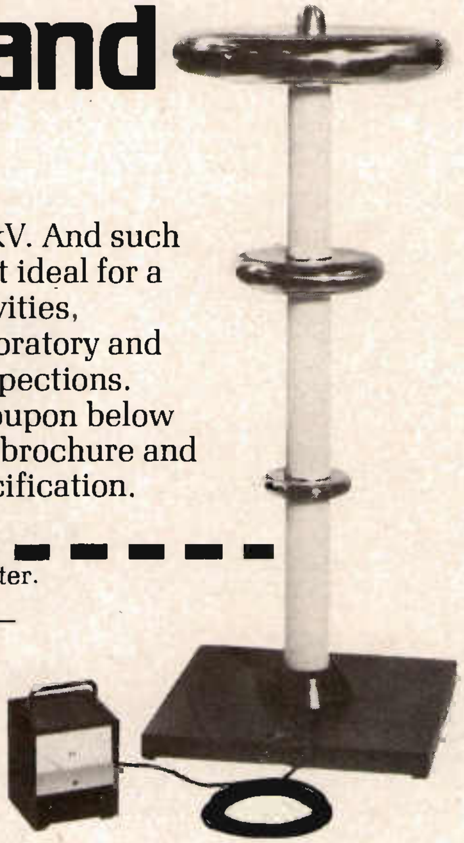

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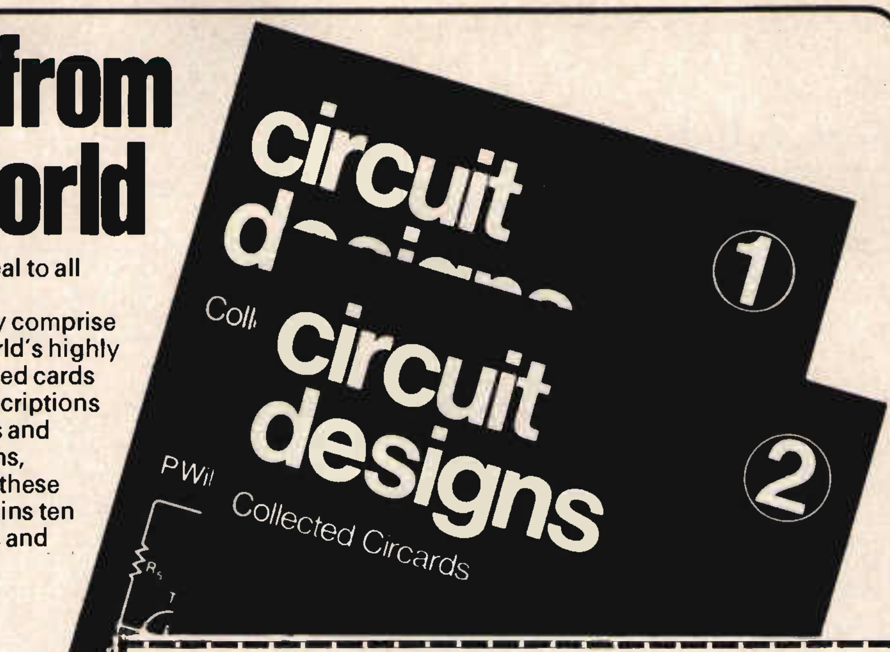

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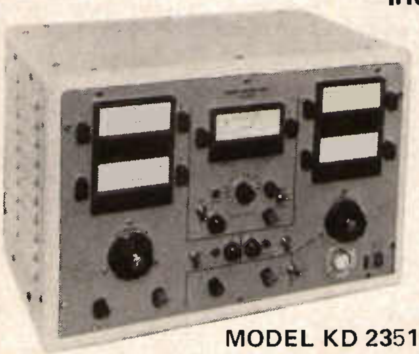

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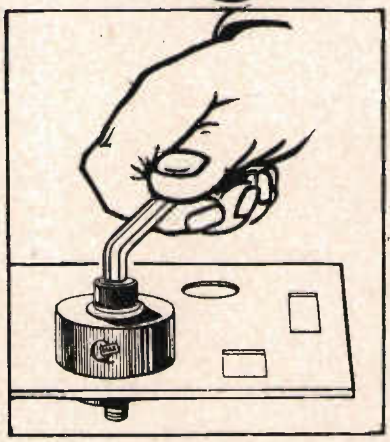

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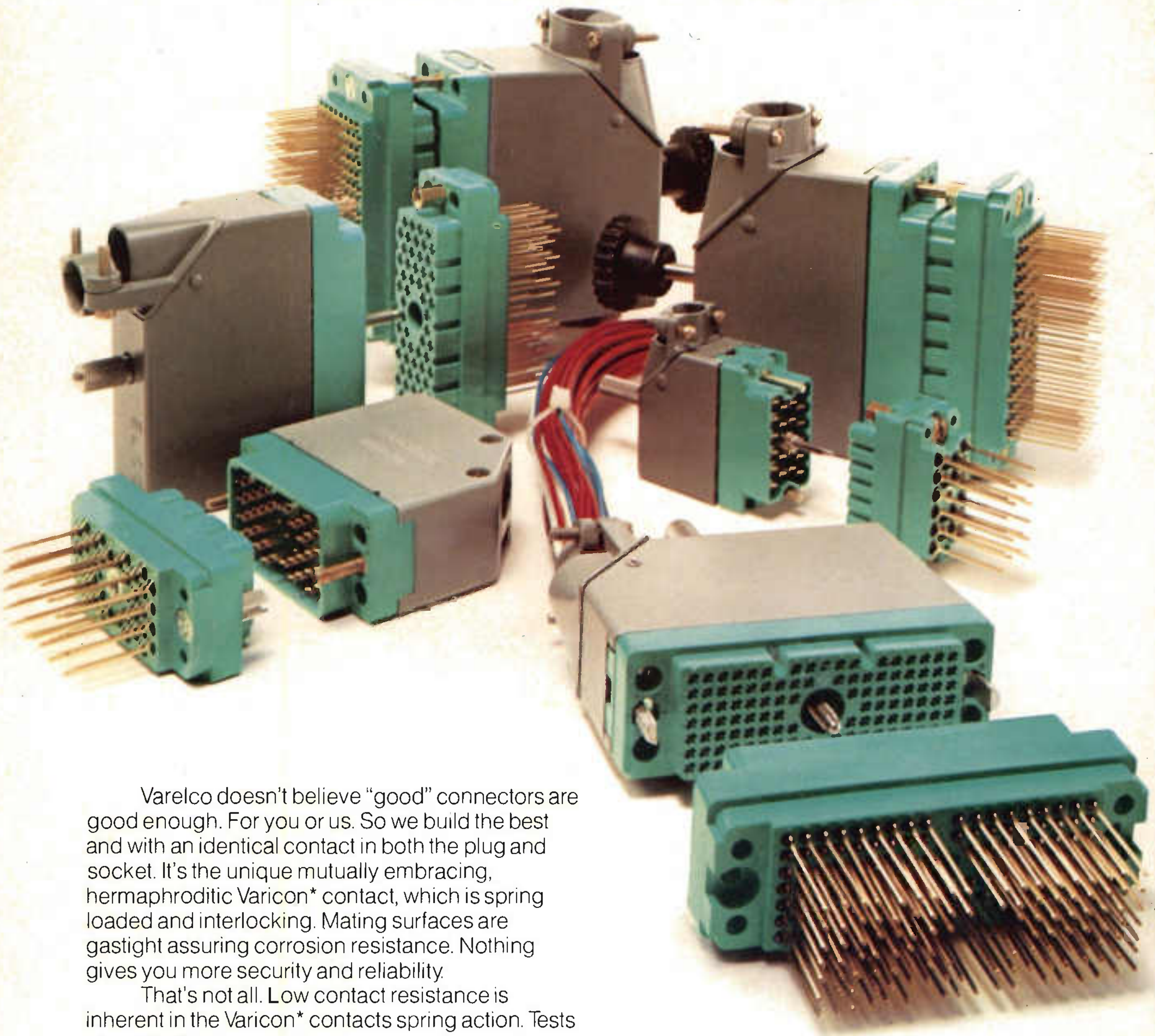

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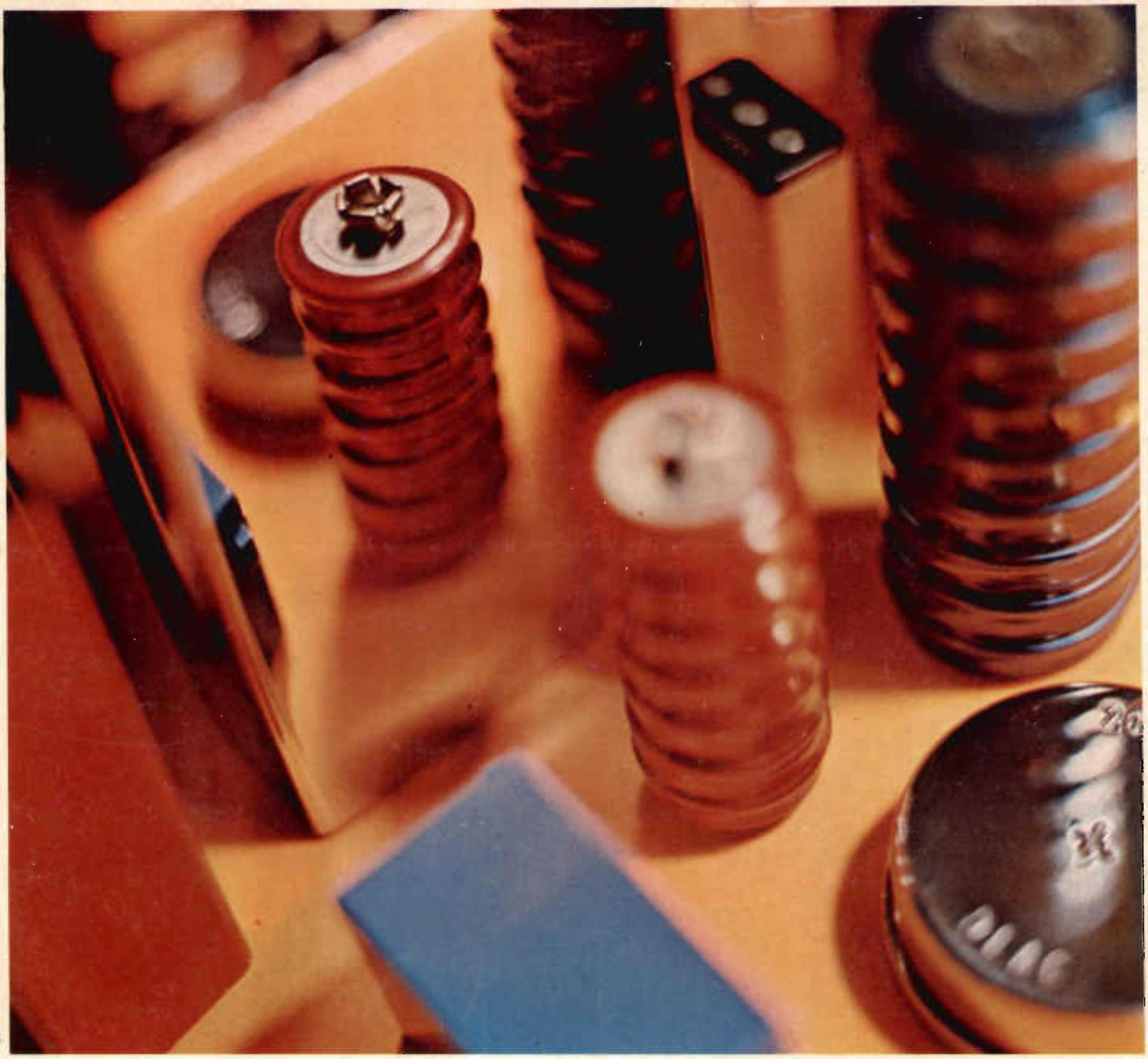

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