LASERS: AN OVERVIEW

The MAC System
The Compact Disc
A new audiophile quality high fidelity amplifier kit

The GATE ONE amplifier kit is a top quality professionally engineered amplifier that has the sonic performance, build quality and finish of amplifiers in the £300 - £400 price range, yet costs only £161 inclusive. Available from Gatehouse Audio, the amplifier specification includes a host of features common to most mid-range ready built amplifiers combined with various aspects of design and performance normally associated with more esoteric products. A ready built version is available for £201.25. Features include a 40 + 40 watt output, a fully stabilised high current power supply, high current TO3 power supply and output transistors, 225VA transformer with 6 reservoir capacitors, double sided earth plane pcb, minimum capacitor passive RIAA and tone control equalisation, sub-sonic filter, low end bass boost switch and MM/MC, CD, Radio, Tape 1, Tape 2 inputs and tape output phono sockets mounted on an isolated input panel to eliminate eddy current effects in the amplifier chassis.

A solder resist and a component legend on the pcb simplify assembly. Inputs are connected directly to the selector switch and not routed across an unscreened pcb or subject to multiple stages of potentially unreliable switch contacts (as is common with some designs). All resistors are 1% metal film and film capacitors are used wherever possible. An earth plane on the pcb aids sonic performance by screen- ing sensitive components and signal tracks and also allows an ideal power supply star feed and earth return network. The fully stabilised supply has no ripple. Other designs require over complicated preamp stages to increase ripple rejection. Removal of the cause of the ripple is a more elegant solution.

Specification and design philosophy

Inputs ....... Phono MM, 2mV into 47K. Input overload 60mV (29dB).
Phono MC, 200mV into 470 ohms. Input overload 9mV (26dB).
Radio, Tape 1, Tape 2: 50mV into 100K. Input overload 2V (32dB).
CD, 200mV into 10K. Input overload 8V (32dB).

All voltages are RMS, all sensitivities refer to 40 watts output at 1kHz.

S + N ratios . Phono MM ref 5mV input, 80dB. (input terminated into 1K).
Phono MC ref 500µV input, 70dB, (input terminated into 330 ohms).
Line inputs ref 100mV input, 85dB. (input terminated into 10K).

All noise figures are unweighted RMS 20Hz - 20kHz bandwidth. They are a direct measure of the output noise when the volume control is set to obtain 40 watts output into 8 ohms from the stated reference input level.

Controls ....... 6 position Input Selector.
Volume, Low Lift, Tone Cancel, Balance, Bass, Treble.
MM/MC selector on rear panel.
Mains on/off, green LED on indicator.

Features .... Passive RIAA equalisation and low insertion loss tone control stage.
Dual action volume control for optimum signal overhead and signal to noise ratio.
Fully regulated DC supply to all stages including output stage.
Rugged TO3 complementary Darlington output and PSU transistors.
High current design. Star earthing arrangement.
Automatic switch on delay.
Simple construction, comprehensive instructions.
Double sided PCB with solder resist and component overlay. Earth plane top layer considerably reduces component interaction.

Outputs ....... 40 + 40 watts into 8 ohms. 80 watts into 4 ohms.
Buffered Tape Output, 200mV nominal.

Functions ... Treble range +/-5dB at 12kHz. Bass range +/-5dB at 60Hz.
Infra cut facility on phono inputs, -6dB at 10Hz.
Low lift maximum of +5dB at 30Hz, user definable at build stage.

Dimensions .440w x 240d x 85h mm.

The outer case has a high quality black gloss finish and the separate front panel is printed in gloss white. All metalwork is ready drilled and the appearance and performance of the fully built amplifier will make all constructors proud of their work.

The sonic ability of the amplifier is quite superb, the sound is detailed, articulate yet not over clinical. Dynamics are produced with a bite that brings good recordings alive. Unfortunately, poor recordings are quite likely to sound even worse! In this case, the tone controls can help.

Gatehouse Audio
105 High Street
EVESHAM
Worcestershire WR11 4EB
Telephone: (0386) 48873
Editorial

News from the world of electronics

Mobile satcoms for the future: Dr Norbury of the Rutherford Appleton Laboratory explains the advantages of a highly elliptical orbit for communications satellites over a geostationary position.

Solar power generation: many of us would like to see a real alternative to nuclear and oil or coal burning power stations. Solar energy which is freely available and in plentiful supply is, therefore, taking on new importance.

Lasers: an overview. Since the first lasers appeared in the early 1960s, they have become indispensable in such diverse applications as fibre optic communications, surgery, compact disc players and the Strategic Defence Initiative.

The MAC system: the European Broadcasting Union—EBU—has adopted a new family of television standards called MAC—multiplexed analogue components—developed by the Independent Broadcasting Authority. This article explains the aims of the new system.

The compact disc: an introduction to the development of the CD, how it is made; the optical system in the CD player; commercial aspects of CD. The article finishes with a brief survey of the products of 20 of the best-known makers of CD players.

Telecommunications: news from the world of the new telecommunications.

Filters: theory and practice—1. Although a great many filters are nowadays available ready made at reasonable prices, there remain occasions when one has to be designed from scratch. In this first part of a three-part article, A.B. Bradshaw looks at the theory underlying such design.

Where students make their own chips: the University of Dundee gets its electronics engineering graduates to design and make integrated circuits in their own laboratory.

ATN Filmnet decoder: an update on our May article in view of the change in ATN’s scrambling system.

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elsewhere. The kit is supplied complete with high
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instructions. All you need is a mains supply,
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GOODS BY RETURN SUBJECT TO AVAILABILITY
R&D funding in Britain

Much has been said and written in recent years about the decline of British science, the lack of funds for research programmes, and the new brain drain. But is R&D funding in Britain really as poor as depicted by many?

In 1981, Japan launched a ten-year national programme to develop what are known as fifth generation computer systems. This ambitious project aims to bring together the necessary elements of clever computers which, in the 1990s, will be able to demonstrate artificial intelligence and simulate human hearing, speech, and vision.

Britain's response to this challenge was to mount its own advanced research programme. Known as the Alvey Programme, it was started in 1983, and will eventually cost about £350 million, of which £200 million will come from public funds, and the remainder from participating companies.

The Alvey Programme consists of pre-competitive research projects which fit into national strategies in important areas of technology. These involve collaboration between universities, industry, and research establishments; and between different industrial companies.

At about the same time, the European Economic Community, also fearful of lagging behind Japanese and American research, started a similar programme. This is known as ESPRIT (European Programme of Research and Development in Information Technology). Again, collaboration between companies and universities is a major feature of ESPRIT. The programme, in which many British companies and universities are involved, is funded on a fifty-fifty basis by the European Community and the participating industrial firms.

Another programme, started in 1985, is EUREKA (European Research Coordinating Agency), which is aimed at promoting collaboration instead of competition between Europe's research and development organizations. Already, the amount of money committed to research projects under the EUREKA aegis exceeds £2,000 million. More than 100 projects have already been started, in 41 of which British firms and universities are involved. This involvement will cost the British Government about £40 million over the first five years.

A recent OECD report shows that of western nations Britain allocates a bigger share of public spending to research than the United States, Federal Germany, or Japan; only France devotes more. If this were the whole picture, all would be well. Unfortunately, when it comes to gross expenditure on R&D, Britain lags behind all other western industrial nations.

This is not the direct fault of the government, but rather because British industry's spending on R&D has fallen way behind that of other countries since the 1960s. In the intervening period, real spending on R&D by the industry in the USA, Federal Germany, and France has doubled, while it has trebled in Japan. In Britain, it has increased by just about 20% over the same period.

British industry may well need government help in the form of, for instance, a high rate of tax relief on R&D spending, or grants for particular research programmes, but it would appear highly beneficial if it and its backers, the commercial banks, would forgo their current short-term outlook and adopt a long-term strategy as regards R&D funding.
World's fastest integrated circuit claimed

A world speed record for integrated circuits of 18 GHz is being claimed by Hughes Research Laboratories in Malibu, California. The gallium arsenide chip can divide by two, a basic processing function, 18 billion times a second—said to be five times faster than commercially available GaAs integrated circuits and ten times faster than commercial silicon chips.

The new digital circuit will make it possible to raise the processing speed and reduce the cost of information handling for the next generation of digital communications and signal-processing equipment, say Hughes scientists. Applications could include optical-fibre communications links, supercomputers, advanced radars and communications satellites.

"Airbridges", elevated connectors that link the logic gates on the chip (shown in Fig. 2 where the white line at bottom right indicates 10 µm). The airbridges minimize the capacitive loading of the interconnections and keep energy losses to a minimum.

Canon and National Semiconductor to cooperate on development of laser beam printers

Canon Inc. and National Semiconductor Corporation have announced their intention to cooperate on the definition and development of integrated circuits and software for products to be manufactured and marketed by Canon. The first product resulting from the agreement will be a laser-beam printer.

The printer market is one focus for National's Series 32000 family of 32-bit microprocessor products. Although the integrated circuits and software developed are initially intended for laser-beam printers, the companies will explore a broadening of the relationship in the future.

IBM licenses Micro Focus COBOL

IBM has licensed Micro Focus COBOL for the new IBM Personal System/2 range of computers, running IBM Operating System/2, and for its existing IBM Personal Computer range. The newly announced IBM COBOL/2 has an early release called IBM COBOL Version 2.00, which supports IBM DOS Version 3.2 and 3.3. Users of IBM COBOL Version 2.00 will be upgraded by IBM to IBM COBOL when OS/2 becomes generally available.

IBM COBOL/2 is an ANSI '85 compiler with a built-in interactive debugger that can run on both IBM DOS 3.3 or IBM Operating System/2. It is ideal for existing applications from other environments and for developing new high-speed, high-quality business applications.

IBM COBOL/2 generates standard object module format which is linkable with other languages and which provides multi-user support across the IBM PC Network. The wide range of supported COBOL syntax includes ANSI '85 Intermediate Level COBOL, ANSI '74 High Level COBOL, a subset of IBM VS COBOL Version 1.00 and Micro Focus extensions of the IBM Personal Computer.

IBM's Systems Application Architecture (SAA), announced last March by IBM, defines a standard for cross-system compatibility. IBM COBOL/2 meets IBM's SAA standards, providing a mechanism for COBOL applications to migrate across the IBM product line. This is IBM's first announcement of a COBOL implementation which will meet IBM's SAA standard.

Factron wins key ATLAS order

Factron Schlumberger has just won a major order for ATLAS compilation facilities from the UK's Ministry of Defence. The order calls for an ATLAS compiler with a post-processor for MEDIATOR, Factron's own test language. The compiler will be used by the Royal Air Force (RAF) for writing test programs for avionics equipment.

The order signals a major trend within the UK's defence ministry away from purchasing 'special-to-type' test systems, towards general-purpose automatic test equipment (GATE) system, in conjunction with the use of GATE, provides the means for major savings in test system and software costs, allowing test software to be 'transported' across a range of different test systems from different manufacturers. A test program will now only need to be written once during a product's lifetime, and will be able to run on any new test system the RAF obtains.

Newbury Data awarded for production innovation

Newbury Data Recording Ltd has won the "Productivity Enhancement in Electronics" category of the Production Innovation in Electronics (PIE) Award for 1987.

Newbury won this important award against strong competition from Rank Xerox, ICI Chemicals and Polymer Group, Kerry Ultrasonics, Marconi Instruments, BICC Data Network and Luxtec, for its use of state of the art Surface Mount manufacturing techniques to provide a significant and competitive gain in the technically exacting disc drive production environment.

The Surface Mount System is used at the company's 330,000 square ft manufacturing plant at Winsford, Cheshire. It consists of fully automated printed circuit board assembly modules supplied by Manx (UK) Ltd.
PEOPLE

Brian Loader, BSc (Eng), MIEE, CEng., has been appointed director of naval business at Marconi Radar Systems CHELMSFORD.

PAL Components have announced the following promotions and appointments. Derek Newport (see photograph) becomes Development Director, with Eric Vavasour taking the post of Technical Manager.

Martin Fray (see photograph) is appointed Director and General Manager and David Knowles becomes Manufacturing Manager.

Geoff Potts has joined Sentry Test Systems, part of Schlumberger’s C&AS group of companies and a world leader in the ATE market, as UK Manager.

Toby Warson has been named vice president and managing director of Honeywell Limited in the UK. He succeeds Dr Jim McGregor, who retired last March.

ERA Technology Ltd have announced the following the following appointments: Richard Stokes, BSc, CEng, FIIE, and Dr Martin Desvaux become Executive Directors of the company. Jack Donald, BSc, CEng, CDip AF, becomes an Associate Director, and Dr Neil Williams becomes Manager of the company’s Radio Frequency Technology Division.

Grampian Amateur Computer Society

The Grampian Amateur Computer Society was formed about ten years ago. Its members come from all walks of life, are of all ages, and possess a variety of machines and a variety of interests. Although it is an amateur society, great stress is placed on the more serious applications of the computer and on the computer itself, as opposed to games. The society holds regular meetings on Monday evenings. These meetings aim at providing organized talks, demonstrations, and visits whenever possible. There is a two-monthly newsletter which gives details of forthcoming events. Further information from Paul Cuthbertson at 18 Morningside Crescent, Blackhall, INVERURIE AB5 9FA, telephone (0467) 24030, or from Bruce Edelsten at (022) 639911.

ATE Systems International has announced the appointment of John Amos of Amos Mitchell & Associates of ONTARIO as their new Canadian representatives.

High Technology Electronics has appointed Rex Hanson as telecomms business manager, and Brian Petty as major accounts manager to spearhead a new push into the telecommunications end-user market.

Marconi for London City Airport

Marconi Command and Control Systems of Leicester has received an order from London City Airport Ltd for the supply of a two field site instrumented visual range and meteorological system for the new STOL-port at Newham in the heart of London’s dockland. The system will provide METAR (Meteorological Area Report) data in serial format for the Aeronautical Fixed Telecommunication Network as well as local displays. These new facilities are to be installed by Marconi to enable the airport to commence operation in October 1987. The airport will be handling up to 120 aircraft movements per weekday and has been designed for a capacity of up to 1.5 million passengers a year mainly travelling within a 400 mile radius in one of the world’s biggest markets for business travellers.

London’s disused docklands are coming alive again. A huge area of more than 2000 hectares (about 5000 acres) just down river from Tower Bridge is being transformed into an exciting place for Londoners to live, work, and enjoy themselves. The most dramatic development will be a Stolport — a short take off and landing airport — between the Royal Albert and King Georg V docks. This will be serviced by quiet De Havilland Dash Seven turboprop airliners to provide City businessmen with convenient services to mainland Europe and other British cities. Seen in the photograph are new office blocks and high technology workshops.
Three-way race for diamond thin film

During the thirty years prior to 1977, it began to dawn on various members of the worldwide scientific community that synthetic diamond material might possibly be made in thin-film form, using chemical vapor deposition (CVD) techniques, says an IRD report. Important early work was done by Angus et al at Case Western Reserve in the US and by Derjaguin et al at the Institute for Physical Chemistry (Moscow). A 1977 paper by Derjaguin might have been the match which ignited worldwide interest in this area. Start-up company Crystalline (Palo Alto, CA) may chip its first diamond film products year or next. In Japan, diamond film coated knives for electron microscopy are already being shipped by Sumitomo Chemical Company, and Sony is marketing a loudspeaker tweeter which uses diamond film. Sumitomo is expected to soon be releasing its first diamond film based chips for applications involving hostile environmental conditions (such as in spacecraft or automobile engines).

ITT Instrument appointment

ITT Instruments, whose products include oscilloscopes, multimeters and related general purpose test & measurement equipment, has appointed the newly created Test & Measurement Division of Feedback Instruments Ltd. as its first UK distributor.

Products covered by the new agreement include realtime and digital-storage oscilloscopes, and bench power supplies in addition to the established digital and analogue multimeter range. Most of the product range is manufactured at ITT's plant in Annecy, France, and marketed in the UK via its recently established ITT Instruments operation at Slough, Berks. Feedback Instruments has a strong market base in the educational and research markets, resulting from many years' experience in supplying its own manufactured products to these markets - and it is now expanding on this success by adding other companies' products to its range via its new Test & Measurement Division.

Photographed after the signing of the agreement are (left to right): Peter Rummer, General Manager of ITT Instruments in the UK and Tony Morris, Feedback's Test & Measurement Division Manager.

Light-show multiscan

A laser graphics/effects controller developed by Laserpoint Ltd. of Cambridge can project beams, patterns, words, pictures, logos and animated sequences. It is claimed to be the first capable of presenting a complete light show by controlling both laser-effects output and other effects devices within a room.

The projection unit (effects head) is particularly suitable for an argon-ion laser and/or a krypton-ion laser. Respectively emitting blue/green and red light these will, when combined, produce a full range of colours including white light. In the projection unit are a pair of XY scanners and a prism assembly which is used for colour section. An interface with its own separate microprocessor links the effects from the MultiScan to the motion of remote reflectors. Further options include disk storage of effects, tape control for preprogrammed sequences, a digitiser for entering artwork, and an oscilloscope output monitor permitting complex sequences to be set up without the laser source being switched.

New Franchise for Brabury

Brabury Limited has been appointed international distributor for the full range of television test-chart products manufactured by Porta-Pattern Inc. of Los Angeles. The trading agreement between the two companies gives Brabury the exclusive franchise for sales of these products in most countries outside the American continents.
EVENTS

The Electronics Publishing & Print Show will be held in London from 29 June to 2 July. Further information from Online International Ltd o Pinner Green House o Ash Hill Drive o PINNER HA5 2AE o telephone 01-868 4466.

The Light and Sound Show will be held at the Novotel Hotel in London (W6) from 30 August to 2 September. Further information from Professional Lighting and Sound Association o 1 West Ruislip Station o RUISLIP HA4 7DW o telephone (08956) 34515.

Multivariable control for industrial applications from 5-10 July at the University of Strathclyde, Glasgow. History of Electronic Engineering from 10-13 July at Trinity College, Dublin. Computer-aided tools for VLSI systems from 19-24 July at the University of Lancaster. Transmission for Communications from 19-24 July at the University of Ashton. Satellite communication systems from 26-31 July at the University of Surrey.

Software engineering for microprocessor systems in July. Radio frequency techniques at the University of Bradford during the summer. Details of the above vacation schools may be obtained from The Secretary, IEE o Savoy Place o LONDON WC2R OBL o telephone 01-240 7735.

Fibre optic communication systems and application areas at the Caransa Crest Hotel, Amsterdam, 13-15 July.

Microelectronics packaging at the Crest Hotel, Amsterdam, 14-17 July.

Microelectronics interconnection and surface mounting at the Crest Hotel, Amsterdam, 20-24 July. Information about these courses may be obtained from Anne Thomas at the Centre for Professional Advancement o Palestrinastraat 1 o 1071 LC AMSTERDAM o telephone (020) 623050.

1987 Innovation competition prize winners announced

Dr Anthony Barker, a Medical Physicist at the Royal Hallamshire Hospital, Sheffield, has been announced as the 1987 winner of the IEE Prize for Innovation Competition. Dr Barker won the award for his development of a magnetic nerve stimulator for use in the diagnosis of disorders of the central and peripheral nervous system (see Elektor Electronics, June 1987, p. 25).

MP for Wokingham opens new Printronix UK headquarters

Conservative MP for Wokingham, Sir W Van Straubenzee recently opened the new UK headquarters of Printronix Ltd., a subsidiary of Printronix Inc., the third largest computer printer manufacturer in the United States. Occupying part of the Lodden Vale Centre in Woodley near Reading, Printronix have now moved from their temporary base in Wrexham to be closer to their main OEM business clients in the South East.

Hawker Siddeley buys another US instrument company

Hawker Siddeley, the London-based international electrical and mechanical engineering group, has bought Modutech Inc in the US from Thorn EMI for £5.1 million in cash. It is the fourth US company acquired by the group this year. Modutech, which will retain its distinct identity, is the US's leading supplier of analogue and digital panel meters. Customers include manufacturers of power generation and distribution, process control and portable electronic equipment. Based in Norwalk, Connecticut, Modutech also has manufacturing sites in New Hampshire, Pennsylvania and Barbados.

The acquisition of Modutech marks a further expansion of Hawker Siddeley's control and instrumentation activities, which include the manufacture and supply of electrical indicating instruments, electronic control and protection products, sensors and potentiometers and advanced data acquisition and control systems. The Modutech purchase follows the acquisition of Metermaster in January (US$9.8 million) and Flight Accessory Services (US$9.0 million) in March.

HTE acquired by venture capital company

HTE (High Technology Electronics Limited) has been acquired in a £1.1 million deal by Alan Patricof Associates (APA), the venture capital arm of the MMO Pacifco Group plc.

HTE supplies computer-based equipment for a wide range of market sectors, including process control, telecommunications, city information systems, defence and broadcasting. Started up in 1979 and purchased a year later by Grand Metropolitan, the company has maintained an impressive growth rate and is now recognised as a market leader with a current turnover around £5 million. Immediate plans for the company include extensive investment to broaden the product base and address new markets. Further penetration of the UK and European telecoms markets are early objectives. An expanded product line in systems level and finished products, with new emphasis on distribution and added value, is set to yield a projected annual growth rate of 40% for the next four years.
Management buys Norwich capacitor division from STC

A team of senior managers has acquired the Norwich-based components division of STC, the international electronics group, with financial support from institutional investors led by the Cambridge office of 3i, Investors in Industry. The other major institutional investor supporting the buyout is CIN Industrial Investments, while substantial banking facilities have been provided by Barclays Bank.

The company, which has been renamed Syfer Technology Ltd, specialises in the manufacture of multilayer ceramic capacitors — small components made up of layers of conductive precious metals and ceramic insulator. The capacitors are used mainly in computer memories where they store the energy needed to allow the Random Access Memory (RAM) to function. About a quarter of the company's sales go abroad.

Complex chips promise better TV pictures

Two Very Large Scale Integration (VLSI) silicon chips, designed by a group of nine final-year students at Kent University, would lead to the elimination of fuzzy pictures on television screens and cracking interference on telephones. These are the first undergraduate chip designs to be carried out with the facilities of Kent's recently established Electronic Computer-Aided Design (ECAD) Laboratory. Kent is one of the few universities in the UK where students can undertake this kind of work. Graduates of this degree programme are in much demand by industry.

Each chip, which measures a mere 3 mm by 4 mm, contains 15,000 transistors. The students began their project in October 1986 and completed it in four months on schedule in January. The design of a 15,000 transistor chip requires powerful design tools. The work was carried out on the Apollo Workstations in the ECAD Laboratory with a variety of software tools, some of which were designed in Kent, the rest provided by industrial partners. The students' chips are at present being fabricated by European Silicon Structures Ltd on their Californian production line. Their designs will be developed by members of the Digital Systems Group at Kent's Electronic Engineering Laboratory with a view to a marketable product being produced.

Industrial computer sales in Western Europe

Owing to the decline in the European data processing market, large computer firms are forced to look outside office automation for growth—and industry is where they will be turning, according to Computers in the Industrial Environment in Europe ($5899), a new report from Frost & Sullivan. The study claims that Federal Germany will remain largest in national sales volume, followed by the UK. The French emphasis on communications in the computer field is somewhat marginal to mainstream industrial computers.

Industrial computer sales in Western Europe amounted to $751 million in 1986, and they are likely to reach $837 million by 1991 (in constant 1986 dollars). If expressed in units, the market is growing faster—from 22,000 to 61,000 over the same period. This is because a high proportion of the installations will be small systems, and because the current average selling price of most systems (hardware only) of $33,000 will have dropped to less than $15,000 by 1991.

Standalone Point of Sale wins Marks and Spencer business

THORN EMI Micrologic has received a major order from Marks and Spencer PLC for its Standalone Point of Sale systems (SPOS). The order follows a successful pilot of 300 terminals, which took place in nine stores during the peak Christmas shopping period. The order to equip a further fifty stores is for 1400 sales points to be installed by September this year and is valued at £7.2m. This order is part of Marks and Spencer's overall plan to install POS systems in all their stores during 1986. The system is part of THORN EMI Micrologic's TEM 2000 product range.

Details of each day's trading are recorded at each sales point onto a CMOS cartridge, which is removed from the control unit at the end of the day, or as required. It is plugged into a multiple memory unit (MMU) along with the cartridges from all the other sales points within the store. The MMU, also designed and developed by THORN EMI Micrologic, is polled by an in-store computer which collates all the data and transmits it during the night, using the public switch network, to Marks and Spencer's own central computer facility. Updated prices, product changes and credit card information are then transmitted to the MMUs, in each store for the following day's trading.
MOBILE SATCOMS FOR THE FUTURE
by Dr John R. Norbury, Rutherford Appleton Laboratory

We have come to regard the geostationary satellite as the norm for communication between fixed stations and mobile stations such as ships and aircraft. Recent studies show the advantages of a highly elliptical orbit when planning satellite communications with land-based mobile stations, offering much better coverage at higher latitudes.

Nearly all recent proposals for satellite communications systems to provide a service to mobile stations have common features. They include the use of geostationary satellites, operating at radio frequencies around 900 MHz or 1.5 GHz; either low-gain omnidirectional antennas or higher-gain steerable directional antennas for the mobile terminals; and communication on narrow frequency bands which permits only a single channel to be carried on each allocated frequency (known as single channel per carrier, or SCPC, access techniques, which means restriction of data transmission rates to the low figure of some 16 kilobits/s).

Communication via geostationary satellites gives global coverage from a threesatellite constellation, which is ideal for most maritime and aeronautical applications, but it suffers from somewhat severe propagation problems when the line-of-sight path from the ground station to the satellite is at a moderate angle of elevation. This is especially so with land mobile satellite services (LMSS), where the low angle may lead to multipath propagation effects, attenuation by trees and blockage of the signal by buildings or uneven terrain. These factors place considerable constraints on the type of system that can be planned. For land mobile stations, there has to be a tolerance of fading of the signal power by a ratio of about 30:1, which in the communications engineer's parlance is a 15 dB (decibel) fading margin, to ensure a 90 per cent probability of acceptable speech communication over 90 per cent of the terrain covered in suburban and rural areas of North America.

Europe, with its more northerly situation and its mountainous terrain both in northern and southern regions, may need an even greater margin if there is to be a good enough service. Cost considerations of land mobile stations call for simple, low-cost antennas, that in turn means the satellite should have a very large effective transmitter power to provide a service of commercial standard. This criterion could be met by using high-power transmitters and large satellite antennas, but only at a considerable penalty to the overall system cost.

The Molniya Orbit
An alternative to the geostationary orbit is the 12-hour Molniya orbit, used extensively by the Soviet Union and illustrated in the first diagram. It is a highly elliptical orbit which provides a satellite position giving angles near to that at zenith, when viewed from Earth at moderate latitudes, for eight hours of its orbit time. On alternate orbits it provides a further eight hours for a region at the same latitude but 180 degrees different in longitude. For 24-hour coverage over one region means using three satellites in three orbital planes separated by 120 degrees. Obviously, any such constellation of satellites also gives coverage for a region 150 degrees different in longitude from the originally planned region. Elevation angles for Europe and polar regions would be high, as is shown by the 'beam footprints' in the second diagram. The left-hand part of the diagram shows the view of Earth from a satellite in a Molniya orbit with its apogee at 3.5°W. To the right is the view from the equivalent geostationary position. Coverage of the polar region is seen to be excellent using the Molniya orbit, in contrast to that provided by geostationary orbit where the elevation angle to the satellite is zero at about 81 degrees North or South. This means that to provide complete polar coverage, even for fixed point-to-point communications services, satellites in non-geostationary orbits are needed.

Several satellite configurations are possible for LMSS, selected to reduce the overall power needed in the satellite and, thereby, the overall system cost. Constellations of satellites in low orbits have been proposed in the USA, and Canadian scientists have studied 12 and 24-hour elliptical orbits in detail. British studies, published by the UK Institution of Electrical Engineers, have investigated the application of Molniya orbits to provide UK coverage for LMSS. Such systems have several advantages for Europe. The elevation angles are greater than 60 degrees and there is the possibility of using high-gain non-steerable antennas for the mobile stations. Furthermore, the reduction of multipath propagation with such an orbit adds to these factors to remove many of the constraints imposed by a geostationary orbit system. It means the fading margin that has to be tolerated is reduced to a few decibels, and the gain of the mobile station antenna could be as high as 15 dB, so the link can be engineered taking into account a starting advantage of...
some 100 times more antenna-to-antenna power being available, from base station to mobile, than in the geostationary system. And, although it is necessary to provide a threesatellite constellation for coverage over 24 hours, the launch energy needed to place a satellite into a Molniya orbit is roughly half that for a geostationary equivalent.

The capital cost of a satellite system tends to be related directly to the amount of radio-frequency power needed for the link. So any configuration that reduces the power needed per voice channel, as in the case of the elliptical orbit satellite, makes the system a great deal more commercially attractive. The provider of a satellite mobile service would have the choice of an initial system of satellites working at relatively low radio-frequency power per voice channel, or have many more revenue-earning channels for the same capital cost as in a geostationary system.

Studies conducted recently in the UK favour a 12-hour elliptical orbit, because it would be the lowest cost option for a demonstration satellite. But the orbit does pass through the Van Allen radiation belts, which could degrade electronics devices and solar panels. A so-called Tundra orbit, taking 24 hours, enables this high radiation environment to be avoided. When deciding on the best orbit for an operational system, it will be necessary to compare the threesatellite Molniya constellation, using a low launch energy and small satellite antenna, with the two-satellite Tundra system where launch costs are higher, antennas are bigger but the radiation environment is better.

Transmission Frequencies

Procedures for allocating frequencies for radio systems are co-ordinated through the International Telecommunication Union (ITU). Radio transmissions do not respect national boundaries, so agreeing uses of the radio spectrum tends to be rather lengthy. A series of World Administrative Radio Conferences (WARC) are held at suitable intervals to agree international usage. However, at the last major conference, WARC 79, no part of the spectrum below 20 GHz was allocated to land mobile satellite services in the European region (Region 1), whereas a small allocation at UHF was allocated for use in the Americas (Region 2) and Asia (Region 3). This lack of spectrum is a big stumbling block for any commercial satellite land mobile service. A special conference, WARC MOB 87, has been organised to take place during 1987 to tackle the problem. Several solutions seem possible, with frequency slots in the regions of 1.5 GHz, 2.5 GHz and 5 GHz being topics for discussion. Although the conference might be mainly devoted to considering geostationary systems, some attention will also be given to elliptical orbit systems.

Payload Study

For several years a university consortium in the UK, whose members are listed in the accompanying table and whose activities are co-ordinated by Rutherford Appleton Laboratory, has been studying advanced ideas for satellite communication systems under the banner of Communications Engineering Research Satellite (CERS). Two ideas that have generated considerable interest are the use of on-board processing of signals in satellite systems and the application of the Molniya orbit. This group is now in the middle of a two-year project in which an electronic model of a mobile payload with full on-board processing is being built: The design of the proposed payload is outlined in the final diagram. A simple reflector of 1.5 m diameter is planned for the antenna, the necessary steering to point to Earth in a Molniya orbit to be achieved by manoeuvring the satellite. Depending on the data rate, a transmitter power of between 10 W and 20 W will be needed. Full demodulation and decoding of the received signals would be included, using a variety of schemes. There are several modulation schemes to be considered, including one in which the carrier is phase-shifted by the data keying process. Decoding would be possible for a variety of coding schemes. An on-board microprocessor would control an electronic buffer store to allow re-formatting of data and re-transmission using modulation and coding schemes that would be independent of the up-link channel.

Access schemes for communication with the satellite are, first, time division multiplexing (TDM) on the down-link to mobile stations with time division multiple access (TDMA) on the return path from mobile station to satellite; second, TDMA on the down-link to mobiles with SCPC on the up-link. The payload, by using dual channels for each system of access, allows full duplex (simultaneous two-way) operation. Both up and down channels would operate in the L-band (1.5 to 1.6 GHz), with data rates of 64, 128, 256 or 512 kilobit s⁻¹. The motion of the satellite in the Molniya orbit causes a doppler shift in the transmitted and received signals. It is intended to compensate for this on board the satellite by controlling the

Table

<table>
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<tr>
<th>Member of consortium</th>
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<td>Bradford University</td>
<td>Mobile system/system design</td>
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<td>King's College, London University</td>
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Fig. 3. Proposed scheme for the satellite-borne payload to be used for communication with mobile and base stations.

frequencies of its local oscillators, using either an on-board control system or ground control. Different types of traffic such as short, coded messages or voice or facsimile could be accommodated within the same time frame merely by varying the length of the time slot allocated to each individual service by the multiplexing system. The full capacity of the system, using 4.8 kilobit s⁻¹ voice coding would be about 50 voice channels.

For the mobile station, an antenna with an angle of ± 15 degrees could be used, mounted on the vehicle roof with its axis pointing vertically. Dimensions of less than one metre square are possible for this. The power of the mobile transmitter would need to be about 20 W. The only obstructions that may be expected to impair reception are overhead bridges or vegetation, or multipath scattering that might occur from very tall buildings. System coverage, in time and space, would be better than 99 per cent.

If the justification for satellite systems to provide communication with mobile stations is that they would fill in all the gaps not covered by a terrestrial-based cellular system, it might be questionable whether a geostationary service will be attractive enough commercially at such a level of coverage. An elliptical orbit system, although resorting to the complexity of operating a constellation of satellites, offers almost complete coverage even in urban areas and at greatly reduced signal strength requirement.

Further spinoff might be found if these ideas were implemented in a European mobile system. The technology developed could equally well be applied to both mobile and fixed service systems for the equatorial regions of the Earth operating with a geostationary satellite. If this mobile satellite solution is commercially viable for Europe, then the cost of the transmitter-receiver, produced in quantity, would have to be comparable with those used in terrestrial mobile systems, namely of the order of £1000. The potential for such technology, in regions where satellite systems offer the most practical way of providing mass communication, seems considerable.

GMSVO7 single board computer

General Micro Systems GMSVO7 advanced single board computer is now available from UECS.

This high-performance CPU for the VMEbus provides ultra-high speed data movement, delivering the performance of a minicomputer at a fraction of the cost. Based on the 32-bit 68020 running at 20 MHz, it features up to 1Mbyte no-wait-state RAM, optional advanced memory management and high-speed floating point maths. A real-time clock calendar is standard. Mezzanine options provide VSB(MVMX32) compatibility, as well as a wide range of I/O possibilities. All system configuration is software-controlled, minimising the need for straps and jumpers.

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(3630-16F)
Research and development into the use of solar energy as an alternative source of energy have taken on new importance since the oil crises of the 1970s. Moreover, many of us are afraid of the spread of nuclear power stations, and all of us want to get rid of environmental pollution caused by oil or coal burning power stations.

The sun converts 600 million tons of hydrogen into helium through nuclear fusion every second, and in the process releases enough energy to meet our earthly needs for a million years. Of course, only a tiny part of the solar energy falls onto earth, which is readily seen when it is realized that the sun radiates equally in all directions. Since the average distance from the sun to the earth is near enough 150 million kilometres, the energy (in the form of electromagnetic radiation) takes about 8 minutes to reach the earth. In that time, the total energy radiated by the sun has spread over the inside of a sphere of surface area $3 \times 10^7 \text{ km}^2$. The total surface area of the earth that can be lit by the sun at any one time amounts to $113 \times 10^7 \text{ km}^2$. This means that only about 4 thousand millionth parts of the totally radiated energy falls onto earth. The rest is lost in the universe.

The solar energy that reaches the earth can be converted into heat or electricity by various means, mainly solar collectors, magneto-hydro-dynamic (MHD) generators, and photovoltaic cells (normally called solar cells).

A major drawback to the widespread use of solar power generating systems is their high cost: at present, solar power costs £5-20 per watt as compared with a few pence for commercially produced electricity. On the other hand, solar power generation has a number of important advantages:

- Solar energy is free and in plentiful supply.
- Electricity can be generated, directly or indirectly, where it is needed, which in many cases would obviate the need for a distribution transmission line system.
- In the case of most solar power generating systems, there are no moving parts, which simplifies maintenance and enables unattended operation, for instance, solar cells on board satellites.
- It produces no waste or gases: it is clean.

Although the cost of solar power generation is at present such that it precludes the widespread adoption of solar power generating systems, it is expected that prices will fall dramatically over the next 10-15 years.

Solar collectors

Solar collectors are normally constructed in a way that allows the incident sunlight to be collected and converted into heat. The main types of collector are flat, concave, and heliostat. The flat type has the advantage of being able to operate from diffused light; the other two can only work from direct sunlight.

All solar collectors operate on the same basic principle: sunlight falls onto a blackened absorbent surface and heats the material immediately underneath that surface. The material is often water, but it can also be air—see Fig. 1. To protect the collectors from atmospheric effects and soiling, they are commonly covered by a sheet of Perspex.

Concave (parabolic) solar collectors are able to generate temperatures of up to 4,000°C. They are usually constructed as a dish similar to satellite TV antennas. Heliostat-type solar collectors make use of plane or concave...
mirrors that can be rotated (nowadays usually under computer control) to follow the sun across the sky—see Fig. 2. This type of collector affords efficiencies of up to 30%. Solar collectors generally have good efficiencies and are getting cheaper. This is particularly so in the case of flat types, which are used more and more in the roofs of industrial buildings as well as in those of private houses—see Fig. 3.
MHD generators
Magneto-hydro-dynamic generators convert thermal energy direct into electricity. A schematic representation of such a generator is shown in Fig. 4. The thermal energy is obtained by heating a gas to some 2500 °C by means of a large concave solar collector. When the temperature of the gas reaches 2500 °C, ionization occurs. This causes the gas molecules to accelerate to speeds of well over 300 m/s. The gas is then passed through a magnetic field, which separates electrons and ions, whereby an electric current is generated. This type of generator is still in its infancy, although large prototypes are already in operation in the USA and the USSR. The main problem is the heating of the gas to the high temperature required. None the less, the prototypes work well and show efficiencies of up to 55%.

Solar cells
Solar cells provide an attractive and promising source of alternative energy. Unlike solar collectors, they provide a means of direct conversion of solar energy into electricity.

Types of solar cell
Crystalline silicon, Si. By far the largest proportion of solar cells currently manufactured are made from crystalline silicon. The basic construction of this type of cell is shown in Fig. 5. Its operation will be discussed later in this article.

Amorphous silicon, a-Si. Amorphous silicon is, according to many researchers, the solar cell material of the future, because its production costs are a fraction of the price of crystalline silicon.

Amorphous silicon can be formed by a number of methods, such as sputtering, pyrolysis, and high-frequency glow discharge. At present, the glow discharge method is preferred. In this, a substrate is held at a temperature of about 300 °C in a vessel in which the pressure is about 1 torr. Silicon hydrides, such as SiH₄ or Si₂H₆, or silicon tetrafluoride, SiF₄, are introduced into the vessel. When an HF voltage is applied, amorphous silicon begins to accumulate on the substrate. Dop- ing of the a-Si is achieved by adding a phosphorus hydride, such as PH₃, for n-type, or a boron hydride, such as B₂H₆, for p-type.

Cadmium-Selenium-Copper(I) sulphide, Cu₂CdS. The electrical characteristics of this type of semiconductor are promising, although research into the material is still going on. From early prototypes, it is clear that both high efficiencies and high power outputs can be obtained.

Gallium-Arsenide, GaAs. Although this type of material affords a very high efficiency, it is expensive to produce. However, it has a non-linear light-power characteristic, which makes it particularly interesting for use in combination with concave solar collectors. Moreover, compared with crystalline silicon, GaAs does not dissipate so much heat and, therefore, requires less cooling (smaller heat sinks).

Cadmium-Selenium, CdSe. This type of solar cell is still in the development stage.

Table 1 gives a comparison of these various types of solar cell. A number of other materials are actively being investigated in laboratories all over the world, but at present it does not look likely that these will find commercial application in this century.

Basic operation of a silicon solar cell
The characteristic behaviour of a semiconductor depends on the nature of the constituent atoms and on the way in which these atoms are grouped together. In other words, it is a function of the atomic structure as well as of the crystal structure of the semiconductor. An atom consists of a positively charged nucleus surrounded by negatively charged electrons located in discrete orbits (shells) around the nucleus. Electrons can exist in stable orbits near the nucleus only for certain discrete values of energy, called energy levels of the atom. The allowed energies
of electrons in an atom are represented by horizontal lines in the energy-level diagram shown in Fig. 7. Not more than two electrons can occupy a level; this results in electrons filling up the lowest possible levels first. Since the atoms in a semiconductor are closely packed together, there are very many energy levels associated with each nucleus (because of the interaction between the atoms). This results in the energy-level diagram for the material becoming an energy-band diagram (each band contains very many levels).

The lowest energy band is called the valence band; this is filled with electrons, since there is an electron for each of the energy levels contained in the band. The upper energy band is virtually devoid of any electrons; it is called the conduction band. There is a small forbidden gap between the valence and conduction bands.

At absolute zero, all the electrons occupy the lower energy levels, the valence band is filled to maximum energy, and no higher levels are occupied. This level of maximum energy is called the Fermi level, \( E_F \), which is approximately constant with temperature. When the temperature is at room level, the electrons in a semiconductor are distributed between the valence band and the conduction band, and the Fermi level lies in the forbidden gap.

Since the Fermi level is constant throughout the silicon, the energy bands at the junctions in Fig. 8 are distorted, which causes an electric field across the junction. This field is called the built-in field.

When the silicon p-n junction—see Fig. 8a—is in equilibrium (no bias), the current density, \( j \), is given by

\[
j = nev = e \sum V_i \quad \text{at equilibrium},
\]

where \( n \) is the electron density, \( e \) the electron charge, and \( v \) the average velocity of electrons in the valence band. If the \( k \)th electron crosses to the conduction band,

\[
e^{\frac{k}{n}} \sum V_i = -eV_n \quad \text{[2]}
\]

from which it is seen that the vacancy (hole) in the valence band can be considered as a positively charged carrier fully analogous to the negatively charged \( k \)th electron. The velocity of the hole is equivalent to that of an electron in the same energy level.

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rent \( I \), resulting from electrons diffusing from the n-side is equal to the current \( I \) which arises from electrons leaving the p-side. If a positive voltage is applied to the junction—see Fig. 8b—the built-in field is increased. The number of electrons diffusing from the n-region is then much smaller, since only few electrons have the energy required to overcome the built-in field. However, the number moving from the p-region to the n-region is not affected, because these electrons encounter no field. Therefore, a net current flows, but it is limited by the small number of electrons in the p-region. If the polarity of the applied voltage is reversed—see Fig. 8c—the built-in field is reduced and \( I \) is large because the number of electrons in the n-region is so large. As before, \( I \) from the p-region to the n-region remains unaffected. The net current is then large and corresponds to the forward direction.

The net current, \( I \), under forward-bias conditions is given by the exponential expression

\[
I = I_0 \left[ \exp\left(\frac{eV}{nKT}\right) - 1 \right]
\]  

where \( I_0 \) is the reverse saturation current, \( e \) is the electron charge, \( V \) the applied voltage, \( n \) a factor between 1 and 2 representing the deviation from ideal diode characteristics, \( k \) the Boltzman constant, and \( T \) the absolute temperature.

In a silicon solar cell, in the absence of incident light (called the dark state), the expression for the dark current, \( I_d \) is identical to that for \( I \) in formula [3].

When the cell is illuminated, a photo-generated current, \( I_{ph} \), flows as junction reverse current. This current is directly proportional to the intensity of illumination. From Fig. 11 it will be seen that the net current, \( I \), is given by \( I = -I_{ph} + I_d \)

The voltage \( U \) across the load and the current \( I \) through it produce an output power \( P_0 \), which is equal to \( U \cdot I \) or \( I_d \cdot R_L \), and is the direct result of the incident light falling onto the cell. Finally, Fig. 12 shows that the sensitivity of a silicon solar cell is greatest at a wavelength of about 0.8 \( \mu m \), i.e., at the lower end of the band of visible light towards the infra-red region.

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LASERS: AN OVERVIEW

The development of lasers since they first appeared in the early 1960s has been spectacular. In just over 25 years they have become virtually indispensable in such diverse applications as compact disc players, fibre optic communications, surgery, and the Strategic Defence Initiative.

The first lasers appeared in 1960-61 when Javan, Bennett, and Herriott of Bell Telephone Laboratories announced the helium-neon laser just after Theodore Maiman, working at the Hughes Aircraft Corporation, had made a practical ruby laser. In little over a year later a semiconductor laser had been developed more or less simultaneously in Britain and the USA.

Foundations

An atom may be represented by a Bohr model. Fig. 1 shows that of a hydrogen atom. Bohr considered one electron of charge $-e$ and mass $m$, moving with speed $v$, and acceleration $v^2/r$ in an orbit around a central nucleus of charge $+e$. In classical physics, charges undergoing acceleration emit radiation and would, therefore, lose energy. On this basis, the electron would spiral towards the nucleus and the atom would collapse. Bohr therefore suggested that in those orbits where the angular momentum is a multiple, $n$, of $\hbar/2$, the energy is constant. In the early 1920s, de Broglie proposed that an electron may be considered to behave as a wave of wavelength $\lambda = h/p$, where $h$ is the Planck constant ($4.14 \times 10^{-15}$ eV s) and $p$ is the momentum of the moving electron.

If the electron can behave as a wave, it must be possible to fit a whole number of wavelengths around the orbit. In that case, a standing wave pattern is set up and the energy in the wave is confined to the atom. If there are $n$ waves in the orbit and $\lambda$ is the wavelength,

$$\lambda = 2\pi r/n$$

so that,

$$\lambda = 2\pi\hbar/n = h/p = h/mv$$

from which,

$$mv = n\hbar/2\pi$$

This shows that $mv$, the angular momentum of the electron in an $nth$ multiple of $h/2\pi$.

In Fig. 1, the electron moving around the nucleus has kinetic energy due to its motion and potential energy in the electrostatic field of the nuclear charge $+e$.

Bohr calculated the total energy $E$ of the electron in terms of its charge, mass orbital radius, and the number $n$ which quantizes the angular momentum. He then assumed that the electron can pass from one energy level to another. If, for instance, the electron jumps from energy level $E_2$, corresponding to $n_2$, to a lower level $E_1$, corresponding to $n_1$, the difference in energy is released as radiation of energy $\hbar\nu$, where $\hbar$ is the Planck constant and $\nu$ is the frequency of the radiation. Therefore,

$$E_2 - E_1 = \hbar\nu = hc/\lambda$$

where $\lambda$ is the wavelength of the radiation and $c$ is the speed of light in a vacuum.

Although Bohr's theory of the hydrogen atom was unable to predict the energy levels in atoms with many electrons, its fundamental ideas remain valid. For instance, the angular momentum of the electron has quantum values, and the energy levels of an atom have only discrete values: $E_1, E_2, E_3, \ldots$.

1. $E_0$, the lowest energy level, is called the ground state energy. All physical systems are in stable equilibrium in the lowest energy state.
2. If an atom absorbs energy, and the energy of the atom reaches one of its discrete levels, $E_1$, the atom is said to be in an excited state. Once an atom has been excited to a higher energy level, $E_2$, it will try to reduce its energy. The energy lost if the atom reverts direct to the ground state is $E_2 - E_0$. This energy is radiated in the form of electromagnetic radiation, i.e., quanta of energy $\hbar\nu$—see Fig. 2. These quanta are called photons. The frequency of the photons lies in the range 5 nm to 10 nm. From the foregoing, it follows that

$$\hbar\nu = E_2 - E_0$$

An atom can interact with a photon in three ways: absorption, spontaneous emission, and stimulated emission—see Fig. 3. If an atom absorbs a photon of energy $h\nu$, and the difference in energy levels of the atom is equal to $h\nu$, the photon is absorbed and the atom is said to have been excited.

![Fig. 2. Model of a many-electron atom. When an electron jumps to a lower energy level, a photon is released.](image-url)
The ruby laser is a three-level laser. Lasers are the ruby (Cr³⁺) and neodymium/yttrium aluminum garnet (Nd/YAG) lasers. At present, the main solid-state lasers are gas lasers, which in turn stimulated emission. An atom in the lower level 2 may be stimulated to emit a photon hv by interaction with another photon of the same energy.

If in a system of atoms with an energy level E₃ above the ground state there are no photons of energy E₃-E₂, where E₂ is the ground state energy, the atoms remain stable. If, however, a few photons of energy E₃-E₂ are introduced, this will immediately stimulate the emission of a number of photons of the same kind. This increases the number of photons in the system, which in turn stimulate the emission of more photons. In this way, an avalanche effect is produced, which results in all the atoms in the system rapidly giving up their photons—see Fig. 4. This process is called laser action (light amplification by stimulated emission of radiation).

In a system of atoms in thermal equilibrium, the number of atoms in the ground state is much greater than that in a higher energy state. This is called a normal population of atoms. In such a system at temperature T, the numbers, n₁ and n₂, of atoms in two successive states, E₁ and E₂, are related by the Boltzmann formula (in which \( \alpha \) is the Boltzmann constant, \( 1.38 \times 10^{-23} \) J K⁻¹):

\[
n_2 = n_1 e^{-(E_2 - E_1)/kT}
\]

from which it is seen that at room temperature (T=300 K), \( n_2 \) is considerably smaller than \( n_1 \), i.e., a normal population obtains. If it is possible to make \( n_2 > n_1 \), a population inversion is produced, which enables laser action to take place. The output from a laser may be continuous (CW operation) as is usually the case with gas lasers, or pulsed as that from solid-state lasers. Table 1 lists a variety of lasers and some of their characteristics.

### Three-level lasers

At present, the main solid-state lasers are the ruby (Cr³⁺) and the neodymium/yttrium aluminum garnet (Nd/YAG) lasers. The ruby laser is a three-level laser \( (E_3 > E_2 > E_1) \), with a fast decay between levels 2 and 1, and a slow decay between 1 and 0. A typical construction of this type of laser is shown in Fig. 5.

Ruby consists of a small concentration of Cr³⁺ ions in a lattice of crystalline Al₂O₃. When a high potential is applied to the flash tube, the ions are excited, or pumped, by photons of wavelength 550 nm (green light) and energy \( E_3-E_2 \). The excited ions decay spontaneously to the lower energy state \( E_2 \), emitting photons of energy \( E_2-E_1 \).

The energy state \( E_3 \) has the special property of having a large stimulated emission probability and a low spontaneous emission probability. It is, therefore, filled with a far greater number of ions than the ground state \( E_1 \). There is thus a population inversion between these two levels, so that laser action can be initiated, resulting in the emission of red light \( (1=694.3 \text{ nm}) \).

### Four-level lasers

Except in a few cases, such as in the ruby laser, it is difficult to produce a population inversion between a ground state and an excited state, because initially all the atoms are likely to be in the ground state, and more than half the atoms have to be pumped to level 3 before a population inversion can be achieved. An easier method is possible in a four-level laser in which a population inversion is created between two excited levels—see Fig. 7. Initially, all the atoms are in the ground state \( E_1 \) and none in the excited states 1 and 0 between \( E_2 \) and \( E_3 \). A population inversion is created between levels 2 and 1. As level 2 begins to fill up by stimulated emission at frequency \( (E_2-E_1)/\hbar \), the population inversion will decrease. To minimize this effect, level 1 is chosen so that it has a fast decay to level 0. Gas lasers are examples of a multi-level system, which can be pumped by an electrical discharge rather than by incident radiation. An important model is the He-Ne laser, in which the
active material is a mixture of helium and neon gases contained at low pressure inside a long quartz tube with optically plane mirrors at each end—see Fig. 8. Two terminals near the ends of the tube enable a high potential to be applied to produce a discharge in the gas mixture. A typical construction of a He-Ne laser tube is shown in Fig. 9.

In an electrical discharge, the helium atoms are raised to the 2S and 2P levels which are metastable—see Fig. 10. By collision with these atoms, the neon atoms are excited to level 3, so that a population inversion is produced and laser action occurs as explained above. The wavelength of the emitted light depends on the reflectivity of the mirrors between which the gas is placed. Oscillation will take place at the wavelength for which this reflectivity is a maximum. In Fig. 10 it is—typically—633 nm (red light). It is seen that two other beams are also generated: one at 1.15 μm and one at 1.5 μm, but these are effectively suppressed by filter action of the mirrors.

**Polarization of laser light**

Although laser light is coherent, because all the photons (or waves) are in phase, polarization is random—see Fig. 11. To linearize the polarization, a Brewster window as shown in Fig. 8 is used. Such a window is a disk of plane glass (see Fig. 8) which is set at the Brewster angle to the incident light to ensure that only light of a given wavelength is passed.

Brewster's law states that when light strikes a glass surface at an angle of incidence given by \( \tan^{-1}(n) \), where \( n \) is the refractive index, the reflected light is plane polarized. At this angle of incidence, the refracted ray makes an angle of 90° with the reflected ray.

**Resonance cavity**

The laser emitter is placed between parallel mirrors so that photons can be reflected back and forth many times, resulting in the build-up of a large photon density by the avalanche effect.

**Beam spread**

Many laser tubes are marked with their internal beam radius, \( r_0 \), from which the beam diameter, \( D_0 \), at a distance \( m \) can be calculated:

\[
D_0 = 2m = 2r_0 \sqrt{m / \pi}
\]

where \( 2θ \), the angle of spread, is equal to \( 2r_0 \pi / m \); \( D_0 \) is the wavelength of the laser light.

If, for instance, a He-Ne laser, operating at a wavelength of 633 nm, has an internal beam radius of 0.375 mm, the beam diameter at a distance of 100 m is

\[
D_{100} = 2 \times 3.142 \times 10^{-2} \times 100 / \pi = 107.5 \text{ mm.}
\]

**Lasers and their applications**

Since the development of lasers continues at a spectacular speed, only an outline of the state of the art will be given. He-Ne lasers, because of their small output (0.1–10 mW) are best suited to use in laboratories and measurement techniques, but are also used for medical purposes. Their wavelengths are 632.8 nm, 1.15 μm, and 3.39 μm.

Argon-ion lasers, with outputs of up to 15 W, are frequently used in medicine for photo coagulation. Their bluish green light (488 nm and 514.5 nm) is selectively absorbed by hemoglobin and melanin. Their main application, however, lies in the field of eye surgery.

Carbon-dioxide (CO₂) lasers, operating in the infrared
Fig. 10. Schematic representation of the operation of a He-Ne laser. The capital letter S is a code associated with the value of the total electronic orbital angular momentum quantum number L. The lower case letters s and p are used in the so-called spectroscopic notation, in which the value of the orbital angular momentum quantum number L is indicated. The superscripts to the left of the S give the value of 2S-1, or multiplicity, which is equal to 1 for singlet (S=0) states, and 3 for triplet (S=1) energy states.

Fig. 11. Light may be randomly polarized, but in a number of laser applications it is required to be linearly polarized.

Fig. 12. It is essential that standing waves are generated between the mirrors terminating the resonant cavity. The shape of the mirrors has an effect on the efficiency of the laser.

Fig. 13. Illustrating the operation of a CO2 laser in industrial welding.

regime (9.6-10.6 μm), are primarily used in industrial applications: hardening; drilling; welding; reflowing; and ageing are but a few of these. The use of a CO2 laser for industrial welding is illustrated in Fig. 13. The dye laser is pulse operated and pumped by a xenon flash tube—see Fig. 14—or by a pulsed beam from another laser. Continuous tuning of this type of laser is possible by making the grating that forms one end of the resonant cavity rotatable. With its very narrow line width and large frequency range, the dye laser is eminently suitable for use in spectroscopy and in the chemical industry.

Solid-state lasers find almost universal application in measurement techniques, be it the exact distance from the earth to the moon or the speed of motor vehicles. Many of these techniques are by-products of military research. The only solid-state laser to be used in the medical world is the Nd/YAG laser. Because of its high power output (>100 W continuous) and operation in the infra-red region (0.9-1.35 μm), this type of laser is particularly suitable for operations in soft tissues, such as the removal of tumours in the oesophagus.

Solid-state lasers can produce pulses of extremely high power: a power of 100 TW (=10^14 W) at the peak of a 2 ns pulse has been reported. Such enormous powers are needed in the strategic defence in-
Commercial considerations

In 1986, the world market for lasers amounted to more than £425 million. The largest sectors were research and development, and materials processing—see Fig. 16. When studying this figure, it should be borne in mind that the diode laser for a CD player costs only about £3, whereas an industrial model may cost as much as £30,000. It is expected that the laser market will have grown to around £1,000 million by the early 1990s.

References:
Advanced level physics by M. Nelkon and P. Parker
Optics and its uses by G. F. Lothian
Physics of atoms and molecules by B. H. Bransden and C. J. Joachain
Quantum physics of atoms, molecules, solids, nuclei, and particles by Robert Eisberg and Robert Resnick
Physics by David Halliday and Robert Resnick
Fundamental University Physics by Marcelo Alonso and Edward J. Finn

Fig. 14. Artist’s impression of a dye laser.

Fig. 15. Semiconductor (GaAs diode) laser.

In the forefront of laser development is the excimer laser which uses diatomic rare-gas halides as the active material. This type of laser was described in the February 1987 issue of Elektor Electronics.
THE MAC SYSTEM

An introduction into the characteristics of the television transmission format generally expected to become the follow-up of the by now technically outdated PAL and SECAM systems.

Waiting for MAC

Currently, the majority of satellite TV programmes are transmitted in PAL, using analogue FM and low-power transponders operating in the CSS band (10.9–11.7 GHz). The D2-MAC TV standard is only used for experimental transmissions by the NOS on the ECS-1 transponder.

1. Fig. 1. Illustrating how the various TV transmission formats came into existence.

For semiconductor manufacturers to spring into action and come up with competitive products, which are expected to become widely available once the first MAC signal is being beamed down. Until then, there is nothing but secrecy, preliminary specifications, and confusion on the part of cable network operators and individual viewers.

The shortcomings of PAL

In a standard PAL signal, the luminance and chrominance components are separated in the frequency domain—see Fig. 2a. The presence of the chrominance subcarrier in the transmitted spectrum gives rise to an overlap area with luminance components above some 2.5 MHz. The effect of this can be seen on any PAL compatible colour TV set as spurious cross-colour patterning on areas of fine detail in the picture, and is caused by the receiver's decoder circuits mis-accepting fast luminance (black-white) transitions for chrominance information. Also, sound-on-vision patterning and visibility buzzing occur readily when the PAL TV receiver is not properly aligned, or when the transmitter produces intermodulation owing to non-linear operation or improper filtering.

Figure 2b is a simplified representation of the time structure of one of 625 lines in a PAL colour test signal. The duration of the line is 64 μs, but of this only 53.75 μs contains picture information, namely 8 colour bars. The remaining time (10.25 μs) is the line blanking period, composed of the line sync pulse, front and rear porch, and the 4.43 MHz colour burst. A MAC picture is still made up of 625 lines, but the luminance (Y) and chrominance (UV) components are separated in the time

The curious thing about the new Multiplexed Analogue Components (MAC) TV format is that everybody seems to be waiting for everybody else to start doing something about it. Workers in laboratories of most broadcasting authorities have long since established that MAC is superior in nearly every respect to PAL, SECAM, and certainly NTSC; they laid down the target technical characteristics, and conducted many experiments to verify the performance of MAC in satellite links and cable networks. Why then is MAC not being used at present, when it is such a powerful standard? Answering this question is not easy, and requires considering some aspects not directly related to technical matters, our main concern here.

To begin with, there is the evolution of the MAC standard to study—see Fig. 1. From this it is immediately apparent that there is no single MAC standard, but a series of versions derived from the original A-MAC system, which, like I-PAL, never got out of the laboratory test phases. B (extended) PAL, with the IBA as the main protagonist, was rejected by the Government's Advisory Panel in favour of D2-MAC four years ago. E-MAC was supported mainly by Plessey for use in TV studios and microwave links, but proved impossible to implement on TV satellites. C-MAC has three subsets, developed and supported by different authorities and satellite operators, who are, of course, keen on winning the general acceptance of their particular system. That a single MAC transmission format will be with us soon is very unlikely, however, considering that every system has its own merits for a given application, as will be seen further on. Of the three C-MAC subsets, D-MAC, the version optimized for cable networks using 10.5 MHz band-width and AM VSB (vestigial sideband), can be disregarded in the coming discussion on who is to rule the airwaves. Although both C-MAC and ECMAC (enhanced C-MAC) are claimed to be suitable for the future HDTV format and its BCC-supported derivative, DATV, there are other, important, considerations to this matter, and this will be reverted to in due course.
domain, i.e., transmitted sequentially within the available line time of 64 μs. Figure 2d shows that the analogue Y and U/V components are extracted from the composite input signal, time compressed, and multiplexed together with a data burst, whence the acronym MAC. The process of time-compressing may be carried out digitally or with analogue means (CCDs mainly), but both methods inevitably result in an increase in the bandwidth of the baseband signal. Consider, for instance, the Y component: in the PAL and D2-MAC signal it has a duration of 52 and 34 μs respectively. The compression rate is therefore 52/34≈1.5, and results in the frequency being increased by a factor 0.6, since a shorter period is available for the same number of level transitions. Similarly, the colour difference signal, U/V, is compressed by a factor 3:1. The resulting time multiplexing scheme is shown in Fig. 2c. Note that the sound & data block is entirely digital, and transmitted in 2-4 PSK, a modulation mode that will not be discussed here. Some lines in the D2-MAC picture are reserved for particular applications—see Fig. 3 and consult the technical specification in Table I. The frame organization of an enhanced CMAC (E-CMAC) picture is schematized in Fig. 4. E-CMAC has been developed specifically with

Fig. 2. Showing how the D2-MAC signal is given its basic time-division multiplex scheme.

Fig. 3. A MAC picture analyzed. Note the special function of lines 624 and 625 (courtesy EBUI).
Aerials for terrestrial and satellite TV services.

Transmission multiplex characteristics:
- Duobinary coded, AM/VSB and FM compatible.
- Instantaneous bit rate during data burst halved with respect to C-MAC.
- Recommended deviation (FM): 13.5 MHz/V; pre emphasis transition at 1.37 MHz; energy dispersal f(d) = \( \frac{1}{2} f(V) \)
- Instantaneous bit rate of data burst (2-4 PSK):
  - 10.125 Mbit/s
- Lines per picture: 625
- Lines with data burst: 1 to 625
- Lines with video signal: 24 to 310 and 336 to 622
- Lines with luminance signal: Y in each line
- Lines with chrominance signal: U in odd lines, V in even lines
- Interface ratio: 2:1
- Aspect ratio: 4:3 (53:33)
- Luminance compression ratio: 3:2
- Chrominance compression ratio: 3:1
- Sampling clock frequency: 20.25 MHz
- Instantaneous bit rate of data burst (2-4 PSK):
  - 10.125 Mbit/s
- Samples per line: 1296
- Chrominance samples: 697
- Luminance samples: 697
- Bits per data burst: 105 (6 bits HSW and 99 bits data)
- Line 624:
  - 105 bits and analogue reference signals
- Line 625:
  - 65 bits for data burst
  - 6 for H sync
  - 32 for clock run in
  - 64 for VSW
  - 546 for service identification

Table 1: D2-MAC/Packet

<table>
<thead>
<tr>
<th>D</th>
<th>version indication.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>bit rate division factor with respect to C-MAC.</td>
</tr>
<tr>
<td>MAC</td>
<td>Multiplexed Analogue Components:</td>
</tr>
<tr>
<td>Packet</td>
<td>digital sound and data are transmitted as composite bursts.</td>
</tr>
</tbody>
</table>

MAC: some essential points

A discussion of all the technical characteristics of C-MAC, E-CMAC and D2-MAC is beyond the scope of this article, and interested readers are referred to the publications for further reading. A few basic considerations as to the composition of the signal will help in understanding the implications of an essentially digital transmission format. The discussions apply to both D2-MAC and C-MAC.

Synchronization. Each data burst contains one of two 6-bit line synchronization words (LSWs—see Fig. 3), which are defined as follows: \( W=W_2=010101 \), while \( W=W_2=110100 \). The data processor in the MAC decoder keeps track of the samples in each line, and arranges for the appropriate circuitry in the TV set to be actuated when an LSW is recognized. The pattern of the LSWs at the frame boundaries (odd/even) also provides the interface information. The data burst in line 625 contains a frame sync sequence which immediately follows the LSW and which is defined as four bytes. This is followed by the 64 bits FSW 65AEF3153F41C246h. This is transmitted in its true form preceding even-numbered frames, and in its inverted form preceding odd-numbered frames.

Encryption. Whatever its version, MAC is inevitably tied up with viewers' fears of intricate encryption methods. The fact that picture components U/V and Y are separated in time rather than in frequency makes it possible to use two effective scrambling methods. One is defining so-called cut points whereby the U/V and Y components are cut into two segments, and transposed within the relevant period. To restore the signal to its intelligible form, the cut points (i.e., relative sample numbers) must be identified to reconstruct the time scheme shown in Fig. 2c. The cut points within the periods \( R_C \) and \( R_L \) are derived from a 16-bit pseudo-random sequence generator, whose validation key is only known in authorized receiver systems. The method illustrated in Fig. 5a is called double cut component rotation for now obvious reasons (note that the cut points shown are but examples). The second scrambling method available for MAC entails making the PSK data block unintelligible in the receiver. Bits can be processed as shown in Fig. 5b: a pseudo-random binary sequence is added modulo-2 to the digital sound and data stream, so that another authorization key is required for correct processing in the receiver. The data block enables satellite operators to implement not only pay-per-view systems, but also entitlement checking, multi-channel sound, selective Teletext, over-air addressing for automatic controlling of VCRs, and viewers' status registration.

Fig. 4. A frame of E-CMAC, showing that the length of the sound/data burst is reduced to achieve a wide-screen picture, allowing extra luminance information to be carried (courtesy IBA).

HDTV-compatible D2 services in mind, and is strongly propagated by the IBA in cooperation with the EBU.

Aerials for terrestrial and satellite TV services.
Sound. Contrary to conventional sound transmission systems, the MAC format employs a fully digital, multiple-channel audio format. As already shown, no subcarriers are used; instead, the transmission is switched at RF from an FM signal to a 20.25 Mbit/s (C-MAC) or 10.125 Mbit/s (D2-MAC) 2-4 PSK modulated signal. The 99 data bits of lines 1 to 623 are combined into 82 packets of 751 bits, and interleaved at 94-bit intervals. A packet is thus a combination of sound and data, and consists of a 23-bit header, an 8-bit packet code to distinguish between two types of sound and data, and 720 bits of sound or data. A cyclic (23,12) error correcting Golay code is implemented in the header to ensure correct packet recognition when reception is impaired. C-MAC and D2-MAC support 8 and 4 high quality sound channels respectively (S/N ≥ 80 dB when C/N ≥ 18 dB), but more can be carried when these are expanded (multi-language commentaries).

Compatibility. All versions of MAC are totally incompatible with PAL and SECAM. This means that forseeably MAC decoders are in essence transcoding interfaces which perform all the functions discussed, and in addition process and stretch the compressed U/V and Y components to give the correct length and content for a PAL/SECAM TV set. Inevitably, however, there would be pressure on TV set manufacturers to come up with a multistandard, that is, PAL — SECAM — D2-MAC — C-MAC — E-CMAC compatible, sets.

Fig. 5. Two methods of encoding a MAC signal: double-cut component rotation (a), and Boolean encryption of the data block (b).

Fig. 6. Block diagram of the Type DMA2270 D2-MAC decoder (courtesy ITT Semiconductors).

Abbreviations and terms used in this article:

AM = amplitude modulation
BBC = British Broadcasting Corporation
DRS = direct broadcasting satellite
DATV = digitally assisted television
EBU = European Broadcasting Union
CCD = charge-coupled device
CD = compact disc
CSS = communication service satellite
EIRP = effective isotropic radiated power
FM = frequency modulation
f (50 Hz)
HDTV = high-definition television
IBA = Independent Broadcasting Authority
IARU = International Association of Radio Unions
IRF = Institut für Rundfunk-technik
NHK = Nippon Hoso Kyokai, the national Japanese broadcasting authority
NOS = Nederlandse Omroep Stichting, the national Dutch broadcasting authority
NTSC = National Television System Committee
O/P = orbital position
PAL = phase alternation line
PSK = phase shift keying
QPSK = quadrature phase shift keying
RTL = Radio Televisie Luxembourg
SECAM = Sequential Couleur A Memoire
SES = Société Européenne des Satellites
S/N = signal to noise ratio
VCR = video cassette recorder
VLSI = very large scale integration
U/V = quadrature components of the chrominance signal: U = 0.498(R-Y) and V = 0.877(R-Y)
VSB = vestigial side band
Y = luminance signal
Δ = deviation from the RF carrier in an FM transmitter.
equipped with high quality audio processors also. The first steps towards proposing an all-digital TV receiver were those from ITT Semiconductor. The functional organization of their Type DMA2270 VLSI D-MAC decoder appears in Fig. 6. A pity the device is not yet generally available!

Advantages over PAL. In conclusion of this section, a summary is given of the main advantages of MAC over PAL (and possibly SECAM and NTSC) systems:

- Excellent picture quality thanks to separate transmission of luminance and chrominance components. No cross-colour or cross-luminance effects.
- Ready driving of the decoder from the FM detector's baseband output.
- Less chrominance noise.
- Significantly improved S/N ratio at the same receiver input signal strength.
- Capacity for carrying 4 or 8 CD quality audio channels.
- Provision for additional digital services at 190 Kbit/s.
- Ready implementation of all digital, highly secure, encryption systems without increasing the baseband bandwidth.
- Eminently suitable for incorporation in microprocessor based timing and remote control systems.

MACs, cables and satellites

The coexistence of C-MAC, D2-MAC, and E-CMAC is a result of research carried out in various broadcaster's laboratories. The comparison between these formats focuses on a few main themes as discussed below:

Cable networks: C-MAC has been optimized for satellite transmission, where the channel bandwidth is 27 MHz. This is generally not available in existing cable networks, which allow for a channel spacing of about 8 MHz. Reception of a standard C-MAC signal results in a compressed video bandwidth of about 8.5 MHz, interspersed with data bursts at 20.25 Mbit/s. If re-modulated into VSB AM, the bandwidth is still around 15 MHz, due largely to the sound/data burst. When the sound/data packet is re-coded into duo-binary form, i.e., the data signal is at one of three levels, the 20.25 Mbit/s data stream can be conveyed within a bandwidth of about 8.5 MHz, which then equals the vision bandwidth. This enables the complete signal to fit within the available bandwidth on cable systems. The format so made is called D-MAC. D2-MAC is an even narrower signal that can be derived from D-MAC by halving the bit rate in the data burst. This format results in a baseband bandwidth of around 5.3 MHz, and can therefore be transcoded into VSB AM for use on cable networks where the channel spacing is not less than about 7 MHz. It should be noted here that transcoding always results in some degree of picture impairment, and is, of course, to be abandoned as soon as wideband cable systems and MAC compatible TV sets are available.

Astra satellite is expected to keep using PAL until MAC decoders are available everywhere. Knowing that the BBC and IBA are likely to be assigned quite a few channels on Astra, this one satellite may well beam down TV signals in various formats once it is operative. Its transponder bandwidth should be sufficient for conveying all 16 programmes simultaneously without running into cross-channel interference.

Satellites: Clearly the development of MAC formats was originally prompted by the need for good quality TV transmission via geostationary satellites. The EBU recommends the use of standard C-MAC on their future Olympus satellite, while the IBA proposes the E-CMAC format. The BBC is likely to agree upon using D2-MAC, just as the German and French DBS consortia. RTL on the SES-owned Astra satellite are expected to keep using PAL until MAC decoders are available everywhere. Knowing that the BBC and IBA are likely to be assigned quite a few channels on Astra, this one satellite may well beam down TV signals in various formats once it is operative. Its transponder bandwidth should be sufficient for conveying all 16 programmes simultaneously without running into cross-channel interference.

MAC formats, HDTV and DATV

Although a separate discussion is undoubtedly required to describe the technical characteristics of the many formats already proposed for HDTV, it is worthwhile to study the compatibility of this wide-screen format with the MAC systems described. Successful demonstrations of high-quality large screen pictures with an aspect ratio of about 3.33:2 based on an 1125-line standard proposed by NHK of Japan have given a new impulse to researchers engaged in developing a new wide screen standard, as a follow-up of the 4:3 aspect ratio currently dictated mainly by the size of colour picture tubes. Some of the most commonly used picture aspect ratios are shown in Fig. 7. The system proposed by NHK is called MUSE, and its main technical characteristics are summarized in Table 2. The question now arises which of the MAC transmission formats is most suitable

Table 2

<table>
<thead>
<tr>
<th>Characteristics of the MUSE HDTV system</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>System:</strong> Motion-compensated multiple subsampling, multiplexing of colour signal by time-compression and integration.</td>
</tr>
<tr>
<td><strong>Scanning:</strong> 1125 lines, 60 fields/s, 2:1 interface</td>
</tr>
<tr>
<td><strong>Baseband bandwidth:</strong> 8.1 MHz (-6 dB)</td>
</tr>
<tr>
<td><strong>Resampling clock rate:</strong> 16.2 MHz</td>
</tr>
<tr>
<td><strong>Vertical bandwidth:</strong> Y: 20.22 MHz for stationary picture portions; 12 MHz for moving portions; C: 7.0 MHz for stationary picture portions; 3.1 MHz for moving portions; positive digital sync.</td>
</tr>
<tr>
<td><strong>Audio and additional information:</strong> PCM multiplexed in vertical blanking interval using 4-state DPSK at 2048 Kbit/s</td>
</tr>
</tbody>
</table>

Fig. 7. Commonly used picture aspect ratios normalized to unit area (courtesy EBU).
for conveying HDTV and higher aspect ratio pictures via satellite. Although all systems have been tested in this respect and found to be compatible to some extent, the E-CMAC format developed by the IBA looks particularly promising, since it is claimed to be able to provide pictures of aspect ratio and resolution comparable to those of the NHK proposals. This is mainly thanks to E-CMAC making very efficient use of the available time for the sound & data packet, at the expense of a few audio channels. The sampling rate is 27 MHz, while the video bandwidth of an E-CMAC signal is about 12 MHz, bearing in mind that the picture is composed of 625 lines, and that the uncompressed sampling frequency is 22.5 MHz. Research has shown that E-CMAC 5:3 pictures can be transmitted using conventional DBS channels in the 12 GHz band. The reduced sound/data capacity with respect to C-MAC is still sufficient to convey 2 high quality sound channels. A high degree of compatibility with standard MAC receivers is ensured by virtue of the proportions of left and right extension of the picture being signalled in line 625, the service identification line. The IBA claims that the quality of an E-CMAC picture approaches that of HDTV systems using around 1,000 lines, without the need to resort to a new and incompatible standard. Enhanced C-MAC pictures were demonstrated at the Royal Television Society Convention in Cambridge during September 1985, and were shown to press and industry representatives at the IBA's Brompton Road headquarters in December of that year.

The transmission of true

Fig. 8. Shannon's theoretical channel capacity as a function of four parameters. Note that 27 and 36 MHz are the most commonly used bandwidths for satellite TV, and that C/N=11 dB is roughly the FM threshold (courtesy EBU).
1125-line HDTV pictures by satellite poses problems, however. The reason for this is that the unprocessed HDTV baseband signal from the TV studio is likely to require a bandwidth of about 40 MHz, which equals a bit-rate of about 600 Mbit/s if transmitted digitally. The following considerations will show that this exceeds the capacity of the currently used 12 GHz band, because the required data compression ratio of about 10:1 is as yet technologically impossible.

Shannon has defined the maximum bit rate, (capacity), D, achievable in a communication link with bandwidth B as:

\[ D = \text{Blog}(1 + \frac{C}{N}) \text{ bit/s} \]

where \( C/N \) is the carrier to noise ratio expressed in dB. Figure 8 shows the capacity of the channel in relation to various parameters. Although some researchers have reached within a few dB of the theoretical Shannon limit, this is only at low bit-rates using substantial processing in the receiver. With the sort of bit-rate required for HDTV it will be difficult, if not impossible, to approach half the Shannon bound. Two examples may be considered to illustrate the foreseeable difficulty in transmitting an all-digital HDTV signal:

- **Case 1:**
  - \( B = 30 \text{ MHz} \)
  - \( C/N = 94.3 \text{ dB} \)
  - \( D = 19.18 \text{ MHz} \)

- **Case 2:**
  - \( B = 19.18 \text{ MHz} \)
  - \( C/N = 94.3 \text{ dB} \)
  - \( D = 125 \text{ Mbit/s} \)

C/N is the noise spectral density expressed in dB/Hz, and can be shown to equal a C/N ratio of 20 dB in 27 MHz. Assuming that half the capacities \( D \) can be achieved, the limit is between 60 and 100 Mbit/s depending on the maximum frequency degree of interference. QPSK signals have been shown to enable transmissions at about 34 Mbit/s, while a relatively simple extension to 8-PSK should allow 51 Mbit/s to be achieved. This may be adequate for HDTV if 3:1 bandwidth reduction is applied in analogue systems, and 10:1 bit-rate reduction (compression) in all-digital systems. In any case, the resulting bandwidth is still far beyond the capacity of the existing DBS band, where channels are allocated with a regular 19.18 MHz spacing, and where the RF bandwidth of transponders should not exceed about 35 MHz to ensure acceptable levels of interference. Conclusion: 1125 line, all-digital HDTV is currently impossible to implement in the 12 GHz DBS band, and already experiments have been conducted to assess the propagation and attenuation characteristics of higher bands allocated to DBS services, i.e., 23, 42 and 85 GHz. The results obtained by HDTV researchers T Long and L Stenger are valid for the average European temperature climate, and appear in Table 3. Note that the stated bands are not available in all IARU regions in the world. Based on these data, calculations have been made as regards downlink budgets and satellite EIRP figures. Depending on the assumptions made for the bandwidth, receiver aerial diameter, and minimum figure of merit, the radiated power is foreseeably of the order of 750 to 1,500 W per channel in the 23 GHz band, and between 12 and 23 kW for the 42 GHz channels. Evidently, regulating action is required from broadcasting authorities to timely avoid allocating too narrow channels for the 40 to 50 MHz wide HDTV services.

Unfortunately, the international frequency planning timetable is such as to make HDTV on 23 GHz impossible before the beginning of the next century. The BBC has recently proposed the concept of DATV, whose main advantage is found in the very effective bandwidth reduction of HDTV signals originating from TV studios. Using DATV it becomes possible to operate bandwidth reduction procedures at the studio level, and arrange for the receiver to be instructed continuously, via the data channel, on the organization of particular parts in the picture. The importance of DATV is that it enables a significant improvement to be achieved in the quality HDTV pictures that can be conveyed in relatively narrow DBS channels, thus efficiently using the available spectrum space. DATV is fully MAC compatible, and can be used to give an aspect ratio of 16:9 with slightly higher horizontal resolution than C-MAC. Like the MUSE and 8-GHz systems, it can make use of so-called motion vectors to effect high spatial resolution in picture areas of predictable motion.

### Table 3

<table>
<thead>
<tr>
<th>Frequency (GHz)</th>
<th>12</th>
<th>23*</th>
<th>42*</th>
<th>85*</th>
</tr>
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<tbody>
<tr>
<td>Percentage of worst month (%)</td>
<td>99</td>
<td>99.9</td>
<td>99.9</td>
<td>99.9</td>
</tr>
<tr>
<td>Attenuation (dB)</td>
<td>1.5</td>
<td>4.5</td>
<td>13.5</td>
<td>19.9</td>
</tr>
<tr>
<td>Cross-polarization (dB)</td>
<td>30</td>
<td>70</td>
<td>15</td>
<td>24</td>
</tr>
<tr>
<td>Sky temperature (K)</td>
<td>85</td>
<td>130</td>
<td>200</td>
<td>270</td>
</tr>
</tbody>
</table>

*The values given are not precise; cross-polarization data for 85 GHz are not available.*

Conclusions

Although the first MAC signals will almost certainly be transmitted within a year or so, there is no certainty as yet on the preferred format for the various services. In this context, it is hoped that semiconductor manufacturers will provide multistandard MAC decoder chips based on design information from the research and engineering departments of the various broadcasting authorities mentioned. As to the future of HDTV, the main concern of researchers in this field will be further studies into baseband compression, strong bit-rate reduction, and ways of improving and enlarging existing frame store devices. The IRT in co-operation with the EBU has planned field trials with HDTV for this and next year using experimentally operated transponders in the Olympus and Kopernikus satellites.

For further reading:

1) Specification of the systems of the MAC/Packet family. Document Tech. 35/5, available from the EBU Technical Centre Avenue Albert Lancaster 32 B-1180 Brussels Belgium. The price is BF 2,000 including postage.

2) EBU Technical Review no. 21: Compatible Higher Definition Television. Available from the Independent Broadcasting Authority Engineering Information Service IBA Crawley Court 9 Winchcombe Street Cheltenham GL52 2QA.

3) EBU Review (technical) no. 219 (special issue on HDTV). For availability see 1).

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*The values given are not precise; cross-polarization data for 85 GHz are not available.*
THE COMPACT DISC

In the mid-1970s, engineers at the Dutch electronics company Philips felt they had developed just what the world had been waiting for. They called it the Laser-Vision videodisc. This is an optically scanned disc which gives an hour of colour video and sound. Unfortunately for Philips, the video disc arrived too late: too many people already had a video cassette recorder.

Undismayed, the engineers continued their development, and in early 1979 Philips unveiled a trimmed down version of the videodisc, much smaller and containing sound only. It was called the compact disc.

Because of the very favourable reception of the compact disc system, Philips felt it had a new world standard to replace the conventional (and vulnerable) gramophone record. Wisely, it came to a joint agreement with Sony to perfect the system. The first compact disc player went on sale in Japan in late 1982, and in Britain six months later. At that time, a player cost around £500 and the discs about £10. Now, just over four and a half years later, a reasonably good player can be bought for under £200, and it is expected that prices will be under £100 by Christmas. The discs have, however, risen slightly in price to about £12-14.

Production technique

The master (or blank) is made of a glass disc that is ground and polished to optical flatness—see Fig. 1. This is coated with a layer of photoresist, the thickness of which is controlled very accurately. The coating is oven-cured, after which the disc is ready for cutting. Strictly speaking, the term "cutting" is incorrect, because the recording is created photographically, but because of some parallels with the production of a vinyl gramophone record, it has been retained.

Cutting is carried out by a continuously operating helium-neon (HeNe) laser, which is intensity-modulated by the audio signal via an acoustic modulator. In the absence of an audio signal, light can pass through the modulator, but with an audio input light is scattered. The laser travels from the centre of the disc to the outer as the master revolves. The rota-

![Fig. 1. Some of the stages in the production of a compact disc.](https://via.placeholder.com/150)

![Fig. 2. A bubble arises where the laser beam hits the surface of the coated glass disc.](https://via.placeholder.com/150)
Fig. 3. The surface of the master after the developing and etching process.

The speed of the disc is reduced gradually in a way to ensure that the speed of the laser beam over the surface of the blank remains constant. The photore sist is then developed during which the unexposed areas are hardened. Subsequent etching removes the exposed areas, which has the effect of creating pits in the surface of the resist as shown in Fig. 3. These pits represent the digital information of the audio input. The disc is then given a thin silver coating to make it electrically conductive. At this stage, it would be possible to produce a commercial compact disc from the master. However, to preserve the master, only a few (negative) copies, called "father" are made. From these, a number of (positive) intermediate copies, called "mother" are made, and these in turn produce a number of "sons" (negative). These sons are the disc used to stamp compact discs. Since there are an even number of processes, the compact disc is identical to the master.

The compact disc is made of 1.2 mm thick polymethylmethacrylate, better known as Perspex, or of Makrolon, a polycarbonate plastic. The surface of the side of the CD that contains the audio information is then given a thin layer of aluminium, followed by a protective coating of laquer. The thickness of the aluminium layer is of the order of only 10 nm, while that of the laquer is about 5–10 μm. This side of the disc is called the label side, because the identifying label is printed or affixed here.

The information is read from the disc by a laser at the underside, i.e., through the Perspex or Makrolon. The laser, therefore, sees the pits as bumps. A typical construction of a laser pick-up unit is shown in Fig. 4.

Structure of the compact disc

Figure 5 gives a cross-sectional view of a compact disc. The lead-in track contains all the necessary information regarding the recorded music or speech. A total of some 20,000 tracks are contained within the 33 mm wide recording surface. The digital data are defined by the length of the pits and the distance between them. The length of the pits varies from 833 nm to 3.56 μm, their width is 500 nm, and their depth is 110 nm. The distance between two adjacent tracks is 1.6 μm.

The disc contains some $7 \times 10^9$ bits. At a constant linear velocity-CLV-of 1.2 m/s, the maximum playback time is 74 minutes. The Perspex from which the disc base is made has a refractive index, $n$, of 1.46. The diameter of the laser beam when it enters the Perspex is 0.8 mm, but because of refraction this is reduced to 1.7 μm at the recording surface—see Fig. 6.
Affect the reproduction of the dust particle of 0.5 mm does not Fig. 6. This small diameter is
Since the diameter of the laser index of the disc base.
Fig. 6. This small diameter is

Pits and bits

The pits and the reflective (aluminium) surface represent logic 0s and is respectively. When the laser beam is focused on a pit, ideally no light should be reflected. To achieve that, the depth of the pit, a, is approximately equal to \( \lambda /4 \), where \( \lambda \) is the wavelength of the laser light and \( n \) is the refractive index of the disc base. Since the diameter of the laser beam at the recording surface is 1.7 \( \mu \text{m} \), and the width of a pit is 0.5 \( \mu \text{m} \), some light is reflected from the pit. Because of the relationship between the depth of the pit and the wavelength of the laser light, there will be a phase difference between light reflected from a pit and that reflected from the aluminium layer of \( \lambda /4 = 180^\circ \) (in an ideal case). This means that due to the interference effect the two reflected light beams will cancel one another. In practice, this cancellation will not be complete, however, but the reduction in the total reflected light is none the less sufficient to actuate the focusing detector unit. The reflected light is consequently modulated in a manner that depends on the length of the pit.

The optical system

The laser, optical system, and detector are contained in one unit as shown in Fig. 7. The collection and telescope lens assemblies focus the light emanating from the laser diode. The correction prisms shape this to an annular beam. This beam is deflected by a routing mirror assembly to a polarizing beamsplitter and \( \lambda /4 \) plate assembly, where the plane of polarization is shifted 90°. From there, the beam passes through the objective lens to the recording surface of the CD. The reflected light is taken from the objective lens, aligned parallel, and then falls onto the \( \lambda /4 \) plate. The plane of polarization is again shifted 90°, after which the beamsplitter directs the beam to the focus error prism, from where it travels to the detector (photo-sensor).

Sampling frequency

In the Sony laser head used in commercial CD players, shown in Fig. 8, the photo-sensor is a four-quadrant type. This head contains two extra sensors (E and F) for the side spots. Control signals from these sensors drive the two-axis device. Input signals for the audio amplifiers, servo systems, and associated circuits in the compact disc player are also taken from the photo-sensor unit.

Sampling frequency

The sampling frequency should be greater than twice the frequency of the highest audio frequency the system is required to process. Taking also the anti-aliasing requirement into account, a world-wide standard of 44.1 kHz was chosen. With a sampling frequency of 44.1 kHz, the upper audio frequency range must be limited to just above 20 kHz. Although this is considered satisfactory by many, there are also many who feel that this limitation is unacceptable. Since manufacturers of CD players can not change the agreed sampling frequency, they have developed a technique called digital filtering or oversampling.

In oversampling, the original sampling frequency is seemingly doubled or even quadrupled by electronic means. In twice oversampling, there are 44,100 real samples coming off the disc, and a special electronic circuit adds a sample between each pair of real ones to give a total of 88,200 samples. These added samples are an electronic prediction as to what they would have been had they been recorded on the disc. In four times oversampling, the number of predicted samples increases to three between each pair of real ones. In some CD players, the previous thirty samples are used to predict every set of three guessed samples. With all oversampling, extra bits are generated: one in twice oversampling, and two in four times oversampling. These bits are in addition to the 16 bits already coming from the disc. Unfortunately, the signal processing circuits of CD players can cope with 16 bits only, so that, ironically, some of the information has to be discarded.
Disc production

At present, there are only a dozen or so CD producers in the western world and two in the USSR. Most of these make their name through gramophone record production and have been in existence for a long time.

The largest CD producer is currently PolyGram, a subsidiary of Philips, with plants in Federal Germany and Britain. The first British company to produce CDs was Nimbus of Monmouth, which started in 1984. There is now also Thorn-EMI in Swindon. Single unit production at present amounts to only about 100 million per year, it is clear that with nearly 20 million CD players in use in the western world, demand outnumber supply, which will keep the price of the disc high. It will take a year or so yet before supply will start catching up with demand: only then will there be a likelihood of CD prices coming down from their present level.

The biggest bottleneck in production is the metallization of the disc with aluminium, which ensures that the disc can be read by the laser in the player. Until recently, this was done in large chambers that held hundreds of discs at a time. It takes about 15 minutes to create a vacuum in the chamber and another 10 minutes to deposit the aluminium. New machines from Balzer in Switzerland bring the cycling time down by more than a half. These evaporation chambers are held at a permanent vacuum. The discs are loaded at one end on a conveyor and passed through a series of bulkheads that create a pressure gradient from atmospheric to high vacuum and up to atmospheric again.

In spite of the strict clean-room procedures at CD production plants (in most the disc does not come into contact with humans until it has been given the protective lacquer coating: all previous operations are performed by robots), the rejection rate remains high at over 10% over the entire production process. It should, of course, be realized that this involves no fewer than 80 stages from tape mastering, through disc mastering, electroplating, pressing, metallization, and so on, to packaging.

An interesting aspect of the siting of a CD production plant is that the foundations must be very stable: deep rock is preferred, because its natural movement is not more than a few micrometres at very low frequency. This stability requirement becomes clear when it is realized that the track dimensions of the high density master discs are less than 1 micrometre.

The CD video

During the preparation of this article, Philips, Sony, and a number of other Japanese manufacturers announced the CDV player. This type of player, whose commercial launch is planned for the coming autumn, can handle normal audio compact discs as well as the new CDV discs which hold 5 minutes of colour video as well as 20 minutes of sound only.

It appears these manufacturers' intention to use CDV as a means of marketing pop music video clips. Polygram, Philips' subsidiary record, CD and tape manufacturing plant in Federal Germany, is in full support of the new system, and claims that most of the world's large record companies have confirmed their backing.

The video picture signal is recorded towards the outer edge of the disc, where it is easier to get a high tracking speed. Normally, a digital audio disc spins between 156 and 486 rev/min to give a constant linear velocity (laser tracking speed) of 1.2 m/s. This is too slow even for analogue video.

It appears that with the new system it is linked to TV standards, at least as far as the video section is concerned. For PAL CDV discs, with 25 pictures/s, the rotational speed varies from 1512 to 2250 rev/min, giving it a CLV of between 9.2 and 10.2 m/s. For NTSC video (30 pictures/s), the spinning speed will be 1815 to 2700 rev/min, resulting in a laser tracking speed of between 11 and 12 m/s.

Commercial aspects

During the 1980s, the audio equipment market in general grew moderately in size, but hardly at all in value. The exception was the CD player sector, which saw a boom towards the end of last year that continued into this year. An estimated 192,000 players were sold in November and December alone: a three-fold increase compared with the same months in 1985. If new buyers follow their predecessors' purchasing patterns, the sale of CDs should rise quite sharply. Gramophone Magazine's CD survey showed that 69% of CD player owners own more than 80 discs. However, although compact discs offer hitherto unacceptable quality, at nearly twice the price of LPs and cassettes they still appeal mainly to the serious music enthusiast.

Figures just released by the British Radio & Electronic Equipment Manufacturers' Association (see Table) show that during last year CD player deliveries were at more than four times the level achieved in 1985. The major development in 1986 was the increasing availability of combination products, primarily CD music centres, which contributed to a high level of consumer interest. These products accounted for over one tenth of total music centre deliveries. The CD separates sector was very active and registered a more than three-fold increase over the 1985 results. These represent faster growth than that achieved by any other consumer electronics product.

<table>
<thead>
<tr>
<th>Table 1</th>
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<tr>
<td>Separators</td>
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<td>Q3</td>
</tr>
<tr>
<td>Q4</td>
</tr>
<tr>
<td>147</td>
</tr>
</tbody>
</table>

The figures show quantities in thousands.

CD players and manufacturers

There are some 150 manufacturing plants in the world licensed to produce compact disc players. It is, of course, not possible to list all of them and some of their products, so that only the 20-odd best-known have been selected (with apologies to the others).

AKAI (UK) LTD
Unit 12
Haslemere Heathrow Estate
Silver Jubilee Way
HOUNSLOW TW4 6NF
Telephone: 01-897 6338

Akai produce a number of players in the price range £220-425. Three of the players use a 3-beam diode-laser, and one, the CD-A70, comes complete with infra-red remote control.
Allied International's AMCDS-1000A programmable CD player holds 100 CDs, features automatic random access to disc, and is equipped with a main microprocessor for system control and a secondary microprocessor for CD playback operations. Intended primarily for commercial and broadcasting applications.

Bang & Olufsen produce two CD players, the CDX at £435 SRP, and the CD50 at £576 SRP. They also make a beautiful combination unit, the Beocenter 9000, which contains an FM/AM tuner with automatic station search, a fully automatic cassette recorder, and a latest-generation compact disc player. The SRP of the 9000 is £1,235.

Cambridge Audio Systems International Ltd
Home Farm
Diddington
Cambridgeshire PE18 9XU
Telephone: (0480) 811711
For some time now, Cambridge's CD1 CD player has probably been the very top-quality player on the market. With 18-bit D-A conversion, 4 times oversampling, a S/N ratio (weighted) of 120 dB, cross-talk between channels of 115 dB at 1 kHz and 100 dB at 20 kHz; a linearity of within 0.2 dB from 0 to 60 dB, that is not surprising. The SRP of about £1500 is, however, probably a little high for the average household.

Cambridge have also recently introduced the CD2 player, which, in contrast to the CD1's 18-bit, 4 times oversampling technology, is the first player in the world to feature 16-bit x 16 times oversampling.

Denon produces professional broadcasting and studio recording equipment as well as consumer audio products. Their range of CD players comprises the DCD-300, the DCD-500, the DCD-900, and the DCD-1500. The Denon machines have always been known for their mechanical soundness and good quality sound.

Hitachi produce four quality disc players, from the impressive, fully programmable DAD-005 (with infra-red remote control) to the DA5000 and DA6000, and the new DA400.

JVC is one of the select band of manufacturers that produce a portable CD player. Their XL-R10K is one of the few personal players currently available; it is priced at about £250. Additionally, the company offers a range of six separates, all fitted with JVC's own 3-beam laser pickup.
MARANTZ AUDIO (UK) LTD
15-16 Saxon Way Industrial Estate
Moor Lane
HARMONDSWORTH UB7 0LW
Telephone: 01-897 6633
In addition to their already impressive range of CD players (all providing 4 times oversampling), Marantz have just introduced the CD94. This player is built around a non-magnetic aluminium chassis and also has a solid aluminium top cover. It has full infra-red remote control, FTS, 20-track programming and variable headphone output, and its digital output is available in both optical and conventional form. The optical form allows connection to the unit with total electrical isolation. The CD94 has a SRP of £799; other prices in the Marantz range are: CD45 - £199; CD56 - £249; and CD65 - £349.

MERIDIAN
BOOTHROYD STUART LTD
13 Clifton Road
HUNTINGDON PE18 7BR
Telephone: (0480) 52339
One of only a small number of British CD player manufacturers, Meridian have earned a reputation as the leading designers and manufacturers of the world's finest sounding compact disc players. Their latest player, the 207-PRO (shown in the photograph with the 201 preamplifier, 209 remote control unit, 204 FM tuner, and M30 active loudspeaker) has 14-bit D-A conversion with 4 times oversampling. Recommended prices are: CD94 - £850; 201 - £495; 209 - £169; 204 - £450; and M30 - £725.

MITSUBISHI ELECTRIC UK LTD
Hertford Place
Maple Cross
RICKMANSWORTH WD3 2BJ
Telephone: (0923) 770000
One of the few companies (so far) to offer a multi-play CD player, the DP409R, which has a capacity for loading 5 CDs that are selected automatically. Complete with full infra-red remote control, the DP409R has a SRP of £329. Other players in the range include the DP107 (£199); DP209R (£249 with IR remote control); and the mid-sized DP603 (£199).

NAD ELECTRONICS
Cousteau House
Greycaine Road
WATFORD WD2 4SB
Telephone: (0923) 26499
Sold throughout the world, NAD products are well-known for their sophisticated engineering, excellent sound reproduction, and excellent price-performance value. The company produces a fine CD player that is available in two models: the 5355 at a SRP of £399 and the 5355E (£329).

NAKAMICHI B&W UK LTD
Marlborough Road
Churchill Industrial Estate
LANSING BN15 8TR
Telephone: (0903) 750750
The two CD players produced by this well-known company are definitely top-of-the-range. Unlike most other CD players, the Nakamichi models use a separate D-A converter for each channel to prevent frequency-dependent phase error. Moreover, left- and right-hand samples are separated while the signals are still in digital form so that the de-interleaving switch does not introduce noise and distortion as in a conventional player. Recommended prices are £795 for the OMS-5E and £1195 for the OMS-7E.

PHILIPS CONSUMER ELECTRONICS
City House
42-430 London Road
CROYDON CR3 3QR
Telephone: 01-686 2166
As would be expected, Philips is one of the very few companies that offers not only mains-operated CD players, but also a battery-operated personal model, and a model that can be connected to any car tuner-cassette player. Top of the range is the CD650, which offers 16-bit D-A conversion with quadruple oversampling, FTS (favourite track selection), and infra-red remote control. It is priced at £399. The CD10 portable player is priced at about £220, and the Type DC085 car model at about £300.
Recent additions to an already impressive range of CD players are the PD-M60 and PD-M70, both multi-play models. This means that Pioneer can now offer no fewer than three players that can load up to six discs at a time. These can be played back one by one, or in order of (preset) choice, or at random. Both the new players have infra-red remote control: that of the PD-M70 is very interesting in that it has its own memory, enabling the storage of up to 8 separate programming sequences, and its own volume control, which operates in the digital circuits. The company also offer a portable player, the PD-C7 (BK) and two models intended for installation in a car: the CDX-1 and the CDX-PI.

Fig. 17. PIONEER's PD-M70 is a multi-play CD player that can load up to six CDs at a time.

SANYO MARUBENI (UK) LTD
Sanyo House
Otterspool Way
WATFORD WD2 8JX
Telephone: (0923) 46363
The three players in Sanyo's range, CP08, CP500, and CP667, all fall in what may be termed the budget range: £199-299. There is also a good-value-for-money portable player, the CP10 at about £270.

SONY (UK) LTD
Sony House
South Street
STAINES TW18 4PF
Telephone: (0784) 61888
This giant of the compact disc world has no fewer than eleven players in its range, at prices from £200-700. The range includes two portable models: the Discman D55T at about £300, and the Discman 50 at around £260. The portables are smaller than the average handbag and probably lighter than most of those.

TANDBERG
TAN AUDIO (UK) LTD
P 0 Box 31
CHICHESTER PO20 7RX
Telephone: (0243) 56342
Norwegian audio equipment specialist Tandberg produces only one CD player, but this is of the highest quality. The TCP3015A, priced at about £1,100, offers 4 times oversampling, flat phase response, separate headphone amplifier, full programmability, and full infra-red remote control.

Some other useful addresses.

CBS RECORDS
17-19 Soho Square
LONDON W1
Telephone: 01-734 8181

DECCA RECORDS
15 Saint George Street
LONDON W1A 2BR
Telephone: 01-499 0422

DEUTSCHE GRAMMOPHON
15 Saint George Street
LONDON W1A 2BR
Telephone: 01-499 0422

EMI RECORDS
The Quadrangle
West Mount Centre
UXBRIDGE ROAD
HAYES UB4 0HB
Telephone: 01-948 3611

NIMBUS RECORDS LTD
Wyastone Leys
MONMOUTH NP5 3SR
Telephone: (0600) 890682

PHILIPS RECORDS
( PHONOGRA M)
15 Saint George Street
LONDON W1A 2BR
Telephone: 01-499 0422

POLYDOR RECORDS
15 Saint George Street
LONDON W1A 2BR
Telephone: 01-499 0422

POLYGRAM INTERNATIONAL LTD
45 Berkeley Square
LONDON W1X 5DB
Telephone: 01-493 8800

RCA RECORDS
1 Bedford Avenue
LONDON WC1
Telephone: 01-636 8311

Some other useful addresses.

CBS RECORDS
17-19 Soho Square
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RCA RECORDS
1 Bedford Avenue
LONDON WC1
Telephone: 01-636 8311

Some other useful addresses.
EDI market takes off

After a sluggish start, Electronic Document Interchange (EDI) is finally beginning to take off. According to Electronic Document Interchange Markets—USA and International, a new report (#732) from International Resource Development, the market will grow from just over £80 million this year to over £1 billion by 1994.

Third-party service suppliers, providing VAN services for EDI (which include protocol conversion, validity checking, batching, etc.) will be the major beneficiaries of this growth. Current leaders include McDonnell Douglas, General Electric, and Transsetlements, while the IBM Information Network service is a fast-growing contender.

According to the report, the standardized nature of the EDI messages, and the fact that they must be transmitted over government-controlled PTT transmission facilities will inevitably attract a tax on document transfer in some European and Third World countries.

Granada/HTE deal a promising one for the punters

Granada Business Systems Division has placed a contract worth £41/2 million with computer specialist High Technology Electronics.

The contract is for viewdata computers to which software TV monitors will be added by Granada Business Services Division. The equipment will form part of the new satellite studio, text and visual service for Britain's bookmakers which has been developed by Satellite Information Services nationwide.

LAN fault simulation

A unique Local Area Network fault simulation capability from HBB Europe was announced during the British Electronics Week. Known as LANA (Local Area Network Acceleration), this capability reduces the cost of simulation by integrating accelerated simulation into existing workstation environments without the major investment of an acceleration engine.

The LAN extension to CADAT allows a single workstation to command the distribution of the fault simulation task to multiple CPUs over Ethernet. A CADAT user on any workstation could initiate a fault simulation and elect to request "service" from any number of other LANA-equipped workstations.

The LANA software automatically checks the availability of each, and dynamically configures the tasks to fit the currently available resources. LANA is "intelligent" enough to detect if a SERVER goes offline and reconfigures the tasks "on the fly" to handle the new conditions. LANA fault simulations are run interactively or under "batch processing" control.

Six thousand visitors expected at APRS show

More than 6000 visitors from Britain and overseas are expected by the organizer to attend the international APRS Exhibition for the professional audio market at London's Olympia exhibition centre from 24 to 26 June 1987.

Now in its twentieth successive year, the show has been over-subscribed since before the end of January. There will be 150 stands on two floors occupying a total net display area of 3000 m².

This year's show catalogue will include for the first time the names of manufacturers whose products are being shown on the stand of agents. These will be cross-referenced to the agent's stand number so that visitors will be able easily to check the entire range of products being shown.

* Association of Professional Recording Studios Limited o. 163A High Street o RICKMANSWORTH WD3 1AY

British Telecom backs electronic payments

British Telecom has declared its continued support to Britain's financial institutions and retailers in bringing a fully automated system of cashless payments to shops, stores and other retail outlets throughout the country.

National introduction of the system, known as electronic funds transfer at the point of sale (EFTPOS), is scheduled to begin towards the end of 1988.

EFTPOS is an automated payment systems designed to transfer value from purchaser to seller more conveniently and at a cost less than for payments by cash, cheque or credit card.

The system will enable the financial institutions to contain or even reduce costs and to manage the increasing volume of transactions more efficiently. It will also enable them to develop a new range of electronically delivered services.

The concept currently being considered involves a plastic debit card which, in conjunction with a signature or personal identification number (PIN), identifies the card user. Payment is made by wiping the card through a slot in the EFTPOS terminal at the point-of-sale, entering details of the purchase, obtaining PIN or signature verification from the customer, and in most cases obtaining authorisation from the card issuer's computer over an on-line connection. Finally, settlement takes place between the purchaser's and retailer's banks.

3Com announces support for new IBM computers

3Com Corporation is supporting IBM's Personal System/2 series of computers, providing network operating software and network interfaces that allow the new machines to be integrated into existing 3System workgroup systems.

Currently, there are about 300,000 3Com-adapted personal computers on 30,000 3Com networks worldwide. 3Com provides Ethernet, Token Ring and AppleTalk connectivity.

3Com is modifying its 3+ network software to work under DOS 3.3, ensuring compatibility with current Personal Systems/2 machines and IBM's new Token Ring adapter for its Micro Channel architecture. 3Com's current version uses 3+ network software (version 1.2) will work with DOS 3.3 and support the new IBM Token Ring adapter. In addition to the traditional 5.25-inch format, 3+ will be offered in the 3.5-inch floppy disk format required by the new computers.
Conference on rural communications

The Institution of Electrical Engineers (IEE) is to hold an International Conference on Rural Telecommunications at the IEE, Savoy Place, London WC2, from 23 – 25 May 1988. The Conference will consider the ways of providing modern telecommunication services to the world's rural communities by means of appropriate modern telecommunication technology.

Cost effective provision and operation of rural telecommunication systems continue to present major difficulties for the telecommunications engineer. The problem is not confined solely to the developing world. Most rural telecommunication services in developed countries run at a loss and need to be supported by cross subsidy from more profitable city and urban services. This situation is, however, changing. Privatization and competition requiring high profitability and efficiency make cross subsidy unattractive. This, coupled with the regulatory requirement to continue providing services to rural communities, is creating the incentive to find new approaches to the provision and operation of rural telecommunication systems. In developing countries the scope for cross subsidy is often very limited and rural telecommunications consequently very restricted. The need is again for more economic solutions to be found.

Technological developments in the fibre optic radio, and satellite fields offer the prospect of new, more cost effective solutions. In addition, with main network digitization well advanced in many developed countries, there is a pressing need for industry to find new outlets for the future. Considering that approximately two thirds of the world's population live in rural areas and are provided, for the most part, with indifferent telecommunication services, the market represented by rural telecommunications is potentially very large.

Racial communications for Atlantic balloon challenge

Accurate and reliable communication and navigation systems will play a key role in the forthcoming attempt to make the first crossing of the Atlantic ocean by hot-air balloon. As with Don Cameron's near successful attempt to cross the Atlantic by helium balloon in 1978, Racial Electronics is again providing high technology communications and navigation equipment. Racial will also set up and operate the vital control centre at one of its UK locations in the Thames Valley.

Towards the end of the flight, Cameron and Howard will need to know their location with great accuracy so that they can make the critical decision to release themselves from the large balloon at the right time. For this reason, they will be carrying a Racial-Decca DYN IV (Decca Yacht Navigator) which plots its position by using the worldwide Decca radio navigation system.

During the preparation period for the attempt, the balloon team will be supplied with Racial-Vodafone cellular telephones to enable them to keep in touch at all times, especially during trials when the team will be in remote parts of the country.

BT an NTT expand relationship

British Telecom and Nippon Telegraph and Telephone Corporation (NTT) have signed a memorandum on collaboration for the exchange of personnel and information over a three-year period from April 7, 1987. The memorandum represents an expansion of exchanges between the two telecommunications leaders which have been taking place over many years. The new relationship includes mutual exchanges of personnel and reciprocal visits by executives and middle managers, plus the sharing of business experiences after the privatization of the two companies.

The plan is designed to promote increased business activities of both firms.

Incomtel for Samoa

The London – based Incomtel systems engineering group have won a major contract for the expansion of existing facilities at the Western Samoa Post Office Satellite Earth Station near Apia. The contract has been awarded to Incomtel by the South Pacific Bureau for Economic Cooperation and will be funded by the European Development Fund. A large proportion of the contract will be completed at Incomtel's well-equipped test complex, in their West London headquarters, prior to shipment.

Incomtel will be responsible for the supply, installation and commissioning of the entire system interfacing with the existing single channel per carrier service. The upgrading of the earth station will be effected by the introduction of compared frequency division multiplex services with New Zealand.

In addition to this expansion programme, Incomtel's contract will also include the upgrading of the system at the Apia telephone exchange. This includes supervisory and engineering service circuit facilities.

Marconi Radar wins major Plessey order

Marconi Radar Systems Ltd (Gatehead) is to supply approximately 100 'isolator' mobile shelters to Plessey Military Communications to aid its fulfilment of the MOD contract for the Home Defence Radio System (HDRS). The Isolator range is designed specifically to provide a pressurized environment for sensitive electronic equipment. The contract calls for the lightweight shelters for use with small prime movers – Landrover GS vehicles and fighting vehicle trailers.
Cashless phoning gathers momentum in Europe

Coin and cashless calls from payphones in seven European countries are set to become easier following the recent award of contracts totalling £10 million to Plessey Telecommunications Products.

Systems chosen range from "intelligent" payphones equipped with telemetry sensors which can alert a central control point of faults, vandalism and coin capacity, to those in which credit cards, prepaid phone-cards and verbally-communicated personal identification numbers can be given to an operator.

Televerket of Sweden chose the Plessey credit card system following a successful six-month trial at Stockholm's Arlanda Airport. Telefonica of Spain is working closely with Plessey to develop both a coin and credit card system. This includes a verbal software package in which the caller is advised in either Spanish or English how to proceed and insert cards which are "read" by the installation for future billing.

In the wake of these successes the Finnish PTT has invited Plessey to install a field trial of a similar credit card system. Plessey is already supplying its range of "intelligent" coinphones to Finland, Denmark, Spain and Cyprus. Cardphones from Plessey have also been ordered or are on trial in Denmark, Norway and the Republic of Ireland.

A contract has been awarded by British Telecom for the development of systems that enable a caller to have charges transferred to his home or business account when using either a public box or another person's private phone. This will be done by transmitting a personal identification number known only to the caller and an accounting point. These cashless services processor units will be available by mid-1988.

Three methods of card payment are currently being used. These may be international credit cards such as Amex, Access, Diners or Visa. The second category is cards issued by national telecommunications authorities. At the end of a call the cost is displayed by the phone and then relayed to the credit card billing centre for inclusion on standard monthly statements. The third member of the cashless payphone family is the pre-paid payphone card which can be bought from post offices and shops.

Referring to the recent export orders valued at £10 million, Plessey managing director Mr Peter Brown said that three European countries - Spain, Sweden and Britain - were now leading the world in implementing credit and account call payphone technology, and in each country Plessey was supplying the system.

Call for papers

A call for papers has been issued by the organizer of the Fourth International Conference on High Frequency Radio Systems and Techniques to be held in London from 11 to 13 April 1988.

The aim of the conference, explains the organizer - the Institution of Electrical Engineers - is to bring together and focus presentations on recent advances in the theory, design, performance and operation of HF communications systems and networks, and to provide a discussion forum for researchers, designers, manufacturers, users and other workers in the field.

Offers of contribution are invited on any theoretical or practical aspects of HF communication and other radio systems. Further information from Conference Services o The Institution of Electrical Engineers o Savoy Place o LONDON WC2R 0BL.
Acron PAL encoder

Two Acron model 608P colour encoders are now being used by London Weekend Television as part of a novel system for distribution of ITV network programme information to other independent television companies.

The information system, known as 'NETFAX', is located in the Master Control area, and is based on three BBC Microcomputers, which output the alphanumeric and graphics data in the form of RGB signals. These are encoded to PAL by the Acron units for transmission as part of the Company's network material.

This method of communication is a particularly convenient way of passing scheduling details and similar information to the recipients of network programmes, obviating the need for separate communication channels. In practice the information is entered at the computer memory on "scratch-pad" basis for transmission when appropriate, the formatting data, individual headings etc. being held on floppy disc. Transmission is initiated by simple manual command to the computer.

Statusline for HTE

Contec's Statusline has been acquired, and will continue to be supported, by High Technology Electronics.

The acquisition confirms HTE's commitment to the telecommunications industry and marks a new initiative in product diversification triggered by the company's takeover by Alan Patricoff Associates. The entire Statusline team, including development, manufacturing, sales and service personnel, has been retained by HTE and will continue to operate in the Basildon area and through the existing distribution network.

Statusline was conceived about two years ago and has achieved widespread popularity. The cost-effective system fills the gap in manager/secretary communications brought about by the absence of a visual indication of telephone line status in modern PABX systems. It uses single or multiple lamp displays to allow the secretary to monitor the status of one of up to ten lines, making more efficient use of the many valuable features of the new exchanges.

Barry Brinkman: HTE and Patricoff will continue to take the initiative in support for the telecommunications industry.

Gentech-Theta J agreement

Telecommunications relay manufacturers Gentech International Ltd have been appointed distributors for the MOSFET-based range of telecom solid state switching devices manufactured by the Theta-J Corporation of America. The MOSFET-based design of Theta-J solid state switches and relays is ideal for switching and control of telecommunication circuits and is suitable for DC or AC loads up to several megahertz. The high input impedance and low input drive voltage dramatically reduce the minimum input power required for operation.

European Data Communications Market

The United Kingdom will remain the largest data communications equipment market in Europe, followed closely by France, but Federal Germany will be the fastest growing of the three. These are the findings of a two-volume report (8326) just published by Frost & Sullivan. The report predicts that the market will grow from $835 million in 1987 to more than $1.1 billion in 1990.

The UK's partly privatized and enthusiastic British Telecom is given much credit for keeping data communications charges low in Britain. The UK constitutes by far the largest computer market relative to its GNP in Europe and this creates a demand of 30% of the total European market for data communications equipment, amounting to $827 million in 1986.

France's Transac public packet-switched data network is "clearly the most widespread and popular" in Europe: the country represents nearly a quarter of the European market by value ($382 million in 1986).

The highly restrictive attitude of the Federal German Bundespost caused the German market to be smaller than a tenth of the European total ($72 million in 1986).

According to the report, modems are an endangered species, although they will still represent more than 40% of the European market by value in 1990 (down from 60% in 1986). In contrast, multiplexers are growing and will account for more than a quarter of 1990 sales. Network control systems will expand to nearly 20%, and protocols will approach 10% of the total market. Low-speed modems will shrink dramatically (by 50% a year), although RF models (for use in wideband LANs) will rise nearly as fast. Fibre optic multiplexers will be the fastest-growing of the muxes.

COBOL for X/OPEN

The X/OPEN Group has adopted Micro Focus Level II COBOL as the basis for its standard portable COBOL for UNIX. Micro Focus is a pioneer in the development of COBOL compilers and related programmer productivity tools for microcomputers.

The X/OPEN Group is an industrial consortium consisting of AT&T, Bull, DEC, ICL, Ericsson, Hewlett Packard, Nixdorf, Olivetti, Philips, Siemens, and UNISYS. Its objective is to establish a Common Application Environment (CAE) to the mutual advantage of end-users, software vendors, and computer suppliers. The CAE enables software to be moved easily from one computer system to another at a fraction of the cost.
The design of filters remains a topic of considerable interest to practitioners in many branches of electronics, in spite of the fact that many of such networks can nowadays be purchased at relatively low prices. None the less, there are still many occasions when a filter has to be designed from scratch. This series of articles will look at the theory underlying such design, and in the last part two practical designs will be discussed in detail.

As long as there has been electronic engineering there has been a need for filters: low-pass, high-pass, band-pass, and band-stop. Basically, a filter is an electrical network that will pass signals with frequencies within certain ranges and suppress signals with other frequencies. A network is essentially a number of impedances connected together to form a system the behaviour of which depends on the values of the resistances, capacitances, and inductances from which it is made up, and on the way in which they are interconnected. In the 1920s, Zobel developed the so-called image parameter theory, which formed the foundation for filter and network design until comparatively recent times. This theory met the needs of designers working on filters for multi-channel telephone links and VF teleprinter links quite adequately. Television, radar, data transmission, and other techniques developed during the 1940s and 1950s showed up the limitations of image-parameter theory. The higher precision and more exact characteristics required of filters from then on caused the image-parameter theory to give way to the modern network theory that uses synthesis techniques and digital computers. One of the latest products of modern filter technology is the surface acoustic wave filter, which has an exciting performance, and can already be obtained at relatively low prices. Murata, for instance, produce a 10.7 MHz SAW that retails for less than £5 (available from Cirkit), and Plessey make units for the IF stages in TV receivers.

Surface acoustic wave filters have a superb rectangular frequency response with constant group delay: it is possible to make these filters and shape the two features separately—this is unique to SAWs. Their only disadvantages are a high insertion loss (20–30 dB), which results from the necessity of suppressing certain transmission reflective modes, and the necessity of temperature stabilization of the unit for certain applications: there is usually a price for everything!

General network concepts

Networks can be shaped like a T, a π, or an L, as shown in fig. 1. There is also a ladder network and a lattice network. The boxes in the diagram (and all others in this article) represent an impedance. This impedance may be a pure resistance, a reactance, or a combination of the two. It is customary to show series impedances in half, i.e. \( Z/2 \), and parallel (or shunt) impedances double, i.e. \( 2Z \). It will be seen that this eases the calculations.

Most networks and filters are unbalanced and one side is usually grounded. A notable exception is found where high levels of electromagnetic hum or RF interference prevail. This situation can arise in sound studios, particularly when these are co-sited with their parent transmitters. In these circumstances, the sound line distribution system is usually balanced. The balanced arrangement is made to cancel out induced currents in each leg of the lines.
**Characteristic impedance Zo**

The characteristic impedance, $Z_0$, is defined as the value of the input impedance of an infinite number of cascaded identical networks—see Fig. 2. From this definition, it follows that a network with a terminating impedance of $Z_0$ behaves as if it were infinitely long. Such a network is said to be matched—see Fig. 3.

Since the network in Fig. 3 is infinitely long, no signals can return from the far end. This reasoning also applies to a network matched in its own $Z_0$. It should be noted that even if a network is not matched in its own $Z_0$, and contains lossy impedances, it can be shown mathematically that it still tends to behave as though it were infinitely long.

**Symmetrical or asymmetrical**

A network is symmetrical if its input and output terminals can be interchanged without causing any change in its electrical performance.

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**Maximum power transfer theorem**

For a generator to supply power to a load at maximum efficiency, certain conditions must prevail. In Fig. 6, $Z_0$ is the complex impedance of the generator and $Z_{load}$ is the complex load impedance.

The total loop impedance is $Z_{loop} = Z_0 + Z_{load}$.

The impedance at one pair of terminals of network $N$ produces a like impedance at the other pair of terminals. Similarly, an impedance $Z_{in}$ at the other pair of terminals produces a like impedance at the first pair of terminals. Impedances $Z_{in}$ and $Z_{out}$ are called iterative impedances. If the two iterative impedances are equal, their common value is the characteristic impedance of the network.

In Fig. 5, impedance $Z_{in}$ connected across one pair of terminals of network $N$ causes an impedance $Z_{out}$ at the second pair of terminals, and an impedance $Z_{out}$ connected across the second pair of terminals causes an impedance $Z_{in}$ at the first pair. These two impedances are called image impedances.

In symmetrical networks, the iterative and image impedances are equal.

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In symmetrical networks, the iterative and image impedances are equal.
Symmetrical \( n \) network. In Fig. 10,
\[
Z_{0n} = \frac{2Z_1Z_2-Z_1-Z_2}{Z_1Z_2-Z_0}
\]
from which, after cross-multiplication and making \( Z_0 = Z_{0n} \),
\[
Z_{0n} = Z_0 / \sqrt{(Z_1Z_2+Z_0^2/4)} \tag{9}
\]
When the output terminals of the \( n \) network are open- and short-circuited, the results are similar to those for the \( T \) network, i.e.
\[
Z_{0,0} = (L_{or}L_{sc}) \tag{10}
\]
By inspection, a further relationship between the \( T \) and \( n \) networks is
\[
Z_{0n} = Z_1Z_2 \tag{11}
\]
In Fig. 12a,
\[
Z_{0,1a} = Z_1/2 + Z_2Z_0/(2Z_2 + Z_0)
\]
so that,
\[
Z_{2a}Z_0 + 2Z_2Z_0 - (Z_1/2 + 2Z_2)Z_0 = Z_1Z_2 \tag{12}
\]
From Fig. 12b,
\[
Z_{0b} = 2Z_2(Z_1/2 + Z_0)/(2Z_2 + Z_0)
\]
so that
\[
Z_1Z_2 - 2Z_2Z_0 + (Z_1/2 + 2Z_2)Z_0 = Z_1Z_2 \tag{13}
\]
Expressions [12] and [13] can be added and subtracted from one another. Subtracting gives
\[
4Z_2Z_0 - (Z_1/2 + 2Z_2)Z_0 = 0
\]
from which
\[
Z_{0b}Z_0 = (Z_1/4 + Z_0)/Z_2 \tag{14}
\]
Adding gives
\[
Z_{0a}Z_0 = Z_1Z_2 \tag{15}
\]
Combining [14] and [15] and removing \( Z_{0a} \) gives
\[
(Z_1/4 + Z_0)/Z_2 = Z_1Z_2 / Z_0 \tag{16}
\]
In similar fashion, it can be shown that
\[
Z_{0a} = Z_0 / Z_1 \tag{17}
\]
The results obtained—shown in Fig. 13—make clear the value of the half section for matching purposes.

Propagation constant
In a finitely long cascade of similar networks, the parallel elements provide current paths back to the sending end. These return currents do not flow through the load terminating the cascade. Likewise, the series elements cause voltage drops along the cascade. The net result of these factors is that power is lost in the networks. Of course, if the cascade is infinitely long, all voltages and currents would have decayed to zero. This decay of, for instance, a voltage, \( U \), is expressed by the exponential function
\[
U = E \exp(-yl)
\]
where \( E \) is the starting voltage, \( y \) is the propagation constant, and \( l \) is the length down the cascade. Note that when \( l = 0 \), \( U = E \).
This function is true for the ratios of currents and voltages down the cascade, provided this is a regular array of series and parallel elements.
Therefore,
\[
\begin{align*}
11/12 &= 12/13 = 1/1 = \exp(yl) \tag{18}
\end{align*}
\]
The propagation constant \( \gamma = a + j \beta \), also called propagation coefficient or image transfer constant, is of special significance in network theory. It is a complex number, of which the real part, \( a \), is called the attenuation coefficient or image attenuation coefficient, and the imaginary part, \( \beta \), is called the phase shift coefficient or the image phase constant.
\[
|1/\exp(\beta)| \text{ gives the amplitude variation, whence}
\]
\[
a = \log_2(|1/\beta|) \text{ [neper]} \tag{17}
\]
Similarly,
\[
|1/\exp(\beta)| \text{ gives the phase between the currents, whence}
\]
\[
\beta = \log_2(|1/\beta|) \text{ [radians]} \tag{18}
\]
One neper (Np) equals 8.686 decibels (dB),
Summing the voltages around the loop A-B-C-D in Fig. 14 gives
\[ \frac{\exp(y)}{\exp(2y)}Z_1 + \frac{\exp(-y)}{\exp(2y)}Z_2 = 0 \]
which, when divided by \( \exp(2y) \) gives
\[ \frac{\exp(y)}{\exp(y)} = \frac{\exp(-y)}{\exp(y)} = 0 \]
Note that when \( y = 0 \), \( \cos y = 1 \); the hyperbolic cosine is symmetrical about the Y axis.

Part 2 of this article will appear in our September issue.

Complex numbers
For some readers, it may be useful to reconsider briefly the properties of complex numbers, sometimes called complex quantities.

A good way to understand complex numbers and algebraic operations with them is to consider that they represent a point in a plane. In the diagram, the complex number \( a + jb = 3 + 3j \) represents a point \( P \), which has the abscissa \( a = 3 \) and the ordinate \( b = 3 \). The distance of \( P \) from the coordinate centre is the hypothenuse of the right angle ONP, which is
\[ OP = \sqrt{(a + b)^2} = \sqrt{(3 + 3)^2} = 5.83 \]

The angle \( \theta \) that \( OP \) makes with the x-axis is given by
\[ \tan \theta = \frac{NP}{ON} = \frac{b}{a} = \frac{3}{3} = 0.6 \]

Instead of representing a complex quantity by its rectangular coordinates \( a \) and \( b \) in the form \( a + jb \), it can also be represented by its polar coordinates, i.e., the distance, \( r \), of \( P \) from the coordinate centre, 0, where
\[ r = \sqrt{a^2 + b^2} \]
and the phase angle \( \theta \) between the radius \( r \) and the x-axis, where
\[ \theta = \arctan \left( \frac{b}{a} \right) \]
which is read as "the angle whose tangent is \( b/a \)."

With reference to the diagram
\[ a = r \cos \theta \quad \text{and} \quad b = r \sin \theta \]
so that the complex quantity, \( P = a + jb \), can also be written as
\[ P = r (\cos \theta + j \sin \theta) \]

which is often abbreviated to \( r \) \( \cos \theta \) or \( r \) \( \cos \theta \), and sometimes written as \( r / \theta \), which is read as "\( r \) at the angle \( \theta \)."

Note that mathematicians use "\( i \)" to denote the concept of \( \sqrt{-1} \), while electrical engineers use the "\( j \)" to avoid confusion with the use of "\( i \)" to represent an electric current. The distance \( r \) in the diagram is called a vector by mathematicians but a phasor by electrical engineers.

Two complex numbers are equal only if their real and imaginary parts are equal. If, therefore,
\[ a +jb = c + jd \]
then \( a = c \) and \( b = d \).

Consequently,
\[ (a + jb) + (c + jd) = (a + c) + (b + d) \]

The same rule applies to the subtraction of two complex numbers.

The multiplication of complex numbers is carried out in the conventional manner, but it should be borne in mind that \( j = -1 \) and, therefore, all higher powers of \( j \) can be eliminated:
\[ j^1 = j, \quad j^2 = -1, \quad j^3 = -j, \quad j^4 = +1, \quad j^5 = j \quad \text{and so on.} \]
\[ (a + jb)(c + jd) = ac + jad + jbc + j^2bd = (ac - bd) + j(ad + bc) \]

The division of complex numbers is carried out by multiplying both numerator and denominator of a fraction by the conjugate of the denominator. For instance, in the fraction \( (a + jb) / (c + jd) \), multiply both parts by \( (c - jd) \). Thus,
\[ (a + jb)(c - jd) / (c + jd)(c - jd) = [(ac + bd) + j(bc - ad)] / (c^2 + d^2) = (ac + bd) / (c^2 + d^2) + j(bc - ad) / (c^2 + d^2) \]
WHERE STUDENTS MAKE THEIR OWN CHIPS

by Brian Lawrenson, Department of Physics and Electronic Engineering, University of Dundee

Electronics engineering graduates entering industry often meet difficulties in translating theory into practice. The advanced technology of making chips is probably one of the biggest hurdles they have to face. A Scottish university is tackling the problem by getting its students to turn out chips in the laboratory.

When the Irish dramatist George Bernard Shaw wrote his condemnation of the teaching profession, 'He who can, does. He who cannot, teaches', he came close to identifying one of the main difficulties in educating engineering students. It lies in ensuring that the teaching of theoretical principles is firmly identified with the real world of engineering design and manufacture.

Most degree courses in electronics engineering include lectures on the principles of semiconductor devices, explaining how such components as transistors and diodes operate. At the University of Dundee we have taken this study one stage further: undergraduates are regularly designing and making silicon chips as part of their normal project and laboratory work. Our involvement with this branch of engineering began several years ago because the University is close to makers of semiconductors in central Scotland, in an area known as 'Silicon Glen'. When we took part in the usual type of organised student visit to these companies it was clear that many of the undergraduates were very attracted to their high technology and ultra-clean working conditions, so we invited a number of semiconductor engineers to make regular visits to the University to contribute to some of the lecture courses.

From these early beginnings we have been able to set up a microelectronics laboratory which has all the facilities needed to design, manufacture and test silicon integrated circuits. The very high capital costs usually associated with this type of work have been largely avoided by obtaining professional equipment from industry, either by donation or by paying a modest amount. It has often meant that we have had to wait patiently for suitable items to become available and a lot of time has been spent on repairs and modifications. It has taken some 11 years for the laboratory to reach its present level of operation.

In spite of the fact that the term silicon chip has been much paraded by journalists and broadcasters, relatively few people know how the devices operate or how it is possible to make something which is so small and yet so complex. Most chips are made from silicon (Si), an abundant chemical element which has two fortuitous properties. First, it is easy to oxidise its surface in a furnace to produce a stable coating of silicon dioxide glass (silica), which is an excellent electrical insulator. Second, it is easy to change the value of its electrical conductivity by adding relatively small amounts of either phosphorus or boron.

The electric currents which flow in silicon are due to the movement of negatively-charged electrons (n-type Si) or, on the other hand, due to what appear to be positively-charged particles known as positive holes (p-type Si). The latter behaviour is somewhat surprising; it arises from the way in which electrons interact with atoms of silicon, especially in the presence of certain other types of atom such as boron. The simplest active component of an integrated circuit is the MOSFET (Metal Oxide Semiconductor Field Effect Transistor). Its structure is shown in the diagram, where phosphorus and boron have been used selectively to form regions of differing conductivity and silica of varying thickness has been used to provide electrical insulation where required. This transistor will switch on if an electric field is created below the gate electrode by applying a positive voltage to it. Electrons are attracted into the central region of the device and a current can then be made to flow through it from the source to the drain contacts: the MOSFET is then acting as a switch which has no moving parts and which is actuated by electrical means.

This switching property means that groups of transistors may be used to transmit and process information presented in the form of a binary code. A complete digital integrated circuit may have more than 100,000 MOSFETs formed just below the surface of the silicon and interconnected by a top layer of fine aluminium tracks. A most important characteristic of such a circuit is that it is fairly insensitive to differences in the per-

Fig. 1. Structure of the basic MOSFET (left). Application of a positive voltage V to its gate (right) switches the transistor into the 'on' stage.
formance of individual transistors; as long as each switches on and off, all is well.

In making a chip, the details of every feature in one layer of its structure are first recorded on a high definition photographic plate. For instance, all of the sources and drains in the entire circuit would appear in the photograph as transparent rectangles on a black background each measuring some five micrometres square. Because the whole chip will be only about five millimetres square or even smaller, there is room on the plate for the detail contained in at least 200 identical chips, arranged on the photograph like a sheet of stamps. This detail is then transferred to the surface of the silicon by a process called photolithography. It means coating the oxidised surface of a thin disc of silicon (called a silicon wafer) with a layer of a substance known as photoresist, which is sensitive to ultraviolet light. Using the photographic plate and UV light produces an image of the circuit features in the photoresist which, when treated with acid, reveals the source and drain regions as tiny rectangular holes in the silica and exposes the surface of the silicon.

Manufacturing processes that follow include the diffusion of boron or phosphorus through the holes in the silica into the surface of the wafer, in furnaces at temperatures of about 1100°C. Finally, the whole wafer is coated with a thin layer of aluminium in a vacuum chamber, and photolithography etches it into the pattern of metal tracks which connect the transistors. The details of each layer derive from its particular photomask.

Fig. 2. Photomicrograph of a chip 1.8 mm square made by a student.

Our microelectronics laboratory is equipped for all these processes, in a suite of cleanrooms with a filtered air supply to exclude dust. It has its own photographic unit with cameras for making the photomasks. One cleanroom is reserved for photolithography and another for the 10 electrically heated furnace tubes with their associated gas supplies. The largest area has probing equipment for making electrical test measurements on the finished wafers. There is also equipment for sawing the wafers into separate chips and for mounting them in their familiar plastic boxes with metal legs.

Project Time
A student at Dundee who opts for this work will spend some 300 hours of project time designing and making a chip to his or her own specifications. The circuit has to be fairly simple, of course, with fewer than 150 transistors. We find that MOSFETs with p-type channels are simplest to make and we are usually content to turn out devices with a separation of 10 μm between source and drain. The layout details for each chip are designed with the aid of a mainframe computer and are stored on magnetic tapes. Initial artwork is produced from the tapes using equipment for reproducing weather satellite photographs (we have not been fortunate enough to obtain the appropriate pattern generator for this stage). The main fabrication processes are then undertaken. To make working conditions as realistic as possible, everyone wears a full set of cleanroom clothing resembling a surgical hood and gown. Students are also asked to assess the cost of bringing each design to fruition.

This activity provides a wealth of practical experience and puts the importance of the lecture courses into perspective. Students are encouraged to consult key research papers as well as standard textbooks, to help them identify causes of unexpected results or failures that arise from time to time in the work. The aspiring integrated circuit engineer soon begins to appreciate the importance of mastering the required blend of electronics engineering, solid state physics, chemistry, crystallography and metallurgy, backed-up by computer-aided design techniques.

Almost 40 Honours students have now been introduced to integrated circuit engineering through the work of the microelectronics laboratory. Postgraduate research and industrial contract work are supported, too. Dundee graduates in this field are now working for major manufacturing companies in the UK and overseas, including GEC Plessey, Ferranti, Hughes Microelectronics, National Semiconductors, Motorola, British Telecom, INMOS, Mullard and Siemens. The chips our former students have been working on include the Transputer and many other devices. Through this we gain useful feedback about the content of lecture courses and the areas that are interesting for research.

Employers have been enthusiastic about this practical approach to microelectronics. When our graduates go to their first job interviews carrying silicon chips that they have made themselves, their starting salaries have been good.

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Extensive range of phone sockets
As part of its rapidly expanding service supplying high-quality Japanese components to the UK, Watts International announces an extensive range of phone sockets. The Emden manufactured range features a remarkable number of socket types, including single, double, and multiple connectors. The multiple units are available as complete items, or they can be ganged from a variety of single or double interlocking connectors. Complete multiple assemblies are available with three, four, five, six, and ten connectors. The outer earth cap may be standard or chamfered.

Watts International Components Limited
Suite 6
Wyvern House
46-48 High Street
BOGNOR REGIS PO21 1SF
Telephone: (0243) 863322
(3650-28F)
Believe it or not, but a few days after our May issue was sent to the printers, the engineers at ATN Filmnet altered the station's scrambling system. The next thing that happened was Sky Channel abandoning encoding altogether for roughly a fortnight.

An article written for naught and circuits doomed to end up in the junkbox? Here is the update!

The speed at which dramatic changes take place in the satellite TV world is very hard to keep up with. After the publication of 1, we saw Europa TV disappear and their 3WH transponder temporarily assigned to 3 Sat. Music Box change into Super Channel, and ATN Filmnet adopt the Matsushita scrambling system, all on ECS-1. The launch of the DBS services for Federal Germany and France was postponed for the umpteenth time, the flat dish was developed to eventually replace the LNB, the Matsushita scrambling system has now evolved into several scrambling modes.

Information on the new scrambling method, proposed in 2, was briefly noted here in our May issue, as follows: it is being used to shield receivers already equipped with the old scrambling system. But there was no indication that mode 2 would be operative this year, as already stated, mode 2 is an extension of mode 1, so that the design idea brought forward in 3 remains the basis for any further designs.

New circuits for new modes: 2 all

The circuit diagram in Fig. 2 shows how the functional blocks of Fig. 3 in 2 have been worked out into a practical decoder. The 7.6 MHz FM receiver for obtaining the composite blanking signal is purposely shown as a separate unit here to make clear that it is always required for decoding ATN Filmnet, whatever scrambling mode is, or will be, adopted (it may well be that mode 3 or even 4 is operative when this article is being published...). The PLL and pulse timing sections are largely identical to those used in the Sky Channel decoder 2, so that a detailed description of these is not required here.

As already stated, mode 2 is an extended version of mode 1. In addition to shifting the DC component of the blanking, and inversion of the entire signal, the polarity of the video signal is now toggled for each raster in the interface picture. This is very simple to put right by dividing the 50 Hz blanking component by two in bistable FFs, and alternately selecting the DC-corrected VIDEO or VIDEO signal from the NES92 differential amplifier on the vision/sound/PSU board in the Elektor Electronics Indoor Unit for Satellite TV Reception 2. Provision has been made to ensure that a viewable signal is always available at the AC coupled input.

Lights when the signal from ATN is encoded. When it is not encoded, which is sometimes done on purpose between films and during announcements of forthcoming programmes, the carrier at 7.6 MHz is simply left unmodulated.

Since it was intended to keep the decoder as simple as possible, no provision has been made for automatically selecting the correct frame polarity of the video signal. This means that the sync button may have to be pressed a few times to obtain a properly decoded picture. The decoder remains synchronized when ATN switches between encoded and non-encoded transmissions, but loses synchronization if the signal strength at the receiver input is too low, since spikes then upset the operation of the filters and the PLL Type 4046.

In practice

It must be pointed out here that the decoder experiments discussed require a certain amount of feeling for dealing with RF and video signals. Also, the material presented here is essentially but a design idea, and the construction and align-
Fig. 2. Suggested design of an experimental mode 2 decoder for ATN Filmnet, the Dutch pay-TV channel on ECS-1.

D-A converter for I/O bus
In Fig. 3, the order of the databits Do-D8 should be reversed both at the bus connector and the inputs of IC1.

Universal control for stepper motors
January 1987, p. 46.
Table 5a should be amended as follows:
M21 = 5Ah. In Table 5b, the databyte at M3E should read 00h.

CORRECTIONS

Literature references:
New voltage selectors

Bulgin have recently added two new voltage selectors to their range of electrical and electronic components.

A.F. Bulgin & Company PLC
Bypass Road
BARKING IG11 0AZ
Telephone: 01-594 5588

Macroscope magnifier

Ideal for inspecting components or magnifying for assembly, the 03-0600 Microscope illuminated magnifier from OK Industries provides four times magnification without a microscope but its 1.5in (38 mm) field of vision is considerably more than a microscope’s.

The 4½in (11 mm) diameter lens, made from special index glass, is housed in a frame with a 22 W fluorescent lamp and mounted on adjustable steel arms to provide 36in (914 mm) reach. A clamp base is provided for secure bench fitting and finish is textured black. The unit conforms to MIL Spec WS633BE section 3.2.7.

OK Industries UK Limited
Barton Farm Industrial Estate
Chickenhall Lane
EASTLEIGH SO5 5RR
Telephone: (0703) 619841

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Electrolube Limited
Blakes Road
WARGRAVE RG10 8AW
Telephone: (073 522) 3014

New telephone connection boxes from Rendar

Rendar’s range of telephone network connector boxes caters for most internal interconnection requirements. The range of five boxes includes units which protect sensitive terminal equipment against RFI and transients. Both A and B lines are protected, with advanced design filtering.

Further types provide six separate wire links from IDC (Insulation Displacement Connectors) to IDC, or from IDC to screw terminals. Another box allows IDC connection to standard and non-standard cable diameters, and also to spade terminals.

Rendar Limited
Durban Road
South Bersted
BOGNOR REGIS PO22 9RL
Telephone: (0243) 825811
Digital timer

A new and improved version of their popular Type ECT-1 timer is now available from Cobonic at £17.50 (excl. VAT). Apart from clock and timer, the new version has a genuine stopwatch function and second intervals. The timer is eminently suitable for commercial, domestic, educational, medical, or industrial use. It is fitted with a spring-loaded clip for carrying on the person, and a magnetic attachment. The clip can also be used for standing the timer upright on a table or desk. It weighs only 40 g and measures 60 x 60 x 14 mm.

The clock, which can be used independent of the timer, can be used in the 12- or 24-hour mode as required. The timing span is from 1 second to 23 hours 59 mins 59 secs. The LC display is 8 mm high and shows hours, minutes, and seconds. A 60-second alarm signal is sounded when the timer has completed its set cycle.

Cobonic Limited
32 Ludlow Road
GUILDFORD GU2 5NW
Telephone: (0483) 505260

Monitor tester has wide range of signal outputs

Now available in the UK exclusively from Electronic Brokers is the Grundig MT700 tv monitor tester. The MT700 has a range of signal outputs including composite colour, RGB, and RGB-TTL, making it suitable for testing a wide variety of monochrome and colour tv monitors. The tester provides the common standards of 625/750/1023 lines with 50 Hz, 525/625/753/1023 lines with 60 Hz, and three additional line patterns between 5212 and 1535 lines with a maximum line frequency of 36 kHz (50 Hz).

The instrument has a power consumption of 25 VA, 45-65 Hz. Easily portable, the MT700 monitor tester measures 300 x 112 x 227 mm and weighs 4.5 kg.

Electronic Brokers Limited
140-146 Camden Street
LONDON NW1 9PB
Telephone: 01-267 7070

Automatic FM/AM modulation meter

Electronic Brokers has introduced the Marconi Instruments TF2304 FM/AM modulation meter which combines battery-portable operation with high accuracy, automatic tuning and automatic level setting. Designed primarily for the servicing and production testing of mobile radio communications systems, the TF2304 covers carrier frequencies from 9-12 MHz and from 18-1000 MHz.

FM deviation is measured in eight ranges from 1.5-50 kHz full scale and A.M. depth is measured in two ranges of 30% and 100% full scale, with a further uncalibrated range of 10%. Accuracy for both f.m. and a.m. measurements is ±3% of full scale.

Electronic Brokers Limited
140-146 Camden Street
LONDON NW1 9PB
Telephone: 01-267 7070

Thermal-array recorder

Gould has developed a new thermal-array recorder which incorporates advanced digital writing technology to provide high recording performance and flexible formatting of results — while maintaining compatibility with Gould's standard 4600 and 5600 families of signal-conditioning modules. Features of the new TA2000 recorder include high frequency response, fast peak capture, complete alphanumeric annotation, RS-232C computer interface capability, full-scale overlapping traces, high-resolution trace quality, multiple grid patterns, and a low-cost thermal-writing medium.

The TA2000 can record up to eight channels of analogue information with an amplitude resolution of eight dots per millimetre (200 dots per inch) and a maximum chart speed of 200 mm/s.

Gould Electronics Ltd
Roebuck Road
HAINAULT IG6 3UE
Telephone: 01-500 1000(3630-6F)
Pocket-sized gas-powered soldering iron

A powerful soldering iron that can be carried in a top pocket, Portasol is completely portable and is available from Freetrade (TEP) Ltd. No larger than a felt-tip pen and offering a range of outputs from 10 to 60 W, the Portasol is refilled from cigarette lighter butane gas containers. It is suitable for all types of precision with a choice of tip diameters — 1.0 mm, 2.4 mm, 3.2 mm, or 4.8 mm. Maximum tip temperature is 400°C. Safe and reliable, it runs for approximately one hour on a single refill. The clip-on cover has a built-in igniter and, when in position, allows the Portasol to be carried like a pen in a top pocket.

The T-1200SR scanning receiver

Fieldtech Heathrow's new T-1200SR Scanning Receiver, the T-1200, is a microprocessor controlled, digitally synthesized scanning receiver which features direct and remote electronic signal analysis. The T-1200SR scanning receiver integrates signal analysis function of several instruments into a signal compact and portable unit which is capable of monitoring communication signals within the 100 kHz to 999.9999 MHz frequency range in 100 Hz steps.

Fieldtech Heathrow Limited
Huntavia House
420 Bath Road
LONGFORD UB7 0LL
Telephone: 01-897 6446

Continuity and short-circuit tester

Cablecheck Systems have introduced a new continuity and short-circuit tester. The PA4000 is IBM-PC compatible and it can test PCBs, backplanes and cable harnesses. It also doubles as a manufacturing aid. The PA4000 is an easy-to-operate, multi-user system. A VDU guides operators through all assembly operations. Products are automatically tested after each stage. Faults are displayed and can be rectified before proceeding. The assembly is fully re-tested at the end of each sequence.

Cable Check Systems
Sanderson Centre
Less Lane
GOSPORT PO12 3UL
Telephone: (0705) 528396

Datapulse announces new switchboard traffic analysis system

Datapulse has announced TAB, a new system which provides a series of engineering reports on switchboard and exchange line usage. The reports are designed such that they can be readily understood by non-technical personnel who may be responsible for a company's communications.

TAB is currently available for the IDX family of switchboards and examines data from the V24 call logging port. The unit can operate in two modes either as a line analyser or as a systems analyser. In the former, TAB converts binary records from the IDX port, turns them into an easily recognisable format and, through the optional use of numerous selection parameters and flags, concentrates only on data which is relevant to the user's current requirements.

Datapulse Ltd
Aubrey Watson House,
Quebec Road
HENLEY-ON-THAMES
RG9 1HA
Telephone: Henley (0491) 519955

A powerful gas-operated heater gives a stable output that superior to battery-operated portable types. This frees the user from having to work near a mains power point or bother with extension cables.

Freetrade (TEP) Ltd
Moor Lane
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BIRMINGHAM B6 7HH
Telephone: (021) 356 2592
Digital multimeter has built-in data collection facilities

Electronic Brokers has introduced the Philips PM2535 digital multimeter designed for applications involving data collection, reduction, and processing. The PM2535 utilises Philips' own advanced VLSI technology to provide a resolution of 100 nV on a 300 mV measurement; a short term stability of 0.002%; and a long term accuracy of 0.005%. To ensure total measurement integrity at such high resolution, the instrument features a true, fully guarded input which eliminates parasitic lead voltages and noise.

Microprocessor-controlled AM/FM signal generators have wide frequency range

Electronic Brokers has introduced the Marconi Instruments 2018A and 2019A AM/FM synthesized signal generators, two new microprocessor-controlled instruments covering the frequency ranges 80 kHz to 520 MHz and 80 kHz to 1040 MHz respectively. Microprocessor control provides simple and rapid operation by direct keyboard entry of settings and the non-volatile memory, which can store up to 100 settings, further reduces measurement time.

Pascall's own range of military/industrial PSU's

The POWERMITE series is the first major new range to emerge from Pascall's analogue p.s.u. facility. The units are British designed and manufactured at the company's recently extended factory at Ryde, Isle of Wight. 30 and 50 Watt units are available in single, dual and triple output versions. They are all MIL-spec products and are shielded to MIL-STD-461B for EMC/RFI. They are also environmentally tested to military specifications. Units in the range have a switching frequency of 200 kHz and offer a maximum efficiency of 85%. They operate from inputs in the range +18 to +32VDC and produce a variety of different outputs from 0.5 to 10 A, depending on version. Single output versions provide a +5, +24 or +28 V output; dual output units have ±12 V or ±15 V and triple output units offer ±5 and ±12 V or ±15 V outputs.

New switches from ITT Cannon

Aimed directly at the telecoms market, and other applications on PCBs where space is at a premium, are ITT Cannon's new RTE/02 and RTE/03 switch styles. The switches are auto inserter, flow solderable, and immersion cleanable, making them particularly suited to the latest high volume assembly lines.

ITT Cannon

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Viables Estate
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January's Elektor gave an excellent summary on capacitors. AUDIOKITS supplies E4.50 - E22 each.

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For full details of AUDIOKITS components and services, including some of the very best complete amplifier kits available, please send a 9" x 4" SAE to AUDIOKITS Precision Components, 6 Mill Close, Borrowash, Derby DE7 3GU, England. Tel. 0332 674929.

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EVEN MORE SUMMER SAVERS!!

If you are already a Maplin customer, soon you will be receiving (if you haven't already) a bumper bundle of smashing Summertime specials. plus the chance to win a beautiful, sleek Ford XR3i (if you register in the prize draw before 1st July 1987).

If you are not a Maplin customer, but would love to know more about the special offers and have a chance to win the car, fill in the coupon below with your personal details, tick the appropriate box, and post it now.

The Apache

A superb ready-built scale-model off-road racer complete with a 2-CHANNEL DIGITAL PROPORTIONAL RADIO CONTROL SYSTEM – for the price of the RC system alone!

All this is included in the price:
- Ready-built 1:10 scale model car (overall size 325 x 186 x 130mm, 12.8 x 7.3 x 5.1in.),
- Front and rear low-profile semi-pneumatic rubber tyres,
- Front wheel independent suspension,
- High or low gear selection,
- Sealed box with differential gearing,
- Powerful motor gives scale speeds up to 140 mph,
- Front and rear coil-spring/shock absorbers,
- 2-channel digital proportional radio control transmitter (and receiver) (Standard 27MHz AM – no licence required in UK),
- Servo-controlled proportional steering,
- Proportional motor speed control in forward and reverse.

I'LL BE RACING THIS SUMMER WITH MY SUPERB APACHE CAR!

Please rush me my Apache model racer, with 2 channel digital proportional radio control system. I wish to receive:

<table>
<thead>
<tr>
<th>Code</th>
<th>Qty</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>SX08J</td>
<td>1</td>
<td>£49.95</td>
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All prices include VAT. Please add 50p towards postage.

I have never been a Maplin customer, but I would be pleased to receive details of the super Summertime special offers.

If you have already received the Summertime special offers, please use the Order Coupon supplied with that.

I wish to receive:

<table>
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<tr>
<th>Code</th>
<th>Qty</th>
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<tr>
<td>SX08J</td>
<td>1</td>
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</table>

Total

I authorise you to debit my Credit Card account for the cost of goods despatched.

Credit Card Number

Access American Express / Maestro Visa

Credit Card Details

Send to:
Maplin Electronic Supplies Ltd.
P.O. Box 3, Rayleigh, Essex, SS6 8LR. Telephone: Credit Card Sales (0702) 554161 Enquiries (0702) 552911

Debit as required

Note: Goods will be despatched only if the address given is the cardholder's address.

If ordering by Credit Card please sign:

Signature

Send to:
Maplin Electronic Supplies Ltd.
P.O. Box 3, Rayleigh, Essex, SS6 8LR. Telephone: Credit Card Sales (0702) 554161 Enquiries (0702) 552911

Shots at Lyndon Square, Perry Barr, Birmingham, Tel. 021-358 2922 159-161 King Street, Hammersmith, London W6 Tel. 01-748 0026 9 Oxford Rd, Manchester Tel. 061-236 0711
46-48 Bears Valley Rd, Southampton Tel. 0703 75431 282-284 London Rd, Woodcote-on-Thames, Oxford Tel. 0702 554000.