December 1987

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1987 cumulative index
Readers' survey

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Volume 13
Number 151

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GUIDE LINES

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The main theme is Radio Techniques: apart from an overview, there will also be some HF/VHF projects. Other items will include:
- The rise and rise of the micro
- European education software
- Test & measuring equipment — 2
- Stereo limiter
- Solar cell thermometer

Front cover
Solartron’s Type 1255 HF Frequency Response Analyser can be used for electronic, mechanical, and electromechanical analysis in research and production. Accurate analysis of components operating at frequencies up to 20 MHz has been difficult until now because available instruments could not cope with the high-speed calculations needed to assess the signal magnitudes and phase shifts. The instrument has many applications, including the design and testing of RF and video amplifiers and filters, crystal filters, and audio components.
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<th>Description</th>
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<tr>
<td>DAC80-CB-V</td>
<td>B8</td>
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<td>K133A</td>
<td>Dual Band Radio Gen</td>
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<td>AV-3-4701</td>
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<td>£15.00</td>
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<td>L217</td>
<td>L-Red Emitter 950nm</td>
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<td>BPM90</td>
<td>Transistor 650nm</td>
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<td>MAB003AH-125</td>
<td>Sig</td>
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<td>LM350</td>
<td>Alt. 35 Amp</td>
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<td>SN7548</td>
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Rechargeable Batteries

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<tr>
<td>6V 16Ah</td>
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Capacitors

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<th>Value</th>
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<tr>
<td>±5% 63V 2.2uF</td>
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Motors

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<th>Model</th>
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<tr>
<td>SANYO</td>
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<tr>
<th>Product</th>
<th>Description</th>
<th>Price</th>
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<tr>
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REGULATION AND LIBERALIZATION

The recent seminar at 10 Downing Street on the future of British broadcasting highlighted once again that there is no one view on the need for regulation, although there seems to be a general consensus that a great many of the existing regulations are outdated and unrelated to today's needs.

On the one hand, there is a strong lobby that wants the Government to abide by the popular demand for consumer sovereignty, while on the other, there are many who want it to make sure that viewers and listeners can not watch, or listen to, programmes that in their opinion is unduly full of sex or violence. This presents a serious dilemma, of course, because the vast majority of television viewers, for example, would rather watch Rambo II or Sex Kittens on the Loose than Triumph of the West or The Great Philosophers.

But the problems do not end there. In their deliberations over the white paper on the future of broadcasting, the Government will have to recognize that the quality of programmes received in this country can in future no longer be controlled solely by the BBC, the IBA, or British regulations. That requires agreement among broadcasters and advertisers in many other countries, particularly Europe and the United States. Undoubtedly, not all of these see the purposes of broadcasting in the same light.

Fortunately, a commission appointed by the European Institute for the Media and the European Cultural Foundation is already engaged on finding ways to unify the views of at least those in Europe concerned with programme making.

Similar problems abound in the world of telecommunications. Like the television viewer or radio listener, the telecommunication user will judge the aptness of regulations by their obtrusiveness. Unlike the television viewer, who may simply see certain regulations as an infringement of his personal freedom, the telecommunication user is likely to be a business man, who may consider some regulations as constraints, preventing him from carrying out his business as he feels the should.

Unfortunately, and this is an old problem in telecommunications, national regulations often can not be adopted internationally. It is, of course, right that countries can, and should, decide for themselves what their national regulations should be. But it is to be hoped that in formulating new regulations, countries in this day and age will take into account the situation in other countries. Fortunately, there is an intergovernmental organization, the International Telecommunication Union-ITU—that provides the regulatory framework for trans-frontier telecommunications structures.

In the interest and furtherance of individual freedom, the overriding importance of consumer sovereignty must be emphasized. Regulations are necessary, but they must not have the effect of restricting the consumer's choice. A proper balance needs to be sought, and maintained, between regulation and liberalization that will be in the interest of everybody.

The past year has been one of recovery and subsequent stabilization for Elektor Electronics after its divorce from Glentop. During the year, we had the great misfortune to lose, through his unexpected death, our Info/Data card Editor. This has meant the (hopefully temporary) suspension of our Info/Data card service. This will probably be resurrected soon, but in a rather different form.

The subscription service, which on occasion has been (rightly) criticized, is now being handled by World Wide Subscription Service Ltd, which will mean a much prompter response to subscribers' queries.

We thank all our readers for their continued support and wish you all

A Prosperous and Peaceful New Year!

December 1987
GEC endowment for London University
Recently opened new electronics engineering laboratories at University College, London, were a gift from the General Electric Company. The laboratories will provide greater opportunities for advanced research into communications, microprocessor, and space technology.

Ferranti merges with ISC
Ferranti, the Manchester-based electronics giant, has merged with International Signal and Control of Lancaster, Pennsylvania. The new company has a worldwide turnover approaching £1 billion, and will be particularly active in the world's defence, space, and industrial electronics markets.

Thermal picture synthesizer
A solid-state thermal picture synthesizer has been developed by British Aerospace. It consists of a matrix of thermally-emitting thin-film resistors deposited on a thermal insulation layer built on a silicon substrate. The substrate contains a corresponding matrix of integrated-circuit diodes used in the control of the resistor matrix. The image area of the device is 35 mm² and contains 10,000 resistors arranged in a 100 x 100 matrix. Each resistor representing an infra-red pixel can be electronically addressed and activated independently of its neighbours. A resistor's temperature can be increased by a maximum of 25 °C above the nominal baseline operating temperature of the device. The degree of heat emitted by a resistor depends upon the current flowing through it and can be programmed to be one of 200 values so providing a graduated range of temperature colours for the generation of high-resolution infra-red images. The substrate also functions as a heat sink. It forms the base of a chamber containing a fluorinated hydro-carbon liquid and is cooled by the latent heat of vaporization of the liquid as it boils. This arrangement ensures the thermal response of the resistors is sufficiently rapid for dynamic infra-red images to be produced in real time by the thermal picture synthesizer at frame rates of up to 50 per second.

Continuing growth in component sales
The Association of Franchised Distributors of Electronic Components—AFDEC—whose members account for half of the distributors' share of total UK sales of electronic components, forecasts an overall UK market growth of 9% to £1,577 million for these products during 1987, and a further 11% to £1,746 million in 1988. The forecasts are contained in a special report to AFDEC members. They are based on information supplied by members and other reliable sources and represent an encouraging improvement on 1985-86 figures, which showed an overall decline of 4.5% per cent from those of the previous year. The document is priced at £225 plus VAT, to include quarterly updates, and is available from AFDEC • Owless Hall • Owles Lane • BUNGINGFORD SG9 9PL.

John Walker (left), Chairman of AFDEC, and Christopher Sawyer, Deputy Chairman of AFDEC.

Co-ordinate measuring machine
A co-ordinate measuring machine, which has absolute measurement scales in all three axes and uses UNIX-based software, has been introduced by the Swedish quality assurance specialists C.E. Johansson. Initially, customers can specify delivery with either IBM or Hewlett-Packard computer systems, but the manufacturer intends to make other systems available according to market demand.

Further details on the Cordinatic 7000 from C.E. Johansson Ltd • 66 High Street • Houghton Regis • DUNSTABLE LUS 5BJ • Telephone (0582) 867711.

Westinghouse Cubic just the ticket
New 'Quickfare' automatic ticket machine from Westinghouse Cubic, now undergoing trials at London Bridge Station, are speeding passengers to 40 British Rail destinations in south and southeast London, as well as to stations in Kent and Surrey. Westinghouse Cubic, the automatic fare collection and revenue systems specialist, is jointly owned by Hawker Siddely and Cubic Corporation. Since their installation last June, the two custom-built machines, strategically placed at the main barrier next to the ticket office, have recorded a total of over 40,000 ticket sales. A variety of ticket combinations are available to travellers from the automatic machines. Each machine has an electronic clock capable of calculating off-peak periods, weekends, bank holidays, and even leap years.
Bumper ELECTREX again

ELECTREX '88, Britain's major international electrical and electronics exhibition, promises yet again to be another bumper show: to date more than 1,000 companies will be represented on 485 stands occupying over 24,000 m² of space. The exhibition will be held at the NEC, Birmingham, from 29 February to 4 March 1988.

ELECTREX '88 will be visited by an inward mission of about 20 top level potential buyers from selected markets around the world, each of whom has purchasing influence in their particular sphere. The mission is being organized for ELECTREX by BEAMA with financial assistance from the British Overseas Trade Board.

New future for video discs

Video disc players marched into the consumer markets in 1978 with much fanfare, only to limp out again a few years later in defeat: they were no match for the cheaper video cassette recorders.

But video disc technology has some definite advantages over video tapes, particularly for training applications in the non-consumer industrial, government, professional and commercial markets. High-resolution, high-quality visual images give video disc programmes a long leg up, for instance, in the medical training market. Video disc technology also makes possible interactive programmes that can accept user input and respond to that input. According to The Non-consumer Market for Videodisc Technology (+A1665), a report from Frost & Sullivan, sales of non-consumer video disc programmes will rise in value from an estimated $140 million in 1987 to some £606 million by 1991. Although the report is cautious about the future of non-consumer video disc technology, it makes clear that this is a technology with considerable potential, which may be realized sooner than many analysts think.

Cossor IFF for Abu Dhabi

Cossor Electronics has received an order to supply four Identification Friend or Foe—IFF—systems, which will be installed in patrol vessels being built for Abu Dhabi by the German shipbuilders, Lurssen. The total value of the installed systems exceeds £0.5 million. The order is the first for the new Type 850/4 system which incorporates the Mark XII compatible cryptographic capability.

The transducer market in Europe

A Frost & Sullivan analysis suggests that the transducer market in Europe will amount to £4.1 billion between 1987 and 1992. The study covers any device that couples a sensing element for pressure, temperature, flow, level, motion, etc. to an output element that generates an electronic signal. It deals with more than 25 types of transducer and says that the prospects for many hinge on the accelerating trend toward the integration of microprocessor technology into instrumentation and device design.

AFDEC support for new show

AFDEC, the electronic component distributors' association, has agreed to officially lend its support to the new international Components in Electronics exhibition to be held in London from 8 to 10 March 1988. The show has further received a boost with the news that Norman Merritt, Manager of the MOD's Electronic Component Standardization Scheme, and an internationally highly respected figure in the area of component quality, has agreed to become Chairman of the Conference Programme Management and Papers Vetting Committee.

Further information from Nutwood Exhibitions Ltd.  Guardian House.  Borough Road.  GODALMING.  GU7 2 AE.  Telephone (04868) 25891.
£650,000 for Hatfield Polytechnic

The Department of Trade & Industry has announced that Hatfield Polytechnic is to receive over £650,000 in two separate projects. The first is to set up an "awareness and training" centre at Hatfield for Advanced Manufacturing in Electronics, and the second to support activities by Cimtech, the polytechnic's National Centre for Information Media and Technology. Similar Advanced Manufacturing in Electronics (AMIE) centres are being created in a number of other polytechnics and universities throughout Britain. Initially, six centres were to be funded, but because of strong demand it was decided to set up 12 over two years. The funding going to each will cover 50% of costs over the initial two-year period, says the DTI.

The Hatfield centre will cover virtually the whole of south-eastern England. The polytechnic has a well-known track record in the field of electronics and industrial systems and control.

Further information from Hatfield Polytechnic • College Lane • HATFIELD AL10 9AB

Flat panel display market in Europe

The major driving force, according to an analysis by Frost & Sullivan, has been the goal of companies to hold capacity available to execute them in due course," he says. "Our industry is a wonderful opportunity for wealth creation and, in order to achieve our maximum potential, we do need Government policies which will give us greater possibilities for increasing our throughput in this country as a base from which to expand our export activities."

The key role of Government in the affairs of industry is stressed in the report by BEAMA's Director General, Mr Gordon Gaddes. The year had seen further emphasis on the case for more investment in the electro-technical infrastructure. The British electrotechnical industry in 1986 had a total production of £38,993 million, of which £10,408 million, or 43.5 per cent, were exports. The 1985 revised figures were £23,326 million, of which £10,336 million or 43.9 per cent, were exports.

Production in those product groups coming within the BEAMA scope (that is, excluding such items as computers and consumer durables) accounted for £10,038 million (1985 revised: £12,788 million), of which 38.9 per cent (39%), or £5,863 million (£4,801 million), were exports.

Imports in the BEAMA sectors were £4,544 million (1985: £4,472 million, giving a favourable balance of trade of £5,080 million (438 milliom)."

Winning overseas power station orders extremely competitive

In his report for 1986-87, Sir William Barlow, the President of BEAMA, the federation of 17 manufacturers' trade associations, says that Britain's industrial electrical and electronic industry is having to win power station orders overseas under extremely competitive situations.

Sir William looks forward to early announcements of CEGB orders for coal-fired power stations. "Every month of delay in the placing of orders makes it increasingly difficult for

Radio Code Analyser

Solartron's Type 4922 Radio Code Analyser provides all the test facilities required by the expanding pager market. It is designed for production and repair environments, but is also a valuable tool in development. As well as performing selective call, cellular, and DTMF system testing, the unit incorporates generation facilities for testing beepers, numeric pagers, and message masters using POC-SAG, and generation/analysis facilities for FMS, ZVEI Binary, and user-defined signalling systems.

Selection of freely definable data transmission allows for operation in NRZ, MANCHESTER (RZ), FFSK, FSK, DPHK, DPHK, FSK, Biphasic mark and Biphasic space transmission modes. User-defined transmissions can be programmed and recorded in non-volatile memory.

The 4922 incorporates an IEEE-488 interface as standard to follow for use in automated systems and output of signalling results to a printer.

Further information from Solartron Instruments • Victoria Road • FARNBOROUGH GU14 1TW • Telephone (0252) 544433.

Fluke & Hilevel Technology alliance

John Fluke Manufacturing Company Inc of Everett, Washington, and Hilevel Technology Inc of Irvine, California, have signed a letter of intent to form a strategic alliance between the two firms.

Under the proposals, Fluke would purchase about 25 per cent of Hilevel for about $5 million, providing the Californian firm with added capital for expansion. In turn, Fluke would be granted licences to use technology developed by Hilevel in non-competing applications.

Fluke is a leading maker and marketer of electronic test, measurement, and control equipment. Hilevel Technology has a growing leadership position in ASIC verification systems and ASIC applications support.
UK start for new Atlantic link

Work in Britain on laying the world's first transatlantic optical fibre cable - code-named TAT8 - has started. At Widemouth Bay in Cornwall, the UK shore end of this £220 million undersea system is being installed by staff from British Telecom International.

The shore end of the cable will be floated ashore from a cableship, secured, and sunk into position by divers. The cableship will then move off to lay the remainder of the first 12 km of the UK section of the cable.

Next spring, the main 520 km UK section of TAT8 will be laid by BTI's cableship CS Alert. She will carry out the laying with the aid of BTI's remotely controlled plough, which will bury the cable beneath the seabed to protect it from damage by ships' anchors and trawling.

The UK section of the cable will be connected by a further 20 km link to a special junction device on the ocean floor, 540 km south of Widemouth Bay. This will join the UK cable to a similar section from France, connecting both to the main 5,000 km span of the cable to the USA.

When TAT8 comes into service next summer, it will have the potential capacity to carry the equivalent of 40,000 simultaneous telephone calls, or their equivalent in data, facsimile, graphics, or TV pictures.

British Aerospace, Marconi, and STC jointly pursue new submarine communications package

British Aerospace, Marconi Radio Systems, and STC have formed a team to jointly tender for the communications system of the Royal Navy's next generation of submarines.

The direct capability and expertise of this combination is formidable. For the first time, a single organization will have the effective expertise to address all aspects of naval communications.

The individual strengths of each company are complementary and include Marconi's breadth of involvement in naval communications through products such as ICS3 and SCOT; British Aerospace's background in naval procedures and programmes such as the shipborne SAMHADS and DIMPS data handling systems, and with STC providing a valuable capability in the area of specialized antennas and fibre optics.

New hi-tech facility for Cincinnati Electronics

Cincinnati Electronics, the world's leading developer of manpack transceivers, has opened a new hi-tech facility in Mason, Ohio. The ultra-modern structure will house Cincinnati Electronics' growing Aerospace Division. About half the 9,000 square feet of floorspace is dedicated to eight highly sophisticated laboratories specifically designed for advanced-technology research and development work.

Cincinnati Electronics Corporation has been active in military and commercial electronics for over 60 years. Business areas include tactical communication systems and equipment; electronic warfare systems; space electronics; radar and contract manufacturing. Their Aerospace Division is the leading producer of range safety receivers for space launch vehicles, which have been on board 75% of all US launch missions in the past five years.

VAN services in Europe

A recent report from Frost & Sullivan, Value-added Network Services in Europe (#E940), predicts that the VAN market will be rising about 40% a year as an average compound growth rate. From £800 million in 1986 to almost £4.9 billion by 1991. The greatest gains are expected to come in the period 1988-90, when the compound growth rate is forecast to average 57%.

As might be expected, businesses users of VANs, which range from data bases, electronic mail services, and videotex to paging services, account for more than 80% of the volume generated (£726 million in 1986).

The report explores the national markets of Federal Germany, Britain, France, Italy, and Scandinavia in detail, and also develops figures for the rest of Europe as a whole.

As shown in the figure, the UK is the largest VAN market, accounting for some 35% of the European total (E220 million in 1986). France's FF1.5 billion in 1986 ranks it second, accounting for about a quarter of the European volume. Both these countries, however, will lose in share due to faster growth elsewhere, such as in Federal Germany, which in 1986 accounted for only 12%, or DM220 million, of the European market.
GEC-Plessey Telecommunications merger
Negotiations are proceeding on the proposed merger of the telecommunications businesses of General Electric Company and Plessey. The aim of the new company is to offer a more powerful and competitive range of telephone systems worldwide.

Although GEC's turnover (£5,939 million) is vastly greater than that of Plessey (£1,430), their telecommunications turnovers do not differ much—GEC: £749 in 1986; Plessey: £681 in 1985. Both companies were, therefore, at pains to stress that they would have an equal number of directors on the board to the new organisation.

Although the Monopolies and Mergers Commission last year rejected GEC's bid for Plessey, it is reported to be strongly in favour of the telecommunications merger.

The telecommunications market in Britain is worth about £1.6 billion, of which GEC and Plessey together take about half. It is expected that the new company would be predominant in Britain in the markets for multiplexing equipment, microwave radio, optical transmission systems, PABX equipment, as well as having more than a third of the telephones market.

Mercury service through Vanderhoff
Mercury Communications Ltd., a wholly owned subsidiary of Cable & Wireless PLC, has appointed Vanderhoff Business Systems to be the first distributor for the Mercury 2200 telephone service. This uses a Smart Box to connect customers to the Mercury network.

The Mercury Smart Box is installed on the exchange side of customers' PABX equipment. Its purpose is to work to the customer's advantage in deciding when a call can be more economically handled by Mercury and automatically routing it accordingly. Mercury 2200 customers benefit from call cost savings of an average of 15% on long-distance connections and itemized billing at no extra charge.

In addition to the Mercury Smart Box, Vanderhoff are also national distributors for Mercury Paging and are undertaking the billing of air time to subscribers.

Further information from Vanderhoff Business Systems Ltd. • 19 Station Approach • FLEET GU3 8QY.

From these, the risk of locust infestation can be assessed, so that effective counter measures may be taken if and where required.

It is hoped that the satellite system will prevent recurrences of the plagues of the past, notably that of 1974-75 when a large part of the total grain crop in the Sahelian zone was lost. (The Sahelian zone is the vast strip of land between the Sahara and the savanna regions from the Red Sea to the Atlantic.)

Land-mobile satellite communications
INMARSAT and the Centre National d'Études des Télécommunications (CNET) have conducted a series of successful trials involving the reception of messages transmitted to a moving vehicle via satellite.

The compact trials equipment was identical to that which will be used for maritime communications applications when INMARSAT introduces its Standard-C service next year. It consists of an electronics unit measuring 73 x 214 x 279 mm and a conical antenna with a diameter of 190 mm. The two units together weigh less than 4 kg. Standard-C is a data-only system which permits the transmission of test messages at a rate of 1500 bits/s. Mobile users are connected via satellite to the standard telex and other data transmission networks.

Measurements taken on motorways, secondary routes, mountainous routes, and in cities from Calais to the Spanish border yielded very encouraging initial results. On the motorway or open road, for example, the percentage of messages received correctly the first time was higher than 96%. Because messages are retransmitted until received, the reception of a given message is virtually guaranteed. Obstacles like bridges, electrical power lines, and trees caused practically no degradation of reception.

Marconi upgrades to standard 'A' for Mercury
The Satellite Communication Department of Marconi Radar Systems has just completed a contract for Mercury Communications which provides that company with its first Intelsat Standard 'A' earth station.

The work involved the upgrading of an existing Marconi 13 metre antenna—which was previously operating as a Standard B—through the use of readily available parametric low-noise amplifiers to become the first antenna in the world of its size to meet the new Standard 'A' Specification since its revision by Inmarsat.

Remarkably, the antenna meets the required G/T of 35 dB/K down to 14° elevation; no mean feat considering the antenna's physical location in the bowl of what was previously a quarry.

The entire exercise was made possible only because of the advanced RF design techniques used by Marconi on its antennas. Marconi is world leader in the synthesis of the main and sub-reflector profiles of cassegrain antennas. To achieve this lead, a variety of software packages has been developed which provides the basic design tools. These programmes are based on a rigorous vector implementation of physical optics, and form the core of Marconi's design techniques known as Diffraction Profile Synthesis-DPS. Practical comparisons have shown this technique to have a significant advantage over classical design tools based on the Geometrical Theory of Diffraction—GTD. DPS—unique to Marconi—allows an interactive design of optimum surface profiles to be achieved from a given primary feed system, which in turn allows reflector system efficiencies (including the effects of main and sub-reflector spill-over, sub-reflector blockage, and non-uniform phase in the aperture fields) of up to 98% to be achieved.
Local Area Networks in Europe

The United Kingdom's early lead in computers has given it the edge in creating networks in the workplace, but by 1990 both Federal Germany and France may eclipse the UK in what will be a $466 million a year market to link machines together.

Local Area Networks in Europe (CBE57), a 307-page Frost & Sullivan report, says that the impetus to link computer-related devices to each other is so great that the 298,000 nodes in place in Europe at the end of 1986 will quadruple by 1990, approaching an installed base of 1.4 billion.

There is a relatively higher installed base in the UK and this will tend to reduce the uptake of new systems. In 1986, though, the UK represented nearly 30% ($69 million) of European LAN shipments by value. There is a disproportionately low installed base in Federal Germany. Corporate business there is moving away from central mainframe computers towards more distributed processing—creating extremely strong sales that account for well over a quarter of Europe's 1990 shipments.

The strongly centralized organization of French business and government and lack of strong support of LAN products by distributors and dealers are factors in France's low share of the LAN market.

The report cites four major reasons for the pace of LAN growth in western Europe: the price of the technology will continue falling; the need for data sharing will intensify; consensus on technical operating standards is arriving, bit by bit; and LANs help control office cabling costs.

Frost & Sullivan Ltd
Sullivan House
4 Grosvenor Gardens
LONDON SW1W 0DH

Computer lease/rental in Europe

Close to half the new computer business generated in Europe by 1991 will stem from lease arrangements, according to Computer & Communications Lease/Rental in Europe (CBE57), a study from Frost & Sullivan. It predicts that half the $55 billion annual computer/telecommunications gear investment then will be in equipment that the end user does not own.

Leasing is of particular benefit in a field such as computers, enabling the user to update to the latest equipment without the difficulty of disposing of existing equipment, the report says. Furthermore, a lease arrangement enables a firm to acquire an asset without a large capital outlay, only incurring regular, budgeted operating expense. Of course, tax authorities are not blind to this situation, and many of these fiscal advantages are being eradicated.

Leasing will become the dominant form of computer acquisition in the UK by 1990; that year, close to $2.9 billion worth of computers will be leased, but only $2.8 billion sold new.

Frost & Sullivan Ltd
Sullivan House
4 Grosvenor Gardens
LONDON SW1W 0DH

Brother moves printer factory to UK

Brother printers are now being made in Britain. The decision to transfer production from Japan to Wrexham (where operations started on 1 October) follows the success of establishing a typewriter and microwave oven production plants in Wrexham over the past two years to supply EEC markets.

A complete range of dot matrix printers will be produced, starting with the company's popular 1700—a wide carriage model that is compatible with all computers and suited to a variety of business applications. With an average planned production rate of 3,000 printers per month, rising to a projected 10,000 per month, the production is expected to reach 30,000 per month in 1988. The revolutionary architecture is based on a unique, low-cost implementation of multi-cellular frame buffers. The performance level available with Fairchild's patented architecture is 10 times the performance of current systems, doubling or tripling the performance for polygon, bit, and characters. The new architecture is expected to have a significant influence on new workstations and PC add-on designs reaching the market in 1988.
Changes in IT industry

According to a report from Diebold, the US computer consultancy firm, the IT industry will undergo vast changes in the years leading up to the 21st century. The report says that today's methods cannot cope with the fast changes and that new ones are needed. Many medium-size companies will disappear, either through bankruptcy or by being swallowed up by bigger ones. Such companies will find that they are neither big enough to compete with the giants, such as IBM, AT&T, and Apple, nor have they the flexibility of smaller concerns.

The report sees the structure of the IT industry, which comprises computer, office automation, and telecommunications producers, consisting by the end of the century of a small number of giant producers and a large number of small entrepreneurial firms. The study feels that the giants have the enormous advantages of low-cost manufacturing, high-volume output, worldwide presence, political influence, credibility, and financial resources.

Half height VME processor

PSI Systems of Cambridge have announced a new half height VME 6000 single board computer. The card is British made and is ideally suitable for target applications or as the system processor of a VME development system. The card is packed with features which allow it to be used as part of a 68000 development system, and in target systems ranging from single-board controllers to complex multi-tasking and multi-processor control systems. A major advantage of this approach is that experience gained in development can be directly transferred to the target application thus reducing valuable engineering time.

Cambridge Microprocessor Systems Ltd
Brookfield Business Centre
Twentyspence Road
Cottenham
CAMBRIDGE CB4 4PS

Amstrad reports record sales

In his statement to the annual report for the twelve months ending 30 June 1987, Mr Alan Sugar, Amstrad's chairman, reported record sales of £512 million, an increase of 68% compared with last year's sales, and record pretax profits of £135.7 million, an increase on last year of 80%.

The report comes just a week after the launch of the new word-processing computer, the Type PCW9256, and just a day after the announcement of Amstrad's acquisition of Indescomp SA. The PCW9256, successor to the PCW8256, has a better printer, larger disc storage, and improved word-processing software with a spelling checker. The screen now displays black characters on a white background.

Amstrad is clearly the market leader in the UK, but it has also made tremendous inroads into a number of European markets. In Italy, it has recently formed Amstrad SpA, which started trading last month. In the USA it has recently acquired its distributor. Mr Sugar was, however, at great pains to explain that the USA "is also a very dangerous market; we have always expressed caution with respect to this territory and will continue to do so. The USA will not be allowed to drain our resources. None the less, no effort will be spared to ensure success and I will take a personal interest in the development of this market".

In France, Amstrad International SA has traded very well in its home market, where there is an excellent nation-wide distribution network in place for all Amstrad products.

That sales and marketing success is well rewarded by Amstrad is shown by the announcement that both Mr Jose Lois Dominguez, the founder of Indescomp and now the Managing Director of Amstrad Espana SA, and Ms Marion Vanvier, Chief Executive of Amstrad International SA, are appointed to the main board of Amstrad PLC.

Amstrad in Spain

Amstrad recently announced that it has agreed to acquire the total shareholding in Indescomp SA, the Spanish company responsible for the distribution of Amstrad PLC products in that country, subject to the approval of the Spanish General Directorate of Foreign Transactions.

Amstrad will pay a total price of £21.65 million consisting of 8,812,518 ordinary shares with the balance in cash.

Indescomp SA, which has been Amstrad's exclusive distributor in the Spanish market for the past three years, and has devoted itself solely to the distribution and marketing of Amstrad PLC products, earned profits before tax for the half year ending 30 June 1987 of £1.9 million and had net assets of £5.1 million. On completion of the transaction, it will change its name to Amstrad Espana SA.
Sir—In your admirable tribute to Alan Turing (EE, October, 1987) you say that Turing’s work laid the foundations for modern computer science. Be that as it may, the Science Museum is at present trying to find an answer to the question as to whether Charles Babbage (1792-1871) succeeded in designing the world’s first computer during the middle of the nineteenth century—just about 100 years before the work at Bletchley Park.

Babbage’s Analytical Engine is thought by many to be the first design of a computer. The giant machine, using gears, axles, and pulleys, could be programmed (by punched cards) to perform computations many times faster than human operators. It is not known whether it had some sort of memory and, if so, what form that took.

Since Babbage did not succeed (as far as is known) in constructing a practical form of his design, the Science Museum is attempting to do this on the basis of the many drawings Babbage left behind. The Science Museum is undertaking the project as a tribute to Babbage on the two-hundredth anniversary of his death.

Roger Harrison
London University

Sir—It would have been informative to your readers if The INMOS transputer and OCCAM (EE, November, 1987) had included a note indicating the ingenuity of choosing the name OCCAM for the language in question. The name comes from William of Occam (c. 1285-c. 1349), an English philosopher best known for his doctrine non sunt multiplicanda entia praeter necessitatem (things should not be multiplied unnecessarily).

Dr. S. Whitehorn
Gloucester

Sir—I am writing to ask for an (admittedly subjective) assessment as to which of the two pre-amplifiers, Top-of-the-range (EE, Nov. 1986) or Valve (EE, March/April, 1987) sounds better.

Cameron Brook
Swanbourne, Australia

Sir—There has been much talk, and even more writing, over the past 18 months or so as to bigger and faster microprocessors. It is my, and many other chip designers’, belief that the recently introduced 32-bit chips will control the computing world for the next decade, perhaps even into the next century. The world does not (yet) need a bigger, but rather a faster microprocessor. Look at it this way. A 32-bit chip can address roughly $2^{32}$ bytes, and at present computing speeds (0.1 ns), it takes 620 seconds to access each of these. A 64-bit microprocessor would be able to address $2^{64}$ bytes. Even if the computing speed would be increased to 1 ns, it would take 506 years to access each of these addresses. That is why the big three, Intel, Motorola, and National Semiconductor have, at present, no intention of developing a 64-bit device, but rather look at more and better ways of exploiting the existing 32-bit designs.

Martin Callagher
Boston, Mass.

Sir—In your previous issue, the valve preamplifier is intended for dyed-in-the-wool valve enthusiasts.

Ed.

Sir—I must add my small voice in protest: stop publishing rubbish?

I look forward to reading in the near future some small comment published in your magazine which will set the record straight with regard to the above matters, and also show me that I have not wasted my time in writing to you.

In conclusion, I am quite sure that the original authors of both articles are aware of their mistakes, but it would be no difficult task for me (or many other people, for that matter) to furnish you or your readers with adequate proof of their most basic errors.

C.W. Pollard
Wellington Borough
Northants

As regards the article by T. Scherer, I admit that that contained some errors which should not have been published. Our difficulty at the time the errors were discovered was that Mr. Scherer (a contributor to our German sister magazine) had moved and could not be traced for comment. In response to your criticisms of the recent article, the author replies: “Your correspondent is, of course, absolutely right when he says that the radiation pattern is determined by the distance between the loudspeaker units. It is, however, also a function of frequency. When a cross-over network is added to a system, it may adversely affect the radiation pattern, and it is this that the phase-linear filter does NOT do. In other words, this type of filter does NOT affect in any way the natural radiation behaviour of a loudspeaker system. It is this latter aspect that was meant in the article: unfortunately, I did not specifically mention that, and I fear that this has given rise to the misunderstanding.” Ed.
Not so long ago, colored LED bars were welcomed as the more robust and fast replacement for moving coil meters in VU (volume unit) indication units. An additional, important advantage of the LED VU meter was that it enabled realizing the peak hold function. An additional, important, advantage of the LED VU meter was that it enabled realizing the peak hold function, which is useful, if not indispensable, for determining the recording level on tapes. The major drawback of the LED-based VU meter is its relatively high current consumption, which poses considerable problems in portable equipment. The VU meter described here is based on a liquid crystal display (LCD) with modest power requirements. The read-out is logarithmic with a scale of 60 dB, which is adequate for the dynamic range of, for instance, a CD player. The built-in peak hold function has an option for automatic reset after approximately 2 seconds. Wire links or jumpers make it possible to select dot or bar indication, but it should be noted that the peak hold function operates in the bar mode only.

The proposed LCD VU meter is composed of 2 units, namely a logarithmic amplifier and a linear LC display driver. The printed circuit boards for these have the same size to enable building a compact indication unit using a sandwich construction—see the introductory photograph and Fig. 1. The amplifier board holds 2 logarithmic amplifiers for stereo applications. Both the amplifier and the display board can, of course, also work as a separate module in applications other than those described here: the amplifier, for instance, is also suitable for driving a moving coil VU meter, which is arranged to display a linear dB scale. Similarly, the LC display board may be used as an indication unit in, say, an electronic thermometer.

Table 1

<table>
<thead>
<tr>
<th>i1</th>
<th>i2</th>
<th>DISPLAY MODE</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>X</td>
<td>dot mode; 18 steps</td>
</tr>
<tr>
<td>L</td>
<td>H</td>
<td>dot mode; 9 steps</td>
</tr>
<tr>
<td>H</td>
<td>L</td>
<td>bar mode; no peak value</td>
</tr>
<tr>
<td>H</td>
<td>H</td>
<td>bar mode; peak value, automatic reset</td>
</tr>
<tr>
<td>H</td>
<td>H</td>
<td>bar mode; peak value, reset: i2 = low</td>
</tr>
</tbody>
</table>

H = no wire link
L = wire link fitted
X = immaterial

The linear LC display
The circuit diagram of this part of the VU meter is given in Fig. 2. It would have been possible to use a single display driver chip with a suitable multiplexing circuit for the LCD, but this would have been at the expense of the peak hold function. The inputs of the relatively expensive driver ICs are protected against overvoltages by networks D1 - D2 - R5 and D3 - D4 - R6. Selection between the various available display modes is accomplished with the aid of wire links, jumpers or a switch as summarized in Table 1. The LCD board has only 4 inputs, which are readily connected to the respective points on the amplifier board—Fig. 3 shows the completed sandwich construction. The linear scale of the LCD gives a read-out which is directly proportional to the input voltages applied to points L and R, having between the voltage on the respective REF LO and REF HI input (0.5 and 4.5 V). The level of the supply voltage applied to the LCD board is governed by the maximum permissible supply for the LCD display (6 V), and the minimum supply level for correct operation of the driver chips (5 V).

The logarithmic amplifier
Figure 4 shows the circuit diagram of 1 of 2 identical logarithmic amplifiers, and the power supply for the VU meter. Opamp A1 raises the input signal and feeds this to a peak rectifier circuit. The logarithmic amplifier, composed of A2, A3 and matched transistors T2 and T3, is driven with Uic, which is directly related to the amplitude of the input signal. The matched transistors are housed in an IC Type CA3046.
The completed display driver board (l) and the logarithmic amplifier board (r) have the same size.

The 2 boards can be fitted in a sandwich construction to make the VU meter as compact as possible.

Fig. 2 Circuit diagram of the linear LCD driver.

The linear variation of the rectified input voltage is converted to logarithmic by means of an opamp with a feedback circuit that comprises a conventional bipolar transistor. Under certain conditions, the collector current of a bipolar transistor rises exponentially with the base-emitter voltage. Figure 5 shows how this phenomenon is exploited: the transistor forms the resistance in the negative feedback circuit of an opamp, which thus functions as an amplifier that translates its linear input signal into a logarithmic output.

The voltage transfer of this circuit is given as

$$U_0 = -\frac{kT}{q} \log e \frac{U_1}{I_{neR}}$$

in which $a$ is the current amplification of transistor $T$, and $kT/q$ at room temperature works out at about $26 \times 10^{-3}$. The weak point of this circuit is that the term $I_{ne}$ is strongly temperature dependent. Figure 6 shows a slightly more complex circuit whose voltage transfer is less affected by temperature variations. The voltage transfer of this circuit is

$$U_0 = \frac{(R_6 + R_9)kT}{q} \log e \frac{U_{IR}}{U_{neR9}}$$

The factor $kT/q$ is the same as in equation (1), while $I_{ne}$ has been eliminated, ensuring reasonable temperature stability. Compensation of $kT/q$ was found unnecessary for the given application, since it proved to have little effect on
the relatively low resolution of the LCD. Returning to the circuit diagram of Fig. 4, operational amplifier \( A_1 \) inverts the logarithmic voltage, so that the LC drivers receive a signal with the correct polarity.

The resolution of the display is fairly low at 18 bars. The logarithmic amplifier is dimensioned such that a variation of the input voltage of 3 decades results in an output voltage variation of 0.5 to 4.5 V. This corresponds to 1.33 V per decade. The full range then corresponds to a scale of 60 dB (-50...+10 dB) as shown in Table 2 and Fig. 7. Considering that \( 0 \) \( \text{dB} = 775 \text{ mV} \) on \( C_2 \), a dynamic range of 60 dB means that the minimum voltage for illumination of the lowest bar is 2.45 mV, which is about equal to the offset of the input voltage. It should be noted that the value of 775 mV on \( C_2 \) is not related to the definition of 0 dB as 1 mW (775 mVrms) in a load of 600 \( \Omega \).

The drive margin of the logarithmic amplifier is ensured by feeding it from the input voltage for the 5 V regulator, ICs. Resistors \( R_7 \) and \( R_s \) are dimensioned such that the output voltage of \( A_1 \) can not rise above the supply level of the LCD board.

### Construction and setting up

The components are fitted as per the directions in the parts list and Figs. 8 & 9. The LCD used is the type LTD-321-001 from Mullard/Videlec. The outer 2 bars of each row of 20 on this LCD are not used in the present application. The virtually symmetrical pinning of the display, in combination with the layout of the printed circuit board, make it possible to fit the display upside down also. The contrast of the LCD is maximum when this is viewed straight, or from one side. The display is fitted either normally or reversed—but always at the copper side—depending on whether it is to be viewed from above or below. It is recommended to use terminal strips for mounting the LCD. Take note of the position indicator, which is at the left side of the LCD when this is viewed in the normal position, i.e., facing straight or from below. The PCB should be held such that the EPS number is always upside down. In the normal position, the display (2 x 26 pins) is fitted as far as possible to the right-hand end of the terminal strips (2 x 28 pins). In the reversed position, the PCB is still held as stated before. However, the position indicator on the LCD is then at the right, and the LCD itself is fitted as far as possible to the left-hand end of the terminal strips.

**Table 2**

<table>
<thead>
<tr>
<th>Indication (dB)</th>
<th>( U_{(C2)} ) (mV)</th>
<th>( U_o ) (( A_1 )) (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>+10</td>
<td>2450</td>
<td>4.5</td>
</tr>
<tr>
<td>0</td>
<td>775</td>
<td>3.83</td>
</tr>
<tr>
<td>-10</td>
<td>245</td>
<td>3.17</td>
</tr>
<tr>
<td>-20</td>
<td>77.5</td>
<td>2.6</td>
</tr>
<tr>
<td>-30</td>
<td>24.5</td>
<td>1.83</td>
</tr>
<tr>
<td>-40</td>
<td>7.75</td>
<td>1.17</td>
</tr>
<tr>
<td>-50</td>
<td>2.45</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Preset \( P_1 \) is adjusted such that 0 dB corresponds to a direct voltage of 775 mV on junction \( R_7-R_s \). This results in 3.83 V at the output of the logarithmic amplifier, and illumination of 15 bars on the LCD. A different dB scale can be set up by redimensioning of \( R_7 \)...\( R_{10} \) inclusive. If the input signal has a DC component, blocking capacitor \( C_1 \) may be used.

**Fig. 4** Circuit diagram of the power supply and 1 of 2 identical logarithmic amplifier channels.

**Fig. 5** The most rudimentary form of the logarithmic amplifier.

**Fig. 6** This circuit is derived from that in Fig. 5, but is less affected by temperature variations.
is fitted with the corresponding polarity. The reset period of the peak detector is the product of $R_1$ and $C_3$. This period can be kept relatively short thanks to the fact that peaks in the input signal are already retained and displayed with the aid of the peak hold function. The input signal level can be adjusted with $P_l$. If necessary, $A_i$ can be dimensioned for a higher amplification by increasing the value of $R_3$. 

Fig. 7 Showing the position of the dB values on the face of the LC display.

Fig. 8 Track layout and component overlay of the LCD board (circuit diagram: Fig. 2). The LCD is fitted AT THE TRACK SIDE.

Fig. 9 Track layout and component overlay of the stereo logarithmic amplifier board (circuit diagram: Fig. 4).

Parts list

**DISPLAY BOARD** (Fig. 8):

Resistors ($\pm 5\%$):
- $R_1:R_2 = 1\,\text{k}\Omega$
- $R_3:R_4 = 1\,\text{k}\Omega$
- $R_5:R_6 = 10\,\text{k}\Omega$
- $R_7 = 12\,\text{k}\Omega$

Capacitors:
- $C_1:C_2 = 390\mu\text{F}$
- $C_3 = 100\text{nF}$

Semiconductors:
- $D_1: D_2 = 1N4148$
- $IC_1:IC_2 = HEF4754$

Miscellaneous:
- LCD = LTD - 321 - C01 (Mullard/Videlec; for distributors see Infocard 507 in the April 1987 issue).
- $K_1:K_2 =$ jumpers or terminal strips; $2 \times 3$ contacts.
- PCB Type 87505 (available through the Readers Services).

Available from Universal Semiconductor Devices Limited
- 17 Granville Court
- Granville Road
- Hornsey
- London N4 4EP. Telephone: (01) 384 9420. Telex: 25157 usdco g. Fax: 01 348 9425.

**STEREO LOGARITHMIC PREAMPLIFIER** (Fig. 9):

Resistors ($\pm 5\%$):
- $R_1:R_1 = 390\,\text{k}\Omega$
- $R_2:R_2' = 390\,\text{k}\Omega$
- $R_3:R_4:R_7:R_7' = 1\,\text{M}\Omega$
- $R_{10}:R_{10}' = 100\,\text{k}\Omega$
- $R_8:R_9:R_9' = 220\,\text{k}\Omega$
- $R_4:R_4' = 390\,\text{K}\Omega$
- $R_6:R_6' = 1\,\text{k}\Omega$
- $R_8:R_8' = 1\,\text{k}\Omega$
- $R_{12}:R_{12}' = 3\,\text{k}\Omega$
- $R_{14}:R_{14}' = 120\,\text{k}\Omega$
- $R_{16}:R_{16}' = 3\,\text{K}\Omega$
- $R_{17}:R_{17}' = 15\,\text{k}\Omega$
- $R_{18}:R_{18}' = 5\,\text{M}\Omega$
- $P_1:P_1' = 100\,\text{k}\Omega$ preset

Capacitors:
- $C_1:C_1' = 4.7\mu\text{F}; 16\,\text{V}$
- $C_2:C_2' = 22\,\mu\text{F}; 16\,\text{V}$
- $C_3:C_3' = 10\mu\text{F}$
- $C_4:C_4' = 680\mu\text{F}$
- $C_5:C_5' = 100\mu\text{F}$
- $C_6:C_6':C_7 = 10\text{nF}$
- $C_8 = 330\text{nF}$
- $C_9 = 100\text{pF}; 3\,\text{V};$ tantalum bead

Semiconductors:
- $D_1:D_1': D_2:D_2' = 1N4148$
- $T_1:T_1' = BC5578$
- $IC_1:IC_1' = LM3534$
- $IC_2 = CA3046$
- $IC_3 = 7805$

Miscellaneous:
- PCB Type 87520 (available through the Readers Services).
When we speak of British Aerospace, we normally think of Concorde and the company’s other work in aircraft production and engineering. But, in the first 10 years of its existence, this industrial giant has also become world renowned for its work in space engineering and electronics.

British Aerospace was born on 29 April, 1977, by the amalgamation of British Aircraft Corporation, Hawker Siddeley Dynamics, and Scottish Aviation, companies whose antecedents can be traced back to the dawn of powered aviation in the first decade of this century.

Lord Beswick was its first Chairman. He was succeeded in March 1980 by Sir Austin Pearce. This was the final year in which BAC operated as a nationalized corporation. On 1 January, 1981, the business was vested in British Aerospace PLC.

In 1983, Sir Raymond Lygo was appointed Managing Director of BAE, and in 1985, the year that BAE was fully privatized, he was appointed its Chief Executive. Today, BAE is the UK’s largest exporter of manufactured goods, with an order book approaching £10 billion. By comparison, the order book in 1977 stood at £2 billion. Then, sales were £800 million, of which £300 million were exports. Today, the respective figures are £3 billion and over £2 billion.

BAE has established itself as Europe’s largest aerospace company with the widest range of products of any such company anywhere in the world. Its portfolio of products stretches from underwater systems, through ship-launched missiles, ground-launched missiles, military aircraft and air-launched missiles, civil airliners and business aircraft, to satellites for communications and scientific research.

This position owes much to the substantial investment British Aerospace has made in developing a total product strategy, which is most evident in the launch of no fewer than six new civil aircraft programmes. Although British Aerospace consists of seven divisions, employing a stable workforce averaging 75,000 people, this article deals primarily with the activities of the Electronics and Equipment Division (3,200 personnel) and the Electronic Systems and Equipment Division (3,800 personnel).

Electronic Systems and Equipment Division

The Division produces a wide range of navigation and guidance systems for land, sea and aerospace use, plus data handling, message switching and electronic warfare systems. A new activity is the development of autonomous cargo examination systems. Avionic products include laser gyro, inertial navigation systems, strapdown attitude and heading reference systems, gyrocompasses, twin-gyro platforms, flight instruments, crash-protected flight data recorders and engine health monitors. Missile aerodynamic and rocket-thrust vector control systems are supplied as well as electro-hydraulic power units. Missile gyroscopes produced include the Microflex gyro.

Sea Archer gunfire control systems are supplied for naval ships. The Interceptor surveillance and gunfire control system for offshore patrol craft is offered. Compass equipment and vertical reference units for ships are also available. A field artillery battery computer is manufactured for the Swiss Army. Tilt sensors are supplied for tanks. Ajax is a sensor and fire control system for anti-armour off-route mines using LAW-type projectiles.

Data handling, message switching and disc memory systems are built. A Royal Navy main communication centre has been equipped with an advanced message switching system, and smaller message switching and formatting systems are made for naval vessels. An infra-red jammer for helicopters to counter infra-red missiles is available. Electronic warfare, electronic warfare simulation, electronic support measures, allied with experience in communications and message handling, provides the Division with a C4I capability.

Antennas and antenna systems are produced for aircraft, land vehicles and ground based use.

Space and Communications Division

British Aerospace is Britain’s leading space engineering contractor, and the Division is the largest organisation of its type in Europe. It has its headquarters at Stevenage where work on the design and construction of communications satellites is concentrated.

Com munications satellites in service for which the Division was prime contractor include OTS (now retired), Maracs, A and B, and ECS-1 and 2. The Division is responsible for a further nine communications satellites now under construction. These are ECS (2-off) Skynet 4 (3-off), Olympus and Inmarsat 2 (3-off). As principal subcontractor, the Division is also participating in the largest contract for communications satellites yet placed. It is to build Intelsat VI satellites. The Eurostar communications satellite is also marketed in association with Matra.

Other projects of the Division are HOTOL (horizontal take-off and landing launcher), and Space Platform, a free-flying vehicle to operate in conjunction with manned space stations. The Division also includes a major space engineering facility at Bristol concerned with scientific satellites and equipment, the development of solar arrays, and the Skylark sound.
European Communications Satellites

The European Communications Satellites (ECS) provide a European communications network for telephone, telex, business data, facsimile, and TV traffic. The programme calls for five satellites in all, of which ECS-1 and ECS-2 are in service. ECS-3 was lost because of an Ariane launcher failure in September 1985. ECS-4 was launched, together with RUSAT (an Australian communications satellite) in the early hours (BST) of 16 September last by Ariane 3. It is at present being tested before it is taken into service and will then be designated Eutelsat 1-F4. Its geosynchronous position will be 10° E. These satellites are operated by the European Space Agency for Eutelsat—the 20-nation assembly of European PTTs—and for the European Broadcasting Union (pan-Europe TV). They contain 12-14 transponders capable of handling up to 12,600 telephone circuits and two TV transmissions. Their power (1,200 W) is derived from 13.8 m-span solar arrays.

Maritime Communications Satellites (MARECs)

The role of MARECs is to provide global communications between ships and shore stations. MAREC-A was launched in December 1981 and is operating in geosynchronous orbit positioned over the Atlantic at 26° W. The first MAREC-B was lost in September 1988 due to a failure of the Ariane launcher. Its replacement was launched on 10 November, 1984. It is positioned in geosynchronous orbit over the Pacific at 177.5° E. The satellites have one 2 m diameter dish for ship-to-satellite communications in the 1.5 GHz and 1.6 GHz bands, and two horns for satellite-to-shore transmissions in the 4 GHz and 6 GHz bands. Power (750 W) is derived from 13.8 m-span solar arrays. MARECs are operated by the European Space Agency and used by INMARSAT—the multinational International Maritime Satellite Organization.

Olympus

Olympus satellites are large multi-purpose, high-power communications satellites with direct broadcast capabilities. Members of the Olympus family will vary in size and weight, and power-generation and communications facilities, according to the particular operational role for which it is required. The largest versions could generate 7.7 kW from solar arrays of 60 m span. Olympus satellites can be equipped with up to fifty 50 W transponders capable of handling 200,000 half-telephone circuits or the equivalent facsimile, telex, data, and TV transmissions, or up to 12 full-power direct broadcast TV services. Typical communications frequencies are direct-broadcast TV 11.7-12.5 GHz; specialized business services: uplink 14-14.25 GHz, downlink 12.5-12.75 GHz; high-power communications 20 to 30 GHz. Olympus-1 has a pre-operational direct-broadcast TV channel for Italy and a second steerable channel for experimental use by members of the EBU. It will be launched from Kourou, French Guiana, in the near future and be positioned in geosynchronous orbit at 16° W.

Under the leadership of the Space and Communications Division, an international consortium comprising Aerospatiale, Selenia-Spazio, Fokker, and Spar Aerospace will build Olympus communications satellites and market them worldwide.

Eurostar

Eurostar is a medium-size satellite, larger than ECS-class satellites, but smaller than the Olympus series. It can be carried by, and launched from, Space Shuttle Orbiters, or it can be one of two satellites launched by Ariane, being carried aloft on the Ariane's Spelda structure specially developed by BAE for dual-launch missions. Eurostar is the first product of Satcom International, a joint venture of BAE and Matra of France to design, build, and supply communications satellites on the international market. Eurostar can accommodate communications payloads up to 250 kg mass and supply them with 700 W RF power. Maximum power generated by its solar arrays is 3.2 kW.

Skyynet 4

Skyynet 4 is a series of military communications satellites for the UK armed forces. Its design is based on that of ECS with communications equipment operating in the X-band supplied by Marconi. Each satellite's 16 m of solar arrays
Intelsat, a consortium of over 100 nations, provides international communications services by satellite. Structures for the Intelsat III series were supplied in an association with this series of communications satellites dating back to 1966. Subsequently, BAe's involvement increased and it became the principal overseas contractor in the Intelsat IV and IVA programmes. BAe was also the only non-American contractor to supply equipment for the US domestic Comsat satellites developed from the Intelsat IV design.

BAe is the principal offshore contractor to Hughes for the Intelsat VI programme. Spacecraft structures, power electronics, cable harnesses, C and X band antenna reflectors, and the complete cradle for supporting and launching spacecraft from Space Shuttlles will be supplied for this programme. The C-band dish, three metres in diameter, is one of the largest antennas made from carbon fibre to be constructed for use in space. The antenna must withstand the harsh conditions of satellite launch and remain dimensionally stable in space, retaining its accurate profile, despite daily temperature changes from -150°C to +140°C.

**The Big Communicator**

The geosynchronous orbit in which communications satellites are positioned is already becoming crowded. This is especially true of sectors in which satellites are placed to cover specific geographical areas generating high volumes of communications traffic, such as Europe and North America. The demand for communications services provided by satellites is increasing and within the next 15 to 20 years the network could be saturated unless some technological solutions are found to expand the available capacity.

Following studies of the problem, one answer proposed by British Aerospace is to establish clusters of satellites at particular orbital stations. The separate satellites forming a cluster would be dedicated to fulfilling different roles. An initial cluster could comprise three satellites. One to provide direct broadcasting services, a second communications with mobile vehicles, and a third communications with fixed ground stations. As the traffic associated with a particular region increased, extra satellites of the required type could be added to a cluster to provide the extra facilities needed.

All the satellites of a cluster would be able to intercommunicate, information being relayed between them via laser links to avoid interfering with the communications traffic between the satellites and Earth. Laser links would also be employed to relay communications between adjacent satellite clusters. This would enable a connection to be established directly between two users on different continents, situated remotely from each other without the need for multiple Earth-satellite-Earth hops to be set up as is now the case.

This concept of satellites operating in clusters has been named the Big Communicator by British Aerospace. The geometry of Big Communicator satellites differs from present-day satellite designs. With the latter, if it is a three-axis stabilised spacecraft, the solar arrays are aligned North to South. In contrast, the solar arrays of the equivalent Big Communicator satellite are aligned East to West and remain fixed pointing at the Sun. They are attached to an open framework which comprises the outer body of the satellite. Mounted on bearings inside this framework is a drum that contains the satellite's communications equipment and other systems. The communications antennas are deployed from one end face of the drum, the rotation of which is controlled so that the antennas always point towards Earth. One advantage of this layout is that the drum is shielded by the solar arrays from the direct rays of the Sun. Better heat dissipation from the interior of the satellite is also obtained through the drum's ends which permanently face outer space.

**Fig. 5. Big Communicator satellite clusters.**

Giotto

Launched on 2 July 1985 from

**Fig. 6. Giotto - the Halley's Comet spacecraft.**

**Fig. 7. Columbus space platform.**
Kourou by Ariane 1. Giotto was initially placed in a geosynchronous transfer orbit, following which it was boosted into a heliocentric trajectory to intercept Halley's Comet. Giotto intercepted Halley's Comet during the night of 13 March 1986. Conditions became increasingly hostile during the encounter. Giotto penetrated the dust cloud surrounding the nucleus and because Giotto and Halley's Comet orbit the sun in different directions, this occurred at the very high relative velocity of 88 km/sec (about 150,000 mile/hour).

Giotto's mission was the most successful space science event of 1986. Of the five satellites sent to observe the comet, Giotto made the closest approach, passing within 608 km (378 miles). Close-up photographs relayed back to Earth by Giotto show a potato-shaped object measuring 16 km by 8 km by 7.2 km. The nucleus is very porous with a density less than that of water. The comet rotates once every 53.6 hours and has a very dark surface that reflects only 3% of the incident sunlight. The pictures taken by Giotto show clearly a number of active areas from which masses of gas and dust are continuously ejected. Evidence indicates that Halley's Comet consists mainly of water (80%), with carbon dioxide as the next most abundant compound. Other experiments carried out by Giotto measured the chemical composition, size and abundance of dust grains, and the surrounding atmosphere of electrically charged particles. Giotto continues in orbit and will arrive back in the vicinity of Earth in 1990, when it may be given another scientific task to perform, such as intercepting Comet Grigg-Sjellerup in 1992.

**Ulysses**

BAe has developed attitude and orbit control equipment and the 1.6 metre high-gain antenna for Ulysses, the European satellite to be used for the deep-space International Solar Polar Mission. During the 4.5 years of this mission, the satellite will use the gravitational pull of Jupiter to swing it out of the ecliptic plane over the poles of the Sun. The satellite's mission is to investigate the solar wind and solar magnetosphere, the structure of the sun/wind interface, the interplanetary magnetic field, solar and galactic cosmic rays, and dust. The magnetosphere of Jupiter will be examined in the way.

**Hipparcos**

Hipparcos is being built for ESA and is Europe's first astronomical satellite. It will accurately measure the positions and proper motions of more than 100,000 stars.

BAe is supplying the power system and electrical distribution network and, with Matra, the attitude and orbit control units for the satellite.

Hipparcos has a design life of 2.5 years and is scheduled to be launched by Ariane in the course of next year.

**Hubble Space Telescope**

The Hubble Space Telescope will enable objects to be observed that are over seven times further away than can be seen with terrestrial telescopes. The universe accessible to telescopic observation will be increased by the huge factor of 350, and objects 14 billion light years distant will be seen.

Under contract to the European Space Agency (ESA), (BAe) designed and built the solar arrays for the NASA/ESA Hubble Space Telescope to be launched into orbit by a Space Shuttle. These are the largest solar arrays to be constructed in Europe. The total area of the two arrays is 60 sq metres. (Further details are given on entry on Solar Arrays).

BAe has also developed and made the ultra sensitive Photon Detector Assembly (PDA), which is the sensor of the faint object camera, one of the five focal plane experiments associated with the Hubble Space Telescope. The PDA detects individual photons emanating from the object under observation so that a visual image of the source can be built up revealing objects 50 times fainter than those now visible from the Earth.

**Space platform**

Space Platform is a British aerospace concept that was proposed by Britain and adopted by the European Space Agency as one of the four major projects in the European Columbus programme which could be part of Europe's contribution to the manned space station being developed by NASA. The Platform would provide the station with an equipment carrier, controlled to operate with it, but at a sufficient distance for the Platform not to be affected by the contamination and clutter surrounding the station, or to impede visiting traffic. Whenever required, Space Platform could be manoeuvred to dock with the station. As a free flyer, the Platform could be placed in a polar orbit for earth observation applications or be controlled to co-orbit with the space station. It could also fly at higher or lower altitudes than the station, depending upon the requirements of the equipment being carried.

Space Platform is a vehicle that can be replenished and, if necessary, refurnished in orbit to act as a permanent satellite bus in space. The Platform would provide all the services required for a variety of payload modules. These would be carried up from Earth by Space Shuttle, or a similar reusable launch system, and attached to the Platform. At the conclusion of their missions, the modules would be retrieved and returned to Earth.

Typical payloads would be communications equipment, astronomical instruments, earth observation sensors, material manufacturing systems, biological experiments and other scientific equipment. The main structure of the Platform and all the systems could be carried up to low-Earth orbit and assembled there during one Space Shuttle mission. During a second mission the payload modules would be added. The Platform has its own propulsion system which would be used to move it into the desired orbit.

Space Platform is designed to be extendable. Initially the Platform could, typically, have four payload module berthing points, generate up to 3kW electrical power, have a fully active cooling system and a data communications link, via a data relay satellite, operating at
up to 300 MBPs. It would orbit at altitudes between 600 and 8000m.

**Hotol**

Hotol (horizontal take-off and landing launcher) is an unmanned reusable single-stage vehicle for placing spacecraft in low-Earth orbits. It will be capable of lifting payloads up to 7000kg mass transported in a cargo bay 4.5m in diameter by 9m long. In effect, Hotol is an unmanned aircraft powered by an air-breathing and rocket propulsion system. It can take-off and land-on runways from which the Concorde could operate.

It is proposed as a more economical vehicle than the Space Shuttle for the task of launching spacecraft. Hotol can lift loads similar to those carried currently by Ariane, and would provide Europe with the facility it needs both to remain competitive with the US Space Shuttle in the future, and to retain its general capability in space.

The reasons Hotol will be able to operate at a lower cost than Space Shuttle or other conventional launchers are:

- It uses atmospheric oxygen as fuel during the initial flight phase resulting in a great saving in the all-up weight of the vehicle at take-off. Currently all spacecraft are launched by rocket-powered vehicles using fuels in which the oxygen content can account for as much as 85% of the total fuel weight at take-off. Fuel weight at take-off can be greatly reduced by using a combination of air-breathing and rocket propulsion to provide power. Hotol's air-breathing engines drive it to Mach 5 at 26km (85,000ft) altitude before rocket power is required.
- It is unmanned and, therefore, from the engineering point-of-view is a much simpler and less costly vehicle to design and build.
- It is completely reusable having no costly expendable parts such as boosters, or external fuel tanks.

Hotol could be built and operational by the early years of the 21st century. Later versions could carry men into orbit to service space platforms or other equipment in low-Earth orbits. £3 million, contributed equally by the British Government and industry, has been allocated to fund a proof-of-concept study of Hotol. The study will last up to two years.

**Skylark**

Skylark is a sounding rocket for space research supplied by BAE. It can carry experiment payloads to altitudes of 1000km and is being used by the West German Space Agency, DFVLR. The first Skylark rocket was launched in 1957. To date 400 have been launched from ranges around the world in various research programmes. One of these is the West German Texus project in which the nature of materials under microgravity conditions is being investigated.

Depending upon the payload carried and the version of Skylark used different space missions can be performed. Payloads from 100kg to 400kg in weight can be carried to altitudes ranging from 150km to 1000km. The useful time available for microgravity experiments can be eight minutes, with significantly longer periods available for extraterrestrial research projects.

**Ariane**

BAE designed and installed the Ariane hold-down release systems used on the launch platform at Kourou, French Guiana. BAE also supplies a variety of high technology products for Ariane including the auto-pilot electronics unit, solenoid valves, gaters and carbon-fibre struts for gimbalizing the engines of the second stage.

A second launch-pad hold-down release system was installed in 1984 for Ariane 3, and a third system has been built ready for the first Ariane 4 mission in 1986. BAE is also building the Spelda structure which will enable Ariane 4 to carry and launch two satellites during the same mission.

**Spelda**

Spelda (structure porteur extérieur pour lancement double Ariane) is part of Ariane 4's payload-bay primary structure. Available in two versions — short (3.28m, 346kg) and long (4.78m, 393kg) — Spelda is a cylindrical structure 3.97m in diameter with a truncated conical upper section. One satellite is carried on a mounting ring fitted to the top of the conical section, and the second satellite is enclosed within the cylindrical portion. After the Ariane 4's nose cone is jettisoned, the top satellite is released then a pyrotechnic line charge splits Spelda in two around its circumference and the upper section is propelled away by a pre-compressed spring system leaving the second satellite free to be released into orbit.

Spelda can accommodate two Class 1 or Class 2 satellites of between 800 and 1400kg mass each.

Spelda is of monocoque sandwich construction comprising an aluminium honeycomb core bonded to multi-layer carbon-fibre skins, with outer glassfibre layers covered with aluminium foil.

BAE designed Spelda and has completed two engineering development models and the first flight unit which is to be used on the first Ariane 4 mission scheduled for July 1986. Work has begun on a further five production Speldas required for the initial series of Ariane launchers.

**Satellite launch cradles**

BAE has built and delivered a reusable cradle for carrying and launching Hughes Leasat military communications satellites directly into space from the cargo bay of a Space Shuttle Orbiter. A Leasat satellite weighs 6000kg at launch. The cradle is a primarily aluminium structure weighing 780kg. It is 2m wide and measures 5m across its open face.

BAE also has the task of designing and supplying reusable support cradles for carrying and launching Intelsat VI series communications satellites from Space Shuttle Orbiters. Intelsat VI satellites weigh 3500kg at launch.

**Spacelab shuttle pallets**

As a member of the nine-nation Spacelab consortium BAE was responsible for the design and manufacture of Spacelab Shuttle pallets — large structures (height 2.24m, width 4.35m, length 2.93m) that act as platforms on which unmanned experiments are mounted for carriage in the cargo bays of NASA Space Shuttle Orbiters. Up to 4130kg weight of experimental equipment can be carried on a pallet. Eighteen Spacelab pallets have been manufactured and delivered.

A pallet equipped with five OSTA-1 experiments was carried in the cargo bay of NASA's Orbiter Columbia in November 1981 during the second Space Shuttle mission and another with OSS experiments was carried on the third mission in March 1982. A pallet formed part of the manned Spacelab assembly which was carried into space for the first time in November 1983 aboard NASA's Orbiter Columbia. Two pallets were used in the recovery of space of the Palapa and Westar satellites by Space Shuttle Discovery in November 1984, and a three pallet 'train' formed part of the Space Shuttle Challenger Spacelab 2 mission in July 1985.

Half and quarter-length pallets have been designed, and a study has been completed for a proposal to use Spacelab pallets as autonomous general-purpose free-flying spacecraft.
Solar arrays
For the past 20 years, BAe has built solar arrays and deployment mechanisms for a number of spacecraft. These have included the Ariel 3, 4 and 6, X-3 (Prospero) and X-4 (Miranda), and Cos-B scientific satellites. Twelve solar array sets were provided for Intelsat IV and IV A communications satellites, and four sets for the American Comsat satellites.
More recently, BAe has been developing the flexible roll-out arrays having a total area of 60sq m for the NASA/ESA Hubble Space Telescope. Each wing of this array measures 11.82m (span) by 283m. The complete array comprising some 48,760 silicon solar cells, weighs 160kg and generates 6kW at the beginning of its life in orbit.
The arrays are unreel from drums and deployed automatically either side of Space Telescope. A duplicate drive and duplicate wiring is provided. Provision has also been made for the arrays to be unraveled manually by astronauts using special tools. The arrays can be deployed and retracted independently and also repositioned in space, the dismounted arrays being returned to Earth for refurbishment.

Spacecraft assembly hall
In 1984 a new spacecraft assembly hall was completed. This new facility was established to enable the larger satellites now being developed to be assembled at Stevenage. At any one time as many as four satellites can be under construction in the hall. Satellites currently being assembled include the Olympus-1 large multi-role communications satellite for ESA, and Skyset 4 military communications satellites for the UK Ministry of Defence.
The assembly hall is a windowless building 27m (88ft) long, 27m (88ft wide) and 11m (36ft) high. It has two hydraulically powered platforms, each 7.5m (25ft) square, which can be lowered 4.5m (14ft) below floor level permitting satellites over 12m (40ft) tall to be built. Class 100,000 cleanliness conditions prevail, and the temperature is maintained at 20°C ± 1°C with relative humidity at 45% ± 5%. The steel framed building provides limited electromagnetic protection and the floor is electrically conductive to prevent residual electric charges accumulating. Electromagnetic compatibility tests can be conducted on satellites in the hall. In an adjacent room are four computer-controlled checkout stations used for testing satellites and their equipment at various stages in their construction.

Spacecraft equipment
BAe has built power-conditioning equipment for more than 30 satellites, stabilisation systems for both spinning and three-axis stabilised satellites, and has developed and tested reaction and momentum attitude control wheels. BAe supplies a range of solar array drive units capable of supporting producing up to 6kW per driveline.

Instrumentation sensors produced include sun sensors orienting solar arrays, a sensor for detecting microwave emissions from sea surfaces, and an infra-red radiometer which was installed aboard the American Nimbus 7 advanced atmospheric research satellite to monitor energy output from the Earth's upper atmosphere.

Utilizing the hardened version of the Texas Instruments 999399 microprocessor, BAe has built a spacecraft microcomputer module (SMM) for general use in satellite systems requiring data processing services. Up to 64 SMMs can be linked together, if required. Software needed to control the operations of SMMs is available. The SBP 9999 was selected as it is bipolar FL device resistant to radiation damage.

Forced to compete for the long-distance market with lower-priced carriers like MCI/SS and US Sprint, AT&T has nevertheless kept more than 70% of that market. In this and other areas where AT&T has always been strong, it remains strong. But how well can the company use its traditional strengths to offset weaknesses in such areas as computer products where it has less experience?
Frost & Sullivan's report AT&T Market Strategy to 1991 (# A1823) says that the company's strategy looks to boost its revenues and modest earnings by cost cutting, by more capital spending to strengthen core businesses, by increasing its efforts in the international markets, and by continued efforts to get federal authorities to remove the cap from what AT&T can earn from long-distance service (efforts the report predicts will succeed).
AT&T is not modest about its long-term goal. It simply wants to be the world leader in the integrated management of voice, data, and video information. Moves to achieve this goal range from internal restructuring to joint ventures abroad with strategic overseas partners (e.g., Philips in the Netherlands; Korea's Lucky Goldstar group; 17 companies in Japan; the National Telephone Company of Spain; and a 25% equity stake in Italy's Olivetti).
AT&T is pushing to make ISDN a reality, providing one transmission path and one telephone number for speech, data, text, and image worldwide. It supports international standards (which reduce design and manufacturing costs) and open architecture for systems (which ensures the longevity and usefulness of AT&T equipment). AT&T's fibre optic network, 10,000 miles at the end of 1986, is expected to grow to 1.4 billion miles by 1990 and to be 50% digital by then.
In the computer business, where AT&T has suffered heavy losses, the company is now stressing data networking and positioning itself to compete in the communications market for small and medium-sized computers. Computer revenues by 1991 are expected to lead all product revenues ($2.8 billion for computers, followed by $2.7 billion for central office switches, and $2 for PBX sales).
The field of electronic test and measuring equipment is large and still growing. Although not so long ago even an electronics engineer could get by with a multimeter, an oscilloscope, and a signal generator, nowadays even a small laboratory or workshop is equipped with an array of general purpose instruments, such as multimeters and power meters, various signal generators, a frequency counter, distortion meter, wave or spectrum analyser, and one or two oscilloscopes. In many cases, this is complemented by an LCR meter, Q meter, waveform recorder, a storage oscilloscope, and others.

To help readers find their way in this sometimes bewildering variety of equipment, we start this month a regular series of reviews of such equipment. Since the oscilloscope, after the multimeter, is probably the most frequently used instrument in an electronics environment, the series is started with a review of a number of dual-trace oscilloscopes.

The author of the series is Julian Nolan.

Hitachi V-212

Hitachi is a Japanese company which is perhaps best known for its consumer products, especially in the video and hi-fi fields. The V-212 is one of a comprehensive range of oscilloscopes manufactured by the company, covering from the V-053C, a dual trace 5 MHz ultra compact scope, to units such as the VC-6155, a 100 MHz DSO. The V-212, which can be purchased for £320 +VAT, is the dual trace version of the cheaper V-211. The accessories available include carrying cases, rack mounting kits, and viewing hoods. High-quality probes are also available, but at £27.50 each (x10/x1) it is well worth considering alternatives such as the Cline range of modular probes, which start at £13.66 (x1); the switchable x1/x10 version costs £17.84.

High voltages, x10 probes have to be used, especially in the dual trace mode to prevent over-scanning of the trace. Although not restricting the versatility of the instrument, it can cause a small amount of inconvenience; a 20 V/div range as fitted to many instruments would have helped solve this problem. A x5 magnifier control extends the range of the Y amplifiers to 1 mV/div; by x5 control, increases error by 2%. Min sensitivity 12.5 V/div; variable control; fully anti cw.

The packaging of the V-212 takes into account the instrument

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**Table 1. Specification**

**ELECTRICAL CHARACTERISTICS:** — Protection class 1.
- Line voltage: — 110, 120, 220, 240 VAC ± 10%, Externally adjustable. Power 30 Watts. Line frequency 50, 60, 400 Hz
- Input coupling: AC, DC or Gnd.
- Input impedance: 1 MQ!25 pF; Max input voltage 300 V (peak including DC voltage), or 500 Vp-p AC at 1 kHz or less.

**MECHANICAL CONSTRUCTION**
- Dimensions: — W 310 mm, H 130 mm, D 370 mm
- Housing: — aluminium sheet
- Weight: — approx. 6.5 kg

**Y AMPLIFIER ETC.**
- Operating modes:
  - CH 1 alone.
  - CH 2 alone or inverted alternate or chopped (250 kHz) CH 1/CH 2.
  - CH 1 = CH 2.
- Frequency range 0...20 MHz (—3 dB). Decreases to 7 MHz at 1 mV.
- Risetime = 17.5 nsec.
- Deflection factor 10 steps: 5 mV/div...5 V/div ± 3% extends to 1 mV/div; by x5 control, increases error by 2%. Min sensitivity 12.5 V/div; variable control; fully anti cw.
- Input coupling AC, DC or Gnd.
- Input impedance 1 MΩ/25 pF; Max input voltage 300 V (peak including DC voltage), or 500 Vp-p AC at 1 kHz or less.

**X-Y MODE**
- CH 1 X-axis, CH 2 Y-axis. X Bandwidth DC to at least 5 MHz.
- Less than 3° phase shift at 50 kHz.

**TIMEBASE**
- Deflection factor 0.2 μsec/div...0.2 sec/div ± 3% with 1/2/5 divisions.
- Expansion x10, extends max. timebase speed to 20 nsec/div;
  - expansion error ≤ ± 2% extra.
- Uncalibrated control full cw extends range to 0.5 sec/div.

**TRIGGERING**
- Trigger modes: — Auto (bright line), Normal, active TV (line and frame) sync.
- Trigger coupling: — AC only.
- Trigger sources: — CH 1, CH 2, Alternate Line, Ext.
- Triggering slope: — positive or negative, switchable.
- Triggering sensitivity: — Internal ≤ 15 div at 20 MHz, External ≤ 500 mV at 20 MHz, Normal mode.

**MISCELLANEOUS**
- CRT make Toshiba, measuring screen 100 x 80 mm, accelerating voltage 2 kV; beam rotation by front panel adjustment.
- Compensation signal for divider probe: amplitude approx. 0.5 Vp-p (—3%), frequency 1 kHz.
- Z modulation 5 Vp-p noticeable modulation; Max input voltage 30 V (DC +, peak AC).
- CH 1 output at least 20 mV/div to 5 MHz.

Covered by 2 year warranty.
ment's very compact design, and the cardboard box in which it is packed is, therefore, not much bigger than the instrument itself, which is held securely in place with poly-


styrene cutouts. On inspection, the Hitachi turned out to be a relatively small at 310 mm (W) x 130 mm (H) x 370 mm (D). The absence of the normal swivel stand adds to its compactness. A small one-position stand is fitted to the underside of the instrument to facilitate tilting, and for those who require the scope to be easily portable there is a carrying strap on one of the side panels. One advantage of the small stand is that it can easily be tucked under the scope, thus making the stashing of other pieces of equipment above or below the scope possible. The V-212 is supplied with a good length of mains lead, connecting to the scope via a standard IEC socket. Power consumption is low: only 30 W at 240 V. Unusually, the scope is also equipped with a vertical signal out BNC socket, which provides at least 20 mV/div into 50 Ω.

The specifications are shown in Table 1. From these it can be seen that the maximum Y amplifier sensitivity is an excellent 1 mV/div, while the minimum is 5 mV/div (calibrated) or approx. 12.5 V division (uncalibrated). When measuring relatively deep, increases the versatility of the Y amplifiers throughout the range, providing a calibrated step outside the standard 1-2-5 sequence, i.e., in a 2-4-10 sequence. This does however introduce a ± 2% increase in Y amp error, bringing the total to a maximum of ± 5%. Putting this into perspective in relation to, say, a waveform of typical total deflection of 40 mm, it may be that with even a ± 5% Y amp error, a total deflection error of more than ± 2 mm is unlikely to be generated. In the x5 mode, however, the Y amps are limited in bandwidth to 7 MHz (-3 dB). On the whole I did not find this restriction limiting as the full bandwidth is still usable at 5 mV, at which sensitivity the Y amps performed very well at their maximum bandwidth, being well inside their -3 dB specified limit. The input amps also exhibited practically zero drift during their warm up.

Fig. 2. Close-up of V212 controls

<table>
<thead>
<tr>
<th>TABLE EXPLANATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRIGGER FACILITIES—The triggering facilities offered by the scope, eg alternate triggering, TV sync, auto trigger, etc.</td>
</tr>
<tr>
<td>TRIGGER PERFORMANCE—is an indication of how well and easily the scope triggers on a wide variety of waveforms, as well as the maximum triggering frequency.</td>
</tr>
<tr>
<td>CRT BRIGHTNESS—This is an indication of the brightness available on a fully triggered waveform at the maximum deflection speed. Note: some scopes have internal brightness presets, setting the maximum and minimum brightness, this is not taken into account.</td>
</tr>
<tr>
<td>CRT FOCUSING—The standard of the focusing over the whole range of deflection speeds and display modes.</td>
</tr>
<tr>
<td>Y AMP PERFORMANCE—An indication of the maximum sensitivity of the Yamp, along with its performance across the bandwidth.</td>
</tr>
<tr>
<td>INTERNAL CONSTRUCTION—This rating assesses the scope's internal construction, the main criterion being the quality of the PCBs and other components, the general neatness and layout with a view to servicing and the mechanical robustness.</td>
</tr>
<tr>
<td>EXTERNAL CONSTRUCTION—The strength and quality of the materials used, along with the finish are among the criteria here.</td>
</tr>
<tr>
<td>OVERALL SPECIFICATION—This takes into account other features which may be provided on the scope, such as trigger hold-off or a third channel, as well as the general specification of the scope.</td>
</tr>
<tr>
<td>EASE OF USE—This assesses the general layout of the controls, and ease of use for a first time user, and not the ease of operation of the range switches etc.</td>
</tr>
<tr>
<td>MANUAL—Takes into account the actual information included in the manual which is likely to be useful to the user.</td>
</tr>
</tbody>
</table>

The vertical modes of the V-212 are fairly standard, including alternate and chopped (250 kHz) modes for dual trace operation. Only one channel (2) of the V-212 is invertable for subtraction purposes, this being implemented, as are some of the other functions, by pulling an associated control (in this case CH 2 position) to its out position. This does have advantages in that it helps provide an uncluttered layout, but it also means that when this 'secondary' function is operated, it is very easy to offset the 'primary' function from its original value.

Triggering on the Hitachi is of a very high standard, incorporating the usual feature of an alternate channel triggering mode. This permits stable, fully triggered traces to be produced in either dual trace mode from two non-synchronised sources, as each channel is triggered independently. This is invaluable for taking measurements where more than one signal source is being used within a circuit, and is also helpful for single trace measurements, enabling the stable display of either channel without having to manually alter the triggering channel. Active TV frame and line triggering are also provided on the V-212, making triggering on video signals an easy task. The performance of this was good, triggering even at very low levels and over an acceptable range of line and frame frequencies. Two notable exceptions from the V-212's triggering facilities are HF and LP coupling, and although it is possible to get around this problem when these functions would normally be required by fine adjustment of the triggering threshold, the necessary filters would have made operation easier. Selection of the triggering criteria is made by a number of lever operated switches, making for fast, reliable and convenient operation of the scope. Trigger sensitivity was satisfactory at 5 mm initially and 800 mV externally in the 20 Hz to 2 MHz range, increasing to 10 mm internally and 800 mV externally in the 2 MHz to 20 MHz range. Generally the triggering performance was very good, with the alternate triggering being a particular bonus: this is nor-
mally only found on models outside this price range. A stable trace was produced in nearly all cases; the trigger threshold control did, however, prove to be sensitive and it was very easy when pulling this control out (for triggering on the trailing edge of a signal) to offset it outside the triggering threshold, thus causing the timebase to free run, producing an unlocked trace.

Maximum timebase speed is 200 ns/div; this is however extendable to a maximum deflection speed of 20 ns/div (not 100 ns/div as stated in the manual) by means of a x10 control, although naturally this is at the expense of trace intensity. Speed selection is by means of a 19-position rotary switch. The minimum speeds being 0.2 s/div (calibrated) or roughly 0.5 s/div (uncalibrated). On the maximum deflection speed of 20 ns slight defocusing occurs towards the end of the trace, which is unfortunate, because for the remaining speeds focusing from the Toshiba tube is excellent for a 2 kV acceleration voltage. Despite this, the performance of the scope in this area is particularly good, many of its rivals not offering a 20 ns/div sweep speed, although, as I have said, accurate measuring over the last third of the trace at this speed is limited by the 2 mm wide trace over this area. The screen itself is filtered a sky blue and has full graduation for risetime measurement. The V 412 is equipped with Z-modulation and CH 1 vertical signal output facilities; the BNC connectors for both these functions are mounted on the back panel. For noticeable intensity modulation a 5 V p-p signal is required, the input bandwidth for this function going up to 2 MHz. The CH 1 output on the other hand provides a buffered output from channel 1 which could be used to drive, for example, a counter/timer, thus providing an accurate readout of frequency, etc.

Aluminium plays an important part in the V-212's construction, both the outer housing and frame are manufactured from this, which contributes to the scope's light weight of 6.8 kg. Plastic is used for the front fascia surround, and this could prove to be fragile, especially around the top corners if the scope is used in rugged conditions. Robust feet/cable holders are featured on the rear panel and protect the instrument to a large extent from any damage which may occur if, for example, the instrument is dropped while being carried. In contrast to many other scopes, the all the controls have a very positive and fairly light action, making for easier, more precise operation. Some, however, notably the Y amplifier fine controls, protrude a good distance from the front panel, making accidental damage more likely in the event of a fall. My only major criticism of the Hitachi, if it can be called that, is the internal construction. The main circuitry is mounted on two PCB's of equal size, but larger components, such as voltage regulators, etc., are mounted on the chassis itself for good heat dissipation. This wide variety of mounting points coupled with the three remaining PCB's housing the tube base, etc., necessitates the use of a large number of wire connections and links, giving the inside of the Hitachi an appearance not dissimilar to one of the company's tapes. All of the interconnections appear to be of a very high quality, however, and have been assured by Hitachi that the number of interconnections in no way affects the reliability of the scope. This is proved by the fact that Hitachi oscilloscopes using the same construction technique are offered for hire by some of the electronic equipment rental companies, where reliability is obviously at a premium.

Ignoring the number of interconnections, internal construction was generally good; the large number of connections making the mounting of high power dissipation components on the subframe possible. The internal construction itself is extremely compact: the two main PCBs are mounted horizontally above one another at the front of the instrument. Unlike the Y amplifiers, the CRT section of the circuit is completely shrouded, thus helping to prevent the build up of dust, as well as helping to prevent any possible shock should be outer housing be removed.

Not surprisingly, most of the semiconductors are manufactured by Hitachi themselves; other components come from a variety of manufacturers and are fairly standard, ranging from miniature resistors to the industry standard 78 and 79 series monolithic fixed voltage regulators. The 36 page manual contains a number of detailed sections, among which how to set up to scope initially, and a particularly good section on measuring procedures. There are no sections on calibration or servicing, and the roughly A5 size of the manual makes the circuit diagrams small and difficult to understand as they are spread out over a number of pages. There is also no circuit description. Overall, although containing some good sections, the manual missed out on several important points and could have been accurately summarized in a considerably shorter space.

**Conclusion**

The Hitachi V-212 is generally a

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**Other Hitachi scopes under £1000**

**20 MHz**

V-222: As V-212 plus alternate magnify, swivel stand, scale illumination, uncal. indicators. Probes are also included. £395 + VAT.

V-223: As V-222 plus sweep delay, 1 usec to 100 msec. £450 + VAT.

V-225: As V-223 plus on-screen cursor measurement of voltage and time difference. £550 + VAT.

**40 MHz**

V-422: As V-222 plus signal delay line. £580 + VAT.

V-423 and V-425: As V-223 and V-225 respectively, but with increased bandwidth. V-423: £650; V-425: £695.

**60 MHz**

V-650F: Similar to V-422 + dual timebase, trigger view, delay multiplier: £780 + VAT.

**PORTABLE**

V-209: 1 mV sensitivity 3.5” tube, lightweight miniature format, battery/mains, NiCd batteries included : £680 + VAT.
The company of Crotech was formed in 1981, and now designs a wide range of test equipment from frequency counters to signal generators. The 3133 is one of a range of six oscilloscopes manufactured by the company. The range extends from the single trace 3031 at £159 to the 3339 which features a 30 MHz bandwidth, as well as a VDU mode, enabling the scope to act as a monitor, at £570. The new 3133 is priced at a competitive £319. The 3133, which replaces the 3339, is unique in its price range in that it incorporates a component comparator and a power supply outlet in its design, and has a bandwidth of 25 MHz (−3 dB). Probes are also supplied, but these are of the ‘crocodile clip’ x 1 design, so their usefulness for RF work is limited. A x1/x10 probe may be purchased as an optional extra, along with a light hood and trolley.

The 3133 is somewhat unusual in its layout, with the CRT situated in the centre of the scope and the Y-amp and timebase/trigerring controls positioned at either side of it. This gives the scope the average size of 330 (W)x395 (D) mm, although the height is somewhat higher than normal at 165 mm. The weight of the 3133 is also on the somewhat heavy side at 8.5 kg. A three position swivel stand is fitted, which, given the external graticule of the tube, is just as well, since it enables the scope to be positioned to minimize the small parallax error. Mains connection is by means of a fixed lead, i.e., no socket, which is a pity, since it is of only average length so that in some cases it may be necessary to extend its length. As I have already mentioned, the 3133 incorporates some rather unusual features, these in the main being the power supply, component comparator, and the more common trigger hold-off facility. The front panel layout is fully colour coded, and this should make first-time operation no problem, as well as contributing very significantly to the scope’s ease of use. Most of the functions are selected by a series of push-button switches, which are arranged in four groups: CH1 input coupling; CH2 input coupling; Display mode; and trigger functions etc. While these provide an easily identifiable, and in some ways more flexible, method of function selection, I found that operation is perhaps slightly more time-consuming than the more usual ‘slider’ type switches.

Table 3. Specification

<table>
<thead>
<tr>
<th>ELECTRICAL CHARACTERISTICS</th>
<th>MECHANICAL CONSTRUCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line voltage: 115, 220, 230, 240 VAC, Internally adjustable</td>
<td>Dimensions: W 330 mm, H 165 mm, D 395 mm</td>
</tr>
<tr>
<td>Power: 40 Watts</td>
<td>Housing: aluminium sheet</td>
</tr>
<tr>
<td>Line frequency: 27-65 Hz</td>
<td>Weight: approx. 8.5 kg</td>
</tr>
</tbody>
</table>

Y AMPLIFIER ETC.

Operating modes:
- CH 1 alone
- Inversion capability on CH 2 only.
- Alternating or chopping (120 kHz) CH 1/CH 2
- Frequency range 0...25 MHz (−3 dB)
- Rise time ≤ 14 nsec
- Deflection factor 12 steps: 2 mV/div...10 V/div ± 3%; no variable attenuation controls.
- Input coupling AC, DC or Gnd.
- Input impedance 1 MΩ/25 pF; Max input voltage 400 V (DC + peak AC).

X-Y MODE

CH 1 Y-axis, CH 2 X-axis. X Bandwidth DC to 1 MHz (−3 dB).
- Phase shift at 50 kHz ≤ 3°.

TIMEBASE

Deflection factor 0.2 μsec/div...0.5 sec/div ± 3% with 1/2/5 divisions.
- Expansion x 5, extends max. timebase speed to 40 nsec/div (variable control fully anti clip, expansion error ≤ 2% extra; typical variable control error ± 2%.

TRIGGERING

Trigger modes: Auto (bright line); Normal; active TV (line and frame) sync.
- Trigger coupling: AC, DC, HF reject.
- Trigger sources: CH 1, CH 2, Line, Ext.
- Triggering slope: positive or negative, switchable.
- Triggering sensitivity: Internal ≤ 0.5 div at 25 MHz, External ≤ 1 V at 25 MHz, Auto mode.

MISCELLANEOUS

CRT—made NEC, 13 cm front rounded tube (viewing area approx. 100 x 80 mm); accelerating voltage 2 kV, beam rotation by front panel adjustment.
- Compensation signal for divider probe, amplitude approx. 0.2 Vpp (± 3%), frequency 1 kHz.
- Z modulation 20 Vp-p for complete blanking (−).
- Power Supply: 5 V at 1 Amp, +12 V floating at 200 mA continuous.
- Component Comparator: test voltage 8.6 V r.m.s., test current 28 mA max; line frequency = test frequency. Covered by 2 year “Blue Chip” warranty.
The Y-amplifiers, which are positioned to the left of the tube, surprisingly have a bandwidth of 25 MHz; 5 MHz more than the 20 MHz offered by its direct competitors. Performance of the Y-amps is certainly good, meeting the 25 MHz bandwidth well inside its -3 dB limit. The 5 mV/div maximum Y-amp sensitivity is effective across the whole bandwidth, allowing accurate measurement of low amplitude RF signals. This range extends up to a useful 10 V/div. I found calibration accuracy on all of these ranges very good, and well within the quoted ±3%. It is a pity, however, that both Y-amps have no variable control. This among other things makes accurate rise-time measurements difficult, unless the deflection amplitude of the signal matches that of the rise-time graticule. Both Y-amps have a 14 ns rise-time to accommodate their wider than usual bandwidth and this does, of course, help in giving more accurate high frequency pulse deflection representations than the more common 17.5 ns rise-time. This reduced rise-time is largely due to the use of faster FETs in the input stage and in my view is well worth the trouble, not only having the advantages outlined above, but also that at 20 MHz the attenuation is way below the -3 dB level, enabling more accurate vertical measurements to be made across the whole upper bandwidth.

The display modes on the 3133 are fairly standard, with the exception that in single trace mode only CH1 can be displayed, instead of the more usual switchable CH1/CH2 option. This is certainly not a major setback, but it can entail a certain amount of lead swapping, or trace repositioning, if, for example, it is necessary to display a signal connected to CH2 for a full 8 cm vertical deflection amplitude. A 1 kHz 200 mV (±2%)p-p divider probe compensation square wave output is provided. An ever increasingly popular feature is the trigger hold-off facility, which is now finding its way into the 'under £350' price bracket. This, along with the increase in bandwidth and slimline appearance, is one of the main differences between the new 3133 and the older 3132. Trigger hold-off facilitates stable triggering on complex and irregular waveforms, and as such is useful for displaying, for example, complex pulse trains in digital work over a wide range of timebase speeds. The 3133's hold-off facility coupled with a wide variety of timebase speeds and waveforms, ranging from a simple double pulse to a complex pulse train. Other triggering functions include the more standard HF reject and TV synchronization. Triggering performance is good for the vast majority of waveforms. When the scope is in auto mode and the TV frame sync is in operation, however, it is difficult to lock on to the frame sync pulses during a steady video signal; a changing video signal with a low signal content makes this next to impossible. No problems were encountered in the line sync mode and reliable TV (both frame and line) triggering was present in Normal mode. AC and DC coupling and Normal and Auto modes are also provided, making triggering effective across a wide range of signals. Alternate, or Vertical triggering, is not a feature of the scope, and consequently non-synchronized waveforms cannot be stably displayed on both traces. Triggering sensitivity is very good, typically being 2 mm up to 25 MHz internally, which is well inside the 0.5 div deflection quoted, or approximately 200 mVp-p externally, again well inside the quoted 1 Vp-p. To obtain these sort of sensitivities, fairly critical adjustment of the triggering threshold is, however, required, although triggering on the quoted sensitivities is more easily accomplished. Timebase speeds range from 0.2 secs/div to 0.5 secs/div; the maximum speed being increased to 200 nsec/div by the use of a variable control. Calibration accuracy of the timebase is ±3%, the variable control, when fully clockwise, adds about 2% to the error. A ×5 control is provided, which increases the maximum deflection speed to 40 nsec/div and brings the maximum error at this speed to approximately 7%, which I found acceptable for all tests carried out on the scope. The maximum sweep speed of 40 nsec/div gives a 1 division horizontal resolution for a 25 MHz sine wave and should be enough for most purposes. The 3133 is one of the few scopes which still use an external graticule CRT. On the 3133, a parallax error is kept to a minimum by sticking the graticule template directly onto the CRT, and, although a small parallax error is obviously still present, I found that the extra measuring error incurred when taking measurements is practically zero, if the screen is viewed from a constant angle. The external graticule does, however, slightly obscure the trace along its markings to a small extent, and in some circumstances it may be necessary to slightly alter the viewing angle to clearly observe the whole of a low intensity trace. The 2 kV CRT itself is round and because of this the trace cannot be observed at the corners of the viewing screen. However, under normal conditions, this in no way affects the measuring capability of the instrument, as most measurements are taken at or around the centre of the screen. It may, however, slightly affect dual trace operation, causing a small adjustment in waveform amplitude or position on, for example, a pulse waveform, where visibility of the initial leading edge could otherwise be partly obscured. Automatic focusing is not incorporated, and consequently a small adjustment is necessary when, for example, changing deflection speeds from 50 nsec/div to 40 nsec/div in order to maintain the optimum focus of the trace. The focusing of the CRT at low to medium intensities is quite good, although at higher intensities' slight defocusing did occur, although with the good brightness available this is not surprising. Despite this, the tube's performance on the focusing side does not quite match that given by some of the better 2 kV internal graticule, rectangular tubes. The CRT is
protected by a deep blue plastic faceplate and is mounted in a bezel which also has camera mounting cut-outs. The cost saving on the external graticule tube allows extra features, such as the power supply, to be incorporated. This has three outputs which consist of a negative ground 5 V 1 Amp supply, suitable for driving TTL etc., and to floating ground outputs which can be configured as ±12 V (200 mA each), -24 V or -24 V supplies, suitable for driving a whole host of devices from op-amps to CMOS logic. This facility should prove useful to most users, even those who already have their own power supplies, mainly because in contrast to the average power supply, with perhaps 1 or 2 supply rails, the 3133 has 3, already configured to supply simultaneously both analogue and digital circuitry. For those users who already have a comprehensive power supply, this feature may be of more limited use, but I feel still worth while. The component comparator consists of two component testers, which generally display a V1 type curve of the component under test. The test signal is an 8.6 V r.m.s. sine wave, which produces, for example, a sharp right angle for a typical diode, or ellipse for a capacitor. Although it does not provide any accurate information as to the component’s value, it does provide a very clear indication of whether the component is operational, if it is, for example, 'leaky'. Component comparison is also possible with the 3133 two testers, enabling a known good device to be accurately compared with other examples. It is also possible to compare complete circuits with this technique, each circuit effectively having its own 'signature'. Initially, I was a little sceptical of the component tester, mainly because I was unsure if its usefulness, in view of the fact that the vast majority of scope users possess a multimeter. This opinion was, however, quickly changed by the component tester, which proved to provide a quick and very clear method of both testing and comparing components, allowing the user in most cases to see their actual characteristics.

Both the internal and external construction are of a very high standard. Internal construction is based around a relatively large number of PCBs, totalling seven in all. The timebase, Y-amplifiers, power supply, etc., are all mounted on different boards, thus making servicing greatly easier. All the PCBs are silk screened with the various component identification numbers, and, where appropriate, their function. Both the attenuator stage in the Y-amplifiers and the EHT section are fully shrouded, as is the CRT. The components themselves come from a wide variety of sources and all appear to be of a good quality. All internal wiring is neatly grouped, giving the inside of the scope a very neat appearance. External construction of the scope is to the same high standard, being almost completely aluminium. This also includes, unusually, the front panel, which is silk screened with the appropriate markings. None of the front panel controls extends beyond the display bezel, which further increases the robustness of the scope. With the construction in mind, it is not surprising to learn that among the users of the 3133's predecessor, the 3132, are British Nuclear Fuels, GEC, UKAEA and several large industrial companies. A comprehensive manual and a book entitled Getting The Best From Your Scope are included with the 3133. Both are very good, the manual covering initial setting up, servicing and calibration, while the book deals with a wide range of applications, including TV servicing. The manual also includes a full circuit diagram, as well as diagrams of both mechanical construction and PCB layout.

Conclusion

The Crotech 3133's extra functions and higher than normal bandwidth turn what otherwise would perhaps be an unexceptional scope into one which is well worth looking at, especially when the price of £319 is taken into account. While the CRT gives a reasonable performance, its external graticule can make accurate measurements slightly more time consuming. It is probable, however, that the extra bandwidth and functions offered by the 3133 over its rivals will be worth this to the many users who require a scope which can be used for a large number of applications. The high standard of construction is also one of the 3133's assets. The 3133 is particularly suited to new users of scopes, as it is particularly easy to operate and it is supplied with two good manuals. To sum up, the 3133 certainly represents value for money, offering as it does a number of useful extra functions and a reasonable performance, while maintaining a very high standard of construction. If you require a versatile scope, with a wide range of features along with good construction quality, I can certainly recommend it.

I have been informed by Crotech that they intend to improve the TV triggering performance of the 3133, the review model was a pre-production prototype. The Crotech 3133 was supplied by Crotech Instruments Ltd., 2, Stephenson Road, St. Ives, Huntingdon, Cambridgeshire PE17 4WJ. Tel. (0480) 301818

Other Crotech scopes

DUAL TRACE
3135—Preceding model to 3133, main differences 20 MHz bandwidth, no trigger hold-off, design. Currently £285 + V A T.

3337—30 MHz version of 3132, main differences 10 KV acceleration voltage, no component tester, signal delay. Currently £425 + V A T.

3339—Same as 3337, except VDU mode facility and the addition of a component tester and power supply. Currently £570 + V A T.

SINGLE TRACE
3031 and 3032—single trace, 20 MHz, component tester, 3031 0.5 cm rectangular tube, 3032 1.3 cm round tube. Currently £199 and £220 respectively (both + VAT).

Next month, Julian Nolan reviews the Gould OS300 and the Grundig MO20 oscilloscopes.
**EVENTS**

**IEE meetings this month**

3 Inter-satellite links and on-board optical techniques
3 Testing expert systems
7 Practical implementation of expert systems in industry
7 The UK space programme
8 Silicon sensors give microprocessors new eyes and ears
9 When the chips are down...
11 Control of time delay systems
11 Education in circuit theory and design
14-17 Land mobile radio
17 Using computers in quality control

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**ICS courses this month**

**Introduction to Datacomm & networks**
1-4 London

**Implementing local area networks**
1-4 Stockholm (in Swedish)
8-11 London

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**CUMULATIVE INDEX 1987**

**Audio & music**

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- Digital driver for R/C motors
- Display intensity control
- Dimmer for inductive loads
- Facsimile interface
- Flashing lights
- Flashing rear light
- Halogen lamp dimmer
- Long-range infra-red transceiver
- Metal detector
- Section indication for model railway
- Selective calling in CB radios
- Speed control for DC motors
- Speed control for R/C models
- Timer for fixing bath
- Tracking window comparator

Power supplies & ancillaries

- Band-gap voltage reference
- Current indicator for 723
- Current monitor and alarm
- Digital voltage/current display
- Dimmer for inductive loads
- High-current switching regulator IC for SMPSUs
- Low voltage drop regulators
- Tunnel diode battery charger
- RF, infra-red & video
- ATN Filmnet decoder
- Decoding satellite TV signals
- Four-way aerial switch
- High level passive DBM
- High level wideband RF preamplifier
- High level two-tone test generator
- Indoor unit for satellite TV reception
- Interfacing Atari ST and MSX computers to SCART/TTL colour monitors
- Long-range infra-red transceiver
- Morse filters
- Multi-mode μP-controlled IF module
- Passive infra-red detector Type PID-11
- RF module for IDU
- SCART adaptor for IBM PC
- SMA FM stereo receiver
- SSB adapter
- SSB receiver for 80 and 20 metres
- Switchable bandsselector
- Synchronization separator
- Synthesizer for SW receiver
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- Analogue wattmeter
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- Headphone amplifier
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- IDU for satellite TV reception
- Preset extension for function generator
- Printed resistors
- Single-chip microcontrollers
- SSB receiver for 20 and 80 m
- Stream encryption
- Synthesizer for SW receiver
- Toilet pointer
- Top-of-the-range preamplifier
- True RMS meter
- Universal control for stepper motors

Corrections

- Corrections
- 16 Kbyte CMOS RAM for C64
- Active phase-linear cross-over network
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- Synthesizer for SW receiver
- Toilet pointer
- Top-of-the-range preamplifier
- True RMS meter
- Universal control for stepper motors

S = in supplement of construction projects.
17 Why do you buy *Elektor Electronics*?
- Appealing cover □ (1)
- Professional appearance □ (2)
- Interesting articles □ (3)
- For the advertisements □ (4)
- For the INFO cards □ (5)
- For want of something better □ (6)
- Because I've read it for years □ (7)
- For my hobby □ (8)
- For my study □ (9)
- For my occupation □ (10)

**Readership profile**

18 Is electronics your profession? □ (1)
- study? □ (2)
- hobby? □ (3)

19 Education in electronics:
- No formal qualifications □ (1)
- Qualified technician □ (2)
- Professionally qualified □ (3)
- Corporate engineer □ (4)
- Other education:
  - CSE □ (5)
  - O level □ (6)
  - A Level/Scottish higher □ (7)
  - ONC □ (8)
  - HBC/HND □ (9)
  - University degree □ (10)
  - Still studying □ (11)

20 In what country do you live?

---

Thank you!

Please use this space for any further comments.
Since our last readership survey three years ago, *Elektor Electronics* has undergone a number of changes, brought about in the main as a result of your responses to the questions asked then, and also to keep abreast of our fast changing electronics environment.

To make sure we remain on the right track, we ask all of you to take a few minutes to answer the 20 questions here by ticking the relevant box and post the completed form to:

_Elektor Electronics_
_Readership Survey_
_FREEPOST TK756_
_1 Harlequin Avenue_
_BRENTFORD_
_MIDDLESEX TW8 8BR_
_England_

No postage stamp is required if the form is posted in Great Britain or Northern Ireland.

---

### Your likes and dislikes

1. What areas of electronics are of most interest to you?
   - [ ] Audio & hi-fi (1)
   - [ ] Electrophonics (2)
   - [ ] TV & video (3)
   - [ ] HF/VHF/UHF (4)
   - [ ] Computers (5)
   - [ ] Computing science (6)
   - [ ] Telecommunications (7)
   - [ ] Test & measurements (8)
   - [ ] Domestic applications (9)
   - [ ] Hobby applications (10)

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### Buying habits

10 What do you look for in advertisements?
   - [ ] Components (1)
   - [ ] Measuring equipment (2)
   - [ ] Computer hardware and software (3)
   - [ ] Other commercial equipment (audio, video, domestic, etc.) (4)
   - [ ] Books (5)
   - [ ] Tools (6)

### Reading habits

11 On average, how thoroughly do you read *Elektor Electronics*?
   - [ ] all articles (1)
   - [ ] most articles (2)
   - [ ] a few articles (3)
   - [ ] I only leaf through (4)

Could you estimate how many hours, on average, you spend on this? ______ hours

12 On average, how thoroughly do you look at the advertisements?
   - [ ] I check them all (1)
   - [ ] I look through most of them (2)
   - [ ] I study a few (3)
   - [ ] I only leaf through (4)
   - [ ] I never look at them (5)

Could you estimate how much time, on average, you spend on this? ______ hours

13 How do you usually obtain *Elektor Electronics*?
   - [ ] on subscription (1)
   - [ ] from a newsagent (2)
   - [ ] from a specialist electronics shop (3)
   - [ ] borrowed from a friend, library (4)

14 If you are a subscriber, since when?
   - [ ] recently (1)
   - [ ] about a year (2)
   - [ ] about two years (3)
   - [ ] 3 to 5 years (4)
   - [ ] more than 5 years (5)

15 If you buy your copy, how many other people read it?
   - [ ] just myself (1)
   - [ ] one other (2)
   - [ ] several others (3)

16 How many other specialist periodicals do you read regularly ______
Isaac Newton was born on 25 December 1642 in the manor-house at Woolsthorpe, near Grantham, Lincolnshire. He died on 20 March 1727 at Kensington, London and was buried in Westminster Abbey. Thus he lived under seven monarchs, as well as two protectors, in what can surely be described as an age of revolution. Against this politically turbulent background the world of learning was undergoing, after a similarly turbulent start, its own albeit quieter evolution. The ancient philosophy of Aristotle, despite the efforts of Aquinas, had already sunk into decline. Of the three Philosophies, Metaphysical, Moral and Natural, the latter was poised for its most dramatic development. Man’s place in the physical universe had been redefined by Copernicus and Bruno. Bacon and Galileo had initiated a new science, based on observation and mathematically precise description, so immediately exemplified in Kepler’s three laws of planetary motion. The most influential philosopher of the seventeenth century was Descartes, whose attempt to construct an all-embracing philosophy of the world, failed even to resolve his own conflict between reason and authority. Nevertheless it had a lasting impact on the future development of natural philosophy through its reduction of all reality to matter and motion. Newton’s “Principia” represented the next step along this road. Matter was invested with certain intrinsic properties, both active and passive, while motion became a series of events in space and time subject to quantitative analysis based on premises of cause and effect. Later on the combination of Descartes’ analytical geometry and Newton’s differential and integral calculus would become powerful tools in forging a complete mechanistic philosophy.

Due to the death of his father two months before his birth, Newton spent his early years with his maternal grandmother in Woolsthorpe. In 1654 he entered the grammar school in Grantham, but left in 1656 to help manage the family farm, returning to school in 1660 to prepare for college for he showed a remarkable precocity in mathematics. In 1661 he matriculated at Trinity College, Cambridge, where he became a scholar in 1664 and graduated B.A. in 1665. He became a fellow of Trinity College in 1667 and in 1669 was elected Lucasian professor of mathematics in succession to Isaac Barrow whom he had impressed as “a very ingenious person” and “a man of exceptional ability and remarkable skill”. He was elected to fellowship of the Royal Society in 1672 and represented the university in parliament in 1689 and in 1701, and was finally appointed to the post of Warden of the Mint in 1696 and Master in 1699. In 1703 Newton became president of the Royal Society, which office he retained for life. He was knighted by Queen Anne on the occasion of her visit to Cambridge in 1705.

During the years 1665-1666, at a time of enforced absence from Cambridge due to the plague, Newton lived in Woolsthorpe with his grandmother.
at Woolsthorpe, Newton made a number of advances in optics, mathematics, mechanics and gravity. It was mainly with the last three topics that the "Principia" would be later concerned, but it was during this rural retreat that the seeds of that bountiful harvest were sown. Newton himself wrote later "... from Kepler's rule of the periodical times of the planets [Kepler's third law] ... I deduced that the forces which keep the planets in their orbs must be reciprocally as the squares of their distances from the centres about which they revolve: and thereby compared the force requisite to keep the Moon in her orb with the force of gravity at the surface of the earth, and found them answer pretty nearly. All this was in the two plague years of 1665 and 1666 ... for in those days I was in the prime of my age for invention and minded Mathematics and Philosophy more than at any time since. ... between the years 1676 and 1677 I found the proposition that by a centripetal force reciprocally as the square of the distance a planet must revolve in an ellipse about the centre of force as focus [Kepler's first law] ... and with a radius drawn to that centre describe areas proportional to the times [Kepler's second law]". Christian Huygens had already published in 1673 the rule of centripetal force for uniform circular motion. What Newton did was to define the concepts of quantity of motion (momentum) and force, and the laws relating to them. He also made the conceptual move from centripetal to centrifugal force and generalized from the circle to the ellipse, having already postulated the universality of the gravitational force on the falling terrestrial body and that acting on the Moon and other heavenly bodies. The story of the apple falling from the tree in the garden at Woolsthorpe was told by William Stukely in recounting his conversations with Newton in 1726, and also by Voltaire who obtained it from Newton's step-niece. The tree was cut down in 1820 but a portion of the trunk may be seen in the library of the Royal Astronomical Society in Burlington House, Piccadilly.

The events leading up to the publication of the "Principia" began with the visit to Newton in 1684 of Edmund Halley (soon assistant secretary of the Royal Society and editor of Philosophical Transactions) to pose the question, prompted by a discussion with Robert Hooke and Christopher Wren, as to what orbit a planet would follow if attracted to the Sun by a force varying inversely as the square of the distance. Halley, impressed by Newton's immediate answer, asked for the proof, which Newton sent and was received by Halley with such great satisfaction that he visited Newton again to discuss the matter. He reported to the Royal Society the "curious treatise, De Motu (On Motion)" which Newton had promised to send to the Society. This was received in February 1685, Halley's intention being to secure the position until Newton could publish his work; as he was encouraged to do by Halley and by the Royal Society. In April 1686 the Royal Society received a manuscript, in the hand of namesake and amanuensis Humphrey Newton, of what Halley referred to as an "incomparable Treatise on Motion" entitled "Philosophiae Naturalis Principia Mathematica" and dedicated to the Society by Newton. This was in fact the first part of the "Principia", comprising the "Definitions", "Axioms or Laws of Motion" and "Book I - On the Motion of Bodies", bearing the full title of the whole work. The Society resolved to have the manuscript printed without delay at its own expense, and furthermore entrusted Halley to supervise the printing. For financial reasons the Royal Society shortly ordered that Halley print it at his expense which he engaged to do. In June 1686 Newton informed Halley that he had intended the "Principia" to consist of three books, of which the third would concern the system of the world, which he now proposed to suppress because "Philosophy is such an impertinently litigious Lady that a man had as good be engaged in Law suits as have to do with her". Newton realized that the title of the whole work would no longer be as appropriate, considered changing it, but on second thoughts retained the former title to help the sale of the book. Halley begged Newton "not to ... deprive us of your third
book", adding that it would make the "Principia" acceptable to those that will call themselves philosophers without mathematics, which are by far the greater number". Newton deferred to Halley and duly delivered to him "Book II — On the Motion of Bodies in Resisting Media" in March 1687 and "Book III — On the System of the World" in April 1687. On 5 July 1687 Halley wrote to Newton that he had "at length brought your book to an end, and hope it will please you". Halley had written a Latin ode, dedicated to Newton, with which he prefaced the work. In his own preface Newton paid a glowing tribute to the assistance which Halley had given him. The title page bore the "imprimatur" of Samuel Pepys, President of the Royal Society. The number of copies printed is unknown but has been estimated as high as four hundred. Newton received twenty for himself and forty for disposal through booksellers. The price to the trade was six shillings in sheets, reduced to five shillings for cash, but nine shillings leatherbound and lettered.

News, emanating from Halley and John Flamsteed (first Astronomer Royal), of the impending appearance of the "Principia" had generated much excitement. Reactions to the book were quick to follow publication. Two reviews appeared in French (Journal des Scavants, Bibliothèque Universelle) the latter being attributed to John Locke, one in Latin (Acta Eruditorum), and one in English (Philosophical Transactions) by Halley. Readers were left in no doubt as to the scope and scale of Newton's achievement. Newton's work appealed particularly to mathematicians like James Gregory (St Andrews and Edinburgh) and his nephew David Gregory (Edinburgh and Oxford). Perhaps the first continental student of Newton was Nicolas Fatio de Duillier, a Genevese mathematician who was instrumental in spreading news of the "Principia" to Huygens in Holland and to Leibniz, otherwise known for his controversy with Newton regarding the calculus, in Germany. An early casualty was Descartes' philosophy, particularly as it applied to mechanics, including his theory of vortices relating to celestial motions. However, to Newton the concept of action at a distance was an absurdity, a point of some importance when considering the later revolution due to Einstein. Newton also made it clear that while inferring gravity as a cause of (change of) motion, he was making no statement regarding the cause of gravity itself and permitted himself but one reference to God in the first edition. Richard Bentley, Master of Trinity College, in his Robert Boyle Lectures (1692), noted that the dispositions of the planets relative to the Sun were critical for the sustenance of life thereon, leading him to "discern the tokens of Wisdom in the placing of our Earth". George Berkeley, Bishop of Cloyne, attacked Newton's concepts of absolute space, absolute time and absolute motion as inadmissible since they entertained "something besides God which is eternal, uncreated, infinite, indivisible, unmutable". Joseph Addison too upheld the thinking of Descartes, although both Berkeley and Addison would later publish defences of the Newtonian notion of mind.

Leibniz considered that gravity "without any mechanism... or by a law of God... without using any intelligible means, ... a senseless occult quality...". Roger Cotes (first Plumian Professor of Astronomy), editor of the second edition (1713) of "Principia" under Bentley's supervision, advised Newton to counter the criticism of Leibniz. For the second edition Newton thus prepared the famous General Scholium containing the sentence "...and thus much concerning God: to discuss of whom from the appearance of things, does certainly belong to Natural Philosophy...". Herein too is found the famous declaration "...hypotheses non fingo... (I frame no hypotheses)" which must be taken only in the context of the cause of gravity, for Newton framed many hypotheses. The third edition (1726) was prepared for Newton by Henry Pemberton who also, a week after Newton's death, announced a translation of the "Principia". This was never published and the first English translation was that of Andrew Motte in 1729. Fatio was the author of the epigram on Newton's tomb: "Sibi gratulatur Mortales, Tale tantumque exstrictu Humani Generis Decus (Let mortals rejoice that there has existed such and so great an ornament of the human race)". Amongst the many tributes that have been accorded Newton's "magnum opus" few are as generous as that of Laplace in referring to the causes "which will always assure the "Principia" a pre-eminence above all the other productions of the human intellect".

PEOPLE

British Telecom have announced the appointment of Dr Sydney O'Hara as Managing Director of its British Telecom Enterprises (BTE) Division. Prior to his appointment, Dr O'Hara was Director, Products and Services, in BT's UK Communications Division.

On 1 October last, the following took office at the IEE for the 1987/88 session.

President
Professor Eric Ash, CBE, PhD, FEng, FIEE, FRSA, Rector, Imperial College of Science and Technology.

Deputy Presidents
Dr T. Bryce McCirrick, CBE, FEng, FIEE, formerly Director of Engineering, BBC.

James C. Smith Esq, CEng, FIEE, Chairman, Eastern Electricity Board.

Divisional Chairmen

Electronics Division
Dr John R. Forrest, MA, DPhil, FEng, FIEE, Director of Engineering, Independent Broadcasting Authority.

Computing & Control Division
Professor Bhachandra V. Jaya-\-\-wan, PhD, DSc, CEng, FIEE, School of Engineering and Applied Science, University of Sussex.

Power Division
Kenneth M. Odell Esq, CBE, BSc(Eng), ACGI, CEng, FIEE, Engineering Director, Balflour Beatty Ltd.

Management & Design Division
David G. Jeffries Esq, CEng, FIEE, Deputy Chairman, The Electricity Council.

Science, Education & Technology Division
Derek R. Edwards Esq, BSc(Eng), CEng, FIEE, Consultant Engineer.

Mr Alan Nicholson, BSc, CEng, MIMechE, has been appointed Marketing and Sales Director of British Aerospace Naval and Electronic Systems Division.

Mr Tony Asprin has been appointed Sales Director of Syfer Technology Ltd, the wholly UK owned manufacturer of multilayer ceramic capacitors.

Carole Whittaker has joined Grundig International as Marketing Manager in the company's home entertainment division.

Andrew Trollope has been appointed Export Sales Manager at Electronic Brokers, the specialist supplier of test and measuring instruments and second-user DEC computer equipment.

In a move to meet the growing demand for its PC local area networking products, 3Com has appointed Paul Trowbridge to head up its newly established Product Consultancy Group.
MULTI-FUNCTION FREQUENCY METER

An advanced, versatile and user-configurable test instrument capable of accurate measurement of frequency, frequency ratio and time interval. In addition to all this, it can be used as a period and event counter.

The multi-function test instrument described here is based on the 8-digit counter/timer IC Type ICM7226B from Intersil (GE/RCA). This chip combines all the functions expected from a good and versatile counter, and requires very few external components. The chip handles frequency measurement from DC to 10 MHz, period measurement from 0.3 μs to 10 s, unit counting up to 10 million events, frequency ratio measurement, and time interval measurement.

The inputs of the proposed instrument can accept a wide range of alternating (analog) voltages as well as digital pulses at TTL or CMOS levels.

Circuit description

The circuit diagram of the frequency meter is given in Fig. 1. It would be beyond the scope of this article to give a detailed description of the internal operation of the ICM7226B, and the following, therefore, an outline of the simple peripheral circuitry needed to obtain a complete instrument. A prescaler for extending the input frequency range to 1.2 GHz will be discussed in a forthcoming issue of Elektor Electronics.

The ICM7226B has internal timebase circuitry, display decoders, segment and digit drivers. The 8-digit read-out is composed of common cathode LED displays multiplexed at 300 Hz and a duty factor of 0.12 per digit. Leading (non-significant) zeroes are blanked when the meter is set to frequency measurement in kHz or period measurement in μs. LED D9 indicates an overflow condition, i.e., the counter is "full", and all digits read 9.

The counter, IC5, has an on-chip timebase oscillator which operates at 10 MHz (X1). It is possible to use a 1 MHz quartz crystal provided S5 is closed. Similarly, S7 makes it possible to apply an external clock signal of 100 kHz or more to pin 33. When switch S5 is closed, the position of the decimal point on the display is controlled externally via the respective input, pin 20. The decimal point can thus be positioned for the prescaler used. Switches SS-SS and the associated diodes, DS-DS, are intended for the above options on the frequency meter, and may be omitted when the relevant function is not required. It is, of course, also possible to replace the switches with wire links for permanent operation in a particular mode.

The maximum input frequency applied to input A of the instrument is 10 MHz in the frequency and unit count modes, and 2 MHz in the other modes. The counter modes and functions that can be selected with the range switch, SS, and the function switch, SS, are summarized in Table 1.

<table>
<thead>
<tr>
<th>Position</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (K1)</td>
<td>frequency (Hz)</td>
</tr>
<tr>
<td>2 (K8)</td>
<td>period (μs)</td>
</tr>
<tr>
<td>3 (K2)</td>
<td>frequency ratio (fA/fB; fA &gt; fB)</td>
</tr>
<tr>
<td>4 (K5)</td>
<td>time interval (μA-μB)</td>
</tr>
<tr>
<td>5 (K4)</td>
<td>unit counter</td>
</tr>
<tr>
<td>6 (K3)</td>
<td>oscillator test</td>
</tr>
</tbody>
</table>

Switch SS: RANGE

<table>
<thead>
<tr>
<th>Position</th>
<th>Accumulation time / cycle(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (K1)</td>
<td>0.01 s / 1 cycle</td>
</tr>
<tr>
<td>2 (K2)</td>
<td>0.1 s / 10 cycles</td>
</tr>
<tr>
<td>3 (K3)</td>
<td>1 s / 1,000 cycles</td>
</tr>
<tr>
<td>4 (K4)</td>
<td>10 s / 1,000 cycles</td>
</tr>
</tbody>
</table>

S5 is used for checking whether the internal oscillator works, but not for verifying the frequency of oscillation. It should be noted that input B is only used for measuring frequency ratios and time intervals. The frequency of the signal applied to input A should be higher than that applied to B. Similarly, the pulse transition on input A should occur before that on input B.

The protective networks fitted at the inputs of NS and NS enable applying alternating voltages as well as CMOS or TTL (digital) pulses. For small alternating voltages applied via C1-C6, diodes D6-D8 or D9-D10 do not have a limiting effect, so that inverters NS-NS operate as amplifiers. When the input amplitude is greater than about 2 Vpp, the inverters operate as buffers. Limiting of the input signal takes place when the input signal at the digital inputs is lower than -0.6 V or higher than +5.6 V. This means that AC coupled input voltages are clipped to about 6 Vpp. The input sensitivity stated in the circuit diagram is an average and frequency dependent value. When the Type 74HCT04 in position IC6 (NS-N9 incl) is replaced with a 74HCU04, the input sensitivity increases by a factor 5 to 10.

The circuit around NS-N9 incl. and XOR gates NS-NS is used for measuring time intervals, i.e., the period that lapses between the positive edges of the signals applied to inputs A and B. A bistable internal to the ICM7226B is set and reset by the pulse transitions at input A and B, respectively. When the bistable is set, the oscillator pulses are internally fed to the counter input. Evidently, the longer the bistable remains set,
the more pulses are counted, and the higher the read-out on the display. Push-button PRIME is pressed before measuring the time interval for a single event. Inverters N5-N7 generate a brief pulse for chip input A; N5-N7 a slightly delayed pulse for input B. The internal logic in the ICM7226B is thus primed ready for measuring the interval for one event, delimited by the positive edges of the pulses applied to instrument input A and B. Pressing PRIME is not required when these inputs are driven with a repetitive signal, as the first alternating signal states cause automatic priming of the counter chip.

The read-out can be retained ("frozen") as long as the HOLD switch, S9, is pressed. The counter's internal circuits—and hence the read-out—can be cleared at all times by pressing the RESET key, S1. Capacitor C7 is connected in parallel with S1 to prevent hang-ups at power on. The 3 push-buttons can be fitted on the counter's front panel as suggested in Fig. 2.

Construction

Virtually all parts shown in the circuit diagram are fitted on a single printed circuit board, whose track layout and component mounting plan are shown in Fig. 3. Commence the construction with fitting all the wire links. Do not forget the 8 short capacitors underneath the displays! Electrolytic capacitor C12 is fitted at the track side of the board. Make sure that it is fitted securely and slightly off the board to prevent sharp solder points piercing the insulating material and causing short-circuits with the grounded metal can. It is recommended to use good quality sockets for all integrated circuits. The displays are also fitted in 10-way sockets, made from terminal strips or 14-way IC sockets. Use

Fig. 1 Circuit diagram of the multi-function frequency meter.

Fig. 2 Lay-out of the ready-made front panel foil for the frequency meter.
Fig. 3 Track layout and component overlay of the PCB for building the frequency meter. Capacitor C12 is fitted AT THE TRACK SIDE.

short lengths of strong wire to ensure the correct height of the displays above the board. LED D9 is a high brilliance type whose leads are lengthened to make its top level with the displays in the sockets. Voltage regulator IC4 should be mounted with a heat-sink. The RANGE and FUNCTION switches, S4 and S2, are soldered directly onto the board, or with short lengths of left over component wire, to minimize stray inductance and capacitance. This measure effectively prevents unwanted effects such as indeterminate illumination of digits ("ghosting"). As already stated, function switches S5-S8 may not be required on the front panel of the instrument. Inputs A and B are made in flange-type or single hole BNC sockets. Two more of these are required when it is intended to

The completed printed circuit board (prototype version).
extend the frequency meter with the prescaler to be introduced. Inputs EXT OSC, EXT DP, and output BUFFER OSC can be made in suitable sockets on the rear panel of the enclosure. The signal at BUFFER OSC can be used for setting the oscillator frequency to 10.000 MHz precisely with the aid of trimmer capacitor Cs. It is also possible to use the signal for driving other circuits, provided the BUFFER OSC output is fitted with a 10K resistor to the +5 V rail.

The supply voltage for the prescaler is available on 2 soldering pins next to the EXT DP input.

The completed PCB is mounted vertically in the moulded guides provided in the bottom plate of the Vero enclosure. The ready-made front panel foil for the frequency meter can be used as a template for drilling the metal front panel provided with the enclosure. The shafts of the rotary switches, S1 and S2, are cut to size to enable fitting suitable knobs. The LED displays are fitted in a rectangular clearance cut in the front panel. The visibility of the read-out is enhanced by the semi-transparent bezel in the ready-made front panel foil. The OVERFLOW indicator, D6, is fitted immediately below the right-hand side of the display bezel. The position of the various controls and indicators is evident from Figs. 2 and 4.

It is, of course, possible to use a ready-made mains adapter with 8 VAC output for powering the instrument. In many cases, this is safer and less expensive than incorporating a mains transformer. When it is still intended to use the frequency meter with its own, internal, mains supply, the mains socket and fuse should be fitted at safe locations onto the rear panel of the enclosure. The mains transformer should be preferably an 8 V, 0.5 A type.

The current consumption of the circuit is about 55 mA with all displays blanked, and 175 mA with all displays illuminated.

Reference:
- Beech House 373-399 London Road Camberley Surrey GU15 3HR. Telephone: (0276) 685911. Fax: (0276) 685255.
NUMBERS AND THE MACHINE

by C.H. Freeman

Computer science depends largely on the properties of real numbers. The correct use of these requires an understanding of the mathematic basis of the real number system. Unfortunately, many people shy away from anything mathematical, even if it has only to do with numbers. This article attempts to allay these misgivings.

Modern man counts in base ten, that is, he uses the ten individual symbols 0, 1, 2, ..., 9. Obviously, you might say, but it hasn't always been so. Some races have been known to count in base 20 (by using their toes and fingers in arithmetical operations) and the concept of zero itself is quite new; consequently, the Romans, who had no representation for zero, had endless trouble with arithmetics. In general, an n digit integer, No, can be represented by

\[ No = d_1R^n + d_2R^{n-1} + \ldots + d_nR^0 \]

or

\[ No = \sum_{i=0}^{n} d_iR^i \]

where \( d_1, d_2, \ldots, d_n \) are the decimal symbols in the counting system and \( R \) is the number base we are working in. When we count in decimal, the symbols used are 0, 1, 2, ..., 9 and \( R \), the base (or radix), is 10. Thus we can represent, say, 50463 as

\[ 5 \times 10^3 + 0 \times 10^2 + 4 \times 10^1 + 6 \times 10^0 \]

Now, although this suits us humans very nicely, digital systems do not use ten discrete values when representing numbers; the engineering problems introduced in using such a system would be too great. Instead we use base two, more commonly referred to as binary. The binary system has just two decimal digits in its counting system: 0 and 1. Now, this is handy because a switch, be it electronic, mechanical, hydraulic, pneumatic etc., can be either on or off and can thus be made to represent a single binary digit (or bit). The derivation arising from Binary digit). So, using the above expression, a string of binary digits, such as 11001, can represent the decimal number

\[ 1 \times 2^4 + 1 \times 2^3 + 0 \times 2^2 + 0 \times 2^1 + 1 \times 2^0 = 25 \]

and we can now see how any positive decimal integer can be represented in binary, and also how to transform a binary number into its decimal equivalent. But what about translating decimal into binary? What do we do then? The answer is, we simply divide our decimal repeatedly by 2, recording the remainder at each stage of the division. The series of remainders, when read "from the bottom up," form our binary number. Let's try an example, converting 229 into binary

\[
\begin{array}{c|c}
229 & \text{sum} \\
229 / 2 & 114 \\
114 / 2 & 57 \\
57 / 2 & 28 \\
28 / 2 & 14 \\
14 / 2 & 7 \\
7 / 2 & 3 \\
3 / 2 & 1 \\
1 / 2 & 0 \\
\end{array}
\]

Thus 229 = 11100101. Check this for yourself by converting the number back into base 10.

What we have just discovered about converting decimal to and from base two applies equally well to base 3, base 7, base 9 or, in fact, any base you care to name. Actually, two other bases, base 8 and base 16 (known as octal and hexadecimal respectively), are important, but more of this later. For the moment, though, you may well be wondering about base 16 (or hex as it is usually known). After all, base 16 will have 16 individual symbols in its counting system and after going through the symbols 0-9 we run out. Mathematicians, when faced with problems such as these, invariably do the decent thing - and cheat. In this case the letters A-F are pressed into service and the full counting system runs 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F.

Binary addition

Two binary numbers are added together in the same way two decimal numbers are added together: by adding together individual digits, paying due attention to any carry digits generated. As there are just 2 digits in the binary system, there are 4 possible sums which can be formed. These are

\[
\begin{array}{c|c|c}
\text{sum} & \text{carry} \\
0 & 0 \\
0 & 1 \\
1 & 0 \\
1 & 1 \\
\end{array}
\]

Using this principle, we can generate a table of binary numbers alongside their decimal equivalents. Part of such a table for a 4 bit binary is shown in Table 1.

<table>
<thead>
<tr>
<th>DECIMAL</th>
<th>HEX</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
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<td>3</td>
<td>3</td>
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<td>9</td>
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<tr>
<td>10</td>
<td>A</td>
</tr>
<tr>
<td>11</td>
<td>B</td>
</tr>
<tr>
<td>12</td>
<td>C</td>
</tr>
<tr>
<td>13</td>
<td>D</td>
</tr>
<tr>
<td>14</td>
<td>E</td>
</tr>
<tr>
<td>15</td>
<td>F</td>
</tr>
</tbody>
</table>

Signed integer representation

So far we have considered binary representation of positive integers only. What happens if we want our computer to hold a negative integer? Our system has so far made no allowance for such eventualities so what can be done? Fortunately, there are three possibilities exist. They are

(a) sign-magnitude representation.

This is the simplest possible method and relies upon the fact that computers hold numbers in fixed length registers. These registers are usually 4, 8, 16 or 32 bits in length, but the important fact is that their length is constant. If we have an n bit register, we can use the most significant bit as an indicator (or flag) to represent a positive or negative number. It is usual for
this bit to be set (i.e. 1) when representing a negative number and reset (i.e. 0) when representing a positive. The rest of the n - 1 bits hold the absolute value of the number. The greatest absolute value which can be held in such a register is \(2^n - 1\), so it follows that if a number is held in an n bit register in this form

\[\text{range} = 0 \to (2^{n-1} - 1)\]

inclusive

(b) diminished radix complement.

For an n digit number \(N\) in base R, we can form what is known as its diminished radix complement by applying the formula

\[\text{DRC} = (R^n - N) \div R^n\]

The name of the complement depends upon the base in which operations are being performed and takes the name of the highest decimal digit in the system. Thus the DRC of a decimal number is known as its ones complement, whilst that of a binary is referred to as its ones complement. With the above equation as a springboard, it is not difficult to show that the ones complement of any binary can be formed simply by inverting each bit, that is changing 1 to 0 and 0 to 1. For example,

\[0001\] represents 1
\[1100\] represents -1

Thus in an n bit system the greatest positive number will be held by only n - 1 of the bits. Therefore, the greatest positive number = \(2^{n-1} - 1\). The greatest negative will be represented by a 1 in the most significant bit followed by n - 1 zeros. Hence

\[\text{range} = 0 \to (2^{n-1} - 1)\]

inclusive

(c) radix complement representation.

The radix complement of an n digit number \(N\) in base R can be calculated using the equation

\[\text{RC} = R^n - N\]

and the radix complement of a binary number is referred to as its twos complement. It should be clear that adding a number to its twos complement will result in all zeroes plus an overflow carry. If the system in use ignores any digits in excess of n then the above equation reduces to

\[\text{RC} = -N\]

in other words, the radix complement represents the negative of a number in the same number of bits.

Computer circuitry can easily form a twos complement by firstly inverting all the bits of the number (to obtain a ones complement) and then simply adding 1 to the least significant bit. For us mortals there exists an easier method of translating a binary into its twos complement. Starting with the least significant bit, we copy all the bits in the number up to and including the first occurrence of one. The remaining bits are then inverted. Table 2 shows comparative representations for a 4 bit register. Note that in the case of twos complement representation

\[\text{range} = -(2^{n-1}) \to (2^{n-1} - 1)\]

inclusive

and the minimum negative number cannot be negated.

Why bother?

If all this seems as if it is merely some abstract mathematical stuff, then let me assure you that it is not. All this maths has a very practical consideration in the design of computer hardware. You see, it is easy to build circuitry which can perform inversion of a binary and addition of two binaries, but it is far less simple to build circuitry which can perform subtraction directly. This means that the process of subtracting one binary number from another is invariably reduced to two distinct operations: forming the complement of the subtrahend, and then adding this complement to the minuend. This leaves us with the decision as to which complement to use: ones complement or twos complement? If we choose to use twos complement, we simply add and then discard any carry which may arise from the most significant digit. If we use the ones complement, however, any such carry must be added to the least significant digit. If this generates further carry digits, they must be added until no further carries are generated. This end-around carry means that arithmetic performed with the twos complement system is a much simpler business than all that mucking about in ones complement. Consequently, twos complement is the method computers will normally use when representing negative numbers. Let's look at an example, subtracting 13 from 42 to leave 29.

\[42 = 101010\]
\[13 = 001101\]
\[29 = 011101\]

Discarding carry leaves
\[01101 = 29\]

This looks more complicated than it actually is. To a person, performing such a process seems quite alien, but computer circuitry finds the process beautifully simple. And speaking of simplifying, the world of numbers is not limited to the simple system of integers. We must now examine how we can represent the system of natural numbers in binary.

The real world

In our earlier look at binary numbers we saw how an n digit integer, \(N_0\) in base R could be represented in the following manner:

\[N_0 = d_nR^n + d_{n-1}R^{n-1} + \ldots + d_1R^1 + d_0R^0\]

We now extend this to enable us to represent any finite length real number using the following representation:

\[N_0 = d_nR^n + \ldots + d_1R^1 + d_0R^0\]

Now, when we use binary to represent such a number, we are using

\[N_0 = d_n\times 2^n + d_{n-1}\times 2^{n-1} + \ldots + d_1\times 2^1 + d_0\times 2^0\]

and it should be easy to see that we can hold a binary fraction in a register, using the most significant bit to represent \(2^{-1}\), etc.

<table>
<thead>
<tr>
<th>MSB</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2^{-1}</td>
<td>2^{-2}</td>
<td>2^{-3}</td>
</tr>
</tbody>
</table>

**TABLE 2**

<table>
<thead>
<tr>
<th>REGISTER</th>
<th>POSITIVE INTEGERS</th>
<th>ONES COMPLEMENT</th>
<th>TWOS COMPLEMENT</th>
<th>SIGN MAGNITUDE</th>
<th>HEX</th>
<th>OCTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>0001</td>
<td>0010</td>
<td>0011</td>
<td>0100</td>
<td>0101</td>
<td>0110</td>
<td>0111</td>
</tr>
<tr>
<td>01</td>
<td>11</td>
<td>10</td>
<td>01</td>
<td>10</td>
<td>01</td>
<td>11</td>
</tr>
<tr>
<td>+7</td>
<td>+6</td>
<td>+5</td>
<td>+4</td>
<td>+3</td>
<td>+2</td>
<td>+1</td>
</tr>
<tr>
<td>+7</td>
<td>+6</td>
<td>+5</td>
<td>+4</td>
<td>+3</td>
<td>+2</td>
<td>+1</td>
</tr>
</tbody>
</table>
Table 3 shows a three-bit register holding binary fractions in just such a way, along with the decimal equivalent of its contents. This table also shows the method of converting a binary fraction into a decimal fraction. By inspection, it should also be easy to see that such an n bit register can hold values in the range 0.0 to (1.0 - 2^-n) in steps of 2^-n.

Before going any further, we'll take a look at how we convert decimal fractions into binary fractions. Decimal integers, as we saw earlier, are converted into their binary equivalents by repeated division by two, recording the remainder at each stage. Decimal fractions, on the other hand, are repeatedly multiplied by two. At each stage, the resulting integer part is separated from its fractional part and forms a bit in the resulting binary. The process is better illustrated by example than by words so let's convert 0.375 into binary:

\[ 0.375 \times 2 = 0.750 \]
\[ 0.750 \times 2 = 1.500 \]
\[ 1.500 \times 2 = 3.000 \]

The last notation is, in fact, the usual method of writing binary reals, with the most significant set bit coming immediately after the decimal point. Such a number is said to be NORMALIZED. In point of fact this is almost exactly how computers do store real numbers within their memories, as two distinct series of bits representing mantissa and exponent. You've probably also noticed by now that numbers stored in this way will have the most significant bit of the mantissa apparently redundant (as it appears it will always be zero). This is no accident. Negative as well as positive mantissas and exponents must be catered for and in such cases the mantissa is held in two's complement form, the most significant bit being taken as a sign bit.

\[ 1.000, -0.875, -0.750, -0.625 \]
\[ -0.875, 0.625, 0.750, 0.875 \]

The exponent can take the range +7 to -8 in steps of 1, of course. The numbers we can represent in our 'machine', therefore, will be

\[ 0.625 \times 2^7 = 112 \]
\[ 0.750 \times 2^7 = 96 \]
\[ 0.875 \times 2^7 = 63 \]
\[ 0.500 \times 2^4 = 4 \]
\[ 0.625 \times 2^{-8} = -6/2048 \]
\[ -0.750 \times 2^{-8} = -6/2048 \]
\[ -0.875 \times 2^{-8} = -6/2048 \]
\[ -1.000 \times 2^{-8} = -128 \]

Notice that because of the two's complement method of storing our mantissa there are two numbers which cannot be negated: the minimum positive real and the minimum negative real.

Floating point representation

Floating point representation relies on the fact that any number in base R can be split into two parts, its mantissa, M, together with its corresponding exponent, E, and depicted as

\[ M \times R^E \]

In decimal, of course, this corresponds to the familiar exponential notation (powers of ten) we all know and love. If we consider the binary number 1.1010101 (for example) then it can be written in mantissa and exponent form as

\[ 101.10101 \times 2^1 \text{ or } 1010.101 \times 2^{-3} \]

Let's try and illustrate this by considering a fictional computer holding numbers in two 4 bit registers:

**Range and accuracy**

It is clear, judging by the example above, that there are some decimals which can never be represented exactly, for the reason that there simply aren't enough bits available to fit the number in. For example, 0.109 = 0.110101. But the binary equivalent is too big to fit into our 4 bit mantissa. In cases such as these there are two options open. We can simply 'chop off' (or TRUNCATE) the excess bits and store as

\[ 0.109 \times 2 = 0.110101 \times 2^1 \]

or we can ROUND the number up (or down accordingly) to

\[ 0.111 \times 2 = 1.10 \]

Whatever happens, it should be realized that there will invariably be a degree of error in computer arithmetic. Usually such errors present no big problems and can be allowed for. As far as range is concerned, if a machine stores numbers as M bit mantissas and N bit exponents, the greatest possible positive mantissa will be equal to

\[ 0.11 \ldots 1 \]

and will be equal to \(1 - 2^{-(M-1)}\) and the greatest possible exponent will be given by \(2^{N-1} - 1\). So,

---

**Table 3.**

<table>
<thead>
<tr>
<th>REGISTER BIT PATTERN</th>
<th>SUM</th>
<th>DECIMAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 0 0</td>
<td>0 + 0 + 0</td>
<td>0.000</td>
</tr>
<tr>
<td>0 0 1</td>
<td>0 + 0 + 2</td>
<td>0.125</td>
</tr>
<tr>
<td>0 1 0</td>
<td>0 + 2 + 0</td>
<td>0.250</td>
</tr>
<tr>
<td>0 1 1</td>
<td>0 + 2 + 2</td>
<td>0.375</td>
</tr>
<tr>
<td>1 0 0</td>
<td>2 + 0 + 0</td>
<td>0.500</td>
</tr>
<tr>
<td>1 0 1</td>
<td>2 + 0 + 2</td>
<td>0.625</td>
</tr>
<tr>
<td>1 1 0</td>
<td>2 + 2 + 0</td>
<td>0.750</td>
</tr>
<tr>
<td>1 1 1</td>
<td>2 + 2 + 2</td>
<td>0.875</td>
</tr>
</tbody>
</table>
greatest positive number: 
\((1-2^{-(N-1)}) \times (2^N - 1) \)
As far as the smallest positive real is concerned, the mantissa will equal 2\(^{-1}\) and the exponent will be 2\(^{-2(N-1)}\).
Smallest positive number: 
\(2^{-1} \times 2^{-(2N-1)}\)

Try and work out the largest and smallest negative reals which can be represented. So there you have it! Computer arithmetic is not just so much arcane theory, but is a fascinating branch of mathematics: a branch which is in constant daily use in fields as diverse as spacecraft navigation to preparing and printing your gas bill. The modern world is so very heavily dependent upon computers that it is doubtful whether it could function without their assistance. Love them or loathe them, you’ve got to admit that we need them!

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Maplin’s 1988 Buyer’s Guide to Electronic Components is up in size by 40 pages to 512, as compared with the 1987 issue. Up also is the amount of information packed onto each page, with the opportunity taken, for example, to move from 2 to 3 column pages for the Projects section. All sections are expanded, with communications — as could be expected — showing the greatest growth. Overall, hundreds of new products are featured, each priced highly competitively. The catalogue is available from Maplin or from W.H. Smith stores at £1.60.
NEW LITERATURE • NEW LITERATURE

Electronic Systems and Techniques
by K. F. Ibrahim
ISBN 0 582 98817 9
267 pages — 245 x 188 mm
Price £7.50 (soft cover)

This is a most welcome book aimed at students taking the City & Guilds 224 Course (Electronic Servicing) Parts I and II, and BTEC students at levels I, II, and III taking electronic engineering. It is, however, also useful for practising engineers who would like to back their practical background with theoretical knowledge.

The reader is taken from a basic knowledge of Ohm's Law to an understanding of electronic circuits. It clearly and concisely explains the fundamentals of electronic systems, including radio and television reception, digital and microprocessor systems, amplifiers, oscillators, digital gates and counters. I particularly liked the chapter on fault finding (not found in many books), which tests the student's grasp of the book's contents admirably.

The author's stated aim has been to meet the challenge of conveying complex electronic concepts and systems in a manner that may be understood by those who have no mathematical background, but who may none the less wish to acquire the necessary skills to service modern electronic equipment. In my opinion, he has succeeded in this very well.

Longman Group UK Ltd
Longman House
Burnt Mill
HARLOW CM20 2JE

IEE Wiring Regulations

The 15th edition of the IEE Wiring Regulations for Electrical Installations have now been reprinted and incorporate all amendments up to and including those of June 1987. The reprint is identified by its brown cover. Copies are available, price £20 (UK Inc.)

p>£20, cash with order from the Institution of Electrical Engineers • Publications Sales Department • P.O. Box 26 • HITCHIN SG4 8SA.

Computer-aided Engineering for Manufacture
by D. A. Milner & V. C. Vasilion
ISBN 1 85091 093 6
264 pages — 215 x 135 mm
Price £17.95 (hardback)

One of Kogan Page's successful New Technology Modular Series, Computer-aided Engineering for Manufacture is intended principally for undergraduate and postgraduate students of production, mechanical, and general engineering, but it is also suitable as a technical reference source for the practising professional who is faced with making financial and engineering decisions concerning computer-aided manufacturing projects.

The emphasis of the book is on computerized systems used in the discrete manufacturing industries and it provides a comprehensive study of the technical topics related to computer-aided manufacture. Areas considered include numerical control, robotic technology, flexible manufacturing systems, computer-aided production management, and artificial intelligence. The book provides an overview of these specialized topics and demonstrates how they are all related within a manufacturing organization.

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120 Pentonville Road
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Instruments for Industry Blue Book

256 pages — 150 x 210 mm

In an attempt to break away from the traditional catalogue approach used by most electronics companies, Electronic Brokers has introduced a 256-page Blue Book including virtually all the technical information needed by the prospective user of test and measurement equipment.

The new publication, free to qualified users, is broken down into 16 sections covering different categories of instrumentation, each of which is preceded by a general introduction to the instruments included in that category and the type of measurement they make. Categories included, all covering product lines supplied by Electronic Brokers, are oscilloscopes (both real-time and digital); analysers; multimeters (digital and analogue); signal sources (pulses, function, and RF); TV and communications test equipment; counter/timers; power supplies; power meters; recorders; and plotters.

Product ranges listed in the Blue Book include authorized distribution lines from major manufacturers such as Philips, Marconi, Grundig, Lloyd, Thurby, Thamcor, Hameg, and Siemens. In addition, a selection is included that covers the computer products available from Electronic Brokers, and a review of the company's second-user test equipment and computer activities.

Electronic Brokers
140-146 Camden Street
LONDON NWI 9PB

Transistor Selector Guide

by J. C. J. Van de Ven
ISBN 0 85091 129 8
192 pages — 178 x 128 mm
Price £4.95 (soft cover)

Prepared from a vast database of electronic component specifications, with the aid of the latest computer techniques, this unique guide offers a range of selection tables compiled so as to be of maximum use to all electronics engineers, designers, and enthusiasts.

Section 1 gives a detailed introduction, covering component markings, codings, and standards, as well as explaining the symbols used and how the tables are arranged.

Section 2 tabulates in alphanumeric sequence the comprehensive specifications of over 1,400 JEDEC, JIS, PROELECTRON, and brand-specific designated devices. Section 3 tabulates the devices in a fashion similar to that in Section 2, but here by case type.

Section 4 considers particular limits to the electrical parameters and is subdivided into six parts, each dealing with a particular type of transistor.

Section 5 illustrates package outlines and leadouts.

Section 6 gives an SMD (surface mounting device) markings conversion list.

Bernard Babani (Publishing) Ltd
The Grampians
Shepherds Bush Road
LONDON W6 7NF
As reported elsewhere in this issue, this month we start a regular series of reviews of a variety of test and measurement equipment. The series starts with a review of a number of dual-trace oscilloscopes, and will continue with storage oscilloscopes, signal generators, power supplies, multimeters, frequency counters, pulse generators, LCR meters, and more. Since it is, however, appreciated that many readers in schools and small workshops, laboratories and electronic design centres remain interested in constructing some test equipment themselves as an attractive alternative to the more costly commercial equipment, we thought it helpful to remind you all of the number of test equipment projects that have been published in Elektor Electronics over the past few years. The accompanying photograph shows that the majority of the Elektor Electronics instruments are housed in a standard Verobox enclosure, which makes for a neat and uniform appearance.

A comprehensive series

Shown to the left in the photograph is the LCR Meter on top of the Computerscope. Below in the centre stack is the Loudspeaker Impedance Meter. Then come the Microprocessor Controlled Frequency Meter, the True RMS meter, the Digital Sine-wave Generator. The 2-channel and standard, single-channel, version of the VLF Add-on Unit for Oscilloscopes seen on top of the stack are housed in flat Verobox enclosures. The right-hand stack is composed of the Pulse Generator at the bottom, supporting the Digital Capacitance Meter, the Spot Sine Wave Generator. The 2-channel extension circuit will be discussed in a forthcoming article.

Overview of publications:

- **Audio Sweep Generator (-)**: November 1985, p. 34 ff.
- **Autorangeing Digital Multimeter (+)**: June 1987, p. 31 ff.
- **Barometer/Altimeter (+)**: November 1986, p. 20 ff.
- **Capacitance meter (digital) (-)**: February 1984, p. 2-52 ff.
- **Capacitance meter (analogue) (+)**: May 1987, p. 33 ff.
- **Computoscope**: September 1986, p. 60 ff., and October 1986, p. 41 ff.
- **Digital Sine-wave Generator (+)**: February 1987, p. 24 ff.
- **Function Generator (+)**: December 1984, p. 30 ff.
- **Loudspeaker Impedance Meter (+)**: September 1986, p. 50 ff.
- **Pulse Generator (+)**: April 1984, p. 26 ff.
- **RLC Meter (+)**: February 1985, p. 56 ff.
- **Spot Sine-Wave Generator (-)**: May 1987, p. 28 ff., and June 1987, p. 38 ff.
- **Temperature Probe for DMM (+)**: December 1986, p. 61 ff.
- **True RMS Meter (+)**: December 1986, p. 40 ff.
- **Variable Dual Power Supply (+)**: April 1986, p. 32 ff.
- **VLF Add-on Unit for Oscilloscopes (+)**: February 1987, p. 38 ff. The 2-channel extension circuit will be discussed in a forthcoming article.

- (+) Printed circuit board(s) available.
- (-) Printed circuit board(s) not available.
- (*) Printed circuit board(s) available in limited supply.

Please consult the Readers Services page and the Order Form in this issue for details on ordering back issues, printed circuit boards, and copies of the stated articles.
The circuit described here is based on pulse-width modulation of power FETs at a frequency of 1 to 2 kHz. The motor driver can be tailored to individual needs, which means that the number of FETs fitted in parallel in the power output stage depends on the current requirement of the motor used. Flyback diodes are included to ensure a smoothly running motor at all speeds. Two presets not only enable adjusting the zero point and the maximum speed in accordance with the R/C system used, but in addition select operation of the motor in the single or dual quadrant mode. Single quadrant operation is particularly useful for non-reversing motors in model aircraft. The proposed controller makes it possible to stop the motor when the control lever is pulled fully backwards, while the trim adjustment is pushed ahead. The entire operating range of the lever is then available for regulating the motor speed (forward), and the trim is used for accurate control of the compensatory reverse force that ensures a smooth touch-down of the model.

Reversal of the direction of travel of the motor is effected with the aid of an external relay or polarity change-over. An all-electronic reversing circuit version was found too inefficient since it required quadrupling the power stage. A motor reversing relay is, of course, not required for single quadrant applications.

The 5 V supply on the driver board is used for powering the R/C receiver and, if applicable, any additional servo motors. Clearly, the absence of a separate battery for the receiver means a welcome reduction in space as well as weight, but due care should be taken not to exhaust the motor battery. The motor driver board is protected against thermal overloading and output short-circuits.

The digital approach
A speed control for small electric motors is essentially a pulse-width to voltage converter. The decoder in the R/C receiver supplies pulses with a period of the order of 1 to 2 ms. The pulse-width determines the position of the relevant actuator in or on the model. Sufficiently fast (real time)—hence accurate—control of the model is ensured by repeating the control pulses at a rate of about 50 Hz. In a traditional (analogue) motor control system as shown in Fig. 2, the input pulse is compared with a reference pulse, whose width corresponds to the neutral position. The width of the error pulses so obtained is multiplied by a specific factor, and the resultant signal is then used for direct control of the power stage, or averaged and subsequently fed to a pulse-width modulator that drives the power stage at a relatively high frequency. A major drawback of this system is the fact that average output voltage is not only a function of the pulse-width, but also of the control pulse repeat rate. Notably in modern multi-channel radio control systems, this rate is often dependent on the status of other channels, i.e., it is variable due to circuitry that optimizes the density of the information stream. This arrangement readily leads to undesirable, mutual, cross-effects on multiple channels. The circuit presented here is an all-digital design, and is completely free of the above-mentioned drawbacks.

Block diagram
The block diagram of Fig. 3 shows a conventional input section. The input pulse triggers a monostable multivibrator (MMV) that supplies the reference pulse. The error pulse is fed to a second MMV dimensioned for a relatively short mono time, which serves to create the inoperative span around the neutral position. The error pulse must be longer than the inoperative span for the motor driver to be activated. MMVs also reset a 4-bit binary counter, and synchronizes the internal oscillator. The counter
Circuit description

The practical realization of the previously discussed functions is apparent from the circuit diagram of Fig. 4.

The reference pulse is generated by MMV₁, while P₁ sets the zero point. XOR gate N₁ subtracts the input pulse from the reference pulse, and so supplies the error signal. The negative error pulse triggers MMV₂, which resets 4-bit counter IC₃ and defines the start state of the oscillator via D₁ and an input on N₃. The counter is enabled when the period of MMV₂ has lapsed. The trailing edge of the error pulse loads the current counter state in 6-bit latch IC₄, which can so supply the dataword for the pulse-width modulator.

Components D₃, R₁ and N₄ effectively limit the number of counter steps to 16 by disabling the oscillator when CO (CARRY OUT) goes low, and the error pulse is still active. Output CO goes low when the counter reaches state 15 (counting up from 0), freezing the counter state until the error pulse is finished, and the maximum
value is loaded in the latch. Bit D6 in the latch is used as the reverse/forward indicator. The corresponding input on IC1 receives the slightly delayed reference pulse from network Rs-Cs. When the input pulse is shorter than the reference pulse, the latter causes the end of the error pulse. Assuming that link f is fitted, the polarity bit will be loaded as a logic high level. When the input pulse is longer than the reference pulse, the former determines the end of the error pulse, and Ds is logic low when the new dataword is latched. The polarity bit is output on Q6 of the latch, and controls relay driver T2, a darlington transistor that can switch coil loads up to 400 mA. Jumper e or f is fitted in accordance with the control lever position that causes the reversing relay to be energized. In most cases, this will be the "reverse" position.

The 4-bit comparator, IC4, drives the power FETs direct via 100 Ω gate resistors for suppression of spurious oscillation. Notwithstanding the relatively high output impedance of ICs, and the high input capacitance of about 1 nF formed by each FET, the switch response of the power output stage is acceptable due to the "low" switch rate of 1 to 2 kHz. Fast recovery, high current, flyback diodes Ds and Da guarantee that the motor runs smoothly even at low speeds, and at the same time clamp induced voltage peaks on the drain rail to a safe value just above the supply level. XOR gate N4 functions as an inverter for latch output bit Qs, and controls the A=B input of the 4-bit comparator. When this input is logic high, the duty factor of the output signal varies from 0 to 15/16. When A=B is low, the duty factor varies from 1/16 to 16/16. In order to enable varying the duty factor over the full available range of 0 to 16/16, the A=B input is made logic low by N4 when the error pulse is longer than the inoperative span. The timing diagram relevant to the various signals discussed is given in Fig. 5.

Transistors T1 and T2 are included as safety measures.

---

Fig. 4 Circuit diagram of the digital motor controller. The heavy lines indicate high current paths.

Fig. 5 Timing diagram for the main signals in the circuit.
The protective circuitry set up around Ti and T3 is effective in 3 ways:

- Too high currents (short circuits) cause a voltage drop across Rs-son, which results in deactivation of the power stage.
- When the supply voltage is low, the output stage tends to operate in the linear range, causing considerable dissipation. The protective circuitry prevents this happening, and at the same time safeguards the motor against excessive load currents.
- Rs-son of the FETs rises with temperature, so that the protective circuitry is active at lower currents, i.e., it becomes more sensitive.

Construction and use in practice

Given the number of components on it, the ready-made printed circuit board for the digital motor controller is of modest size. The PCB shown in Fig. 6 is a double-sided, but not through-plated, type. The large copper areas are cut away where parts' tracks or pads are needed. The component side is easy to access with the tip of the soldering iron.

It was found that the on-board oscillator may require fitting an additional 47 pF capacitor, C11, to ensure a correct output signal and reliable operation. This capacitor is shown with an asterisk in the circuit diagram, and additionally in the white circle in Fig. 7f. As already noted, the number of FETs in the power output stage is to requirement. The minimum number is 1, the maximum 4. As a general rule, each power FET can carry about 10 A, but it should be borne in mind that the overall efficiency of the power driver increases with the number of FETs fitted. A second flyback diode, De, is required when more than 2 FETs are fitted. For motor currents higher than 10 A, 20 A, or 30 A, available in Cricklewood Electronics Limited.

Miscellaneous:
- SPDT or DPDT relay suitable for available battery voltage. Contact current rating as required for the relevant motor.
- 4 off car-type male terminals with mating sockets.
- 4 off 20-way turned pin terminal strips for making IC sockets. Angled 3-way header with mating jumper.
- PCB Type 87098 (available through the Readers Services).

Parts list

<table>
<thead>
<tr>
<th>Resistors (±5%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rs = 22K</td>
</tr>
<tr>
<td>Rs6, Rs7 = 47K</td>
</tr>
<tr>
<td>Rs = 27K</td>
</tr>
<tr>
<td>Rs1 = 10K</td>
</tr>
<tr>
<td>Rs1..Rs10 incl. = 100R</td>
</tr>
<tr>
<td>P1 = 100K miniature preset for vertical mounting</td>
</tr>
<tr>
<td>P2 = 2K miniature preset for vertical mounting</td>
</tr>
</tbody>
</table>

Capacitors:

- C1 = 15n |
- C2 = 1n0 ceramic |
- C3 = 100n ceramic |
- C4 = 680p ceramic |
- C5 = 100p ceramic |
- C6 = 0p22, 6.3 V; bead tantalum |
- C7 = 47p; 6.3 V; bead tantalum |
- C8 = 22uF; 25 V; bead tantalum |
- C9, C10 = 100n (miniature) |
- C11 = 47p (see text) |

Semicconductors:

- D1..D10 incl. = IN4148 |
- T1 = 8C547 |
- Ds (D6) = BYV78/50 |
- T1 = BC547 |
- T2 = BS170 |
- T3 = BS170 |
- C1 = 4030 |
- C2 = 4538 |
- C3 = 4516 |
- C4 = 90174 |
- C5 = 4585 |
- C6 = LM808 |

For motor currents higher than 20 A.

Available item Cricklewood Electronics Limited.

Miscellaneous:

- SPDT or DPDT relay suitable for available battery voltage. Contact current rating as required for the relevant motor.
- 4 off car-type male terminals with mating sockets.
- 4 off 20-way turned pin terminal strips for making the IC sockets. Angled 3-way header with mating jumper.
- PCB Type 87098 (available through the Readers Services).

Fig. 6 Track layouts of the double-sided board, and the component mounting plan.
Fig. 7a Step 1: all components are to hand for assembly. Note that the PCB in the photograph is a prototype without the component overlay provided on ready-made boards supplied through the Readers Services.

Fig. 7b Step 2: a number of components require soldering at both sides of the PCB.

Fig. 7c Step 3: the IC sockets are fitted as terminal strips to enable through-contacting via some of the pins.

Fig. 7d Step 4: Mount the parts at the PCB edges, and the vertical presets. Fit the ICs in their respective sockets.

Fig. 7e Step 5: the power FETs, flyback diodes and the voltage regulator are fitted in a row and secured with insulating PTFE washers and a long M3 bolt plus nut.

Fig. 7f The area in the white rectangle may be tinned when the output current is higher than 15 A or so. Shown encircled is the 47 pF capacitor that may be needed to ensure correct operation of the 32 kHz oscillator.
When the battery used supplies more than 7 V, the gate drive of the power FETs can be slightly improved by cutting the track that forms connection X (see the circuit diagram) and fitting a diode Type IN4148 with the cathode connected to ground. This modification raises the supply voltage—and hence the logic high level—by about 0.6 V, and allows a slightly higher maximum output current per FET.

The connections of the board to the motor, the battery and the reversing relay are shown in the wiring diagrams of Fig. 8a (dual quadrant operation) and 8b (single quadrant operation). The latter circuit enables implementing an electric brake as discussed earlier. The series resistor in Fig. 8a has a value of 0.2 to 0.5 Ω. It prevents current surges, excessive loading of the battery, and erroneous action on part of the protective circuitry, when the motor's direction of travel is reversed at full speed. The resistor does not carry current when the motor runs in forward direction. The function of the fuse in Figs. 8a and 8b is self-evident, as is the fact that the coil voltage of the DPDT or SPDT relay matches the battery voltage. The regulated 5 V supply rail on the motor controller board may be used for powering the receiver and, if needed, the servos and the lighting, but only if their total current drain is less than 400 mA. Remember, however, that a motor requiring a relatively high starting current may cause the battery voltage to drop briefly but considerably. In critical cases it is, therefore, safer to power the receiver from a separate battery.

Voltage regulator ICs should be fitted with a heat-sink of ample dimensions when it is to power a relatively heavy 5 V load (servos, receiver, lighting), at a high input voltage (>10 V) from the motor battery. The power FETs, flyback diodes and the voltage regulator are TO220 style components, and can be secured as shown in Fig. 7e with the aid of a long M3 bolt which is run through PTFE washers and spacers. The metal tabs of the TO220 components should remain insulated, however, and it is not recommended to use a common heat-sink. The FETs and the diodes do not run hot under normal conditions.

Ascertain that the motor is fitted with a proper noise suppression network before connecting the driver board. A single capacitor is usually not enough, and a suggestion for a more effective network is, therefore, given in Fig. 9. The chokes are a few turns of enamelled copper wire on or through small ferrite cores. The 10 nF capacitors are preferably feed-through types for optimum suppression of motor noise at the operating frequency of the receiver. The network is fitted direct onto the motor terminals and subsequently screened using a grounded metal enclosure. Presets P1 and P2 are used for adjusting the zero point and the maximum motor speed, respectively. A jumper fitted in position e (see Fig. 7f) or f causes the reversing relay to be energized only when the motor runs in reverse.

Finally, a number of prototypes of the digital motor controller were built and tested to enable spotting, analyzing and remediing the most frequently encountered malfunctions. The results are summarized in Table 1, to form a guide for trouble shooting, should this be required to get the unit to function satisfactorily.

![Fig. 8 The motor controller can be wired for dual quadrant (8a) and single quadrant operation (8b).](image)

![Fig. 9 Suggestion for an effective noise suppression network.](image)

<table>
<thead>
<tr>
<th>Problem</th>
<th>Possible cause</th>
<th>Possible remedy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overshoot of maximum motor speed.</td>
<td>Oscillator malfunction. Wiper P1 turned to function R10—D1.</td>
<td>Fit C11 (see Fig. 7f). Adjust P2.</td>
</tr>
<tr>
<td>Reversing relay clatters after fast reversal of direction. (see note below).</td>
<td>Protective circuitry activated by peak reversal current.</td>
<td>Fit current limiting resistor (Fig. 8a). Increase gate drive voltage (see text). Decrease value of Rs, or increase Rs.</td>
</tr>
<tr>
<td>Slow motor response on acceleration commands.</td>
<td>Battery voltage drops due to starting current.</td>
<td>Charge motor battery or use a more powerful type.</td>
</tr>
<tr>
<td>Mutual influencing of servos and motor.</td>
<td>Noise suppression ineffective. Battery voltage too low.</td>
<td>Fit noise suppression network (Fig. 9). Recharge battery. Power receiver from separate battery.</td>
</tr>
</tbody>
</table>

Note: for very fast reversing action, the protection can be incapacitated by omitting either Ti or Rs.
Anyone who is, or becomes, involved in encryption operations and cryptosystems must wonder about their connection with Information Theory. In this article, Brian McArdle briefly explains the areas of overlap and difference.

Consider a channel where a message $x_i$ drawn from a set $\{x_1, x_2, x_3, \ldots, x_n\}$ of $n$ possible messages, as illustrated in figure 1, is transmitted between sender A and receiver B. The message could be just a letter from an alphabet of $n$ letters or a symbol. However, it is information of some type and is exchanged between A and B. The electronic representation of $x_i$ could be a particular waveform or a set of binary digits (bits) etc. For example, the English alphabet of 26 letters requires a set of 5 bits to represent a letter and since $2^5=32$ there are 6 redundant combinations. For the present the method of signalling is not being considered. If each $x_i$ has probability $P(x_i)=p_i$ of being chosen for transmission by A the information entropy of the channel is given by the equation

$$H = - \sum_{i=1}^{n} p_i \log_2 (p_i)$$  \hspace{1cm} (1)

The minus sign makes $H$ positive because every $p_i \leq 1$. The base of the logarithm does not have to be 2 but this means that the dimension of $H$ is bits. If a particular message $x_i$ has $p_i=1$ which means that $p_i=0$ for $i \neq i$, then $H=0$. If all messages are equally likely to be transmitted (uniform distribution)

$$H = \log_2(n)$$  \hspace{1cm} (2)

which is the maximum value and is also the number of bits required to represent a message. The larger the value of $H$ the greater the uncertainty in the information transmitted over the channel. If $H=0$ there is no uncertainty and the receiver B does not receive false information. If the channel is very noisy such that the signals are corrupted during transmission this adds to the problems of the receiver. However, the techniques used to reduce the effects of noise are not being examined in this article. And the technical limitations of the channel, such as in the Hartley-Shannon Law are not considered.

A priori and a posteriori information

The receiver may have some advance information before the message is sent. This is known as a priori information and the a priori probability is the probability that it is correct. The a posteriori probability and the associated a posteriori probability refer to the transmitted message after it is received. These are commonly used parameters in Information Theory but are not used in this article.

Encryption operation

If $x_i$ is encrypted as illustrated in figure 2

$$E(x_i) = y_i$$  \hspace{1cm} (3)

the electronic representation of $y_i$ instead of $x_i$ is transmitted. It is easier to keep track of the explanation by taking the $x_i$'s and $y_i$'s to be letters but this is not essential. The encryption operation is varied by changing the parameter K called the key. This is the secret information and should be known only to sender and receiver. The plaintext (or cleartext) and ciphertext are $x_i$ and $y_i$ respectively. An unauthorized listener (cryptanalyst) on the channel would probably know the method of encryption but not the actual key in use. The strength of the encryption operation is determined by the difficulty in deducing the key from the ciphertext. Modern cryptosystems also require that the key should not be deduced from a matched plaintext-ciphertext pair(s). However, this point is not developed further because we are not actually analysing particular systems. The relationship between Encryption and Information Theory is now considered by outlining the results of a famous paper.

Shannon's theory

Shannon (Ref.1) in his paper compared the effects of secrecy operations to the problem of noise. The letters of the ciphertext should appear random with no preference for any particular letter(s) but only the correct key will produce a meaningful message after decryption. He assumes that a cryptanalyst knows or can deduce the method of encryption (which we will not examine here) and has unlimited ciphertext but no plaintext-ciphertext pairs. He explains the requirements of a cryptosystem using the following parameters:

(a) entropy of the plaintext $H(X)$ computed as per equation (1);
(b) entropy of the ciphertext $H(Y)$ computed as per equation (1);
(c) key entropy $H(K)$ computed as per equation (1);
(d) key equivocation computed according to the equation

$$H(K/Y) = - \sum_{(X,Y)} P(X,Y) \log_2 P(K/X,Y)$$  \hspace{1cm} (4)

with joint and conditional prob-
abilities being used. We need not be concerned with the various steps in the analysis but he deduces the following result:

$$H(K/Y) = H(K) - H(Y) + H(X)$$  \hspace{1cm} (6)

where D is defined as the Redundancy. The dimension is bits per symbol which is usually a letter. This parameter requires further explanation because it is central to the theory and conclusions.

Most languages have a peculiarity that certain letters occur more often than other letters. Consider a message which is encrypted by replacing each letter with another letter according to some rule. A good cryptosystem will result in a ciphertext which has a uniform distribution of letters such that no letter or group of letters occurs too often. This means that H(Y) and H(X) have different values. Although they are both measures of uncertainty, the difference between them is a measure of redundancy. Obviously, H(Y) will be larger than H(X) from equation (2). For English D=3.2. If H(Y)=H(X), then D=0 and H(K/Y)=H(K) and even infinite amounts of ciphertext encrypted with the same key do not reveal the key. Thus one of the most important conclusions of the paper is that cryptanalysis is only possible because of language redundancy.

The 2nd important parameter is the Unicity Distance which is given by

$$U = H(K/D)$$  \hspace{1cm} (7)

which agrees very well with practical results. Any reader who wishes to know the actual techniques to deduce the tables should refer to (Ref.2).

**Example 1**

Consider a simple substitution as follows:

Plaintext: ABCDEFGHIJKLMNOPQRSTUVWXYZ

Ciphertext: GZWJPAHIMT

The number of possible tables which is the equivalent of the various keys is 26! such that

$$H(K) = \log_2(26!) = 56$$  \hspace{1cm} (8)

From Shannon's Theory, this means that 18 blocks are required to establish that a decrypted message is meaningful text. If 8 bit ASCII is used, then 18 blocks = 144 symbols. However, since the ASCII alphabet has 128 symbols, the result is not too different from example 1. In reality, a cryptanalyst would not try each key of 2^18 possible keys but the example does illustrate the principle quite satisfactorily. The other parts of Shannon's paper need not be considered in presenting a short overview. However, his results are deduced using many of the parameters and formulae which are now part of Information Theory.

**Conclusions**

Encryption is not really a branch of Information Theory. There are important areas of overlap but the theories and techniques for the evaluation of modern cryptosystems, such as the Data Encryption Standard or RSA, Public Key Cryptosystem (Ref.4) have become subjects in their own right. Any student who wishes to study Cryptology would be well advised to start with his own right. Any student who wishes to study Cryptology would be well advised to start with basic Information Theory and Shannon's paper.

**Appendix**

Equation (4) can also be written in the form

$$H(K/Y) = -\sum_{i=1}^{m} Pr(k_i|y)\log_2 Pr(k_i|y)$$  \hspace{1cm} (9)

where m is the number of possible keys. The other form is commonly used in text books.

**References**

APPLICATION NOTES

The contents of this column are based on information obtained from manufacturers in the electronics industry, or their representatives, and do not imply practical experience by Elektor Electronics or its consultants.

3-PHASE POWER CONVERTER FOR INDUCTION MOTORS

by K. Wetzel & W. Schumbrutzki

A newly developed integrated pulse-width modulator and fast switching power FETs are the key components in a converter design which allows the good control characteristics of DC motors to be achieved with the more versatile 3-phase motor.

The most widely used three-phase motor is the squirrel cage type. Its features are well known. Having no commutator or brushes, it gives a long service life and runs very quietly. As there is no brush arcing, RFI suppression is not required. Because of the three-phase rotating field the motor has high starting and pull-out torque, is overload-proof and takes very little space. The rotational speed is determined solely by the operating frequency and the number of pole pairs in a given type. In rated operation, slip speed is negligible in view of the operating frequency. A three-phase power source is necessary to operate the motor. Line frequencies being low, like 50 Hz, allow only low motor speeds.

Advantages of converter-fed three-phase motors

Converters are designed to generate a three-phase AC voltage from a DC source. If the three-phase voltage is variable in frequency and amplitude and supplies a three-phase motor the above-mentioned operating characteristics of the motor will be extended considerably. Speed is controllable over a wide range corresponding to the frequency variations. A drive capable of handling 0 to 600 Hz has been built and is described here. Used with a two-pole motor this frequency would allow 36,000 rpm. The motor is controllable by its freely selectable rated frequency, in other words, upon starting, the slip frequency is low and thus the multiple starting current can be reduced to the rated value. Furthermore, it is possible to produce a defined excess starting torque or to generate a torque at standstill, e.g. to keep a robot's arm suspended in a fixed position. Reversing the direction of rotation is likewise facilitated. This is usually achieved by reversing the connections of two motor windings. In converter operation only the control pulses are interchanged by software instructions. Almost unlimited control applications are possible if the control logic of the converter is made part of the whole electronic drive system and programmed sequences or measured values are used to control the motor.

These advantages apply to both synchronous and induction motors. The converter-fed three-phase motor is ideal for drives which require:
- long operating times,
- high speed,
- variable rpm,
- frequent reversing cycles,
- low-noise, maintenance-free operation.

Typical applications of variable-frequency AC inverters are: pumps, fans, machine tools, robots, spinning machines, vehicles and washing machines.

The three-phase voltage supplied from the converter to the motor is not sinusoidal.

Figure 1 shows the principle of the converter design, which is based on the Type SLE4520 3-phase generator. Line AC voltage is rectified by a bridge rectifier and smoothed by a reservoir capacitor. The smoothed DC voltage is called the intermediate circuit voltage. The three terminals of the three-phase motor are connected to the outputs of the power inverter (in Fig. 1 six SIPMOS transistors). The desired motor

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frequency is generated in the control block consisting of microcontroller and PWM. Usually, frequency and associated voltage—and thus motor speed—may be selected over a wide range by means of an adjuster. A sinusoidal voltage would increase the power dissipation in the converter to an excessive level. The overall efficiency would be unacceptable. Therefore the undershoot method is applied here. The pulsed voltage applied to each motor winding switches it off at short intervals. On and off times of the pulse sequence are controlled in a way that the average value of all on-cycles represents value short intervals. The overall efficiency would be unacceptable. Therefore the undershoot method is applied here. The pulsed voltage applied to each motor winding switches it off at short intervals. On and off times of the pulse sequence are controlled in a way that the average value of all on-cycles represents a sine-wave shape (Fig. 3). This process is called pulsewidth modulation. Since the motor inductance acts as an energy store, current depends on the pulse width of the voltage pulses. Figures 2 and 3 illustrate the process. Figure 2 shows the current flow in a load with a pulse-width modulated supply voltage. It can be seen that the current approaches the ideal sine waveform with increasing number of pulses (synthesis points) used to build up a sine wave. But the pulse-width also determines the current amplitude. Decreasing all pulse-widths in the positive sinusoidal region reduces the amplitude of the synthesized sine-wave voltage by the same factor. With the same load applied less sinusoidal current flows (Fig. 2). A 1:1 duty cycle of the clock frequency for all pulses results in zero current.

The minimum clock frequency depends on the motor inductance. The clock frequency required rises with reduction of inductance. Consequently small motors and high rotational speeds permit high clock frequencies while large motors and low rotational speeds mean low clock frequencies. The selected clock frequency may, however, exceed the required minimum. One synthesis point of a sine-wave consists of several uniform pulses. Often the clock frequency is chosen much higher than necessary to avoid excessive noise (beyond the limit of audibility). The emitted noise primarily depends on the current characteristic. The closer a current curve approaches the ideal sine waveform, the less noise is generated. Too high a clock frequency would certainly restrict the pulse-time variations for an optimum sinusoidal shape.

Pulse-width modulation

The principle of pulse-width modulation is shown in Fig. 3. A microcontroller with timer and down counter is needed to modulate pulse widths. Another minimum requirement is a register to pre-load the initial count value and a predivider to adjust the counter frequency in steps. As a register and a counter are required in each phase, they are integrated in the new SLE4520 pulse width modulator; together with some additional functions. Functional description: the initial count value is loaded via the register from the microcontroller to the down counter. The down counter runs down to zero using the predivided CLK frequency. In this cycle a negative signal is available at the output (Fig. 4). A time signal is generated simultaneously in the timer of the microcontroller. After this interval has lapsed, a transfer pulse (synchronization pulse) is passed to the down counter to start another count down from the initial value from the register. If, meanwhile, the microcontroller has written a new value into the register, the pulse width generated at the output is modified. To obtain a proper pulse-width modulation the down count period has to be equal to or below the transfer pulse sequence initiated by the timer.

The timer determines the clock or switching frequency and the down counter cycle decides the pulse width. Pulse-width modulation for a sine wave is shown in Fig. 2. The sine wave is divided into a number of synthesis points. To each point an amplitude is allocated which corresponds to a particular pulse width. With a pulse width of 50% the average voltage is zero (see Fig. 3), with 100%, the maximum positive voltage and with 0%, the maximum negative voltage is obtained. The switching frequency (e.g. 15 kHz) is usually kept constant to generate a particular sine-wave frequency whereas the pulse width is varied from one synthesis point to another. Values are compiled in a table.
within the microcontroller. A continually changing frequency is obtained by appropriately reducing or extending the switching frequency period, or, in other words, the timer interval.

As already mentioned, the sine-wave current to be generated is approximated by a number of synthesis points. Each point corresponds to at least one cycle of the switching frequency. The number of synthesis points for each full sine-wave cycle must be a multiple of six as otherwise a 120° phase displacement cannot be achieved for three-phase operation.

For the sinusoidal frequency the following formula applies:

\[ f_r = \frac{f_s}{SN} \]

where

- \( f_r \) = synthesized sine-wave frequency (motor frequency),
- \( f_s \) = switching frequency,
- \( S \) = number of synthesis points,
- \( N \) = number of equal pulses per synthesis point.

The switching frequency is determined by the timer interval in the microcontroller. The timer frequency of the microcontroller used here is 1 MHz. A maximum of 256 \( \mu \)s time interval results for the 8-bit timer corresponding to a 3.9-kHz switching frequency. For higher switching frequencies the timer is counted to below 8 bits with time steps of 1 \( \mu \)s being achieved. For a desired frequency of 20 kHz, for example, 50 steps = 50 \( \mu \)s have to be programmed. The maximum synthesized sine-wave frequency is obtained at a high switching frequency with six synthesis points per period (roughly) and one pulse per point:

\[ f = \frac{15.625 \text{ kHz}}{6} = 2.604 \text{ Hz} \]

There are hardly any objections to generating extremely low sine-wave frequencies as the number of synthesis points and pulses per point may be almost unlimited, e.g.

\[ f = \frac{3906.25 \text{ Hz}}{240} = 0.16 \text{ Hz} \]

If a generated sine-wave frequency is to be varied, minor a major frequency changes may be performed by reducing or increasing the number of synthesis points or pulses per point with a given switching frequency.

The SLE4520

The SLE4520 pulse-width modulator is a control device which reads the data provided by the microcontroller and converts them into pulse-width modulated clock pulses for three phases driving the power half-bridges via intermediary stages. The SLE4520 is compatible with all kinds of microcontrollers and suitable for all types of three-phase motors because of its large variety of selectable clock frequencies and pulse widths. Fig. 5 shows the block diagram of the SLE4520 PWM. The IC is operated at the crystal frequency of an on-chip oscillator which may also clock the microcontroller. The operating frequency (or count frequency) is generated via a programmable divider. The available divisors 4, 6, 8, 12, 16, 24, 32 or 48 and the dead time delay are archived by loading a number into the divider control register and into the appropriate dead-time register. Dead time is a delay required in case the halfbridge transistors exhibit excessive switching delays. Here the delay has to be compensated by decreasing the number of control pulses. The SLE4520 has two outputs for each phase to control individually the upper and lower transistors in the halfbridge. Output pulses may be delayed by a programmable dead time delay to prevent simultaneous switching of the halfbridge transistors, thus eliminating the risk of a short-circuit. This is particularly important for bipolar switching transistors but also if the power transistors have to be driven via a voltage isolating optocoupler susceptible to delays.

In the SLE4520 pulse-width modulator up to 16 dead time intervals can be generated from 0 to 15 \( \times \) 4 (or 6)/f\( \text{cxt} \) in steps of 4 (or 6)/f\( \text{cxt} \). If zero dead time both output pulses of one phase are in inverse to each other without any delay. Data are transferred to the pulse-width modulator by writing into phase registers 1, 2 and 3 via the 8-bit data bus P0 and the address decoder latch. At one output the 3-bit address is decoded and latched at the falling edge of the ALE clock until the data are available at the bus together with the WR signal.

The transfer pulse for the register is produced by an AND-logic operation from the WR-signal and the address stored. The pulse-width modulated signal is generated by a zero decoder and a presetable 8-bit down counter which can be stopped via an enable input. The transfer pulse (one instruction cycle) of the processor determining the switching frequency loads the register contents into the presetable counter and a "1" appears at the 8-bit OR gate output. This 1 digit enables the counter and causes it running down. Upon reaching zero the pulse ends and the counter is

![Fig. 4 General organization of a pulse-width modulator with "intelligent" control.](image)

![Fig. 5 Internal organization of the Type SLE4520 PWM controller for 3-phase systems.](image)
Table 3 Addressable latches in the SLE4520.

Table 1 Allocation of value in the divider register to the divider ratio by which the SLE4520 operating frequency is selected.

<table>
<thead>
<tr>
<th>Value</th>
<th>Divider ratio counter</th>
<th>Divider ratio delay clock</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1:4</td>
<td>1:4</td>
</tr>
<tr>
<td>1</td>
<td>1:6</td>
<td>1:6</td>
</tr>
<tr>
<td>2</td>
<td>1:8</td>
<td>1:8</td>
</tr>
<tr>
<td>3</td>
<td>1:12</td>
<td>1:12</td>
</tr>
<tr>
<td>4</td>
<td>1:16</td>
<td>1:16</td>
</tr>
<tr>
<td>5</td>
<td>1:24</td>
<td>1:24</td>
</tr>
<tr>
<td>6</td>
<td>1:32</td>
<td>1:32</td>
</tr>
<tr>
<td>7</td>
<td>1:48</td>
<td>1:48</td>
</tr>
</tbody>
</table>

Table 2 Word in dead time memory, Divider ratio 1:4 dead time (μs) and Divider ratio 1:8 dead time (μs).

<table>
<thead>
<tr>
<th>Word</th>
<th>Divider ratio 1:4 dead time (μs)</th>
<th>Divider ratio 1:8 dead time (μs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0.33</td>
<td>0.75</td>
</tr>
<tr>
<td>2</td>
<td>0.66</td>
<td>1.5</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>1.33</td>
<td>2.5</td>
</tr>
<tr>
<td>5</td>
<td>1.66</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>2.33</td>
<td>3.5</td>
</tr>
<tr>
<td>8</td>
<td>2.66</td>
<td>4</td>
</tr>
<tr>
<td>9</td>
<td>3</td>
<td>4.5</td>
</tr>
<tr>
<td>10</td>
<td>3.33</td>
<td>5.5</td>
</tr>
<tr>
<td>11</td>
<td>3.66</td>
<td>6.5</td>
</tr>
<tr>
<td>12</td>
<td>4</td>
<td>7.5</td>
</tr>
<tr>
<td>13</td>
<td>4.33</td>
<td>8.5</td>
</tr>
<tr>
<td>14</td>
<td>4.66</td>
<td>9.5</td>
</tr>
<tr>
<td>15</td>
<td>5</td>
<td>10.5</td>
</tr>
</tbody>
</table>

Table 3 3-bit address latch.

<table>
<thead>
<tr>
<th>Address</th>
<th>Latch</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>8-bit latch for PH1</td>
</tr>
<tr>
<td>01</td>
<td>8-bit latch for PH2</td>
</tr>
<tr>
<td>02</td>
<td>8-bit latch for PH3</td>
</tr>
<tr>
<td>03</td>
<td>Dead time latch</td>
</tr>
<tr>
<td>04</td>
<td>Divider latch</td>
</tr>
</tbody>
</table>

Fig. 8 Pinning of the SLE4520.

Table 4 Allocation of the counter frequency and the switching frequency for the SAB8051 microcontroller.

<table>
<thead>
<tr>
<th>Divider ratio</th>
<th>Counter frequency</th>
<th>Operating time Timer 0</th>
<th>Switching frequency</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:6</td>
<td>2 MHz</td>
<td>64 μs</td>
<td>15.6 kHz</td>
<td>7 bit</td>
</tr>
<tr>
<td>1:8</td>
<td>2 MHz</td>
<td>128 μs</td>
<td>7.8 kHz</td>
<td>8 bit</td>
</tr>
<tr>
<td>1:12</td>
<td>1 MHz</td>
<td>128 μs</td>
<td>7.8 kHz</td>
<td>8 bit</td>
</tr>
<tr>
<td>1:12</td>
<td>1 MHz</td>
<td>256 μs</td>
<td>3.9 kHz</td>
<td>8 bit</td>
</tr>
<tr>
<td>1:24</td>
<td>500 kHz</td>
<td>256 μs</td>
<td>3.9 kHz</td>
<td>8 bit</td>
</tr>
<tr>
<td>1:48</td>
<td>250 kHz</td>
<td>2 x 256 μs</td>
<td>1.95 kHz</td>
<td>8 bit</td>
</tr>
<tr>
<td>1:48</td>
<td>250 kHz</td>
<td>4 x 256 μs</td>
<td>1.95 kHz</td>
<td>8 bit</td>
</tr>
</tbody>
</table>

In the pulse-width modulator, the dead time is obtained by linking the pulse-width modulated source signal and its delayed signal. The delay is obtained by passing the source signal through a 14-bit shift register with 16 outputs. The shift pulse is either \( f_{\text{source}}/6 \) or \( f_{\text{source}}/4 \), depending on the contents of the divider counter register.

To select the delay and the dead time, only one output of the shift register has to be addressed and then switched through to the logic circuit. This is provided by three 1:16 multiplexers. 15 dead times are presettable (incl. zero dead time) by writing a value in between \( 0 \) and \( 0FF \) into the appropriate control register.

Dead time depends on the quartz frequency and the preset divider ratio (1:4 or 1:8). For a 12-MHz quartz frequency the programmable dead times are given in Table 3. Without dead time PH 1/2 is inverted to PH 1/1, PH 2/2 to PH 1/1 and PH 3/2 to PH 3/1. The active switching state is low: With a programmed dead time the negative edges of the output signal are shifted to the right by the dead time. The outputs are capable of directly driving TTL devices or optocouplers for voltage isolation of drive blocks and power circuits with currents up to 20 mA.

The SLE4520 is a CMOS device, and non-used inputs should, therefore, be connected to ground or the positive supply rail. Finally, Table 4 shows the relation between counter frequency and switching frequency for a SAB8051 microcontroller operating at 12 MHz.
Dual-channel 40/20 MHz oscilloscopes

STC Instrument Services has extended its growing range of Hitachi oscilloscopes with the introduction of the new high-performance V-312 DC to 20 MHz and V-422 40 MHz single time-base instruments. Both feature dual-channel operation and a high sensitivity of 1 mV/div.

Housed in a compact 310 x 370 x 370 mm package, these versatile instruments offer a wide range of features including a 6 in. CRT with internal graticule; an autofocus circuit and scale illumination (422); an accuracy of +3/0; a graticule; an autofocus circuit; signal delay line for observation of leading edge of fast risetime signals (422); and a convenient XY operation mode to enable phase difference measurements between two waveforms.

STC Instrument Services

Dewar House

Central Road

Harlow

Essex CM20 2TA.

Telephone: (0279) 29522

Telex: 817202 STCRES G

(3678:3)

New intelligent frequency counter

The FC-8100C is a new, microprocessor-controlled, high resolution, frequency counter. Made in Taiwan by GW Instrumentation, the counter is available in this country only from Flight Electronics.

The new counter has two channels in order to cover a wide range of frequencies from DC to 1 GHz. Despite this wide coverage, the counter costs 15% less than competitive products with smaller ranges. It is accurate to typically, <0.01% at 23°C and sensitive down to pulses of 10 mW.

Resolution remains high at both high and low frequencies. At least 7 digits are displayed for a one second gate time, and 5 digits for a 60 ms gate time. The gate time is variable from 60 ms to 10 s or ten periods of input, whichever is the longer.

The counter will be of use to those involved in test and measurement both in educational establishments, and in design and development for manufacturers. It is useful for measuring and verifying signal frequencies, for pulse counting, and as a tachometer or a timer.

The cost of the instrument is £293, including all the connecting cables, a handbook and a one year guarantee.

Flight Electronics Limited

Flight House

Ascupart Street

Southampton SO1 ILU.

Telephone: (0703) 227721

Telex: 477389 FLIGHT G

Fax: (0703) 330039 (5878.11:F)

Protective Transport Cases For Economical Scope Family

ECW (Electronic and Computer Workshop Ltd.) announces a range of carrying cases for the economically priced Crotech range of oscilloscopes. The cases give protection for the instruments while being carried about and when stored. They are available for 20 MHz, 2 mW dual trace 3132, the 30 MHz, 5 mW dual trace 3337 and the 30 MHz, 5 mV VDU mode 3339.

The Crotech range, which includes both single and dual trace types, is available with a useful selection of accessories to improve further their versatility.

ECW offers the carrying cases at a price of £37.98, including post/packaging and VAT. Most Crotech oscilloscopes now include a built-in component comparator for rapid testing of semiconductors and passive devices. Several types, including the 3132 and 3339, also provide a very convenient front-panel ±12 V and +5 V output.

Electronic & Computer Workshop Limited

Unit 1

Cromwell Centre

Stepfield

Witham

Essex CM8 3TH.

Telephone: (0376) 517413(3678:4)
Hand held digital multimeter measures frequency

Electronic Brokers offer the Fluke 8060A series of handheld digital multimeters, the first digital handheld test instrument to offer frequency measurement capabilities. Ranges include 200 Hz, 2000 Hz and 200 kHz, all of which are fully autoranged, thereby enabling easy servicing of a wide range of communications equipment. The instruments are also suitable for other applications in design, manufacturing, and field servicing.

New large can electrolytics

Abacus Electronics has announced the availability of a new range of large can aluminum electrolytic capacitors. The CEL and CELP2 ranges are manufactured by Wimpey-Dubilier and are supplied with solder tag or plug in terminations respectively. The CEL solder tag termination capacitors are available in the capacitance range from 1000 to 220,000 µF with working voltages from 6.3 to 450 V. Capacitance tolerance is -10 to +50% and 0.03 CV or 5 mA. The CEL range is suitable for operation over the temperature range -25 to +85 °C except for 450 V devices which are rated for operation over -25 to +70 °C. The CELP2 with plug-in terminations is a family of low profile devices and is available in the capacitance range from 220 to 15,000 µF. Working voltages range from 16 to 200 V and the devices are suitable for operation over the temperature range -40 to +85 °C. Capacitance tolerance is -10 to +30% whilst maximum leakage current is 0.02 CV or 3 mA. The CEL solder tag devices are supplied with mounting brackets already fitted. Available from stock, these electrolytic capacitors are part of a recent franchise agreement between Abacus and Wimpey-Dubilier.

Low-cost 20 MHz dual-beam oscilloscope

The new GOS-522 dual-beam oscilloscope is now available from Flight Electronics Limited. A highly sensitive instrument, it offers good price performance and a resolution of 1 mV/div. with better than 3 percent accuracy. The scope has a 6 in screen with an internal graticule CRT. Available functions include chop/alternate and hold-off timebase. The timebase range spans 0.2 µs to 0.5 s. Both channels have an alternate triggering function. A separation circuit provides TV synchronisation. Channel one has a signal output at the rear of the instrument.

The unit is easy to operate and ideal for general purpose work in education, service and production. Trigger modes can be set at three levels, normal, automatic, and single. Frequency bandwidth is AC/DC 10 to 20 MHz. Rise times are 17.5 ns (20 MHz) and 23 ns (15 MHz). Chop frequency is around 250 kHz. Overall dimensions are 460 x 310 x 170 mm. Standard unit price is £399. With two switchable probes the price is £319.

Flight Electronics Limited
Flight House
Ascrapur Street
Southampton SO1 1LU.
Telephone: (0703) 227722
Telex: 477389 FLIGHT G
Fax: (0703) 330039 (3662:15:F)
All orders must be sent BY POST to our Brentford office using the appropriate form opposite. Please note that we can no longer accept PERSONAL CALLERS, as no stock is carried at the editorial offices. The postal address is given at the back of the form.

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Rugged, accurate & protected

Two new analogue multimeters are available from Universal Instruments. Hioki models 3000 and 3015 are high quality instruments that are drop proof, have large clear taut band suspension meters with diode overload protection and can withstand 240 V on all resistance and current ranges. Both AC and DC voltages are accurately measured to 1000 V with a DC voltage sensitivity of 20 kΩ per volt.

Hioki model 3015 also measures both alternating and direct current to 10 A, resistance to 15 MΩ in four ranges with a 20 Ω centre scale, dBs from -10 to +23 dB and temperature with an optional probe from -50°C to +200°C and is the ideal general purpose tool. Model 3000 measures direct current to 300 mA, resistance to 1 MΩ with a 20 Ω centre scale, temperature via an optional probe from -50°C to +150°C and has a real battery test function with an integral load to indicate the true condition of the battery under test.

Both instruments have a physical size of 136 x 92 x 39 mm, and come ready for use with test leads, spare fuse, batteries, instructions and carrying case. A range of useful optional accessories includes a clip-on ammeter with a 0 to 300 A range, a 30 kV high voltage probe, thermistor temperature probes, and a fused probe for power line voltage measuring applications.

Model 3000 inc. carrying case

£34.65 exc. VAT
Model 3015 inc. carrying case £40.12 exc. VAT.

Universal Instrument Services Limited
Unit 62
GEC Site
Cambridge Road
Whetstone
Leicester LE3 3LH.
Telephone: (0533) 681544
Telex: 34611
Fax: 0533 866084 (3678:9:F)

Modem evaluation board

Recently introduced by SEIKO EPSON and available through their UK Agent Hero Electronics, is the SEK9401B Modem Evaluation Board. Intended as a tool to help the Design Engineer evaluate the SEIKO EPSON range of CMOS Telecom LSI. It incorporates 300 bps and 1200 bps Modem ICs, a DTMF Tone Dialler, Protocol Controller and 8250A/B Compatible Bus Interface. The SEK9401B is capable of full-duplex communication at 1200/300 bps on a telephone line. Connecting it to an IBM PC-XT/AT System bus implements a complete modem link.

Hero Electronics represents Seiko Epson in the UK, and offers their range of CMOS LSI. This also includes SRAMS, 4 bit microcomputers for LCD and battery drive and Application Specific ICs.

Herio Electronics Limited
Dunstable Street
Ampthill
Bedfordshire MK45 2JS.
Telephone: (0525) 405015
Telex: 825906 (3682:8:F)

Hand held voltage calibrator

Datel has introduced a new hand-held battery-powered voltage calibrator for precise adjustment of analysers, recorders, controllers, data acquisition system computers and many other lab and field applications.

The microprocessor-based DVC-350A provides the user with two entry modes of operation and four output voltage ranges. The outputs feature an outstanding 0.015% accuracy, a figure more usually associated with laboratory-type calibrators. The accuracy and stability are traceable to the US National Bureau of Standards. The DVC-350A possesses a number of powerful features such as switch-selectable mode of entry as either decimal or hexadecimal. Decimal mode output ranges are ±12 V DC in 100 mV increments and ±12 V DC in 1 mV increments. Hexadecimal mode offers output voltage ranges of ±1 V DC in 244 μV increments and ±10 V DC in 2.44 mV increments.

The hexadecimal mode is most useful for computer-oriented calibration of digital panel meters, A-to-D, and data acquisition systems. It eliminates the need for tedious hexadecimal-to-decimal number conversions as the DVC-350A performs these automatically.

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Other features of the DVC-350A include a 4½ digit LCD; right and left binary shift for hexadecimal calibration of A-to-D or D-to-A converters; convenient, easy-to-use membrane keyboard with audible feedback; up to 20 mA source or sink current capability; finger touch cursor control with automatic voltage increment or decrement; and automatic current limiting and low battery indication.

The DVC-350A features rated accuracy down to 6.5 V DC battery level using rechargeable 7.2 V battery or conventional 9 V battery. The calibrator is supplied with water resistant carrying case which also holds the test leads set and spare batteries. A certificate of NBS Traceability and operations manual complete the package.

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GEORGE BRAY LTD brass encased heating elements for sale, total quantity 10 assorted lengths & wattages, 170 - 1150W. Offers invited, E.G. Priestley, 65 Lynnham Avenue, Windmill, Shirley, West Yorkshire BD16 1NF. Tel. 0274 593382.

WANTED: Complete circuit diagrams of Transceivers, CW, SSB, etc. Nothing overly complicated. Will pay reasonable price. R. Parker, 'Dail', 112W at 4A, - 24V at 1.7A, -12V at 0.21, over voltage, over current protection, £19. Tel. 0245 259027.

OLEVITTI PORTABLE COMPUTER and Planter, unwanted gift. Offers invited, to include manual and charger, word proc., clock, A. Miller, 8 Middleden Grove, Great Barr, Birmingham B43 5EU. Tel. 021 356 1843.

FOR SALE: Telephone line micro transmitter, £10. Voice micro transmitter, £12, size 35 x 15 x 15. SAE for list, Izakli Jouvel, 10 Zv1 Filipka St, OR-Jhola, Israel 80-201.


CLEANOUT: 3 printers & VOU5, EPROM programmer + flex8800 system, Zonc 701 Logic Analyser, oscilloscope & drawing board. Viga Thilili, 74 Forlease Road, Maidenhead, Berks. Tel. 0628 36121.

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HAS ANYONE BUILT synthesised shortwave radio 144 mhz transceiver. Practical Wireless. John Saxe, 18 Bedford Close, Pknorth, Swindon, Wilts. SN3 2LB.


FOR SALE: 170 - 1150W. Offers invited. F. Maiorino, Via Atemo 53, 66013 Chieti, Italy.

WANTED: Elektor from January 1985 to June 1987, and Ham Radio catalogue 1974 or 1975, Maclane, Via Atrano 53, 66013 Chieti, Italy.

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From this month we are offering PCBs and kits for the circuits depicted in the L-H1616. All kits feature higher grade components and the circuit from which the kits derive has been modified for improved performance. We are gradually building up a range of components and we will offer these on a regular basis. We recommend that you order all components at once. We are happy to sell kits alone or in combination with PCBs.

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