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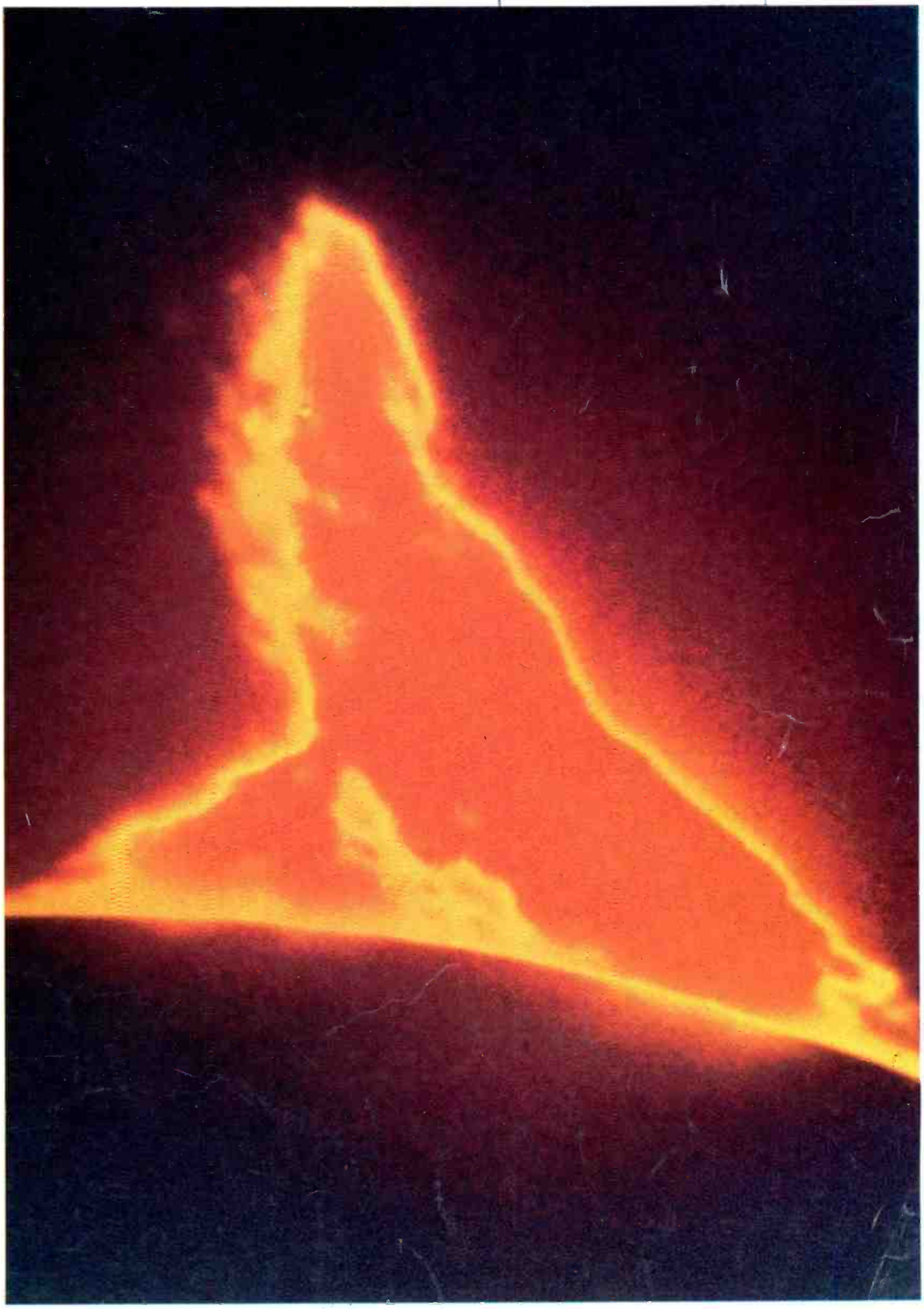

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CONTENTS

NOVEMBER 1986 VOLUME 92 NUMBER 1609

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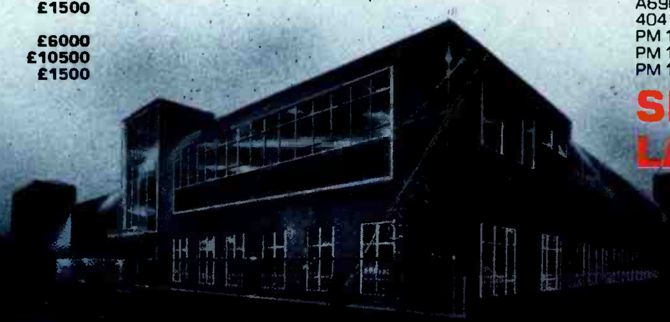

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COMMENT

LATE EXTRAS

It is quite possible that the subject of AEW (Airborne Early Warning) is now so emotive that rational discussion is difficult. Sums of money of the order of nearly a billion pounds are unimaginable to most of us and simply register as rather a lot of cash to pay for something which we have not yet got and which might not be what we need anyway. Whether Weinstock's Wonder or the Grumman Gizmo or any of the other bits of expensive ironmongery is chosen for the RAF, it has all gone on so long that the original requirement itself is now suspect.

What the RAF wanted, all those years ago, was something to give warning of the approach of hostile aircraft – large ones – so that they could go and intercept them. This requirement can be met, even by the AEW Nimrod, albeit with some reported difficulty, but military hardware has advanced in ingenuity in the last twelve years and bombers do not drop things any more. What they do (or are intended to do should the occasion arise) is to lurk about at a sensible distance and launch quite small cruise missiles.

Both u.h.f. and S-band radars are proposed for the RAF system, either of which in its own way would be adequate for the task of detecting large aircraft more or less precisely, depending on the radar beamwidth. But neither of them would find a cruise missile, which is relatively minute with vestigial wings, amongst a lot of land and sea clutter.

Of course, the real question is – why try? What is a defending force going to do about a swarm of tiny objects, each of which could devastate a city, if not several? Launch its own swarm? The very same question could have been posed twelve years ago and received very much the same answer, which is to the effect that the development has been a grotesque mishandling of public resources, but that politics has made it necessary.

Almost any development carried out at the behest of the military exhibits all the identifying characteristics of a lead balloon, so far as its capability of successful flotation is concerned, at least in the UK. There are one or two notable exceptions, but experience indicates that the military specifiers state what they would like to have if the world were built out of sugar icing and marzipan, their wishful thinking becomes enshrined in a Specification, the manufacturer takes it on without pointing out to the military that pie in the sky is often tricky to design and can come expensive, and he is not tough enough to discourage the military from thinking up simple-sounding but enormously expensive modifications every other Thursday.

The result is inevitable: the development has gone on so long that it has already been out of date for about eight years. Not much modern equipment is built from twelve-year-old designs, using even older components. It would have been more sensible to give the £900 million to the Soviets as Danegeld.

Or, perhaps, we could have used the money for something a little more rewarding, like education, the health service or the rebuilding of industry.

NEW-STYLE EWW

As we promised last month, here is the new *Electronics and Wireless World*. The editorial is now slanted rather more than in the past towards the working engineer who forms the majority (over 80%) of our readership. Many of the suggestions that came out of our recent survey have been incorporated, and we are confident that you will like the result.

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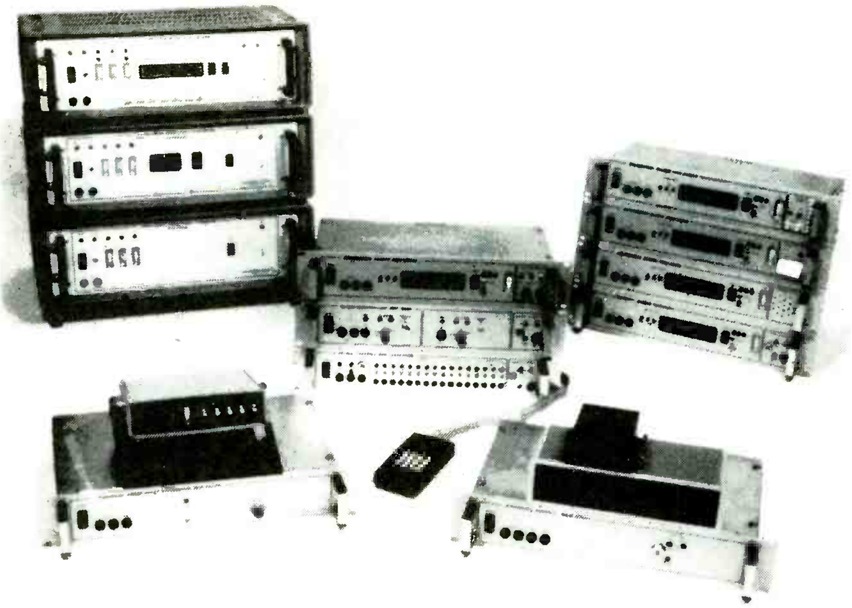

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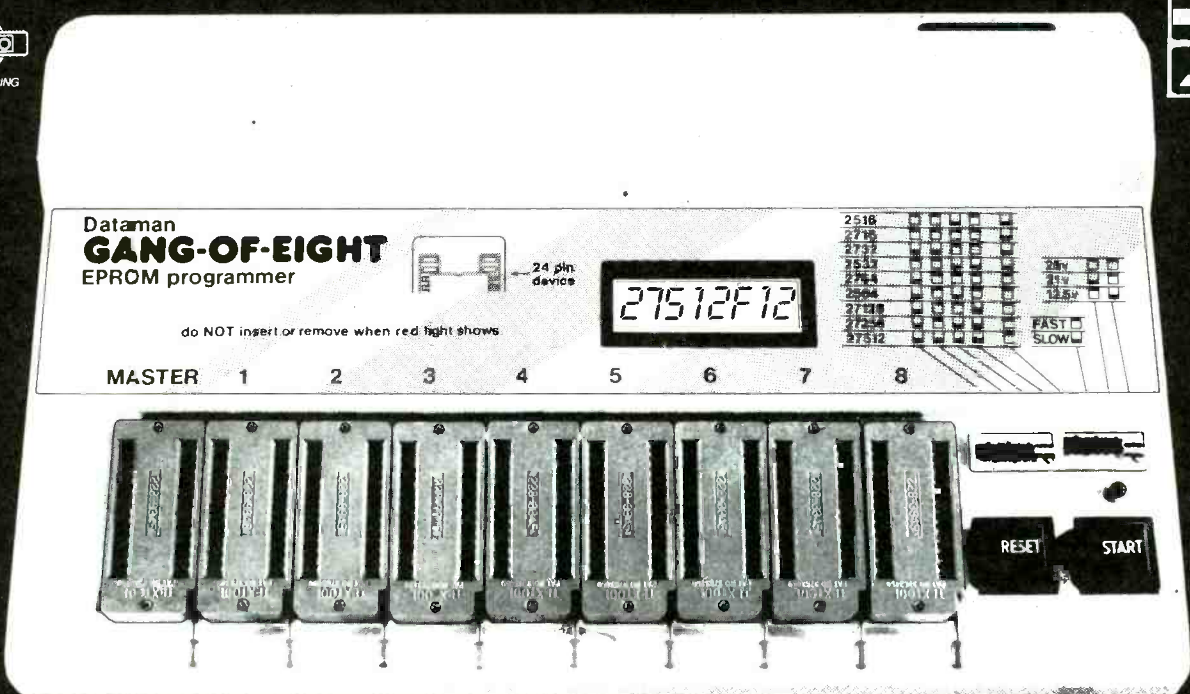

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CIRCLE 39 FOR FURTHER DETAILS

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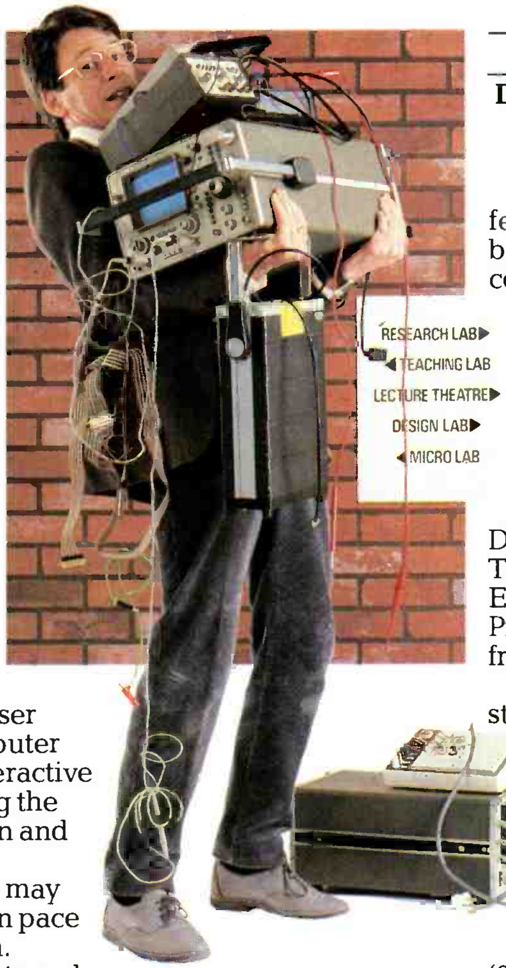

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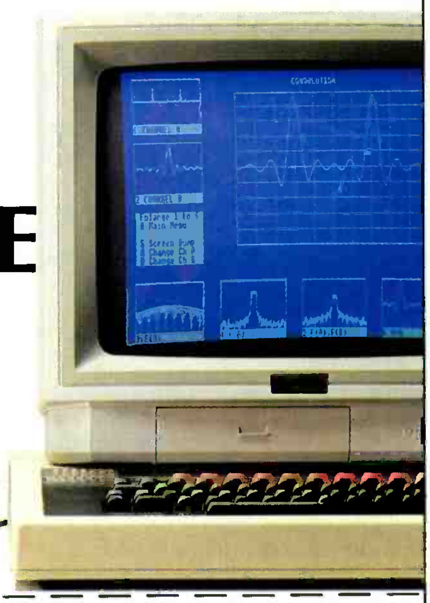

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CIRCLE 43 FOR FURTHER DETAILS

Mobile radio's many options

Changing economics and increased awareness have made mobile radio one of the largest growth areas in communications

MARK NELSON

Messages up to 90 characters long can be received on this display pager, which has a memory capacity of 512 characters. A built-in clock time-stamps each item.

It is wise to recall that mobile radio activity, just as broadcast radio and television, is carefully regulated to avoid chaos on the airwaves, and all use of radio must be licensed. While the regulations, which are administered by the Department of Trade and Industry (DTI), are more liberal than those in some other countries, the amount of radio spectrum available for private radio is limited. As a result, new users will find they must justify their proposals, and applications which could be satisfied with the use of landlines or the normal telephone network are unlikely to succeed. In many districts acute frequency shortages already exist and new users may well be asked to share with existing ones. It was this shortage of airspace which led the government to turn over the v.h.f. channels formerly used for black-and-white tv broadcasting to mobile and other radio purposes.

EQUIPMENT CONSIDERATIONS

As well as a licence most radio equipment also requires type approval. This is granted by the DTI and indicates that the sets meet certain technical and reliability standards and will not cause interference to other users of the airwaves. Private radio users are not trained radio operators and need to use equipment which requires neither regular adjustment nor special technical skills to use it.

Type approval is normally undertaken by the manufacturer or importer and is not a hurdle encountered by the end user. Most mobile radio equipment is supplied by specialist dealers (listed in Yellow Pages) and these will normally assist with licence application as well.

There are several British manufacturers of mobile radio equipment, such as Philips (Pye), Marconi and Burndept/Dymar, while other equipment is imported from the USA, New Zealand, Scandinavia and Japan and sold either under the original manufacturer's name or with a more familiar British label.

While channels may be shared, the actual equipment resources are normally owned (or leased) exclusively by the user. An exception is the aerial site, which must be prominent for good radio coverage. Users may well rent space on a shared radio tower; this solves potential planning permission problems as well.

Another principle is that connection into the public telephone network from mobile radios is not normally permitted (except of course from sets which are radiophones); on the other hand many private radio users can dial into internal private telephone systems.

Few business radio systems can guarantee security of speech and users requiring total confidentiality will have to fit additional scrambler devices. The new cellular and trunked services are difficult to eavesdrop effectively, however, because of the dynamic reallocation of channels as mobiles move around.

Private mobile radio (p.m.r.) or two-way radio is the most common type of business radio and gives a private channel of communication between mobiles and a base station. Systems range in size from a taxi radio net covering a small town to national schemes employed by large undertakings. Both private companies and the nationalised industries use p.m.r. Fire, police and ambulance authorities have similar systems; these are technically not classed as p.m.r. although the techniques are identical.

Transport firms and service engineers all make extensive use of p.m.r. and the demand grows as more firms realize the economies which can be made by better use of their fleets and personnel. Most equipment suppliers will demonstrate costed examples of the savings achievable by the use of p.m.r.

Most p.m.r. operation has been on v.h.f. up to now, but the use of u.h.f. is increasing. The public utilities are located in mid-band v.h.f. but are starting to move to new allocations in high-band; the bulk of private business radio is in v.h.f. high-band, with some on low-band.

Increasing demands on the radio spectrum are forcing new users into u.h.f. (below the tv broadcasting channels), which in turn is displacing the fixed point-to-point links previously accommodated here.

A variety of modern sets is available from the manufacturers; many incorporate modular components and design techniques, simplifying maintenance and the change of band if necessary. Hand portable sets (HTs or handy-talkies) are obtainable, as well as mobiles, for those applications which require them.

While frequency synthesizers have replaced individual crystals for each frequency, channel selection is manually switched to conform with DTI regulations.

A wide selection of mobile and fixed aerials is also supplied.

This synthesized ratiotelephone from Zycomm has a microprocessor-based selective calling system. Among the first users is the Northern Ireland Electricity Service.

RADIOPHONE AND MESSAGE-HANDLING

Another form of mobile radio, not necessarily an alternative to p.m.r., is public radiophone. This is not a British Telecom monopoly, although the British Telecom v.h.f. system is the only direct-dial system with virtually national coverage. But there are several other networks with connections handled by operators, for example Securicor and AirCall. Most of these systems allow phone calls to be made and received on the move, just as from a normal phone.

Other systems – without 'interconnect' – operate on a message-handling basis and direct conversation with the telephone subscriber is not possible.

In metropolitan areas demand for v.h.f. radiophone service was until recently high and the lack of additional channels for expansion led to long waits for joining the service and to make a call; it also increased the pressure for the introduction of the new cellular systems and plans for additional private v.h.f. systems. The availability of cellular radio (mentioned next) put an end to these problems and the capacity of v.h.f. systems now more closely matches demand.

Despite the availability of the cellular alternative there is still a distinct market for the v.h.f. services, which is being stimulated by aggressive pricing of the subscriber equipment.

THE CELLULAR SOLUTION

Cellular radio is a specialized form of radiophone operating on much higher frequencies (900MHz), above the v.h.f. television broadcasting band. The shorter coverage of transmissions at these frequencies is exploited by making the areas covered (cells) much smaller and re-using the same frequencies at other locations. This gives the system greater capacity and another by-product is much improved speech quality.

Sophisticated computer control techniques are employed to ensure that the call is not lost when the user moves from one transmitter area into another, and if a set (cellphone) is temporarily not in use a caller can be informed of this and diverted if necessary to an answering service or conventional wireline telephone.

The cellular system also caters for data transmission, allowing the use of portable computers and telex and fax machines out in the field, although preferably when the vehicle is static. Cellphones are now starting to be introduced for use as payphones on trains and long-distance coach lines, and within the cellular service areas they provide better results than their high-band v.h.f. predecessors.

Another specialized application is cellphones with outward dialling restricted to one or more predetermined numbers: the fixed telephones are linked by direct line to the cellular exchange and the total system is a form of national p.m.r. without the cost of setting up a national network.

CELL COVERAGE

There are two competing cellular networks, both connected to the public telephone network. One is operated by Securicor in partnership with British Telecom: this is known as Cellnet. The other system, run by Racal, is known as Vodafone.

Despite minor technical differences, both networks offer comparable facilities at similar prices and have broadly the same coverage areas. Transmitters cover virtually all towns and cities of significance, together with the motorways linking them and much of the countryside in between. Coverage has also been extended to coastal regions and cellphones work for considerable distances out to sea; for instance, across the English

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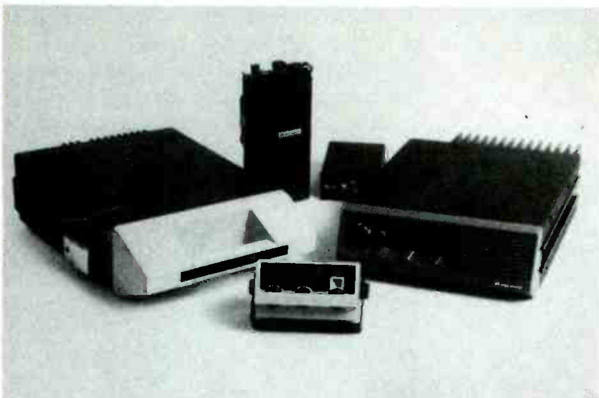

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Channel at its narrowest point.

Both networks are well ahead of schedule of their quoted expansion plans and user take-up has far exceeded expectations. Eventual coverage is planned to include 90% of the population and 64% of the UK landmass, but there will not be the same degree of national coverage as on the v.h.f. systems.

Cellular offers for the first time pocket and briefcase size hand-portable radiophones and the facility to receive dialled calls from overseas. Other innovations are continuity of conversation when transferring from one transmitter area to another (known as hand-off) and speech quality which, at its best, is far better than on previous public radiophone systems.

PAGERS AND PINPOINT

Apart from p.m.r radiophone and cellphones, there are radio systems intended for other specific uses which may offer an alternative. These are radiopagers and personal or citizens' band radio.

Radiopagers or bleepers can be short or long range: local on-site systems are normally privately-owned for staff location purposes and cover just one building or area. Wide-area networks, on the other hand, can cover a complete city or the whole country and are operated by organisations such as AirCall and British Telecom. In some cases users can be alerted by dialling a special telephone number and the actual call may be a bleep or a spoken message. There are also Pocket Telex or Message Master pagers which display a complete message which can be sent by an operator or by any person with access to a data terminal connected to the telephone. The largest national network is operated by British Telecom and is linked to the public telephone network, so that a user may be paged with a free call from any phone.

This system is for tone or display messages only: it cannot handle spoken messages. On the other hand the pager units (bleepers) can give up to four distinctive tones which can be assigned to different messages (ring home, call the office, etc.). Group call – for instance to alert a complete sales team – is also possible.

In all cases people who have been paged can make a phone call to receive a message, and this may be an acceptable substitute for mobile radio.

An innovative use of radiolocation is Pinpoint, a tracking system for vehicles provided by British Telecom initially in the London area. Vehicles equipped with the system signal to the base station their location, which is determined by a combination of dead reckoning techniques and checking by low-power radio beacons. The cost of the system has restricted its use so far to vans carrying high-value loads.

THE CITIZENS' ALTERNATIVE

A relatively unsophisticated but low-cost alternative to p.m.r. is 934MHz personal radio or u.h.f. citizens' band.

Far removed from the 'breaker, breaker' image which taints the 27MHz c.b. system, this band is relatively under-used and is ideal

The Tele-Niros v.h.f. hand-portable is supplied with up to four channels and with open or selective calling (Tele-Nova Ltd).

for short-range, non-essential communication (up to 5 or 10 miles). Professional quality radio equipment made in Japan is now available at around a third of the cost of p.m.r. and speech quality is as good as cellular radio.

As the band's 20 channels are used mainly for leisure purposes they are largely empty during business hours, and in rural areas this is already being exploited by veterinary surgeons and taxi firms.

A more sophisticated variant, currently under examination by the DTI, is a system known as PRS (personal radio service) or SRR (short range radio). Based on Japanese experience and already in operation there and in Switzerland, it uses similar 900MHz frequencies but with the addition of selective calling and dynamic channel and allocation.

To use the system the calling station keys in the number of the set required and presses the push-to-talk key. The digital code of the desired set is sent on a shared data channel, which is monitored by all idle sets. If the called station is switched on it replies automatically, causing the sets to scan the channels available to find an unused one for the conversation. All this is achieved in an instant.

The combination of these features and the f.m. system give privacy and an absence of interference.

Sets for this type of system cost around £400 in Switzerland and offer a potentially attractive system for small business and leisure users alike. As no repeater transmitter its used the range is limited, however, to around three to five miles and the system is no substitute for wide-area mobile radio.

CORDLESS PIRATES

Cordless telephones – sometimes confused with cellular radio – do not come into our consideration since these are purely short-range (about 300 feet) extensions of fixed telephones. Although high-powered and mobile versions exist these are not licensable in the UK and their use is likely to end in grief, as well as causing interference to legitimate users of the frequencies pirated. For this reason the government is introducing strong penalties to curb their sale and use.

CHANNELS CRISIS

Whilst all the sectors of mobile radio are growing, it is p.m.r. which shows the greatest expansion as users find it more affordable and essential. A problem is the shortage of frequencies: recently it was asserted that in the spectrum between 30MHz and 1GHz the allocation to p.m.r. was only 8% and that of this only 20% was usable.

Partly to counter criticism that too much spectrum is allocated to defence uses, a three-man team of eminent authorities has been appointed by the government to carry out a study of the military's use of radio frequencies. The first stage of the study, which is due for submission by December 1987, will concentrate on the frequency range 470-3400MHz.

Another study group is examining the potential for more commercial pricing of available spectrum, with the possibility that frequencies would be sold to the highest bidder. No such system is employed anywhere else in the world, and it has clear dangers. In the meantime, however, fees for some mobile radio licences have been raised, in some cases substantially.

Of Britain's 300,000 or so vehicles fitted with two-way v.h.f. or u.h.f. radio, some 50,000 are in London, with a waiting list of 18 months for frequencies. Several solutions to the frequency shortage are now being developed, involving both new frequencies and new techniques, both separately and in combination.

TRUNKING TECHNIQUES

In Band III (v.h.f. high-band) the government has indicated its intention to reallocate channels to new national private mobile radio networks, as well as to public utilities displaced from Band II channels required for the extension of f.m. broadcasting.

The new national systems will offer the advantage of a ready-made p.m.r. service on which users can rent as many channels as they require, without the need to set up their own system. Sophisticated selective calling systems will ensure that users receive only messages intended for them and do not interfere with or overhear other users. Limited interconnection with the public telephone network may be permitted (in off-peak hours).

The service is likely to open in January 1987 and will offer both voice and data services provided by two operators, GEC and a consortium of Pye, Racal and Securicor.

Trunking techniques, already widespread in North America but new to Britain, will enable a larger number of uses to share a pool of frequencies. Radio sets pick the first free channel from the pool, which is controlled by a computer: users are connected automatically and are unaware of the actual channel being used, which will vary from occasion to occasion in a similar way to cellular radio.

A number of trunked systems are now in operation, though user take-up has not entirely matched expectations, probably because the offerings do not share the glamour (or the amount of media exposure) cellular radio has achieved. Another factor may be the higher cost of the sophisticated equipment, even though it is offset by the economies possible and the opportunity to beat the waiting list.

COMMUNITY REPEATERS

A lower-cost solution, which also uses scarce radio resources more economically, is the community repeater or base station. Frequencies are shared by a number of users and tone-squelch systems are employed to prevent overhearing. Light signals indicate whether the channel is free or in use, and calls between mobiles and the various users' base stations are relayed by a well-sited communal transmitter or repeater station.

Other new techniques currently under investigation aim to make better use of frequency resources, and include transparent-tone-in-band and tone-above-band systems for shared speech and data. In addition there are revertive and overlay paging systems which can be added to existing p.m.r. systems to alert mobile users to a call when they are away from the vehicle.

SATELLITE POSSIBILITIES

Looking to the longer term, future mobile radio systems may rely on satellites to give wider area coverage and to increase the number of users accommodated. A number of schemes have been presented for consideration.

In the United States, papers have described how a geostationary satellite could extend cellular radio service into rural and remote areas which are either impossible or uneconomic to cover by terrestrial transmitters on account of low user density. Fixed telephone service to isolated homes could also be provided at lower cost by satellite than conventional wireline.

A British proposal by a number of UK universities and the Rutherford Appleton Laboratory envisages a satellite paging system whereby cellular telephone users are paged by satellite when a fixed telephone caller wishes to get in touch. Such a satellite system would also have advantages in situations where terrestrial radio systems were not yet harmonized or standardized, although potential frequency clash may rule out this solution in Europe. Geographical and economic considerations make this scheme more likely to take off in North America, although even there the sub-1000 MHz frequencies desired for this kind of service are unlikely to be allocated.

Any eventual service is more likely to be accommodated around 1.5GHz, with corresponding higher equipment costs.

THE PROSPECTS FOR MOBILE

Mobile radio is now the most dynamic sector of the telecommunications market, and user awareness is greater than ever before.

Opportunities for manufacturing and sales are being seized aggressively. Currently the British market is served mainly by British and associated European producers, with a growing percentage of USA and Japanese imports. Three firms, however, have set up plants for the manufacture of cellphones, which augurs well even if large numbers are still imported from Japan. With luck, the continuing boom in demand will be matched by a supply situation which satisfies the best interests of all concerned.

This article is an expanded and updated version of one which originally appeared in The Mobile Telecommunications Guide '86, edited by Adrian Morant and published by IBC Technical Services Ltd.

Wide-area binary paging

Many mobile communication requirements can be satisfied by one-way data transmission. And as the prospect of spectrum pricing looms, attention is turning to paging networks as an effective low-cost alternative to radio telephones. This artile explains how a radiopaging system works.

J.C. KIRBY

A wide area paging system, almost by definition, needs many radio transmitters to provide the high field strengths needed for an effective service. The antennas inside pagers are not as efficient as vehicle antennas, and so more transmitting sites are required to provide coverage similar to that of p.m.r. systems.

Nevertheless, at many locations within a zone, pagers will be receiving signals from more than one site. If each transmitter were to transmit its message in sequence, not only would most pagers receive duplicate calls, but valuable air time would be wasted because subsequent calls would have to wait until the previous call had been transmitted at each location.

Quasi-synchronous operation (or more simply, simulcast) is the solution. This technique allows transmission from all locations within the zone simultaneously; but care must be taken to ensure that when a pager receives signals from more than one source, the signals combine in a beneficial manner. This can be achieved by careful system design.

Radio signals in the proximity of buildings are reflected, causing interference patterns with non-reflected signals resulting in small (less than half-a-wavelength) areas where no signal is received (nulls). Users of hand-portable radio sets will be familar with the effect a movement of only a few inches can make to the strength of a wanted signal in an urban environment.

Introduction of signals from a second transmitting location creates another pattern of nulls. The areas of no signal are now only those where nulls from both sources coincide. Small movements of the receiver now have less effect on the strength of the received signal.

Correct quasi-sync operation occurs when the modulation from all transmitters in the system is identical, both in phase and amplitude. The level of the modulation, whilst very important for voice quasi-sync systems, is fixed for binary data. It may take only two possible values, +5 or −5kHz of the operator's frequency. During normal operation, the transmitter never actually radiates on the centre frequency, that which appears in the licence!

Absolute synchronization of the carrier wave is not required, but a high-stability frequency source should be used to maintain constant low-frequency offsets between adjacent sites.

Surprisingly perhaps, simulcast proves easier to implement for the transmission of data than voice. Let us consider why.

PHASE-DELAY TOLERANCE

Human speech transformed into an electronic signal gives a complex waveform. Analysis of this waveform reveals a mixture of frequencies at differing amplitudes with different phase relationships. Voice frequencies range from 40Hz to 15Hz, but only frequencies between 300 and 3000Hz are required to provide reasonable speech quality for private radio systems.

Consider a voice signal divided into two channels, one of which is delayed by 1ms. All speech frequencies at 1kHz on the delayed channel will be 360° behind the undelayed channel. A 360° phase difference is, to the human ear equivalent to no phase difference; and so the 1kHz part of the speech would sound undistorted if the channels were re-combined. Frequencies of 2kHz and 3kHz with 720° and 1080° phase difference would also sound undistorted.

However, those components of speech at 500Hz will be 180° out of phase and will try to cancel each other. Components at 1.5kHz

TABLE 1: delays in a typical system configuration with landline distribution

1200 baud modem:	180μs
Radio link transmitter:	140μs
Radio link receiver:	200μs
Landline:	10μs/mile
Paging transmitter:	140μs
Paging transmitter rise-time:	250μs
Delay equalization unit range:	min.30μs max.50ms

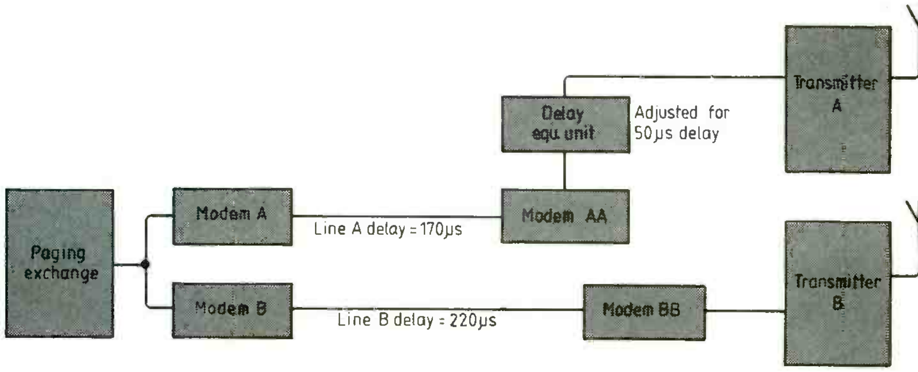


Fig.1. Typical system configuration: landline distribution.

and 2.5kHz with 540° and 900° phase difference will also try to cancel, and the ear would certainly notice differences at these frequencies.

Speech systems demand not only that delay differences are minimized between sites, but also that any variation of delay over the frequency band (the group delay) must also be constant. Data occupies less bandwidth than speech and so the group delay problem is less significant.

Data must therefore be radiated from each site on the system in phase. But how can this be done when these sites are varying distances from the paging exchange, and longer landlines mean longer delays? Let us now discover how closely this data must be synchronized between transmitters.

DELAYS

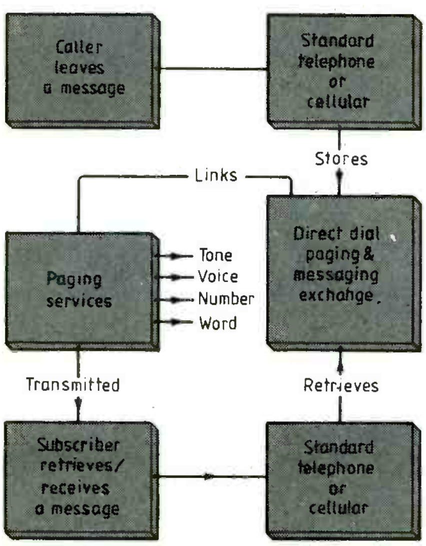
Tests show that the maximum delay difference which can be tolerated on a voice channel is about 10% of the period of the highest modulating frequency (3kHz), which amounts to 33 microseconds.

The same calculation can be applied to binary signalling. The maximum bit rate is 512 bits for current generation radiopaging code and tests in Japan during 1977 found that at low signal levels there should be no more than 25% confusion period in any one bit. (The confusion period is the time between transmitter 1 changing from binary 0 to 1, and transmitter 2 changing from 0 to 1.) The maximum delay difference in seconds is therefore 1/512×25%, or 488 microseconds.

If the pager is not midway between two

An office viewdata terminal can be used to send calls to radiopagers or to retrieve stored messages.

Fig.3. How voice-messaging works. Instructions and warnings to the caller are in speech form too.



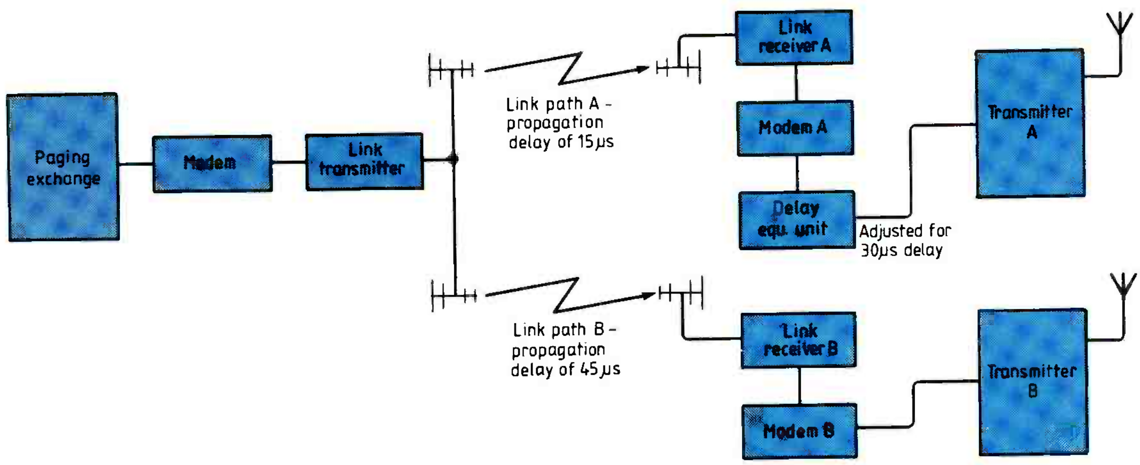


Fig.2. Typical system configuration: link distribution. Delay is essential for quasi-synchronous working.

transmitters, yet is receiving signals from both, then the user is introducing more confusion time by virtue of location. For example, if site 1 is 20km away and site 2 is 10km from the user, the path difference is 10km. Since radio signals propagate at 3.34μs/km, the speed of light, the signals arrive at the pager with a delay difference of 33.4μs. As the path differential increases, the likelihood is that the signal from the nearer transmitter will completely capture the receiver, and effects from the more distant site will be eliminated.

Equipment used in distribution and transmission of the data introduces additional delay. Some typical values are given in Table 1.

The delay equalization unit is an essential part of any quasi-synchronous system. It compensates not only for variations between modems and transmitters due to manufacturing tolerances, but also for different landline or link path lengths.

Usually the most remote site exhibits the greatest distribution delay, and is taken as reference. Other sites having less delay now have to be synchronized with the reference. The delay equalization unit is made to introduce additional delay such that delay to all sites is equal. Only then can the benefits of quasi-synchronous operations be realized fully.

Suitable binary delay units are not readily available off-the-shelf and at least three of the network operators produce their own units in-house.

ACCESS METHODS

Often callers telephone the system operator's message bureau, are answered by an operator, quote a pager number, leave a message and ring off. The message is entered by means of speech or keyboard usually by the operator who answered the call. This method occasionally resembles 'Chinese whispers', especially with the handling of technical or coded messages. In addition, all callers must remember two numbers: the telephone number to ring and the pager number to ask for.

If the numbers can be combined into a ten-digit telephone number, the 'phone number itself then indentifies the pager. And, because the paging exchange has a database, the number also indentifies which service the caller expects. Changes of pager or extension of service need not mean a change of 'phone number.

Digital Mobile Communications operate such a direct dial service; all numbers are ten digits long. The first five digits route the call from any telephone in the UK into Digital's PX2000 radiopaging exchange. Digits 5 –10 (99 999 numbers) are presented to the paging exchange on up to 32 trunks. The PX2000 responds according to the service allocated to that number. Services are:

- tone-only paging
- tone-and-voice paging
- message paging
- voice messaging
- retrieval of voice messages
- number not allocated (returns 'number unobtainable' tone to caller)

Following a call to a tone-only pager, the phrase "call accepted" is spoken automatically. A call to a tone-and-voice pager is answered by the exchange which announces the number dialled and invites the caller to leave a message. It is reassuring for the caller to hear a human voice rather than bleeps. Fewer calls are abandoned because of confusion or the "I don't like talking to a machine" syndrome.

The length of a voice paging message is restricted to fifteen seconds, after which the caller hear the words "call accepted". The message is sent immediately to the pager, but remains stored in a digital form on disc in case the user wants to retrieve it again later.

Display-pager calls are diverted to an operator, and at the same time the pager user's details are sent on to the operator's v.d.u. The operator answers the call, usually with the user's company name, and takes a message.

Voice mailbox calls (Fig.3) may or may not initiate a page. On answering, the voice of the mailbox subscriber (stored in digital form on disc) is played to the caller. Callers are usually invited to leave a message, by speaking after a tone. A linking feature within the exchange automatically informs the subscriber, by means of paging, that a message has been taken.

A time limit of 30 seconds is placed on voice mailbox calls. If they exceed it, callers are informed, and told that the first part has been recorded. Mere pips could never explain that!

Retrieval calls are also routed to the paging exchange. Only the subscriber knows his retrieval number, and incoming calls are played back automatically. Some of Digital's subscribers want a higher degree of security on collection of messages, and so a touch-tone pad is available to give password indentification. The exchange speaks the words "Please enter your password" on answering. Use of a d.t.m.f. pad allows the subscriber to change or re-record the answer phrase as required.

OPEN ACCESS

The use of data terminals over public telephone lines is ever increasing. At last, viewdata is gaining popularity in the business world, and the choice of terminals is growing. Digital find that many subscribers with a dozen pagers or more are likely to have a Viewdata terminal in the office already, probably to access Prestel or some similar service.

Subscribers are often surprised to learn that the terminal can also be used for sending calls to message and tone only pagers. Retrieval of messages is another facility offered to Viewdata users.

To be continued.

Chris Kirby is technical manager of Digital Mobile Communications Ltd. which operates one of the four wide-area binary paging networks in the UK.

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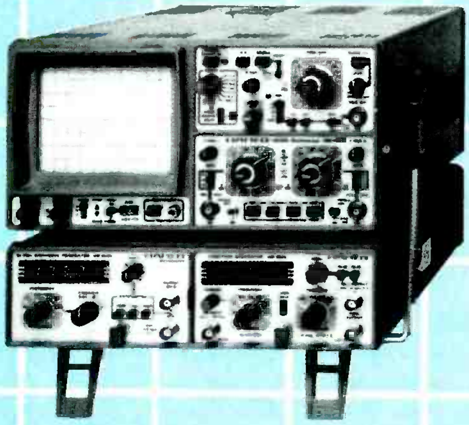

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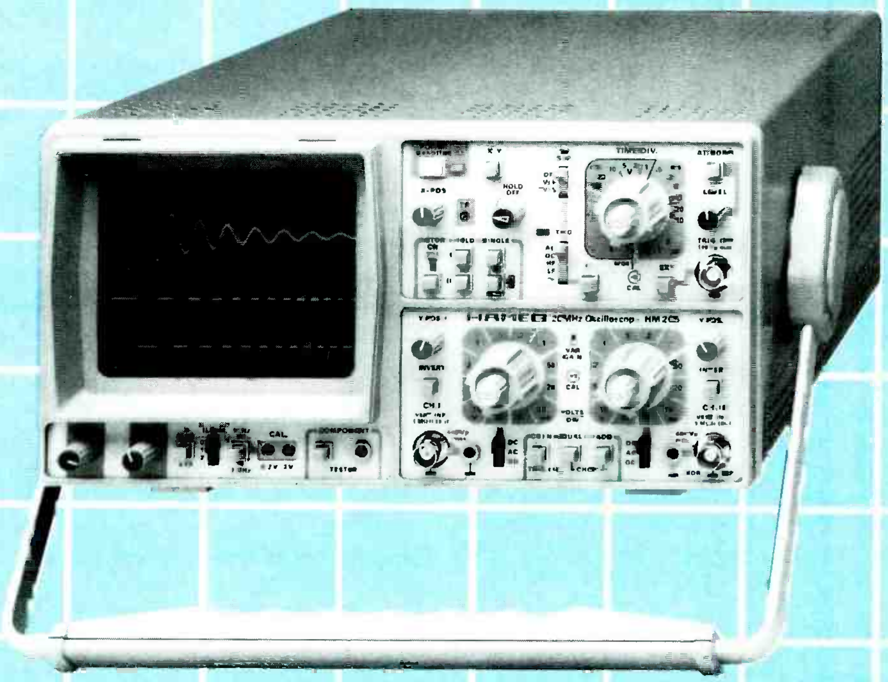

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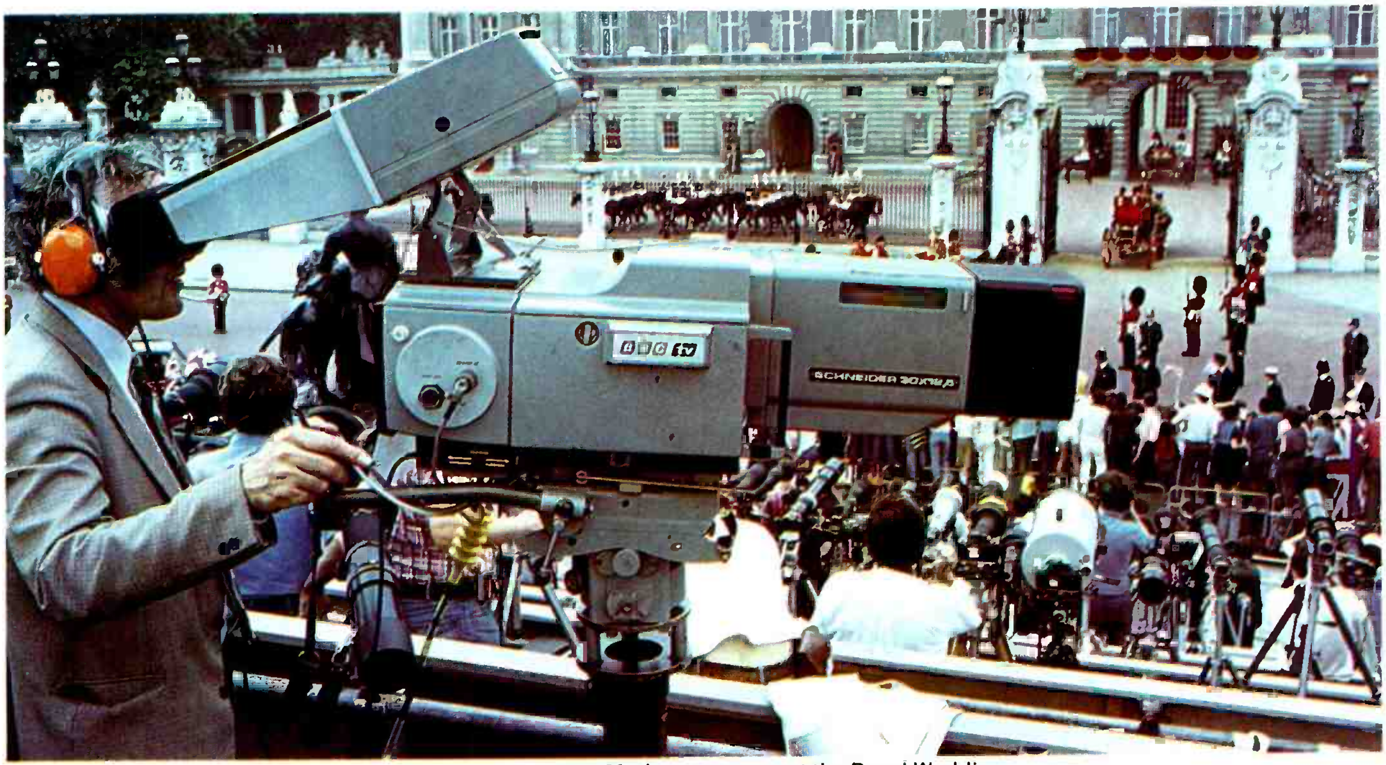


Viewing the p-esent. Modern cameras at the Royal Wedding.

BBC television looks back – and forward

It is 50 years this month since the world's first high-definition television service opened. Pat Leggatt reviews progress and looks ahead.

D. P. LEGGATT

Fifty is a nice round number and a good basis for Golden Jubilee celebrations. But this year sees several different anniversaries of the BBC's association with television, the first being an even more venerable Diamond Jubilee.

It is just over 60 years since, in July 1926, television signals were first radiated from a BBC transmitter. The brief experimental transmissions, from the medium wave 2LO on the roof of Selfridges, carried 30-line vision signals supplied by Baird.

Next in line is the 57th anniversary of the start of the *regular* experimental transmissions, again from the BBC's 2LO station, in August 1929. The programmes came from the Baird studio at Long Acre but, since only one transmitter was available, the audience could be offered pictures or sound but not both at the same time. A few months later, in March 1930, simultaneous vision and sound was radiated from the new twin transmitters at Brookmans Park.

We must now note the 54th anniversary of the BBC Television Service. In August 1932 a BBC television studio in the new Broadcasting House took over programme production from Baird (still on 30 lines) and the BBC Television Service was born. It started with a staff of one, in the person of the engineer Douglas Birkinshaw, who supervised the installation of the studio equipment supplied by Baird.

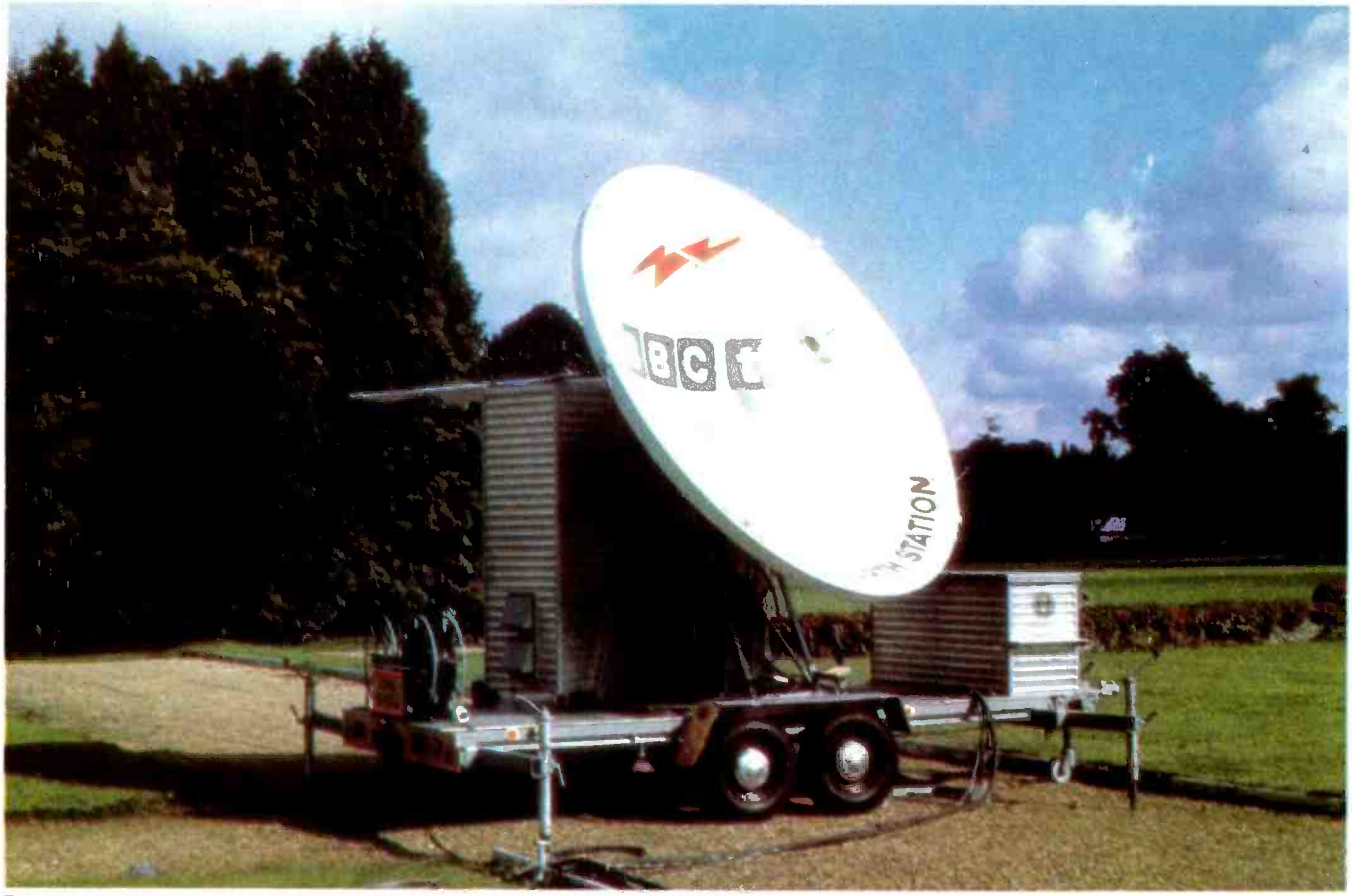
Passing over the closure of the 30-line service in 1935, we come finally to the 50th anniversary of the world's first regular high definition television service. The BBC 405-line service from Alexandra Palace was formally opened on November 2nd 1936, alternating each week with the Baird 240-line system until February 1937, when 240-line transmissions ceased. Even this 50th anniversary date must be slightly hedged, in that a 10-day preview of the service had been transmitted for the Radiolympia show from August 26th, followed by trial programmes on an irregular basis during September and October.

Despite the earlier events, regular television of real entertainment value started in November 1936 and it is to this date that the BBC now looks back.

THE PRE-WAR YEARS

Things started on a fairly modest scale. In Alexandra Palace in the early days there were two 2000 sq. ft studios, each with three Emitron cameras; studio sound and lighting control equipment; two telecine machines comprising intermittent-motion projectors with Emitron cameras; and the vision and sound transmitters. Although not lavish, this complement offered the essential tools for production and a good range of programming was achieved, including outside broadcasts in the grounds of the Palace as far as the weather and the 1000ft camera cables allowed.

In early 1937 the Post Office installed a balanced-pair vision cable from central London to Alexandra Palace, enabling the first major outside broadcast to be undertaken on



Forseeing the future. A BBC satellite terminal at Kingswood Warren in Surrey.

the occasion of the Coronation in May 1937. Soon after this the BBC acquired two 3-camera o.b. vehicles and v.h.f. radio links, so that a wide variety of outside events could be covered. A considerable advantage for outside broadcast work was the introduction in November 1937 of the Super Emitron. In this camera tube the photo-electric emission function was separated from the mosaic target and the photo-electric efficiency could be considerably increased; furthermore, this tube gave electron-multiplication by secondary emission from the scanned target. The Super Emitron was about twenty times as sensitive as the Emitron, directly useful in poor lighting conditions and useful also in its potential for increasing the depth of field of the camera.

On the telecine front, the Emitron was not a very good tube for the purpose: and indeed the quality of film reproduction was about the only aspect in which the Baird apparatus had been superior to the Marconi-EMI system. The spurious shading signals (tilt and bend) of the Emitron proved very difficult to correct in the film scanning application where abrupt changes of scene lighting balance could be expected: and because the telecine system involved a brief flash exposure during the scanning flyback period, the resulting large Emitron "photo pulse" proved troublesome. This latter difficulty was later removed by replacement of the intermittent-motion projector by a Mechau film transport in which successive tilting mirrors produced a stationary image from continuously moving film. The Emitron could therefore be exposed for the full television field period, avoiding the "photo pulse" and incidentally taking advantage of the tube's storage capabilities to reduce the required illumination.

The Marconi transmitters, with antennas on the roof of the Palace, gave 34kW vision e.r.p. and provided a good signal to London and about 30 miles around. The audience was, of course, slow to build up at first and by August 1939, after which the service closed down for the duration of the war, there were some 23,000 licensed receivers.

POST-WAR 405-LINE DEVELOPMENT

Towards the end of the war, the Government's Hankey Committee decided that the television service should re-open on the original 405-line standard. British television therefore returned in June 1946, the first service in Europe to re-open.

Transmitter coverage. There were many things to be done, perhaps the most urgent being to spread coverage beyond south east England and make the service a truly national one. By 1952, four new high-power (100kW e.r.p.) transmitters had been built at Sutton Coldfield, Holme Moss, Kirk O'Shotts and Wenvoe, extending coverage to 81% of the population. Five medium-power stations followed, including one in Northern Ireland and one in north east Scotland, giving 93.5% coverage by 1955. The Alexandra Palace transmitter was replaced in 1956 by one at Crystal Palace with an e.r.p. of 200kW.

A number of low-power relays were added in succeeding years, many in the form of frequency transposers (with no demodulation to baseband) specially developed by the BBC. The last transmitter for the 405-line service was installed in 1970, the population coverage finally achieved being 99.5%.

Nearly all the BBC 405-line transmitters were in v.h.f. Band I, with a few in Band III. Only five television channels were available in Band I, and considerable ingenuity and care with geographical locations, choice of channels and polarizations was needed to achieve the final virtually countrywide coverage. The adoption of vestigial-sideband operation for all stations other than the original Alexandra Palace transmitter was valuable in reducing channel bandwidth requirements.

Programme-origination. On the programme-origination front there was also an urgent post-war need for expansion and enhancement. It was outside-broadcast facilities that first received attention, with improved cameras using CPS Emitron tubes in 1947; zoom lenses in 1949, with only 2:1 range but still an important advance on lens turrets; and a car-mounted Roving Eye camera unit in 1954.

Studio availability was expanded with the acquisition of Lime Grove in 1950, the Shepherds Bush Empire theatre in 1953 and the Riverside studios in 1956. With an eye to the future, a 13½ acre site at White City had been purchased by the BBC in 1949 for a comprehensive new Television Centre, although it was not until 1960 that the first studio came into service there.

Regional studio facilities were not neglected of course, starting in a modest way with a converted chapel in Manchester used on a drive-in basis with equipment temporarily demounted from an o.b. unit. Later regional expansion saw provision of major production centres in Glasgow, Belfast, Cardiff, Manchester, Birmingham and Bristol, with smaller studio centres in a number of other areas.

Studio equipment steadily improved, with the old Emitron cameras replaced by the CPS Emitron (orthicon), Photicon (image iconoscope), and 3in and 4½in image orthicon. Twin-lens flying spot telecine replaced the Emitron camera types. Special effects systems such as the BBC-developed inlay and overlay offered new production opportunities.

Video recording. In 1947 the first attempts were made to provide the much-needed facility of video recording. With a vision bandwidth of 3MHz, waveform recording was not then practicable and only image recording on photographic film seemed feasible. Using a conventional 35mm intermittent-motion film camera directed at a television c.r.t. display produced rather indifferent results, since the time which had to be allowed for film pull-down meant that only one television field in each picture period could be recorded. The resulting 202½ line structure produced obstrusive alias components when rescanned on telecine.

This suppressed-field system was later much improved by the application of vertical spotwobble to the displayed picture, thereby removing the line structure; but a further advance was made by storing the "lost" field in the form of afterglow in the display tube phosphor and presenting both fields simultaneously to the film during its stationary period. The stored-field technique gave good results with stationary pictures, but the long-persistence phosphor gave rise to considerable blurring of moving parts of the scene. This shortcoming was eased by use of a special fast pull-down film mechanism which, while not achieving pull-down within the 1.4 millisecond field blanking period, at least left only a few lines at the top of the picture to be recovered by storage in a shorter-persistence phosphor.

Another approach was to use the Mechau continuous film transport to immobilize the television image on the film frame. This also produced quite acceptable results, but the mirrors on the Mechau drum required frequent and very careful adjustment to avoid inter-frame exposure variations and movement jitter.

These film recording methods were of course largely superseded by the introduction of the Ampex video tape recorder in 1958. In company with other broadcasters, the BBC has followed the succession from 2in quadruplex to 1in C-format and other helical-scan standards. The BBC has made original contributions in the way of sophisticated video tape editing systems.

30 lines, 405 lines, 625 lines, 1000+ lines: where will it all end? The BBC looks forward, not to the end, but to the centenary of television, with the next 50 years as full of progress and excitement as the last.

Standards conversion. Another important post-war development of BBC television was the introduction of international operations. The first live programme from overseas was in 1950 when pictures from a BBC 405-line o.b. unit in Calais were radio-linked back across the Channel. In 1952 a French-produced television programme from Paris was standards-converted for UK viewers; and 1954 saw the first large-scale European exchange with eight countries taking part.

For these early international exchanges, optical standards converters were employed in which a display on the incoming standard was exposed to a camera on the outgoing standard. The performance of these optical systems left much to be desired and investigations were later undertaken into purely electronic methods. In 1963 the BBC developed the world's first all-electronic line store converter, for interchange between standards with the same field rate. Not only did these converters give greatly improved quality for European exchanges, but they were ready to play a vital role in the mixed 405/625 economy which was to start in the UK in 1964. A few years later, in 1967/68, another BBC first was scored (and a Queen's Award earned) with the all-electronic field store converter for programme exchange between 50 and 60Hz field rate systems.

THE 625-LINE ERA

U.h.f. transmitter planning. Matching the general movement in Europe, it was decided in the early 1960's that British television, by then including ITV as well as the BBC service, should adopt 625-line standards transmitted in the u.h.f. Bands IV and V. A new BBC service, BBC2, opened on 625 lines in black and white in 1964; while BBC1 and ITV waited for their 625-line debuts until they went into colour in 1969.

Development of u.h.f. transmitter networks was, and still is, undertaken as a joint BBC/IBA project. Planning was for country-wide coverage of two BBC and two commercial services with co-sited transmitters radiating all four services from a common aerial at each site. The ownership and building of the stations is shared equally between the BBC and the IBA, each being landlord at half the sites and tenant in the other half. With this co-operative system, the viewer at home needs only a single aerial to receive the four services.

With only eleven 4-channel frequency groups available in Bands IV and V, very sophisticated frequency planning is needed to secure maximum coverage without interference between UK transmitters, or between the UK and neighbouring countries. The comprehensive computer-based system has achieved better than 99% population coverage of four services, a record unequalled on u.h.f. in any other country.

The coming of colour. Although the BBC's opening on BBC2 in 1967 was the start of the first colour service in Europe, the United States had been operating in colour for many years and the Europeans's late entry gave them a valuable opportunity to build on American experience.

Up to this point the American operations and the British experimental work had been conducted with three-tube image orthicon cameras. The image orthicon was not well suited to the task of producing three separate colour signals matched in grey-scale and geometry; and of course the large tubes resulted in a very unwiedly camera. Fortunately the Philips Plumbicon appeared just in time to enable the BBC2 colour service to start with cameras of excellent performance and reasonable size. To begin with, both the British manufacturers, EMI and Marconi, produced 4-tube cameras; but as designers mastered the art of tube registration, the necessity for a separate luminance tube disappeared and 3-tube cameras became standard.

Although the development of colour studio equipment and techniques required much expert and dedicated work, perhaps the most innovatory aspect of colour television was the coding system. The American NTSC was well established and there was a strong movement in the BBC for its adoption in the UK. In Europe the French SECAM and German PAL derivatives of NTSC had been proposed and the CCIR recommended that European countries adopt one or other of these. The UK, and the majority of other Europeans, opted for PAL.

The March of the Digits. For many years the BBC has been prominent in the application of digital techniques to broadcasting. In 1972 the BBC developed the sound-in-syncs system whereby the sound content of the television programme is carried within the vision waveform as digital pulse code modulation during the line synchronizing periods: this development was more or less coincident with that for distribution of stereo radio programme in p.c.m. form to the v.h.f.-f.m. transmitter network.

Sound-in-syncs signals are decoded at the transmitters and radiated in normal analogue form: the first actual transmission of digital signals to the viewer came with the introduction of the teletext service in 1974. Digital teletext signals are transmitted during four or more otherwise unused lines in the field blanking period, and control a character generator in the receiver. Recently the system is being used to carry computer programs which may be directly loaded into a computer rather than displayed as screen

Looking back. Remembrance day, 1946. Television cameras at the Cenotaph.

text; this application is termed telesoftware.

In the distribution of vision signals in digital form, the BBC has done, and continues to do, significant work on bit-rate reduction. Digitally coded 625-line PAL has been successfully compressed into a 34 Mbit/s channel; and good progress had been made in reducing the requirement for 625-line component signals from the basic 215Mbit/s down to 68 Mbit/s.

Perhaps the most significant attribute of digital operation is the ease with which digital signals may be stored and subsequently manipulated. A relevant application is standards conversion, where new lines and fields can be synthesized from a digitally stored input signal: the IBA's DICE converter of 1972 was a notable archetype; and the BBC ACE equipment, storing four fields, is a current leader in the market. Other BBC exploitations of digital storage are the television noise reducer, in which random noise in successive fields is averaged out while coherent picture signals are preserved; and the BBC-designed still picture storage manufactured and marketed worldwide by Rank Cintel as "Slide File".

THE NEXT FEW YEARS

As might be expected, virtually all developments in the foreseeable future are likely to be rooted in digital technology.

Television signal distribution, internationally, within the country, and within studio centres, will increasingly be in digital form with optical fibres providing an appropriately wideband medium. Already there are signs of success in the search for methods of switching signals in optical fibres without intermediate conversion to electrical form.

The digital video tape recorder has been seen in experimental form and is almost with us as a commercial product. No doubt video tape editors will soon find reason to go to one hundredth generation dubbings!

Direct broadcasting by satellite will at last emerge from its protracted gestation, although not initially as a BBC service. It will probably use one form or another of the IBA's MAC system, in which the vision components are analogue, but which qualifies as a digital development since the time compression and expansion processes are effected with the signals in digital form.

Stereo sound is of course a feature offered by MAC; but we should quite soon be enjoying stereo with existing terrestrial television. BBC development of digital sound on a second carrier within the 8MHz transmission channel offers stereo or dual-language sound without the interference between sound and vision which can be a shortcoming of second-carrier analogue systems.

Looming largest, perhaps, is the prospect of h.d.tv; not the "high definition" television of 1936, but with something more than 1000 lines. The choice of h.d.tv standards is a matter of international controversy, focussing mainly on acceptance or otherwise of the Japanese 1125/60 field proposal. It is generally agreed that this system gives excellent pictures, but many countries currently on 50Hz field frequency have doubts as to the acceptability of a 60Hz cuckoo in their nest. It now seems that the problems of impairment-free 60-50 fields standards conversion will be overcome to an acceptable degree, but anxieties remain in such areas as the 10Hz difference between 50Hz lighting supplies and a 60Hz field scanning rate.

Two other outstanding problems made it sensible for the recent CCIR Plenary meeting to postpone a decision on h.d.tv standards, pending further development work. First, there is as yet no domestically convenient high-quality picture display device capable of giving the large picture which is needed for h.d.tv to be seen at its best. C.r.ts of 36in or more seem unduly cumbersome; and projection systems of adequate quality and stability could be bulky and expensive.

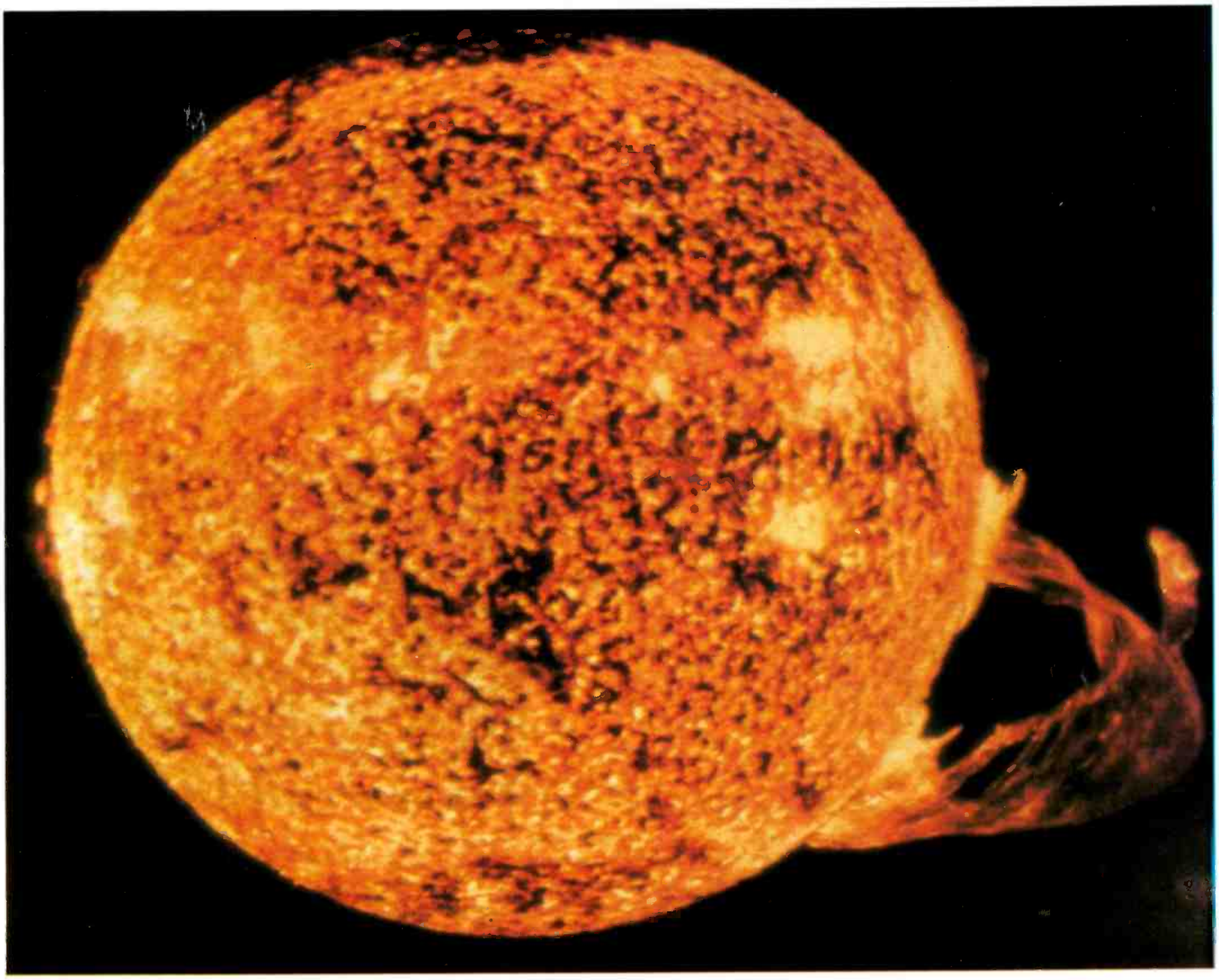
The second problem arises from the large bandwidth requirements of h.d.tv. In the absence of special measurements, more than 30MHz is needed and this could not be accommodated in the presently-planned satellite broadcasting channels. Still pictures present no difficulty – a 1Hz bandwidth will suffice if you don't mind waiting some time for the picture to build up! It is moving scenes that require high information rates and the solution will probably lie in passing additional information to the receiver to enable its electronic processing to handle moving areas in the best way.

The Japanese MUSE system transmits signals limited in bandwidth to about 8MHz, together with motion vectors related to moving areas. A more advanced development is the BBC's digitally assisted television (d.a.t.v.) proposal in which a similarly bandwidth-limited signal is accompanied by digital data to assist receiver processing towards the optimum treatment of individual moving areas within the picture.

HISTORY OF TELEVISION

The Institution of Electrical Engineers (IEE) is to hold an international conference on 'History of Television – from early days to the present' from 13-15 November, 1986. The conference, which will be held at the IEE, Savoy Place, London WC2 will commemorate the 50th anniversary. IEE tel. 01-240 1871 x222.

I am grateful to the Director of Engineering of the BBC for agreement to publish this article.



Eleven years in the ionosphere

An investigation by ionosonde of a complete cycle of sunspots, showing by means of an original graphical method their effect on the F2 layer variations and maximum usable frequency.

KURT FELDMESSER

The other day I had to explain the function of the ionospheric observatory to our local contractor. The existence of the ionosphere proved a stumbling block, but eventually his face brightened and he commented: "You mean it's like a natural communications satellite?" Although, of course, this view is quite correct, it is chronologically inverted – but then we describe ionosondes as 'atmospheric radars' even though radar was invented because engineers were familiar with the techniques of ionospheric echo sounding.

Like all natural resources the ionosphere is a highly variable commodity whose vagaries are still the subject of continuing research world wide, about one hundred observatories contributing to a global picture of ionospheric variation.

The generally accepted record, standardized in the literature[1], is a graph of apparent echo range versus frequency, called an ionogram. The 'apparent' range is plotted on the assumption of a constant velocity of propagation equal to the velocity of light. But once the exploring radio pulse enters the ionosphere, it is slowed down due to the effect of the ionization: the deeper it penetrates, the greater is the delay it experiences and the greater the 'apparent' range.

The process is illustrated in Fig. 1. A ground-based transmitter emits a series of pulses at radio frequency, the transmitted frequency being increased with each successive pulse, the repetition frequency, however, remaining constant. Common p.r.f.s. are 50 or 100 Hz and sounding frequencies would typically cover from 0.5 to 20 MHz, depending on conditions in the ionosphere.

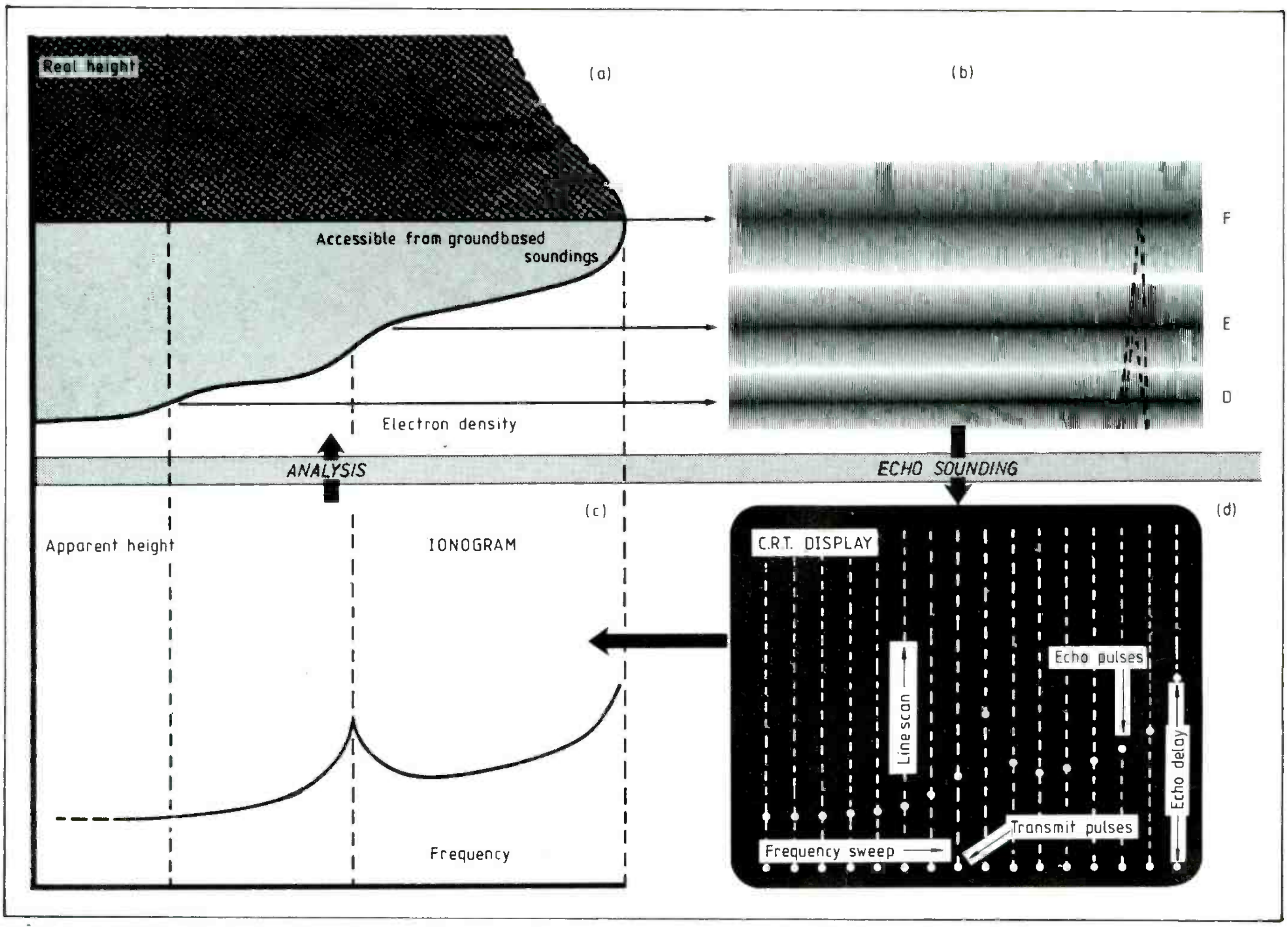


Fig.1. A vertically directed radio pulse is reflected with a delay dependent on the effective distance to the ionospheric layer, each radio frequency being returned at a particular electron density. The successive delays are used to form a c.r.t. display at (d); this is recorded as an ionogram at (c) and analysed to reconstruct the electron density profile at (a).

A normal sounding sequence lasts about one minute. The sound of an ionosonde picked up on a radio receiver is quite characteristic, though the signal lasts only long enough for the ionosonde to sweep through the passband of the receiver. Ionosondes are thus no great source of interference.

As the sounding frequency increases, the transmitted pulse penetrates each ionospheric layer in turn until the so-called critical frequency of the F2 layer is reached. All higher sounding frequencies are not reflected but pass out into space. By plotting the delay of each returned echo with respect to the corresponding instant of transmission the ionogram is obtained. Mathematical analysis then allows the true height profile of electron density to be derived.

The graphs are, of course, plotted automatically nowadays, the techniques having kept pace with the advance of technology, from the manual in the early thirties to the automatic analogue, to the computer-compatible digital with synthesized frequency stepping, producing a database extending over 55 years.

The equipment currently in use in the oldest ionospheric observatory at Slough is shown in Fig.2. Designed by the University of Lowell[2] it is a totally programmable instrument, every sounding parameter being under program control.

Several typical ionograms are shown in

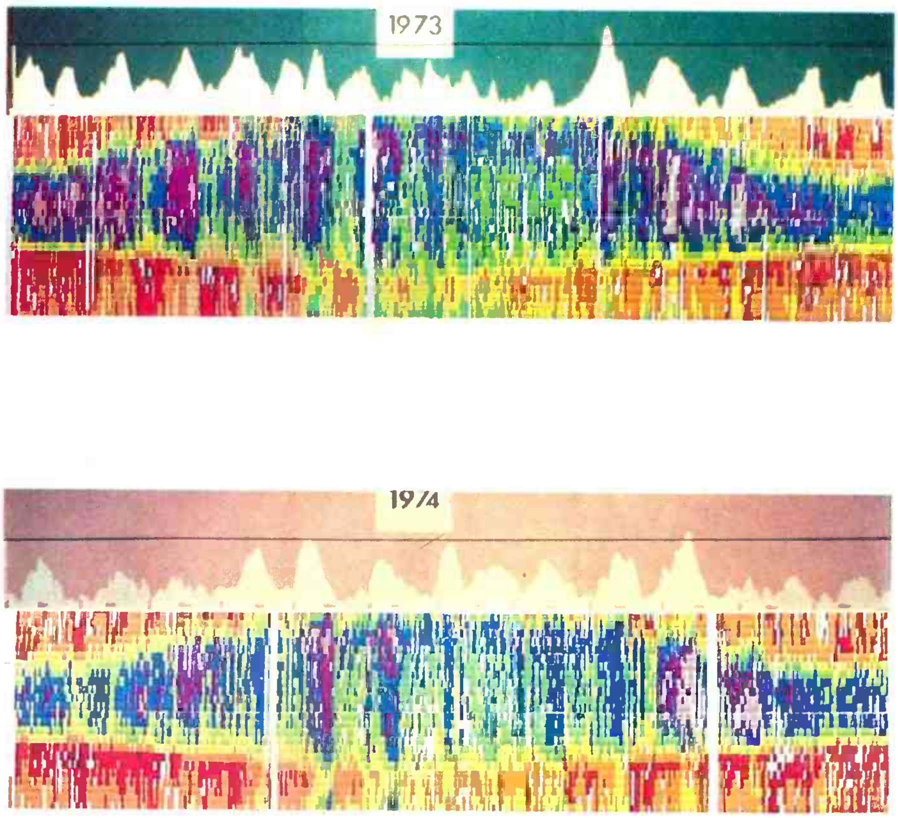


Fig.7. Eleven-year chronagram cycle, with daily sunsport number graphs.

Fig. 3. They illustrate the great variability of the ionosphere and the consequent need for experience and a measure of skill in the interpretation of records. Although the F2 layer is the most useful for long-distance communication, as can be seen from Fig.4, of the three recorded layers (E,F1 and F2), it is the least predictable; a feature which gives amateur radio one of its challenges and the professional still obliged to use the ionosphere his perennial problems.

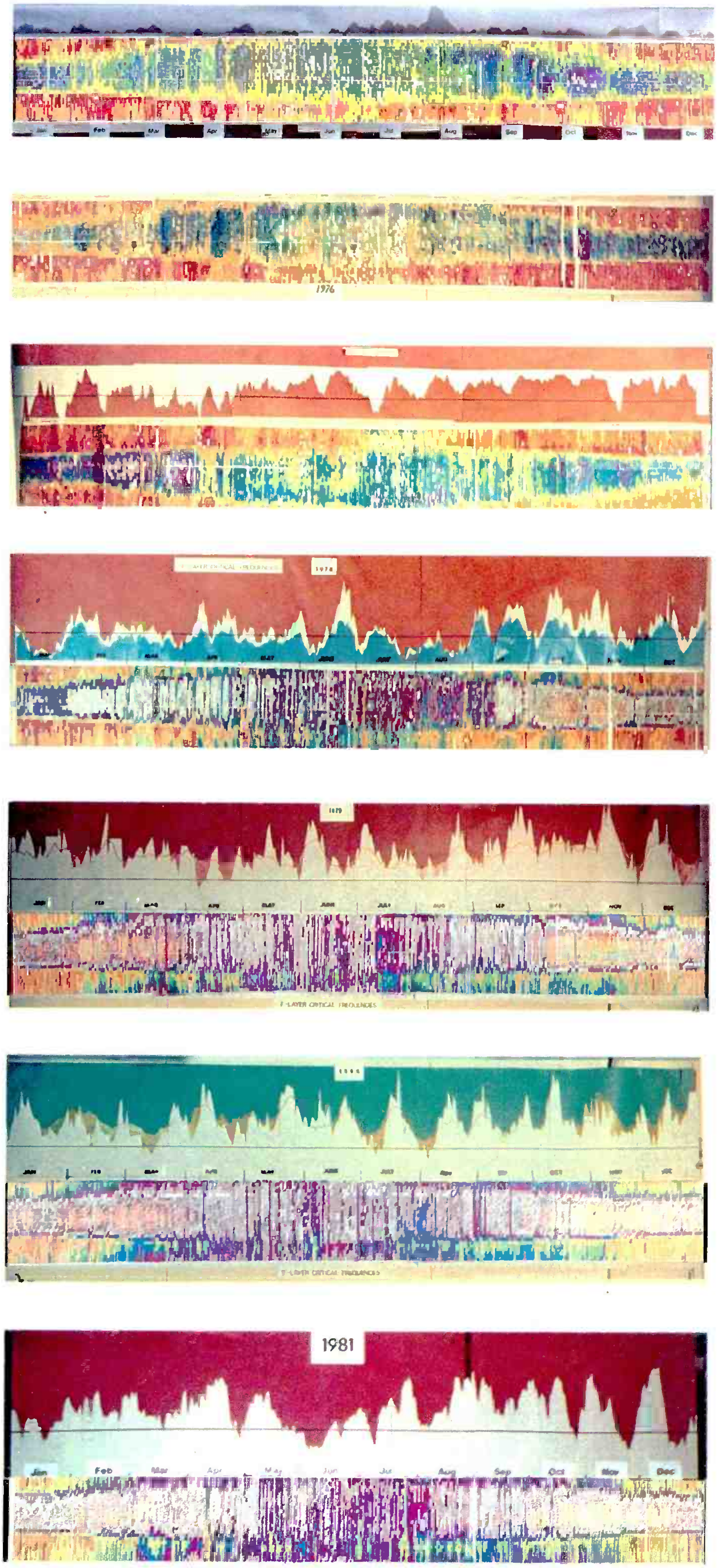
This article presents a method of visualizing the F2 layer variations, using a graphical method published a few years ago[3]. The method proved so extremely useful that I decided to call the resulting diagram a 'chronogram'. It is basically a graph of the 24 hours as ordinate versus the 365 days as abscissa with the parameter under investigation plotted as one of a sequence of colours much like a contour map. The colours follow the resistor colour code in megahertz steps as far as 8 MHz, modified thereafter to give another sequence up to 17 MHz (the highest echo frequency ever recorded at Slough). Although 1 MHz steps may appear crude, if we plot hour to hour variations, the changes can easily exceed 2 MHz.

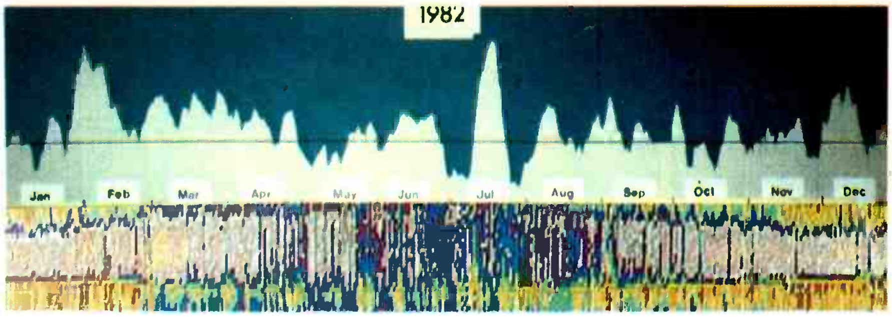
The chronagram has the basic shape of the sunrise and sunset graph of Fig.5. If the F2 layer were totally controlled by solar illumination it would simply have the shape of that figure. The parameter represented in the present chronagrams is the intensity of F layer ionization as measured by the highest vertically incident – frequency of radio pulse returned as an ordinary ray echo; the critical frequency. This can readily convert to the maximum usable frequency.

It is the departure from the basic shape of the sunrise/sunset graph that throws much light on the nature of the F2 layer. The curve of sunrise is outlined well enough by the sudden increase of ionization at F2 layer dawn (about two hours before that at sea-level).

The level of ionization persists well after sunset. However, it does so variably and is frequently correlated to sunspot number. Although not measured by normal ionosondes directly, we do know from other measurements that, like the E and F1 layers, the D layer (the lowest layer of ionization – highly absorbing to h.f. waves) de-ionizes after sunset. Thus h.f. signals, freed from D region absorption, still meet an efficient reflecting region at a respectable height some hours after sunset, giving excellent propagation conditions – a phenomenon well known to short-wave listeners.

In the small hours (or a little earlier during sunspot minimum) the F2 region ionization begins to decay, seen as a decrease in critical frequency and reaching its lowest value just before dawn. In mid-latitude winter the short days do not allow a prolonged energy input to the ionosphere and so the lowest values of ionization are seen during winter nights. As we near the spring equinox the daytime ionization tends to a maximum and persists more and more into the night. With the approach of summer two new factors make themselves felt. Firstly, during the height of summer (about six weeks around mid-summer in southern





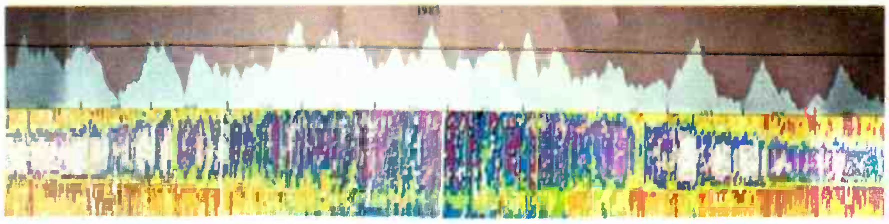
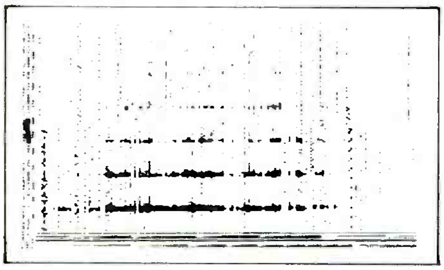
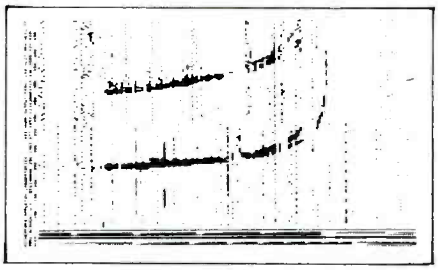
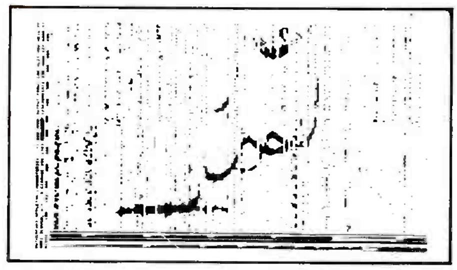
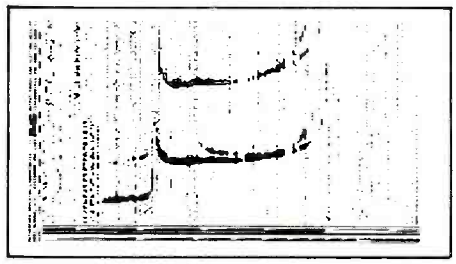


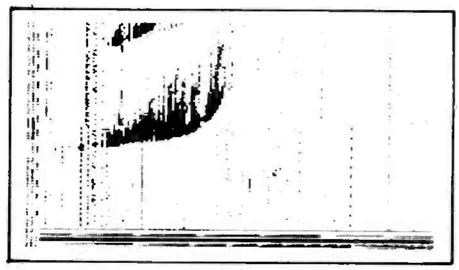
Fig.2. Modern ionospheric observation equipment at the Rutherford Appleton Laboratory at Slough.

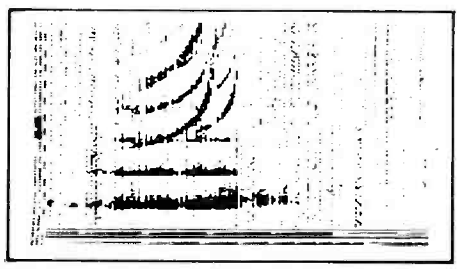












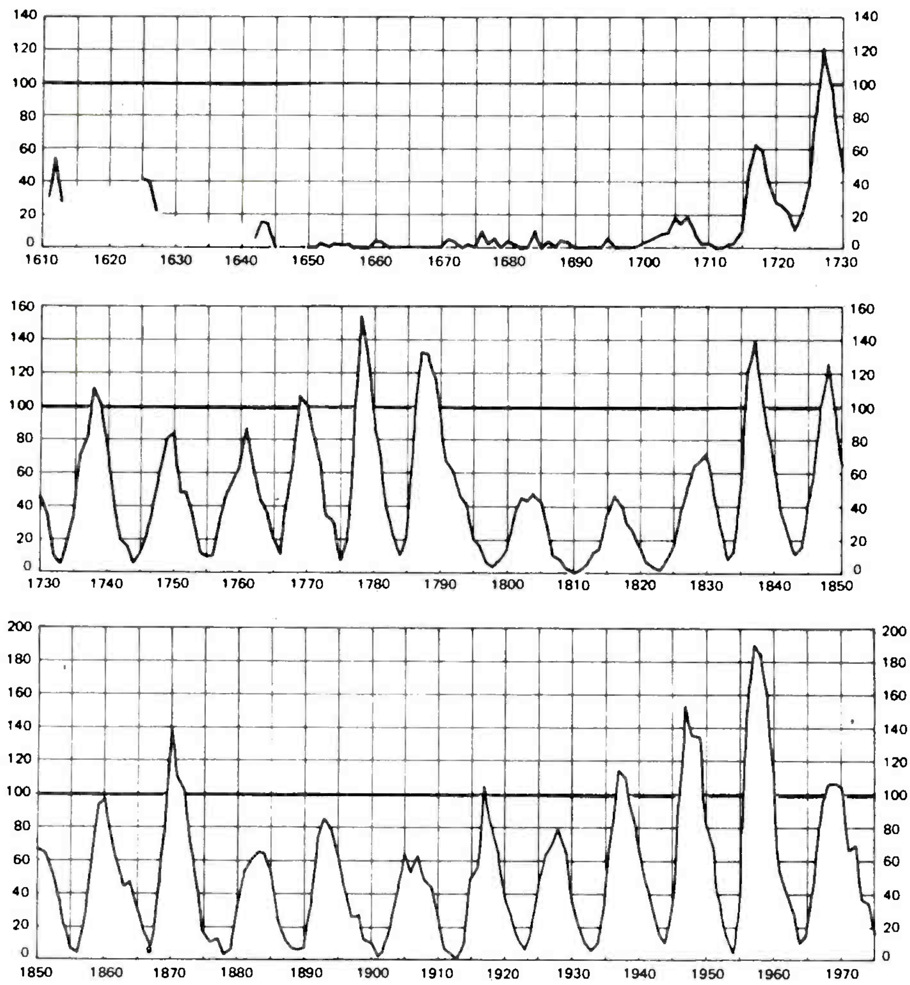


Fig.6. Annual mean sunspot numbers over 375 years. Comparison with Fig.4 suggests that solar activity and therefore ionospheric propagation could yet have a few surprises in store.

Fig.3. Representative ionograms. The splitting of the trace (seen especially in the F region) is due to double refraction in the presence of the earth's magnetic field.

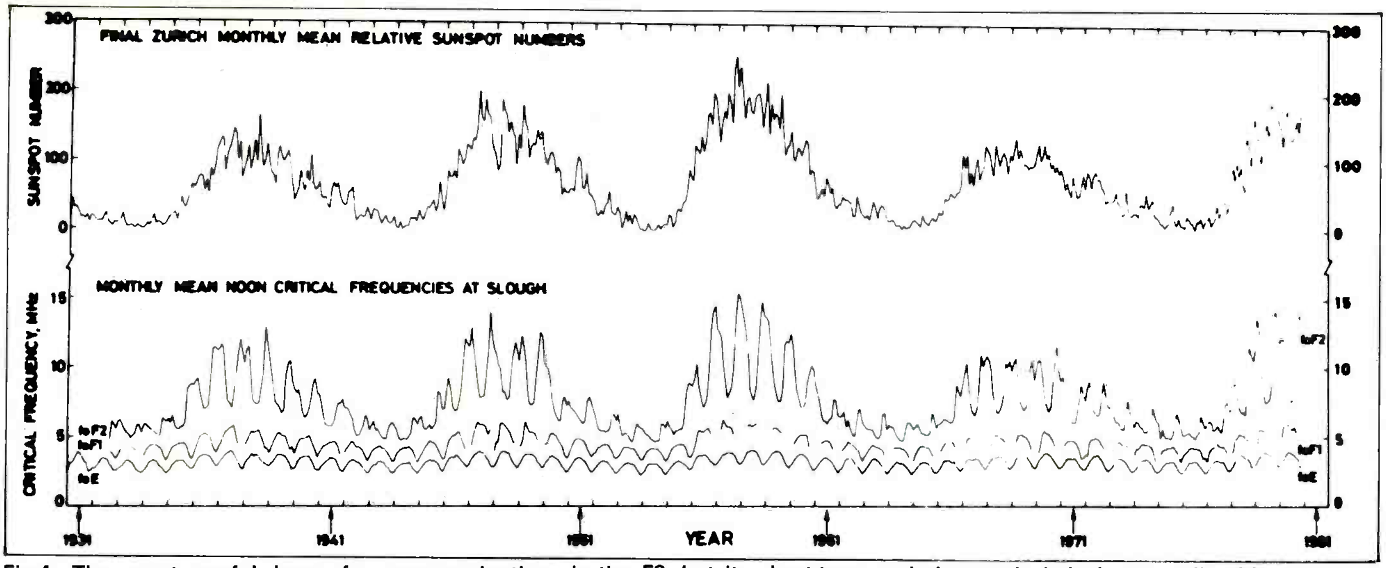


Fig.4. The most useful layer for communications is the F2, but its short-term variations make it the least predictable.

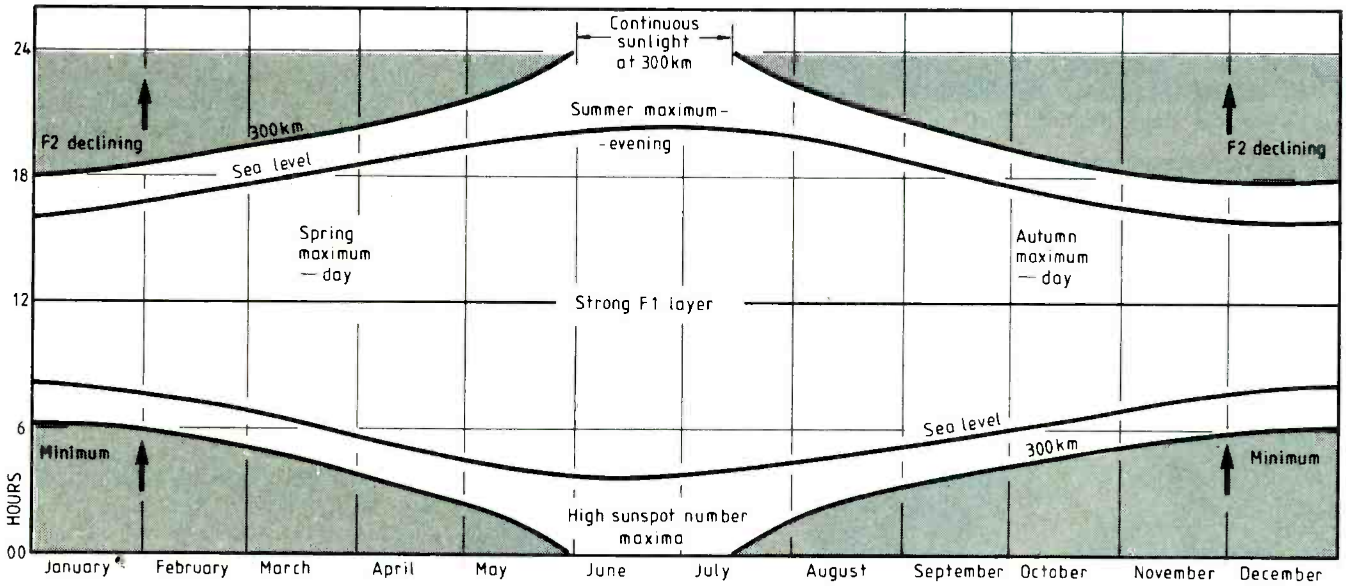


Fig.5. F layer variation with solar illumination – the basic shape of a chronagram in the absence of other influences.

England) the ionosphere remains in constant illumination throughout the 24 hours – resulting in a more or less constant level of ionization, depending on sunspot number. Secondly, the F1 layer becomes more and more marked. It has been shown[4] that the total electron content of the ionosphere varies much more slowly than the electron *density* of the individual layers. Whilst broadly speaking, electron content modifies the apparent height of the layer as the pulse passes through the plasma, the local density determines the critical frequency.

The F1 layer, being controlled by intensity of illumination as measured by the height of the sun above the horizon, ionizes increasingly with the rising sun and behaves as if it derived its free electrons at the expense of the F2 layer, which in mid-summer rarely achieves the levels of ionization of spring or autumn when again the F1 layer is less intense. This can also be seen in summer on a smaller scale, where on cessation of the F1 layer in late afternoon, there appears a sudden brief increase in the F2 layer ionization before its settles down to the evening values.

To the communicator the presence of the F1 layer with its highest critical frequency at about 5 MHz puts a limiting value on the highest usable frequency well below what he could reasonably expect from the F2 layer. Days when the F1 layer dominates the ionosphere curtail the shortwave spectrum drastically and since everybody has to employ lower frequencies, cause congestion. Fortunately, such days rarely persist for more than three or four consecutively and they stand out clearly on the chronagrams.

As autumn approaches and the F1 layer weakens, the F2 layer reaches a second maximum of ionization, generally a little after the equinox. These equinocial maxima are particularly interesting since they are a ready pointer to solar activity. If, for instance, the spring maximum following the autumn maximum exceeds the latter then solar activity is on the increase and if lower than the one in autumn then solar activity is on the decline.

The sequence of eleven chronagrams (Fig.7) of F2 layer critical frequency plotted for the years 1973 to 1983 illustrates the changes in F2 layer ionization. The graphs of daily sunspot number plotted to the same base demonstrate the manner in which the ionization intensity follows changes in sunspot number.

Sometimes the correlation is very evident, at other times perhaps less so. It is this factor as well as the diurnal and seasonal variations that have bedevilled statistical attempts to correlate sunspot number and ionization intensity. However, examination of the chronagrams will amply repay the time spent, by revealing many relationships that can be applied in the study of F2 layer propagation. There are years in the sunspot cycle when correlation with sunspot number is clearly very good (e.g. 1973 and 1974), and during any year in the period around the equinoxes. On the other hand in the summer of solar maximum years correlation is best found after sunset, perhaps because the high general level of ionization tends to obscure

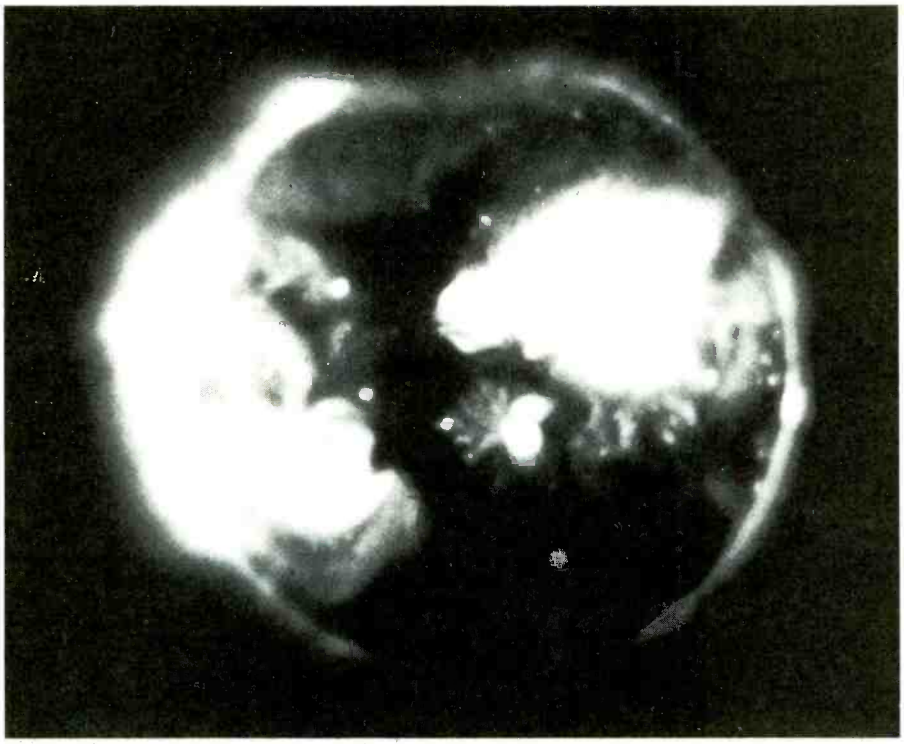


Fig.8. A coronal 'hole', pictured by Dr L Golub. (Science Photo Library)

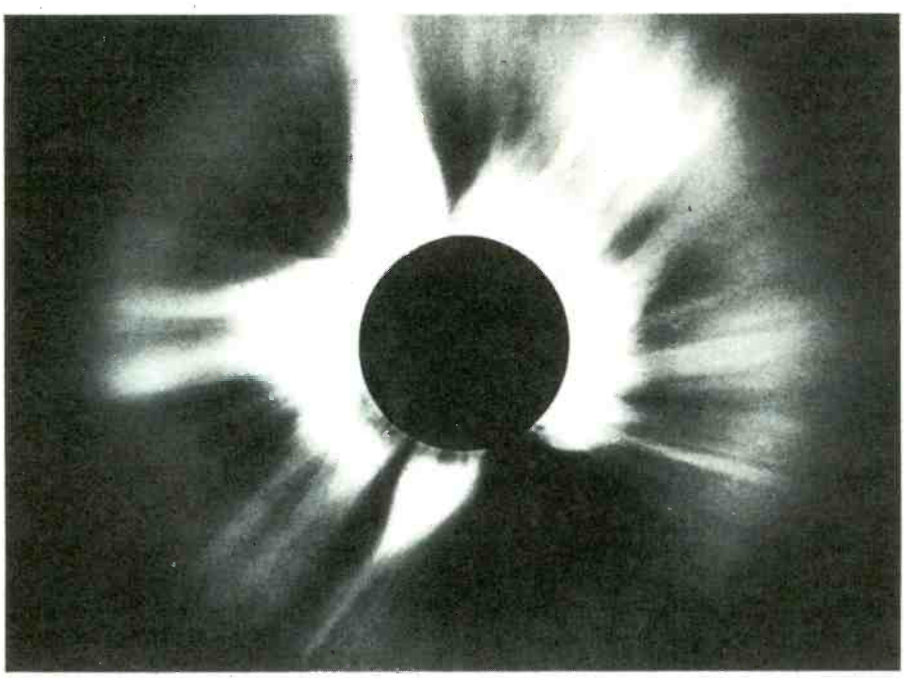


Fig.9. Solar corona taken by a ground-based telescope during the total eclipse of March 7, 1970 (National Center for Atmospheric Research USA/Science Photo Library).

the variation in energy input until the sun is low in the sky. I feel one ought to bear in mind that sunspot number is only the most readily observable indication of solar activity. It is because of this observability that we have sunspot records extending for 300 years – since Galileo's time, in fact (Fig.6) – with sporadic reports of non-instrumental sightings even much earlier.

Which feature of solar surface activity is connected with terrestrial effects is the subject of intense research, nowadays greatly aided by numerous satellites and orbiting laboratories. Some of the candidates for investigation regarding effects on the ionosphere are, beside sunspots, foci of X-ray emission, coronal 'holes' (Fig.8) and the corona itself (Fig.9) with its exceedingly high plasma temperature. Direct UV and X-ray emission reaches the earth simultaneously with visually observable changes (as from a solar flare during a Dellinger fade out), but charged particles emitted during such an event will reach the Earth some time after the emitting region has passed the solar meridian, the delay being a function of the rather variable velocity of emission.

During a solar flare shown in the heading picture and – following the Dellinger fade due to intense ionization of the D region over all the illuminated half of the earth's surface – these particles reach the ionosphere several hours later, producing yet further disruption of radio signals. Since the particles travelling earthwards are electrically charged, they can only enter our atmosphere via the polar regions, hence the 'northern lights' – and only then does their effect penetrate to mid and lower latitudes.

An ionospheric disturbance observed in the north of Scotland may take twelve to twenty four hours to affect the ionosphere in the south of England and generally with considerably less severity. In the polar regions, on the other hand, severe communication blackouts occur under these conditions, affecting all signals traversing the Arctic circle.

The advent of satellite links has tended to obscure the existence of large sections of users of traditional h.f. radio, even in the cognizance of the professional engineer. Because INMARSAT exists, it is assumed to be in general use, or just about to be. In fact, only a fraction of the world's shipping is so equipped and there are some problems for the smaller vessel. The cost of about £20,000 for an installation has to be justified, whilst fitting a 200 kg stabilized platform at the highest point of the vessel poses problems of stability. Oddly enough, though, the fitting of such installations to the 'motherships' of fishing fleets has proved very popular with, for instance, Japanese ships fishing off Newfoundland, by providing good quality voice-links with Japan which are difficult to achieve by h.f. radio for the reasons given above.

The boost to crew morale is an important selling point and so is the secure communication provided in the traditionally secretive fishing industry. On the other hand, the ionosphere is free and there are few problems, either structural or financial, with the use of h.f. equipment. Only the expertise required to use the ionosphere effectively presents a major obstacle. It is hoped that this article has helped to dispel some of the mystery. Much work in many quarters is directed towards that end and the author readily acknowledges the help received from colleagues over the years. However the opinions expressed are the author's own and do not necessarily represent any official view.

Kurt Feldmesser recently retired from the Science Research Council, where for the last fourteen years he has been concerned with ionospheric observation at Slough and South Uist for the Rutherford Laboratory.

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Acknowledgements

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Fig.6. "A New Sun" The Solar Results from Skylab. John A. Eddy Ed. Rein Ise, N.A.S.A. Washington D.C. 1979.

Fig.9. National Center for Atmospheric Research, U.S.A./Science Photo Library.

Fig.8. Dr L. Golub/Science Photo Library.

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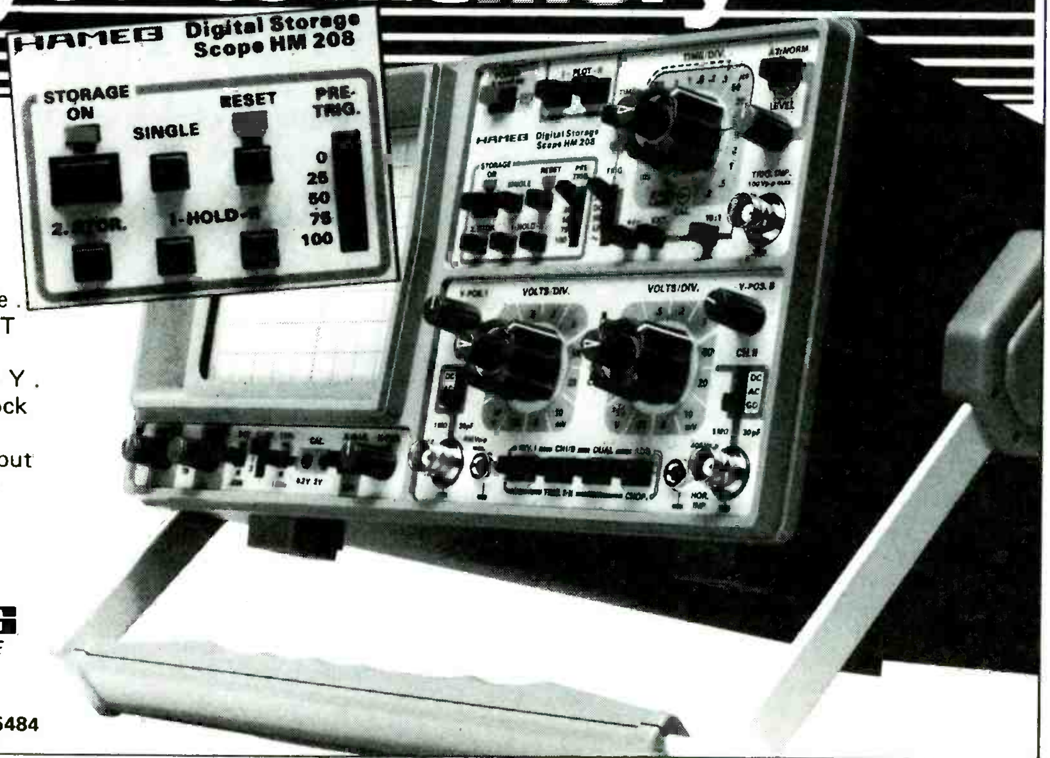

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Heatsink simulation on a personal computer

Take a cool look at your next heatsinking problem with this versatile analysis technique

BY J M HOWELL

Distributors' catalogues nowadays offer a bewildering variety of heatsinks, ranging from tiny clips similar in size to the device on which they are fitted, to massive aluminium extrusions with provision for forced air cooling. The material, shape and surface finish are chosen to conduct heat away from the attached devices and dissipate it to the surroundings in an efficient manner. Selecting such a component is usually a simple task: the maximum acceptable thermal resistance is calculated by dividing the heat load in watts by the temperature gradient in degrees C, and a heatsink with a similar or slightly lower resistance can be picked out of the catalogue.

This approach is adequate when the designer feels a stock item is satisfactory but it is often worth considering alternative methods of heat removal. A frequent possibility is to use the metal case of the equipment, though any metal component has potential as a heatsink. Unfortunately the average equipment enclosure is not designed with heat transfer in mind, and thermal resistance is not usually quoted in the specification. The properties of a thin metal sheet are substantially different from a professionally designed heatsink of similar area.

Although the only certain way of assessing a heatsink system may be to actually manufacture and test it, advantage may be taken of modern technology to narrow the range of possibilities. This article develops a mathematical model of a simple plate heatsink and shows how a personal computer may be used to solve the resulting set of equations.

MATHEMATICAL THEORY OF HEAT TRANSFER

Of the three ways in which heat is transferred only conduction is relevant within the bulk of the metal heatsink, and the other two are responsible for the removal of heat from the surface. The quantity of heat transferred is directly related to the temperatures of the components and their physical properties.

The fundamental relationship that describes the steady-state temperature distribution T(x,y) across a uniformly conducting plate, Fig.1, is the Laplace equation:

$$\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}=0.$$

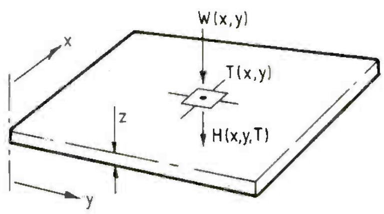

Fig.1. Mathematical model is based on a thin plate which gains heat from devices at several points on its surface. This heat is distributed throughout the plate by conduction and removed by radiation and convection.

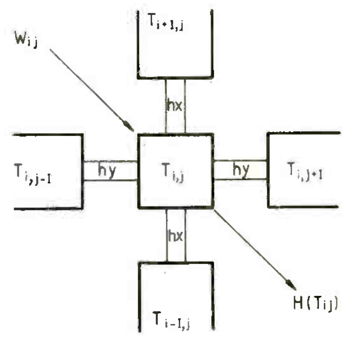

Fig.2. Numerical method treats the plate as a patchwork of small tiles joined by imperfectly conducting glue. Smaller tiles give greater accuracy but require more computer time to solve.

This is modified in our case by the presence of one or more heat sources W(x,y) and the effect of heat lost to the surroundings by convection and conduction, H(x,y,T). The conductivity of the metal, k_m, is also introduced now to give

$$k_m z\left[\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}\right]+W-H=0$$

As no heat is lost from the narrow edges of the plate the boundary conditions along all edges will be

$$\left.\frac{\partial T}{\partial x}\right|_{y=o}=\left.\frac{\partial T}{\partial y}\right|_{x=o}=\left.\frac{\partial T}{\partial x}\right|_{y=ymax}=\left.\frac{\partial T}{\partial y}\right|_{x=xxmax}=0$$

These equations constitute a complete mathematical description of the problem, but they do not have a known analytical solution, since the loss term H is a nonlinear function of temperature. However, a numerical solution is still possible if we divide the plate up into a rectangular grid and derive the corresponding set of finite-difference equations.

This is equivalent to assuming that the plate is actually built up from a number of perfectly conductive tiles which have been joined at their narrow edges with imperfectly conducting material, Fig.2. As the tiles become smaller, the finite-difference solution approaches the true one. For a section which does not lie on the edge of the plate:

$$(T_{i+1,j}-2T_{i,j}+T_{i-1,j})h_x+(T_{i,j+1}-2T_{i,j}+T_{i,j-1})h_y+W_{i,j}-H(T_{i,j})=0$$

where $h_x=k_m z\Delta y/\Delta x$ and $h_y=k\Delta x/\Delta y$.

The boundary conditions are introduced by modifying the above equation for sections which lie on the edges, to remove the terms which represent the temperature difference beyond the plate edges.

The Stefan-Boltzmann law, which relates the temperature of a surface to the radiated heat loss, can be used to find the corresponding part of term H. The convective loss part is more difficult to determine, since it depends on the size, attitude and shape of the surface. An empirical relationship for small rectangular vertical plates has been chosen as the most useful case:

$$H(T)=[k_r((T+T_{amb}+273)^4-(T_{amb}+273)^4)+k_c(T+T_{amb})^{1/4}]E\Delta x\Delta y.$$

NUMERICAL SOLUTION OF THE EQUATION SET

Each grid point of the plate has one equation associated with it, and the temperature profile is the simultaneous solution of all these equations. The distribution of unknown variables (temperatures) within the equations and the presence of nonlinear terms forces us to adopt an iterative scheme. In this, we guess a temperature distribution and gradually improve on it until all the equations are satisfied. Naturally the guess and improvements are the result of some fairly complex computations, which are derived next.

Rewriting the equation set in matrix form, at the solution

$$At+w-h(t)=0,a$$

and at a point **dt** away from it,

$$A(t+dt)+w-h(t+dt)=e.$$

Here, A is a matrix with positive constant terms h_x and h_y appearing symmetrically about the leading diagonal and the negative sums of these terms along this diagonal, and **t, w** and **h** are the vector forms of the respective terms in the earlier paragraph.

Taking the first term of the Taylor expansion of **h** and subtracting the two equations we obtain the relaxation of the iteration scheme. This will determine the step dt which should reduce **e** to zero:

$$dt=-(A-\frac{d\mathbf{B}}{dt})^{-1}\mathbf{e}.$$

To solve this equation, the matrix (known as the Jacobian) does not need to be inverted but still needs to be factorized, that is, reduced to lower and upper triangular factors. This is a lengthy process which, if repeated at each iteration, would add greatly to the task. Fortunately, the only term which changes from one iteration to the next is the derivative of **h**, and in practice a small error in its value makes little difference. Consequently, a good estimate at the start will suffice for all subsequent iterations and the same factorization can be used repeatedly.

The initial guess for the temperature profile is found by assuming the whole plate is perfectly conducting and applying a crude substitution algorithm. The derivative term then follows from the change in H for a unit increase in T.

```
STEADY STATE HEATSINK SIMULATION

 1 . ALUMINIUM
 2 . COPPER
 3 . BRASS
 4 . MILD STEEL

SELECT MATERIAL (1-4) ? 3
EXPOSED SURFACE RATIO (0.5-4) ?  1.2

ENTER 0 TO FINISH
HEAT INPUT (WATTS) ? 11.92
GRID LOCATION (1- 3 ,1- 5 ) ?  1  1

HEAT INPUT (WATTS) ?  0

STEADY STATE HEATSINK SIMULATION

PLATE DIMENSIONS
LONG EDGE (MM) ? 262
SHORT EDGE (MM) ? 114
MATERIAL THICKNESS (MM) ? .9

Factorising Jacobian
Solving Equation Set
At iteration  1   Error in T = 33.1598
At iteration  2   Error in T = 1.80991
At iteration  3   Error in T = .181643
At iteration  4   Error in T = 2.01621E-02
At iteration  5   Error in T = 2.48715E-03


STEADY STATE HEATSINK SIMULATION

BRASS HEATSINK IN AIR AT 25   DEG C
SIZE = 262 BY 114 BY .9 MM
WEIGHT = 223.114 GRAMS

HEAT SOURCES (WATTS)
 11.92          0              0
 0 -            0              0
 0              0              0
 0              0              0
 0              0              0

TEMPERATURE DISTRIBUTION (DEG C)
 114.62         77.94          63.87
 64.97          57.38          52.6
 45.74          44.04          42.69
 37.34          36.93          36.57
 34.02          33.9           33.78

Break in 1480
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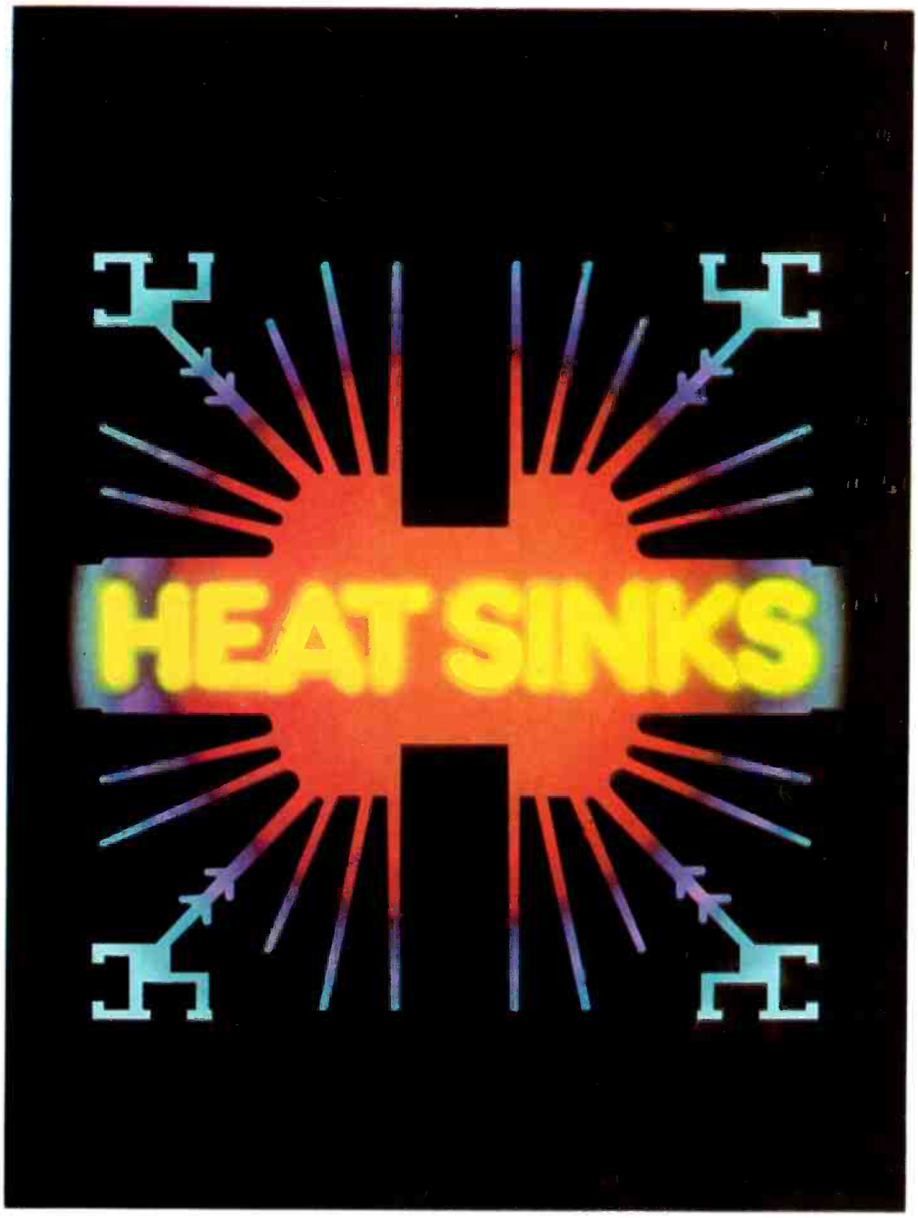

PROGRAM DESCRIPTION

The solution method described above involves a great many repetitive calculations, and is only practical when programmed into a suitable machine. To this end, a program has been written in Microsoft Basic for use on a personal computer (actually an IBM PC), but special care has been taken to avoid machine-specific features, so it should run with little or no modification on a wide range of machines.

The program starts by setting up the data structures and constants it will need later. The most important of these is the size of the grid used to build the set of finite-difference equations, preset by NX,NY to 3 by 5. There is nothing to stop this being altered except that the computation time increases as the cube of the product of NX and NY. The values above will give computation times of around half a minute on an IBM PC or similar.

The next part of the program is concerned with reading and validating the problem by asking the user a series of simple questions.

SYMBOLS IN EQUATIONS

A	Matrix of heat transfer coefficients h_x,h_y
dt	Relaxation step in **t**; residual error in t
E	Exposed surface ratio
e	Vector of residual errors in equations
i,j	Grid indices along short and long edges
H(x,y,T)	Heat loss from unit surface area
h(t)	Vector of surface heat losses from each grid point
k_c	Coefficient of convective heat loss per unit area
k_m	Heat conduction coefficient of plate material
k_r	Coefficient of radiative heat loss per unit area
n_x,n_y	Number of grid points in x and y directions
T(x,y)	Temperature above ambient, deg C
t	Vector of temperature profile $=[T_{1,1}...T_{nx,ny}]$
W(x,y)	Heat input per unit surface area
w	Vector of heat sources to each grid point
x,y	Positions along short and long edges
Δx,Δy	Grid spacing along short and long edges
z	plate thickness

Reporting of errors by the program has deliberately been kept to a minimum to reduce program length but this is easily remedied.

Any number of heat sources may be specified in any order. The answers should be self-evident apart from the 'EXPOSED SURFACE RATIO'. This parameter enables the user to allow for the effect of surface finish and exposure. A single thermally black surface is treated as 1.0, a heavily finned surface would be around 2.0, and a highly polished metal surface, 0.5. If both surfaces of the plate are exposed, the ratio should be doubled.

Once the data has been collected the numerical algorithm can begin. The solution method described above has been implemented, and to speed up the process, given an understanding of popular Basic interpreters, a number of intermediate variables have been introduced. REM statements in the listing explain the principal sections. A subroutine is used to find the heat loss H on one grid rectangle at temperature T. Step-by-step progress reports are included for verification purposes and can be deleted if required. The algorithm terminates when a weighted average of the step vector DT falls below 0.02°C.

Finally a summary of the problem and the table of temperatures at the centre of each grid point are printed. The weight is included as a convenient check that the plate dimensions are reasonable.

```
10 REM HEATSINK MODELLING PROGRAM
20 REM J.M.HOWELL JUNE 1986
30 DEF FNA(X)=INT(X*100)/100
40 NX=3:NY=5:N=NX*NY
50 TAMB=25:KR=5.14E-14:KC=1.98E-06
60 DIM W(N),T(N),A(N,N),E(N),DT(N)
70 RESTORE
80 DATA "ALUMINIUM",0.230,2.7,"COPPER",0.377,8.9
90 DATA "BRASS",0.112,8.3,"MILD STEEL",0.052,7.8
100 GOSUB 1490
110 FOR I=1 TO 4
120 READ M$,X,X
130 PRINT I;". ";M$
140 NEXT I
150 PRINT
160 INPUT "SELECT MATERIAL (1-4) ";M
170 IF M<1 OR M>4 THEN GOTO 160
180 INPUT "EXPOSED SURFACE RATIO (0.5-4) ";E
190 IF E<.5 OR E>4 THEN GOTO 180
200 WI=0
210 PRINT:PRINT "ENTER 0 TO FINISH"
220 INPUT "HEAT INPUT (WATTS) ";W
230 IF W<=0 THEN GOTO 340
240 PRINT "GRID LOCATION (1-";NX;",1-";NY;") ";
250 INPUT I,J
260 IF I<1 OR I>NX OR J<1 OR J>NY THEN GOTO 310
270 K=I+J*NX-NX
280 W(K)=W(K)+W
290 WI=WI+W
300 GOTO 320
310 PRINT I;",";J;" IS BEYOND EDGE OF PLATE"
320 PRINT
330 GOTO 220
340 GOSUB 1490
350 PRINT "PLATE DIMENSIONS"
360 INPUT "LONG EDGE (MM) ";Y
370 INPUT "SHORT EDGE (MM) ";X
380 INPUT "MATERIAL THICKNESS (MM) ";Z
390 PRINT
400 IF Z>0 AND X>=Z AND Y>=X THEN GOTO 430
410 PRINT "PLEASE ENTER IN CORRECT ORDER"
420 GOTO 360
430 REM Determine Heat Transfer Properties
440 RESTORE
450 FOR I=1 TO M
460 READ M$,KM,RHO
470 NEXT I
480 HX=KM*Y*Z/X*NX/NY
490 HY=KM*X*Z/Y*NY/NX
500 REM Define Dissipation Coefficient constants
510 B4=(273+TAMB)^4
520 S=X/NX*Y/NY*E
530 REM Find average plate temperature
540 T=50
550 FOR I=1 TO 5
560 GOSUB 1540
570 T=T+WI-NX*NY*H
580 NEXT I
590 REM Find slope of heat loss curve
600 GOSUB 1540
610 HO=H
620 T=T+1
630 GOSUB 1540
640 DHDT=H-HO
650 REM set up jacobian matrix
660 FOR I=1 TO NX
670 FOR J=1 TO NY
680 K=I+J*NX-NX
690 A=DHDT
700 IF I>1 THEN A(K-1,K)=HX:A=A+HX
710 IF I<NX THEN A(K+1,K)=HX:A=A+HX
720 IF J>1 THEN A(K-NX,K)=HY:A=A+HY
730 IF J<NY THEN A(K+NX,K)=HY:A=A+HY
740 A(K,K)=-A
750 NEXT J
760 NEXT I
770 PRINT "Factorising Jacobian"
780 REM perform LU decomposition on jacobian
790 FOR I=1 TO N-1
800 FOR J=I+1 TO N
810 A=-A(I,J)/A(I,I)
820 A(I,J)=A
830 FOR K=I+1 TO N
840 A(K,J)=A(K,J)+A(K,I)*A
850 NEXT K
860 NEXT J
870 NEXT I
880 PRINT "Solving Equation Set"
890 L=0
900 REM Main iteration loop start
910 REM Find error term
920 FOR I=1 TO NX
930 FOR J=1 TO NY
940 K=I+J*NX-NX
950 T=T(K)
960 GOSUB 1540
970 E=-H+W(K)
980 IF I>1 THEN E=E+HX*(T(K-1)-T)
990 IF I<NX THEN E=E+HX*(T(K+1)-T)
1000 IF J>1 THEN E=E+HY*(T(K-NX)-T)
1010 IF J<NY THEN E=E+HY*(T(K+NX)-T)
1020 E(K)=E
1030 NEXT J
1040 NEXT I
1050 REM solve matrix equation for DT
1060 FOR I=1 TO N-1
1070 FOR J=I+1 TO N
1080 E(J)=E(J)+A(I,J)*E(I)
1090 NEXT J
1100 NEXT I
1110 FOR I=N TO 1 STEP -1
1120 DT(I)=E(I)
1130 FOR J=N TO I+1 STEP -1
1140 DT(I) =DT(I)-DT(J)*A(J,I)
1150 NEXT J
1160 DT(I)=DT(I)/A(I,I)
1170 NEXT I
1180 REM compute norm of DT and update T
1190 D2=0
1200 FOR I=1 TO N
1210 D2=D2+DT(I)*DT(I)
1220 T(I)=T(I)-DT(I)
1230 NEXT I
1240 DT=SQR(D2/NX/NY)
1250 REM Loop monitoring
1260 L=L+1
1270 PRINT "At iteration ";L;" Error in T =";DT
1280 IF DT>.02 THEN GOTO 900
1290 REM Output Results
1300 GOSUB 1490
1310 PRINT M$;" HEATSINK IN AIR AT";TAMB;" DEG C"
1320 PRINT "SIZE =";Y;"BY";X;"BY";Z;"MM"
1330 PRINT "WEIGHT =";X*Y*Z*RHO/1000;"GRAMS"
1340 PRINT:PRINT "HEAT SOURCES (WATTS)"
1350 FOR J=1 TO NY
1360 FOR I=1 TO NX
1370 PRINT TAB(I*12-11);FNA(W(I+J*NX-NX));
1380 NEXT I
1390 PRINT
1400 NEXT J
1410 PRINT:PRINT "TEMPERATURE DISTRIBUTION (DEG C)"
1420 FOR J=1 TO NY
1430 FOR I=1 TO NX
1440 PRINT TAB(I*12-11);FNA(T(I+J*NX-NX)+TAMB);
1450 NEXT I
1460 PRINT
1470 NEXT J
1480 STOP
1490 REM Print title
1500 CLS
1510 PRINT:PRINT "STEADY STATE HEATSINK SIMULATION"
1520 PRINT
1530 RETURN
1540 REM Find heat loss H for temp rise T
1550 A=T+TAMB+273
1560 HR=KR*(A*A*A*A-B4)
1570 HC=KC*SQR(SQR(ABS(T+TAMB)))*T
1580 H=(HR+HC)*S
1590 RETURN
```

PROGRAM VERIFICATION

To check the results of the simulation program a practical test was conducted. The conditions were chosen to exaggerate the known weaknesses of the solution method, so it may be regarded as an extreme case.

A bright, unpolished brass plate was marked off with the appropriate grid and a power transistor mounted in the centre of a corner rectangle. Fourteen small transistors were press-fitted into holes at the centre of each remaining rectangle for use as temperature sensors, and a 15th fitted to one side of the power transistor. This equipment was run for 30 minutes under the specified conditions to reach a steady state and the temperature distribution measured. The results are shown in Table 1.

Table 1. Temperature profiles deg C

63	60	50	41	39	
81	66	52	43	39	Horizontal plate
104	74	52	43	40	
64	58	46	38	35	
80	62	47	39	35	Vertical plate
98	68	46	38	35	
64	53	43	37	34	
78	57	44	37	34	Simulation program
114	65	46	37	34	

Table 2. Test conditions

Plate material: 70/30 plain brass sheet
Plate dimensions: 0.9 by 262 by 114mm
Heat sources: 11.9 watts into grid point 1,1
Exposed surface ratio: 1.2

Apart from the hottest corner, the vertical plate temperatures show fair agreement with the simulation. The horizontal attitude was tried to determine the validity of the empirical convection equation under such circumstances. The discrepancy in the hot corner is probably due to the relative position of the sensor, which lay midway between the grid centre and the plate edge.

The simulation results can of course be used to verify the program after it has been typed in. For this reason the screen output for a complete run is included, and the output from any Microsoft-type Basic should agree very closely with this. Any deviation indicates a typing error or some non-standard aspect of the Basic interpreter. An example of the latter is the BBC computer, which executes all FOR-NEXT loops at least once, even if the loop range is actually nil. This introduces a bug which makes the program take many more steps than are needed. For correct operation in this instance an extra line is required: 1125 IF I=N THEN GOTO 1160.

USING THE PROGRAM

The main benefit of a program of this nature is that a large number of possibilities can be considered at an early stage of a project and the non-starters eliminated without wasting effort on them. The program has been written for flat metal plates and if lower accuracy can be tolerated any shape or structure may be analysed as a plate of similar thickness and area. The effect of mounting several devices on the same heatsink can also be studied.

The results need to be tempered with a degree of engineering judgement. For example, the individual rectangles of the grid are assumed to be perfectly conducting, and if an exceptionally thin or poorly conducting plate is modelled then this assumption will not be valid. In consequence the temperature of the centre of each hot rectangle is appreciably higher than predicted by the model. To overcome this problem a finer grid must be used. A more powerful computer may then be needed, or the Basic program could be compiled, to avoid long run times.

Despite the limitations, many will find this program a valuable addition to their software library.

Dr. Howell worked as chemical and systems engineer for various companies, and is presently control engineer at ICI, Billingham. He gained his Ph.D. for research into optimal control of large chemical process networks, and has interests in electronics, computing, and amateur radio.

LOGS AGAIN

Flushed with success at demystifying decibels, Joules Watt has not yet finished with logarithms...

JOULES WATT

A short while ago I commented upon what might be called slovenliness, regarding the use of decibels [1].

If not slovenliness, at least loose thinking about such matters causes confusion for the poor student. This has become true for novice radio amateurs as well. One confided to me, "It struck a little fear into nearly all the RAE class, when the mysterious dB arose in transmitter power discussions". I hope my short discourse earlier helped dispel some of the mystery.

But we are not out of the wood yet, because two colleagues took me to task with criticisms. One said, "You got no further towards helping anyone see the meaning of response curves. Are the 6 dB per octave slopes a drop-off in power gain or voltage gain?" The other fellow suggested I too was being a little slovenly, in that doubling the power is not exactly 3 dB up, therefore four times is not exactly 6 dB, and so on. He is right, of course, but the differences are very small, as Table 1 shows.

Much of all this argument appears to rest on the properties of logarithms. Long gone are the days when we slaved away looking up columns of figures in tables for something called the mantissa and something else called the characteristic – or are they? Nevertheless, it was only when we arrived at the integral calculus that we discovered a mysterious "irrational" number called e. As with π before it, we were told that "it has an unending, never repeating decimal part, which arises naturally..."

It soon became obvious that logs arise from this number e, as well as via the laws of indices generally. A logarithmic result to the base e is obtained when the area under a rectangular hyperbola is sought by using the integral

$$y=\int\frac{dx}{x}=\ln x \qquad (1)$$

The symbol "ln" reads "The natural logarithm of..." and is also written "$\log_e$". The common logs to the base ten (written $\log_{10}$, or just log for short from now on), cropped up recently in the discussion of decibels[1]. Log to the base 2 ($\log_2$) is seen in discussions concerning information and communications theory.

When physical quantities, instead of pure numbers, become involved in this kind of calculation, trouble tends to arise. Pure mathematicians avoid all that by claiming that they work with pure numbers only. Dimensions never come into things. Engineers, on the other hand, are always talking about so many amps, volts, newtons, watts and the question is asked as to whether the unit is inside the symbol – or attached separately. In other words, is the quantity R a number complete with dimensions ohms within it, or should it be written R ohms, where R is a pure number?

From the integral (1) y is certainly dimensionless, because if x has dimensions, the small bit of it, dx, has the same dimensions, and these cancel in the ratio. But if x does have dimensions, say watts, then the question is whether log of watts can equal a dimensionless number? This is not a real problem, because I have neglected the fundamental need for a constant to add on to any integration. In this case (for example) we can say "let x = p watts when y = 0" so that the constant is $-\ln p$ and the complete answer is:

$$y=\ln\frac{x}{p}$$

and everyone is happy, as we have a pure ratio of watts over watts again.

But this is not so for the 'quantity-calculus' people [2,3,4], who argue that the symbols of the units can be handled and juggled just like numbers. You can square them, divide, take logs of them. And so, as you might expect, a fairly hot controversy has raged over the claim to do this.

After considering these arguments, I incline towards the old view that quantities cannot have logs taken of them – or the sine, tangent and so on, for that matter. We can only use *ratios* of same-dimensioned quantities in the arguments of the transcendental functions. Of course, all the modernists will label my stand as reactionary.

In practice there is no trouble, because the measure of quantities is really a ratio in every case. A voltmeter reading 20 volts is really saying, "The basic unit (volt) goes into the value being read (20 volts) 20 times. i.e., 20 volts/volt equals 20 times." Therefore if we take logs of a power in watts, we are really taking cognizance of a number of times a quantity is in a ratio to the basic unit. Therefore 10log P is really 10log P(watts)/watt or so many dBW.

If we are told that the comparator unit is milliwatts, then the operation can be written

$$10\log\frac{P(\text{watts})}{\text{milliwatt}}=10\log\frac{10^3P(\text{milliwatts})}{\text{milliwatt}}$$

$$\therefore \quad \text{dBm} = (30+\text{dBW})$$

TABLE 1

P_2/P_1	$10\log(P_2/P_1)$	Usually taken as:
2	3.0103	3dB
4	6.0206	6dB
8	9.0309	9dB
10	10	10dB
64	18.0618	18dB
100	20	20dB
2.749×10^{11} (30 doublings)	114.3914	114dB

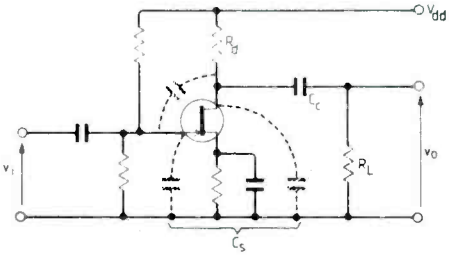

Fig.1. This typical j.fet resistance-capacitance coupled amplifier stage is typical of all such active device gain blocks, (with appropriate attention to input and output impedances). The unmarked components are assumed not to affect the frequency response. In other words, C_c dominates at the low end, while the strays can be lumped together as C_s to limit the performance at the high end.

THE PLOT THICKENS
(at least towards the high values..)

Displaying data logarithmically to expand the detail at the low end of the scale and compress it at the high end enables a huge range of information to be shown on one sheet of graph paper. This explains why log – log and log – linear graphs are so ubiquitous in engineering reports and scientific papers. You can get log paper in so many cycles (decades usually) along the two axes. One consequence is that the true origin goes off to infinity downwards and to the left along the axes. ($\log 0 \rightarrow \infty$).

Another reason why log plotting is so useful is that many phenomena vary logarithmically, which means many data measurements produce straight line plots on log – log paper. Other "laws" which would produce curves on linear-only paper, will produce straight line plots on log – lin paper.

Again, to overcome the "worry" about the meaning of units along the log axes, we think of the numbers as 'so many units per unit' of the quantity, so that you are never taking the log of anything but a pure ratio. (A ratio is a pure number, but a *rate* is a quotient of different quantities – like 'miles per hour'.)

IT BODES WELL

By measuring the power output of an amplifier and (with the same power meter) the power input, we can take their ratio and thus write down the power gain in dB. Whether this is the available power gain, or the transducer gain, or matched power gain and so on, is another confusion, as it dawns upon us that different people define power gain differently. Nevertheless, the ratio of two powers to give decibels is now basically simple.

The question might arise as to *relative* gain over, say, the frequency band of an amplifier. It might also be asked for in terms of the voltage gain. But we sigh with relief because the relative gain will be measured at the same point (the output terminals) and therefore across the same impedance, assumed to be a non-reactive load for instance. This means that voltages can be measured for the decibel levels.

All amplifiers suffer shunting-capacitance losses as the frequency rises. These strays cannot be eliminated, so gain falls off somewhere at the high end. Many amplifiers have series coupling capacitors (except d.c. amplifiers) so however large these are, eventually the gain will drop off towards the low frequency end as the magnitude of the reactance increases beyond the resistance values. In other words, all amplifiers are bandpass circuits. The bandwidth B is the frequency interval between the "3 dB down" points. Of course, specialized amplifiers might depart from this simple scenario. Baxandall tone control stages would do so, for example. Figure 1 shows how a simple voltage amplifier fet stage appears.

Figure 2 shows the well known equivalent generator circuit for such a stage incorporated into the mid-frequency range, where the capacitances have no effect; the low frequency region, where C_c dominates, but the shunt strays do not; and at the high frequency end where the total shunt capacitance C_s dominates, but C_c does not. These notional independent regions are the usual assumptions made about a fairly wide-band amplifier, but for narrow-band cases other methods have to be used.

The mid-band voltage gain is simply the voltage-controlled generator current multiplied by the total equivalent resistance at the output:

$$A_{mid} = \frac{v_o}{v_i} = -g_m R_{eq}$$

where $R_{eq} = \frac{r_d R_d R_L}{r_d R_d + r_d R_L + R_d R_L}$

In order to see the effect of C_s at high frequencies, it is added in shunt to R_{eq} as shown in Fig.2(b)

$$A_h = \frac{v_o}{v_i} = -g_m Z$$

where Z is $\frac{-jR_{eq}X_s}{R_{eq}-jX_s}$ or $\frac{R_{eq}}{1+j\frac{R_{eq}}{X_s}}$

and $X_s = \frac{1}{\omega C_s}$

But $-g_m R_{eq}$ is A_{mid}

therefore: $\frac{A_h}{A_{mid}} = \frac{1}{1+j\frac{R_{eq}}{X_s}}$

This can be written $\frac{1}{1+j\frac{\omega}{\omega_2}}$

where $\omega_2 = \frac{1}{R_{eq}C_s}$

The ratio of the high-frequency gain to the mid-frequency value, is called *normalization* – in this case, normalizing to the mid-frequency gain as a reference. It is as though we have set the mid value to unity, but normalization does more than that, it removes any dimensions of the quantities in the ratio, (although in this case, the As are already dimensionless).

The result derived for the normalization voltage gain is a complex number. You probably remember such numbers have real and imaginary parts. Because I introduced phase shifts resulting from the circuit reactances by using the operator j, the complex result arises naturally. It has the advantage that when written down in the polar form, the amplitude (or magnitude) and the phase angle are immediately given. In the present context, these two pieces of information tell us all we want to know about the amount of amplification on the one hand and the shift in phase of the output relative to the input, at any given frequency, on the other.

$$\therefore \frac{1}{1+j\frac{\omega}{\omega_1}} = \frac{1}{\sqrt{1+\frac{\omega^2}{\omega_2^2}}} \angle -\tan^{-1}\frac{\omega}{\omega_2} \qquad (2)$$

I have written this result using the rather out of fashion notation for amplitude A, and angle $\angle\ \theta$, but which has merit and perhaps we should rehabilitate it a little.

Returning to Fig.2(c) where I show the equivalent circuit for the low-frequency end, the effect of C_s is now negligible, but that of C_c rises into prominence. The generator current divides into r_d and R_d in parallel as one path, and C_c in series with R_L as the other. I have combined the result of r_d and R_d in parallel as R_D and, using the current divider formula, the current through R_L can be written down. Knowing the current through the load resistor will give the voltage across it, namely, v_o.

$$\therefore \quad v_0 = \frac{-R_D g_m v_i R_L}{R_D + R_L - jX_c}$$

where $X_c = \frac{1}{\omega C_c}$

The algebra can be re-arranged to give a 1 +j term in the denominator to make it look like the first result:

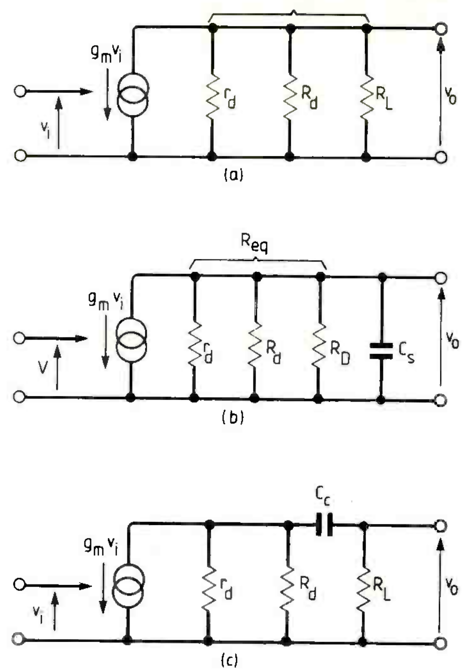

Fig. 2. In (a) the mid-band equivalent circuit is shown. The 'mid-band' can be defined as $\omega_{mid} = \sqrt{\omega_1 \omega_2}$. At (b) is the effect of C_s which shunts the output circuit. The "3 dB down" frequency is that at which the magnitude of the reactance of C_s becomes equal to R_{eq}. This frequency, also known as the 'high-frequency cut off point', is denoted ω_2, where ω_2 is $2\pi f_2$. f_2 is the frequency in hertz.

The low-frequency case shown in (c) is a little more awkward, in that C_c is in series with R_L and this is in shunt across the rest of the resistive components. ω_1 is the cut off frequency at the low end and it occurs at the frequency where the reactance of C_c has a magnitude equal to R_L summed with the resultant of r_d and R_d in parallel.

$$\frac{v_0}{v_i} = \frac{-R_D g_m R_L}{R_D + R_L - jX_c} = \frac{-R_{eq} g_m}{1+j\frac{R_D+R_L}{X_c}} \cdot \frac{j(R_D+R_L)}{X_c}$$

$$= \frac{-R_{eq} g_m \frac{\omega}{\omega_1}}{1+j\frac{\omega}{\omega_1}}$$

Where R_{eq} is the same as before.

Writing the final line for the normalized gain at low frequencies, we obtain:

$$\frac{A_L}{A_{mid}} = \frac{1}{1+j\frac{\omega}{\omega_1}} = \frac{\frac{\omega}{\omega_1}}{\sqrt{1+\frac{\omega}{\omega_1^2}}} \angle \pi - \tan\frac{\omega}{\omega_1}$$

This time ω_1 stands in for $1/(R_0+R_L)C_c$ and is another cut-off point – the low frequency one. These values, ω_1 and ω_2, are also called "break" frequencies. The reason for these terms becomes obvious when we get back to logs shortly.

Before taking logs of the amplitude of the low and high-frequency gain variations, I have plotted in Fig.3 the linear amplitude versus frequency result as an instructive illustration of a direct attack. This turns out to be less useful than at first thought. A log –

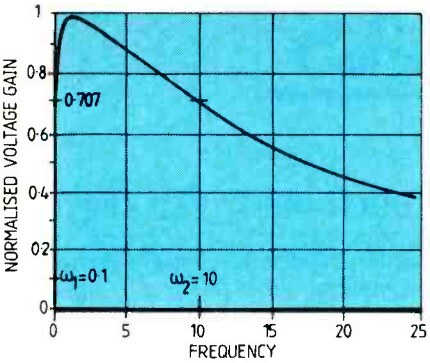

Fig.3. A very lop-sided result occurs if linear plots are attempted for frequency response. Also such curves accord very badly with subjective results, considering the logarithmic response of the ear.

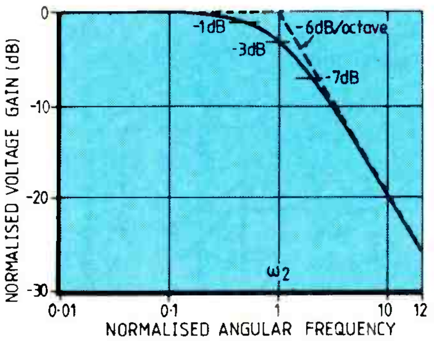

Fig.4. A Bode plot such as that shown here for the high-frequency response, is a very convenient way of using a logarithmic presentation to give a rapid overview of data quickly.

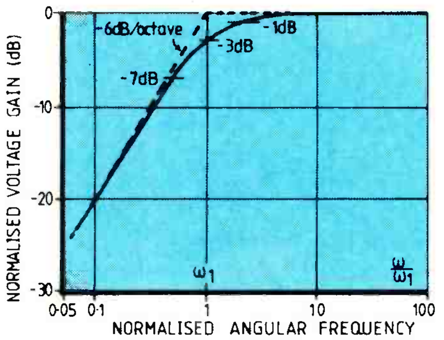

Fig.5. A similar plot at the low-frequency end of an amplifier's response gives similar information just as conveniently.

log plot (on log – lin paper, because decibels are used on the vertical axis) is much more fruitful. The log plots turn out to be "piece-wise linear" and they are all associated with the name Hendrik Bode[5]. These Bode plots are a very quick way of seeing the frequency characteristics of an amplifier, once the complex gain equations have been derived and the logs taken.

Consider the high-frequency end of the amplifier response I have discussed above. We take common logs of the normalized gain expression (equation 2):

$$20\log\frac{A_h}{A_{mid}}=20\log\frac{1}{\sqrt{1+\frac{\omega^2}{\omega_2^2}}}=-20\log\sqrt{(1+\frac{\omega^2}{\omega_2^2}}$$

Taking twenty times the log is no mistake – as we now have the normalized voltage gain in decibels to plot against the log of the frequency.

If you take a look at the log equation above with $\omega<<\omega_2$ then the right-hand side approaches log 1, which is 0. Therefore, on the log plot there is a horizontal line at 0 dB which corresponds to the normalized mid-band value. Now consider $\omega>>\omega_2$. The "1" can be neglected now in the bracket of the log argument:

$$\therefore \quad \left(\frac{A_h}{A_{mid}}\right)dB=-20\log\frac{\omega}{\omega_2}$$

Plotting this on Fig.4 gives a straight line with a slope of −20 units for every factor of ten times ω increase. The units here, of course, are decibels. The two asymptotes have a common point at $\omega=\omega_2$. Therefore on the log plot, an approximation to the amplifier response has been obtained with a sharp "break" point at ω_2. You can see that in practice, at $\omega=\omega_2$, the argument of the logarithm is $\sqrt{2}$, and the actual response is down 3 dB at this point. When the frequency is at twice the cut off value, then the actual response is $20\log\sqrt{5}$ = 7 dB down. This is one decibel lower than the asymptote at the $2\omega_2$ point. Similarly, at half ω_2 the response is again one dB lower. This means we can sketch the actual smooth response curve quite accurately. The last notable comment to make is that the slope of the response curve approaches "6 dB per octave". We now have all the 'jargon' commonly met in these discussions. The "3 dB down" point; "6 dB per octave" or "20 db per decade"; "break point" and so on.

This kind of response is typical of a "one-pole system", where the pole is at the frequency which makes the denominator zero in equation 6. The lower break point is obtained in the same way, except that there is a "zero" in the numerator (see equation 3) as well as a pole at ω_1. I will "leave it as an exercise for the student" as the saying goes, to sketch the Bode plot at the low end. You should get a curve such as that in Fig.5. I have also left out of the discussion the plot of the phase angle from the $\tan^{-1}$ information. For completeness this should be done and readers can do it themselves, if interested.

I have mentioned poles and zeros. They have arisen naturally in logarithmic discussions of response curves via Bode plots. But any further look at them is a whole topic, and suffice it must be for now to hope that I have answered my critic's point about "what does it mean about 3 dB down on response curves?" and in doing so might have pointed up for you a few of the mysteries of these curves...

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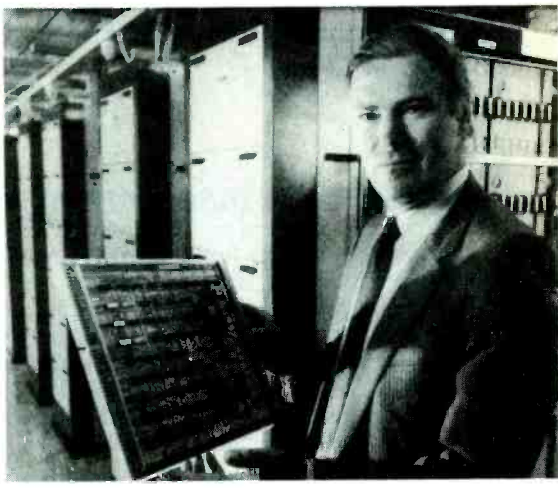
System X speedup



The benefits of digital switching came to a further 3500 telephones in the City of London when this System X exchange went into service at the end of August.

A panel from the 600 exchange is demonstrated here by Ian Vallance, British Telecom's chief of operations. The new equipment forms one of two exchanges housed at Wood Street and it replaces two floors of 39-year-old Strowger electromechanical switches. The other exchange, 726, will be commissioned shortly.

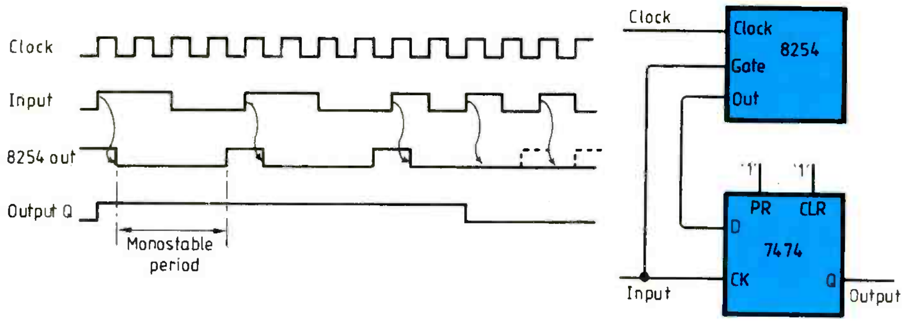
All telephone users should benefit from an improvement in the quality of service. But System X offers many new features to suitably-equipped customers, such as direct digital interfacing.

BT's System X programme has been lagging some 15 months behind schedule because of supply problems. But over 70 System X local exchanges are now in operation nationwide and new digital exchanges are entering service at the rate of one every working day. By the end of the decade, half the BT network and all its trunk circuits will be digital.

Even rural communities are gaining the facilities of System X with the introduction of the smaller UXD5 digital exchange: some 200 are now in use and a further 300 are being installed or are on order. But seven million subscribers will remain on analogue TXE4 systems.

The switch-over at Wood Street took place at lunch-time on a Friday, which is reckoned to be the quietest time in the City. With military precision a squad of exchange staff completed the conversion in a two-minute operation: tugging on handfuls of string festooning the distribution frame, they disconnected the old system by pulling out thousands of tiny plastic wedges. On a further command, with more string-pulling they switched in the new.

CIRCUIT IDEAS



FREQUENCY DISCRIMINATOR

Analogue techniques like the charge-pump and level detector are usually used for frequency discrimination. These require a d-to-a converter to make them digitally programmable and suffer from a limited operating range.

Digital discriminators count pulses and then periodically compare the count with a reference, giving a large threshold range but requiring an amount of software that rises with increasing input or reference frequency.

This discriminator uses a programmable timer configured as a monostable device (the Intel 8254 in mode 1) to provide an above/below indication. Extra software is not required and the threshold is programmable over a 1:2^{16} range.

Input leading edges trigger the monostable device. If input is slower than the monostable's timing, a high level is latched in the 7474 and if input is faster a low level is latched.

Pulse widths from 1 to 2^{16} multiples of the input clock can be programmed. Other timers in the same i.c. package can be used to generate the clock. This provides a very wide range of threshold frequencies.

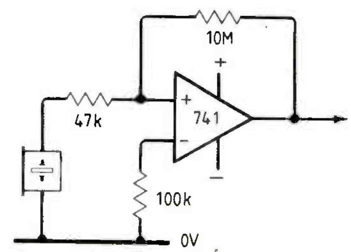
Adrian Godwin
Bedford

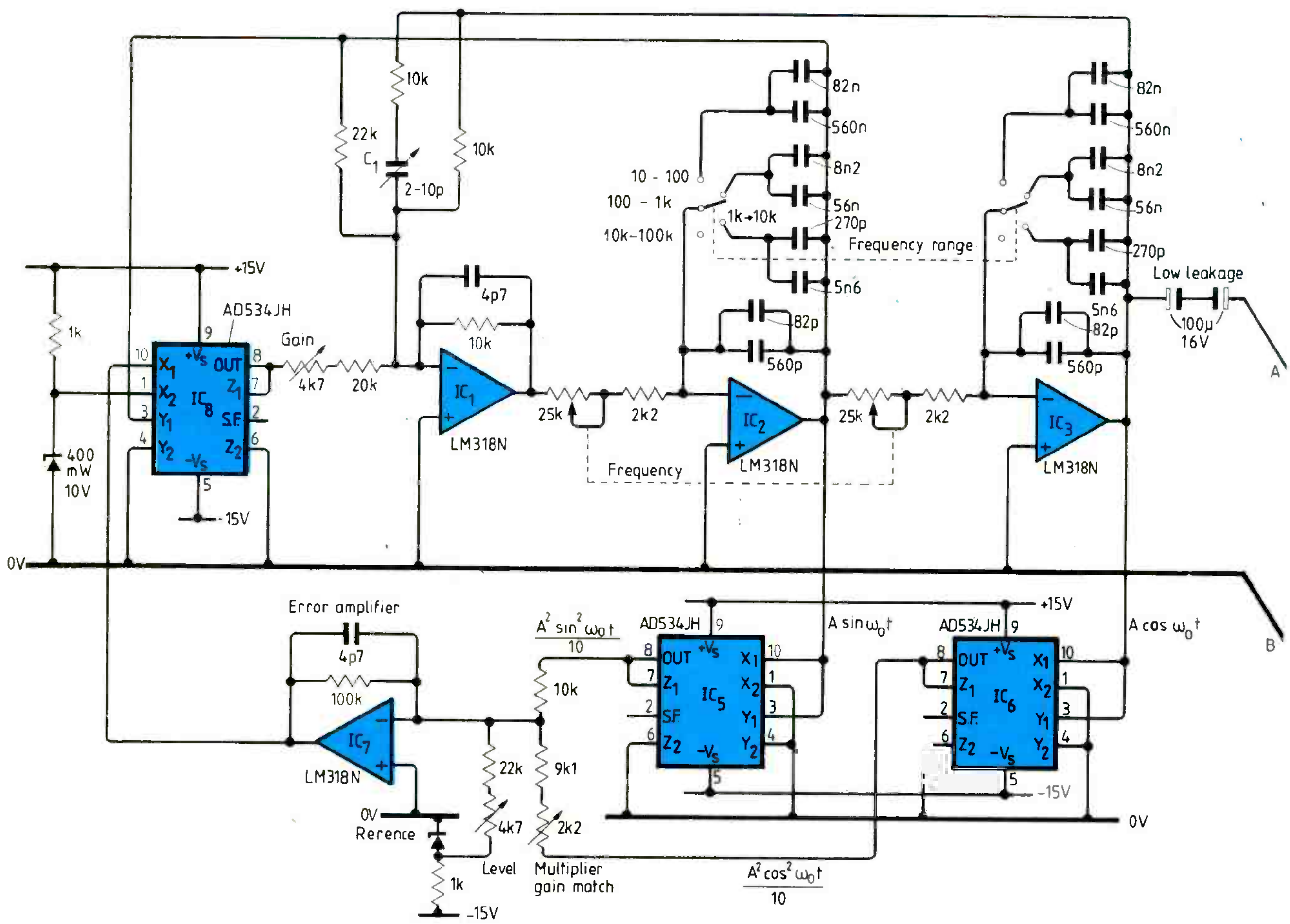
TOUCH-OPERATED SWITCH

Resistive and capacitive touch switches can give problems. When distorted by only light finger pressure, the piezo-electric transducer produces quite a high signal which can be passed through a Schmitt trigger to give a clean switched output.

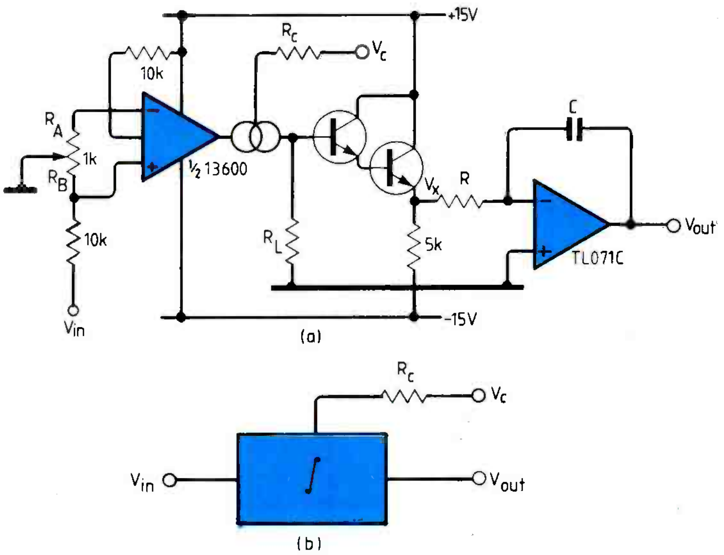
I used a 23-by-0.3mm piezo-electric buzzer element. To completely isolate the transducer, it may be glued to the inside of a plastic container. Turning the transducer over reverses the switch action.

G. Sullivan
Redditch
Worcestershire



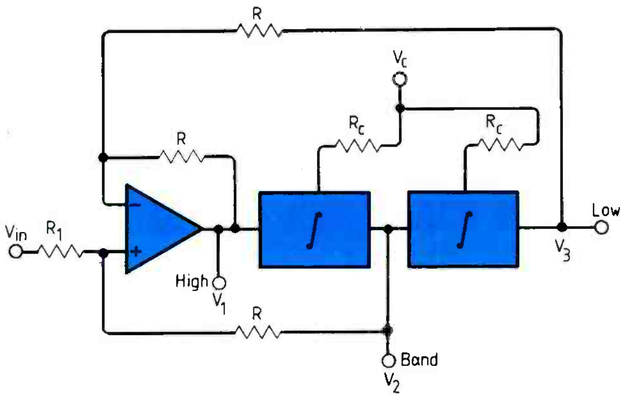


VOLTAGE-CONTROLLED STATE-VARIABLE FILTER



There is a lack of a combination of transconductance amplifier and voltage op-amp on one chip. An application for such an i.c. is this voltage-controlled filter shown using discrete components.

Compared with widely used switched-capacitor networks, this design has a wider dynamic range, higher upper frequency and gives no errors due to clock feedthrough and aliasing.



Output voltage of the voltage-controlled op-amp, V_x, is given by V_{in}/F where F, the scaling factor, is $2V_TR_c/AR_L$. Voltage V_T is 26mV and A is $1+R_B/R_A$.

Integrator output voltage is given by

$$V_{out}=-(V_{in}/F)(1/_{s}CR/V_c).$$

The resistor feeding the integrator inverting input may be seen as a linear voltage-controlled resistance.

With this integrator, shown schematically, the Kerwin-Huelsman-Newcomb state-variable second-order active filter with three op-amps may be altered to make a voltage-programmable filter as shown in the third diagram.

Resonance frequency ωo and Q factor of this filter are given by

$$\omega_0=\frac{V_c/F}{CR\sqrt{R_4/R_3}}$$

and

$$Q=\frac{\sqrt{R_4R_3}}{R_1}$$

Any value of resonance frequency can be set using control voltage V_c and R_1 alone determines the Q factor.

Grain of various filter types is $R_2/\sqrt{R_3R_4}$ for band-pass, R_2/R_3 for low pass and R_2/R_4 for high pass. Bandpass operation gives negative output voltage; otherwise output voltage is positive.

Kamil Kraus
Rokycany
Czechoslovakia

SINE WAVES WITH FAST AMPLITUDE STABILIZATION

Output of this oscillator stabilizes very rapidly because the feedback signal requires no filtering. Any ripple fed back is due to multiplier non-linearities, integrator component mismatch, offsets and op-amp open-loop gain limitations.

Circuits IC_{1-3} form a quadrature oscillator similar to the one presented by Filanovsky *et al.* Multipliers $IC_{5,6}$ square the output; ideally, the summed output contains no ripple ($\cos^2x+\sin^2x=1$). This output is compared with the reference by IC_7 to produce an error signal for controlling gain of IC_8.

With frequency set to 1kHz and output at maximum, adjust the gain-match potentiometer for minimum ripple at output of IC_7. Set the gain-adjust potentiometer so that output of IC_7 is closest to 0V. The level potentiometer is set to give 5V r.m.s. output and C_1 is adjusted to give the flattest frequency response to 100kHz.

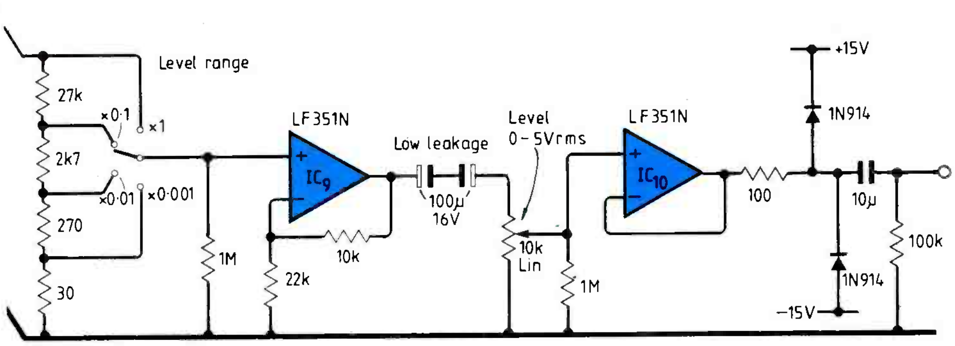
Output amplitude is up to 5V r.m.s. and amplitude variation with frequency is within 0.3dB using ganged potentiometers matched to better than 1%. Distortion is about 0.2% at 1kHz.

Decoupling is needed and stray capacitance should be avoided, particularly around the LM318 inputs and outputs.

Paul W. Chisholm
Maidenhead
Berkshire

Reading

Applications of operational amplifiers, J.G. Graeme, McGraw-Hill.
Fast amplitude stabilization of an RC oscillator, I.M. Filanovsky *et al*, *Wireless World*, July 1982, pp. 52,53.



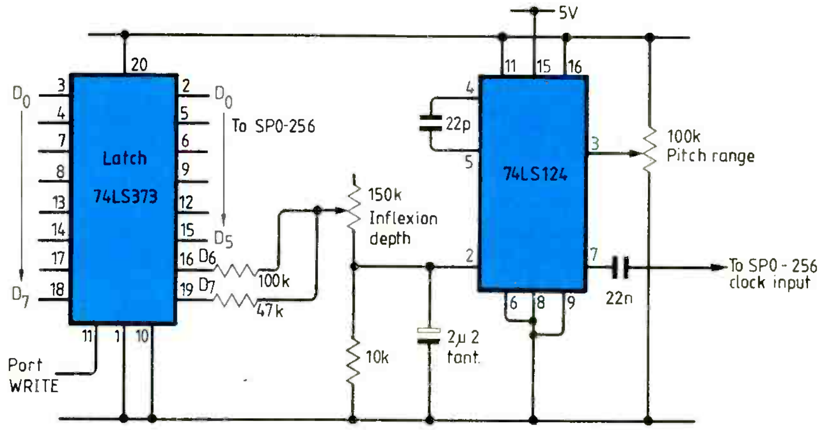
CIRCUIT IDEAS

SPEECH CONTROL FOR THE SPO-256

By replacing the usual 3.12MHz crystal clock with a v.c.o., four programmable levels of inflexion and manual pitch control can be added to most speech processor circuits using the SPO-256AL2 chip.

As the 256 only holds 64 allophones it only has 64 memory locations and therefore only needs six address/data lines (D_{0-5}). Lines $D_{6,7}$ can control a two-bit d-to-a converter, output of which feeds the LS124 v.c.o. through an inflexion-depth potentiometer. This gives four inflexion levels. Pitch range is set on a second potentiometer.

Mel Saunders
Leicester



SWITCHING SERVO AMPLIFIER USING INTEGRATION

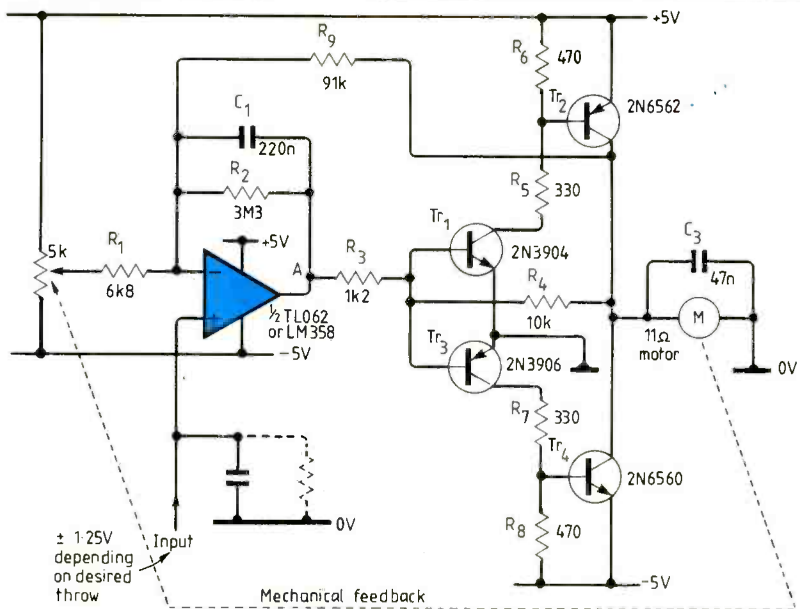
In radio control and robotics, so called digital servos are normally used because they are readily available and give good performance not easily matched by simple analogue servos.

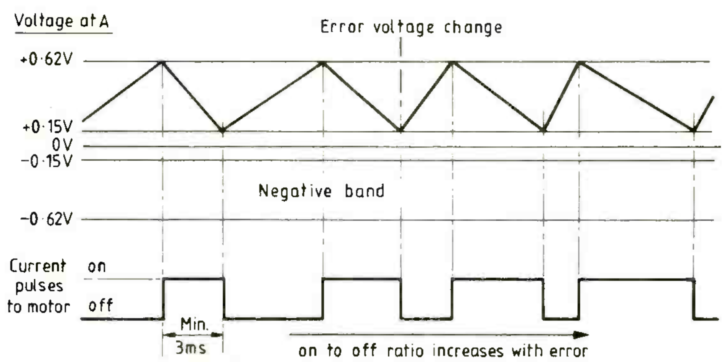
This improved analogue servo amplifier is simple, yet it performs as well as the digital servo and allows deadband and drive-pulse width adjustment for fine tuning. Output switches. The trick is to combine an integrating gain stage with a symmetrical double-trigger output stage.

With a TL062 error amplifier, standby current is about 2.5mA, most of which flows through the servo potentiometer. By increasing the value of R_9, supply voltages down to about ±2.4V can be used. The ratio of R_1:R_2 sets the dead band.

Error measurement is done during the motor-off period so the circuit is noise-resistant.

J.M. Piednoir
Le Rainey
France





STEREO PHASE AND LEVEL DISPLAY

In October's circuit ideas, the ground line at the bottom of the stereo phase and level display circuit fell out of view of the printer's camera. The three unterminated points at the bottom of the drawing connect to ground.

RESEARCH NOTES

C-mos failure mode confirmed

Recent work at BT Research Laboratories at Martlesham confirms a theory about how c-mos integrated circuits break down when they are subject to electrostatic discharge. The assumption has been that such transients drive the protection diodes into second breakdown where heating melts silicon and produces a conductive channel which then shunts the gate in question. This can happen either as the result of a single high-energy transient or cumulatively from a number of lesser static discharges whose total energy exceeds a certain value. In this last case the junction behaves as if each current pulse causes the defect to grow a bit further, like a sort of filament.

Confirmation that this is indeed the mechanism has come now from a mathematical model that predicts the behaviour of real circuits under different transient testing regimes. Two methods are used: one in which fixed pulses are applied to a c-mos gate until failure occurs, the other using a sequence of progressively higher voltages to the same end. Chip failure is arbitrarily defined as a leakage current greater than 1μA.

The BT group predict from their mathematical model that there ought to be a clear relationship between the results of the two different methods of i.c. testing. Not only that, but it ought to be possible to precisely predict the conditions under which any particular i.c. type would fail. Experiments in which dozens of circuits were carefully and systematically written off have demonstrated that this is the case. They have also shown beyond reasonable doubt that c-mos circuits break down in exactly the way that had been assumed.

Uncluttered radar returns

As part of a programme to develop its Blue Vixen doppler radar Ferranti engineers have found a new way to get rid of unwanted reflections from the ground. It was such reflections from objects like cars that lead to severe problems with the Nimrod early warning system.

Ferranti are employing a new approach to software development, historically the most difficult part of complex radar development. Instead of taking an aircraft aloft each time a test run is needed, the Ferranti team have brought the radar scene down to earth using high-density recorders. Developed by Ampex, these machines record data during a test flight at 20 Mbyte/s which can then by played back on the ground to exercise the radar software as often as desired.

The software validation programme has paid attention to the problems of land/sea interfaces and the need to reject echoes from fast moving vehicles. In conjunction with the Royal Signals and Radar Establishment at Malvern, Ferranti are accumulating a design archive which will not only validate the software for their own Blue Vixen doppler radar project – as used on the Sea Harrier – but also accelerate the design of a new radar for the European Fighter Aircraft (EFA).

World's strongest magnet?

A research team at the Massachussetts Institute of Technology has produced what is claimed to be the world's most powerful magnetic field. The static in question is 336,000 gauss, that's getting on for 700,000 times more powerful than the earth's magnetic field.

This phenomenal magnetic field is in fact the product of two electomagnets in one. The first is a more-or-less conventional unit with water-cooled windings. It consumes a mere nine megawatts of power. The second magnet uses niobium wire, rendered superconducting in liquid helium. The two fields are combined and concentrated in a 3mm gap between two rods of holmium.

The purpose of the device is not to break records but to study the properties of electrons in semiconductors as part of a research programme into new materials. Professor Lawrence Rubin, who heads the work, is now determined to make an even bigger magnet, though not simply to break records. Three millimetres is a very small space to do much in the way of experiments, so it's now necessary to construct a unit with the same magnetic field operating over a larger volume. This next generation super-magnet may not exceed the record gauss rating, but at $2 million it could well be the world's most expensive magnet.

Solar cell costs

Every month sees the announcement of some development that pushes the efficiency of solar cells a little bit nearer the magic 25%. But for the end user the cost per watt still remains obstinately high. A new development from the University of Erlangen-Nürnberg in Germany now promises to combine improved efficiency with low fabrication costs to bring the price down by half.

The cell consists of a layer of silicon dioxide grown onto a p-doped silicon substrate from which aluminium contacts extract the powder. These are applied using an inexpensive mechanical mask. The real key, however, to the low cost is a vapour-deposited silicon nitride layer. This gets round the usual lengthy high temperature diffusion process necessary to create the p-n juction. The nitride film, when chemically treated with a caesium solution, forms a sort of 'induced' p-n junction, at the same time as protecting the cell from corrosion and ensuring maximum absorption of light.

At present the electrical efficiency of these polycrystalline cells is about 14%, a figure which the Erlangen group think can be improved to about 17%. They also hope to see the cells in commercial production some time next year.

Fluorescent lamp u.v. radiation

Research at the UK's National Radiological Protection Board has recently dispelled anxieties about possible health hazards arising from long exposure to fluorescent lamps. These lamps generate their light from phosphors which act as wavelength converters, absorbing the necessary energy from ultraviolet radiation produced in a low pressure mercury vapour discharge. It has been known for a long time that u.v. radiation especially of short wavelength can lead to photokeratitis (arc eye) and malignant melanoma (skin cancer). Concern has therefore centred on the fact that fluorescent tubes inevitably emit a small amount of u.v. radiation in addition to the wanted visible light. NRPB scientists tested a whole range of different fluorescent tubes, selected at random from different production batches. The same tubes were also tested after 100 hours' use.

With all tubes there are inevitable peaks of u.v. output at the mercury spectral lines of 313nm and 365nm, though 'warmer' coloured tubes generally have a smaller output than 'cool' ones. For most tubes the u.v. output appears to decrease with age faster than the loss of visible light, possibly due to a photochemical reaction which makes the glass less transparent in the u.v. region.

At no time, however, does the u.v. output of any tube come near the limits adopted in the UK for occupational exposure. This appears to be so even at the lighting levels recommended for machine shop areas (1000 lux). It can therefore be assumed that no danger exists from any visible-light fluorescent tube under normal conditions of use.

Locating lighting strikes

To evaluate protective measures against lightning the Electricity Council's Research Laboratories at Capenhurst have devised a system that plots the occurrence of lightning strikes in real time. It makes use of the fact that lightning generates powerful electromagnetic pulses in which the bulk of the energy is concentrated at frequencies between 1 and 100kHz.

Three special d.f. stations listen out on a frequency of 2kHz for the characteristic 'signature' of a lightning strike. Each station uses a combination of loop antennas to compute the bearing of the strike to within 0.05 degrees. This information is then fed by telephone line to a computer at Capenhurst which generates a 'fix' by combining the information from all three stations. Strike data arriving within any 2.5 ms window are assumed to relate to the same event.

The output appears on a v.d.u. as a series of crosses superimposed on an outline map of the UK from which it is possible to watch a storm as it develops and moves across the country. The information will be available directly to local electricity boards and also archived for future reference.

Laura Scott, who heads the project, says that the information will make it safer for linesmen working up pylons and may also allow power to be diverted away from a line that is threatened by a storm.

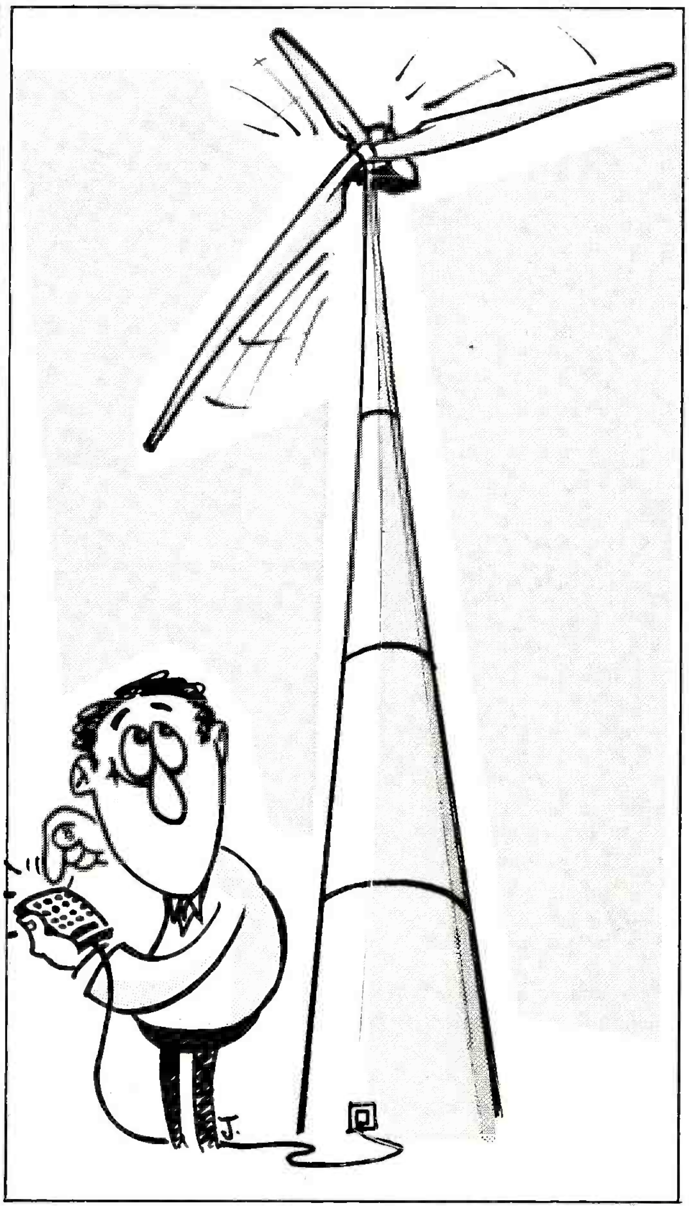
Lightning costs the electricity supply industry £1 million per year in damaged equipment and lost revenue.

Fusion – 'when' rather than 'if'

Another step in the race to generate a useful amount of power by nuclear fusion was taken recently by a research group working at Princeton University in the USA. In their tokamak reactor they generated a temperature of 200 million degrees celsius for a third of a second. That is ten times hotter than the centre of the sun and the highest temperature ever recorded in a laboratory. Such temperatures are necessary to make hydrogen atoms fuse together to produce helium and, in the process, release energy. (Solar fusion can occur at lower temperatures due to the huge gravitational force). During the short time the Princeton reactor was able to sustain the high temperature, an estimated 10×10^{12} hydrogen atoms fused, releasing about 10kW of energy. Had the experiment used a deuterium/tritium mixture, this might just have topped 1MW.

Although nuclear fusion did in fact take place, the overall efficiency of the reactor is still far below unity. The hydrogen plasma had to be heated ohmically, by r.f. energy, and by the injection of energetic particles. This last method alone consumed 17MW of power. Yet fusion scientists are now talking about 'when' rather than 'if'. The European tokamak reactor at Culham in Oxfordshire still holds the record for the longest sustained plasma confinement – a factor just as important as ultimate temperature.

So if safe, clean, inexhaustible fusion power isn't just around the corner, it is at least making the sort of steady progress that justifies the confidence of those working in the field.



Auto speed trap

Over a hundred years ago the first traffic lights – gas powered – blew up. Fifty years later they made a comeback, then electrically powered and controlled by pressure pads set in the road. Now work at the University of Manchester Institute of Science and Technology, the University of Sheffield and the Transport and Road Research Laboratory is on the verge of creating a third generation of traffic control systems.

Instead of pressure pads, a system has been devised which enables information to be taken from a video camera so that passing vehicles can be counted automatically and their speeds measured accurately. If a commercial manufacturer can be found, the image anlaysis of Trip (traffic research and image processing) should lead to greatly improved traffic control. Team leader Dr Michael Hartley of UMIST anticipates that this might well require a venture capital sum of over £½ million.

The work so far has involved a system to analyse pictures from tv cameras mounted on motorway bridges and high buildings. This research has thrown up many problems associated with variations in lighting and a high data rate. Trip has nevertheless now reached a stage where it can recognise even small motorbikes under the foulest weather conditions.

Film vs h.d.tv

Although the Japanese 1125-line 60-Hz h.d.tv system failed to achieve world-wide acceptance at the CCIR meetings last May, it has succeeded in wakening up the film industry to the need to consider new technology and techniques that could provide in cinemas greatly improved picture and sound quality. Last year the Society of Motion Picture & Television Engineers (SMPTE) set up a powerful study group to consider the possibility of changing the frame rate of cinema and television films from the long-established standard of 24 frames per second to the 30 frames per second already used for some TV film commercials in the USA.

The use of 30 frames (60 images or "flashes" a second) permits much brighter and crisper pictures without introducing any perceptible flicker. At present British cinemas rarely use screen brightness levels more than about 12 foot-Lamberts, compared with the 16 ftL of many American movie-houses. One result is that British film producers admit that their films look better when shown in the USA. The adoption of 30 frames would permit screen brightness to be raised to over 20 ftL.

The SMPTE have also been studying the possibility of multi-channel digital sound recorded on compact discs (or digital audio tape?) electronically tied to the film by the adoption of the television VTR-editing technique of time-coding each frame. With this system the sound would not lose sync. even if the frames had been cut from the film or reels projected out of sequence.

For European tv, a 30 f.p.s. film standard would end the practice of running 24 f.p.s. film at 25 f.p.s. to facilitate the use of flying-spot telecines, but at least some television engineers would welcome 30 f.p.s. film though opposed to a 30 f.p.s. (60 Hz) tv production standard.

World's smallest windmill?

According to a press release issued by the Department of Energy, two major wind energy projects are under way. One is a 3mW (sic) 60m diameter horizontal-axis machine in Orkney whilst the other is a novel 25m vertical axis machine at Carmarthen Bay. Negotiations are said to be well advanced for a '1 mW stretched version' at Richborough in Kent. Should be enough to power about three pocket calculators.

FEEDBACK

FFT

David Gibson (Letters Sept.86) is being unfair to the Fourier transform! The Fourier transform, put simply, is a mathematical tool which can transform or 'map' from one domain to its inverse. Frequency and time are inverse domains, and so the Fourier transform can be used to map from one to the other. There are limitations to what the transform can handle, (many of which are overcome by using the Laplace transform – but that's another story), but low-pass filters whether real or 'perfect' are not among them.

A non-repeitive frequency domain function, such as low pass filter (l.p.f.) whose frequency response never quite reaches zero at any frequency, has a finite-length time-domain transform. This is the realm of real filters. As a filter approaches perfection, and has more and more ultimate attanuation, the time-domain response last longer and longer (the filter 'rings') and in the limit, a perfect filter with infinite attenuation in the stop-band would have an infinitely long time-response (it would 'ring' for ever). The Fourier transform of such a frequency response is sint/t where t is the reciprocal of the filter bandwidth.

A feature of all time-domain transforms is that they are symmetrical about $t=0$, and so there is apparently as much response before $t=0$ as afterwards.

This leads to the realisation that the 'well known phenomenon' mentioned by Mr Gibson that the Fourier transform predicts that a perfect l.p.f. has a time response which begins before the impulse at $t=0$ is going to be true also for real l.p.s. So what has gone wrong?

The answer is that this is a misapplication to the transform. The process of predicting a filter's time-domain response resulting from an excitatory impulse involves convolution. It would need a complete article to satisfactorily explain what convolution is; however the salient features of convolution are as follows:

a) it runs for the time interval required for the resulting impulse response to die away to zero. Let us call this time interval t.
b) as the convolution proceeds, the excitatory impulse is scanned from 0 to t in the time domain, while the filter's time-domain response* is scanned backwards from t to 0

Fourier transforming the convolution gives us

$$F[f(t)*h(t)] = Ff(\tau).Fh(t-\tau) = F(\omega).H(-\omega')$$

where τ runs from 0 to t (1) during the convolution

F represents the Fourier transform, and * represents convolution.

If f(t) is the vanishingly short unit impulse, and h(t) is the wanted response to this impulse, then the L.H.S. of equation (1) is simply equal to h(t). On the R.H.S. of the equations, Ff(t) is unity, and so we can rewrite equation (1):

$$h(t)=H(-\omega') \qquad (2)$$

What equation (2) says is that the impulse response is given by the inverse Fourier transform of not $H(\omega)$ (the frequency response) but $H(-\omega')$, *the frequency response run backwards, with an offset of t.* Now t is simply the time required for the impulse response to delay to zero, so we take the inevitably symmetrical $H(\omega)$, reverse it, and move it so that $t=0$ correspondents with the point where the response reaches zero.

As the l.p.f. response becomes steeper, t becomes longer, and tends towards an infinitely large value for a perfectly steep filter. This accords with experience, which is that the sharper the wanted filter cutoff, the more elements the filter requires, and the larger the group delay becomes. The mystical perfect filter would need infinitely many elements, t would be inifinite, and so the filter would never given any output (thereby never having a chance to 'ring' indefinitely as suggested earlier in the analysis)

Brian J Pollard
Watford

*i.e. the time response to a vanishingly short unit impulse – the response we are interested in deriving.

Relativity

Professor Butterfield has presented a welcome and delightfully simple approach to explaining the seeming oddities of relativity. I am, I confess, still not fully convinced of the "correctness" of the whole concept (Butterfields' article aside).

The invited assumption that "energy has inertial mass" is not at all straightforward (like the reasons to assume c is constant). I would suggest the only reason it seems to be more acceptable is that from experience we know it is worse to be hit by a fast moving object than by a slower moving object. To hedge a 'little' extra mass on top of this is, I suppose, more easily grasped. However, to explain it (this small extra mass) one needs the results based on this assumption! (equation 5).

The evidence in favour of relativity is overwhelming, considering observed effects in nuclear physics (e.g. particle decay times) and astronomy (gravity lens), yet I feel sure most people would agree that although relativity gives a possible (and quite usable) explanation for observed events, it does not give a reason and is far from complete.

Indeed, if one were to assume our hypothetical observers were blind, and must use sound to transmit and perform the necessary logical steps, we see that these poor observers believe their object has disappeared upon reaching (or passing) the sound barrier: all talk of aether and such aside, no convincing could persuade our blind friends that the object was still there.

Despite my allegiance to relativity, I'm still anxious to know whether anyone has tried, for example, weighing a spinning centrifuge rotor or a very large charged capacitor to measure any weight differences between the high and low energy states. Other relativistic ideas which bother me are, I'm sure, often suggested brain teasers, such as "What happens to a top spinning at a high angular velocity?" or what happens to the magnetic field of a superconducting ring as it is lowered into a black hole?"

It seems gravity is inextricably involved, and will remain a dark horse until a grand unified theory is put forward. I fear, that by then, the mathematics will be quite incomprehensible to this humble reader. Meanwhile, time has once again won by eluding true definition, and quietly slipping by.

Michael J Snoswell
Adelaide, 5067
South Australia

Professor Butterfield is being fishily eel-like with his shoals of evidence, and apparently cannot digest the worm which he nibbles at. In all my letters over the past couple of years or so I have never doubted Einstein, and my attack has been an effort firstly to enlighten those who do not understand the matter, and secondly to enable the specialists of the world to understand it better than they do, and that without inaccurate presumption.

Before wielding my two-edged fishing rod with its horse's head handle, let me congratulate the Prof. upon coming up with creation and catastrophe as a vital part of the picture (poor Albert) even if he only did it subliminally with a Freudian slipping clutch like the monetarist snake!

The Prof. states: "Since a packet of energy should not be instantaneously movable from A to B as we see it, then it must have inertial mass!"

NOT SO, Prof.: if the energy is carried by a wriggling device which has inertial mass, it will be similarly delayed. Can't you see that? Such a device is the LSM, the basic postulate which Einstein seems to me to have had at the back of his mind when he stated that he could not conceive an empty space with nothing in it, a postulate which he found difficult to communicate to the specialists of the world because he had not completed his concept. I say again, back to the drawing board, Prof.!

The concept at which I believe Einstein would have arrived, had he had enough time, is in the hands of Mr Editor who might publish it when and if he sees fit, or may not because it is better for improvement of mind to come from within by personal solving of the puzzle, rather than from without: logic which is a part of personal experience is more easily believed than that which is provided by others.

FEEDBACK

I recommend that Prof. Butterfield differentiates again in order to clarify his mind by separating energy from mass, so making it an individual entity: he might then learn something to his advantage (which simplifies his envisaged mind-boggling rules) and discover how Einstein evolved out of Newton without denying him. A second further differentiation will bring him to time alone, and there is nothing simpler than that.

Finally, I congratulate Prof. Butterfield in recognising (if again subliminally) that I am a Leo, but crouching in his den and lying in wait!

James A. MacHarg
Wooler
Northumberland

In his June article 'Relativity Simplified' Professor Butterfield attempts to derive Special Relativity by considering accelerated motion rather than uniform motion (i.e. motion in which no internal stresses are generated). By so doing he completely obscures Einstein's major achievement. That achievement was to realise (with some assistance from Minkowski) that the contemporary view that in a vacuum electromagnetic effects propagate as waves in an ether could be replaced by the view that in a vacuum the propagation of electromagnetic and gravitational effects is determined by the geometrical structure of the space-time continuum. This view takes some swallowing, but I do not believe that any consistent picture of Special Relativity can be developed without it. Generalisations which attribute increasingly elaborate structures to the space-time continuum underlie not only Einstein's very successful theory of gravitation, but also the much more recent developments in the theory of the early history of the universe.

In all these theories the idea of simultaneity (i.e. of a universal time) has to be abandoned. However Special Relativity retains reasonably close links with classical physics because in its simultaneity remains a valid concept in any particular inertial frame. The weakness of most presentations of the theory is that no attempt is made to find an explicit expression for the effect of simultaneity breakdown, and Professor Butterfield's is no exception. I have given the required expression elsewhere[1]. His statement, at the beginning of the section 'Simultaneity and measuring rods', that 'the length of an object *must* be defined in terms of simultaneous measurements at the two ends', is therefore incorrect. Instead this is merely a convention, and a bad one at that, since it leads to all the familar difficulties with the assertion that the length of a rod changes as a result of its motion, even though it is free from internal stresses.

In the section "Light and the 'Impact Theory'" the moving clock can be regarded as passing two distinct clocks at rest in the L_1 frame at the positions x_1 and x_2. These encounters remain distinguishable events in the frame L_2 of the moving clock however fast it moves, even though in that frame the measured time interval between them may be very small. Thus all his conclusions about 'impact theory' are simply special pleading. It is true that the 'interval' in space-time between any two events on the world line of a photon is zero, but in this complex four-dimensional space the statement turns out to embody Einstein's hypothesis about the invariance of the velocity of light.

I have little doubt that the key to understanding Special Relativity is to concentrate on unaccelerated motion and on events. Accounts in terms of such concepts as time diltation (time intervals), and especially of the so-called Lorentz-Fitgerald contraction (space intervals) tend to run into difficulties, which can usually be resolved as soon as one takes the trouble to specify the events involved.

C.F. Coleman
Grove
Oxfordshire

Reference
C.F. Coleman, *Eur Jour. Phys.* 4(1983)240-247

In view of the interest in relativity shown by many *Wireless World* contributions, it is opportune to draw attention to the experimental discovery reported by E.W. Silvertooth in the 14th August issue of *Nature*. His findings are important because they clearly invalidate Einstein's Principle of Relativity. I have had the opportunity of discussing this experiment at some length with Mr Silvertooth and offer the following comments on its significance.

Essentially, it has been found that the spacing between nodes in a standing wave set up by two oppositely-directed light rays from the same laser source varies with orientation of the apparatus. The effects observed, which were monitored over several months, indicate a detection of the Earth's motion relative to the preferred frame in the direction of constellation Leo, at a speed indicated by a typical measurement to be 378 km/s. This should be impossible according to Einstein's theory.

The feasibility of the experiment, which was sponsored by the US Air Force, depended upon the prior development and fabrication of a special type of standing wave sensor, described in *Applied Optics* in 1983[2]. This could scan through the laser beam and detect the position of the standing wave nodes with high precision.

Crucial to the justification for the experiment was the realization that the null finding of the 19th century Michelson-Morley experiment is not a conclusive test of light speed anisotropy. It merely tells us that the round-trip transit of a light signal over a given distance is invariant with motion or change of orientation of the apparatus. Though consistent with isotropy, this can equally be consistent with anisotropy, meaning that the light speed in opposite directions along any given orientation of the light path and referenced in the preferred (ether) frame can be the same, but that it might vary with the orientation. There could be physical interactions between the two waves that set up the standing wave system, modifying the common light speed in the preferred frame.

An example of such a condition is provided by a resonant spherical cavity of fixed radius R moving through the preferred optical frame. It can sustain radial oscillations of fixed round-trip duration 2R/c in a direction of a motion-component velocity v given by:

$$R/(c'-v)+R/(c'+t)=2R/c$$

provided the light speed increases from c to c′ equal to $c(1+v^2/c^2)$. The conventional interpretation of the Michelson-Morley experiment is that c′ must equal c, but this need not be the case if we accept light speed anisotropy.

In reality one can suppose that the properties of the ether are regulated by resonance effects which account for the null of the Michelson-Morley experiment. However, the properties just described must then show up in an experiment which measures the spacing between the standing wave nodes and this is exactly what the Silvertooth experiment accomplishes. In effect, over the test length L. he measures the difference:

$$L/(c'-v)-L/(c'+v)$$
$$=2(L/c')(v/c)$$

and so determines the v with first-order precision.

The fact that the test gives a positive result and not a null confirms the existence of an ether and disproves Einstein's theory. It sustains an argument by Ives[3] that the Sagnac effect, by which rotation is sensed optically as if there were an ether, need not depend upon a rotation of the apparatus to justify its operating principle. Indeed, Silvertooth claims that his experiment is a linear adaption of the principles of the Sagnac experiment.

References
1. E.W. Silvertooth, *Nature, 322,* 590 (1986).
2. E.W. Silvertooth and S.F. Jacobs, *Applied Optics, 22,* 1274 (1983).
3. H.E. Ives, *Jour. Opt. Soc. Am., 28,* 296 (1938).

H. Aspden,
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The vector equation below gives the magnetic field $\bar{H}$ associated with an electric field $\bar{E}$ moving with velocity $\bar{V}$ in free space of permittivity e:

$$\bar{H}=e\bar{V}\times\bar{V}$$

If $\bar{E}$ is due to an electric charge of mass m, its magnetic energy in free space of volume τ and permeability u, can be equated to the kinetic energy to obtain

$$\tfrac{1}{2}u\int H^2 d\tau=\tfrac{1}{2}ueV^2\int eE^2 d\tau=\tfrac{1}{2}mV^2$$

which gives $E_n=\tfrac{1}{2}mc^2$

where $E_n=\tfrac{1}{2}e\int E^2 d\tau$ is the electrostatic energy of the charge and $c=(ue)^{-1/2}$ is the speed of light in free space.

I would be grateful to have readers' comments on the discrepancy, by a factor of ½, between the derivation made here and Einstein's law $E_n=mc^2$

M.D. Abdullahi,
NCATC,
Zaria,
Nigeria.

Mathematical Rake's Progress

In the September letters, D. Gibson states that, if Fourier transforms are used to calculate the response of an ideal low-pass filter to a pulse input, the calculated output begins before the input pulse itself. Since he fails to mention the phase response of the filter, it seems that he has arbitrarily assumed that the filter has no affect on the phases of the components of the spectrum of the input signal.

However, in the frequency domain one cannot make an arbitrary choice of the amplitude response as a function of frequency, and then go on to do the same thing for the phase response, without running the risk of describing a physically unrealisable waveform filter, and that is what he has succeeded in doing. An amplifier with a pass band stretching from d.c. to a sharp high-frequency cut-off can be regarded as a kind of low-pass filter. It is notorious that the sharper the cut-off is made the more rapid is the phase variation near cut-off, and the more ringing one sees on the leading and trailing edges of square-wave pulses passed through it. If Mr Gibson carries out a calculation using realistic values of the phase shifts produced by his low-pass filter he will find that the response to any feature of the input waveform comes after that feature, as it should.

The conditions under which a filter transfer function may represent a physically realisable filter have been expressed in terms of Hilbert transforms (see Bracegirdle's book on Fourier transforms). It is worth remarking that Fourier transforms can be applied to functions of spatial coordinates as well as to functions of time, in which case the preferred direction given by 'time's arrow' does not exist, and the entities analogous to filter transfer functions are subject to no such limitations. Entities of this kind are widely used in image processing.

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Reference

R. Bracegirdle, The Fourier Transform and its Applications, McGraw-Hill Electrical and Electronic Engineering Series, McGraw-Hill, New York, 1965.

S5/8

In reply to Mr Hayward's letter in the September issue, I agree that international standardization is desirable and has always been a goal I have sought to achieve, and will continue to seek after S5/8 becomes a British Standard.

Criticizing the quality of DIN connectors is as pointless as praising the quality of D-type connectors. Any connector for which there is a volume demand will attract the attention of the 'cheap and nasty' manufacturers and I have seen atrocious examples of both D-type and "Centronics" type multiway connectors as well as very poor quality BNC and UHF coaxial types. Judging DIN connectors by the worst available is a gross injustice. There are high quality metal-shell versions available, such as those maufactured by Futters (as sold by RS and Verospeed), that are quite satisfactory for both home and office use. Beyond that, I am confident that Belling-Lee would be pleased to inform you of the industrial and military success of the Bleecon DIN range. The already popular DIN connector is all set to become even more widely used for data interconnections, with the inevitable trend toward serial transfer.

Beyond quality of construction, how much performance is one to expect from a connector fitted to an item of IT equipment with a three or five year life? Just how many insertions and withdrawals is it likely to experience?

The question of bipolar signalling is a non-question. It is nothing more than a historical hangover from polarized teleprinter magnets and has no place in modern, low-power, single supply equipment. The choice of Epson portable equipment, as an example, for the use of RS-232 in a battery-operated environment is interesting, as it proves my argument. Yes, Epson have put an RS-232 interface into all three of their portable computers. However, in the PX-8, the RS-232 interface adds over 55 components and such a significant battery drain that a software-controlled switch circuit is used to disable it when not in use, to save power. Epson first used this approach in their HX-20, where turning on the RS-232 interface roughly doubles the battery consumption. The lower the power consumption of the processor, memory and display, the worse the problem becomes.

The use of RS-232 voltage levels by Epson to communicate with their PF-10 battery disc drive is particularly pointless. It is a non-standard interface, communicating in a non-standard protocol at a speed outside the RS-232 specification, and solely dedicated to Epson equipment, yet they felt it necessary to go to considerable expense to use bipolar signalling in units that will never be called upon to interface with RS-232 equipment and where there is no technical justification whatever for using d.c.-to-d.c. converters to generate bipolar voltages to send data down one metre of cable.

There is no question that differential, balanced signalling, such as RS-422, or the newer RS-485 party-line system, offers better data transmission, but at a financial and power cost which has rendered it less popular. RS-449 was not exactly a runaway success and, more recently, the SCSI standards offers the choice between single-ended (open-collector) or differential interfaces – guess which most manufacturers are implementing!

The MC3486 receiver and MC3487 transmitter are out of the question for battery-operated equipment, together having a worst case power consumption of 190 milliamps, a value embarrassing even in mains equipment, with devices such as the highly capable 64180 containing processor, memory manager, dual uarts, bit-rate generators, dual timers, interrupt controller, dual d.m.a. controller and clock generator, all consuming only 20 mA maximum at 4MHz. The days of "200mA doesn't matter" thinking in equipment design are over. Also, I do not consider the MC3486/7 pairing as low-cost. It costs at least three times as much as 1488/9 combination and over five times as much as an HC14 gate, not taking into account the cost of providing that 200mA and ventilating the heat dissipation thereof!

Finally, to achieve a "plug-and-run" interface (the goal of S5/8 and, I suspect, the goal of us all), a standardized data structure is essential. Eight-bit working is now the norm and there is no point in accommodating shorter word sizes by changing the framing. Lateral parity is also questionable. It is seldom possible to organize retransmission on a per-character basis and block error detection is much more efficiently performed using CRC, or similar, techniques and does not impose a 10% burden on the character frame.

On the question of the data signalling rate, the increasing use of microprocessors in devices removes the need to match the data interchange speed to the physical restrictions of the attached device. 9600 bauds is already a de-facto standard with IBM, DEC and Intel and is being incorporated into new standards including the ISO Standard 'smart cards'.

A.S. Hardie
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Having reviewed the early proposals for S5/8, and contributed, along with many others (all unheralded), to the development of a useful idea into a proposed standard, I read Mr Hardie's articles with interest and waited for the criticism. So far, you have published only one letter (from L. Hayward, September, p.13) and, as expected, his criticisms miss the point in all except one area: the lack of international agreement.

Mr Hayward objects to using DIN circular (audio) connectors on the grounds that they are not

FEEDBACK

robust enough for office use. Some cheap DIN connectors are indeed of very poor quality, but others are very acceptable. Why else would IBM use them as keyboard connectors on the PC range, or Hewlett-Packard on bar code reader wands? We purchase cast-body 5-pin DIN connectors for 50p each – compare that with a 25-pin D plug plus a good quality cover (i.e. one that stays in place and clamps the cable properly and provides r.f.i. screening) for around £1.50. And DIN connectors are at least rewireable, unlike telephone-type connectors.

Unipolar signalling with a ground reference has been used successfully for many years in small computer systems snd computer terminals. The t.t.l. level Centronics printer interface is one example, microcomputer disc interfacing is another, and many computer keyboard interfaces are t.t.l. In some cases, the equipment at both ends of the signal cable is mains-powered, yet well designed interfaces performly reliably. S5/8 follows this long line of development.

S5/8 is a very low-power system. The recommended S5/8 circuitry consumes only microwatts of power. RS232 consumes about 50mW, RS422 more like a 1/4 watt. S5/8 is intended for use in lightweight battery-powered equipment. Yes, I would prefer to see a bipolar system, if only because S5/8 cannot interword with RS423 (as used, for example, in the BBC micro), but S5/8 is a case of 'horses for courses'.

S5/8 is intended to be a 'plug in and go' system. Hence the fixed signalling rate and word structure. No configuring, no debugging, no technicians, no test gear – just buy it and use it. The increasing use of 'intelligence' (i.e. an on-board microprocessor) in items of equipment which would use S5/8 means that Mr Haywards 'differing requirements' will be catered for by software in each product.

New RS232 interface circuits are making designers' lives easier – e.g. the MAX232 from Maxim, incorporating two transmitters, two receivers, and ± 10V charge pump generators in one 16 pin i.c. – but there is still no easy way of designing a very low power bipolar interface. C-mos circuitry implementing a high impedance version of RS423 (with receiver input threshold voltage control so as to allow interfacing with S5/8 or t.t.l. transmitters) would be a great step forward, as long as a transmitter and receiver could be packaged in one i.c. running off a single 5 volt supply. Semiconductor manufacturers please take note.

Peter W Tomlinson
Managing Director, IOSIS

British Telecom and the amateur morse test

In September 1986 issue of your magazine the reference in 'Communications Commentary' to BT's activities in connection with the amateur morse tests contained inaccuracies which I should like to correct.

It was the Department of Trade and Industry (DTI) which decided to put to competitive tender the contract for conducting the amateur morse tests. BT have never given notice, formally or otherwise, of a desire to relinquish its involvement in the tests. Therefore your statements that BT first decided to give up the tests and then changed its mind are quite untrue.

Also, I should like to explain why BT issued a notice to its employees to seek advice from the appropriate Department before committing themselves to assisting RSGB in running morse tests. (BT did not 'order' its employees to take no part in running the RSGB tests as stated in your article). The reason for this was that due to the loss of contract an additional redundancy was created in a small specialized workforce which is already having to be reduced due to other factors outside our control. BT hopes to have the opportunity of re-tendering for the work in future and would not be acting in the interests of its staff if it supported the provision of unpaid examiners to replace a job.

No directive was ever issued to our employees to give up their existing RSGB activities such as teaching morse or providing equipment at test centres; I hope they will avail themselves of the enquiry facility included in the notice before assuming that they cannot participate in any RSGB activity connected with the amateur morse test.

F.R. Barnfather
British Telecom

'Q' and bandwidth

In his stimulating article on 'Q' (*E&WW* July 1986 pp51-3) Dr Smith omits to mention a frequently overlooked fact concerning a series-resonant circuit in which frequency (ω or f) is the variable – the 'approximate' relationship between Q_0, the resonant frequency ω_o and $\Delta\omega$ the frequency range between the −3dB points is *exact*. An outline proof is given here.

$$Z=R[1+jQ_of(\omega)] \quad (1)$$

where $f(\omega)=[(\omega/\omega_o)-(\omega/\omega)]$ (2)

The −3dB points occur at ω_H and ω_L for which

$$Q_0f(\omega_H)=-Q_of(\omega_L)=1 \quad (3)$$

From (2) and (3), after some algebraic reduction,

$$\omega^2_o=\omega_H\omega_L \quad (4)$$

and $\Delta\omega=(\omega_H-\omega_L)=(\omega_o/Q_o)$ (5)

Note that the derivation of (5) does not require Q_o to be 'large' or $\Delta\omega \ll \omega_o$

B.L. Hart
Leigh-on-Sea, Essex

Uncivil Servants

In a letter (July, 1986) John C. Rudge remarks "If any civil servants in the British Standards Institute...". No government departments are called Institutes. Certainly the Federal Bureau of Standards is a government department in the States but the British Standards Institution is independent.

I'm reminded of a note in that amusing publication "The Collapse of Flats at Ronan Point, Canning Town" which blamed the Institution for a Standard it had not even contemplated producing, on the robustness of tower blocks, without appreciating that the Institution had absolutely no responsibility to anybody in these matters.

Bernard Jones
London W1

Q

As the author of an article with the above title in your issue of July 1949, perhaps I may be allowed to comment on 'Q' by Dr K.L. Smith in a more recent issue (July 1986). As Dr Smith starts his discourse by referring to a student using a (presumably direct-reading) Q-meter, I was surprised he didn't go on to point out that an instrument of this kind (unless unknown to me it has been radically redesigned) does not read Q unless the tuning inductor has negligible self-capacitance. For $Q = Q'(C + C_o)/C$, where Q' is the meter reading, C_o is the self-capacitance and C the added capacitance. And that is not the only cause of error in these meters.

And although the Q of a resonant circuit can be correctly measured from a resonance curve (Dr Smith's Fig. 3), it is perhaps desirable to mention that resonance curves come in many kinds, as I explained in January 1953. Admittedly, the differences are negligible unless the Q is less than about 5.

Q is often equated with the magnification factor m, but again it is only for small values that the differences can be appreciable.

Cathode Ray

The author replies

Cathode Ray is quite correct in pointing out the effect on Q when an inductor with a self capacitance c_o is measured. I did not concentrate on methods of measuring Q in my review article on the topic, but any interested reader could very well look up Cathode Ray's original article, or his books on laboratory technique.

One other interesting application that I omitted from my article, is the Q of space itself. Lossless empty space has an infinite Q, so an EM vibration propagates for ever without losing any energy – it is just dispersed according to the inverse square law. On the other hand, a lossy region, such as the ionosphere, has a Q given by the ratio of the magnitude of the displacement current density to the conduction current density

$$Q = \frac{\omega\epsilon}{\sigma}$$

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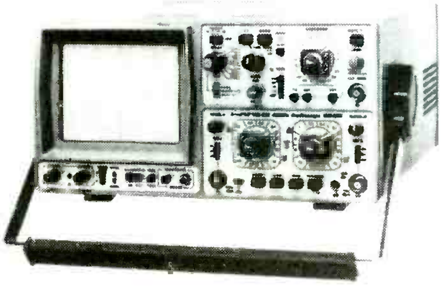

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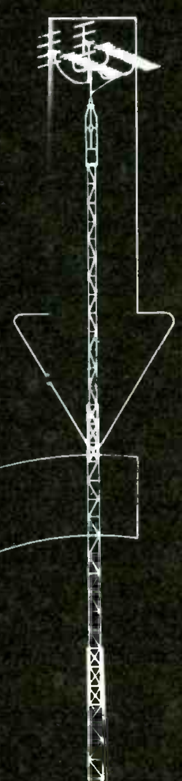

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.2N3553	.2N4933	.2N5109	.2N3375	.2N5016	.589
.2N4128	.2N5070	.2N5591	.2N6080	.2N4427	.2N5090
.2N5634	.2N6083	.2N4431	.2N5102	.2N5918	.2N6084

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Active op-amp compensation

This general method for simulating non-inverting voltage-controlled voltage-source building blocks reveals several new structures, all with negligible phase and magnitude error.

AHMED M. SOLIMAN

The non-inverting voltage-controlled voltage source is a basic building block in active filters and oscillators. Unfortunately with the exception of some very low frequency applications, the assumption of ideal behaviour cannot always be sustained and in particular the complex nature of the voltage gain must be accounted for. It is well-known that the finite gain-bandwith product of the operational amplifier degrades both the phase and the magnitude of the conventional v.c.v.s. building block[1]. Most recently, active-compensated v.c.v.s. networks using two and three op-amps have been reported in the literature[2-5].

This paper presents a method for generating the generalized active-compensated non-inverting v.c.v.s. structures employing three op-amps. Several novel actively-compensated networks are given. The proposed compensated non-inverting amplifiers have negligible phase and magnitude errors up to an extended frequency range.

Figure 1 represents the generalized active-compensated non-inverting amplifier employing three op-amps. The basic circuit equations are represented by the matrix equation 1, where a_i and b_{ij} are real coefficients having magnitudes ≤ 1, and A_i is the open-loop gain of the op-amp, which for all practical applications is represented by the single-pole model[6], $A_i(s) \approx \omega_{ti}/s$, $(i = 1,2,3)$ and where ω_t is the gain-bandwith product of the op-amp. Without any loss of generality let V_{o1} represent the output of the compensated non-inverting amplifier as shown in Fig. 1. From equation 1 the generalized expression for the transfer function of the circuit, equation 3, can be written in the form $T(s) = (C/B).E(s)$, where $E(s)$ is an

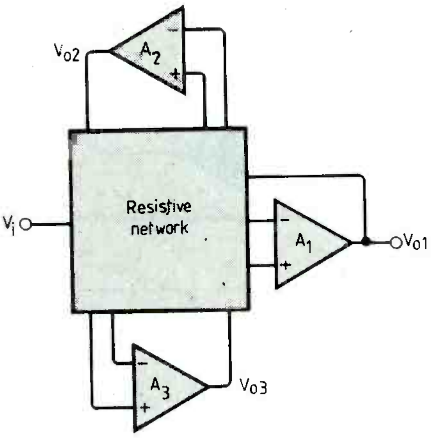

Fig.1. This generalized compensated non-inverting amplifier uses three op-amps. By writing the transfer function in the form of an error function and equalizing the s and s^2 terms of its numerator and denominator three classes of phase-compensated amplifier are identified – Figs 2 to 5.

TABLE 1. The signs of transfer function coefficients a_i, b_{ij} for i, j = 1, 2, 3.

Class	a_1	a_2	a_3	b_{11}	b_{12}	b_{13}	b_{21}	b_{22}	b_{23}	b_{31}	b_{32}	b_{33}
1	+	–	–	–	–	–	+	0	+	+	0	0
2A	+	0	0	0	–	0	+	0	–	0	+	–
2B	+	0	0	0	–	0	+	0	+	0	–	–
3	+	0	0	0	–	0	+	–	–	–	+	0

TABLE 2. Compensation conditions, normalized magnitude errors, where $\tau_i = (K_i+1)/\omega_{ti}$, i = 1, 2, 3

Class		Compensation conditions	Normalized phase error $\Phi_n(\omega)$	Normalized magnitude error $\gamma_n(\omega)$
1	Fig.2	$K_1 = K_2 = K + a$	$(K_1+1)^3/KK_1$	$(K_1+1)^4/K^2K_1$
2A	Fig.3(a)	$\frac{\tau_1}{K_2+1} = \frac{\tau_2}{2} = \tau_3$	$2\left(\frac{K_1+1}{K_2+1}\right)^3$	$4\left(\frac{K_1+1}{K_2+1}\right)^4$
	Fig.3(b)	$\tau_1 = \frac{\tau_2}{2} = \tau_3$	$2(K_1+1)^3$	$4(K_1+1)^4$
2B	Fig.4	$\tau_1 K_2 K_3 = \frac{\tau_2}{2K_2K_3} = \tau_3$	$2[(K_1+1)K_2K_3]^3$	$4[(K_1+1)K_2K_3]^4$
3	Fig.5	$\tau_1 = \tau_2 \frac{(K_3+1)}{(K_2+1)} = \tau_3\left(\frac{K_2-K_3}{K_3(K_3+1)}\right)$	$(K_1+1)^4/K_1$	$(K_1+1)^6/K_1^2$

It is assumed that $\omega_{t1} = \omega_{t2} = \omega_{t3} = \omega_t$ and $\omega \ll \omega_t$.

error function and which ideally must have a unity magnitude and a zero phase. It is well-known that to reduce the phase and the magnitude errors to negligible limits, the coefficients of the s and s^2 terms in the numerator and denominator (equation 7) must be identical,[4,5].

In the next section phase-compensated non-inverting amplifiers are classified according to the signs of coefficients a_i and b_{ij} $(i,j = 1,2,3)$.

Class 1 non-inverting amplifiers: In this class the compensation conditions are independent of the gain-bandwith of the three op-amps employed in the circuit. From equations 6 and 7 it follows that $b_{22} = b_{33} = b_{23}\,b_{32} = 0$. Without any loss of generality, take $b_{32}=0$ and $b_{23} \neq 0$. The compensation conditions for this class are

$$\frac{a_1}{b_{11}} = \frac{a_2}{b_{21}} = \frac{a_3}{b_{31}}$$

and it is thus not necessary to use matched op-amps with this class of amplifier.

Examining the transfer function for this class the coefficient signs are obtained and given in Table 1. Fig. 2 represents a class 1 non-inverting amplifier generated from the coefficient signs. This circuit is a special case from the Geiger-Budak zero second derivative finite-gain amplifier[4] after removing one resistor, also reported in ref. 7. Table 2 includes the compensation conditions and normalized compensated phase and magnitude errors assuming matched op-amps are used. Normalized phase and magnitude errors are defined as:

$$\Phi_n = \left(\frac{\omega_t}{\omega}\right)^3 \arg E(j\omega), \quad \gamma_n = \left(\frac{\omega_t}{\omega}\right)^4 (E(j\omega)-1)$$

Class 2 amplifiers: Here $a_1 = 1$ and $a_2 = a_3 = b_{11} = b_{13} = b_{31} = b_{22} = 0$ and the compensation conditions are given by:

$$\frac{b_{23}b_{32}}{b_{12}b_{21}}\frac{1}{\omega_{t1}} = -\frac{b_{33}^2}{2b_{23}b_{32}}\frac{1}{\omega_{t2}} = \frac{1}{\omega_{t3}}.$$

The compensated transfer function for this class is

$$T_{2c}(s) = p\frac{1+2ps_n+2p^2s_n^2}{1+2ps_n+2p^2s_n^2+2p^3s^3}$$

$$\text{where } p = -\frac{b_{23}b_{32}}{b_{12}b_{21}b_{33}} \quad \text{and } s_n = \frac{s}{\omega_{ti}}.$$

For this class the product $b_{23}\,b_{32}$ must have a negative sign. Thus two types are defined for this class and are classified as types 2A and 2B with coefficient signs as given in Table 1. Fig. 3 represents two circuits which belong to class 2A and Fig. 4 represents a class 2B

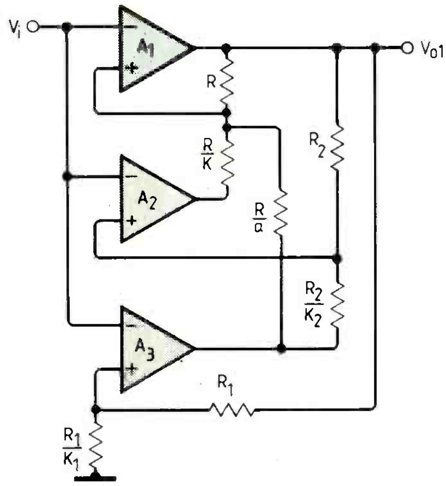

Fig.2: class 1

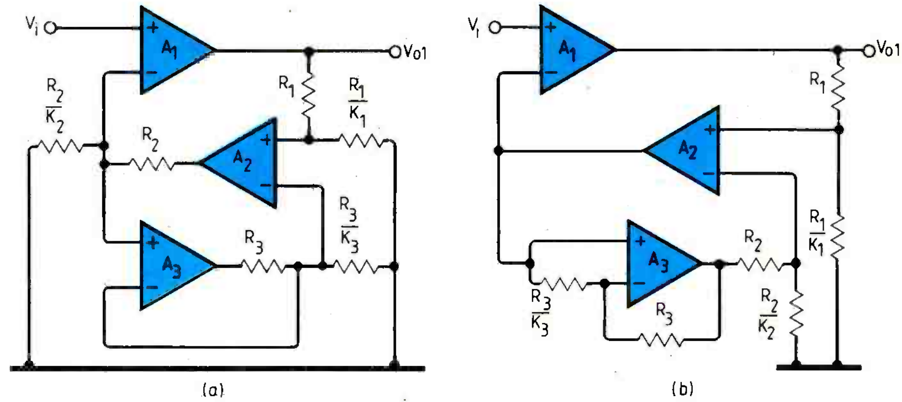

Fig.3: class 2A

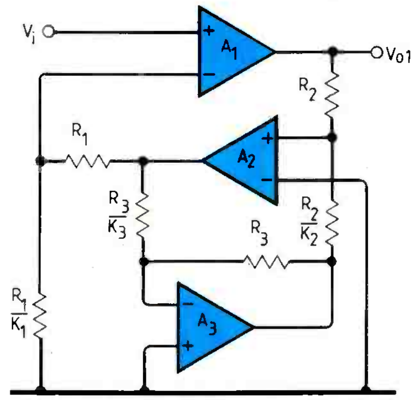

Fig.4: class 2B

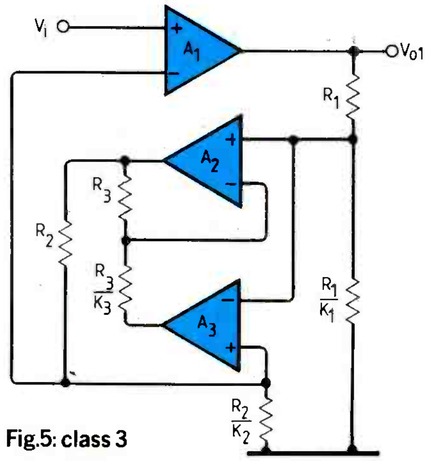

Fig.5: class 3

circuit. It is worth noting that the circuit reported in reference 3 belongs to a different type since it has negative b_{13} and b_{22} coefficients.

Class 3 amplifier. Fig.5 represents a new circuit whose properties are given in Tables 1 and 2.

It is worth noting that the circuits reported in reference 7 do not belong to either class 2 or 3 defined in this paper.

Dr Soliman is chairman and professor in the electrical engineering department of the United Emirates University at Al-Ain, UAR. He graduated from Cairo University and received M.S. and Ph.D. degrees from the University of Pittsburg.

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Equations

The basic circuit equations are represented by the matrix equation

$$\begin{bmatrix} \frac{V_{o1}}{A_1} \\ \frac{V_{o2}}{A_2} \\ \frac{V_{o3}}{A_3} \end{bmatrix} = \begin{bmatrix} a_1 \\ a_2 \\ a_3 \end{bmatrix} V_i + \begin{bmatrix} b_{11}b_{12}b_{13} \\ b_{21}b_{22}b_{23} \\ b_{31}b_{32}b_{33} \end{bmatrix} \begin{bmatrix} V_{o1} \\ V_{o2} \\ V_{o3} \end{bmatrix} \qquad (1)$$

where a_i and b_{ij} are real coefficients having magnitudes $\leqslant 1$. A_i is the open-loop gain of the op-amp which for all practical applications is represented by the single-pole model (ref.6):

$$A_i(s) \approx \frac{\omega_{ti}}{s} \quad (i=1,2,3) \qquad (2)$$

where ω_i is the gain-bandwidth. From equation 1, the generalized expression for the transfer function of the circuit is

$$T(s) = \frac{V_{01}}{V_i} = \frac{N(s)}{D(s)} \qquad (3)$$

$$\text{where } N(s) = a_1B_{11} + a_2B_{21} + a_3B_{31} + \frac{a_3b_{13} - a_1b_{33}}{A_2} + \frac{a_2b_{12} - a_1b_{22}}{A_3} + \frac{a_1}{A_2A_3} \qquad (4)$$

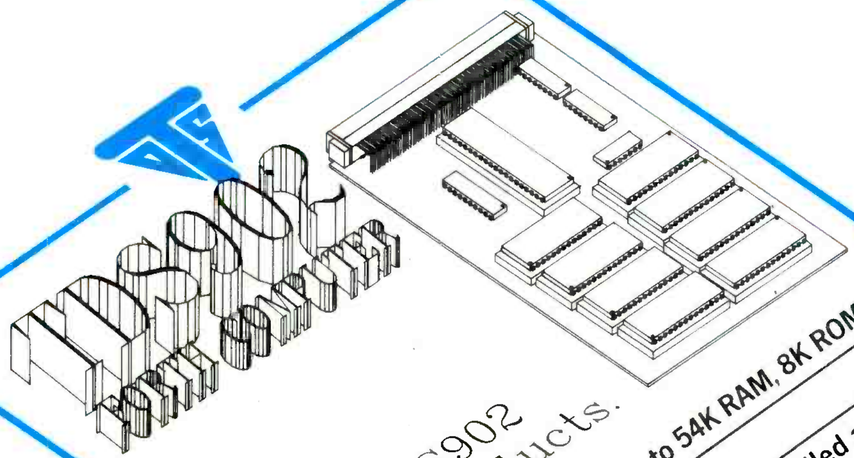
$$D(s) = -b_{11}B_{11} - b_{21}B_{21} - b_{31}B_{31} + \frac{B_{11}}{A_1} + \frac{B_{22}}{A_2} + \frac{B_{33}}{A_3} - \frac{b_{11}}{A_2A_3} - \frac{b_{22}}{A_1A_3} - \frac{b_{33}}{A_1A_2} + \frac{1}{A_1A_2A_3} \qquad (5)$$

$$\text{and } B_{11} = b_{22}b_{33} - b_{23}b_{32} \quad B_{21} = b_{13}b_{32} - b_{12}b_{33} \quad B_{31} = b_{12}b_{23} - b_{13}b_{22}$$
$$B_{22} = b_{11}b_{33} - b_{13}b_{31} \quad B_{33} = b_{11}b_{22} - b_{12}b_{21} \qquad (6)$$

Using equations 2 to 5, the transfer function of the circuit can be written as:

$$T(s) = \frac{C}{B} . E(s) \quad \text{where} \quad C = a_1B_{11} + a_2B_{21} + a_3B_{31}, \quad B = -(b_{11}B_{11} + b_{21}B_{21} + b_{31}B_{31}),$$

$$E(s) = \frac{1 + \frac{1}{C}\left[\left(\frac{a_3b_{13} - a_1b_{33}}{\omega_{t2}} + \frac{a_2b_{12} - a_1b_{22}}{\omega_{t3}}\right)s + \frac{a_1}{\omega_{t2}\omega_{t3}}s^2\right]}{1 + \frac{1}{B}\left[\left(\frac{B_{11}}{\omega_{t1}} + \frac{B_{22}}{\omega_{t2}} + \frac{B_{33}}{\omega_{t3}}\right)s + \left(\frac{b_{11}}{\omega_{t2}\omega_{t3}} + \frac{b_{22}}{\omega_{t1}\omega_{t3}} + \frac{b_{33}}{\omega_{t1}\omega_{t2}}\right)s^2 + \frac{1}{\omega_{t1}\omega_{t2}\omega_{t3}}s^3\right]} \qquad (7)$$



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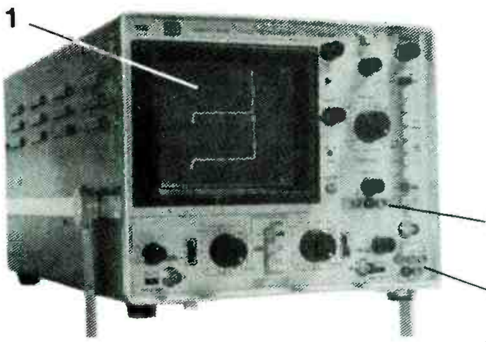

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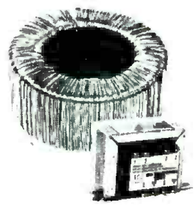

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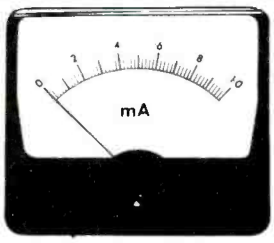

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Fifty years of computer science

An appraisal of A.M. Turing's paper "On computable numbers" published in November 1936

TOM IVALL

If computer science can be separated from computer technology, it can fairly be said to have started half a century ago, in November 1936. This was when a young Cambridge mathematician, Alan Mathison Turing, published his now famous paper "On computable numbers, with an application to the Entscheidungsproblem".

Written as a contribution to pure mathematics, this paper nevertheless described, as a central part of its method, the essentials of the modern, automatic, stored-program digital computer. Although the arrangement described was a purely abstract, theoretical computing machine, and Turing apparently had no engineering considerations in mind at that time, it was nevertheless a feasible system. It had to be, because a requirement of the paper was to make concrete in the imagination a finite, physical construction that would perform systematically a sequence of logical steps equivalent to those going on in the mind of a human computer. It was a sort of 'thought experiment'. Turing showed that the mental operations a human can perform can be analysed into sequences of the very simple 'mechanical' operations that his theoretical machine was capable of going through.

A highly significant aspect of 'Turing machines', as these theoretical constructions later became known, was that their internal functioning was entirely described by groups of symbols. The concreteness of a Turing machine existed not in any particular form of mechanical or electrical hardware but in a precise, complete description of its rules of operation – a "standard description" as Turing calls it – expressed entirely in letters or numbers.

Rules of operation expressed in symbols are what we now call instructions, and a particular selection of these is what we call a program. Since these rules of operation are not permanently set in the machine as a particular arrangement of hardware but can be altered at will simply by changing the symbols, the Turing concept was essentially that of the stored-program computer. It was Turing who first demonstrated that the *actions* of computing machines, as well as the data processed by these machines, could be specified in the abstract form of mathematical symbols. You could say he invented software.

With the benefit of hindsight this imaginative concept may not seem all that remarkable. But those who have lived through the half century of development of the digital computer appreciate it fully. And apart from the engineering perspective, Turing's whole idea of introducing a theoretical but workable machine into a paper on pure mathematics was quite novel to the academic establishment of that time. As Norbert Wiener, the American mathematician, remarked in his book *Cybernetics*, Turing was perhaps "first among those who have studied the logical possibilities of the machine as an intellectual experiment...."

MATHEMATICAL BACKGROUND

To understand how Turing's paper came to be written, we have to digress slightly into the history of the philosophy of pure mathematics. First, the title of the paper requires a quick look. Here the process implied by "computable" means computing in the broadest sense at that time – as done mentally by human beings, perhaps with the aid of mechanical desk calculators. Forget electronic computing at this stage. When Turing refers to a "computer" in his paper he means a human computer.

The term "computable numbers" in the title means numbers like π or e which can be computed from well known formulae. More generally, Turing explains, "The 'computable' numbers may be described briefly as the real numbers whose expressions as a decimal are calculable by finite means... According to my definition, a number is computable if its decimal can be written down by a machine." Such numbers include, for instance, the real parts of all algebraic numbers.

The term "Entscheidungsproblem" in the title can be translated as "decision problem". It was written in German because this was the name of a particular problem occupying a group of German mathematicians at the end of the 19th century. Prominent among these was David Hilbert (1862-1943). Some readers may already know him from the Hilbert transform or the concept of the Hilbert space (a multidimensional space). In the paper, Turing refers specifically to the "Hilbertian Entscheidungsproblem". Broadly, the Entscheidungsproblem is a problem in logic: that of finding a definite method or algorithm that can be relied on to decide whether a mathematical proposition* can be proved to be true.

Hilbert was a formalist in his approach to investigating the fundamental basis of mathematics. (Other approaches are based on logic and on intuition.) In other words, he proposed that mathematics was a kind of game played with symbols, in accordance with a set of rules. It should not be regarded as necessarily true, apart from these formal considerations.

But the formalist view of mathematics could be strengthened and validated if the whole system could be proved to be internally consistent, that is, free from contradictions, and complete, in the sense that every mathematical statement could be either proved or disproved. This was Hilbert's 'programme', as it was called. He and a group of other mathematicians embarked on this project in the early 1900s.

The method adopted for the programme was to justify the whole of mathematics, including arithmetic and set theory, by putting it in a formal system and proving that this system was self-consistent. This was to be done by the simplest and most concrete methods of reasoning. Mathematical statements were to be represented by strings of symbols in formal logic systems. Then proofs were to be given of a consistency of such systems so that they would be shown to be correct in describing meaningful mathematical statements.

But the proofs were the difficulty. A procedure was necessary to decide whether consistency (lack of contradiction) was in fact provable – what was called a decision procedure. Finding a decision procedure was called the decision problem, or Entscheidungsproblem. And this had been recognized as a problem in logic since the late 19th century. (Note that George Boole, the originator of Boolean algebra, had published his famous book *The Law of Thought* in 1854.)

But in 1931 Hilbert's programme received a fatal blow from the now famous Gödel theorem[2]. The Czech mathematician Kurt Gödel showed that it is impossible to prove the consistency of a formal system within the system itself. Mathematics was not complete. Every mathematical statement could not be either proved or disproved.

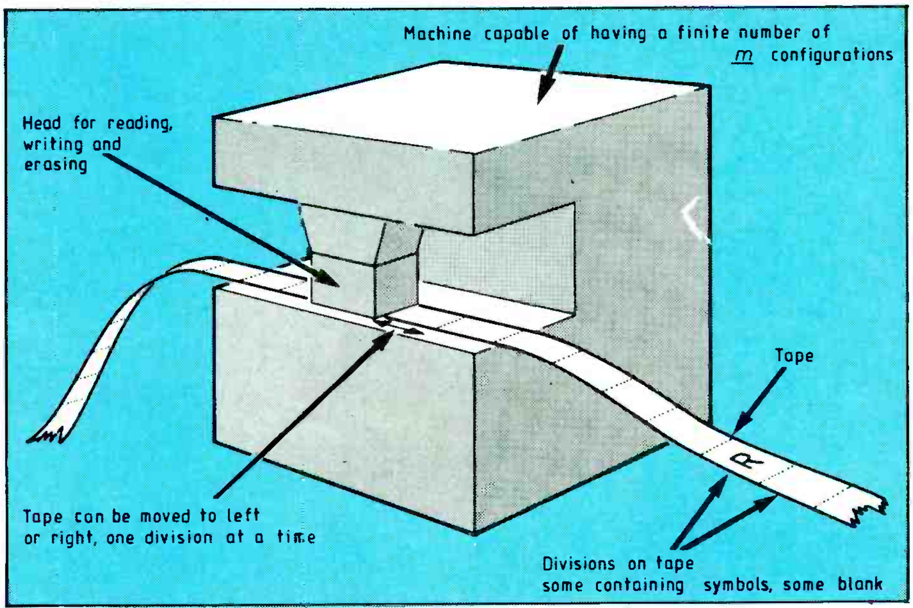


Fig.1. Essentials of the computing machine described in Turing's paper.

By 1936 the Gödel theorem was, of course, well known to Turing. He refers to it in the paper, saying that "conclusions are reached which are superficially similar to those of Gödel. These results have valuable applications. In particular it is shown... that the Hilbertian Entscheidungsproblem can have no solution."

Nevertheless it was the Entscheidungsproblem which stimulated Turing to consider a kind of left-over from the Gödel theorem: whether there could be some definite procedure for distinguishing provable from unprovable mathematical statements. As related by Andrew Hodges in an excellent biography of Turing,[3] this happened as a result of his attending a course of lectures at Cambridge on the foundations of mathematics.

The lecturer was M.H.A. Newman, who, as it happened, had taken part in an international conference in 1928 at which Hilbert had renewed his call for a project to investigate the foundations of mathematics on a formalist basis. Hilbert's notion that there might be a definite method for testing mathematical statements, as discussed above, was interpreted by Newman as the possibility of a "mechanical process" that would churn out answers.

This idea of a possible mechanical process apparently became firmly lodged in Turing's mind. It started him thinking specifically about machines that manipulate symbols – for example, typewriters. He conceived a computational answer to Hilbert's decision problem in 1935, when he was only 23, and this led to the writing of his paper "On computable numbers" in the ensuing months.

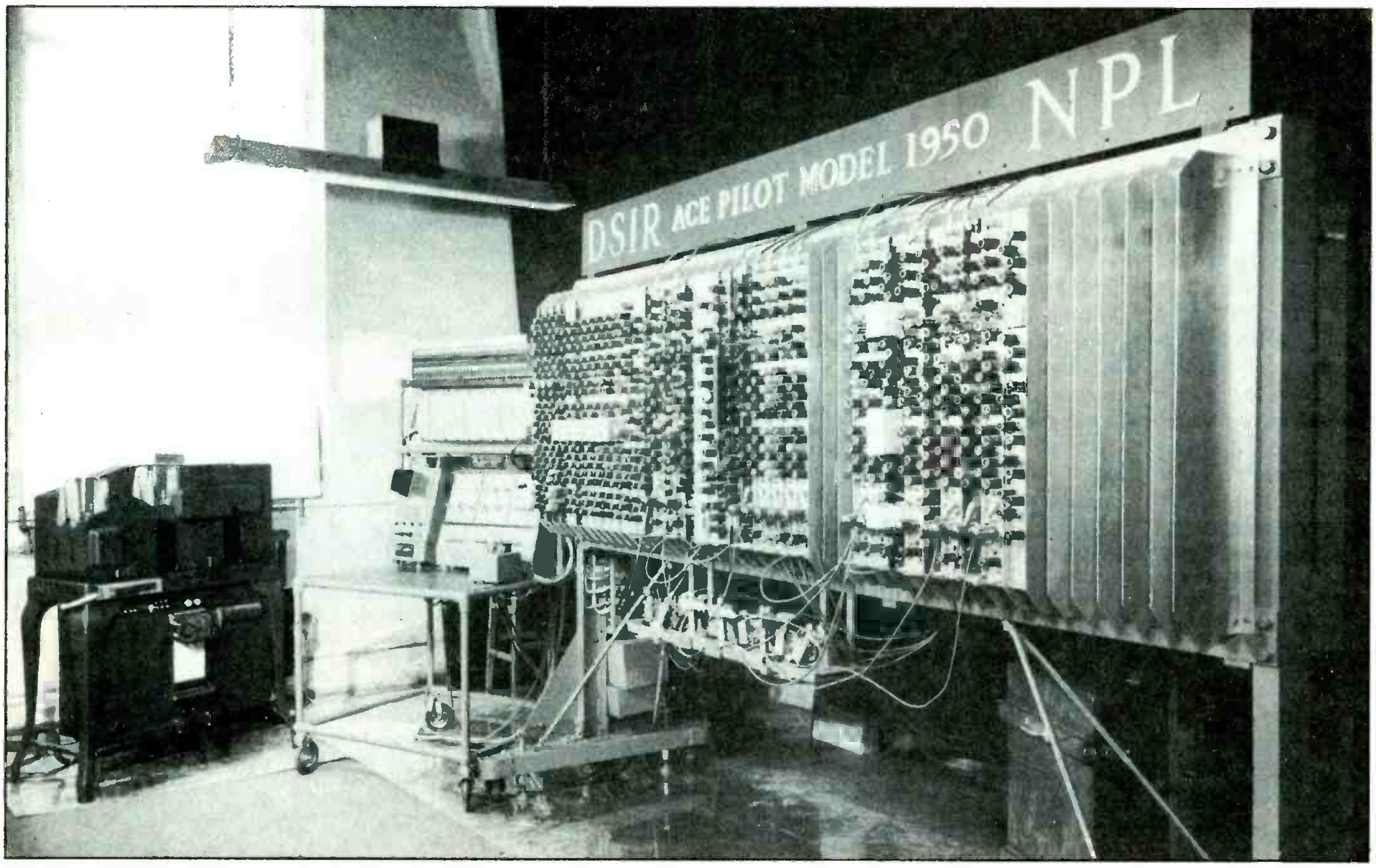
TURING MACHINES

Figure 1 shows the essentials of a Turing machine (though there is no such diagram in the paper itself). This is described by Turing as follows:

We may compare a man in the process of computing a real number to a machine which is only capable of a finite number of conditions $q_1, q_2, \ldots q_R$ *which will be called "m-configurations". The machine is supplied with a "tape" (the analogue of paper) running though it, and divided into sections (called "squares") each capable of bearing a "symbol". At any moment there is just one square, say the* r*-th, bearing the symbol* $S(r)$ *which is "in the machine". We may call this square the "scanned square". The symbol on the scanned square may be called the "scanned symbol". The "scanned symbol" is the only one of which the machine is, so to speak, "directly aware". However, by altering its* m*-configuration the machine can effectively remember some of the symbols which it has "seen" (scanned) previously. The possible behaviour of the machine at any moment is determined by the* m*-configuration* q_n *and the scanned symbol* $S(r)$*. This pair* q_n, $S(r)$ *will be called the "configuration": thus the configuration determines the possible behaviour of the machine. In some of the configurations in which the scanned square is blank (i.e. bears no symbol) the machine writes down a new symbol on the scanned square: in other configurations it erases the scanned symbol. The machine may also change the square which is being scanned, but only by shifting it one place to right or left. In addition to any of these operations the* m*-configuration may be changed. Some of the symbols written down will form the sequence of figures which is the decimal of the real number which is being computed. The others are just rough notes to "assist the memory". It will only be these rough notes which will be liable to erasure.*

It is my contention that these operations include all those which are used in the computation of a number. The defence of this contention will be easier when the theory of the machines is familiar to the reader.

Turing then goes on to say that he is concerned specifically with automatic machines. He defines an automatic computing machine as one in which its motion at each stage "is *completely* determined by the configuration.." (in the



Pilot model of the ACE computer built at the NPL as an outcome of Turing's work there. A part of this machine can be seen at the Science Museum, South Kensington, London. (Crown copyright)

above sense). The complete configuration at any stage is described by the number of the scanned square, the complete sequence of all symbols on the tape, and the *m*-configuration. In other words it is the information itself which pushes the machine along – not some external agency – so that it becomes automatic.

Then Turing explains that the behaviour of such an automatic machine can be described by successive rows of symbols and abbreviations in a table. This table has the column headings:

m configuration	symbol	operations	final m configuration

The first column contains code letters: the next contains tape symbols as defined above. The 'operations' column contains abbreviations like 'R' which means the machine moves one tape square to the right and scans that square. The 'final *m*-configuration' column contains code letters belonging to the same alphabet as in the first column and having the same meanings.

In each row of the table the first two columns describe a machine configuration. For this, the operations indicated in the third column are performed in succession and the machine moves into the final *m*-configuration in the last column. In the context of the paper, this table *is* the machine.

Turing then gives examples of how different machines based on this general principle can be mentally constructed to compute different sequences of digits. He actually uses the binary digits 0 and 1 in the examples, but this has nothing whatever to do with the fact that binary notation was later used in practical computers to suit two-state electrical and electronic devices.

MACHINE ACTIONS AS NUMBERS

After mentioning that the *m*-configuration tables can be abbreviated for convenience in performing frequently used, standard processes, the paper goes on to demonstrate that the rows of a table can be encoded as letters of the alphabet. A group of these code letters is a "standard description" of a machine. What this describes is not some arrangement of hardware but the rules of operation of the machine.

Finally, Turing says, the letters can be further encoded into decimal digits. As a result "we shall have a description of the machine in the form of an arabic numeral. The integer represented by this numeral may be called a *description number*... of the machine." It determines the standard description and the structure of the machine uniquely. Further, there is a description number for each computable sequence.

Thus at this point the paper is dealing with certain computing machines ('Turing machines') which are automatic and have input, output and memory. This kind of machine has an instruction code in the sense that a given machine action is determined by a code consisting of a symbol on the tape and symbols representing the current machine configuration. It has a program – though fixed and not an alterable stored program in today's sense – in that it carries out an ordered sequence of steps to perform a computation. But so far these machines are special-purpose ones: each is mentally constructed to compute one particular sequence and that alone.

UNIVERSAL TURING MACHINES

The crucial point about the special-purpose machines is that each machine is completely described – that is, everything it does in computing its particular sequence – by a code number: its description number. Thus machine operations are encoded as numbers, and as far as the machine is concerned there is no distinction between the numbers of the sequence being computed and the operations performed on those numbers: they are all just symbols. Through these operation numbers the tables can be put on the tape.

But in addition to the particular special-purpose machines described, a table could represent the behaviour of any machine. It follows that a single, general-purpose Turing machine could be made to simulate the actions of a variety of other, special-purpose machines. Turing calls this all-purpose device a "universal computing machine". It is possible, he says, "to invent a single machine which can be used to compute any computable sequence." If this machine is supplied with a tape at the start of which is written the standard description of some particular computing machine then it will compute the same sequence as the particular machine.

In elaborating this general idea the paper goes on to say that the universal computing machine would have the rules of operation of the special-purpose machine written somewhere inside it. Then "each step could be carried out by referring to these rules." In modern terminology, the universal computing machines has a stored program. And the concept of such a stored program being alterable is introduced by the words "We have only to regard the rules as being capable of being taken out and exchanged for others..." Remembering that the rules are expressed as symbols, we see that Turing is here talking about what we now call software. There follows a detailed account of the universal computing machine, all in terms of symbols in tabular form.

MATHEMATICAL CONCLUSION

The second half of Turing's 36-page paper is devoted to its main mathematical purpose: to prove that there is a class of quite elementary arithmetical questions for which there is no decision procedure. As the author states, the results obtained in the paper "can be used to show that the Hilbertian Ent-[1] scheidungsproblem can have no solution." Having given a proof of this, he concludes: "Hence the Entscheidungsproblem cannot be solved."

LATER DEVELOPMENTS

Despite the purely abstract nature of the computing machines discussed in the paper, Turing did go on in later years to build experimental electrical and electronic systems for mathematical purposes. Moreover, during the course of his brilliant code decipherment work at the Government Code and Cypher School in the 1939-45 war he was in close contact with the building and operational use of the Colossus, an electronic cryptanalytic machine constructed with thermionic valves. As a result he acquired a certain amount of electronic engineering knowledge.

He learnt even more about the possibilities and limitations of the current electronics technology when he joined the then new Mathematics Division of the National Physical Laboratory at Teddington. He had been invited there specifically to work on a project officially described as "Investigation of the possible adaptation of automatic telephone equipment to scientific computing" and "Development of electronic counting device suitable for rapid computing." The Division was familiar with Turing's 1936 paper. It was also very much aware of current American work in computing machines, such as the Automatic Sequence Controlled Calculator at Harvard University and the ENIAC (Electronic Numerical Integrator and Calculator) at Pennsylvania University.

At the NPL Turing worked for three years on its computing project, producing what became in effect a specification for the ACE (Automatic Computing Engine). This was eventually built, first as the Pilot ACE and later, in 1958, as a full-scale machine. Meanwhile Turing moved to Manchester University to do similar work there. The Pilot ACE was later produced in commercial form by English Electric under the name DEUCE, while Manchester University's machine was similarly developed into the Ferranti Mark I computer. So Turing played some part in the research which led to the founding of the British computer industry.

There has been a good deal of discussion about the relative contributions of Turing and von Neumann to the concept of the stored program digital computer. It was John von Neumann, the Hungarian-American mathematician, who became an adviser to the ENIAC project and was associated with the idea of introducing a stored program to replace the ENIAC's original plug-and-socket method of setting up instructions. Von Neumann and Turing knew each other. They were together for a while at Princeton University and had discussions there. Furthermore von Neumann had read and was aware of the significance of Turing's 1936 paper. Commentators have therefore suggested that Turing's paper provided the fundamental idea of a program stored as symbols which von Neumann later picked up and utilized, consciously or unconciously, for a practical purpose.

For example, Donald Davies of the NPL has written: "Probably few of the early pioneers had read the remarkable paper (Turing's) but without doubt one man knew it and understood fully its significance – John von Neumann. His comments to Eckert and Mauchly when he first saw ENIAC, and afterwards his own work with Goldstine, led to the flowering of the stored program computer in the USA, while in Britain several influences were at work and one influence was Turing himself."[4].

Other authorities hold that von Neumann was the direct originator of the stored-program concept, and probably from this view comes the term "von Neumann architecture' in general use today. Indeed it is so firmly established that departures from the principle are now being called 'Non-von' computers.

But this discussion about priority in no way diminishes the fact of Turing's 1936 paper and its undoubted originality. Perhaps the only way to assess its significance and contribution to present-day computer science/technology is to read it onself and make up one's own mind.

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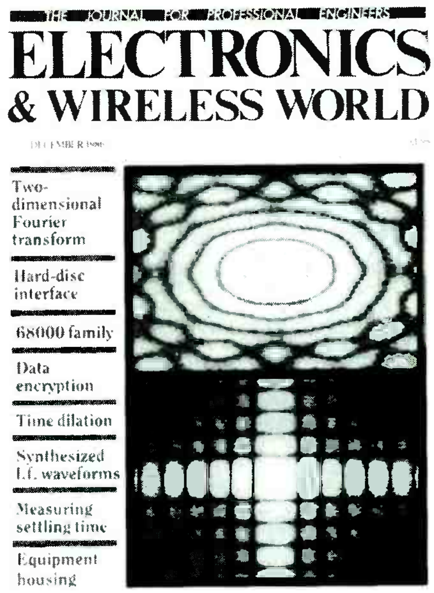
1. A.M. Turing, "On computable numbers, with an application to the Entscheidungsproblem", *Proc. Lond. Math. Soc.* (Series 2), 42, Nov. 12, 1936, pp. 230-265.

2. K. Gödel, "Über formalunentscheidbare Sätze der Principia Mathematica und verwandter Systeme. I", *Monatshefte Math. Phys.*, 38, 1931, pp. 173-198.

3. A. Hodges, *Alan Turing, The Enigma of Intelligence*, Unwin Paperbacks, London, 1985.

4. Quoted from a foreword by D. W. Davies to a reprint of Turing's original proposal to build a computer at NPL; from a report on a discussion on "The Foundations of Computer Engineering" in *The Radio and Electronic Engineer*, Golden Jubilee issue, 45, No. 10, Oct. 1975, pp. 598-602.



NEXT MONTH..

Two-dimensional Fourier Transform

Weysel Omer follows up his article in the June issue and describes the transformation of two-dimensional data on the BBC computer. The results can be applied to image processing in applications such as LANDSAT image analysis, magnetic resonance imaging and filter design.

Electronic encryption

Brian McArdle explains the protection of data using the US Data Encryption Standard and describes interfacing between a DES i.c. and a Z80 microprocessor

Hard disc interface

Byte-for-byte, hard-disc storage is around ten times cheaper than floppy-disc storage. John Adams discusses interfacing a hard-disc drive to a microcomputer with the aid of a practical example.

68000 processor family

Descriptions of the 68020 coprocessor interface and pipelining are included in David Burn's overview of the 68000-series 16/32 bit microprocessors

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A massive purchase of these desk top printer terminals enables us to offer you these quality **30** or **120** cps printers at a **SUPER LOW PRICE** against their original cost of over £1000. Unit comprises of full **QWERTY**, electronic keyboard and printer mech with print face similar to correspondence quality typewriter. Variable forms tractor unit enables full width – up to 13.5" 120 column paper, upper – lower case, standard **RS232** serial interface, internal vertical and horizontal tab settings, standard ribbon, adjustable baud rates, quiet operation plus many other features. Supplied complete with manual. Guaranteed working **GE30 £130.00**. **GE1200 120 cps £175.00**. Untested **GE30 £65.00**. Optional floor stand **£12.50**. Carr & Ins. £10.00.

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TTL 74 Series. A gigantic purchase of an "across the board" range of **74 TTL** series IC's enables us to offer **100+** mixed "**mostly TTL**" grab bags at a price which two or three chips in the bag would normally cost to buy. Fully guaranteed all IC's full spec. **100+ £6.90, 200+ £12.30, 300+ £19.50**

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DH11-AD 16" x RS232 DMA interface	£1,900.00
DLV11-J4 x EIA interface	£350.00
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DUP11 Synch. Serial data i/o	£650.00
DQ200 Dilog – multi RK controller	£495.00
DZ11-B 8 line RS232 mux board	£650.00
KDF11-B M8189 PDP 1123 PLUS	£1,100.00
LA30 Printer and Keyboard	£80.00
LA36 Decwriter EIA or 20 mA loop	£270.00
MS11-JP Unibus 32kb Ram	£80.00
MS11-LB Unibus 128kb Ram	£450.00
MS11-LD Unibus 256kb Ram	£850.00
PDP11/05 Cpu Ram, i/o etc	£450.00
PDP11/40 Cpu, 124k MMU	£1,850.00
RT11 ver **3B** documentation kit	£70.00
RK05-J 2.5 Mb disk drives	£650.00
KL8 JA PDP 8 async i/o	£175.00
M18E PDP 8 Bootstrap option	£75.00
VT50 VDU and Keyboard – 20 mA	£175.00
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Also available less psu, with fans etc. Internal dim. 19"w, 16"d, 10.5"h. **£19.95. Carriage £8.75**

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CIRCLE 62 FOR FURTHER DETAILS

APPLICATIONS SUMMARY

LOW-LOSS REGULATED SUPPLY

Voltage drop in conventional three-terminal regulators is above 1V. In this circuit, one of 11 described in Siliconix' 'Applications No 1', no voltage drop occurs provided that input diode voltage remains above the zener voltage plus the product $I_D \times R_{DSon}$

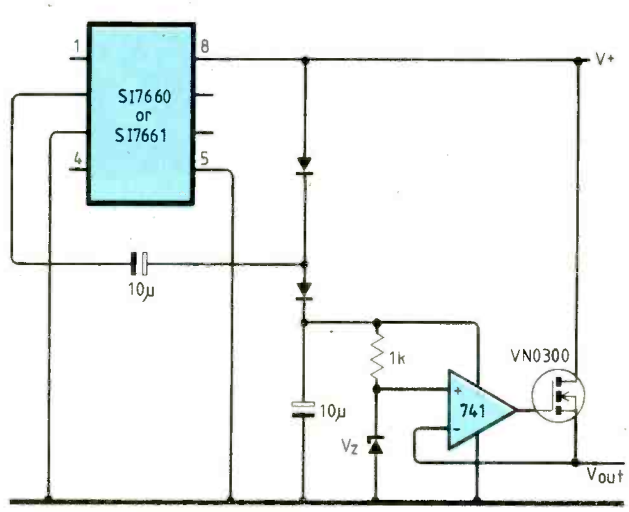
Voltage is doubled by the 7660 then regulated by the op-amp and mosfet. For I_D of 50mA.

$$V_{in} = V_z(I_D \times R_{DSon}) = 5.2V + (0.05 \times 1.2) = 5.26V$$

So as long as input voltage does not drop below 5.26V, output will be as close to the zener voltage as the op-amp common-mode offset voltage allows.

By selection of the zener diode, supply current is greater than 100mA. Output voltage is adjustable up to the input limit of the converter used.

The other ten circuits in the eight-page note are a stepper motor drive, high-voltage mosfet totem-pole, current regulator, two-channel video switch, j-fet op-amp input, memory mapped interface, simple a-to-d converter, bipolar d-to-a converter, a sampler and a processor-controlled multiplexer.
EWW300 on reply card



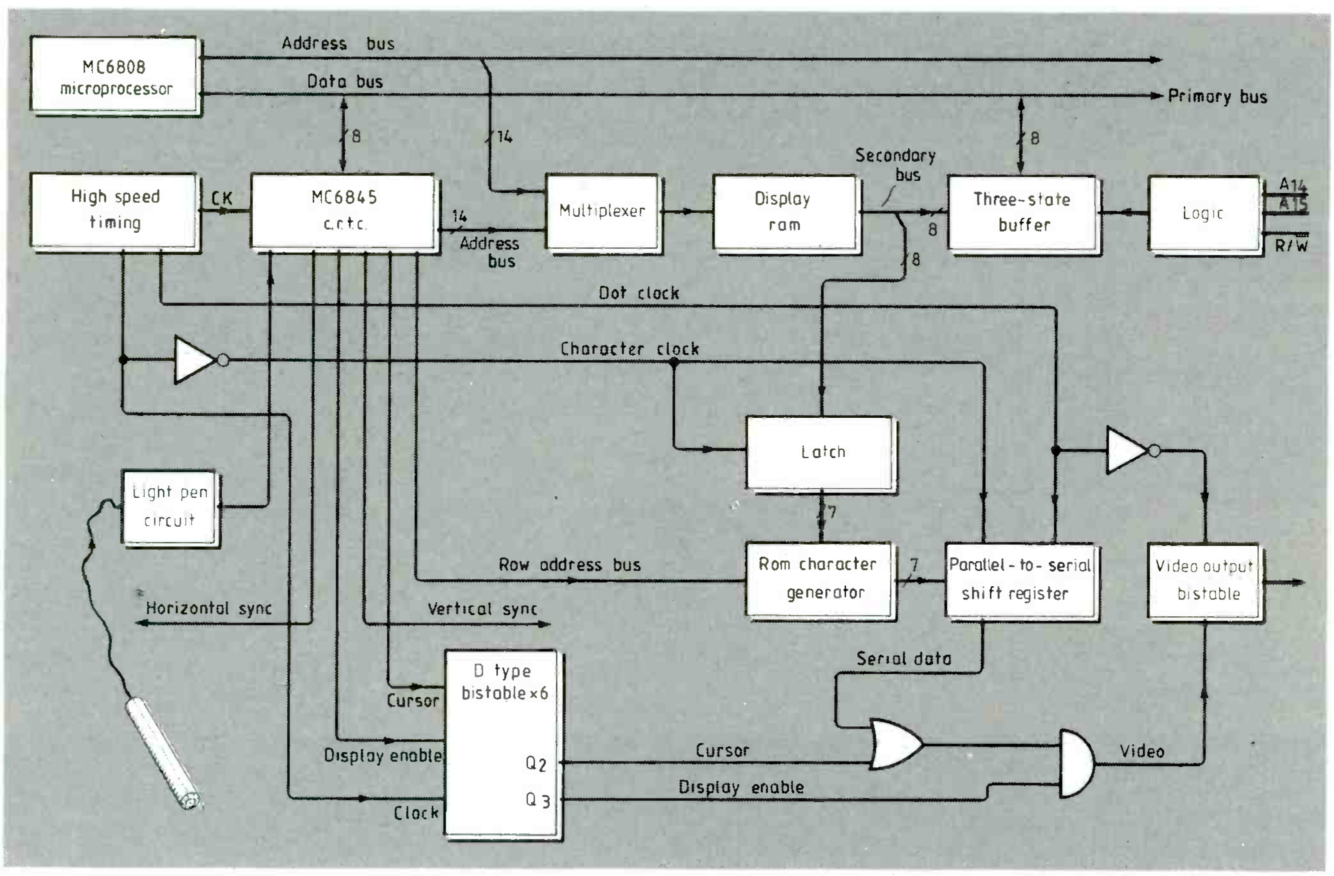
DISPLAY CONTROLLER

Hardware and software for turning parallel data into video-form alphanumeric characters are described in Motorola note AN851. The design includes a microprocessor for display manipulation and interfacing.

Main components are a 6808 microprocessor and a 6845 c.r.t. controller. The microprocessor responds to special character codes to give automatic scrolling, carriage return, line-feed, paging, screen clearing and cursor manipulation.

Eight-bit character data, taken sequentially from screen ram, is turned into 7×9 dot display characters and positioned on the screen by the c.r.t. controller. Shift-register dot clocking and sync generation is also done by the controller.

The circuit and software produce 24 lines of 80 alphanumeric characters but modifications are outlined for graphics and semi-graphics displays. Assembly-language software for the screen-manipulation functions is given and described but both hardware and software for parallel or serial interfacing are left to the user.
EWW301 on reply card



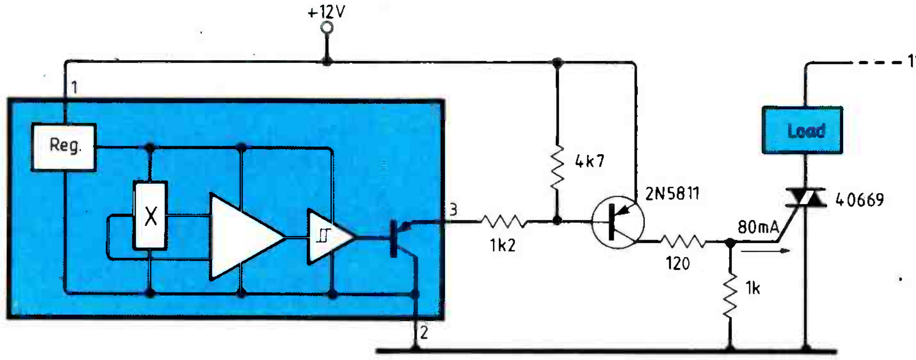
HALL-EFFECT I.CS

Comprehensive magnetic-interfacing and characteristic details for Hall-effect i.cs are given in Sprague's CN207 applications booklet but there are also one or two simple output-conditioning circuits, such as this one for s.c.r. driving.

On-state output current from the Hall-effect switch is low so a transistor amplifier is used to step the 9mA output up to 80mA to turn on the s.c.r.

The 40-page booklet tells how the Hall-effect i.cs work and includes sections on rotary activators, ring magnets, current sensors, magnet selection and operating modes.

EWW302 on reply card



AUDIO DELAY DEVICES

Circuits for chorus, vibrato and reverberation are given in Panasonic's BBD data/application catalogue for bucket-brigade devices. No circuit details are given but the catalogue includes full technical specifications of a range of delay i.cs that directly replace Mullard types.

The MN3005 is a 4096-stage device with 75dB s-to-n ratio for delays from 20.48 to 205ms. This 100ms reverberation circuit is accompanied by a p.c.b. foil pattern.

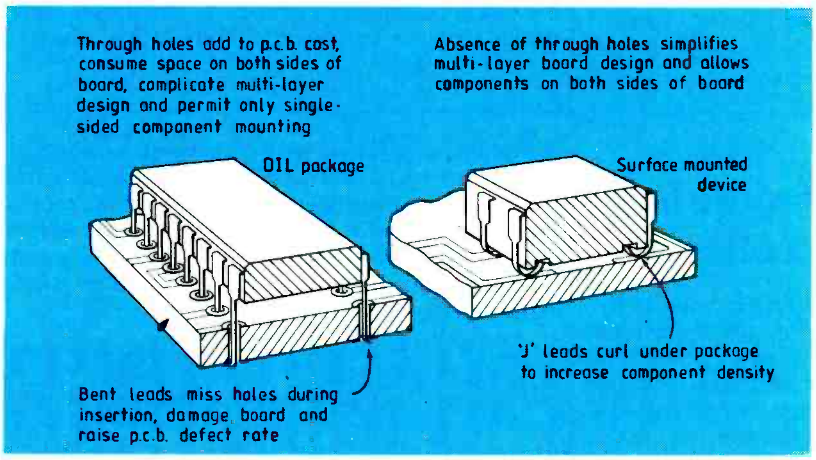
EWW303 on reply card

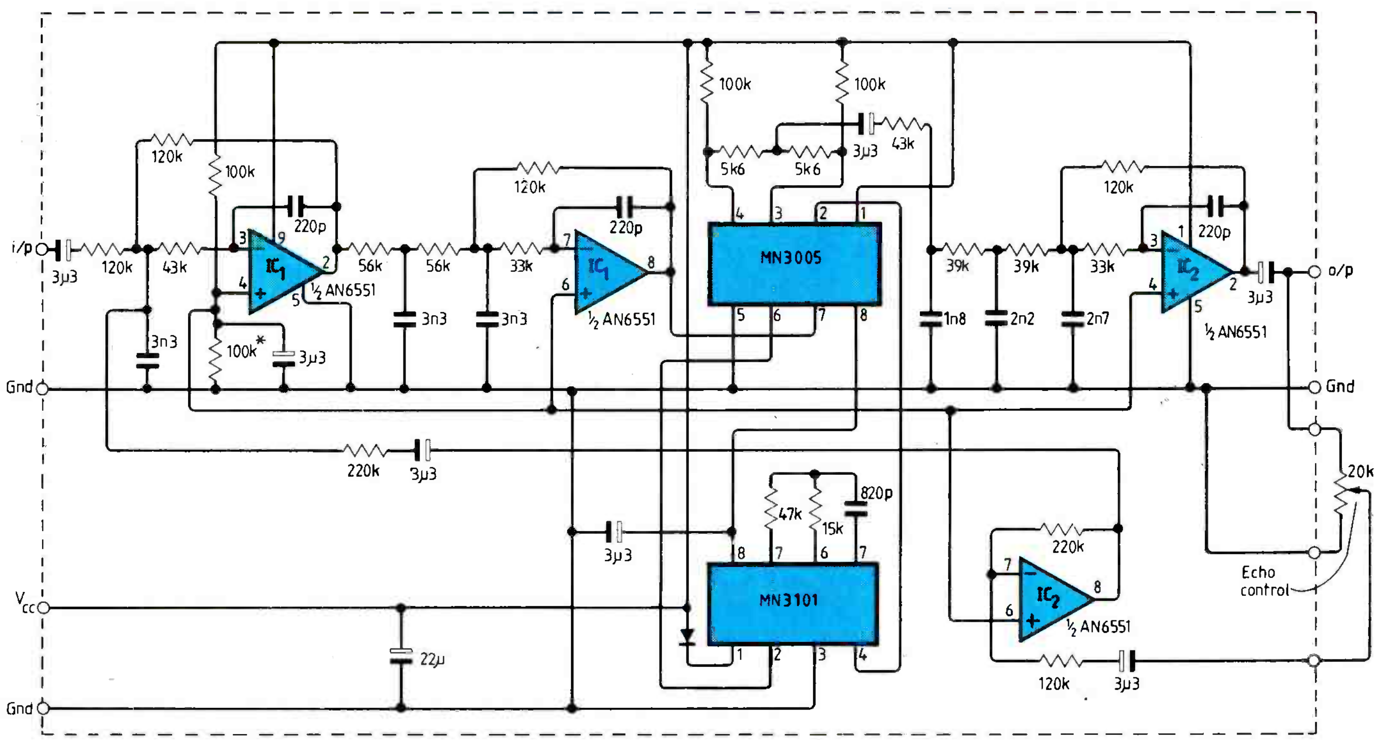
SURFACE MOUNTING

Lower manufacturing costs and smaller board size are the main benefits of using surface-mounted components but there is also a significant electrical benefit.

An MF Electronics' note mainly outlining the commercial advantages of surface-mounting technology for p.c.b. manufacturers points out that because surface-mounted components are closer together, propagation delay and r.f. emission are reduced. Surface-mounted devices also have shorter legs than conventional ones, which further reduces these problems.

EWW304 on reply card





* Adjust to minimize distortion

Stereo tv in US wins award

Zenith Electronics Corp. in the USA has won an Emmy award for its Multichannel tv sound (MTS) stereo tv system. The system allows hi-fi stereo sound to be broadcast with the tv signal. The second channel can also be used to broadcast a simultaneous audio programme which could, for example be another language for translations. According to Zenith, more than 87% of the continental US population is in range of a stereo tv signal. More than 300 stations are equipped with the MTS system. The federal Communications Commission authorized stereo tv broadcasts in 1964, following the endorsement of the Zenith system by the Electonic Industries Association.

Electronic bus data collector

Well actually it's a clipboard covered with barcodes and is being used by transport authorities anxious to make their bus services efficient. Survey staff can interview passengers and use a portable terminal to record the answers. Each clipboard has the relevant details of the bus route encoded on it. So a simple wipe of the optical pickup provides details of the stops, time, purpose of journey, use of travel cards and the like. When the terminals are plugged into a computer, directly or remotely through a modem, the results can be transferred immediately without any human interference. Merseyside passenger transport executive are to get 32 terminals from GE Electronics and are planning to survey 1200 routes.

In brief

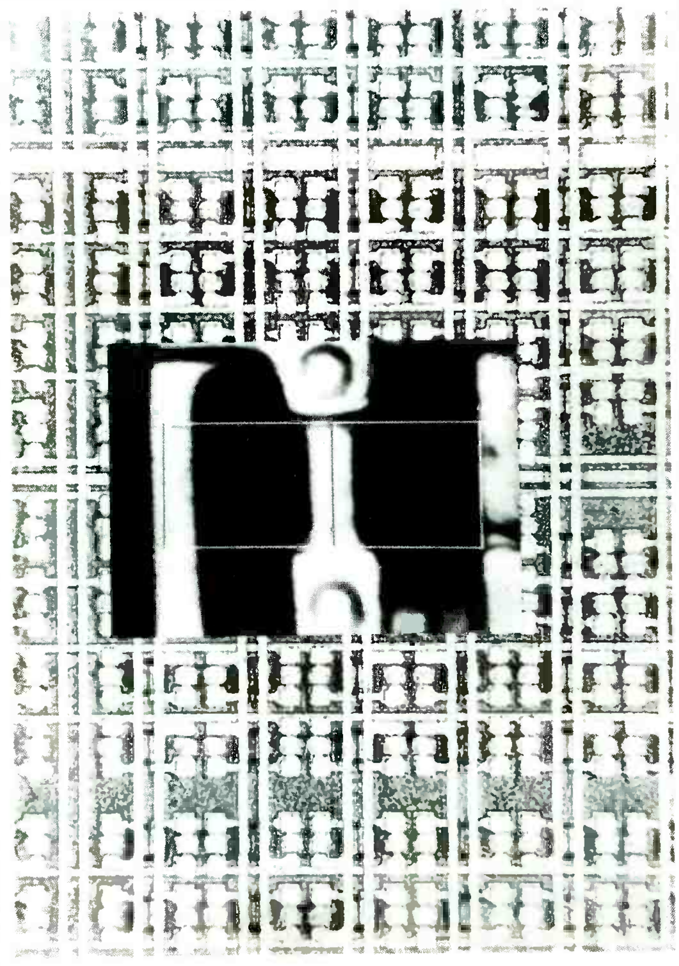
The 1986/87 series of IEE Faraday Lectures, designed to inform and educate young people, are to be presented by ICL who will use the title "The opportunity of a lifetime" to promote the idea that "information and its effective use can be the key to survival and prosperity of Britain as an individual nation."

Euro information exchange

Millions of trade documents could be virtually eliminated by the adoption of ODETTE (Organisation for data exchange by teletransmission in Europe). The documents will be replaced with electronic traffic carrying the same content but travelling much faster than post and requiring no manual processing.

Odette was devised by a number of motor manufacturers and suppliers with the aim of cutting the cost of paperwork in vehicle production and of improving business methods, to provide instant response to a change, like the Japanese 'just in time' system. They key to the system is the Interbridge data standardization package. This translates documents into and back out of standard formats on the United Nations' *Guidelines for Trade Data Interchange*. The scheme has just been adopted by the Society of Motor Manufacturers and Traders and the systems will be installed by Systems Designers, of Fleet, Hants.

Some logic array chips are programmed by lasers severing 2µm links in the metal interconnection circuit. Siemens Production engineers have developed a grey-shade image processing system which can distiguish 256 different brightness values, locate the exact position of a connection point within 30ms and position the laser with an accuracy of 0.2µm. Such a position is indicated by the middle axis in the picture.



MEETINGS AND LECTURES

30 October
Clock recovery and synchronization in digital radio. IEE colloquium at IEE, Savoy Place, London WC2. Tel: 01 240 1871 Ext. 269.

31 October
Future printer and plotter technology. IEE colloquium. As above.

3 November
Millimetre wave component design. IEE colloquium. As above.
System required and system definition. IEE discussion meeting. 14.00h. Further details as above.

4 November
Adaptive man-machine interfaces. IEE colloquium. As above.
3D tv – solid future? IEE lecture by Dr R Borner. As above.

5 November
High integrity systems – theory and practice. IEE colloquium. As above.

6 November
Designing on silicon – the challenge for power engineers. IEE Lecture by D. H. Roberts (GEC). As above.

Nerve activity measurement and analysis. IEE/IPSM colloquium. As above.

6 November
Creative digits – the impact of digital technology on tv production. Royal Television Society 1986 Shoenberg Memorial lecture. At the Royal Institution, Albermarle Street, London W1. 1900h. Details from the Society, Tel: 01 387 1970.

7 November
The Domesday project – engineering aspects. IEE colloquium. As above.

11 November
Small terminal satellite communications systems. IEE colloquium. As above.

Sub-marine telecommunications. IEE lecture by Dr. T. Rowbotham (BTRL). As above.

12 November
High definition tv – the technical challenge. IEE lecture by T.S. Robson (IBA).

17 November
Giotto – the mission accomplished. IEE lecture by R. Jenkins (BAe) Electromagnetic Interference: practical design and construction techniques. IEEIE/IEE symposium. City Conference Centre, Mark Lane, London EC3. Details from IEEIE, Tel: 01-836 3357 Ext. 212.

Wafer fabrication in Scotland

Production has begun in Glenrothes at a new factory for diffused silicon wafers. Sememlab, who manufacture transistors on wafers supplied by other manufacturers, have set up the factory to produce power mos-fet and bipolar transistors with a 3micron geometry. Most of the products will be used by Sememlab themselves but there will be enough capacity to supply wafers to other manufacturers for transistors or mos i.cs compatible with the processes available.

....and in France

Construction work has begun in the South of France of the construction of a very large factory for the production of integrated circuits using direct electron-beam lithography to provide rapid turnaround for the devices.

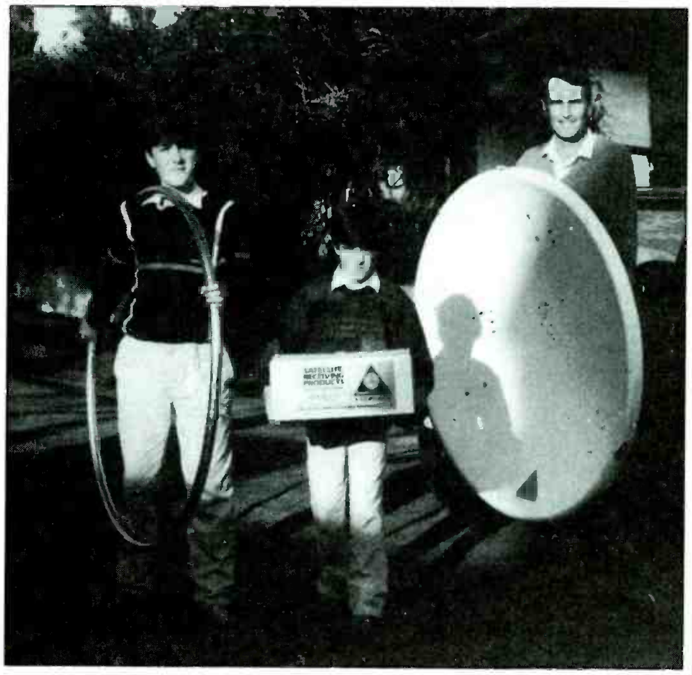
European Silicon Structure (ES2) is a result of collaboration between several leading systems manufacturers in Europe including Philips, Brown Boveri, Saab, Bull, Olivetti, British Aerospace and Telefonica.

The factory is specifically designed to produce application-specific i.cs which would be too specialized for the large manufacturers to tackle with their conventional production methods. Design stages will be developed on a silicon compiler, a software system that reduces design time dramatically.

The shell of the building is to be complete and equipment installed next spring; the first products to emerge in summer.

New pinouts for new logic

The joint development of advanced c-mos (a.c.l) by Philip/Signetics and Texas aims to produce the speed of advanced bipolar logic with the low current consumption of c-mos. The a.c.l. devices will be three times as fast as existing high-speed c-mos logic i.cs while offering 24mA of output drive current, which gives considerably more fanout. In order to take full advantage of these advancements, it was necessary to rearrange the power and signal pins. These will help to reduce noise and overcome the effects of simultaneous switching within the devices. Other changes will reduce the self inductance encountered with some i.cs. The principal changes will be that the supply voltage and ground pins will be in the middle of d.i.l. Package instead of the ends. Inputs will surround the supply voltage pins and outputs will be near the ground pins with control signals at the ends.



Take-away domestic satellite receivers are to be introduced by Rediffusion Radio Systems. Two building blocks, RSR-30 receiver and RKU-10 low noise block, form the basis for both domestic and commercial systems. 1.2, 1.5, and 1.7m dishes are available and a basic home installation is expected to retail at under £1000.

Acorn back in the black

Acorn Computers achieved an operating profit of £298k in the first half of 1986, compared with a loss in the previous six months of £97k and the disastrous £10m loss at the beginning of 1985. The turnaround has been achieved despite the expense of launching new products and maintaining the same level of r & d expenditure. Brian Long, Acorn managing director puts the success of the Master series at the top of his list to explain the recovery. There was also the sale of a licence to VLSI Technology the produce the Acorn RISC chip; the successful expansion into specialist markets, such as health care and doctors' records, and o.e.m. sales to major customer for inclusion in their own products. Long also points out the loyalty of customers who can continue to exploit their existing investments by getting the latest upgrades. Acorn's commitment to continuity has played a crucial role in users' loyalty, he said.

How safe are VDUs?

There have been allegations of adverse effects of working with computer screens for pregnant women. The second international meeting to examine the allegations of reproductive hazards from v.d.u.s is to take place at the Cumberland Hotel, London on 25th and 26th November. Speakers, mostly medical experts from Scandinavia, North America and Europe, will present the results of their studies. The meeting is organized by Humane Technology, a consultancy specializing in the human aspects of computer systems. Further details from HT, Telephone: Nottingham (0602) 475563

In brief

Finland is to become an associate member of the European Space Agency. It will participate in the science programme and in the Earth observation preparatory programme. This latter is a five-year programme to prepare Europe's activities for a further ten years.

The International Train, British Rail Engineering's attempt to sell new rolling stock abroad, has lots of electronics on board. There is a cellular payphone linked to Cellnet. A prototype seat reservation system transmits details to the train before departure. This and other information can be displayed to the passengers, individually or collectively. The screens can also be used to show films and tv programs. British Telecom has provided all this and is also proud of its control and monitoring systems, developed specifically for railway applications.

CONFERENCES & LECTURES

4-7 November 1986
Radio relay systems. European conference in Munich. Details from Dr P. Guls, ANT Nachrichtentechnik GmbH, Gerberstrasse 33, D-7150 Backnang, FRGermany.

13-15 November 1986
The history of television. IEE and others. International conference at IEE, Savoy Place, London WC2. Tel: 01 240 1871 Ext. 222.

18-22 November 1986
Computers in the city. Conference and Exhibition. Barbican Centre, London. Online, Telephone 01 868 4466.

22-23 November 1986
Hands-on show Music recording exhibition, with seminars. Strand Palace Hotel, The Strand, London WC2. Organized by Turnkey, Telephone 01-202 4366.

2-3 December 1986
Satellite Communications. Conference. Tara Hotel, London Online, Tel: 01 868 4466.

2-5 December 1986
Technospace International space industries and technologies exhibition. Bordeaux-Congres, Bordeaux, France. Details: Technospace, 12 Place de la Bourse, 33076 Bordeaux Cedex, France.

Still in the picture

Television South has acquired two systems for the storage of still pictures on optical discs. The pictures are stored in EBU/SMPTE format and a complimentary database system keeps a comprehensive record of the contents of each disc. Each optical disc can store over 1000 full-sized broadcast quality pictures. An add-on option is Picture File which allows the stills to be viewed in full frame or it is possible to get 30 pictures onto one screen for comparison. Other options include video manipulation of the pictures so that they can, for example, be flipped, changed in size, be cropped or repositioned: Art File provides a video "painting" system. The Gallery 2000 system is produced and supplied by Logica.

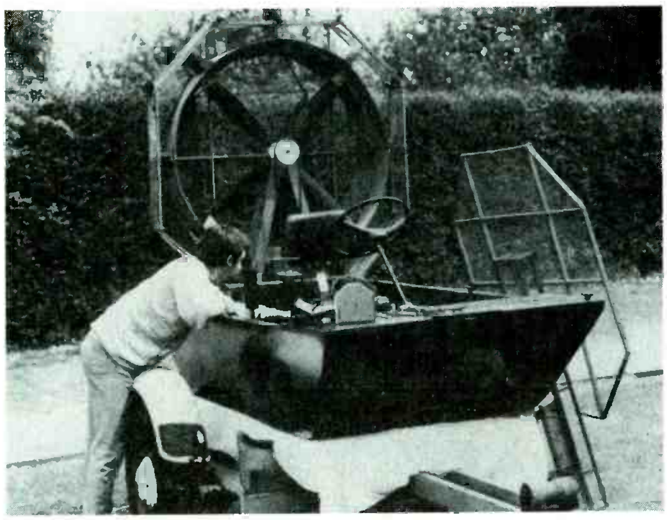
DTI look into parts of the spectrum

The Department of Trade and Industry has commissioned a short-term study on spectrum planning for fixed terrestrial radio services in the unexploited frequency range of 30 to 60GHz. The study will review the future of existing and potential microwave fixed links. It will pay particular attention to the competitive position of UK equipment manufacturers and the likely developments in technology over the next five years.

Outline planning for this band has been completed but the DTI would welcome contact with those with an interest in this frequency range. Comment should go to the consultant, Graham Taylor, Ewbank Preece Consulting Ltd, Prudential House, North Street, Brighton BN1 1RE.

Meanwhile, in another part of the spectrum, more frequencies are to be made available for cellular telephones in central London. The frequencies immediately below those presently used for cellular radio are allocated to the MoD. They have agreed that, subject to certain restrictions, these frequencies may be used by cellular radio operators in London. Initially a further 200 channels will become available to each operator – compared with the current 300. If the demand justifies it, a further 120 channel each could become available. The MoD restriction is that the area of operation should be limited to a 6-mile radius around Charing Cross.

Yet more news from the DTI is that they have published a consultative document on the possibility of establishing an independent third-party quality assurance scheme within the radio communication industry. This in effect could lead to a self regulating radio frequency spectrum, devolved from the RRD. The scheme could also reduce the number of international assessments needed for type-approval. Manufacturers who are certified to certain levels of product conformity will produce better goods. If the responsibility for type approval is put directly on the manufacturers and importers, the loophole, that allows illegal good to be sold legally would be closed. Copies of the document, full title of which is "Proposal for the establishment within the radio communications industry of an independent third party quality assurance scheme under the aegis of the National Accreditation Council for Certification Bodies" are obtainable from the DTI, Room 409, Waterloo Bridge House, Waterloo Road, London SE1 8UA.



Crest awards for young people

At work on his Swamp Rat air boat is 18-year-old Christopher Cox, who designed it as a pilot project for the Crest Award scheme. Crest stands for Creativity in Science and Technology; and the aim of the scheme is to do for young people's scientific and technical awareness what the Duke of Edinburgh's award has done for overall personal development.

Launched by the British Association for the Advancement of Science at its 1986 meeting in Bristol, Crest offers awards at gold, silver or bronze level for knowledge, problem-solving ability and perseverance.

Young people aged 11 to 18 can take part either as individuals or as teams. And their entries may consist of straightforward scientific investigations or design and construction studies.

Prospective gold award winners are to be encouraged to form links with industry and higher education for help and advice. The scheme will undoubtedly give job-hunting school leavers a useful record of achievement to supplement their examination results. But the organizers hope it will encourage scientific and technological activity among all secondary school pupils and in doing help to reduce Britain's present shortage of skilled engineers.

Financial backing for Crest has come from Philips Electronics, BP, the Wellcome Foundation and the Department of Education.

For more details, write to Crest at the British Association, Fortress House, 23 Savile Row, London W1X 1AB.

CONFERENCE & EXHIBITIONS

3-4 December 1986
Satellite Broadcasting. Conference. Tara Hotel, London Online, as above.

9-11 December 1986
Videotex International Conference and exhibition. Wembley Conference Centre, London. Online, as above.

23-27 February 1987
Fiarex 87 international electronics trade fair. Rai Exhibition Centre, Amsterdam. Rai Gebouw, Europaplein, Amsterdam.

3-6 March 1987
International Open Systems Conference (and a MAP seminar, 4 March). Barbican Centre, London. Online, as above Semicon Europa 87 exhibition of semiconductor equipment and materials. Zuspa Convention Centre, Zurich. Enquiries to Cochrane Communications, Tel: 01 353 8807.

24-26 March 1987
Cadcam 87 exhibition. NEC Birmingham.
EMAP int. Exhibitions, Tel: 01 608 1161.

25-26 March 1987
Instrumentation Bristol 87 Exhibition. Bristol Crest Hotel. Trident Int. Exhibitions, Tel: 0822 4671.

6-8 April 1987
Offshore computers conference and exhibition. Heathrow Penta Hotel, London. Offshore Conferences, Tel: 01 549 5831.

28-29 April 1987
Cellular and mobile communications Conference. Barbican Centre, London. Online, as above. Value-added network services (VANS) Conference. Barbican Centre, London. Online as above.

28-30 April 1987
City communications exhibition. Barbican Centre, London. Online, As above.

18-20 June 1987
Television measurements, Third international IERE conference. Montreux, Switzerland. IERE Tel: 01 388 3071.

Broadcast radio-data

As the BBC and IBA prepare RDS services for next year's start, this review describes radio-data on both v.h.f. and l.f.

D.T. WRIGHT AND S.M. EDWARDSON

For more than a decade, broadcasters have been adding auxiliary data signals to their normal radio and television transmissions in such a way that they go unnoticed by viewers and listeners not equipped to receive them. Probably the first application of this kind, which barely warrants recognition as a one-bit data signal, was the addition in the early 1960s of a 23kHz tone to BBC monophonic v.h.f./f.m. radio broadcasts to control the powering of unattended relay transmitters.

For some years after that, attention in the BBC was focused on television. Insertion Communication Equipment (ICE) was an in-house system designed in the early 1970s to add data signals to an unused line in each field blanking interval for such applications as the control of opt-out switching at regional centres, the synchronization of television waveform generators at remote sources, and to provide low-speed teleprinter channels.

Teletext, a public information service which came into use in 1974, made much more ambitious use of the field blanking interval by cramming into each line 40 useful bytes of information, corresponding to one row of characters. Using two data lines per field and 24 rows per page, this allowed a magazine of 100 pages of text to be transmitted in a cycle lasting no longer than 25 seconds. Teletext facilities were included in 20% of television receivers sold or rented in the UK during 1985 and use of the system is widespread abroad. It has been extended to provide for the transmission of computer programs (telesoftware) and, by means of Datacast, for the delivery of specialised information to closed user-groups.

Meanwhile, the possibility of using radio broadcasts also as a means of conveying extra digital information was being investigated.

Around 1978, work was started on a means of adding data signals to v.h.f. radio transmissions. It soon became evident that an additional data-modulated subcarrier offered the best promise. The main aim was to assist in the operation of v.h.f. receivers by providing identification of the transmitter and the programme service; but other uses were envisaged, such as the conveying of brief messages which would appear on a display built into the receiver.

International discussions resulted in an EBU Radio Data System (RDS) specification[1] which has also become a draft CCIR recommendation.

The BBC intends to operate a regular RDS service from late 1987. Sweden began a service earlier this year and the Federal Republic of Germany plans to start in the spring of 1988.

This development prompted the search for a companion service for use on l.f. and m.f. radio, but it was eventually realized that it would be both more convenient and cheaper to include information relating to l.f. and m.f. broadcasts in the v.h.f. data signals. However, by this time a data channel for l.f. and m.f. had been devised which, though of limited capacity, could have a number of useful applications particularly to closed user-groups. The UK electricity supply industry uses l.f. radio-data regularly for various uses in its Radio Teleswitching electricity load management system. Other uses are foreseen.

RDS ON V.H.F.

In the v.h.f. radio-data system[2], a subcarrier at 57kHz is added at low level to deviate the main carrier by approximately ±2kHz. The data signal modulates this carrier using double-sideband suppressed-carrier modulation. The overall bit rate of the data stream is 1187.5 bit/s (1187.5=57000/48) which, with biphase encoding and the specified data-shaping filtering, gives an overall bandwidth after modulation of 4.8kHz.

The data is structured in 104-bit groups, each comprising four 26-bit blocks. Each block contains 16 message bits and 10 protection bits. Two kinds of message are carried by the data blocks – short ones repeated rapidly for automatic tuning and longer ones repeated less often for display to the user.

OTHER SYSTEMS

A number of specialist information systems are in operation in the USA. For example, a service called Telerate provides a data channel using the SCA subcarrier at 67kHz frequency-modulated by data at 4800baud. If this system were used in Europe, its higher bit-rate might prove incompatible with many older receivers. Moreover, because of the high spectral density of v.h.f./f.m. transmissions in some parts of Europe, the question of adjacent-channel interference would need careful study.

RADIO-DATA ON L.F.

At about the same time as work on l.f. and m.f. radio data systems was beginning to succeed, the UK electricity supply industry (ESI) approached the BBC expressing interest in a low bit-rate data channel with national (l.f.) coverage.

The requirements for radio-data on l.f. and m.f. called for the same balance between compatibility (existing reception not impaired) and adequate ruggedness of the data signal. In addition, for l.f. operation there

BBC plans for RDS

The BBC intends to provide RDS radio-data signals on all v.h.f. transmissions in England by September 1987. The initial service will include

- PI — programme identification
- PS — programme service name
- AF — alternative frequencies
- ON — frequencies for other networks
- CT — clock time and date

These data items are the simplest to provide at the programme source, yet at the same time are those which give the greatest help with receiver tuning, both automatic and manual. In this way, the initial service represents the most economic way of encouraging the development of advanced receivers which make use of the new signals.

PI codes enable the receiver to distinguish between countries and areas in which the same programme is transmitted, and identify the programme itself. The code is assigned to each individual programme, to distinguish it from all other programmes. One application of this information would be to enable the receiver to search automatically for an alternative frequency in case of bad reception: the criterion of change-over to the new frequency would be a better signal having the same PI code. This code is not intended for direct display.

PS codes provide text of up to eight characters for display on the receiver to tell the listener what programme is being broadcast by the station to which it is tuned. An example of a name could be "BBC R4". The length of this name is restricted to keep down the cost of the receiver. The programme service code is not intended to be used for automatic tuning.

AF codes list the frequencies of transmitters broadcasting the same programme in adjacent reception areas. Receivers equipped with memory can store the list and use it when switching to an another transmitter, as a faster alternative to searching. Up to 25 frequencies can be transmitted. This facility is particularly useful in the case of car and portable radios.

ON codes can provide up to 25 alternative frequencies for each of up to eight other networks. The relation to the corresponding programme is established by means of the relevant PI code.

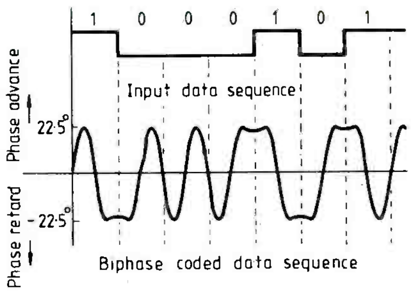


Fig.1. Radio-data modulation of an l.f. carrier as a function of time. Above is the input sequence; below, the same sequence biphase-coded.

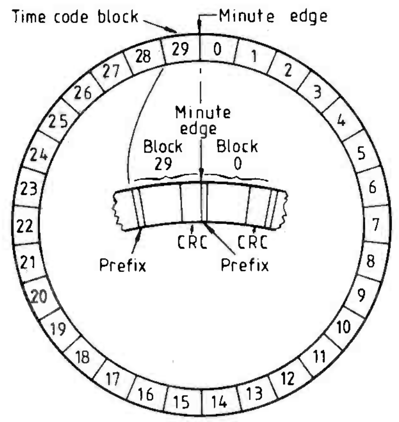


Fig.2. Arrangement of data blocks on the BBC's 200kHz l.f. service. Block 0 begins exactly on the clock-time minute.

was the special problem of the use of a synchronized group of transmitters whose carrier frequency was used as a standard.

Accordingly, the basic phase-modulation parameters already shown to be suitable for use on m.f. and l.f. were further developed specifically for use on the BBC's 200kHz Radio 4 UK l.f. network[3], which uses only three transmitters to cover the whole of the British Isles. This development as carried out under a collaborative agreement between the BBC and the ESI.

Because the 200kHz transmissions are used as a frequency standard, the data was biphase-encoded to ensure that there would be no d.c. component in the phase-modulation (Fig.1). The symbol rate was 50baud and the data rate 25 bit/s.

The data is divided into 50-bit blocks each lasting two seconds. Of the 50 bits, one is a synchronizing prefix, thirteen are used for a c.r.c. check (which also plays a part in the synchronizing process) and four are in effect a packet address, identifying the block as belonging to one of 16 data channels. The remaining 32 bits in each block yield an overall useful bit rate for addressed data channels of 16 bit/s.

Since each block takes exactly two seconds to transmit, there are 30 blocks per minute; and the block boundaries are phased so that one of them occurs exactly on the clock-time minute (Fig.2). The block immediately before the minute carries a data and time code and is identified as channel 0. The remaining 15 channel numbers, or packet addresses, can be used arbitrarily in any of the other 29 time-slots in each minute.

RADIO TELESWITCHING

Although this system is a closed user-group application rather than a broadcast service, it is described here because many of its techniques are likely to be relevant to other broadcast applications.

The ESI's interest in the data channel is primarily for the remote control of electronic time-switches. These switches, which are known as radio teleswitch receivers, are expected to become increasingly cost-effective replacements for the mechanical time-switch driven by a synchronous motor with a clockwork (spring) reserve. The electronic time-switch possesses the great advantage of automatic time resetting, which is especially valuable during changes between winter and summer time. Moreover, after a mains failure, the clock is reset automatically from the time code.

In addition to their use of the time clock, the ESI have contracted with the BBC for the use of up to five of the remaining 29 data blocks in each minute. Each such block can be used to set a group of radio teleswitches with new on and off times. This service has been running with duplicated transmission equipment since 1 April, 1985.

TRANSMISSION CHAIN

Where two or more transmitters carrying the same modulation share a common carrier frequency there are areas of of mutual interference, known as mush areas, between the transmitters where the field strengths are almost equal. The mutual interference can give rise to severe distortion and a loss of service area, particularly where near-cancellation occurs. Timings of the modulations from the transmitters involved are a very important consideration and ideally should be coincident at all frequencies. This condition is difficult to achieve in practice, particularly at high audio frequencies which demand a timing accuracy of about $\pm30\mu s$, but a useful improvement is nevertheless obtainable[4].

A similar requirement applies to timings of the data signal modulations. Both data content and timings must match: any difference in the phase modulations can give rise to phase-to-amplitude-modulation (p.m.-to-a.m.) conversion, which can be heard on a normal a.m. receiver. Fortunately, because the data waveform contains only low frequencies, timing requirements are much less stringent than for the audio signals. The required tolerance in data signal modulation between any two transmitters is ±1ms. Provided this is achieved, interference from the data signal is found to remain inaudible even in the worst nulls of the mush areas where the programme may be severely distorted. Recovery of the data itself if substantially unaffected by modulation timing errors less than about 5ms.

The clock frequency of the source data is locked to a rubidium reference and so the transmitted time code is suitable for use as a time standard provided that the means are available to monitor its continued accuracy. Given such monitoring, the transmitted clock time could be guaranteed accurate to within 5ms at any point in the UK. At present the absolute accuracy is ±0.5s (but the error value is very stable!).

SIMILAR SYSTEMS

For many years a system developed by the Barry Research Corporation of Palo Alto, California, has used phase modulation to carry teleprinter signals on h.f. broadcasts. Certain local electricity supply authorities in the United States use a nearby m.f. transmitter to carry control data connected with electricity metering[5] and, in East Germany, RFZ at Dresden use a transmitter to carry asynchronous data at up to 100bit/s[6]. This four-fold increase over the BBC system is possible because the transmission is not a frequency standard and hence there is no need to use biphase encoding; and because there is no insistence on avoiding disturbance to existing receivers under worst-case mush area conditions.

WEATHER INFORMATION

Several other uses for the remaining unused capacity of the l.f. radio-data channel have been considered but none has yet been implemented.

The most likely use is for coded weather forecast information for sea or land areas. Such a service conveyed by a data channel would make possible an automatic gale-warning alert for boat owners who might not be listening to the radio when the spoken warning was given. It would be possible to code a complex gale warning for a single sea area in no more than two data blocks (64 bits) which could be transmitted in only 4s[7].

A possibility which makes slightly less efficient use of the data channel but offers the prospect of completely automatic operation is dictionary encoding of already-existing forecast texts. A five-minute forecast could be retransmitted in dictionary-encoded form at least once per hour.

This paper was presented at IBC, Brighton in September

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Programmable logic design

This decoder for 68020 dynamic bus sizing is an example of how one programmable logic device can replace a number of standard logic i.cs.

CHRIS JAY

The M68020 is the first full 32 bit implementation of the 68000 microprocessor family. It has a 32 bit address bus and 32-bit-wide data path. Data-bus transfers of 32-bit long word, 16-bit and byte width, Fig.1, are possible using the processor's dynamic bus sizing capability.

When the 68020 writes data it drives all 32 data lines and when reading data it assumes that the port, whether memory or peripheral, is 32 bits wide. The processor receives acknowledgement of the size of the port through two data-size acknowledge inputs, DSACK_0 and DSACK_1. These signals correspond to the DSCAK input of the 68000 microprocessor, Table 1.

The one-of-four binary code at the DSACK inputs indicates whether the port currently being accessed is byte, word or long-word width, or whether wait states should be inserted.

DYNAMIC BUS SIZING

Operands may be accessed on any byte boundary but op-code alignment is restricted to even-byte boundaries for execution efficiency. Aligned-word operands commence on even-byte boundaries and aligned long words reside on even word boundaries. Any misplaced operands from a base address are considered misaligned.

TABLE 1. DSACK codes and results.

H	H	Insert wait states in current bus cycle
H	L	Complete cycle – data-bus port 8 bits
L	H	Complete cycle – data-bus port 16 bits
L	L	Complete cycle – data-bus port 32 bits

TABLE 2. Address offset encodings

A_1	A_0	Offset, bytes
0	0	+0
0	1	+1
1	0	+2
1	1	+3

TABLE 3. SIZE output encodings.

SIZ_1	SIZ_0	Size
0	1	Byte
1	0	Word
1	1	3 byte
0	0	Long-word

During each bus cycle the port size is indicated to the microprocessor via the DSACK inputs, so the processor can dynamically determine the port size during bus accesses.

During execution, optimum performance is achieved when all operands are aligned. Misaligned operands can cause additional bus cycles which degrade overall execution efficiency.

During a processor read cycle the 68020 latches the logic states of all 32 data-bus bits, initially assuming that the port is 32-bits wide. If the data-size acknowledge input reports that the port is long word, operation continues with the next cycle.

If the port is 16-bits wide, two read cycles are produced, the first word followed by the second. A byte-wide port is read over four separate cycles. Data bus allocation for long word is on data lines 31 to zero, for word transfers 31 to 16, and for byte transfers over 31 to 24.

Multiplexing for routing or duplicating any operand bytes is shown in Fig.2. Normal aligned placement for OP_0 would be $\text{D}_{31\text{-}24}$, but in a misaligned transfer OP_0 could be routed to any other byte boundary.

Addressing can be considered to be long-word addressing through address lines $\text{A}_{2\text{-}31}$ with $\text{A}_{0,1}$ providing a four-byte location offset from the long-word base address, Table 2.

DATA ROUTING

Long words are subdivided into four bytes on the data bus, $\text{OP}_{0\text{-}3}$. Normal data routing assigns OP_0 to data lines $\text{D}_{31\text{-}24}$, OP_1 to $\text{D}_{23\text{-}16}$, OP_2 to $\text{D}_{15\text{-}8}$ and OP_3 to $\text{D}_{7\text{-}0}$. This would be the case for aligned data transfer.

To allow misaligned transfer, data bytes $\text{OP}_{0\text{-}3}$ may be routed to any byte section in the 32-bit wide data bus. The microprocessor's size outputs $\text{SIZ}_{0,1}$ and address outputs $\text{A}_{0,1}$ can be decoded to route data bytes to their appropriate positions on the data bus. Table 3 shows the SIZE output encodings for long-word, three-byte, word and byte transfers.

The encoded state on $\text{SIZ}_{0,1}$ indicates how many bytes are to be transferred on the next bus cycle. Numerical encoding of the SIZE outputs will be equal to or greater than the number of bytes to be transferred. For example if a long-word port is read and a transfer to a word-wide port is executed,

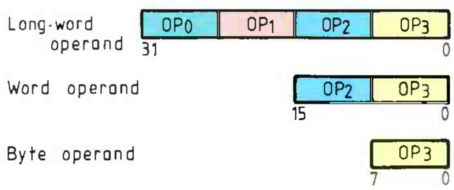


Fig.1. Internal operand representation. Data-bus width of the 68020 can be adjusted dynamically.

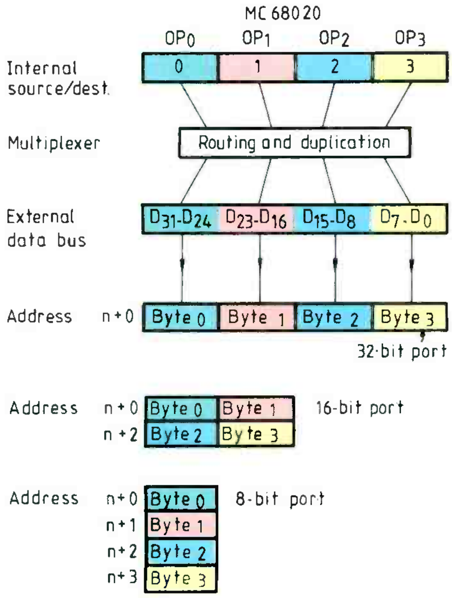


Fig.2. 68020 interface to various port sizes. When a byte-wide port size is selected, bytes pass sequentially.

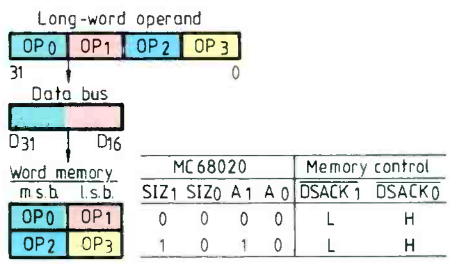


Fig.3. Example of long-word transfer to word bus with control-signal states.

SIZ$_{0,1}$ outputs will indicate a four byte transfer, but only two bytes will be moved.

An example of this is the transfer of data from a long-word port to a word port, which occurs over two cycles with the most-significant word first. Initially, and while transferring the most-significant word, the SIZE outputs indicate a long-word transfer and indicate a word transfer when the remaining least-significant word is transferred, Fig.3.

Figure 4 shows the condition of the SIZE outputs and states of $A_{0,1}$ in a long-word transfer to an eight-bit port. Table 4 shows conditions required for an internal-to-external data-bus multiplexer. If an aligned long-word to byte transfer is performed the long word is latched into the data inputs.

Writing to a byte port is performed in four cycles. Firstly state 1 in Table 4 is performed; SIZ$_{1,0}$ and $A_{1,0}$ are all low as OP$_0$ is written to $D_{31\text{-}24}$. Next, state 2 indicates three more bytes to be transferred at an address offset of one, i.e. 1101 on SIZ$_{1,0}$ and $A_{1,0}$ outputs. Operand OP$_1$ is placed on lines $D_{31\text{-}24}$.

In the third cycle, state 3, SIZ$_{1,0}$ and $A_{1,0}$ contain 10x0 respectively and OP$_2$ is placed on data lines $D_{31\text{-}24}$. In the final cycle, OP$_3$ is sent to data lines $D_{31\text{-}24}$, with SIZ$_{1,0}$ and $A_{1,0}$ in the logic condition of 01xx, as in Table 4, state 4.

MISALIGNED TRANSFERS

Misaligned data can occur for word or long-word operands. Examples of misaligned tranfers are words transferred to odd-address boundaries and long words transferred outside the four-byte boundary of a long word.

Figure 5 shows a long-word transfer to a word-wide port, the DSACK outputs indicating a word-wide port. Three cycles are required. The word boundary is even but OP$_0$ must be routed to an odd byte boundary, to the l.s.b. Contents of the m.s.b. must remain un-

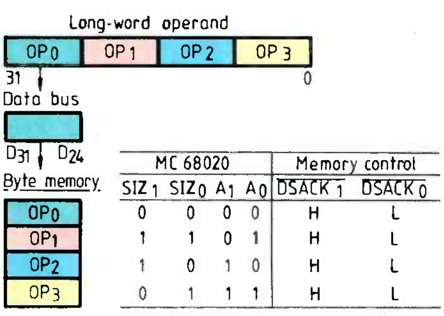


Fig.4. Example of long-word transfer to byte bus.

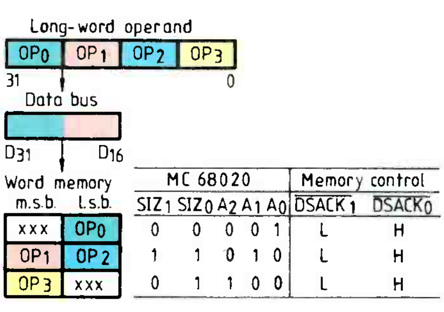


Fig.5. Misaligned long-word transfer to word bus example.

TABLE 4. 68020 internal-to-external data-bus multiplexer.

Transfer size	Size SIZ$_1$	SIZ$_0$	Address A$_1$	A$_0$	Source/destination, external data-bus connection $D_{31\text{-}24}$	$D_{23\text{-}16}$	$D_{15\text{-}8}$	$D_{7\text{-}0}$	
Byte	0	1	x	x	OP$_3$	OP$_3$	OP$_3$	OP$_3$	State 4
Word	1	0	x	0	OP$_2$	OP$_3$	OP$_2$	OP$_3$	State 3
	1	0	x	1	OP$_2$	OP$_2$	OP$_3$	OP$_2$	
3 byte	1	1	0	0	OP$_1$	OP$_2$	OP$_3$	OP$_1$*	State 2
	1	1	0	1	OP$_1$	OP$_1$	OP$_2$	OP$_3$	
	1	1	1	0	OP$_1$	OP$_2$	OP$_1$	OP$_2$	
	1	1	1	1	OP$_1$	OP$_1$	OP$_1$*	OP$_1$	
Long word	0	0	0	0	OP$_0$	OP$_1$	OP$_2$	OP$_3$	State 1
	0	0	0	1	OP$_0$	OP$_0$	OP$_1$	OP$_2$	
	0	0	1	0	OP$_0$	OP$_1$	OP$_0$	OP$_1$	
	0	0	1	1	OP$_0$	OP$_0$	OP$_1$*	OP$_0$	

*On write cycles this byte is output, ignored on read cycles
x = don't care
OP labels on the external data bus refer to a partiuclar byte of the operand that will be read or written on that section of the data bus.

TABLE 5. Data-bus activity for byte, word and long-word ports.

Transfer size	SIZ$_1$	SIZ$_0$	A$_1$	A$_0$	Data-bus active sections $D_{31\text{-}24}$	$D_{23\text{-}16}$	$D_{15\text{-}8}$	$D_{7\text{-}0}$
Byte	0	1	0	0	B, W, L	–	–	–
	0	1	0	1	B	W, L	–	–
	0	1	1	0	B, W	–	L	–
	0	1	1	1	B	W	–	L
Word	1	0	0	0	B, W, L	W, L	–	–
	1	0	0	1	B	W, L	L	–
	1	0	1	0	B, W	W	L	L
	1	0	1	1	B	W	–	L
Three-byte	1	1	0	0	B, W, L	W, L	L	–
	1	1	0	1	B	W, L	L	L
	1	1	1	0	B, W	W	L	L
	1	1	1	1	B	W	–	L
Long-word	0	0	0	0	B, W, L	W, L	L	L
	0	0	0	1	B	W, L	L	L
	0	0	1	0	B, W	W	L	L
	0	0	1	1	B	W	–	L

Note, B are byte, W are word and L are long-word ports.

TABLE 6. Fuse-plot output from the PALASM assembler for the PAL12L6 bus-size decoder, see Fig.8.

	0123	4567	11 8901	1111 2345	1111 6789	2222 0123	2222 4567	2233 8901	
8	X-X-	----	----	----	----	----	----	----	A0*A1
9	-X--	X---	--X	----	----	----	----	----	SIZ0*/SIZ1*/A1
10	-X-X	-X--	X-	----	----	----	----	----	/A1*/A0*SIZ1*/SIZ0
16	--X-	----	----	----	----	----	----	----	A0
17	X---	----	----	----	----	----	----	----	A1
24	X---	----	----	----	----	----	----	----	A1
25	---X	X---	-X	----	----	----	----	----	SIZ0*/SIZ1*/A0
32	---X	X---	-X	----	----	----	----	----	SIZ0*/SIZ1*/A0
40	--X-	----	----	----	----	----	----	----	A0
48	---X	X---	-X	----	----	----	----	----	SIZ0*/A0*/SIZ1
49	-X-X	----	X-	----	----	----	----	----	SIZ1*/A0*/A1
50	-X--	X---	-X	----	----	----	----	----	SIZ0*/A1*/SIZ1
51	-XX-	-X--	X-	----	----	----	----	----	A0*/A1*SIZ1*/SIZ0

X = fuse not blown (L,N,0), – = fuse blown (H,P,1)
Number of fuses blown = 384

LIST 1. Bus-sizing logic design specifications from the PALASM assembler.

```
CHIP DECODE PAL12L6
A0 A1 SIZ0 SIZ1 NC NC NC NC NC GND
NC NC LLD UD LD UMD UUD LMD NC VCC

EQUATIONS
/UUD = A0 + A1
/UMD = A1 + SIZ0*/SIZ1*/A0
/LMD = A0*A1 + SIZ0*/SIZ1*/A1 + /A1*/A0*SIZ1*/SIZ0
/LLD = SIZ0*/A0*/SIZ1 + SIZ1*/A0*/A1
     + SIZ0*/A1*/SIZ1 + A0*/A1*SIZ1*SIZ0

/UD = A0
/LD = SIZ0*/SIZ1*/A0
SIMULATION
TRACE-ON A0 A1 SIZ0 SIZ1 UUD UMD LMD LLD UD LD
SETF /A0/A1 SIZ0/SIZ1
SETF A0/A1 SIZ0/SIZ1
SETF /A0 A1 SIZ0/SIZ1
SETF A0 A1 SIZ0/SIZ1
SETF /A0/A1/SIZ0 SIZ1
SETF A0/A1/SIZ0 SIZ1
SETF /A0 A1/SIZ0 SIZ1
SETF A0 A1/SIZ0 SIZ1
SETF /A0/A1 SIZ0 SIZ1
SETF A0/A1 SIZ0 SIZ1
SETF /A0 A1 SIZ0 SIZ1
SETF A0 A1 SIZ0 SIZ1
SETF /A0/A1/SIZ0/SIZ1
SETF A0/A1/SIZ0/SIZ1
SETF /A0 A1/SIZ0/SIZ1
SETF A0 A1/SIZ0/SIZ1
TRACE-OFF A0 A1 SIZ0 SIZ1 UUD UMD LMD LLD UD LD
```

Note: In PALASM, oblique replaces the negating bar and the asterisk replaces the multiplication sign.

changed during the data transfer. Lines $SIZ_{0,1}$ indicate a long-word transfer.

The next cycle transfers $OP_{1,2}$ with $SIZ_{0,1}$ indicating a three-byte transfer. The final cycle indicates the transfer of OP_3 to the m.s.b. with the contents of the l.s.b. remaining unchanged. Outputs $SIZ_{0,1}$ indicate that a single byte is being transferred.

Aligned and non-aligned transfers are further detailed in the 68020 user's manual.

DATA-SELECT GENERATOR

Hardware for decoding size and address information, Fig.6, must comply with the requirements of the data-bus activity shown in Table 5.

The decoder can be constructed from a number of And and Or gates designed to decode the 68020 address and SIZE outputs or alternatively the logic may be condensed into programmable-array logic (pal) – which reduces the number of packages required from about six 14-pin packs to one 20-pin d.i.l. pack. Reliability is also improved due to fewer packages and interconnections.

This implementation, Fig.6, consists four true and complement inputs, derived from 68020 lines $A_{0,1}$ and $SIZ_{0,1}$, feeding an array of internconnections. These drive a sum of products configuration.

Decoded outputs UUD, UMD, LMD, and LLD are used for accessing 32 bit ports and are designated upper-upper data, upper-middle data, lower-middle data and lower-lower data. Upper and lower-data lines UD and LD are used in accessing 16-bit wide ports. The relationship of these signals is shown in Table 5.

PAL CONSIDERATIONS

To select a pal to perform this or any other combinational function, digital designers need to make two initial observations about the logic circuitry.

First the number of inputs and outputs to and from the circuit should be fewer than or equal to the number of inputs and outputs of the pal itself. This constraint is imposed by the number of pins on the d.i.l. package.

Secondly the number of product terms or And gates available in the pal device and, equally important, their distribution to the summation or Or gates must be considered.

Figure 7 is a simplified view of a pal device. Inputs are connected to true/complement buffers, outputs of which drive a large fuse array. In bipolar devices, the array consists of titanium-tungsten fuses whereas in c-mos types, floating gates are used.

The fuse array connects to And gates or 'product terms', each column representing a discrete input to the product term. Output of the product term drives a non-programmable interconnecting array connected to 'sum terms' (Or gates) which drive the output pins through buffers. Using a pal programmer, the logic designer removes all unwanted fuses in the array.

The byte data-select generator for 16 and 32-bit ports shown in Fig.6 is an ideal circuit for encoding into pal. One potentially suitable device is the PAL12H6. There are 12 inputs to the 12H6, only four of which would be needed for microprocessor outputs $A_{0,1}$ and $SIZ_{0,1}$. All six outputs of the 12H6 would be needed for decoded outputs signals UUD, UMD, LMD, LLD, UD and LD.

Signals LLD and LMD require four product terms each and UMD and LD both require three product terms. Of the six outputs, two are the summation of four product terms and four are the summation of two product

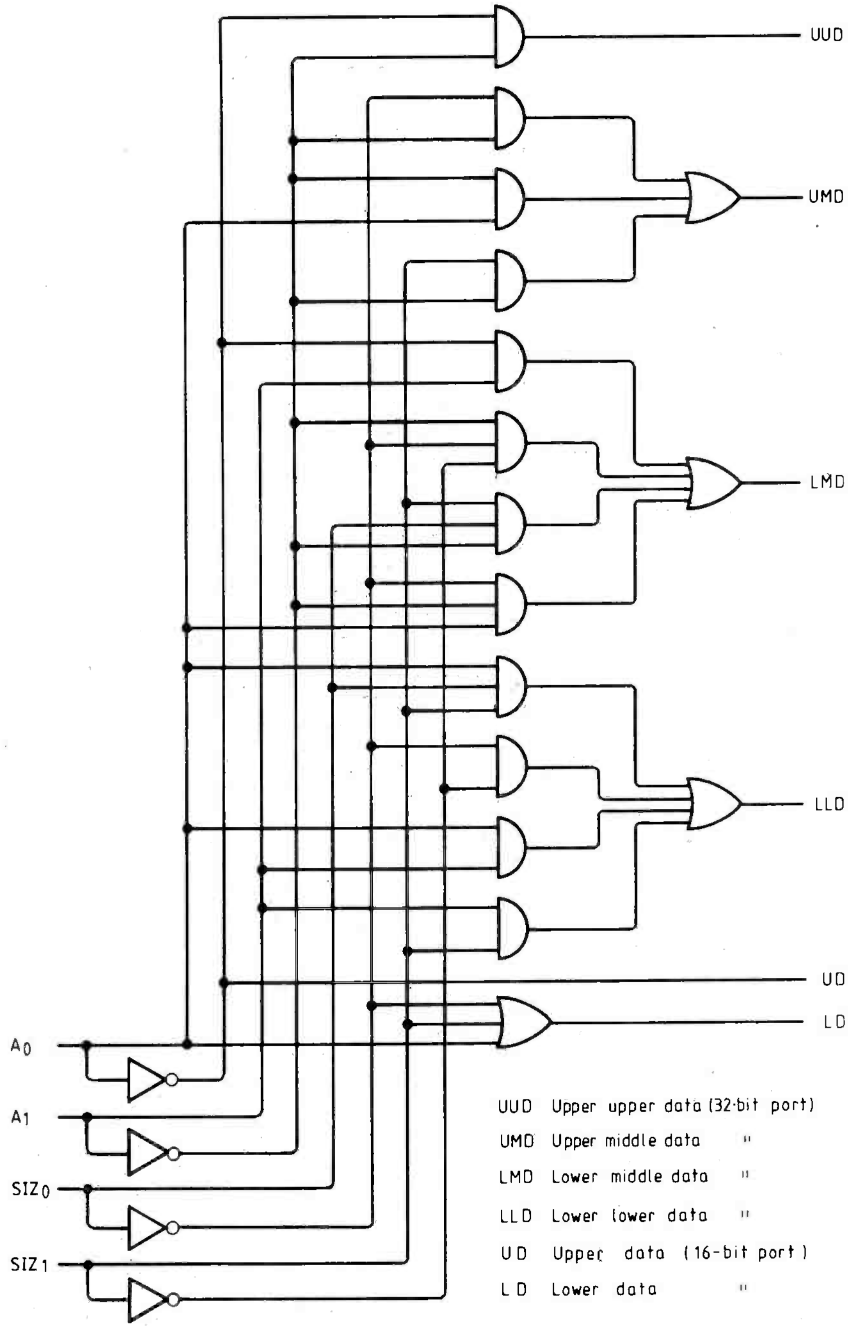


Fig.6. Byte data-select logic for 16 and 32-bit ports.

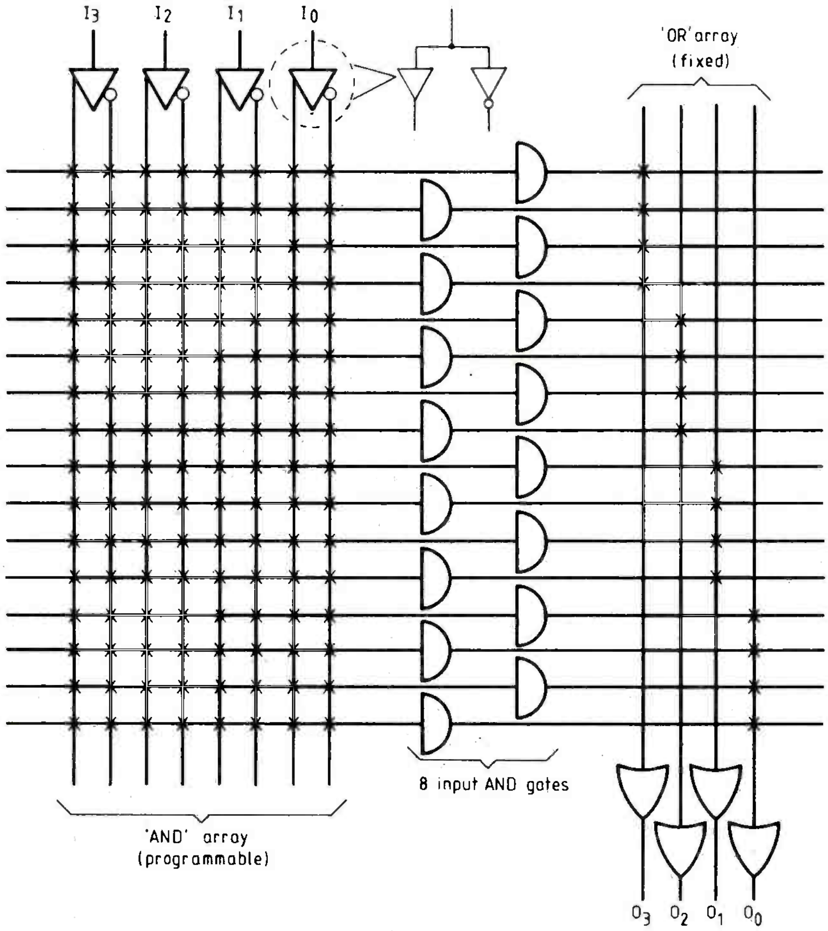
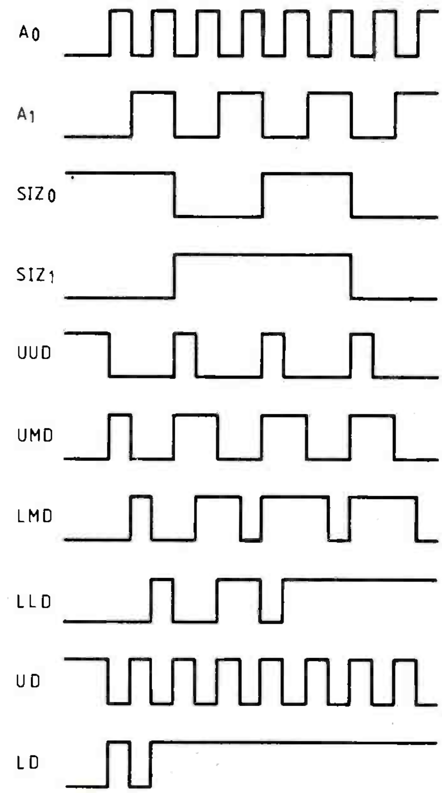


Fig.7. Simplified programmable array logic. The And gates are referred to as product terms and the Or gates as sum terms. Equivalent logic for the true/complement buffers driving the fuse array is shown separately.

Fig.9. States of the dynamic bus sizing logic generated using the PALASM2 pal assembler.



VTRACE output generated from test vectors.
Test vectors are derived from the PAL design specification by running the simulate option in PALASM2

terms each. This means that the product term allocation of the 12H6 is unsuitable for this application.

Using Karnaugh-map manipulation to reduce the number of product terms though, a 12H6 device with active low outputs – the 12L6 – is suitable, Fig.8.

COMPUTER DESIGN

Fuse plots of earlier pals can be assembled using a program written in Fortran called PALASM1. A more advanced assembler written in Pascal for both newer and older devices — PALASM2 — is currently under development. This new software runs on IBM p.cs under PC-DOS, or VAX under the VMS operating system.

From the original design specification shown in List 1, PALASM2 automatically converts the Boolean statements into a fuse plot as shown in Table 6. Positions marked x on the fuse plot remain intact and positions marked – are programmed. Numbering at the fuse-array column heads relates to individual inputs to each product term. In the 12L6 there are 32 inputs to each product term. Row numbering on the left-hand side of the fuse array indicates the individual product terms. Here, only product terms with programmed fuse inputs are shown. Although there are only 16 product terms in a 12L6, the numbering system assigned to the array is general for a range of pal devices with a varied distribution of product term input and product term distribution.

In PALASM, the original design specification is entered as a Boolean entry design file, List 1. First comes a documentation field giving the user information about the design. After the reserved word CHIP the assembler expects to see a single description word, in this case DECODE followed by the pal type, PAL12L6.

Next is the pin assignment or input-constant declaration section. Any string constant equations may also be declared here, but no string constants were used in this specification. The assignment section is terminated by reserved word EQUATIONS.

All the Boolean equations are written in the equation field up to reserved word SIMULATION. From these equations PALASM generates a fuse plot and Jedec* output file This file can be transferred to a pal programmer through an RS232 serial interface using a software-programmable interface package. The Jedec fuse-plot standard is favoured by most programmer manufacturers.

To generate test vectors automatically from the design, the designer can write a simple simulation program to exercise set and reset functions on some or all inputs of the pal. When running the simulator, logic inputs and outputs can be traced using the TRACE ON option to verify whether or not a design will function correctly before comiting it to the pal's fuse array.

The hardware analogy is the logic analyser where probes are tied to nodes in the circuit and a multiple signal trace is produced on a c.r.t. With PALASM, test vectors are generated as logic high or low conditions in a tabular form. Using software called VTRACE a graphical waveform output can be generated, Fig.9.

All possible input combinations, shown in Table 5, are generated in the simulation section of the design specification as SET and RESET (more accurately SET and INVERSE) operations on $A_{0,1}$ and $SIZ_{0,1}$.

Running PALASM2 on an IBM p.c. or compatible system is quite straightforward. The program is menu driven and prompts the user for commands.

Once the designer has created a design file with a text-editor package, the file may be assembled into a fuse plot as shown in Table 6.

If a simulation section is included in the specification file, then selecting 'simulate' from the menu results in the generation of a further three files containing test vectors. One file is the Jedec programmer file with the test vectors appended to the end of the

*Joint Electronic Device Engineering Council's 'Standard data transfer between the data preparation system and programmable logic device programmer'.

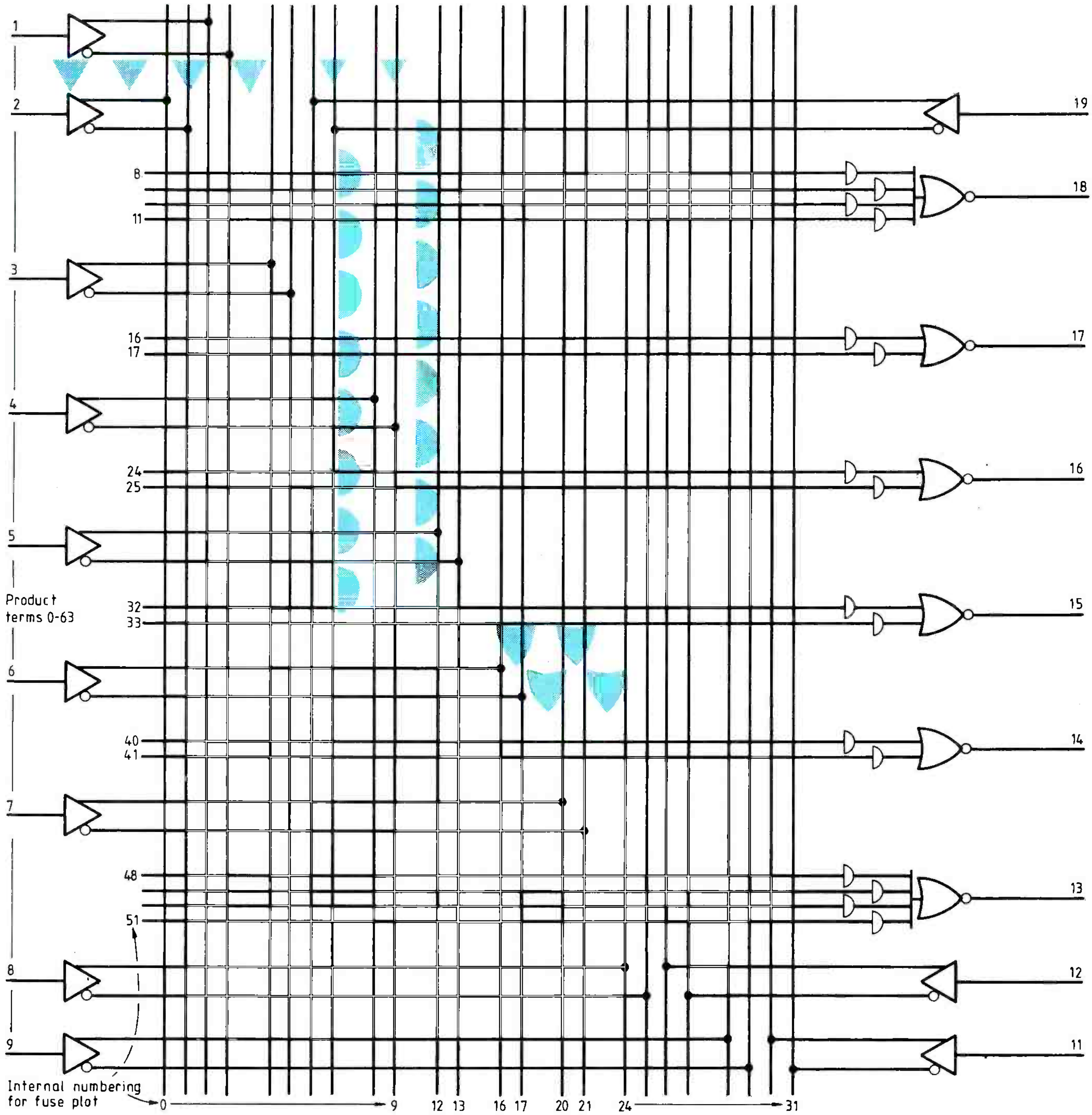


Fig.8. Logic diagram of the PAL12L6. Each And gate has many inputs each connected to one vertical line by a fusible link.

fuse-plot information. The second is a trace file containing all test vectors generated for input and output pins that are qualified by the TRACE ON command. Thirdly, a history file containing a full test-vector plot of logic high and low conditions on every signal pin in the pal is produced.

Test vectors are appended to the end of the Jedec file so that the pal may be functionally tested after programming has taken place. The programmer sequentially exercises inputs from the individual vectors and compares the actual pal output conditions with those logic states supplied by the current test vector.

Writing of the simulation to generate test vectors is similar to writing commands in a high-level language program. Logic conditions to input pins can be set high or low by a SETF command; SETF A will set input A high and conversely SETF/A sets it low.

For repetitive events, a FOR LOOP directive may be used; <FOR N := 1 TO 16 DO> causes a statement or statements between BEGIN and END to be executed 16 times. Conditional branching or control is possible with IF or WHILE directives. A more comprehensive guide on writing programs for test vector generation is given in chapter five of the MMI Programmable logic handbook mentioned later.

With the data-byte selector design, PALASM2 has provided a route from logic design to silicon and the simulator gives the designer confidence in the functional integrity of the design. Using a pal in this application has saved approximately six dil packages and simplified printed-circuit board, layout.

Further reading

Programmable-logic handbook. MMI, Lynwood House, 1 Camp Road, Farnborough, Hampshire.
M68020 32-bit microprocessor user's manual, Motorola, 88 Tanners Drive, Blakelands, Milton Keynes MK14 5BP.

Chris Jay is with Monolithic Memories.

Celeste The new standard for high performance on STE

Control Universal, the largest UK manufacturer of single Eurocard products, have established the CUBE range as the most popular choice in industrial and laboratory applications.

Control Universal have now designed Celeste to maximize the real-time performance of the new generation of 16/32 bit processors on the STE bus.

Celeste/188

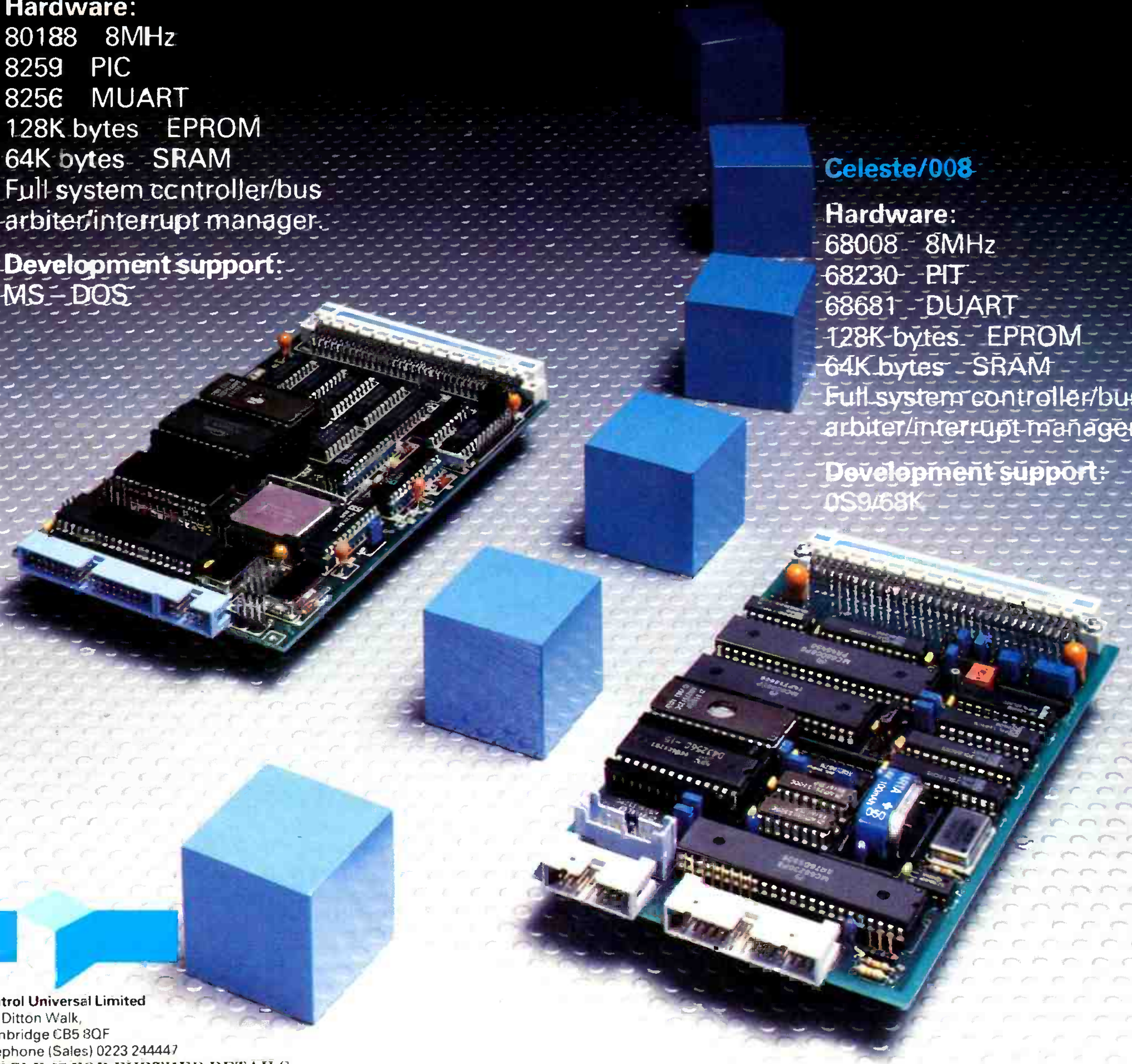
Hardware:
80188 8MHz
8259 PIC
8256 MUART
128K bytes EPROM
64K bytes SRAM
Full system controller/bus arbiter/interrupt manager.

Development support:
MS – DOS

Celeste/008

Hardware:
68008 8MHz
68230 PIT
68681 DUART
128K bytes EPROM
64K bytes SRAM
Full system controller/bus arbiter/interrupt manager.

Development support:
OS9/68K



Control Universal Limited
137 Ditton Walk,
Cambridge CB5 8QF
Telephone (Sales) 0223 244447

CIRCLE 37 FOR FURTHER DETAILS

STE
Standard Eurocard bus

Applications of Standard Eurocard bus range from simple control to multi-processor systems – and all boards are interchangeable.

ANTHONY WINTER

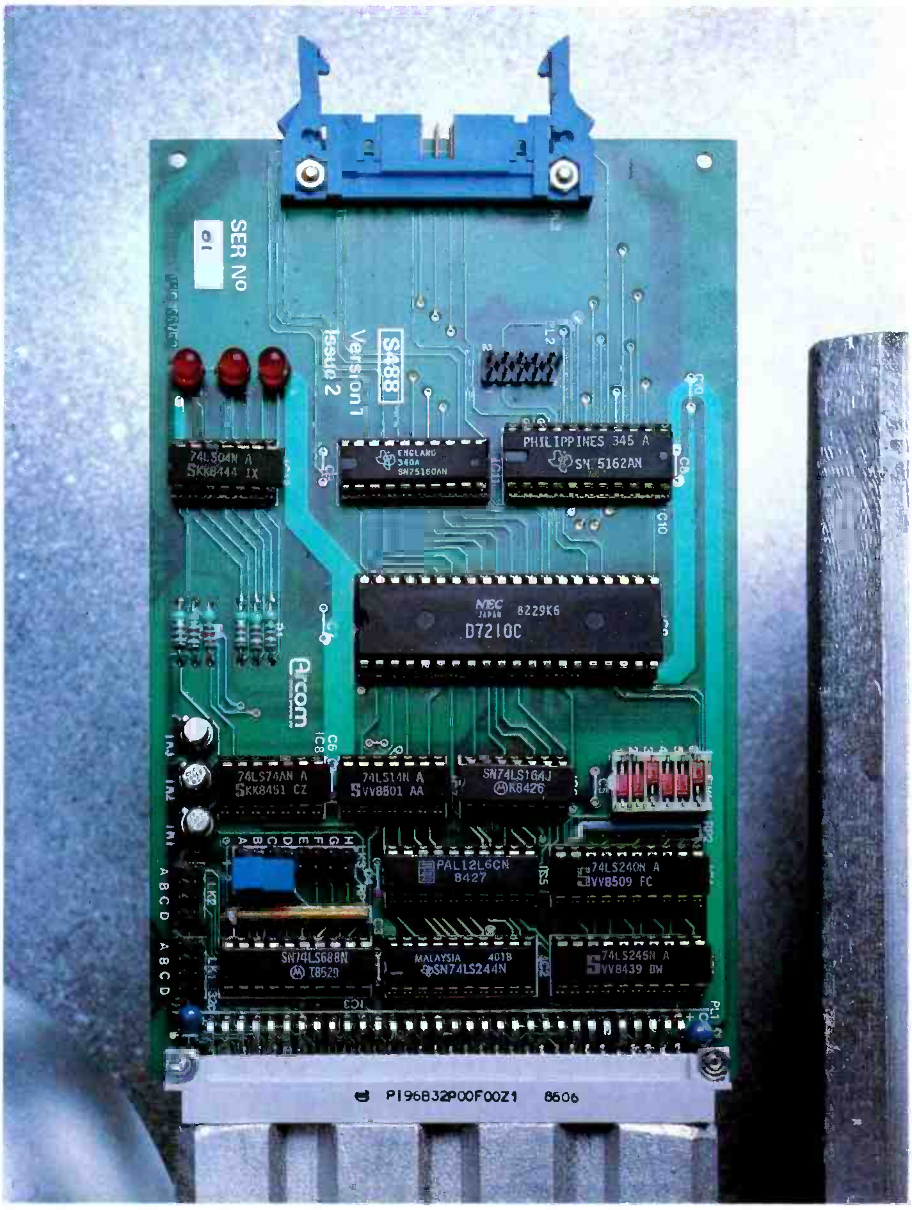
In low-to-medium complexity designs, STE bus suits the kinds of applications that buses like STD are currently used for, but with performance, security and cost advantages.

Being based on the DIN connector and Eurocard, STE can be used with other buses to form relatively low cost multiple-bus systems. And, in relation to edge connectors, the DIN connector is more reliable.

Although designed for eight-bit data buses STE can be used with the latest generation of 8/16-bit processors. The bus was first specified in 1982, and the first boards were available in mid 1984. Since then, it has been widely adopted by board manufacturers. There are now hundreds of processor, peripheral and signal-conditioning modules. Moreover STE is a standard backplane bus and so you can mix boards from any sources.

Processing units now available span a broad application range, with microprocessors from the popular Z80 to newer and more powerful devices like the 80188, Fig.1.

In the UK so far, STE has an estimated 100 users and at least 18 companies manufacturing boards, backplanes and packaging. Applications range from software development, through real-time control, to laboratory computing.



BUSES ARE CHANGING

As more complex v.l.s.i. circuits become available, backplane buses have grown in importance helped by their recent improvements in quality. Most growth is in the high-performance 16-bit buses such as VME and Multibus-II, which include advanced features and are based on the Eurocard standard and DIN connector.

If you are looking for a standard at lower performance levels, however, choice is limited. Two current popular choices, STD and S100, are edge-connector based, with outdated signal schemes originally designed for a single 8-bit processor family. Although they have been modified to take account of more advanced processors and large memories, the patches are showing.

The situation is similar with Eurocards. There are dozens of single-Eurocard buses but almost all are designed for a single processor family and intended for simple one-processor systems. Here, none has emerged as a standard with worldwide use and support.

A typical example is G64, which uses Motorola 6809 signals. The G64 bus has now been 'enhanced' to cope with other processors, often at the expense of compatibility with earlier designs.

STE was originally conceived as a Eurocard replacement for STD. It is similar to VME, and can be viewed as an 8-bit version of that standard but, unlike VME, STE has been designed from scratch to be an independent bus, suitable for a broad range of processors and tasks.

BUS ATTRIBUTES

The STE signal scheme may be summarized as an eight-bit data path, with 1M-byte of memory space, 4K-bytes of i/o space, asynchronous data transfer, board position-independence, multiple master capability and inter-module flags for interrupts or d.m.a. Using Eurocard form boards with 64-way (rows A/C) DIN connectors makes STE reliable.

An eight-bit data path is used, but this is not a disadvantage. There are already good bus standards for 16-bit data paths like VME but there is no standard eight-bit Eurocard bus. Also, STE goes beyond most existing eight-bit buses in two respects. First, it can accommodate the latest generation of eight-bit processors, and of course, most 16-bit processors are also made in eight-bit versions. Secondly, the bus has multiple-master capability; up to three processors may work in a system. Another point worth noting is that almost all peripheral i.c.s are designed for eight-bit operation.

The bus is equally at home in simple systems with a single processor and a few expansion modules. Used as a vehicle for systems using familiar and popular processors like the Z80, it suits applications for which STD is currently being used.

Another advantage of STE over STD is the expansion potential given by the Eurocard packaging. The bus can be used alongside VME as a low-cost i/o channel for instance, or as a local bus for processing.

Many systems are hampered by the restricted addressing ranges of earlier buses, which were generally designed around processors limited to 64K-byte. STE provides two separate addressing fields; 4K-byte of i/o locations and a 1M-byte memory addressing space.

Processors like the Z80 can switch the top four address lines with a latch. This form of bank switching is used to advantage in operating systems like CP/M-plus, which uses this extra memory to speed up disc operations by a significant amount.

Input/output capability is similarly large. Twelve i/o address lines provide 4096 i/o locations, enough for most conceivable small-to-medium systems. Processors with no i/o space, like the 6809 pr 68008, can set aside a 4K memory block for bus i/o accesses.

A significant problem with nearly all buses is their inability to work with boards designed later in the standard's life. This is primarily because most buses use synchronous operation.

Data from a peripheral board, for example, must be available to the c.p.u. within the defined time. Processor speeds are currently doubling every four or five years, and peripherals may not be able to keep up.

To overcome this lifetime limitation, STE uses asynchronous handshaking. For example, slave boards need to acknowledge that they've received data from a master. This has two main advantages. It makes it easy to interface devices of differing speeds, and provides technology independence. As better devices become available, they will still work with boards based on earlier technology.

STE compared with other popular backplane buses.

Feature	STE	STD	G64
Signal lines	64	56	64
Address range	1M-byte	64K-byte*	64K-byte
Data path	8 bit	8 bit	8 bit
I/O space	4K-byte	256-byte*	1K-byte
Multiple masters	up to 3	off-bus connection required	yes
Error checking	error line	none	yes
Primary board size	100×160mm	114×165mm	100×160mm
Connector	DIN	Edge	DIN

*various expansion schemes

CONFIGURING STE

Users of only modest experience should be able to assemble systems successfully. STE is free from 'levels of compliance' which means that all boards are compatible with all other boards and no slots are reserved. Boards are truly position-independent.

Another feature is STE's multiple processor or multi-master ability. Up to three processors may reside on the bus, taking control of the common bus resource after going through an arbitration procedure.

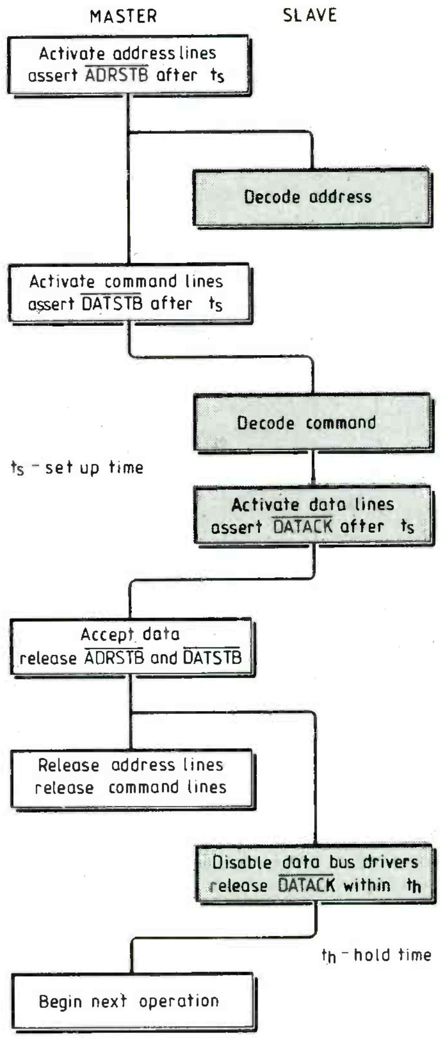
Typically, masters are c.p.u boards and d.m.a. devices. A bus slave must be able to respond to bus signals to produce an acknowledge signal when addressed.

The bus is used for communicating between boards, for example to transfer data or handle interrupts. Often, if there is enough circuitry on one board, a master can do its processing locally, freeing the STE bus for other masters to use.

For example, the Arcom SC88D board includes an 80188 processor, 256K-byte ram, and serial i/o. It only needs to use the bus to program an eprom or, say, read a value from an a-to-d converter module. Simultaneously (within a microsecond or so) another c.p.u. could be processing the converter values stored in ram on a common memory board.

Using multiple processors allows highly fault-tolerant designs to be made or reduces the cost of high-performance systems by allowing several simple low-cost masters to take the place of an expensive state-of-the-art c.p.u. board.

The STE specification permits up to three bus masters, one default and two others termed 'potential'. A default master is a board with a bus arbiter and a master, for example a c.p.u. The bus arbiter deals with requests from the master on its own board and from any other potential masters in the system.



DATA TRANSFER

An important feature of STE is asynchronous operation which increases a system's useful lifetime by allowing mixing of devices of different generations and operations speeds for example. An example of a read operating illustrates how this works in practice.

Data transfers from a slave to a master are designated read sequences. First, the master places the address of the memory or i/o location to be selected on the address lines. After a set-up time, during which the address lines become valid, the master asserts the address strobe $\overline{\text{ADRSTB}}$. The master then activates the command lines to indicate the type of transfer, i/o or memory read, asserting $\overline{\text{DATSTB}}$ after an appropriate set-up time, thus indicating that it is ready to accept data.

The addressed slave now enables its bus drivers, placing the requested data on the data lines, then asserts $\overline{\text{DATACK}}$ after a set-up time to indicate that data is available. In response to this signal, the master accepts the data and then releases $\overline{\text{ADRSTB}}$ and $\overline{\text{DATSTB}}$. When the slave sees this operation, it disables its data bus drivers and releases $\overline{\text{DATACK}}$ to indicate a completed sequence.

No time restrictions are placed on this operation, but designers have the option of specifying an 8μs timeout value, which serves to notify the c.p.u. of a board failure.

Bus arbitration works at high speed so that if the bus is free the master requesting it will be granted access without unnecessary delay, typically 125ns. If the bus is busy, there may be a delay of a few hundred nanoseconds while the new master takes control, and the arbiter ensures that no contention takes place during this process.

A system error signal provides integrity of data transfer. This is asserted by the system controller if an acknowledge is not returned within a reasonable period of time. The signal can also be asserted by a slave should a local error occur during a transfer.

Integrity of the bus is also aided by careful layout of the signal lines on the DIN connector to facilitate connection while minimizing crosstalk. Ground lines are evenly distributed across the connector. Another contributing factor is increased reliability compared with edge-connected arrangements through use of the two-part DIN 41612 connector (64-way, rows a/c).

There is an intricate system for dealing with inter-modular communication, using up to eight 'attention-request' lines. Such communication usually occurs when interrupts or d.m.a. signals need to be processed, although the STE bus specification does not limit designers to these.

Interrupts can be processed in several ways. At the simplest level, no acknowledge is necessary (a power-fail interrupt for example), and an attention-request line is asserted (pulled low) by the interrupting module. With a common interrupt, the interrupting module is acknowledged by a read or write operation on one of its registers; this is also easy to arrange.

Bus-vectored interrupts are the most powerful. Here, an interrupt handler uses the command modifier lines to indicate an acknowledge cycle and puts the encoded attention-request line number onto the address bus as a three-bit address. The module which interrupted on this attention-request line can then put an interrupt vector onto the bus, which the handler reads in the acknowledge cycle.

PACKAGING

Boards for STE can be either single or double Eurocards, though the single card is the preferred size, and is expected to be used by the majority of suppliers Board depth is 160mm and extended versions are not accommodated. Small boards allow a high degree of system partitioning, i.e. they allow boards performing a narrowly-defined function such as digital i/o, serial i/o, memory etc. to be used which conceptually simplifies the system and eases fault-finding.

However some modules, especially processor boards, can be very high-density. This allows the board to work with few bus accesses, avoiding the potential bandwidth limitation that any bus imposes and thereby increasing system-throughput potential.

Most users buy boards off-the-shelf, but in some cases specialized i/o is required. With STE bus, making special i/o is relatively simple because the majority of protocol conversion circuitry required for interfacing is concentrated on the master c.p.u. boards. These boards are the ones most likely to be bought off-the-shelf and designed by a specialist board maker.

To interface a simple slave i/o board is relatively easy. A design has been published by the STE manufacturers and users group, and prototyping i/o boards, are available from Arcom.

APPLICATIONS

Where will STE be used? The answer is in all areas from data-acquisition and control to information-processing applications. These areas range from those currently catered for by STD to many of the less demanding VME applications.

Simple data acquisition and control systems are a first example. Being single Eurocard, STE allows the same kind of system partitioning as STD, but it can be used for simple control as well as for advanced 8-bit processor and multi-processor systems. An example is a Z80 c.p.u. running a disc operating system such as CP/M Plus on the same bus as a secondary Z80 board doing real-time process control; both these boards are available.

Data processing systems are another application for STE bus. Reliable rapid movements of large data blocks are possible using d.m.a. transfers and STE has a large memory addressing range.

For example, Arcom's SC88 can access 1M-byte of memory on the bus directly, and uses the on-board d.m.a. system to transfer data from the floppy and s.c.s.i. controllers at high speed, powerful operating systems like Concurrent DOS from Digital Research can be used.

Being capable of accommodating advanced processors and having other advanced design features, STE will certainly take some of the lower-level applications for which VME is often considered. It goes a step further, however.

Eurocard compatibility means that designers will be able to mix buses in a system for the best cost/performance ratio.

By selecting STE as an i/o channel for instance, you can cut costs by removing the unnecessarily complex bus-interface circuitry of VME which also increases the system's effective bandwidth by removing slow or lengthy i/o transfers.

Boards with dual-bus interfaces for this new kind of architecture have been appearing for around two years and you can now buy a VME-to-STE interface board for dual-bus systems. You will probably soon see a VME board with secondary STE bus interface on the second connector.

Anthony Winter is with Arcom Control Systems in Cambridge.

Standard progress

Specification of STE is nearing completion. The P1000 Working Group, formed at the request of the IEEE Microprocessor Standards Committee, recently voted to accept draft 3.2, and the standard is now awaiting final approval. We should see publication in late-1986.

STE BUS PIN-OUT

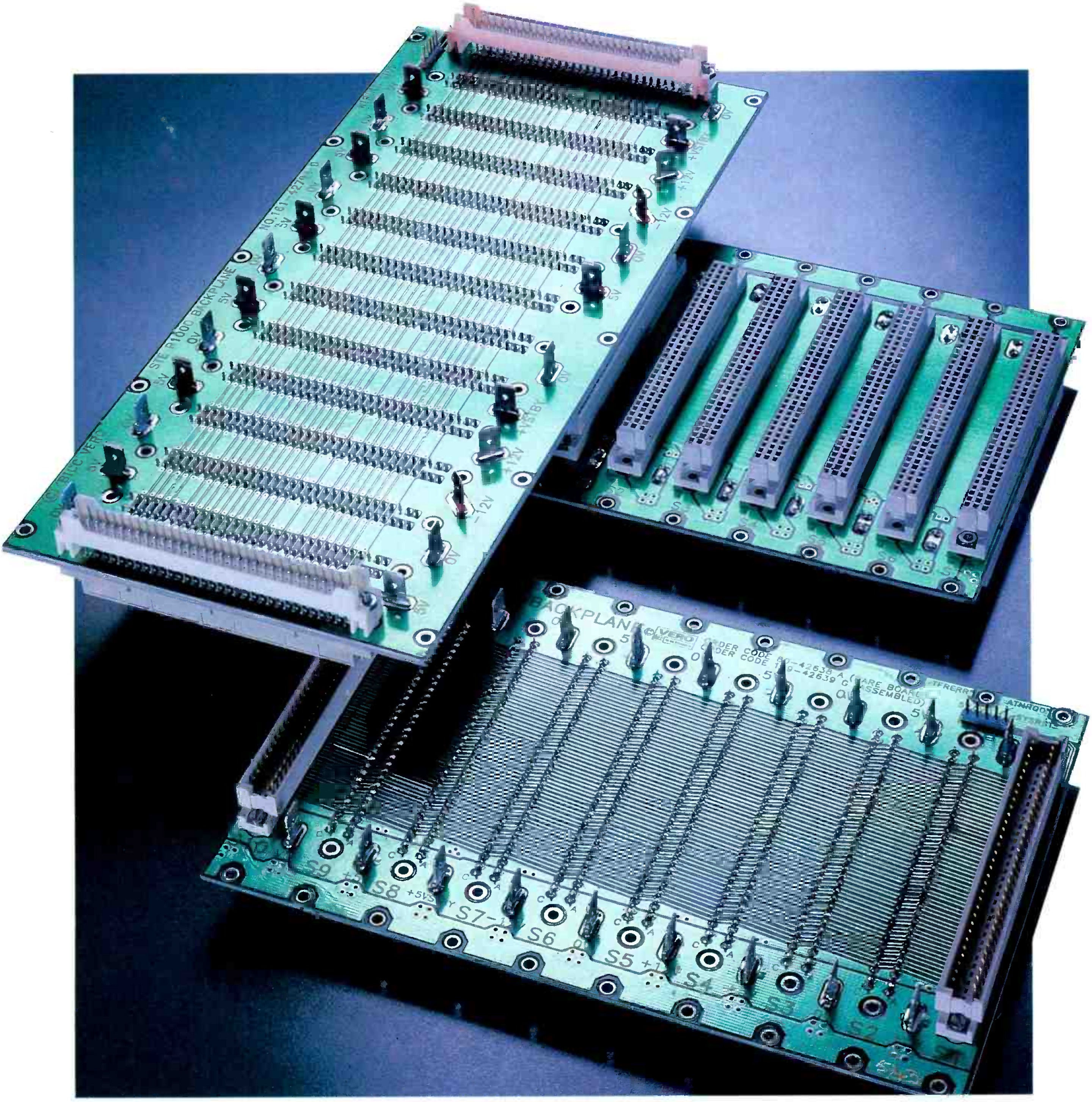
Below is the 64-signal STE bus pin-out defined on rows a and c of a DIN41612 connector. Address lines $A_{0\text{-}19}$ provide 1M-byte of main-memory addressing. Depending on the cycle, $A_{0\text{-}11}$ are used to address the 4K-byte of i/o space and $A_{0\text{-}2}$ provided a three-bit ackowledge address.

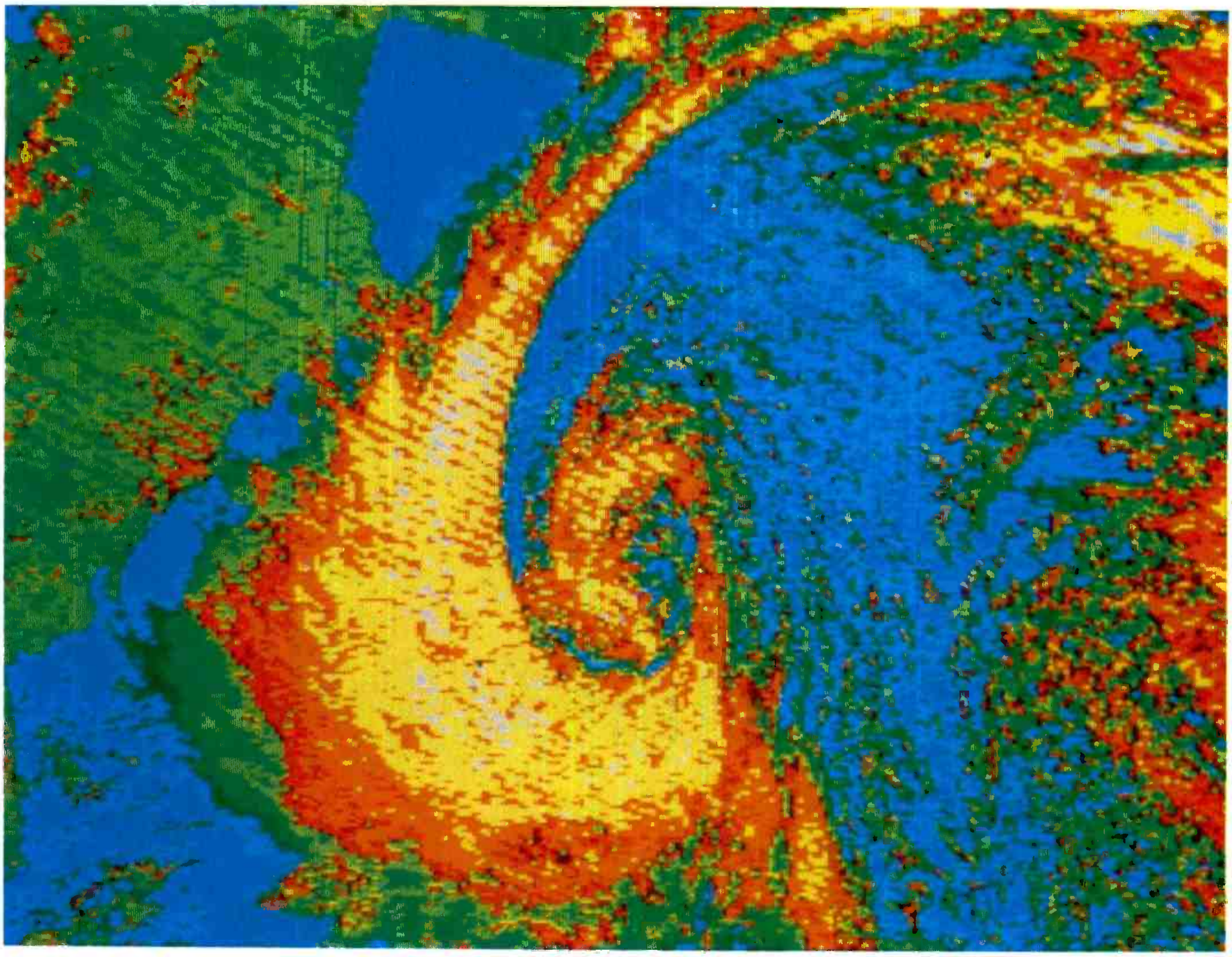
Lines $D_{0\text{-}7}$ are the eight bit data bus. Signals $\overline{ADRSTB}$ and $\overline{DATSTB}$ are address and data strobes. Lines $CM_{0\text{-}2}$ define the type of bus cycle in progress, i.e. whether it is memory or i/o read or write, or an acknowledge; three codes are free for future expansion.

Request lines $\overline{BUSRQ}_{0,1}$ are for use by temporary masters, $\overline{BUSRQ}_0$ being higher priority. The bus is asynchronous and DATACK is asserted when a master accepts data (on a read cycle) or when its data is valid (during a write) signal TFERR is used if data from a slave is wrong.

Signals $\overline{ATNRQ}_{0\text{-}7}$ are attention-request lines and $\overline{SYSCLK}$ and $\overline{SYSRST}$ are for 16Mkz system clock and reset functions. Remaining lines are for power with fully distributed grounds.

Pin	Row a	Row c
1	0V	0V
2	+5V	+5V
3	D_0	D_1
4	D_2	D_3
5	D_4	D_5
6	D_6	D_7
7	A_0	0V
8	A_2	A_1
9	A_4	A_3
10	A_6	A_5
11	A_8	A_7
12	A_{10}	A_9
13	A_{12}	A_{11}
14	A_{14}	A_{13}
15	A_{16}	A_{15}
16	A_{18}	A_{17}
17	CM_0	A_{19}
18	CM_2	CM_1
19	$\overline{ADRSTB}$	0V
20	$\overline{DATACK}$	$\overline{DATSTB}$
21	$\overline{SYSERR}$	0V
22	$\overline{ATNRQ}_0$	$\overline{SYSRST}$
23	$\overline{ATNRQ}_2$	$\overline{ATNRQ}_1$
24	$\overline{ATNRQ}_4$	$\overline{ATNRQ}_3$
25	$\overline{ATNRQ}_6$	$\overline{ATNRQ}_5$
26	0V	$\overline{ATNRQ}_7$
27	$\overline{BUSRQ}_0$	$\overline{BUSRQ}_1$
28	$\overline{BUSAK}_0$	$\overline{BUSACK}_1$
29	$\overline{SYSCLK}$	+VSTBY
30	−AUXV	+AUXV
31	+5V	+5V
32	0V	0V





VIDEO FRAME STORE

With this versatile unit, video images can be captured, processed and displayed. Later articles will introduce the rapidly developing field of image processing and analysis.

D.E.A. CLARKE

Many future developments in robotics and industrial automation will involve the application of image analysis techniques. Image analysis is becoming necessary because the limitations of dumb sensors and mechanical actuators in the current generation of industrial robots restricts their use to only the most basic of repetitive, well-ordered tasks.

The addition of vision sensors with interactive computer image processing dramatically increases the range of useful tasks a robot can accomplish and enables it to compensate for the disorder of the real world.

An ability to acquire and process images electronically is useful in many other fields. For example, an image can be stored, manipulated and transmitted over an ordinary telephone line at a rate the limited bandwidth of today's analogue telephony circuits can handle. Thus, an X-ray picture can be digitized and transmitted from one hospital to a specialist at another for diagnosis, and the image enhanced using computer techniques to bring out relevant features and mask unwanted ones. Similar techniques are useful for remote surveillance and finger-print matching, for example.

Once a computer has the means to acquire and process an image and to display the result, these and many other exciting applications become possible.

APPLICATIONS

The original impetus for this project came from an idea for fund-raising at a Christmas bazaar. The scheme was to use a tv camera, a frame store and a computer to print portraits on a standard dot-matrix printer.

The prototype frame store was constructed and a program written to print portraits such as that in Fig.1. Experiments with dot patterns for simulating grey scale and pixel dither for smoothing contours proved interesting and I shall discuss these techniques in a later article.

Weather satellite pictures are transmitted in the 136-138MHz band by polar orbiting satellites. Decoding methods for these broadcasts have been described in *Electronics & Wireless World* and construction kits are available: but the full range of grey levels cannot normally be displayed on a low-cost computer.

Displaying the received pictures on a monochrome monitor using a frame store is an attractive alternative. The full range of 256 grey levels gives a high quality tv picture suitable for photography, such as the example shown in Fig.2. The computer can be used to

Version shown here (on top of monitor) has the colour palette fitted.

enhance certain features and a colour look-up table may be programmed with a suitable range of colours for display on a colour monitor.

Figure 3 shows an X-ray plate which was captured with an inexpensive tv camera. The contrast has been boosted and the result stored on disc, along with the original image, for future reference.

3-D DISPLAYS?

Commercial units are now appearing which exploit the dual image nature of interlaced raster-scan displays to produce pseudo-three-dimensional effects. The principle is simple: each of the two fields which constitute a frame is arranged to be a separate view of the object, as would be seen by each eye of the viewer. The viewer wears liquid crystal spectacles which blank each eye alternately in synchronism with the field scan of the tv monitor, thus producing a 3-D illusion flickering at 25Hz.

With the enhanced frame store in 512×512 (interlaced) mode and a pair of the special l.c.d. spectacles plus scan interface, the user could try interesting experiments with computer-generated 3-D images.

Another possibility (which I have not tried), might be the generation of 3-D illusions with alternate fields in different colours (say red and blue). Cheap spectacles with appropriately coloured filters for each eye (such as those issued for recent 3-D broadcasts on tv), may give a similar illusion. To implement this

Fig.1. This 16-level image was reproduced by a dot-matrix printer.

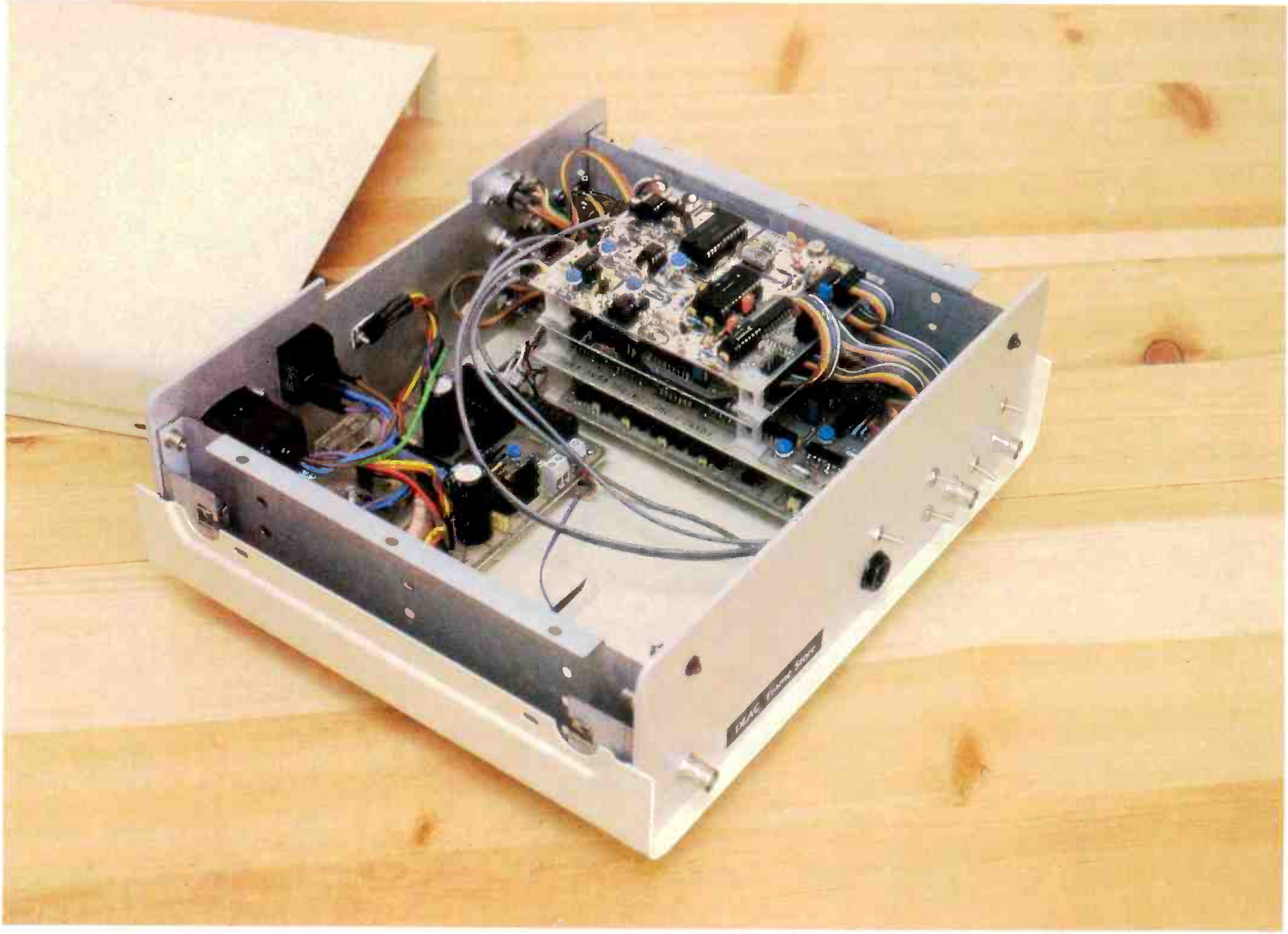


Fig.5. This prototype system is built on single-height Eurocards.

scheme, the colour palette board to be described in a later article would be used to switch colours between successive fields.

These applications are a few I have experimented with; others such as slow-scan tv, surveillance, picture processing I leave to your ingenuity.

TYPICAL INSTALLATION

A small system (Fig. 4) might comprise a basic frame store (with or without a colour palette), a black and white tv monitor (or a domestic tv plus u.h.f. modulator) and a computer with an eight-bit parallel output port and a bi-directional eight-bit parallel port. The frame store could then be used to display weather satellite pictures, slow-scan tv pictures or high quality computer generated images.

However, any source capable of providing 1V peak-to-peak video would be suitable: this could be a tv camera or even a video cassette recorder. Images could then be captured, stored, manipulated and displayed.

With the colour palette option, spectacular colour effects can be achieved on an r.g.b. (t.t.l. or 1V p-p) colour monitor.

The unit has a manual freeze switch, so it could even be used without the aid of a computer to produce amusing strobe effects with a tv camera, for example.

Second-hand tv cameras can now be easily obtained for well under £100 and are the ideal video source for experimenting with image processing.

The frame store described here is of the variety commonly referred to as a frame grabber. The frame grabber is distinguished

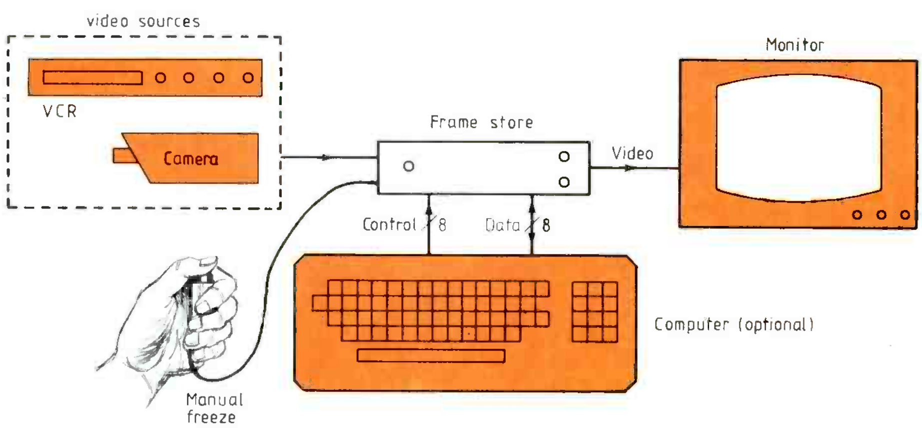


Fig.4. Layout of a basic picture-processing system. The frame store can instantaneously capture a picture from any standard video source.

by its ability to acquire a tv image in a single frame interval. Other less versatile designs use slow analogue-to-digital converters with sample-and-hold amplifiers, and acquire the image over several seconds. They have the disadvantages of slow capture rate with consequent loss of definition on moving or unstable parts of the picture.

The present unit suffers from none of these disadvantages and yet is simple to build, operate and expand. Two key developments have made it possible:

– the arrival of cheap, high density (64K and 256K) static rams, which has simplified control circuitry, reduced power consumption and eased computer interfacing.

the recent introduction of low-cost 'flash' analogue to digital converters (a.d.cs) and fast digital to analogue converters (d.a.cs) with high resolution (7/8 bits) at video rates.

COMPONENTS

A kit of semiconductors for this project will be available from Technomatic Ltd, 17 Burnley Road, London NW10 1ED.

The video converters (PNA7518 and PNA7509) have proved popular because of their low prices and may be in short supply. It would be advisable to order these parts early.

FEATURES

- single frame acquisition from tv camera, v.c.r. etc.
- resolution (64K ram): 256×256×128-bits (8 bits displayed)
- resolution (256K ram): a) 512×512 interlaced b) 512×313 non-interlaced
- variable sampling frequency (to over 11MHz), with variable sampling window.
- computer interface for read/write access to frame memory
- colour palette option:
  - –16 colours from palette of 4096
  - –t.t.l. r.g.b. outputs
  - –1V p-p r.g.b. outputs
  - –external r.g.b. inputs for programmable colour-keying on main picture
- dual image storage in 512×512 mode.
- modular construction allowing retrospective enhancement.

Link options enable straightforward upgrading to 256K rams when their cost becomes reasonable.

Fig.2. Weather satellite picture from NOAA-9 (1 August, 1986), showing a large weather system directly over the UK. France and the Bay of Biscay are visible at bottom right.

The latter has been brought about by developments in digital television technology and the need to produce low-cost digital signal processing circuitry for the new generation of tv sets.

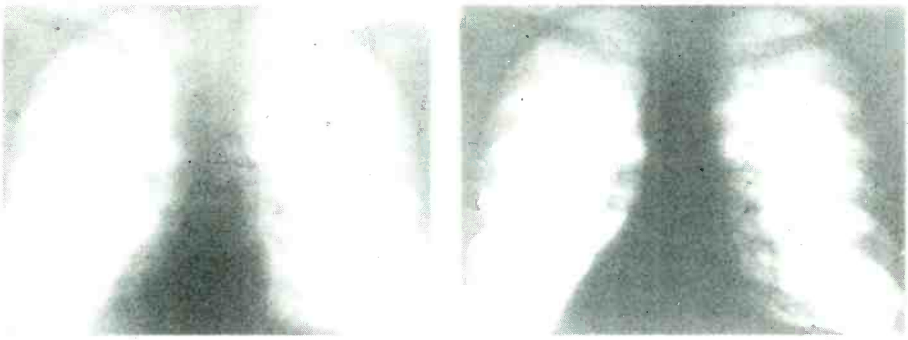


Fig.3. Image processing applied to an X-ray plate: the original image (left), and (right) a contrast-enhanced version. Note extra detail at bottom right.

CONSTRUCTION

The basic unit can be constructed on five single-height Eurocard breadboards as follows:

1. Data conversion and signal conditioning board with an on-board video test generator.
2. Control and computer interface board.
3. Static ram board: 64K-bytes, upgradeable to 256K-bytes.
4. Colour palette board (optional)
5. Power supply board (optional)

The frame store is shown as a block diagram in Fig. 6. The colour palette can be added at any time after the basic system is constructed.

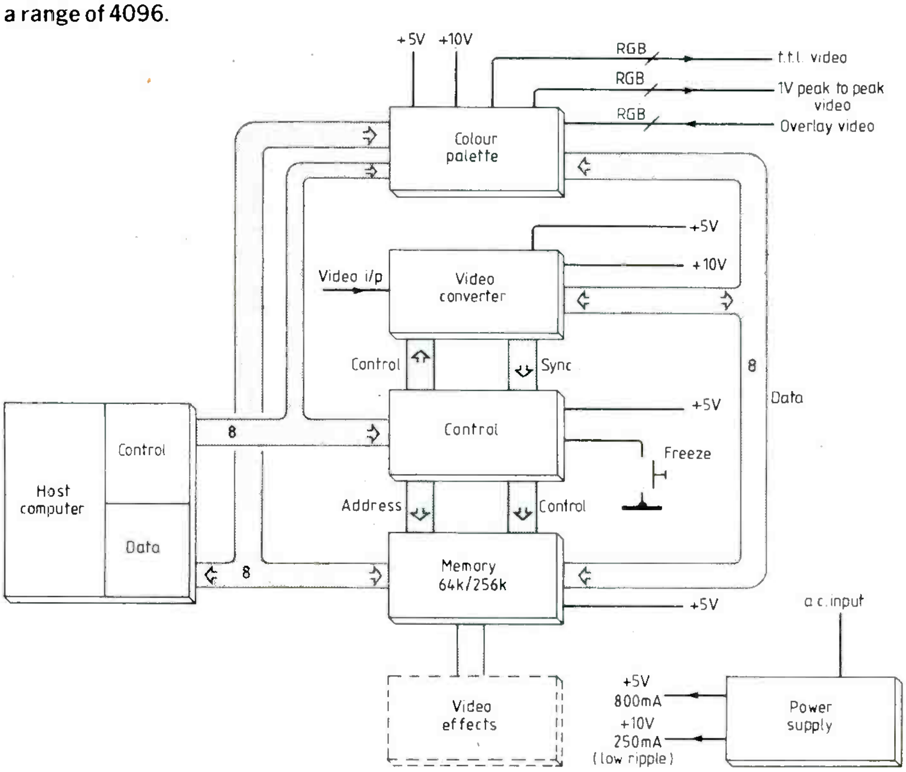
Spectacular real-time video effects can be achieved with simple devices such as adders and shifters connected to the video bus. Alternatively, extra memory, an arithmetic logic unit and control circuitry could be added to achieve real-time image manipulation or time-averaging for noise reduction. Such enhancements will be the subject of a further series of articles.

The host computer interface consists of eight control lines which would typically be connected to an eight-bit output port. Data is transferred to and from the memory via an eight-bit bidirectional port. A push-button freeze control has been found very useful for setting-up and operating the unit.

To be continued

Don Clarke is an electronics engineer in the telecommunications industry. After studying for an HNC at Colchester Institute whilst working as a trainee technician, he went on to Essex University where in 1981 he gained an honours degree in computer systems. Leisure interests include preserving historic buildings, the technical side of theatre, and politics.

Fig.6. Block diagram of the frame store. The colour palette option offers 16 colours from a range of 4096.



NEW PRODUCTS

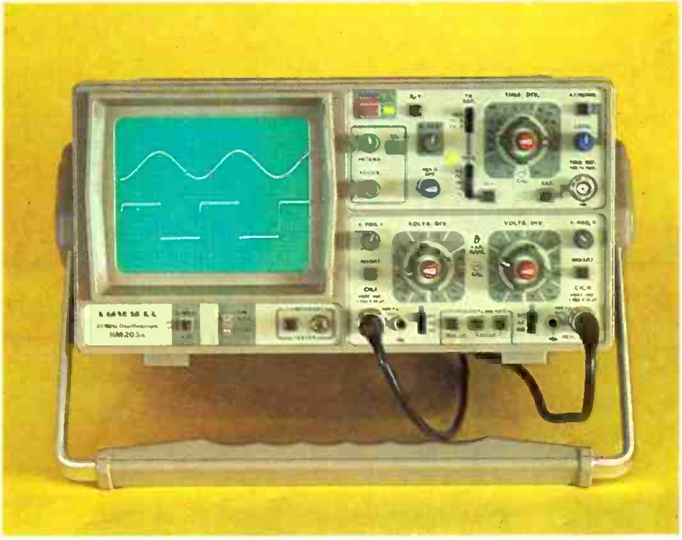
Remote controlled oscilloscope

An infra-red remote controller, similar to that used with tv sets has been added to the 350MHz Philips PM3295 to produce the PM3296. The remote unit permits the selection of up to 25 front panel settings (optionally expandable to 75). Each setting must be preset manually or through the GPIB, rather like tuning the tv, and a 'save' button on the hand unit is pressed to store the selection. Each setting can then be recalled by dialling the appropriate number on the remote controller. This facility is useful when there is no need for an external controller, for routine measurements, particularly in conditions where it may not be possible to touch the instrument. Examples are in climatic chambers or in high-voltage environments.

To make this possible all the internal controls on the oscilloscope have been digitized, including the rotary potentiometers. The instrument, like its predecessor has two input channels, real and delayed timebases, trigger view and versatile triggering.
220 on the reply card

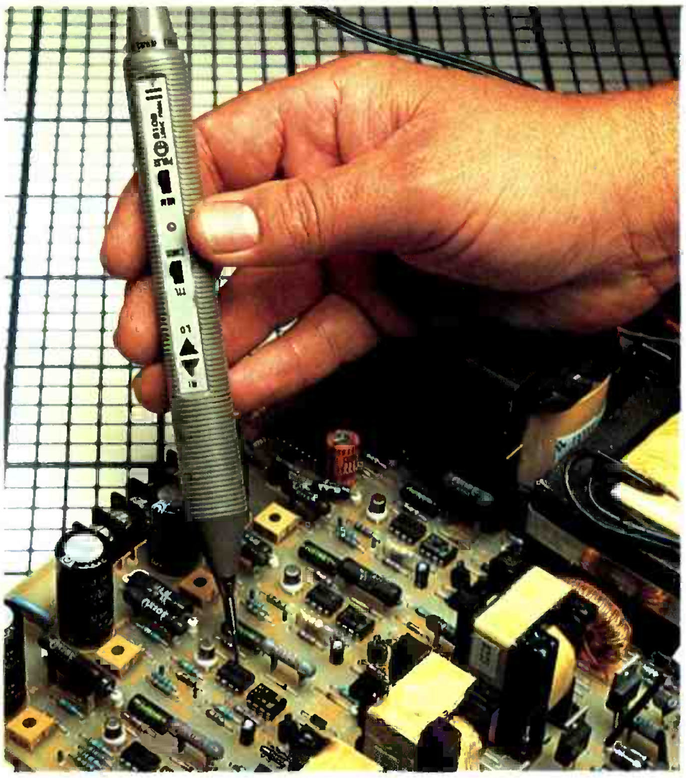
Digital pulse and delay generator

Five picoseconds is the claimed resolution of the Stanford DG535 delay/pulse generator. It has four separate delay channels each with a 1000s range. The internal trigger can be operated in single-shot or burst modes and is programmable from 0.001Hz to 1MHz. The output levels are continuously adjustable to precise settings but can also be seen to select standard levels such as t.t.l. or e.c.l. Both high and low impedance loads can be driven with a slew rage of 1V/ns. The four outputs can be programmed directly through the front panel with confirmation of all settings on the display. Delay levels can be entered individually or linked to follow each other in any desired sequence. A non-volatile ram can hold up to nine instrument settings which can also be set by computer through the GPIB. Available through Lambda Photometrics.
218 on the reply card



20MHz oscilloscope

Latest in the Hameg 203 series is the 203-6 a dual-trace oscilloscope with a 20MHz bandwidth and a maximum sensitivity of 2mV/division. It is possible to display the sum and difference of two signals. Triggering facilities include h.f. (up to 40MHz) and d.c. as well as line and tv sync triggering. The time resolution is 20ns/div. including a 10× magnification. The c.r.t's internal graticle gives parallel-free viewing over a wide angle. The instrument has a built-in component tester with test voltages and currents at a suitable level, for in-circuit testing and semiconductors. The oscilloscope was designed for general purpose use and it ease of use makes it suitable for training.
215 on the reply card



Audible logic probe

In addition to the standard green/red leds, the 610B logic probe offers an audible bleeper to indicate high or low state, pulse state and pulse trains above and below 200kHz. Suitable for both t.t.l. and c-mos circuits, the minimum detectable pulse width is 30ns. Exclusively in the UK from Global Specialities.
360 on reply card

Multifunction calibrator

Datron has produced the 4700 Autocal calibrator which offers direct and alternating current and voltage, and resistance ranges of a suitable accuracy to calibrate mid-range 5.5 and 6.5-digit d.m.ms. It can be used by itself or automated into a calibration system. Also from Datron is a range of pulse generators and waveform analysers.
237 on reply card

Microwaves counters "2/3 competitors price"

The Systron Donner division of Thorn-EMI have a new signal/sweep generator which can be externally programmed for automatic testing. Two new microwave frequency counters operating are also being introduced, to be sold at "two-thirds the prices of competitive equipment."

Also new is the Model 1720 microwave signal synthesizer which provides precise signals between 50MHz and 18GHz from a single output connector. Automatic internal and external levelling control provides "extremely flat response over the full frequency range." Accurate control, from −100 to +10dBm, is provided by a step attenuator and vernier control.
236 on reply card

Precision capacitance bridge

Eight-digit accuracy with a resolution of 1ppm or 0.5attofarad is possible with the 2500 capacitance bridge, from Lyons Instruments. Stability is 10ppm/year. Measurements are made at 1kHz over the range −0.015μF to +0.15μS (microsiemens). Eight digits are displayed but up to nine can be sent to a remote device.

The instrument is a true ratio-transformer bridge incorporating a fused-silica reference capacitor. Four different loss units plugs deviation measurements are provided, averaging time and maximum test voltage are selectable. RS232, GPIB and scanner interfaces are provided and allow internal corrections and calibrations against an external standard to be performed automatically. Apart from its use in metrology and component measurement, the instrument can be combined with the appropriate transducers to measure a wide range of physical phenomena.
219 on the reply card

• DATABANK •

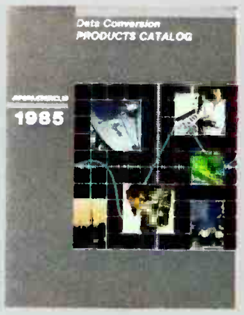
ADVANCE BRYANS INSTRUMENTS

Advance Bryans brings you the best of all worlds in oscilloscope operation! The DS-1520 series has a 20MHz bandwidth for normal dual-channel real time applications, as well as an advanced 2MHz digital storage specification. The many sophisticated technical features – some unique – result in outstanding performance and versatility for an instrument in its price range.

Four versions are available giving hard copy output to Advance Bryans XY recorders or digital plotters as appropriate.

CIRCLE 34
FOR FURTHER DETAILS.

ANALOGIC LTD



Analogic announces a new catalogue of data conversion products as part of its programme to remain a world leader in high speed-high accuracy data conversion products, exemplified by the Adam 826 a 16-bit half megahertz A/D converter which sells for approx £600. The company intends to be aggressive and has appointed distributor Consort Electronics to provide increased service to customers.

CIRCLE 55
FOR FURTHER DETAILS.

MS COMPONENTS LTD

The latest edition of the MS components catalogue features 1,000 new product additions. Bringing the total to 10,000 line items. All products are priced. In stock and despatched on the day of order. The 316 page catalogue details batteries, power supplies, books, cable, capacitors connectors, fuses, circuit breakers, hardware, indicators, meters, instruments, modems, opto, relays, resistors, security, semiconductors, service aids, soldering, suppressors, switches, tools and transformers.

CIRCLE 56
FOR FURTHER DETAILS.

P.S.P.

P.S.P. Electronics have updated their free short form literature which includes photographs and information about their complete range of connectors.

The literature is in full colour, includes stock range additions such as the Sounau 851 series, and can be obtained by circling the number of the Free Product Information card.

P.S.P. is a franchised distributor for ITT Cannon, Thomas & Betts, Transradio, ITT Pomona Electronics, Panduit and Souriau and, as always, P.S.P. are able to provide technical advice and services to meet clients' particular needs.

Manufacturers' catalogues with full product specifications can also be supplied on request.

CIRCLE 66
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ELECTRONICS & WIRELESS WORLD

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NEW PRODUCTS

Ultrasonic wire tracer

A diagostic tool from Cablecheck helps to overcome the risk of damage to senstive components by using an ultrasonic method of tracking wires, indentifying and locating open or short circuits. Ultratrace consists of two instruments, transmitter and receiver. The transmitter is attached to a suspect wire by a alligator clip and the receiver scans the wire, the system works through walls and under floorboards and can trace cables through metal sheets or other materials.
216 on the reply card

"Lowest priced d.s.o." – Hameg

Paxton Instruments distribute the Hameg range of oscilloscopes including the HM203-6 dual-trace oscillosope which has all the features of the HM203-5 but adds an active tv sync separator and two probe kits all for £285 (+tax). Also making its debut is the HM205 digital storage oscilloscope which offers 20MHz real-time readings and 100KHz digital sampling. Complete with probe kits for £448 (+tax) it is claimed to be the world's lowest priced d.s.o.
235 on reply card

Dynamic board testers use d-mos

Dynamic testing of both analogue and digital products is possible with the Spea Digitest 100AD. Using easy to programme multi-mode architecture, the instrument is claimed to offer considerable cost saving in test program generation times. With the use of very high-speed d-mos electronics, there is a great reduction in transmission time delay which eliminates the need to 'descew' the software. The instrument uses a single-chip driver as opposed to the driver circuitry of rival automatic test instruments. Landis & Gyr Communications.
238 on reply card

Modular meter

The Jay range is claimed to have the unique ability to accept a series of plug-in modules to turn the main instrument into a d.m.m, temperature, strain or other meter and also accepts calibration and simulation modules. The carrying case includes a pack of batteries, re-charged through the instrument. CIL Electronics Ltd.
261 on reply card

Scanner/switcher

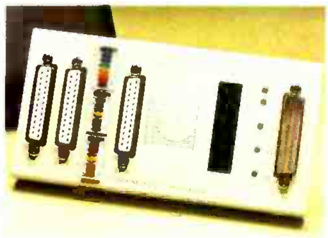
Up to 512 analogue inputs can be scanned and switched between the transducers and analysed/logging equipment with the Kite Series 16 scanner. The channels are scanned in a user-programmed sequence in units of 1, 2, 4, 8 and 16 output to the analysis system for further processing. The instrument can be controlled at the front panel or through an RS232 port with a local display to echo the all setup information including which channels are currently active. Applications include machine health monitoring, noise and vibration signal aquisition, testing of electronics systems and laboratory multi-way signal routing. Kite Developments Ltd. 263 on reply card.

Lab power supply

New from Thurlby Electronics is the PLK series of laboratory bench power supplies. Each has three independent outputs; a high current 5V output which can be varied between 4 and 6V and which incorporates a crowbar over-voltage protection; The other two are fully variable between 0 and 30V and can be fully isolated and independently adjustable or can track each other so that one control adjusts both outputs together. Digital metering has an accuracy of 10mV or 1mA. All outputs are current limited and protected against overloads and short circuits. One of the outputs has fully variable current controls and can be used as a constant current source. Line and load regulation offers less than 0.01% change for a 10% line change and 0.02% for 100% load change. Remote sense terminals ensure the maintenance at the load point regardless of lead impedance. 60W and 120W version are available
217 on the reply card

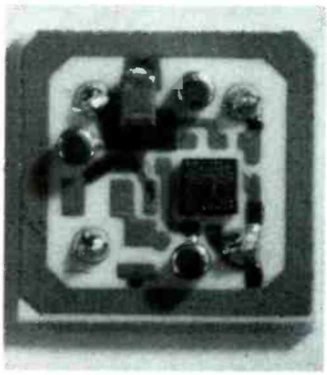
RS232 monitor

A pocket serial monitor, the Cablefaker from Compondex, can be attached to any RS232c port to monitor the signals. A liquid crystal displays the line status and the instrument features a breakout and patch field together with pulse catch and positive or negative logic monitoring. The instrument is powered from the line and needs no batteries.
214 on the reply card



Surface mounted asic oscillator

In our picture, the circular crystal has been removed to show the ceramic substrate of the M1000 clock oscillator. The i.c. includes links to select the frequency from between 4 and 48MHz, with guaranteed stabilities of 0.01, 0.05 or 0.1%. The devices consumes less than 55mA, and the oscillators deliver a 4V square wave output, capable of driving up to 10 t.t.l. loads. The output has better than 60/40 symmetry and the oscillator begins lcock-pulse generation within 10ms of power up. All is included in a 4-pin J-lead surface mounting package. From MF Electronics Corp in America.
266 on reply card



The Archer Z80 SBC

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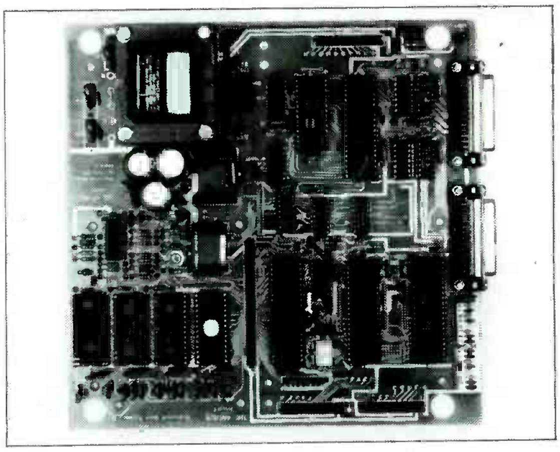

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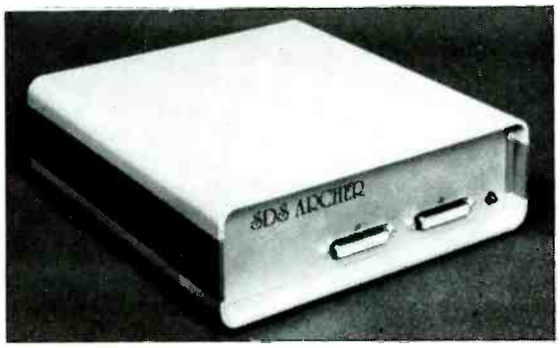

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NEW PRODUCTS

AI and p.c.b. autorouting

We often read about RISC processors and what a marvellous contribution they will make to our futures. Now we have a practical example: The Novix Forth processor is being used in the Calay c.a.d. system for p.c.b. design. It includes an expert system artifical intelligence program for autorouting tracks and can take into consideration the requirements of high-density boards with new component and soldering methods. Boards with over 1000 connections can be automatically routed and optimized 'overnight'. The Calay system uses a DEC 11/73 c.p.u. and the Novix processor is incorporated into a co-processor board plugged into the Q-bus. A five-fold bus structure enables five operations to be carried out in parallel. A designer is not restricted to a standard set of design rules and can set up any rules for a particular board. A special rules memory hold these and an inference calculator derives the precise instructions for the router. A single pass then implements the instructions in the layout. It is also possible to generate automatically several different versions of the same layout and select the best or the best combination to achieve the optimum layout. The RPR-3 hardware accelerator can be retrofitted to any Calay system. UK agents are Automation Systems Ltd.
222 on the reply card

Board designer for Atari ST

An interactive, computer-aided design systemf ro p.c.bs has been developed to run on the Atari 520ST or 104ST. It s facilities includes autorouting of tracks, rerouting and redrawing if required. The program is intended for the smaller business or independent electronics engineers. Available from First Publishing Ltd. 264 on reply card.

STE-bus industrial computer

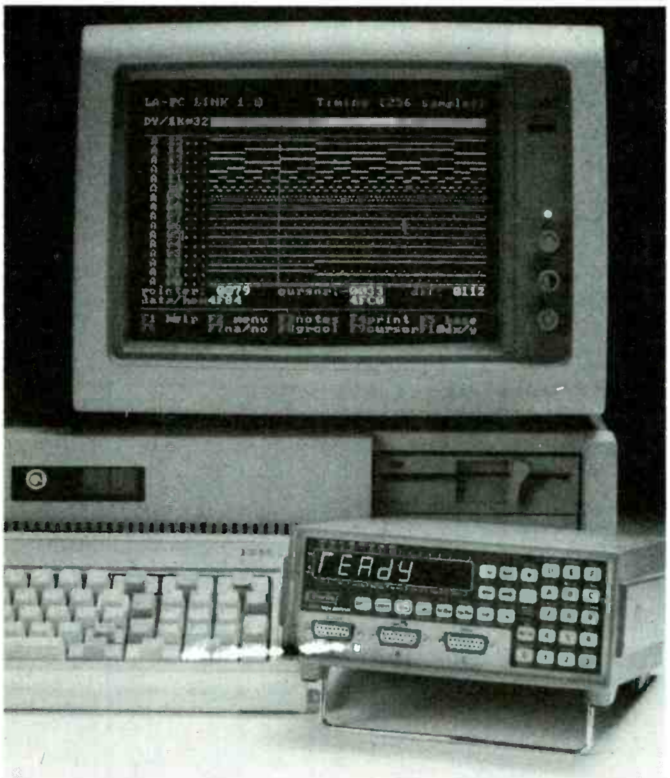
Based on the Hitachi HS64180, an enhanced Z80 processor, the Kemitron STE/RIO computer, offers an STE connector on each circuit board but also connects through the company's own rear input/output connector. The c.p.u. board offers up to 512K d-ram, 256K eprom, or 96K s-ram. Direct memory managment for up to 2Mb. There are four serial channels, three timers, a watchdog timer, real-time clock and battery floppy and hard disc interfaces and an STE-bus controller. All is housed in a standard rack unit. 265 on reply card.

Logic analysis on the PC

An interface package and software allow the Thurlby LA160 logic analyser to be linked to an IBM PC. Data is taken from the 16 or 32-channel logic analyser and loaded into the computer through the RS232 port. The control program produces colour graphics on the computer screen and makes full use of the computer's facilities to provide stored records on disc and print-outs if needed. The screen can display the timing of 16 channels vertically with either 64, 256 or 1024 samples horizontally. The channels can be named and displayed in any order. The screen also shows the value of the cursor and pointer positions and the difference between them. Another display mode lists 32 words of the logic state, rapid scrolling, word search and comparisons with test patterns are all possible.

The LA-PC Link consists of a rom program for the analyser and software on disc for the computer. A cable is provided to connect the serial ports.

221 on the reply card



Cheapest clone (so far)

Claiming to be IBM PC compatible and running MS-DOS (not PC-DOS) the Amstrad PC 1512 starts at only £399 (+ tax). The basic model is monochrome with one disc drive and 512K of ram bug at the top of the range come a 20MByte hard disc model in full colour at less than £1000. There is not intention to produce an AT-compatible model (yet) and any future IBM developments are to be ignored for some years.
224 on the reply card

32-bit workstation

The new Clipper 32-bit processor from Fairchild is implemented on three chips and can work at a rate of 5 million instructions/s. It is incoroporated in the 32C desktop workstations from Intergraph and claim to be faster than most multi-processor microcomputers. InterAct 32C has two screens for full-time production environments, the more compact InterPro has one screen for the normal office environment. Both have high resolution graphics and can show 32 colours at one time from a palette of 4096.
223 on the reply card

New BBC

Taking a leaf from Amstrad's book, Acorn have come up with the BBC Master Compact. This is a cut-down version of the BBC Master but comes with a built-in disc drive and a monochrome or colour monitor. Another departure is the division of the keyboard from the power supply and the 3.5in disc drive which is housed in a separate box. It lacks some the of the expansion facilities of the Master and has less built-in software, some of which is included on the Welcome/utlities disc. It is aimed at primarily schools and the home market. £500 (+ tax) for the colour version.
225 on reply card

D.S.P. with program memory

The latest digital signal processor from Motorola offers 10.25mips and 56bit operation. The DSP56001 features 512 words of on chip program ram, two preprogrammed data roms, two 256, word data rams and special on-chip bootstrap hardware to allow easy loading of user programs into the program ram. Without the need for pre-programmed roms, the device becomes an off-the-shelf product. It offers no contention over the use of the memory bus. Programs can be changed dynamically.

The on chip x and y rams come preprogrammed with A-law and Mu-law-to-linear conversion tables and with a sine table for waveform generation, discrete and fast Fourier transformation. The chip has a wide range of communications interface ports and seven buses. Applications include speech and other communications, instrumentation and control, image processing and in navigation. Available for sampling early in 1987, the device comes in an 88-pin ceramic grid array package. A software package of simulator and macro cross-assembler is available now. 267 on reply card.

NEW PRODUCTS

Telephone-radio interface

A telephone and radio inconnect system, the 27A300 Phone-patch from Racal Acoustics, connects a simplex radio set with the public telephone network. The instrument can monitor the radio and telephone lines and can link them. If either line offers poor reception the operator can manually dial the radio. Automatic keying of the radio is achieved by a voice operated switch. Racal cite search and rescue operations as being a specially useful application where radios at the scene of an accident can access the public telephone system, giving a greater range.
208 on the reply card

Professional c.b. radio

Telecomms claim to market the only 934MHz citizens' band tranceivers available in the UK. The Nevada range of equipment includes transceivers and all related equipment. Several transceivers have been purchased by BT for communications at the Goonhilly satellite station.

Telecomms also have a wide-band aerial for use with cellular radio. The 855 to 955MHz beam aerial can be used to access cellular radio from areas that are not within the cells.
205 on the reply card

Encoders for mobile radio

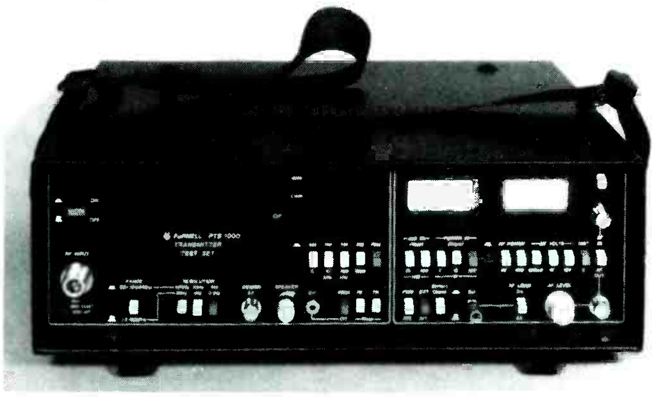
Plug in panels for Storno two-way radio equipment offer c.t.c.s.s. encoding and decoding. With the CTL Radiocom panels installed, the radio has the added facilities of p.t.t. timer, hookswitch monitor, busy lockout, with or without a warning tone and p.t.t. duration limiter. All the additional options can be defeated by links, operated from a rocker switch assembly thus enabling the host radio to be applied to many varying system parameters.
206 on the reply card

Low cost radio-phone

A single-channel mobile radio, the UKV62 from Communique (UK), is designed and made in the UK. At presenmt it is available in the v.h.f. 160 to 175MHz band but a u.h.f. 420 to 470MHz version will be available soon. Various signalling options are available including c.t.c.s.s. encoding and lockout, selcall and base-station adaptors enable the set to be integrated into new or existing systems.
207 on the reply card

Satellite receiver front end

Where the smallest antennae are desired, the FB-1 range of low-noise block-converters (l.n.bs) can be used to receive satellite tv signals. The l.n.b. is positioned at the focal point of a dish antenna and can collect, convert and amplify the satellite signal. Particular care has been taken over the tuning of the gas-fet stages to offer greatly improved performance over previously available systems, with noise figures as low as 1.8dB at 20°C and a guaranteed noise level of <2.1dB over the entire frequency band and temperature ranges covered. Special versions, for data communications, offer highly stable oscillator circuits with phase noise eliminated. Available through Space Communications (Sat-Tel) Ltd.
262 on reply card



Radio test sets

Two instruments from Farnell make testing easier. The PTS1000 is a portable transmitter test set that operates from a battery pack, a vehicle battery or a.c. main power. It has an operating frequency up to 1GHz. It integrates all the instruments normally required to check the performance of a transmitter up to 100W continuous rating: r.f. counter, modulation meter, r.f. and a.f. power meter, a.f. voltmeter, distortion analyser, weighing filters and r.f. power load. It can also measure aerial efficiency using an optional remote directional power head. Combined with a signal generator the set can be used as a complete transceiver test set with only four connections to the device under test. This facility adds frequency, distortion and sensitivity measurement of a receiver.

Another set for communications testing is the CTS520, designed for the service or production testing of simplex or duplex radio transceivers. This adds synthsized r.f. and a.f. signal generators, a sinad meter and a c.t.c.s.s. tone generator to the facilities incorporated in the other instument. The synthesized signal generator offers the benefits of drift-free measurement, absolute setting accuracy, low r.f. leakage and direct offset frequency measurements.
211 on the reply card

Hand portable radios

The Landmaster III from Pace Communications is supplied with one channel already crystalled, a flexible aerial, 500mAh battery and a trickle charger. V.h.f. and u.h.f. models are available. Manufactured in Japan, the sets are claimed to be designed and constructed to a high specification and yet remain competitively priced.
209 on the reply card

...and at sea

All 55 international marine channels are fully synthesized in the Sealine MC-56 hand-held v.h.f. radiotelephone from Shipmate. Also included is the UK Marina channel. The Coastguard channel 'O' can be added for authorized user and Channel 16 can be selected instantly by push-button. The set includes a dual-watch facility and comes with a battery charger. The output power is selectable between 1 and 3W.
210 on the reply card

Marconi test set

Designed for bench and field work, the Marconi 2955 radio communications test set can test all types of amplitude, frequency and phase-modulated mobile radio equipment. Applications include low-power hand portables and mobiles using selective calling, full duplex radio telephones, base stations and repeater equipment. Facilities include r.f. and a.f. signal generators, r.f. frequency and power meters, modulation, sinad and s/n meters and an a.f. frequency meter. The integral digital storage oscilloscope offers single or repetitive sweep in transmitter, receiver and audio test modes, calibrated for a.m. f.m. and p.m. Selcall encoder/decoder facilities are available as is a GPIB interface. Buy from Electronic Brokers, 212 on the reply card, or hire from Electroplan Hire, 213 on the reply card.

NEW PRODUCTS

Graphics design kit

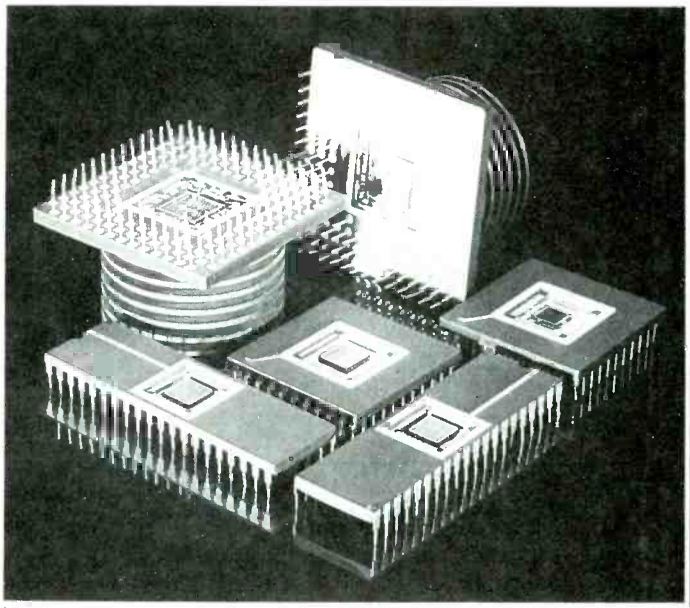
A complete package provides a comprehensive full-colour bit-mapped graphics capability. Six chips comprise the kit which can be interfaced with almost any microprocessor to provide screen resolutions from 256 to 256 pixels up to 4096 by 4096. The Texas TMS34061 video system controller eliminates the need for separate text and graphics systems. A video palette offers almost unlimited colours and the kit is completed by two 64K by 4 video rams two 4-bit shift registers and a 68-pin socket for the controller. Full documentation, application notes and data are provided. We have had identical notices of the kit from two sources; VSI and Online.
234 on the reply card

Miniature d.c. converters

5, 12 and 15V versions of the Newport d.c./d.c. converters are as small as integrated circuits. NM0505i, 1212i and 1515i produce their respective voltages (plus and minus) at 750W from a 5V supply. Input-to-output isolation is 500V. With high efficiency and a wide operating temperature range, the modules can be used at points of load on p.c.bs, elminating complex power bus tracks.
231 on the reply card

Single-chip data system

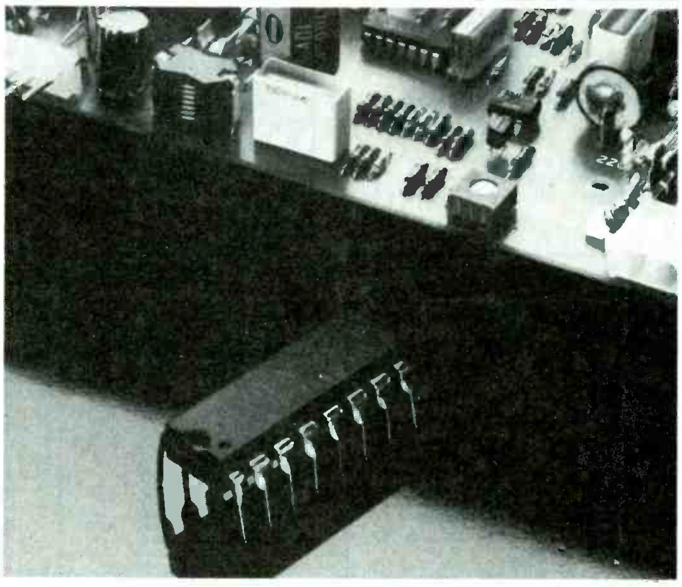
An analogue-to-digital peripheral i.c. is claimed by Texas Instruments to be a complete data aquisition system on single chip. It includes an internal systems clock, sample-and-hold, 8-bit a-to-d converter, data register and control logic. It is designed as a serial interface for a processor or peripheral through a three-state data output and an analogue input. The on-chip systems clock operates typically at 4MHz and allows the device to work independently of serial input/output data timing. Used in conjunction with the i/o clock this allows high-speed data transfer and sample rates of 40 000 cycles/s. Suggested applications include engine and machinery analysis, remote sensing, analogue-to-digital controls such as joysticks in computer applications, and in battery-operated portable instruments. The conversion accuracy is 0.5 of the l.s.b. in less than 19μs, while power consumption of the c-mos device is typically 6mW.
234 on the reply card



ECL/TTL logic arrays

Different logic families; e.c.l. or t.t.l. or both can be combined on a single chip with the AMCC Q3500 series of logic arrays. Three devices have the equivalents of 1300, 2400 and 3500 gates and support respectively 76, 98 and 120 input/output pins with a typical gate delay of 0.275ns. The arrays use 3-level series gating techniques to provide both density and speed improvements.

The QM1600 series can provide up to 1600 equivalent gates in e.c.l. coupled to 1280bit of e.c.l. ram which may be organized to any bit, byte or word configuration. Suitable design software for modelling and testing the devices runs on most c.a.e. workstations. Exclusive distribution is handled by Hi-Tek Electronics.
227 on the reply card



Switch-mode control chip

Switch-mode power supplies with increased efficiency and simplified design are made possible by Rifa's new control circuits; RL3525 for voltage mode and RL3846 for current mode. All functions of a high-performance controller are integrated, needing only a small number of external components to complete the supply. Included are dual totem-pole outputs with high drive capability, soft start, under-voltage control, p.w.m. and voltage references. Wide operating voltage range and high switching frequency range increase the areas of application.
229 on the reply card

BBC or IBM control system

A Eurocard-based control system for laboratory or factory is produced by Paul Fray. The system is designed to run with Spider, the real-time software package that uses BBC Basic to program complex control sequences. A five-card rack connects to the BBC 1MHz bus through an expansion card. Alternatively a 6502 processor card running BBC Basic and Spider software can be connected with up to nine interface or memory cards and built-in disc drives. This system is self contained but can be programmed through its serial port by a terminal, either a BBC or an IBM PC. The 5-card version can also be used with the terminal's discs and printer used for recording/storage of data.Spider is now available as a plug-in rom cartridge for the BBC Master.
226 on the reply card

Toroidal transformers

Designed and made in the UK, these toroidal transformers come in a range of five power ratings from 15 to 130VA, 48 to 60Hz. Maximum ambient temperature is 55°C. Intended for applications requiring low magnetic field and low temperature rise, the transformers incorporate a copper screen between primary and secondary windings. High efficiency ratio with low weight and small size make them useful in many applications.
233 on the reply card
PAGE 83

32-bits and 12.5 mips

Motorola's 25MHz version of the MC68020 32-bit processor and the 20MHz version of the MC68881 floating-point co-processor have been produced. The new processor can operate in bursts of 12.5million instructions/s but a more realistic figure is a sustained throughput of 5mips; seven times as fast as the 16-bit 68000. It owes its speed to the on-chip cache instruction memory, the three-stage instruction pipeline, the instruction set and the addressing modes. It is constructed in high-speed c-mos with 1.5micron geometry. The maths co-processor offers ove 40 floating point functions. It handles full extended precision (80-bit) for trigonometry, hyperbolics, logarithms, square roots etc. all in hardware. The co-processor works concurrently with the c.p.u. and is transparent to the systems programmer.
230 on the reply card

01-208 1177 TECHNOMATIC LTD 01-208 1177

BBC Computer & Econet Referral Centre

AMB15	BBC MASTER Foundation computer 128K	£395 (a)
AMB12	BBC MASTER Econet computer 128K (only ANFS)	£319 (a)
AMC06	Turbo (65C – 02) Expansion Module	£105 (b)

ADF13	Rom Cartridge	£13 (b)	ADF10	Econet Module	£43 (c)
ADJ22	Ref. Manual Part 1	£14.95 (c)	ADJ23	Ref. Manual Part II	£14.95 (c)
ADJ24	Advanced Ref. Manual				£19.50 (c)

BBC MASTER COMPACT
A free packet of ten 3.5" DS discs with each Compact
SYSTEM 1 128K, Single 640K Drive and bundled software **£385 (a)**
SYSTEM 2 System 1 with a 12" Hi Res Mono Monitor **£469 (a)**
SYSTEM 3 System 1 with a 14" Med Res RGB Monitor **£599 (a)**
Second Drive Kit **£99 (c)** Extension Cable for ext. 5.25" drive **£10 (d)**

View 3.0 User Guide £10 (d) .... Viewsheet User Guide **£10 (d)**
BBC Dust Cover **£4.50 (d)** .... 1770 DFS Upgrade for Model B **£43.50 (d)**
ADFS ROM (for B with 1770 DFS & B Plus) **£26 (d)** .... 64K Upgrade Kit for B plus **£35 (d)**
ACORN Z80 2nd Processors **£329 (a)** .... ACORN 6502 2nd Processor **£179 (b)**
MULTIFORM Z80 2nd Processor **£299 (b)** .... ACORN IEEE Interface **£269 (a)**
TORCH Z80 2nd Processor ZEP 100 .... **£229 (a)**
TZDP 240: ZEP 100 with Technomatic PD800P dual drive with built-in monitor stand .... **£439 (a)**

META Version III – The only package available in the micro market that will assemble 27 different processors at the price offered. Supplied on two 16K roms and two discs and fully compatible with all BBC models. Please phone for comprehensive leaflet **£145 (b).**

We stock the full range of ACORN hardware and firmware and a very wide range of other peripherals for the BBC. For detailed specifications and pricing please send for our leaflet.

PRINTERS & PLOTTERS

EPSON
EPSON LX-86 .... **£229 (a)**
Optional Tractor Feed LX80/86 .... **£20 (c)**
Sheet Feeder LX80/86 .... **£49 (c)**
FX85 (80 col) .... **£315 (a)**
FX105 (136 col) .... **£449 (a)**
LQ800 (80 col) .... **£459 (a)**
LQ1000 (136 col) .... **£659 (a)**

TAXAN:
KP810 (80 col) .... **£219 (a)**
KP910 (156 col) .... **£389 (a)**

JUKI
6100 (daisy wheel) .... **£249 (a)**

NATIONAL PANASONIC
KX P1080 (80 col) .... **£159 (a)**

STAR NL10 (Parallel Interface) .... **£239 (a)**
STAR NL10 (Serial Interface) .... **£279 (a)**

BROTHER
HR15 (Daisy Wheel) .... **£299 (a)**

COLOUR PRINTERS
Epson JX80 .... **£420 (a)**
Integrex Jet Printer .... **£525 (a)**
Canon PJ1080A .... **£409 (a)**

Dotprint Plus NLQ Rom for Epson versions for FX/RX, MX and GLP .... **£28 (d)**

PLOTTERS
Epson HI-80 (A4) .... **£325 (a)**
Hitachi 672 (A3) .... **£464 (a)**
Graphics Workstation (A3 Plotter) .... **£609 (a)**

PRINTER ACCESSORIES

We hold a wide range of printer attachments (sheet feeders, tractor feeds etc) in stock. Serial, parallel, IEEE and other interfaces also available. Ribbons available for all above plotters. Pens with a variety of tips and colours also available. Please phone for details and prices.
Plain Fanfold Paper with extra fine perforation (Clean Edge):
2000 sheets 9.5" X 11" **£13(b)** 2000 sheets 14.5" X 11" **£18.50(b)**
Labels per 1000s: Single Row 3½" X 1 7/16" **£5.25(d)** Triple Row 2-7/16" X 1 7/16" **£5.00(d)**

MODEMS

MIRACLE WS 2000 – The world standard BT approved modem covering all standard CCITT and BELL (outside UK only) standards up to 1200 baud. Allows communication with virtually any computer system in the world. Expandability to Auto Dial and Auto Answer with full software control enhance the considerable features already provided on the modem. Mains powered. WS 2000 **£102 (c)**, Data Cable **£7 (d)**, Auto Dial Card **£26 (d)**, Auto Answer Card **£26 (d)**.

WS 3000 RANGE – the new professional series. All are intelligent and 'Hayes' compatible, allowing simply 'English' commands to control its many features. All models feature Auto-Dial with 10 number memory, Auto-Answer, Speed buffering, printer port, data security option etc. All models are factory upgradeable.

WS3000 V21/23 (V21 & V23 + Bell **£295 (a). WS3000 V22** (as above plus 1200 baud full duplex **£495 (a).**
WS3000 V22bis (as above plus 2400 baud full duplex) **£650 (b).**

WS3022 provides 1200/1200 baud full duplex operation. **£395 (b).**

WS3024 provides 2400/2400 baud fd only. **£570 (b).**

GEC Data Cable for WS3000 **£7 (d)**. Data Cables for other micros available. The WS3000 range all have BT approval.

GEC DATACHAT 1223 – An economically priced BABT approved modem complying with CCITT V23 standard capable of operating at 1200/75bps and 75/1200bps and 1200/1200bps pseudo full duplex. It is line powered, does not require external power source. It is supplied with software suitable for connecting to PRESTEL, Micronet 800, Telecom Gold and a host of bulleting boards. Special Offer **£49 (b).**

SOFTY II

This low cost intelligent eprom programmer can program 2716, 2516, 2532, 2732, and with an adaptor, 2564 and 2764. Displays 512 byte page on TV – has a serial and parallel I/O routines. Can be used as an emulator, cassette interface.
Softy II .... **£195.00 (b)**
Adaptor for 2764/2564 .... **£25.00**

SPECIAL OFFER

2764-25 £2:00(d);
27128-25 £2:50(d);
6264 LP-15 £3:40(d);

DISC DRIVES

5.25" Single Drives 40/50 switchable:
TS400 400K/640K .... **£114 (b)**
PS400 400K/640K with integral mains power supply .... **£129 (b)**
5.25" Dual Drives 40/80 switchable:
TD800 800K/1280K .... **£226 (a)**
PD800 800K/1280K with integral mains power supply .... **£245 (a)**
PD800P 800K/1280K with integral mains power supply and monitor stand .... **£263 (a)**
3.5" 80T DS Drives:
TS351 Single 400K/640K .... **£99 (b)**
PS351 Single 400K/640K with integral mains power supply .... **£119 (b)**
TD352 Dual 800K/1280K .... **£170 (b)**
PD352 Dual 800K/1280K with integral mains power supply .... **£187 (b)**

3M FLOPPY DISCS

Industry Standard floppy discs with a lifetime guarantee Discs in packs of 10.

5¼" DISCS				3½" DISCS	
40 T SS DD	**£10.50 (d)**	40 T DS DD	**£12.75 (d)**	80 T SS DD	**£20.00 (d)**
80 T SS DD	**£16.50 (d)**	80 T DS DD	**£16.50 (d)**	80 T DS DD	**£27.00 (d)**

FLOPPICLENE DRIVEHEAD CLEANING KIT

FLOPPICLENE Disc Head Cleaning Kit with 28 disposable cleaning discs ensures continued optimum performance of the drives. 5¼" **£12.50 (d)**
3½" **£14.00 (d)**

DRIVE ACCESSORIES
Single Disc Cable **£6 (d)** — Dual Disc Cable **£8.50 (d)**
10 Disc Library Casae **£1.80 (d)** — 30 x 5½ Disc Storage Box **£6 (c)**
50 x 5½" Disc Lockable Box **£9.50 (c)** — 100 x 5½ Disc Lockable Box **£13 (c)**

MONITORS

RGB 14"
1431 Std Res .... **£179 (a)**
1451 Med Res .... **£225 (a)**
1441 Hi Res .... **£365 (a)**

MICROVITEC 14" RGB/PAL/Audio
1431AP Std Res .... **£195 (a)**
1451AP Std Res .... **£260 (a)**
All above monitors available in plastic or metal case.

TAXAN SUPERVISION II
12" – Hi Res with amber/green options. IBM compatible .... **£279 (a)**
Taxan Supervision III .... **£329 (a)**

MITSUBISHI
XC1404 14" Med Res RGB. IBM & BBC compatible .... **£229 (a)**

MONOCHROME
TAXAN 12" HI-RES
KX1201G green screen **£90**
KX1203A amber screen **£98**

PHILIPS 12" HI-RES
BM7502 green screen **£75**
BM7522 amber screen **£79**

HANTAREX HX12 .... **£69**

ACCESSORIES
Microvitec Swivel Base **£20**
Taxan Mono Swivel Base with clock **£22**
Philips Swivel Base **£14**
BBC RGB Cable **£5**
Microvitec **£3.50**
Taxan **£5 (d)** .... Monochrome **£3.50**
Touchtec – 501 .... **£255**

UVERASERS

UV1T Eraser with built-in timer and mains indicator. Built-in safety interlock to avoid accidental exposure to the harmful UV rays.
It can handle up to 5 eproms at a time with an average erasing time of about 20 mins. **£59 + £2 p&p.**
UV1 as above but without the timer. **£47 + £2 p&p.**
For Industrial Users, we offer UV140 & UV141 erasers with handling capacity of 14 eproms. UV141 has a built in timer. Both offer full built in safety features UV140 **£69**, UV141 **£85, p&p £2.50.**

PRINTER BUFFER

The buffer offers a storage of 64K. Data from three computers can be loaded into the buffer which will continue accepting data until it is full. The buffer will automatically switch from one computer to next as soon as that computer has dumped all its data. The computer then is available for other uses. LED bar-graph indicates memory usage. Simple push button control provides REPEAT, PAUSE and RESET functions. Integral power supply. **£199 (b).** With 256K **£275 (b).**
BBC Cable Set **£30.**

Serial Test Cable

Serial Cable switchable at both ends allowing pin options to be re-routed or linked at either end – making it possible to produce almost any cable configuration on site.
Available as M/M or M/F **£24.75 (d)**

Serial Mini Patch Box

Allows an easy method to reconfigure pin functions without rewiring the cable assay. Jumpers can be used and reused **£22 (d)**

Serial Mini Test

Monitors RS232C and CCITT V24 Transmissions, indicating status with dual colour LEDs on 7 most significant lines. Connects in Line. **£22.50 (d)**

CONNECTOR SYSTEMS

I.D. CONNECTORS

(Speedblock Type)

No of ways	Header Plug	Receptacle	Edge Conn.
10	90p	85p	120p
20	145p	125p	195p
26	175p	150p	240p
34	200p	160p	320p
40	220p	190p	340p
50	235p	200p	390p

D CONNECTORS

No of Ways	9	15	25	37
MALE:				
Ang Pins	120	180	230	350
Solder	60	85	125	170
IDC	175	275	325	—
FEMALE:				
St Pin	100	140	210	380
Ang Pins	160	210	275	440
Solder	90	130	195	290
IDC	195	325	375	—
St Hood	90	95	100	120
Screw Lock	130	150	175	—

TEXTOOL ZIF

SOCKETS
24-pin £7.50
28-pin £9.10
40-pin £12:10

EDGE CONNECTORS

	0.1"	0.156"
2 × 6-way (commodore)	—	300p
2 × 10-way	150p	—
2 × 12-way (vic 20)	—	350p
2 × 18-way	—	140p
2 × 23 way (ZX81)	175p	220p
2 × 25-way	225p	220p
2 × 28-way (Spectrum)	200p	—
2 × 36-way	250p	—
1 × 43-way	260p	—
2 × 22-way	190p	—
2 × 43 way	395p	—
1 × 77 way	400p	500p
2 × 50-way(S100conn)	600p	—

EURO CONNECTORS

DIN 41612	Plug	Skt
2 X 32 way St Pin	230p	275p
2 X 32 way Ang Pin	275p	320p
3 X 32 way St Pin	260p	300p
3 X 32 way Ang Pin	375p	400p
IDC Skt A + B	400p	
IDC Skt A + C	400p	

For 2 X 32 way please specify spacing (A + B, A + C).

MISC CONNS

21 pin Scart Connector 200p
8 pin Video Connector 200p

AMPHENOL CONNECTORS

36 way plug Centronics (solder **500p** (IDC) **475p**
36 way skt Centronics (solder) **550p** (IDC) **500p**
24 way plug IEEE (solder) **475p** (IDC) **475p**
24 way skt IEEE (solder) **500p** (IDC) **500p**
PCB Mtg Skt Ang Pin
24 way **700p** 36 way **750p**

GENDER CHANGERS

25 way D type

Male to Male **£10**
Male to Female **£10**
Female to Female **£10**

RS 232 JUMPERS

(25 way D)

24" Single end Male	£5.00
24" Single end Female	£5.25
24" Female Female	£10.00
24" Male Male	£9.50
24" Male Female	£9.50

DIL SWITCHES

4-way 90p — 6-way 105p
8-way 120p — 10-way 150p

RIBBON CABLE

(grey/metre)

10-way	40p	34-way	160p
16-way	60p	40-way	180p
20-way	85p	50-way	200p
26-way	120p	64-way	280p

DIL HEADERS

	Solder	IDC
14 pin	40p	100p
16 pin	50p	110p
18 pin	60p	—
20 pin	75p	—
24 pin	100p	150p
28 pin	160p	200p
40 pin	200p	225p

ATTENTION

All prices in this double page advertisment are subject to change without notice.
ALL PRICES EXCLUDE VAT
Please add carriage 50p unless indicated as follows:
(a) £8 (b) £2.50 (c) £1.50 (d) £1.00

TECHNOLINE VIEWDATA SYSTEM. TEL: 01-450 9764

Using 'Prestel' type protocols. For information and orders – 24 hour service, 7 days a week

Charge-coupled device technology

Extensive development of a charge-coupled pick-up device has led to a high performance camera that should be ideal for electronic news gathering

KATSUMI SHINODA AND E. TAMURA

The last two or three years has seen application of charge-coupled devices in consumer products in quantities exceeding a million per year. Sony's c.c.d. chip production now exceeds 100,000 per month. The benefits of use of such massive production enables excellent yields of quality c.c.d. chips for professional use.

The most suitable and effective ways in which c.c.ds can be used are those in which the advantages of not only small size, low power consumption but also high sensitivity, low lag, reduced sticking are most important. The most obvious broadcast application is for e.n.g. particularly for lightweight combined camera and v.t.r. in which mobility and handling ability can be dramatically improved.

The currently available c.c.d. still has some practical limitations however compared with conventional tubes, and special care is needed in the camera design to compensate for these drawbacks and at the same time make good us of the c.c.d's beneficial characteristics.

DESIGN GOALS

- **Compact, lightweight, low power consumption without any sacrifice of reliability and robustness.**
- **High picture quality. The c.c.d. chips used are of the best that can currently be made but the number of pixels in the horizontal direction and the dark current are limitations in comparison with tubes. Various strategies can be applied to realize comparable picture quality.**
- **Ergonomic design. Much experience has now been obtained from previous tube modules including user advice and opinion. This enables the camera to be a well-balanced rigid mechanical design.**

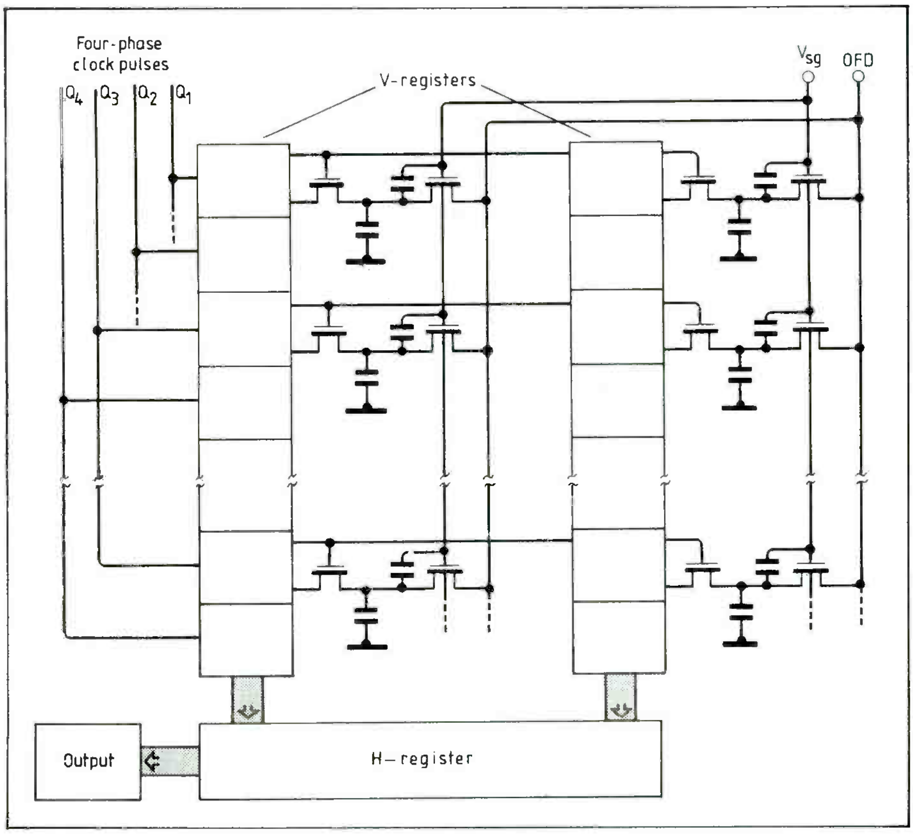


Fig.1. This c.c.d. imager comprises m.o.s. photosensors arranged as rows of 500 elements and columns of 582 elements. In the inter-line transfer technique both photosensor and vertical shift register are "interlined" on the same chip in about half the size of the frame transfer type chips.

The main chip characteristics are shown in Table 1 and the physical structure in Fig. 1. The parameters are typical values, there being some spread in practice. However, a large production quality enables selection of chips specifically for high quality broadcast applications. The three main criteria are freedom from blemishes, low dark current, and high saturation capability.

Three devices are used and several methods are available to implement an imaging system. After careful consideration the conventional beam-splitting prism was used on which the three chips are attached. Thus RGB signals are available in line with tube practice.

Furthermore, as shown in Fig.2, the fixing of the G and the R,B devices are horizontally displaced by half a pixel pitch from the nominal position. Each device has 510 elements in the horizontal direction and spatial offset allows a higher luminance resolution to be obtained than normally expected from this number, at the same time maintaining satisfactory chrominance resolution.

Other advantages are:

- High efficiency in the input light handling enabling good sensitivity to be achieved.
- Colour rendering can be controlled by the prism block design and existing know-how

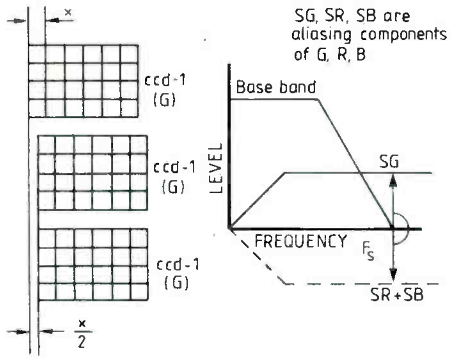


Fig.2. To increase horizontal resolution a spatial offset technique is used that shifts pitch by half an element. Resolution of 550 tv lines is achieved.

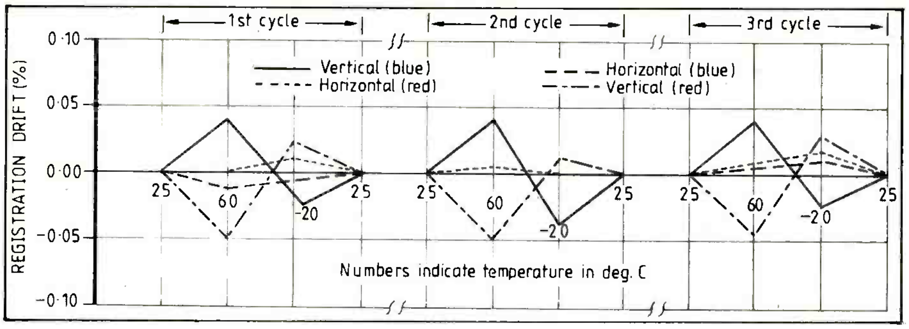


Fig.3. Errors in registration between the three primary devices are reduced by bonding them to three faces of a prism block. The dominant influence on registration, the G-R component, is very low at the unnoticeable level of 0.02%. Diagram shows consistency over three temperature cycles.

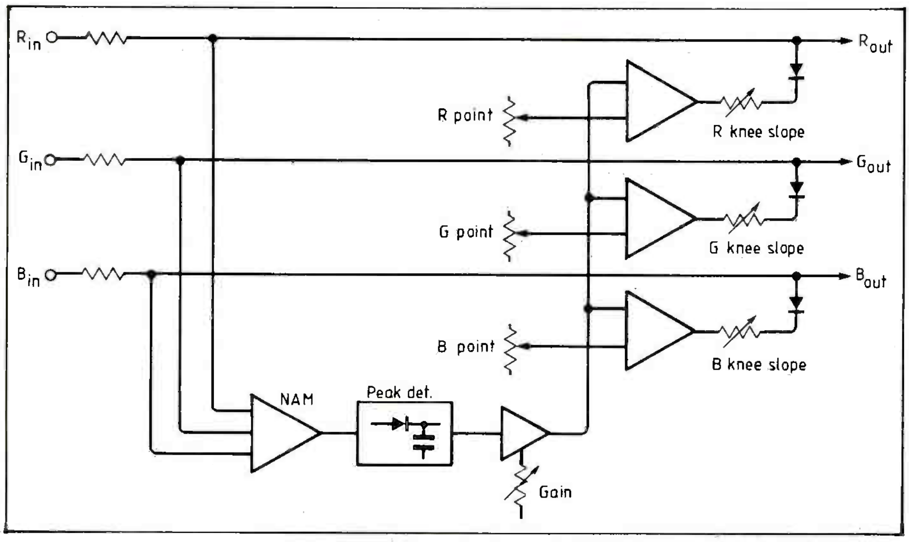


Fig.4. Whereas a conventional three-tube camera normally has a signal handling capability of 400%, the c.c.d. camera has a dynamic range of up to 600% by virtue of the automatic knee control scheme shown. Non-additive mixer detects only the highest level from R,G,B, inputs.

from conventional tube practice effectively applied.

– Errors due to the optical system can be easily compensated and the necessary total characteristics more easily obtained.

It is often assumed that the use of c.c.ds implies that registration is free from the need for adjustment. But the use of multiple chips has its own requirement for accurate initial registration. Additionally, highly stable mechanical positions must be maintained for all three chips, in particular the half pixel offset must be permanently established.

These considerations led to a design in which the chips are bonded directly to the faces of the prism block using a specially made mechanical locating device. With this method excellent stability can be maintained for variations in temperature and humidity and also against mechanical shock.

Fig. 3 shows some typical data in which the registration drift is plotted against ambient temperature. The dominant influence on registration, the G-R component, is very low, being an unnoticeable level of 0.02%.

Sensitivity, s/n ratio and dynamic range are closely related to each other; with the c.c.d. chip selection process the final parameters are as shown in Table 2.

Sensitivity is about half a stop better than conventional 17mm (2/3in) plumbicon tube.

Signal-to-noise ratio. A correlated double-sampling method suppressed the noise generated at the output stage. A newly designed heat dissipation and cooling system limits the temperature rise so reducing the increase in dark current noise which occurs with a rise in temperature. Finally, optimization of RGB spectral characteristics gives an overall benefit in the signal-to-noise ratio.

Dynamic range. A conventional three-tube camera normally has a signal handling capability of up to about 400%. The c.c.d. camera, on the other hand, has a dynamic range of about 600% because of an automatic knee control circuit in the video processing amplifier as shown in Fig.4.

The major parameters given in Table 2 are for both PAL and NTSC models. The PAL version is slightly less sensitive because the effective sensor area is made narrower by the increased number of pixels in the vertical direction.

There are still several drawbacks which

Table 1. Charge-coupled chip parar

Item	Spec. (typical)
Image format	2/3in
Sensitivity, 1000/lux*	160mV
Saturation	530mV
Dark signal†	14mV
Dark Shading†	3mV
Smear	0.01%
Gamma	1
Lag	Not visible

* 3200K with infra-red filter
† at 55°C

TABLE 2. Tentative specification

Pick-up device	Three-chip 2/3in c.c.d
Picture element	510(h) x 492(v) (NTSC), 500(h) x 582(v) (PAL)
Sensitivity	2000in F5.6 (NTSC), F5.0 (PAL)
Minimum illumination	15lux (NTSC) (+18dB) 20lux (PAL)
Signal-to-noise ratio	58dB (NTSC), 55dB (PAL)
Horizontal resolution	550 tv lines
Registration error	0.05% (all zones)
Filter	Clear, 5600 K+1/4ND, 5600K, 5600K+1/16ND
Power consumption	10.5W
Gain up	0/9/18dB or 0/9/24dB
Operating temperature	–20 to +45°C
Weight	3.2kg (without lens)

must be improved for the future high quality broadcast colour camera, particulary in respect of number of pixels in the horizontal direction, dark current, spectral response and the smear characteristics.

The methods presently used for measuring tube cameras may be inappropriate for the c.c.d. camera. For example, the measured maximum resolution is below the value obtained for a tube camera, but the subjective sharpness is higher, particularly for the PAL version.

We expect development to continue toward producing higher quality c.c.d. chips for broadcast use. In the meantime, both tube and c.c.d. cameras have their individual uses, the first for high quality studio use, the last for e.n.g.

Further reading

High resolution c.c.d. image sensors with reduced smear by S. Ochi et al. *IEEE Trans-Electron Devices*, vol.ED-32, no. 8, Aug 1985 pp. 1451-1456.

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E. Tamura is manager of Sony Corporation's c.c.d. camera division. He joined as tv camera designer from Shiba Electric Co in 1972, where he went after graduating from Gonma Technical College.

BBC Datacast – the transmission system

A similar process to that used in the teletext system is used to transmit data-lines which are independent of the normal teletext system.

J. P. CHAMBERS, M.A., C.Eng., M.I.E.E

When the specification of the British teletext system[1] was written, over ten years ago, the prime purpose was to carry pages of text in a fixed format suitable for display on a domestic television receiver. This was to be done efficiently, reliably, ruggedly and at low cost; an objective generally reckoned to have been achieved. There are now over ten million receivers world-wide equipped for this system.

Data is carried on otherwise unused lines in the television field-blanking interval. Its service started with two lines per field used for teletext, but now six or seven are in use. The specification allows for up to 16 lines per field to be used, but there are practical limitations caused by the need for compatibility with existing receivers: the use of lines too early in the field interval can cause the data to be displayed on screen during the vertical flyback period on some receivers, and using later lines can cause a flared image at the top of the picture. This problem varies between countries and some already use more lines for teletext.

Teletext was designed for receivers capable of storing only one page. It is necessary to repeat all pages frequently to allow users freely to choose and acquire pages. So a resource capable of sending 40 000 pages per hour is currently used to send perhaps 300 different pages at any one time. Now that mass semiconductor storage is so cheap it is possible to think of data bases being updated by teletext, only new material being sent with occasional complete replenishments. Even a small portion of the total capacity allocated to such a function could provide very many valuable new data services.

During 1985 the BBC was approached by several organizations interested in the possibility of using teletext data lines for carrying data for commercial purposes.

Anticipation of Datacast. When the teletext specification was written in 1976, 75% of the address codes at the start of the data lines were allocated, but the other 25% were reserved for future use by requiring that the decoders initially produced should ignore them.

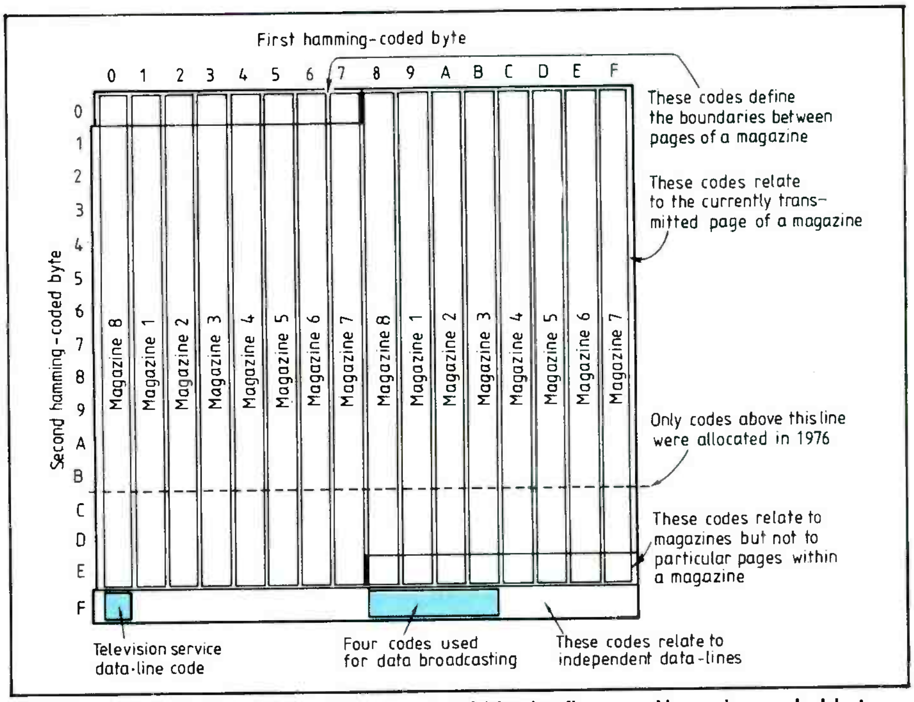

Fig.1. Allocation of the 256 codes available within the first two Hamming-coded bytes of a teletext data line.

This is the only safe way to allow for expansion; new data services using different clock rates, modulation systems or framing codes would always be liable to interfere with one another, particularly if decoders are not designed with knowledge of all the possible systems. Such problems may remain dormant for many years and then suddenly appear when particular combinations of data begin to be used. The only safe way to allow a teletext-like system, with an audience of millions, to develop safely is by reserving codes in the data channel and using them to introduce new services. Ideally these in turn still preserve the potential for further developments.

A transmission system, based on the use of data-lines which were independent of the normal teletext service, was defined and experimental broadcasts began on September 10th, 1985. The BBC Datacast service was announced on October 3rd, 1985 and the first equipment built specifically to originate these signals was installed at BBC Television Centre on March 10th, 1986.

INDEPENDENT DATA-LINES

Each data-line in the teletext format starts with a clock run-in sequence (CRI) and framing code (FC). The next two eight-bit bytes, known as the magazine and row address group (MRAG), are Hamming-coded and each carries four message bits. In the page-organized teletext application, these eight message bits are interpreted as a three-bit magazine number (in the range 1-8) and a five-bit row address (in the range 0-31).

The 1976 specification requires that data-lines with row addresses in the range 24-31 be ignored. Subsequently it was decided that row addresses 24 and 25 represent an extension to the page, intended to be stored with the page and included in its cyclic redundancy check. Row addresses 26,27 and 28 are used, possibily more than once in each page, to carry additional information to over-write characters or to provide special display attributes.

All of these row addresses are still associated only with the current page of their particular magazine. Row address 0 (the page header) is used to define the boundaries between successive pages of a magazine.

The data-lines of different magazines can be mixed in any way in the transmission sequence, as the decoder should see each magazine as a separate data channel. This independence is only broken by the use of the serial magazine transmission mode which allows all incoming page headers, regardless of magazine, to be presented as they arrive and so puts an obligation on the broadcaster to maintain a meaningful sequence when all the page headers are taken together.

Row address 29 is reserved for applications where information relating to an entire magazine is being sent. Only row addresses 30 and 31 remain for applications unrelated to the page and magazine structure of teletext. Taken together with their eight 'magazine numbers' these provide 16 MRAG combinations which can serve as the addresses of 16 independent data channels. These can be used in any way at any time regardless of the content of the teletext service without interfering with the normal operation of a conventional teletext decoder operating according to the specification.

One of these addresses is used for the television service data-line[3] and four others are currently being used with BBC Datacast transmissions, although other formats of signal can also be used here without interfering with Datacast.

It is possible to depict the above allocation of magazine numbers and row addresses on a diagram with eight columns and 32 rows. Unfortunately this leads to confusion when it is pointed out, for example, that magazine 8, row 30 does not belong to any magazine and neither is it row 30 of any page! An alternative diagram is given in Fig. 1, where the 256 possible MRAGS are presented in terms of the contents of their first and second byte. It will be seen that the 16 combinations corresponding to the independent data-lines are selected by the first byte, the second byte having the fixed message bits 1111. So a test of the second MRAG byte is sufficient to separate all the independent data-lines from those relating to a normal teletext service.

DATACAST PACKET STRUCTURE

The self-contained nature of the Datacast data-line within the teletext multiplex makes it appropriate to refer to it as a Datacast packet.

The Datacast packet format is organized in eight-bit bytes as shown in Fig. 2, which emphasizes how certain information in the early part of the packet influences the interpretation of the later part. Moreover, each packet stands alone and it can be interpreted

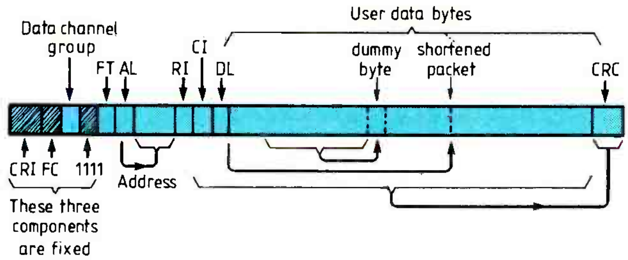

Fig.2. Structure of a Datacast packet

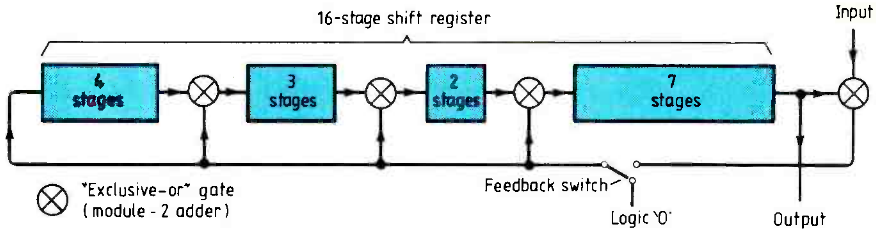

Fig.3. Generation and checking of cyclic redundancy check

without reference to others. Both these points, which are not generally true of page-organized teletext, simplify both the generation and the reception of Datacast services in applications where several teletext-based services are multiplexed together onto a single video signal. It will be seen that the overheads have largely been arranged so that they are only incurred when they serve a function.

The function of the bytes of a Datacast packet are now considered in sequence.

Data channel group. The first byte of the MRAG of a Datacast packet identifies four possibilities. These can be used to distinguish between Datacast services arising at independent sources, such as regional contributions. This makes it possible for the same addresses to be used by more than one source without contention, there is no need for overall control of address allocation.

The data channel group is analogous to the magazine number of conventional teletext; the same page numbers can be used in different magazines and they can be originated independently before combining onto a single video signal. Similarly, the data channel group number is a component of the complete information necessary uniquely to specify a Datacast service.

The second MRAG byte of a Datacast packet carries the Hamming-coded message bits 1111, indicating an independent data-line.

Format type byte (FT). This Hamming-coded byte controls the interpretation of later bytes of the packet. The four message bits, in transmission order, are:
– 0 if Datacast format applies,
– 1 if the RI byte is used later,
– 1 if the CI byte is used later,
– 1 if the DL byte is used later.

If the first of these bits is set to 1 then the meaning of the other three is not defined, neither is the meaning of any subsequent data in that data-line. This allows new formats for use with independent data-lines to be defined without requiring the use of other data channel groups.

Packet address length (AL). The first three message bits of this Hamming-coded byte indicate how many immediately following bytes are Hamming-coded and allocated to the packet address. The minimum is none, the maximum is six, giving a 24-bit address. The 111 state is reserved to extend the address capacity in a way not yet defined.

The last message bit is set to 0 when the access to, decoding and interpretation of this particular Datacast service is to be protected from interference by any other teletext-based services. This facility is provided in anticipation of some proposed uses where teletext and Datacast services may be used to control access to other services, including the option of turning off the decoders.

Packet address bytes. Up to six Hamming-coded address bytes, as signalled by the AL byte, follow the AL byte. The least significant bytes are sent first. The least significant bits within each byte are sent first.

Packet repeat indicator byte (RI). The RI byte is only present if signalled by the FT byte. Only then can the packet be repeated unchanged, noting that the RI byte itself does change.

The first four bits are set to 0 when a new packet is sent and this number is incremented modulo-16 on subsequent repeats of the identical packet. The next three bits are not yet defined. The last bit is set to 0 to indicate that no further repeats of that packet should be expected, but setting to 1 does not necessarily indicate that there will be a further repeat. This last bit is intended to assist certain decoder strategies.

Packet continuity indicator byte (CI). The CI byte is only present if signalled by the FT byte. It is an eight-bit number incremented modulo-256 with each new packet of the same data channel group, address length and address bytes. It does not change during repeated transmission of the same packet.

If a CI byte is not signalled, the eight-bit continuity indicator number is used to modify the CRC byte, so there is always a continuity indicator of one type or the other.

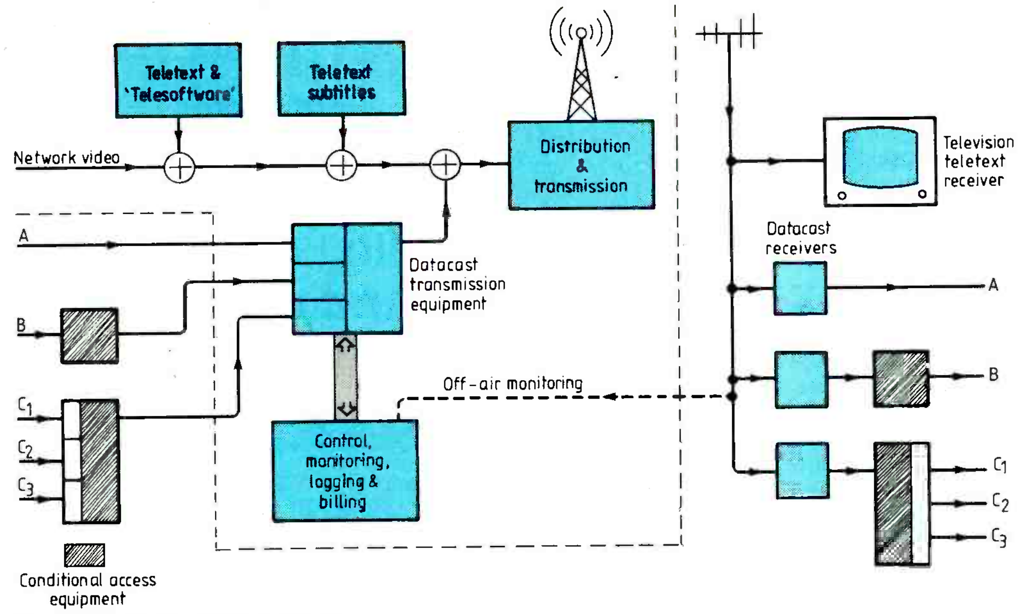

Fig.4. Typical Datacast transmission system

Data length byte (DL). The DL byte is only present if signalled by the FT byte. The first six bits are a binary number defining how many of the immediately following bytes (including dummy bytes) constitute data for delivery to the user. The last two bits are not yet defined.

The DL byte is used when it is necessary to send an incompletely filled packet in order not to delay the transmission of data. Any remaining bytes before the cyclic redundancy check are not defined but are still subject to the CRC. A DL byte may be set to 0000 00XX (in transmission order) to keep a data service open without sending data for delivery.

User data byte group. The remaining bytes in the packet, excepting the last two, and further limited by the DL byte when present, and excluding any dummy bytes, constitute the data carried for the users of that packet. There are generally between 28 and 36 user data bytes in a Datacast packet. There is no restriction on the coding of the user data bytes.

Byte transparency. Although there is no restriction on the coding of the user data bytes, it is, at present, necessary to eliminate long strings of 0s and 1s from the transmitted data to ensure that it is regenerated and decoded reliably. If within any user data byte group, taken together with any CI and DL bytes, a sequence of eight consecutive 0000 0000 bytes or a sequence of eight consecutive 1111 1111 bytes occurs the broadcaster will (except where there is no remaining byte in the user data byte group) insert a following dummy byte which forms part of the CRC but which is otherwise ignored by the decoder. The use of dummy bytes reduces the length of the user data byte group, but only in applications where complete bit-sequence independence is required in the user data. When the data is enciphered it is, in general, very unlikely that such sequences will occur.

The function described above may later be not required. It is therefore recommended that decoders be equipped with a simple method of disabling it at a later date.

Cyclic redundancy check (CRC). The last two bytes of the Datacast packet are a 16-bit cyclic redundancy check on any CI and DL bytes and all bytes of the user data group, including dummy bytes. The data to be checked, with bits in transmission order is, in effect, applied to the circuit shown in Fig. 3, the register having previously been filled with 0s. The gates are modulo-2 adders ("exclusive-or"). When the feedback path is disabled the basic 16-bit CRC in transmission bit-order is produced at the output.

It will be apparent that if the basic CRC is appended to the input data, the process will compare the calculated CRC with the incoming CRC and fill the register with 16 0s. This indicates how real-time hardware can be used to check the CRC, although it is currently more usual to conduct the operation in software.

When the CI bit is set, and an explicit continuity indicator is sent, the basic CRC is sent. When the CI bit is not set, the eight-bit continuity indicator is sent by modifying the basic CRC. This modification is done at the sending end in such a way that the above comparison results in the register containing the eight-bit continuity indicator repeated twice, with the least significant bit at the right-hand end of the bytes in the register. A decoder can then extract the continuity indicator from the CRC and use a 'flywheel' technique to allow it to interpret the CRC correctly during occasional errors or even during packet loss.

This use of a 16-bit CRC in every Datacast packet assures, with high confidence, that any errors will be detected. The decoder will be able to indicate whether data is right, suspect or absent. The extent of the suspect or absent data can be indicated and, where packets are repeated, there is the possibility of recovering some of it.

Over a year of practical experience with Datacast transmissions shows that under normal conditions fewer than one received packet per million fails the CRC check. No corrupted packet has yet been seen to pass the CRC check.

DATACAST ORIGINATION EQUIPMENT

Datacast can be added to a video signal at a different point to teletext without any flow of information between the two although, of course, the same television line numbers in any one field-blanking interval cannot be used! Because there is sometimes a necessary redundancy in the normal teletext output it would be more efficient to combine the two in a device that recognizes this redundancy, but this makes the operation considerably more complex.

Figure 4 shows a block diagram of a typical early use of Datacast, indicating the broadcaster's area of responsibility. The Datacast transmission equipment is a single unit per network, with reserve available. The reserve can be selected in such a way that data in course of transmission is not lost. The unit accepts inputs from six sources, usually via modems over leased lines. Source B is shown with conditional access equipment (encipherment, key distribution and decoder addressing) used before the signal is sent to the broadcaster and after it has been received. Source C comprises three sub-services, each with conditional access, which are combined before sending to the broadcaster along a single line. These sub-services may have different addresses or they may contain a sub-addressing facility within the data carried by a service using a single address.

The transmission equipment includes a unit for monitoring the input data: in particular it counts the number of user bytes and packets being sent against time of day together with measures of peak bit rate and delay through the system. Off-air reception can also usefully be analysed. This information is, of course, the raw material used in charging the users of the service.

DATACAST RECEPTION

Because the data transport mechanism is that of teletext, many of the existing teletext chips can be used directly or adapted for

Datacast reception. The BBC Design and Equipment Department has produced a design which is being licensed to manufacturers.

Much of the development work on Datacast in the BBC has been done using the BBC microcomputer together with its teletext adapter as the receiving device.

DATA SECURITY

Although it is possible to imagine freely available services being broadcast by Datacast, the majority of the applications are likely to be of a commercial nature where it will be necessary to prevent a casual user from understanding the message.

There are already techniques available for enciphering data over a one-way telecommunications link and any of these may be used on a Datacast channel. Methods of embedding individual codes within decoders in such a way that they can be uniquely addressed, enabled and disabled have been developed for direct broadcasting by satellite and adapted for Datacast applications[3].

BBC Research Department has developed particular designs of equipment for Datacast security. One provides data scrambling with modest security without needing any extra data signalling capacity. The other offers greater security and allows control of individual decoders and the possibility of crediting charge units and then debiting them on a pay-per-item basis.

TARIFF POLICY

With such a unique resource it is important to exploit it in the best possible way as a public service. It would be very easy to sell the bulk of the capacity to a few users who could afford to pay for using the system inefficiently and thereby deny access to many small users whose modest needs cannot be met in any other way. The specification has been designed to support an almost unlimited number of individually addressable services and it is hoped that means will be provided for handling such uses without undue technical and administrative overheads.

Acknowledgement
The author wishes to thank the Director of Engineering of the British Broadcasting Corporation for permission to offer this contribution.

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Further information about BBC Datacast can be obtained from:
Head of Data Broadcasting,
BBC Enterprises Ltd.,
80 Wood Lane,
LONDON W12 0TT
telephone 01-576 0563

Repair risks

Electrical and electronic dealers have been expressing concern at some of the proposals contained in the White Paper (Cmnd 9712) "Intellectual Property Rights and Innovations" with a Bill promised for the next session of Parliament. These include far-reaching reform of the copyright law including the legalisation of the use of home video and audio recorders (but with a 10 per cent levy on blank audio tape), extending copyright to cover transmissions from distribution satellites etc. But the point that is worrying the trade concerns the special pattern parts found in many appliances and equipments. In other words any components or fittings specially or fittings specially designed for a particular model.

It has long been common practice when repairing appliances to buy spares from firms other than the original manufacturer. This has been regarded virtually as standard practice not to be confused with deliberate counterfeiting or "passing off" doubtful equipment as coming from well-known brand names.

But if the White Paper proposals become law, they give the original maker and automatic monopoly on all special pattern parts for five years from the date of manufacture and a right to demand a royalty for another five years.

What most worries the trade is that the proposals include a right to search premises and seize goods allegedly in breach of contract, together with the possibility of imposing unlimited fines and/or up to two years' imprisonment on conviction. What may come to worry consumers is that it seems to leave the way clear to manufacturers to charge even more exorbitantly than at present for their pattern spares and so bring near the era of throw-away electronics as repairs become increasingly uneconomic.

Some American commentators believe that their own electronics industry will soon be facing a crisis on the quality of after-sales service they offer. As W.H. Davidow, author of "Marketing High Technology" puts it: "Quality of service is about to become the decisive factor in corporate survival. The cost of technical service on high-tech products now runs an estimated one per cent per month. That's nearly one-half the price of the product in just four years and that doesn't count the cost of down time in lost productivity." Actually his figure seems low in comparison with often quoted estimates of maintaining military communications equipment. Over an operational lifetime this can amount to anything up to ten times the initial cost. But in many fields the reputation of firms, whether they realize it or not, depends on their ability to rectify faults quickly and at reasonable costs.

Mobile safety

A few months ago one began to hear strong rumours that the Department of Transport, which forms part of the enormous Department of the Environment, was planning to introduce into a revised Highway Code a new recommendation aimed at drivers using hand-held microphones and telephone handsets while driving.

It has recently been confirmed that the draft revision of the Highway Code, currently before Parliament, has a new "Rule 49a – Do not use a hand-held microphone or telephone handset while your vehicle is moving, except in an emergency. You should only speak into a fixed, neckslung or clipped-on microphone when it would not distract your attention from the road. Do not stop on the hard shoulder of a motorway to answer or make a call, however urgent."

This new Rule will, if approved, clearly have a major (one is tempted to say devastating) effect on the current practices of the vast majority of cellular radio users and also most other users of mobile two-way mobile radio, including c.b. operators and many radio amateurs. Although the RSGB has for many years recommended amateur radio driver/operators not to use hand microphones or double headphones, the majority of mobile transceivers are sold with hand microphones.

The Highway Code, issued under the Road Traffic Act, sets out rules for safety on the road. The Secretary of State is empowered to revise the code from time to time in such a manner as he thinks fit, subject to the approval of Parliament. Failure to observe a provision of the code does not, of itself, render a person liable to criminal proceedings but a failure to observe it may be used in either criminal or civil proceedings to establish liability.

The possible driving hazards represented by use of the relatively large and bulky handsets currently provided for virtually all models of cellular and many other radiophones has been noted before the "Communications Commentary", as has the curious anomally that a driver seen using an electric razor while driving is liable to prosecution, but the basically similar act of using a hand-held microphone does not constitute an offence. On the other hand it has been pointed out that one-arm drivers are permitted and that the smaller hand-held microphones with coiled leads can be safely dropped when both hands are needed.

Whichever way your sympathies fall, there is little doubt that the revised Highway Code could present a major problem to the mobile radio industry.

Cutting sky-waves

In the medium-waveband, it is well recognised that the service area of broadcast stations tends to decrease dramatically between the approach of dusk until some time after dawn when the D-layer regains its capacity to absorb signals. Service areas, these days, are almost invariably limited by interference rather than signal strength. Apart from the few very high-power stations used for external broadcasting or which attempt to provide national coverage by blasting their way through co-channel interference, the absence of an effective D-layer after dark and the consquent reflection of the skywave signals is regarded as a hindrance rather than a help. What most a.m. broadcasters would like is an antenna that would radiate maximum vertically polarized ground-wave signals, minimum-possible skywave signal.

The conventional mast-radiator unfortunately radiates only about 15 per cent of its energy along the ground, nearly 85 per cent is radiated above the horizon, representing lost power in daylight and unwanted interference to listeners hundreds of miles away at night.

The American National Association of Broadcasters, urged on by their medium-wave broadcasters who have been steadily losing audiences to their f.m. rivals and also by the FCC which would like to see a revival of interest in medium-wave broadcasting which will soon extend in Region 2 up to 1705 kHz instead of 1605 kHz, is now planning a trial of two new experimental antenna systems designed to put more power along the ground, less towards the sky.

Experimental antennas are expected to be field tested in Lees-

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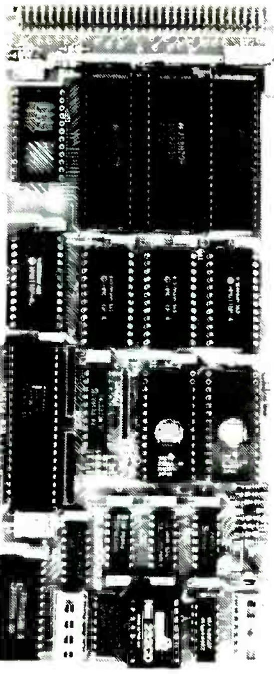

Based on the Intel 8052AH single component Microcontroller the CPU comes complete with a unique implementation of the BASIC language enabling direct access to the special function registers, timers and interrupts available on the 8051 device.

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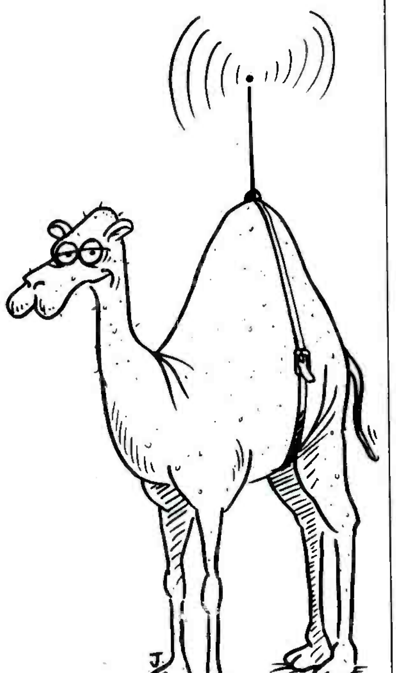
burg, Virginia and Beltsville, Maryland. At Leesburg, a design by Richard Biby will have a series of short vertical radiators placed around the base of a conventional monopole antenna. The theory is that with correct phase and amplitude distribution the short elements will increase groundwave radiation while cancelling out much of the skywave.

The Beltsville installation, based on a design by Ogden Prestholdt, will use a combination of vertical, horizontal and diagonal elements to accomplish a similar radiation pattern.

Provided that FCC and FAA approve the trials, it is expected the new antennas will take a year to build, followed by a year of field trials. There has been surprisingly little fundamental work on medium-wave antenna design since the classic work on directional antennas by Dr George Brown of RCA in the 1930s.



Camel mobiles

It always comes as a surprise to learn that Australia has the largest number of wild camels in the world, the result of bringing in camels from the Middle East in the nineteenth century to provide transport in the dry interior regions of that vast country. Today, numbers of feral camels roam wild in several regions of Australia with even a flourishing business in exporting the sturdy Australian camels to the Middle East for racing and breeding.

According to *Electronics Australia* a current study of the feral camels being undertaken by Sydney University's School of Biological Studies is using American-made radio-tracking collars. These carry both a small v.h.f. transmitter which can be tracked directly over distances of 20-25 km and a one-watt transmitter that is received on low-orbiting weather satellites. The data is recovered and processed in France, from where it can be communicated and displayed on the screen of a personal computer in Sydney.

Similar tracking collars have previously been used to track polar bear and caribou in the Arctic, but are regarded as too heavy for that other Australian bilogical curiosity, the kangaroo. But is also raises the question of whether satellite tracking, as well the established v.h.f. tracking "bugs", is becoming a practical possibility for long-range, secret surveillance of suspect motor vehicles or vessels suspected of being engaged in the international smuggling of drugs.

Using 10.1 MHz

The ITU World Administration Radio Conference of 1979, among its many recommendations affecting amateur radio, formally allocated 10,100 to 10,150 kHz to the amateur service on a secondary basis, with the fixed (point-to-point) service remaining the primary user. Although most frequency changes above 10 MHz were subject to a "transfer" period of five years from July 1, 1984 (below 10 MHz the transfer period is ten years) for changes not involving transfers, the operative date for the new regulations was January 1, 1982.

The Home Office, then in charge of the Radio Regulatory Division, was one of the first national administrations to confirm that amateurs were free to operate in this narrow segment from January 1982. Because the band was so narrow and amateurs were only the secondary users on a non-interference basis, the RSGB and later the IARU recommended that operation should be confined to the narrow band modes of c.w. and r.t.t.y. This recommendation, which is non-mandatory, has been the subject of considerable controversy in the UK, Australia, South Africa, although it is evident that most of the relatively small number of British amateurs currently operating on the band are in favour. Almost everyone agrees that the amount of operation on the band is at a level far below the crowded 7 and 14 MHz assignments, even though radio propagation characteristics of 10 MHz are well suited to the present sunspot-minimum period.

Reasons for the low activity include the fact that transceivers and transmitters of the 1970's or before made no provision for either reception or transmission on this band; that many popular transmitting antennas are not suitable for 10 MHz; that the majority of h.f. operators prefer s.s.b. to c.w., yet have no wish to flout the RSGB/IARU recommendations; and that the number, strength and modes of the many high-powered fixed stations (by no means all of them registered with the International Frequency Registration Board) active for many hours each deay reduce the usable frequencies to just a few narrow gaps for most of the time.

Recently, after an interval of three years, I have been spending some time on this band using a c.w. transmitter with the relatively low output power of 15 to 20 watts in the form of a home-built v.f.o., a paramilitary "Mark 123" valve transmitter of the 1955 to 1970s era and a random length long-wire antenna passing through the roof space to a tree in the garden.

Despite the low power and low activity it has proved surprisingly easy to contact stations in most European countries (Russian amateurs are apparently not yet permitted to use the band) although the skip distance, even at noon, is seldom much below 500 miles. Low-power signals near the m.u.f. tend to build-up or fade-out very rapidly as the boundary of the dead zone fluctuates. When conditions are favourable, long-distance transmissions come through well.

But there remain long periods when few, if any, amateur signals can be heard. For much of the time the high-power commercial stations occupy about 40 of the available 50 kilohertz. With some exceptions the amateur operation is largely confined to frequencies below RMP, a Soviet Navy coast station in Kaliningrad on 10,118 kHz. This uses c.w., but most of the others send streams of multiplexed r.t.t.y. or facsimile signals that spread over several kilohertz. Band-sharing between low-power and high-power services seems more successful on the 3.5 MHz band where the gaps are (usually) wider.

In brief

The first Japanese amateur radio satellite, JAS-1, now renamed "Fuji" was launched successfully on August 12 on a Japanese H-1 launch vehicle along with two other satellites.

The 1987 RSGB National Amateur Radio Convention is to be held at the National Exhibition Centre near Birmingham on March 28 and 29.

EMC problems

The increasing concern with electromagnetic compatibility e.m.c. which now affects virtually all forms of communciations and electronic equipment practice is well illustrated in the range of the papers due to be presented at the IERE conference at York before these notes appear. The term e.m.c. is taken to cover such diverse topics as the potential biological and ignitition hazards of non-ionized electromagnetic radiation; compatibility between v.h.f./f.m. broadcasting and the aeronautical service in the adjacent band of 108 to about 118 MHz; problems of harmonic radiation from microwave ovens (something that may well prove a major problem when 12 GHz DBS begins); interference arising from the intermodulation products at multiple-transmitter sites, etc.

One of the first services to experience serious e.m.c. problems was the amateur radio service which began to encounter tv-interference situations as soon as Alexandra Palace opened its 405-line tv service exactly 50 years ago on November 2, 1936. Then it was found that the third-harmonic from 14 MHz transmitters would need much more attentuation by shielding and filtering than had even previously been found necessary.

Techniques to overcome interference to v.h.f. television were however successfully developed well before the change to u.h.f. tv brought at least temporary relief from the relatively few remaining cases of interference to valve-type receivers. Unfortunately the widespread introduction of solid-state devices (particularly r.f.-susceptible c.m.o.s) into so many domestic appliances, combines with the phasing out last year of the free assistance to viewers and listeners previously given by the DTI's Radio Investigation Service, has

ELECTRONICS & WIRELESS WORLD

Editorial Feature List

DECEMBER

Enclosures

There is a vast range of boxes, racks and enclosures of all kinds in which designers can house their equipment.

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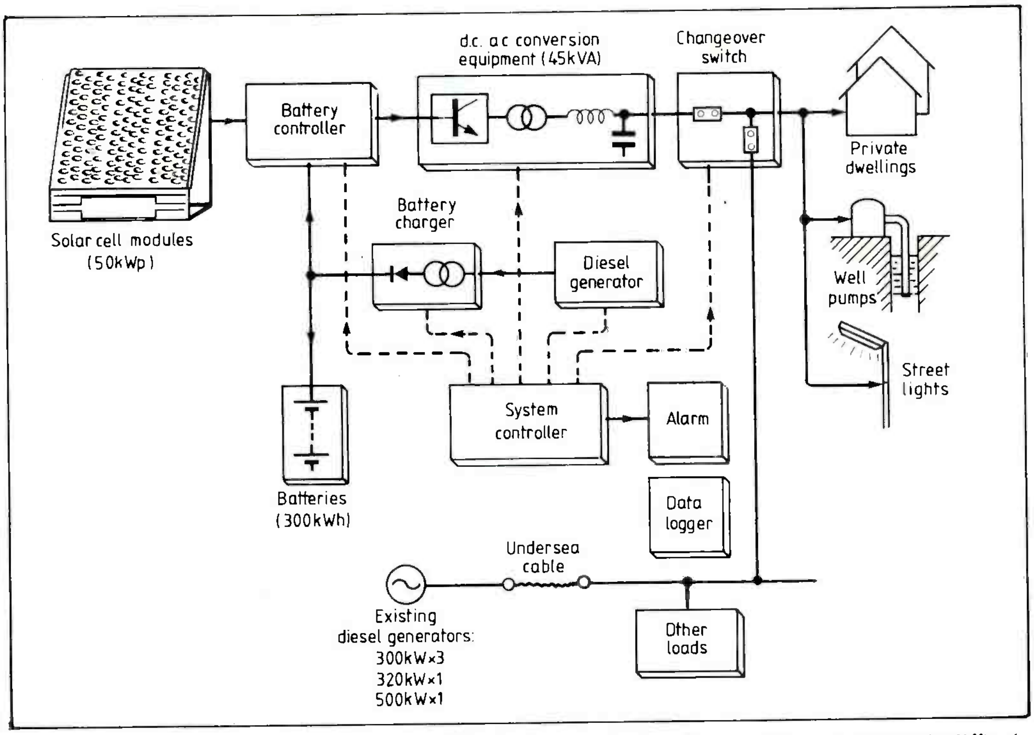
put e.m.c. back as a major concern to UK amateurs. This has been raised still further by the DTI threat to introduce variations to the licence in respect of power and frequency bands in really difficult cases.

The RSGB has announced a "11-point plan of action" to combat e.m.c. problems, though one cannot help feeling that several of the proposals including the establishment of a formal "code of practice" and changes to the syllabus of the Radio Amateurs' Examination could well cause controversy. The society also has the ambitious plans of establishing a database listing case histories for all known radio and television receiver models. It is also going to have a job to convince some of its more prickly members that very few amateurs can expect to be lucky enough to be able to run 400 watts (p.e.p.) into a high-gain 144 MHz antenna located just a few feet away from the neighbour's tv antenna without causing some interference.



Solar power growing

Five or six years ago interest began to grow in Europe, the USA and Japan on the use of solar power or, alternatively, hybrid wind/sun generators as natural energy sources for such applications as terrestrial broadcasting and communications. It has always been more difficult and more costly to generate electricity than to convert an existing supply into r.f. power.

Following experiments by the French broadcasters, both the IBA and BBC mounted pilot experiments, with UK weather conditions favouring the hybrid wind/sun systems. For a couple of years the IBA kept a small four-channel television relay station at Bossiney, on the north coast of Cornwall and serving about 300 viewers, on the air in this way. It was hoped that such a system might prove economically attractive at sites remote from the public supply main, although in practice the Bossiney site was connected to the public supply.

Although the system provided the amount of power it was designed to give and with the aid of large storage batteries was able to keep the station running successfully, it was found that the system required a considerable maintenance effort compared with a normal mains-powered relay; this was particularly the case with a mechanical wind-generator while the large bank of storage batteries also needed considerable attention.

Work on medium-power photovoltaic generators, however, continues elsewhere intended primarily for remote areas enjoying more and stronger sunshine that the UK. Under a Japanese government-funded "Sunshine Project" considerable efforts have been made for several years to increase practical utilization of solar energy for electric power generation by developing lower-cost, higher-efficiency solar cell modules.

One such project has involved the use of a large array of solar modules, capable of about 50 kW peak output, to provide an electric power supply for the small island of Zamami in the Ryuku Islands. Since October 1985 an prototype system developed by Mitsubishi Electric has been supplying power to 14 private dwellings, well pumps and other loads. Normally the many small and remote Japanese islands use small- or medium-power diesel generators with the disadvantages of substantial initial and running costs, comparatively heavy maintenance and often uncertain transport and deliveries.

In the prototype system, solar cell modules are used to charge a bank of 136 tubular-type lead-acid batteries with a total storage capacity of 305 kWh and able to provide roughly one day's reserve of power. An existing diesel generator is available as a back up. A 45 kVA d.c./a.c. solid-state conversion equipment is self-commutated and of the pulse-width modulated type. The system is designed for automatic, unattended operation.

A parallel d.c. connection with the diesel generator reduces the time during which the diesel runs when the reserve battery power falls. With a parallel a.c. connection the diesel, once tripped on due to extended overcast or rainy weather conditions, would run until the battery is fully charged.

Monocrystalline silicon solar-cell modules each have a nominal output of 52 watts peak (22.4V, 2.32A d.c.) under standard conditions (1 kW/m^2, 28°C, 1.5 air mass). The modules are series-connected in groups of 15, with 65 such circuits in parallel.

A description of the system in the Mitsubishi Electric journal "*Advance*" (June 1986) suggests that the operational prototype will lead to systems providing greater supply stability, lower energy consumption and improved resistance to and greater safety under the environmental extremes found in these islands.

Midnight hi-jack

In April this year, a written message appeared for about ten minutes on the American "Home Box Office" satellite-distributed cable tv channel: "Good evening HBO from Captain Midnight. $12.95 a month? No way! Showtime/Movie Channel beware." Viewers had little difficulty in identifying this message as a protest at the introduction of encryption on the premium HBO film channel coupled with the increase in fees.

Until encryption, it had been estimated that about 1.5-million viewers using their own C-band (4 GHz) satellite receiving terminals were watching HBO free. The encryption of HBO and subsequently some of the other premium film channels decimated, at least temporarily, the sales of large-dish home satellite receivers. The USA has had no Ku-band (11 GHz) DBS since 1984.

The intrusion of Captain Midnight's message into the Galaxy 1 distribution satellite transponder sparked off deep and widespread concern among the cable programme providers and the users of satellites for private or business communications. Was it possible that anyone equipped with a dish and a medium or high-power microwave transmitter could play havoc with a satellite with little fear of being caught?

However, this has proved to be a challenge to which the FCC, working with field agents of the Federal Bureau of Investigation, has proved equal. On July 22, it was formally announced that "Captain Midnight" had been identified as a John MacDougall of Oscala, Florida. He had used for the purpose not a private up-link but the facility of the Central Florida Teleport where he "moonlights" as a technician.

PAT HAWKER, G3VA

ELECTRONICS & WIRELESS WORLD

Editorial Feature List

JANUARY 1987

Printed-Circuit board connectors. We look at the morass of types that are used to connect printed circuits to backplanes, to each other, to flat cables and to the outside world.

FEBRUARY 1987

Instrument read-outs. Numerical displays are now used on the humblest of equipments. This feature examines the characteristics of liquid-crystals, fluorescent, plasma and other types and lists those available.

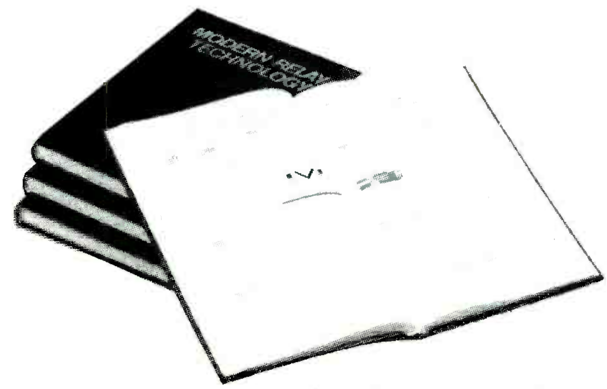
MARCH 1987

Production soldering and re-working equipment, with reference to the techniques used in the surface mounting of components. We include all types from the ordinary soldering iron to flow-soldering machines.

APRIL 1987

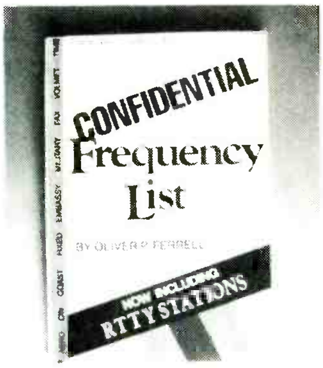
Spectrum analysers. Advances in the application of microprocessors to these instruments have opened up a wider area of use. Those on the UK market are listed and new techniques examined.

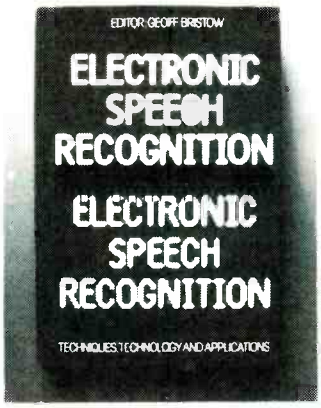
For further advertising details please ring Ashley Wallis on: 661 8641



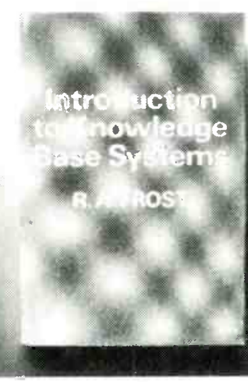
Modern Relay Technology, ed. Hans Sauer, 2nd edition, SDS-Relais Ltd (17 Potters Lane, Kiln Farm, Milton Keynes MK11 3HF), 357 pages, hard covers, single copies free of charge to engineers and students. Encyclopaedic handbook of relay know-how, from A for Absolute Dielectric Constant to Y for Yoke. No sign of a commercial message, not even in the tables of relays on the market, to which other manufacturers have generously been invited to contribute. There is an interesting applications section with many detailed examples and a glossary of 665 technical terms and phrases with their equivalents in French, German and Italian. Would *you* have known that "organe de commande d'excitation" translates as "processing unit"?

Confidential Frequency List, by Oliver P. Ferrell, 6th edition. Duckworth (Gilfer Associates Inc.), 336 pages, soft covers, £12.95. Frequency-by-frequency directory of the h.f. spectrum from 4MHz to 28MHz, excluding only the broadcast bands, compiled from ITU lists and from observations by monitors in both the US and Europe. Entries, a proportion of them inevitably incomplete, include news agencies, weather stations, naval, air-traffic control, diplomatic, and of course spook stuff. There is much to intrigue the curious: how about President Reagan's frequency, 13.440MHz l.s.b., used by Air Force One in flight? An introductory section surveys radio-teleprinter codes, including Cyrillic, and lists commercial Z-code abbreviations.



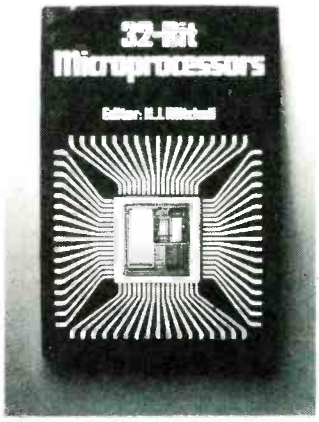


Electronic Speech Recognition, ed. George Bristow (of STC Network Systems). Collins, 395 pages, hard covers, £30. Techniques, technology and applications described by 20 authors from industry and the academic world.

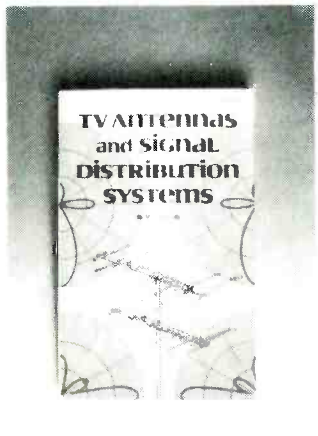


Introduction to Knowledge Base Systems, by R.A. Frost (University of Glasgow). Collins, 698 pages, soft covers, £18. Textbook of AI theory and practice for computing science students at graduate or final-year undergraduate level.

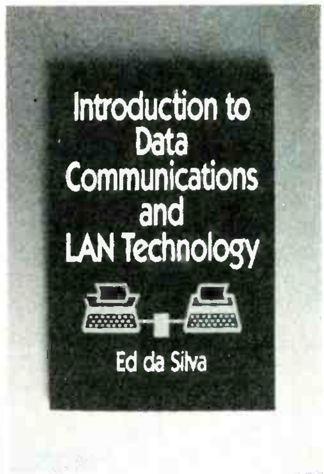
32-bit Microprocessors, ed. L.J. Mitchell (CAP Scientific Ltd). Collins, 248 pages, hard covers, £25. Details of current and future devices, including the 68020, Z8000, 80386, the Inmos Transputer, AT&T's WE32100; plus an examination of RISC architectures.



TV Antennas and Signal Distribution System, by M.J. Salvati. Pitman Publishing (Howard W. Sams & Co.), 256 pages, soft covers, £10.95. Survey of broadcast receiving techniques for v.h.f. and u.h.f. Unfortunately much of the information relates to products available only in the US and to American installation practice. However, some of the more exotic antenna designs have yet to cross the Atlantic, and these could be of interest to aerial experts over here.

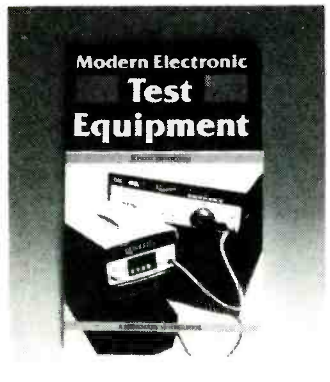


Radio and Television Servicing, 1985-86 Models, ed. R.N. Wainwright. Macdonald, 795 pages, hard covers, £25. Circuits and abridged servicing information for various UK models by British and foreign manufacturers. Radio section includes clock radios, cassette recorders, car audio and personal stereo sets.



Introduction to Data Communications and LAN Technology, by Ed da Silva (of the Open University). Collins, 159 pages, soft covers, £14.95. How the various interfaces and protocols work, and some practical case studies. Clear explanations and helpful diagrams.

Working with Microprocessors, by Ian Sinclair. Collins, 142 pages, hard covers, £25. Hardware aspects of microprocessors and other programmable chips, aimed especially at designers more accustomed to analogue circuits. A case study deals with the Chameleon controller developed by the Electronics Centre of Essex University.



Modern Electronic Test Equipment, by Keith Brindley. Heinemann Newnes, 134 pages, soft covers, £6.95. What's on the market, what it can do and how it works: guide for students and others to the main categories of modern test gear, including meters both analogue and digital, oscilloscopes, counters, signal generators, spectrum analysers and a.t.e. Illustrated with many diagrams and product shots.

NEW OR USED?

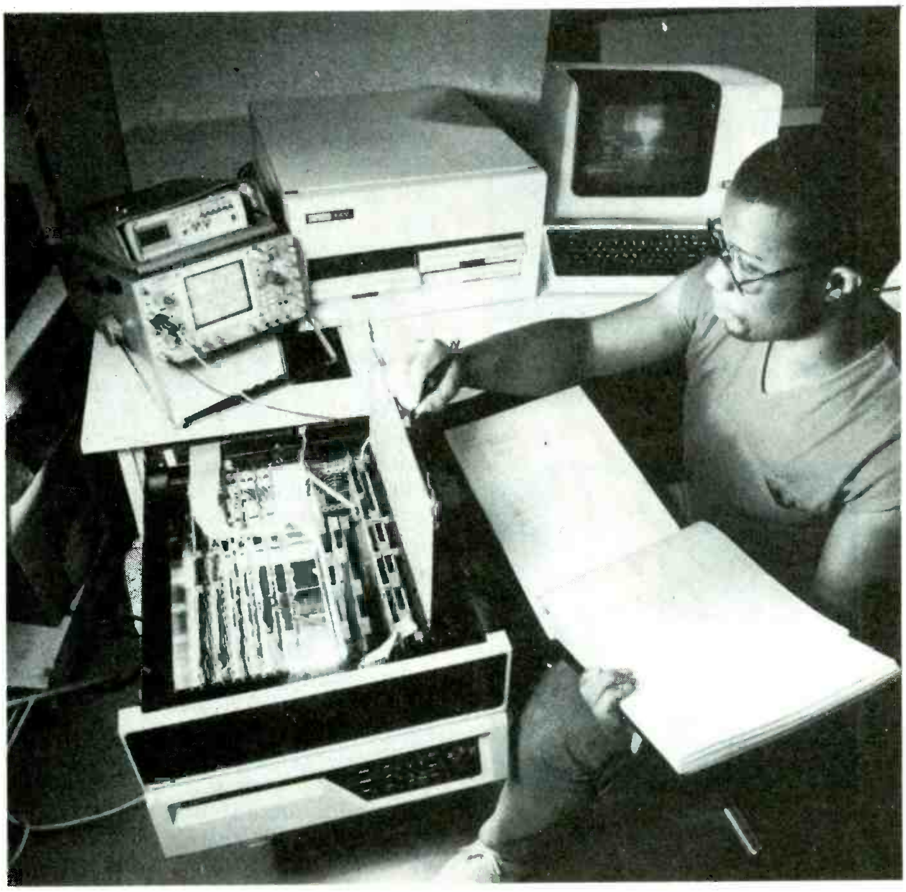
Large companies often choose to buy second-user test equipment, which has been serviced and re-calibrated, in preference to new instruments. Cost saving is not the only reason

PETER FRAIMAN AND DAVID PRICE

In 1985, the total world market for test and measurement products was estimated at \$5000 million, of which 55% was accounted for by the US market. In recent years, the US share of the test and measurement market has been gradually decreasing due to faster growth in both Japan and Europe. It has been estimated that the European proportion of the market now represents about £750 million and the UK alone accounts for £270 million. Excluding sales to the British defence market and indirect sales for export, the British market for test and measurement products (defined as equipment such as oscilloscopes, signal sources, and digital voltmeters that is sold to UK companies) is currently estimated at £40 million per annum.

Hence, assuming this figure of £40m per annum to be, at worst, static over the last seven years, there is at least £300 million worth of test equipment being used by British industry at the present time. It is a moot point how much of this equipment is gathering dust on the shelf, either because it was purchased to fit the specification of a particular project, or because the service manager finds that he now needs more sophisticated and accurate instruments.

Estimates show that 15% of this total pool of £300 million worth of test and measurement equipment is updated annually. The trend is nowadays for test equipment manufacturers to bring out new models more often – mainly because of the increasing speed of technological innovation. British industry is now beginning to replace its older test and measurement equipment much earlier in its life cycle. When Electronic Brokers started business over 19 years ago in the second-user market, it was not unusual to find that companies were using equipment which was in some cases 20 years old and they were fully prepared to buy more of the same. This trend is slowly changing: nowadays manufacturers replace test and measurement equipment when it is 7-10 years old and, for the future, a replacement period of 3-7 years is expected.



A DEC VAX computer undergoing refurbishment at Electronic Brokers' headquarters.

SECOND-USER MARKET

The buying and selling of second-user equipment has been an established part of the test and measurement market for some time. Without doubt, the second-user market is here to stay. Second-user suppliers acquire and re-sell mainly high-end professional products, many of which, because of the trend described above, are only a couple of years old.

An important feature of second-user suppliers is that they deal in 'blue-chip' products, such as are manufactured by Tektronix, Marconi Instruments, Hewlett Packard and Philips. Interestingly enough, the customers for second-user equipment are also to be found at the 'blue-chip' end of the industry.

Another major feature of second-user suppliers – and one that distinguishes them from the traditional second-hand stockist – is that the former do considerably more than just buy and sell equipment. Once acquired, a piece of equipment undergoes a complete electrical and mechanical refurbishment and is then fully re-calibrated to the original specification laid down by the manufacturer. Reputable second-user suppliers will also offer a full 12-month warranty, as effective as if it had come from the original manufacturer, and continuing after-sales support and service even well outside the warranty period. Before a sale is made they will be able to offer impartial advice on equipment types and, where practicable, will even advise on applications.

ADVANTAGES OF BUYING SECOND-USER PRODUCTS

Several advantages accrue from buying test and measurement equipment from a second-user supplier. Cost is an obvious advantage. Buying second-user equipment from a reputable supplier gives the user guaranteed 'as-new' equipment at a fraction

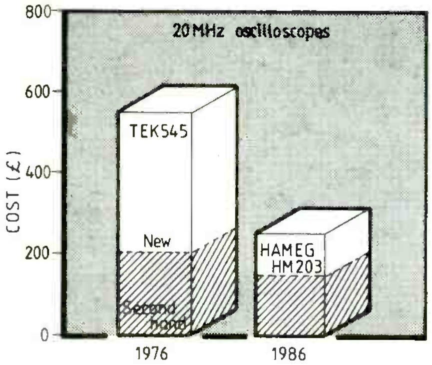


Fig.1. Price comparison: 20MHz oscilloscopes

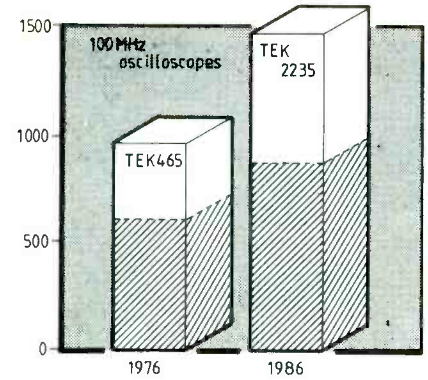


Fig.2. Price comparison: 100MHz oscilloscopes

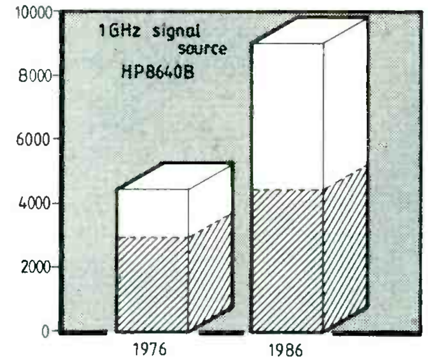


Fig.3. Price comparison: 1GHz signal sources

of the cost of the manufacturer's list price.

Let us examine the question of costs in more detail, and, with particular reference to oscilloscopes, which are one of the most important measuring tools for any engineer. They account for by far the largest proportion of any capital expenditure on test and measuring instruments, not necessarily by value, but in terms of number of units.

PRICE PERFORMANCE

The last 10 years has seen an unprecedented change in the design and cost effectiveness of the lower bandwith oscilloscopes.

As a typical example, in 1976, the Tektronix 545 had a second-hand value of £275. If we look at the price of the equivalent model, bought new, for example the Hameg HM203, we find that the price is only £270.

This relationship is shown diagrammatically in Fig. 1. As can be seen, in 1976, there was a tremendous saving to be made by purchasing second-user. By contrast in 1986, a saving of only £50 on the new price of £270 could be realistically expected, not a real incentive to pursue the second-user route.

If we now turn to the higher bandwith oscilloscopes (Fig. 2), it can be seen that the classic example of early 100MHz oscilloscope technology, the Tektronix 465, had a second-user price of around 60% of the retail price and in 1986, the modern equivalent, the Tektronix 2235 has a retail value of £1430 and a second-user value of approximately 65% of this value.

From this it can be seen that the higher bandwidth models are of comparatively similar prices and enjoy a similar saving if bought on the second-user market.

The indicator here, then, is that the higher the technology, the higher the price and therefore the greater the savings can be.

Extrapolating this relationship upwards to, for example, high-frequency signal sources and spectrum analysers, we find that it does indeed hold true.

If we take as a specific example, the Hewlett Packard 8640B option 002 1GHz signal source, the story is plainly clear as shown in Fig. 3. In 1976, a cost saving of one-third could be realised in purchasing second-user; while in today's market, savings of 50% are quite common.

The reason for this can be traced to the fact that technology has not moved as fast as in the oscilloscope market, but also because the same instrument is still being produced 10 years later: obviously there are some older models available at greater savings than would otherwise be possible.

Consequently, it would seem a fair assumption to make that in the lower, cheaper end of the test equipment market, because of the advent of newer, better but cheaper models, it seems wisest to choose the new machine; however, in the higher technology part of the market, large savings on capital investment can be realised in the wise choice of good, high-quality second-user instruments.

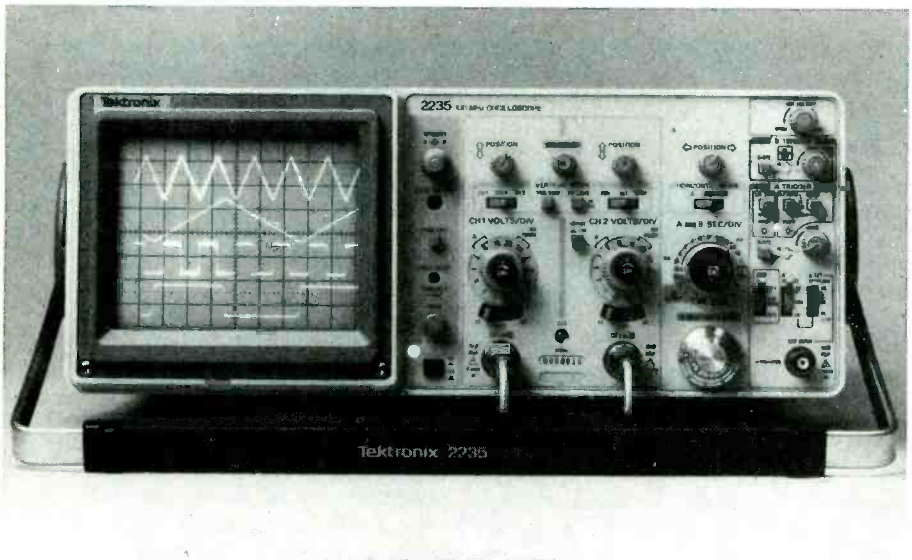
Cost is not the only consideration in buying second-user test equipment. A purchaser may want an instrument that is no longer in a manufacturer's current catalogue but nevertheless is still in perfectly sound working order. Instrument manufacturers are always under a great deal of pressure to adopt the latest technology in new products – a trend which is on the increase, as discussed above. Because of this pressure, it is harder for the manufacturers to service the demand for older products even though, in many instances, there is a very real need for them.

A further advantage from buying second-user test and measurement equipment is that the supplier will often be able to supply equipment which, because of the required delivery date, could not be supplied by the manufacturer.

How, then, is the potential user to establish whether his requirements can be met by buying from a second-user supplier? The obvious answer is "Ask". Suppliers continually receive inquiries about availability, often for particular models of instruments fitted with specific options. General inquiries are also very common – "How can I measure this?". Reputable second-user suppliers should be able to cope with all types of questions and are often in a very good position to give an unbiased answer, because the very nature of his business relies on a good network of contacts among sellers and buyers of used equipment. Ideally, the second-user supplier will maintain a computerized database of possible sources of equipment and individual users' requirements, thereby enabling a speedy response to an inquiry.

The second-user market is today a well-established sector of the electronics and computing industries. As has been discussed, many advantages accrue from buying test and measurement equipment from a reputable second-user supplier. In essence, it makes sound business sense to consider the second-user options when specifying test and measurement equipment. The writers welcome comments from people in the industry.

The Tektronix 2235, an example of larger cost saving in higher-priced equipment.



Peter Fraiman is Managing Director of Electronic Brokers Ltd and David Price specializes in the sale of second-user equipment.

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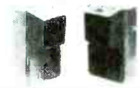

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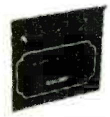

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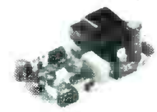
This attractive case is designed to house the control unit CA 1250, together with the appropriate LED indicators and key switch. Supplied with the necessary mounting pillars and punched front panel, the unit is given a professional appearance by an adhesive silk screened label. Size 200 × 180 × 700mm

Control Unit CA 1250



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AC188K	0.37	BC214	0.09	BD520	0.65	BLY48	1.75	TIP120	0.60
ACY17	1.15	BC214C	0.09	BD538	0.65	BRY39	0.45	TIP125	0.65
AD142	0.79	BC214L	0.09	BD597	0.95	BR100	0.26	TIP142	1.75
AD143	0.82	BC237B	0.09	BD589	0.45	BR110	0.49	TIP161	2.95
AD149	0.70	BC238	0.09	BD701	1.25	BR103	0.55	TIP2955	0.85
AD161	0.39	BC239	0.12	BD702	1.25	BRC4443	1.15	TIP3055	0.55
AD162	0.39	BC251A	0.12	BD707	0.90	BT100A/0	20.85	TIS91	0.20
AD161/2	0.90	BC252A	0.15	BDX32	1.50	BT106	1.49	TV106/2	1.50
AF106	0.50	BC258	0.25	BF115	0.35	BT116	1.20	2N1308	1.35
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AF121	0.60	BC303	0.26	BF158	0.22	BU124	1.25	2N3054	0.59
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AF126	0.32	BC328	0.10	BF173	0.22	BU204	1.55	2N3703	0.12
AF127	0.65	BC337	0.10	BF177	0.38	BU205	1.30	2N3704	0.12
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AF239	0.42	BC478	0.20	BF181	0.29	BU3276	1.20	2N3733	9.50
AFZ12	3.75	BC527	0.20	BF182	0.29	BU407	1.24	2N3733	2.75
ASY27	0.85	BC547	0.10	BF183	0.29	BU500	2.25	2N3792	1.35
AU106	4.50	BC548	0.10	BF184	0.28	BU508A	1.95	2N4427	1.95
AU107	3.50	BC549A	0.10	BF185	0.28	BU526	1.90	2N4444	1.15
AU110	3.50	BC550	0.14	BF194	0.11	BU80Y	2.25	2N5294	0.42
AU113	4.50	BC557	0.08	BF195	0.11	BUY69B	1.70	2N5296	0.48
BC107A	0.11	BC557B	0.80	BF196	0.11	MJ3000	1.98	2N5298	0.60
BC107B	0.11	BC558	0.10	BF197	0.11	MJE340	0.40	2N5485	0.45
BC108	0.10	BCY33A	1.60	BF198	0.16	MJE520	0.48	2N5496	0.95
BC108A	0.11	BD115	0.30	BF199	0.14	MPSA13	0.29	2SA715	0.60
BC108B	0.12	BD124P	0.59	BF200	0.40	MPSA92	0.30	2SC495	0.80
BC109	0.10	BD131	0.42	BF241	0.15	MRF237	4.95	2SC496	0.80
BC109B	0.12	BD132	0.42	BF245	0.30	MRF450A	13.95	2SC1096	0.80
BC109C	0.12	BD133	0.40	BF257	0.28	MRF453	17.50	2SC1106	2.50
BC114	0.11	BD135	0.30	BF258	0.28	MRF454	26.50	2SC1172Y	2.20
BC116A	0.15	BD136	0.30	BF259	0.28	MRF455	17.50	2SC1173	1.15
BC117	0.19	BD137	0.32	BF271	0.26	MRF475	2.95	2SC1306	1.40
BC119	0.24	BD138	0.30	BF273	0.18	MRF477	10.00	2SC1307	2.95
BC125	0.25	BD139	0.32	BF336	0.34	MRF838	13.95	2SC1364	0.50
BC139	0.20	BD140	0.30	BF337	0.29	OC16W	2.50	2SC1449	0.80
BC140	0.31	BD144	1.10	BF338	0.32	OC23	1.50	2SC1678	1.25
BC141	0.25	BD150C	0.29	BF355	0.37	OC28	1.50	2SC1909	1.25
BC142	0.21	BD159	0.65	BF362	0.38	OC29	2.25	2SC1945	2.65
BC143	0.24	BD160	1.50	BF363	0.65	OC32	2.25	2SC1954	0.95
BC147A	0.12	BD166	0.55	BF371	0.25	OC42	0.75	2SC1957	0.80
BC147B	0.12	BD179	0.72	BF394	0.19	OC44	0.75	2SC1969	1.95
BC148A	0.09	BD181	0.45	BF422	0.32	OC45	0.55	2SC2028	1.15
BC148B	0.09	BD182	0.70	BF457	0.32	OC70	0.45	2SC2029	1.95
BC149	0.09	BD183	0.70	BF458	0.36	OC71	0.55	2SC2078	1.45
BC157	0.12	BD201	0.83	BF459	0.36	OC72	0.85	2SC2091	0.85
BC158	0.09	BD202	0.65	BF467	0.68	OC75	0.95	2SC2098	2.95
BC159	0.09	BD203	0.78	BF494	0.45	OC81	0.50	2SC2166	1.95
BC1174	0.09	BD204	0.70	BF495	0.45	OC171	3.50	2SC2314	0.80
BC174A	0.09	BD222	0.46	BF595	0.23	R2008B	1.45	2SC2371	0.36
BC177	0.15	BD223	0.59	BF597	0.25	R2010B	1.45	2SD234	0.50
BC178	0.15	BD225	0.48	BFR39	0.23	R2322	0.58	3N211	2.95
				BFR81	0.25	R2323	0.66	3SK88	0.95
				BFR88	0.30	R2540	2.48		
				BFR90	1.50	HCA16334	0.90		

DIODES

AA119	0.80	BY208-800	0.33	IN4001	0.04
BA115	0.13	BY210-800	0.33	IN4003	0.04
BA145	0.16	BY223	0.90	IN4004	0.05
BA148	0.17	BY298-400	0.22	IN4005	0.05
BA154	0.06	BY299-800	0.22	IN4007	0.06
BA156	0.15	BYX10	0.20	IN4148	0.02
BA157	0.30	BYX36-150R	0.20	IN4448	0.10
BAX13	0.04	BYX38-600R	0.60	IN5401	0.12
BAX16	0.06	BYX55-600	0.30	IN5402	0.14
BB105B	0.30	BYX71-600	1.10	IN5403	0.12
BT151	0.79	BZY95C30	0.35	IN5406	0.13
BY126	0.10	CS4B	4.50	IN5407	0.16
BY127	0.11	CS10B	8.45	IN5408	0.16
BY133	0.15	OA47	0.09	ITT44	0.04
BY164	0.45	OA90	0.05	ITT923	0.15
BY176	1.20	OA91	0.06	ITT2002	0.20
BY179	0.63	OA95	0.06		
BT182	0.55	OA202	0.10		
BY184	0.35	IN21DR	5.00		
BT199	0.40	IN23B	5.00		
BY206	0.14	IN23C	5.00		
		IN23ER	5.00		
		IN23WE	5.00		

ZENER DIODES

BZX61 Series	0.15
BZY88 Series	0.10

LINE OUTPUT TRANSFORMERS

DECCA 100	7.95
DECCA 1700 MONO	9.95
DECCA 1730	8.95
DECCA 2230	8.25
GEC 2040	8.95
GRUNDIG 1500	15.45
GRINDIG 510-6010, 2222, 5011-6011	13.45
ITT CVC20	8.20
ITT CVC30	8.25
PHILIPS G8	8.50
PHILIPS G9	8.99
PHILIPS G11	13.99
PYE 725	10.95
RBM T20A	12.40
TANDBERGE 90°	11.15
TELEFUNKEN 711A	11.15
THORN 1590	9.50
THORN 8000	23.50
THORN 9000	9.95
THORN 9800	22.40

CATHODE RAY TUBES Please add £3 additional carriage per tube.

CME822W	19.00	DG7.32	45.00	M38-122GW	65.00
CME822GH	25.00	DG13.2	45.00	M38-140LA	65.00
CME1428GH	45.00	DH3-91	55.00	M38-142LA	65.00
CME1428W	39.00	DH7.91	45.00	M38-341P31	65.00
CME1523W	39.00	DP7 5	35.00	M38-344P39	65.00
CME1431GH	39.00	DP7.6	35.00	M40-120W	59.00
CME1431W	39.00	DN13 78	35.00	M43-12LG/01	65.00
CME202GH	45.00	F16-101GM	75.00	M44-120LC	65.00
CME2024W	45.00	F16-101LD	75.00	M44-120GR	65.00
CME2325W	45.00	F21-130GR	75.00	M50-120GH	65.00
CME3218W	45.00	F21-130LC	75.00	M50-120GR	65.00
CME3132GH	45.00	F31-10GM	75.00	M50-120GV	65.00
CME3155W	45.00	F31-10GR	75.00	M50-120LC	65.00
CRE1400	25.00	F31-10LC	75.00	M61-120W	75.00
CV429	89.00	F31-10LD	75.00	SE3A/P31	40.00
CV1450	35.00	F31-12LD	75.00	SE4/D/P7	45.00
CV1526	19.00	F31-13GR	75.00	SE42BP31AL	55.00
CV2185	15.00	F31-13LD	75.00	SE42BP31	55.00
CV2191	19.00	F31-13LG	75.00	SE5FP31	55.00
CV2193	15.00	F41-123LC	185.00	T948H	65.00
CV5119	85.00	F41-141LG	185.00	V5004LD	59.00
CV5320	85.00	F41-142LC	185.00	V6048CAL	59.00
CVX389	55.00	M7-120W	19.00	V6048J	49.00
D9-110GH	39.50	M7-120GH	19.00	V6064BP31	55.00
D10-210GH	45.00	M14-100GM	45.00	V6069GH	55.00
D10-210GH68B	65.00	M14-100LC	45.00	V6070P31	65.00
D10-230GH	35.00	M17-151GVR	175.00	V7030	59.00
D10-230GM	35.00	M17-151GR	175.00	V7031GH	59.00
D10293-GY/90	55.00	M19-100W	45.00	V7031/67A	59.00
D13-30GH	49.50	M19-103W	55.00	V7035A	49.00
D13-51GL/26	85.00	M23-110GH	55.00	V7037GH	45.00
D13-51GM/26	85.00	M23-111LD	55.00	V8004GR	65.00
D13-45GH/01	55.00	M23-112GM	55.00	V8006GH	65.00
D13-600GM	59.00	M23-112GV	55.00	V8010A	65.00
D13-610GH	59.00	M23-112GW	55.00	VCR139A	11.50
D13-511GH	59.00	M23-112KA	55.00	3BPI	11.50
D13-611GM	59.00	M24-120GM	59.00	3DPI	11.50
D13-630GH	59.00	M24-120LC	59.00	3H/OBM	55.00
D14-150GH	75.00	M24-120WAR	59.00	3WPI	18.50
D14-150GM	75.00	M24-121GH	55.00	4EPI	30.00
D14-162GH/84	59.00	M28-12GH	55.00	5BPI	9.00
D14-172GR	55.00	M28-13LC	49.00	5BHP1	30.00
D14-172GV	55.00	M28-13LG	49.00	5BHP1FF	30.00
D14-173GH	55.00	M28-13GR	49.00	5BHP31	30.00
D14-173GM	53.00	M28-131GR	55.00	5CPI	10.00
D14-173GR	55.00	M28-133GH	55.00	5T01A	15.00
D14-181GH/98	65.00	M31-101GH	55.00	6EP7/S	39.00
D14-181GJ	55.00	M31-182GR	55.00	13BPI	13.50
D14-181GM	53.00	M31-182GV	53.00	13BPA4	17.50
D14-181GM50	59.00	M31-184W	65.00	17DWP4	25.00
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D14-200BE	89.00	M31-184P31	65.00	88D/89B/89D/89L	15.00
D14-200GA/50	85.00	M31-185W	69.00	1273	39.00
D14-200GM	75.00	M31-190GH	55.00	1564	45.00
D14-210GH	75.00	M31-190GR	55.00	1844	80.00
D14-270GH/50	75.00	M31-190LA	55.00	9442E1	75.00
D14-310W	110.00	M31-191GV	55.00	95447GM	75.00
D14-320GH/82	85.00	M31-220W	59.00	95449GM	75.00
D14-340GH/KM	45.00	M31-270GY	65.00	7709631	78.50
D14-340KA	45.00	M31-271P31	65.00		
D16-100GH	65.00	M31-271GW	65.00		
D16-100GH-65	69.00	M31-271W	65.00		
D16-100GH/67	65.00	M36-141W	75.00		
D16-100GH/79	69.00	M36-170LG	75.00		
D16-100GH/97	65.00	M38-101GH	65.00		
D18-160GH	69.00	M38-103GR	65.00		
D21-10GH	65.00	M38-120W	65.00		
DG7-5	55.00	M38-120WA	65.00		
DB7.6	35.00	M38-121GHR	65.00		
DB7 36	55.00	M38-121LA	65.00		

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4 watt	2R4-10K	0.20
7 watt	R47-22K	0.20
11 watt	1R-15K	0.25
17 watt	1R-15K	0.30

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3HSS Suitable for Most JVC and Ferguson models	29.50
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4HSS Suitable for most National Panasonic Models	32.95
4HSS(UIN) Suitable for Panasonic Models 370 and 380	33.95

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PS3B (1 Pin) Suitable for Sony and Toshiba 5000 Series and NEC PV2400	39.50
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DSR-10-R Suitable for Sony SLC5, SLC6, SLC7	39.50
Sanyo Head for VTC9300/9500	41.50
Sanyo Head for VTC 5300/5000	41.50

VIDEO BELT KITS

Akai VS9300/9500/9800	3.75	Sanyo VTC 5500	3.75
Ferguson 3V16	4.50	Sanyo VTC 9300	3.75
JVCH HR 3330/3600	4.50	Sanyo VTC 9300P	3.90
JVC HR 3360/3660	4.50	Sharp VC 6300	3.75
Panasonic NV 300	4.00	Sharp VC 7300	3.75
Panasonic NV 2000B	3.75	Sharp VC 8300	3.75
Panasonic 3000B	3.75	Sharp VC 9300	3.75
Panasonic NV7000	3.50	Sony SL 3000B	3.75
Panasonic NV8600B/8610B/VQII	3.75	Sony SL 8000/8080	4.50
		Sony SL C7/J7	4.00
		Toshiba V5470	4.50

SANYO ORIGINAL VIDEO PARTS

SANYO ORIGINAL PART NUMBER	MODEL	DESCRIPTION	
4-529-10800B	VTC5150	Reel Motor 3.6W	9.95
4-527T-23501	VARIOUS	Motor Assy.	9.75
4-527V-51000	5150	Capston Motor	29.95
143-0-4904-00900	FVHP615	Gear Idler Assy	5.95
143-2-457T-05900	VTC9455	Stopper Reel Base	0.55
143-0-545T-01701	VARIOUS	Pinch Roller Assy	8.95
143-0-545T-01700	VARIOUS	Pinch Roller Assy	1.95
143-0-551T-VTC9300		Idler Assy	0.95
143-0-661T-03800	VARIOUS	Loading Roller	0.95
143-0-662T-01201	VTC5150	Reel Drive Pulley	8.50
143-0-9974-00100	FVHP615	Mod Kit IC BA6304A	1.95

Video Head Cleaning Tape (VHS Automatic wet/dry)	6.50
Video Head Aerosol Cleaner	0.85
Video Copying Lead and Connector Kit 'Z/V'	7.95

VIDEO ALIGNMENT TAPES

S-2P Colour Bars 30 min.	49.50
S-3P Stairsteps 30 min.	49.50

EHT MULTIPLIERS

ITT CVC20	6.35
ITT CVC30	6.35
PHILIPS G8.550	6.96
RANK T20A	6.91
THORN 3000/3500	7.57
THORN 8500	8.00
THORN 9000	8.00
UNIVERSAL TRIPLER	5.45

REPLACEMENT ELECTROLYTIC CAPACITORS

DECCA 30(400-400/350V)	2.85
DECCA 80/100 (400/305V)	2.99
DECCA 1700 (200-200-400-350V)	3.55
GEC 2110 (600/300V)	2.25
ITT CVC20 (200/400V)	1.80
PHILIPS G8 (600/300V)	2.25
PHILIPS G9 (2200x63V)	1.19
PHILIPS G11 (470/250V)	2.35

VARICAP TUNERS

ELC1043/05 MULLARD	8.65
ELC1043/06 MULLARD	8.65
U321	8.25
U322	8.25
U324	11.00

THERMISTORS

VA1040	0.23
VA1056S	0.23
VA1104	0.70
VA8650	0.45
VA1097	0.25

PUSH BUTTON UNITS

DECCA, ITT, CVC20 6WAY	7.95
ITT VCV5-7-WAY	10.19
PHILIPS G8 (550) 6-WAY	14.49

200MA QUICK BLOW FUSES

100MA	8p each
200MA – 5 AMP	5p each

20MM ANTI SURGE FUSES

100MA-800MA	15p each
1A-5AMP	12p each

SPARE & AIDS

HEAT SINK COMPOUND	1.00	PUSH PULL MAINS SWITCH (DECCA, GFC, RANK, THORN ETC.)	1.02
FREEZE IT	0.95	PYE IF GAIN MODULE	6.99
SOLDA MOP	0.64	ANODE CAP (27kV)	0.69
SWITCH CLEANER	0.85		
WD40	1.75		

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C1148A	115.00
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C3E	29.50
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CV Nos prices on request	
D3A	27.50
D63	1.20
DA41	22.50
DA42	17.50
DA90	4.50
DA100	125.00
DAF91	0.70
DAF96	0.65
DC70	1.75
DC90	1.20
DCX-4-5000	25.00
DET16	28.50
DET18	28.50
DET22	35.00
DET23	35.00
DET24	39.00
DET25	22.00
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DF91	1.00
DF92	0.60
DF96	0.65
DF97	1.00
DH63	1.20
DH77	0.90
DH79	0.56
DH149	2.00
DK91	0.90
DK92	1.20
DL35	2.50
DL63	1.00
DL70	2.50
DL73	1.50
DL92	0.95
DL93	1.10
DL94	2.50
DL96	2.50
DLS10	13.50
DLS16	10.00
DM70	1.95
DM160	3.50
DY51	1.50
DY86/87	0.65
DY802	0.72
E80L	29.50
E81L	12.00
E82CC	3.50
E83CC	3.50
E83F	5.50
E86C	9.50
E88C	7.95
E88CC	3.50
E88CC Siemens Special	5.95
E90CC	7.95
E90F	7.95
E91H	4.50
E92CC	3.95
E99F	6.99
E130L	18.50
E182CC	9.00
E180F	6.50
E186F	8.50
E188CC	7.50
E1T	15.00
E280F	19.50
E283CC	10.00
E288CC	13.50
E810F	29.50
E1148	1.00
E1524	6.95
EA50	1.00
EA76	1.95
EA79	1.95
EABC80	0.70
EAC91	2.50
EAF42	1.20
EAF801	2.00
EB34	1.50
EB41	3.95
EB91	0.85
EBC33	2.50
EBC41	1.95
EBC81	1.50
EBC90	0.90

EBC91	0.90
EBF80	0.95
EBF83	0.95
EBF85	0.95
EBF89	0.70
EBF93	0.95
EBL1	2.50
EBL21	2.00
EC52	0.75
EC70	1.75
EC81	7.95
EC86	1.00
EC88	1.00
EC90	1.10
EC91	5.50
EC92	1.95
EC93	1.50
EC95	7.00
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ECC32	3.50
ECC33	3.50
ECC35	3.50
ECC81	1.15
ECC81 Special Quality	2.25
ECC82 Philips	1.95
ECC83	0.65
ECC83 Brimar	1.35
ECC83 Philips	1.95
ECC83 Siemans	2.50
ECC83 Tungsram	1.50
ECC84	0.50
ECC85	0.75
ECC86	2.75
ECC88	0.95
ECC91	2.00
ECC180	0.72
ECC189	1.95
ECC801S	3.50
ECC803S	4.95
ECC804	0.60
ECC2000	12.00
ECF80	1.15
ECF82	1.15
ECF86	1.70
ECF200	1.85
ECF202	1.85
ECF801	0.85
ECF805	2.50
ECF806	10.25
ECH3	2.50
ECH4	3.00
ECH35	3.50
ECH42	1.50
ECH81	1.00
ECH83	1.00
ECH84	1.00
ECH2000	1.50
ECL80	0.60
ECL82	0.79
ECL83	2.50
ECL84	0.74
ECL85	0.69
ECL86	0.95
ECL805	0.69
EF37A	2.50
EF39	1.50
EF40	4.50
EF41	3.50
EF42	3.50
EF50	2.50
EF55	4.95
EF70	1.20
EF71	1.50
EF72	1.20
EF73	1.00
EF80	0.55
EF83	3.95
EF85	0.50
EF86	2.25
EF86 Mullard	4.50
EF89	1.50
EF91	1.95
EF92	2.15
EF93	0.95
EF94	0.95
EF95	1.95
EF97	0.90
EF98	0.90
EF183	0.65
EF184	0.65
EF730	1.80
EF731	3.50
EF732	3.50
EF800	11.00
EF804S	19.50
EF805S	13.50
EF806S	14.50
EF812	0.65
EFL200	1.50
EH90	0.72
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EL32	0.95
EL33	5.00
EL34	2.25
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EL38	6.50
EL41	3.50
EL42	2.00
EL81	6.95
EL83	5.95
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EL84 Mullard	2.95
EL85	4.50
EL86	1.25
EL90	1.75
EL91	6.00
EL95	1.75

EL153	12.15
EL183E	3.50
EL18P	3.50
EL360	6.75
EL500	1.40
EL504	1.40
EL509	5.25
EL519	6.95
EL802	3.65
EL821	8.50
EL822	12.95
EM1	9.00
EM4	9.00
EM80	0.70
EM81	0.70
EM84	1.65
EM85	3.95
EM87	2.50
EN32	15.00
EN91	1.95
EN92	4.50
EY51	0.80
EY81	2.35
EY83	1.50
EY84	5.95
EY86/87	0.50
EY88	0.55
EY91	5.50
EY802	0.70
EX35	0.75
EZ40	2.75
EZ41	2.75
EZ80	0.75
EZ81	0.75
EZ90	1.50
F606	2.95
FWA/800	2.95
G55/1K	9.00
G180/2M	6.95
G240/2D	9.00
GC10B	17.50
GC10D	17.50
GC10/48	17.50
GC10/4E	17.50
GC12/4B	17.50
GD86W	6.00
GDT120M	5.00
GN4	6.00
GN10	15.00
GR10G	4.00
GS10C	16.50
GS10H	12.00
GS12D	12.00
GT1C	14.00
GT1CS/S	13.00
GTN175M	8.00
GTR150W	1.00
GU20	35.00
GU50	17.50
GXU1	13.50
GXU3	24.00
GXU50SS	14.50
GY501	1.50
GY802	1.50
GZ30	1.50
GZ31	1.50
GZ32	1.50
GZ33	4.50
GZ34	2.15
GZ37	4.50
HAA91	1.00
HABC80	0.90
HBC90	0.75
HBC91	0.80
HF93	0.75
HF94	1.50
HK90	1.05
HL2K	4.95
HL23DD	4.00
HL41	3.50
HL42DD	3.50
HL90	0.70
HL92	1.50
HL133×DD	3.50
HT2	4.00
HY90	1.00
HVR2	3.00
JP9-7A	60.00
K3118	85.00
KR6/3	45.00
KT8C	7.00
KT33C	3.50
KT36	2.00
KT44	4.00
KT45	4.00
KT61	5.00
KT63	2.00
KT66 USA	9.95
KT66 GEC	17.50
KT66 Sp. Yellow Spot	19.50
KT67	9.00
KT77 Gold Lion	10.95
KT81	7.00
KT88 USA	10.95
KT88 G Lion	18.95
KTW61	2.50
KTW62	2.50
KTW63	2.00
KTZ63	2.50
L102/2K	6.95
L102/2K	12.00
LB7-20	95.00
LS9B	6.95
M502A	60.00
M537A	60.00
M5143	155.00
M8079	6.00
M8082	7.50
M8083	3.25
M8091	7.50
M8096	3.00
M8098	5.50
M8099	5.00
M8100	5.50
M8136	7.00
M8137	7.95
M8161	6.50
M8162	5.50
M8163	5.50

M8190	4.50
M8195	6.50
M8196	5.50
M8204	5.50
M8223	4.50
M8224	2.00
M8225	3.95
ME1401	29.50
ME1402	29.50
ME1501	14.00
MH4	3.50
MHL6	4.00
ML4	4.50
MS4B	5.50
MU14	3.50
MZ1-100	125.00
N37	12.50
N78	9.85
OA2	0.85
OA2WA	2.50
OA3	2.50
QB2	0.85
OB2WA	2.50
OC2	2.50
OC3	1.50
OD3	1.70
OM4	1.20
OM5B	3.00
OM6	1.75
ORP43	2.50
ORP50	3.95
P61	2.50
P41	2.50
PABC80	0.75
PC86	0.75
PC88	0.75
PC92	3.50
PC97	1.10
PC800	1.10
PC900	1.25
PCC84	0.40
PCC85	0.55
PCC88	0.70
PCC89	0.70
PCC189	0.70
PCC805	0.70
PCC806	0.80
PCE82	0.80
PCF80	0.65
PCF82	0.60
PCF84	0.65
PCF86	1.20
PCF87	0.40
PCF200	1.80
PCF201	1.80
PCF800	0.40
PCF801	1.35
PCF802	0.60
PCF805	1.25
PCF806	1.00
PCF808	1.25
PCH200	1.50
PCL82	0.85
PCL83	2.50
PCL84	0.75
PCL85	0.80
PCL86	0.85
PCL800	0.80
PCL805	0.90
PE1-100	69.00
PEN25	2.00
PEN40DD	2.50
PEN45	3.00
PEN45DD	3.00
PNE46	2.00
PE06-40N	42.00
PFL200	0.95
PL21	2.50
PL36	0.95
PL38	1.50
PL81	0.72
PL81A	0.72
PL82	0.60
PL83	0.52
PL84	0.78
PL88	1.00
PL95	1.75
PL302	1.00
PL345	12.50
PL500	1.10
PL504	1.15
PL508	1.75
PL509	4.85
PL519	4.95
PL802T	3.50
PL820	2.95
PL5557	29.50
PY32	0.60
PY33	0.50
PY81	0.70
PY82	0.70
PY83	0.70
PY88	0.65
PY500A	1.95
PY800	0.79
PY801	0.79
QB3-300	54.95
QB3-1750	139.50
QB5-3500	495.00
QE03-10	4.95
QE08-200	145.00
QF40	65.00
QP25	1.00
QQE02-5	19.50
QQE03-12	7.95
QQE03-20	35.00
QQE06-40	45.00
QQV02-6	19.50
QQV03-10	5.50
QQV03-10 Mullard	15.00
QQV03-20	25.00
QQV06-40A	27.50
QQV06-40A Mullard	45.00
QQV07-50	63.50
QQZ03-20	42.50
QS75/20	1.50
QS75/40	3.00
QS92/10	5.00
QS95/10	4.85
QS108/45	4.00
QS150/15	6.95
QS150/30	1.15
QS150/45	7.00
QS1200	3.95
QS1202	3.95

QS1203	4.15
QS1205	3.95
QS1206	1.05
QS1207	0.90
QS1208	0.90
QS1209	3.15
QS1210	1.50
QS1211	1.50
QS1212	3.20
QS1213	5.00
QS1215	2.10
QS1218	5.00
QU37	9.50
QV03-12	5.75
QV05-25	1.75
QV06-20	29.50
QV08-100	145.00
QV2-2500	45.00
QY3-125	65.00
QY4-250	70.00
QY4-400	76.00
R10	4.00
R16	12.00
R17	1.50
R18	2.50
R19	2.50
R20	1.20
R1169	55.00
RG1-125	4.95
RG1-240A	14.50
RG3-250A	3.50
RG3-1250A	35.00
RK2K25	62.50
RK-208	12.00
RL16	1.50
RPL16	12.00
RPY13	2.50
RPY43	2.50
RPY82	2.50
RR3-250	15.00
RR3-1250	35.00
RS613	45.00
RS685	54.95
RSS688	52.15
S6F17	5.95
S6F33	28.95
S11E12	38.00
A30/2K	12.00
S104/1K	10.00
S109/1K	15.00
S130	5.59
S130P	5.95
SC1/800	5.00
SC1/1100	6.00
SC1/1200	5.00
SC1/1300	6.00
SC1/200	9.00
SP41	5.00
SP42	3.00
SP4B	4.95
SS501	35.00
ST11	1.50
STV280/40	11.95
STV280/80	19.95
SU42	4.95
TB2.5/300	85.00
TB2-300	45.00
TB3-2000	395.00
TD1-100A	25.00
TD03-10F	35.00
TD3-12	4.00
TDD4	5.50
TP25	1.50
TSP4	7.00
TT11	1.50
TT21	45.00
TT22	45.00
TT100	57.00
TTR-31MR	65.00
TY2-125A	85.00
TY4.400	85.00
TY8-600W	365.00
TYS2/250	375.00
U18-20	2.75
U19	11.95
U24	2.00
U25	0.90
U26	0.90
U37	9.00
U41	6.95
U50	2.00
U82	3.00
U191	0.70
U192	1.00
U193	0.65
U251	1.00
U801	0.75
UABC80	0.65
UAF42	1.00
UBF80	0.60
UBC41	2.25
UBC81	1.50
UBF89	1.00
UBL21	1.75
UC92	1.20
UCC84	0.70
UCC85	0.60
UCF80	1.00
UCH21	1.20
UCH41	2.50
UCH42	2.50
UCH81	1.00
UCL82	1.75
UCL83	2.50
UF41	1.15
UF42	1.15
UF80	1.75
UF85	1.20
UF89	2.00
UL44	3.50
UL84	1.50
UL85	0.85
UU5	3.50
UU7	8.00
UU8	9.00
UY41	3.50
UY85	0.70
V235A/1K	250.00
V238A/1K	295.00
V246A/2K	315.00
V2406/1K	225.00
V241C/1K	195.00
V339	3.50
V453	12.00
VLS631	10.95
VP4B	4.50
VP133	2.00

VR75-30	3.00
VR101	2.00
V105/30	1.50
VR150/30	1.15
VT52	2.50
VU29	4.50
VU39	1.50
W21	4.50
W77	5.00
W729	1.00
W739	1.50
X24	4.50
X66/X65	4.95
X76M	1.95
XC24	1.50
XC25	0.50
XFW47	1.50
XFW50	1.50
XG1-2500	75.00
XG2-6400	135.00
XG5-500	22.50
XL628FT	7.50
XNP12	2.50
XR1-1600A	49.50
XR1-3200A	79.50
XR1-6400A	115.00
Y502	25.00
Y65	6.95
YD1100	75.00
YJ1060	265.00
YL1020	29.00
YL1060	195.00
YL1070	195.00
YL1071	195.00
YL1290	65.00
Z77	1.20
Z302C	12.00
Z359	9.00
Z505S	15.00
Z520M	4.00
Z521M	8.00
Z700U	3.00
Z749	0.60
Z759	19.85
Z803U	18.95
ZA1000	12.50
ZA1001	1.50
ZM1005	8.00
ZM1020	6.00
ZM1021	8.00
ZM1023	7.95
ZM1041	14.00
ZM1082	9.00
ZM1084	10.00
ZM1177	9.00
ZM1202	55.00
ZM1263	4.00
ZM1612	3.00
1A3	4.50
1AC6	1.20
1AE4	3.50
1B3GT	1.95
1B22	10.00
1B27	55.00
1B35A	45.00
1B63A	75.00
1C1	2.50
1C5GT	2.50
1FD1	2.50
1G3GT	2.50
1J3GT	2.50
1K3	2.50
1N2	4.50
1N5GT	2.50
1P28	25.00
1P39	19.50
1R5	0.90
1T4	1.00
1U4	1.75
1U5	1.00
1X2B	1.40
1Z2	8.95
2AS15A	11.50
2B7	1.50
2B22	69.50
2C39A	32.50
2C39BA	39.50
2C40	37.00
2C42	29.50
2C43	60.00
2C51	0.75
2C53	45.00
2CY5	1.50
2D21	1.95
2D21W	2.50
2E22	49.00
2E26	7.95
2J42	93.00
2J55	350.00
2K25	35.00
2K25 Raytheon	75.00
2K26	95.00
2K29	250.00
2K48	140.00
2K56	250.00
2X2A	5.00
3A/107B	12.00
3A/108A	9.00
3A/109B	11.00
3A/110B	12.00
3A/141K	11.50
3A/147J	7.50
3A/167M	10.00
3A/2	3.95
3A3A	3.95
3A4	1.10
3A5	4.50
31L5	0.95
3AT2	3.35
3B2	3.00
3B4	4.95
3B7	4.50
3B24	10.00
3B26	24.00
3B28	15.00
3BZ6	1.50
3C4	1.00
3C23	19.00
3C45	24.00
3CB6	1.50
3CN38A	2.50
3CS6	0.95
3CX3	2.50
3CY5	1.50
3D6	4.50

3D21A	29.50
3E22	49.50
3EH7	1.95
3EJ7	1.95
3V4	1.75
3W4GT	2.50
4B5518	115.00
4-65A	59.00
4687A	9.50
4-250A	79.50
4-400A	87.50
4-1000A	425.00
4B32	35.00
4BQ7A	1.75
4BZ6	1.95
4C27	25.00
4C28	25.00
4C35	145.00
4CX1000A	425.00
4CX4000A	1100.00
4CX250B	49.00
4CX250B EIMAC	59.50
4D32	125.00
4CX250BN	75.00
4CX250K EIMAC	95.00
4CX125C EIMAC	125.00
4CX350A	95.00
4CX350F	79.50
4XC1500B	398.50
4E27	195.00
4GS7	2.25
4J52	75.00
4JC6A	2.95
4KT6	1.50
4X150A	35.00
5A/102D	9.50
5A152M	9.00
5A163K	10.00
5A170K	6.25
5A-180M	9.00
5A-206K	10.00
5AM8	2.15
5AN8	1.20
5AR4	2.00
5AU4	1.50
5B 110M	10.00
5B-254M	14.50
5B-255M	19.50
5B-256M	15.00
5B-257M	15.00
5B-258M	14.50
5C22	125.00
5CL8A	2.50
5J180E	2950.00
5R4GB	3.50
5R4GY	3.50
5T4	5.95
5U4G	2.95
5U4GB	4.50
5V4G	1.50
5Y3GT	1.95
5Z4GT	1.50
6/30L2	0.70
6A/203K	9.00
6A7	4.95
6A8G	1.50
6AC7	2.00
6AG5	1.50
6AG7	1.95
6AH6	2.50
6AJ4	2.00
6AJ7	2.00
6AK5	1.95
6AK6	2.50
6AL5	0.60
6AM4	3.25
6AM5	6.00
6AM6	1.95
6AN5	4.50
6AN8A	3.50
6AQ5	1.75
6AQ8	0.85
6AR5	5.95
6AR8	3.95
6AS5	1.50
6AS6	2.50
6AS7G	4.50
6AT6	0.75
6AT8	1.75
6AU4	2.00
6AU5GT	4.50
6AU6	0.95
6AV6	0.75
6AW8A	2.50
6AX4GT	1.95
6AY3B	1.95
6AZ8	4.50
6B7	2.80
6B8G	1.50
6B10	1.95
6BA6	0.95
6BA7	4.50
6BA8A	3.50
6BE6	0.95
6BG6G	3.00
6BH6	1.95
6BH8	1.50
6BJ6	1.50
6BK4	4.00
6BK7A	1.95
6BL6	85.00
6BL8	1.15
6BM6	115.00
6BM8	0.58
6BN4	1.65
6BN6	1.65
6BN7	4.50
6BN8	3.95
6BQ5	0.75
6BQ7A	0.72
6BL7GTA	3.95
6BR5	0.70
6BR7	4.95
6BR8	2.15
6BR8A	2.15
6BS7	5.50
6BW4	1.50
6BW6	5.35
6BW7	1.50
6BW8	4.00
6BX6	0.48
6BX7GT	3.50

6BZ6	2.50
6BZ7	2.95
6C4	1.25
6C5	1.95
6C6	2.50
6C8G	1.50
6C11	2.50
6C18	2.50
6CA4	4.95
6CA7	3.50
6CB5	3.95
6CB6	1.95
6CD6GA	4.50
6CF6	1.50
6CG7	2.25
6CH6	6.95
6CL3	3.95
6CL6	3.25
6CL8A	1.50
6CN5	1.60
6CM7	2.95
6CS6	0.75
6CS7	0.95
6CW4	6.50
6D6	2.50
6DC6	2.35
6DJ8	0.95
6DK6	6.50
6DQ5	5.95
6DQ6B	2.50
6DT6A	1.50
6DW4	2.15
6E5	3.95
6EA4	4.95
6EA7	2.50
6EA8	2.50
6EB8	1.75
6EM5	2.50
6EM7	2.50
6EU7	1.95
6EU8	1.75
6EV7	2.95
6EW6	2.95
6EW7	4.50
6F1	2.00
6F5	4.95
6F6	2.50
6F6G	2.00
6F7	5.50
6F12	1.50
6F13	3.00
6F14	1.00
6F17	2.75
6F21	2.50
6F23	0.60
6F24	1.25
6F25	1.25
6F28	1.25
6F32	1.25
6F33	17.00
6FG5	1.95
6FQ7	2.95
6G6G	5.50
6GE5	3.95
6GH8A	0.80
6GK5	1.50
6GK6	1.95
6GM6	2.65
6GS7	2.15
6GV7	2.50
6GW6	2.50
6GW8	2.50
6GY5	3.95
6H1	9.50
6H3N	2.50
6H6	1.95
6H6GT	1.95
6HF5	5.50
6HF8	2.50
6HS6	4.95
6J4	2.15
6J4WA	3.15
6J5	2.50
6J6	2.00
6J7	4.15
6JB6A	4.50
6JE6C	5.50
6JU8	2.50
6JS6C	4.95
6J7G	4.15
6K7G	2.00
6K8G	3.00
6KD6	6.50
6KM8	2.50
6KT8	2.95
6L1	2.50
6L15	3.15
6L19	3.95
6L6GC	2.95
6L6GC(GE)	4.50
6L6GT	1.95
6LD20	1.15
6LF6	7.50
6LJ8	2.50
6LQ6	5.50
6N7	2.50
6N7GT	2.50
6P15	1.50
6P25	4.00
6P26	4.00
6P28	2.00
6Q7	1.75
6Q7GT	1.20

6R7G	3.15
6S4A	1.50
6SA7GT	1.35
6SC7	1.50
6SG7	2.50
6SH7	1.35
6SJ7GT	1.20
6SK7	1.35
6SK7GT	1.35
6SL7GT	0.85
6SN7GT	1.35
6SQ7	1.35
6SS7	1.95
6U4GT	1.75
6U6WA	3.50
6U8	1.15
6U8A	1.50
6V6G	1.25
6V6GT	1.50
6VGG	1.00
6Y6G	3.95
6X2N	1.00
6×4	1.50
6×5GT	1.00
6×5GTY	1.00
6×8B	2.25
7A6	4.50
7A7	2.00
7AD7	1.75
7AU7	1.50
7B6	3.50
7B7	2.50
7C5	3.50
7C6	2.50
7E7	2.50
7H7	3.50
7J7	5.50
7Y4	2.50
8B8	2.50
8B10	2.50
8BQ5	1.95
8FQ7	1.95
10D2	1.25
10DE7	2.50
10EW7	2.95
10F1	0.75
10GK6	1.95
10P14	2.50
10P18	0.78
10LD12	0.65
11E2R	45.00
11E3	55.00
11R3	5.50
12A6	3.95
12AD6	1.50
12AH7GT	4.95
12AL5	1.00
12AT6	1.25
12AT7	1.15
12AT7WA	2.50
12AU6	1.50
12A17	0.65
12AV6	1.95
12AV7	2.50
12AX7GT	1.00
12AX7	0.65
12AX7WA	2.50
12AY7	3.95
12AZ7A	1.95
12B4A	4.50
12BA6	1.50
12BE6	1.95
12BH7A	2.50
12BL6	1.75
12BY7A	2.75
12C8	2.50
12CA5	1.95
12CX6	1.20
12DQ6B	3.50
12DW4A	3.50
12E1	19.50
12E14	38.00
12GN7	3.95
12HG7	4.50
12HG7A	4.50
12J5GT	3.95
12J7GT	3.50
12JZ8	2.95
12K5	1.95
12K7GT	1.50
12K8	1.95
12SA7GT	1.95
12SG7	4.75
12SH7	1.95
12SK7	1.95
12SJ7	1.50
12SQ7GT	1.95
12SN7GT	1.85
12SR7	2.50
12X4	1.95
13D3	3.20
13D7	3.20
13D9	3.20
13DE7	2.50
13DR7	2.95
13E1	145.00
13EM7	3.50
14S7	1.95
16GY5	2.95
17BE3	2.50
17DW4A	2.95
17EW8	0.95
17JZ8	4.50

18D3	6.00
18GB5	3.50
19AQ5	3.50
19AU4GT	2.50
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810	85.00
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5654	1.95
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5670	3.25
5672	4.50
5675	28.00
5678	7.50
5687	4.50
5692	3.50
5696	3.50
5704	3.50
5718	6.15
5725	2.50
5726	2.50
5727	2.50
5749	2.50
5750	1.85
5751	2.95
5763	5.75
5814A	3.25
5823	9.50
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5842	11.00
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5065	2.25
6005	1.85
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6021	3.65
6057	3.75
6058	3.95
6059	3.75
6060	2.25
6062	4.50
6063	2.00
6064	3.25
6067	7.00
6072	4.20
6080	8.50
6080WA	9.50
6132	10.50
6136	2.50
6146B	9.50
6155	65.00
6156	65.00
6157	2.50
6158	3.20
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6386	14.50
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WORKFILE

We include this round-up of jobs currently on offer in the electronics industry as the first in a regular series on careers. There appears to be a certain amount of confusion about the requirements likely to be specified by employers for the kind of job one would like to do, so to try to help clear the way we are asking personnel officers and directors to give their views on the proper approach to a career in electronics.

It is evident from the list below that a majority of positions are of the degree level, but there is still a large number for which HNC, HND or even O-levels are needed or for which experience alone is enough, particularly in sales. There are even some advertisers who do not mention their requirements at all.

Area	Company	Contact	Personnel needed	Quals	Salary
COMPUTER HARDWARE					
Romsey	Plessey	Freephone Plessey Roke Manor	Research	Degree	
Surrey	-	0784 34322	PBX/comp. interfacing	Degree	20-25k
Southampton	British Gas	0703 31818	Data communications	C.Eng.	11-15k
Derby/Bristol	Rolls-Royce	0322 241099 0272 795319	Wide range of activity	Degree	
Basildon, Borehamwood Bristol, Rochester	GEC Avionics	I. Hickman, GEC Avionics Ltd, Freepost, Elstree Way Borehamwood, Herts.	Design engineers		
South-east	-	0635 33445	Micro control (chief engineer)	Degree, HND	15k
Bristol	Hewlett-Packard	0223 311316	Computer networking	Degree	
Cambridge	Topexpress	0223 355427	Dig. systems(noise & vibr'n)	Degree	
Herts. and Essex	-	0202 292155	Design engineers	Degree	10-20k
Chessington	Racal	01-397 5281	Design engineers (radar)	Degree	
COMPUTER SOFTWARE AND SYSTEMS					
-	US bank	01623 1266	Systems analysts	A lev./deg.	Negotiable
Cambridge	Acorn	0223 214411	Software engineers		
West Sussex	-	01-460 5575	Software engineers		
Gloucestershire	-	021455 6255	Software manager	Degree	19k
-	GEC Avionics	see "Hardware"	Software engineers		
Chessington	Racal	01-397 5281	Software engineers (radar)	Degree	
Romsey	Plessey	Freephone Plessey Roke Manor	Wide range of research	Degree	
East Midlands	-	0533 544 193	Software engineer	Degree	
Bristol	Hewlett-Packard	0223 311316	Software engineer	Degree	
Cambridge	Topexpress	0223 355427	Systems engineers	Degree	
Herts. & Essex	-	0202 292155	Software engineers	Degree	10-20k
Bristol	Bendix	0272 671881	Systems engineers	HND	14k
Wells	Thorn-EMI	0749 72081 x 227	Software engineers	Degree	10-17k
COMMUNICATIONS					
Brighton	British Telecom	Freephone 3027	PABX engineering	Degree	~14-16k
Maidenhead-based	BNR	Freephone 3277	Field engineers	HND/degree	
			Trials engineers	HND/degree	
			Systems test	HND	
Cheltenham	GCHQ	0256 468551	TSOs (radar or aerospace)	Degree/exp.	13-20k
Accra, Ghana	Planet Electronics	152 College Road Harrow, Middx HA1 1BH	C.tv & video comms		No tax, Accommod'n
-	British Gas	0703 31818	Data communications	C.Eng.	12-15k
GENERAL ELECTRONICS					
London	N. London Poly.	01-609 9913. Ref.R9AD	Acoustic/audio research		6.5-7.3k
Warrington	UKAEA	0925 573160	Non-destructive test	Degree	
Lincoln/Wembley	Marconi	0522 688121	I.c. design and production	Degree/HNC	
London WC	University College	Technician (optical fibres)			7.3-8.4k
		" (microprocessors)			7.3-9.9k
Plymouth	Wandel & Goltermann	0752 772773	Des. engrs (test & measure)	Degree	20k
SALES					
Brighton	British Telecom	Freephone 3027	PABX sales	Degree	13.6-15.5k
Midlands	-	Steve Cash, PER, 21 Marble Street Manchester	Sensors/control		5 fig.
Manchester	Center-File	08163 8466	Micro. products (mgr)		25k
Midlands/SE	FOCOM	Personnel Off., Focom Systems, Severn Rd, Leeds LS10 1BL	Defence (optical fibres)	HNC	
Burgess Hill	-	01-235 6060	M/c tool readouts. Manager		22k
S. Hampshire	-	01-387 6667	Components/systems. Manager		25k
Bognor Regis	Sangamo	0243 825011		Degree	
West of London	-	0273 471271	Components		10-14k
N. Midlands/NW	-	04867 6891	Components		12-20k
Home Counties	GSPK	0423 865641	P.c.bs (area manager)	Prev. exp.	4.5 day week
Hainault	Gould	01-500 1000	Instruments	Deg. pref.	10-20k
Corby	RS Components	Personnel Officer RS Components Ltd, Birchington Rd, Corby, Northants NN17 9RS	Opto and instrument mktg		11k
SERVICING/MAINTENANCE					
Croydon	C. Health Authority	01-684 6999 x 4318	Electro-med. servicing	ONC	7.3-9.3k
Birmingham	Automobile Assoc.	0256 492971	Radio maintenance	C&G Fin.	8.5k
Victoria	A. H. Hudson	01-828 3937	Dictation equipment		8.5k
London/S. Coast	Dataller	Dataller Computer Ser. King St, Wigan WN1 1BT	Servicing		9k
Jersey		0534 30289	PCs/home computers		
London	Univ. Inst. of Ed.	01-636 1500 x 254	Microprocessors		8-9k

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The successful applicant should be educated to at least HNC level or equivalent, ideally in Electronics. Your background must include a minimum of two years experience at Test Engineer level, preferably in a supervisory capacity. The ability to react to deadlines and work under pressure is essential, and experience of Automatic Test Equipment/Software would be a definite advantage.

Our client offers an excellent benefits package, including relocation where appropriate and overtime will be available. Applications will also be welcomed from less experienced candidates, as more junior positions exist within the department.

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Interviews are held direct with prospective employer

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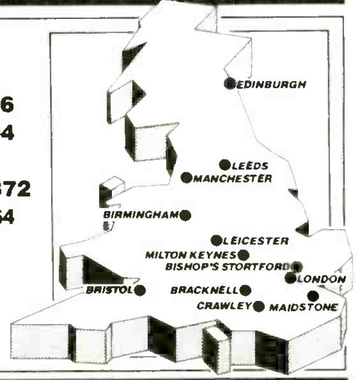

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You should have an engineering or science degree or equivalent, electronic design experience and an interest in computer aided design. Micro- or mini-computer experience is essential; knowledge of VAX/VMS desirable. Training will be given where necessary.

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Further information obtainable from Dr R C Driscoll 01-607 2789 Ext 2166.

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Further details and an application form are obtainable from The Personnel Office, The Polytechnic of North London, Holloway Road, London N.7., quoting ref. R9AD.
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You will be responsible for helping to detect illegal operators – collecting and presenting evidence for prosecution – and for inspecting licensed operators, ensuring that they comply with all relevant regulations. In addition, you will investigate interference to authorised radio and TV services, and advise on remedial action.

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DEPARTMENT OF TRADE & INDUSTRY

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For further details, please contact Prof. A. J. Fourcin, Department of Phonetics and Linguistics, UCL, Wolfson House, 4 Stephenson Way, London NW1 1HE (tel. 01-387 1055) or Dr. B. C. J. Moore, Department of Experimental Psychology, University of Cambridge, Cambridge CB2 3EB (tel. 0223 337733, ext. 3574). 333

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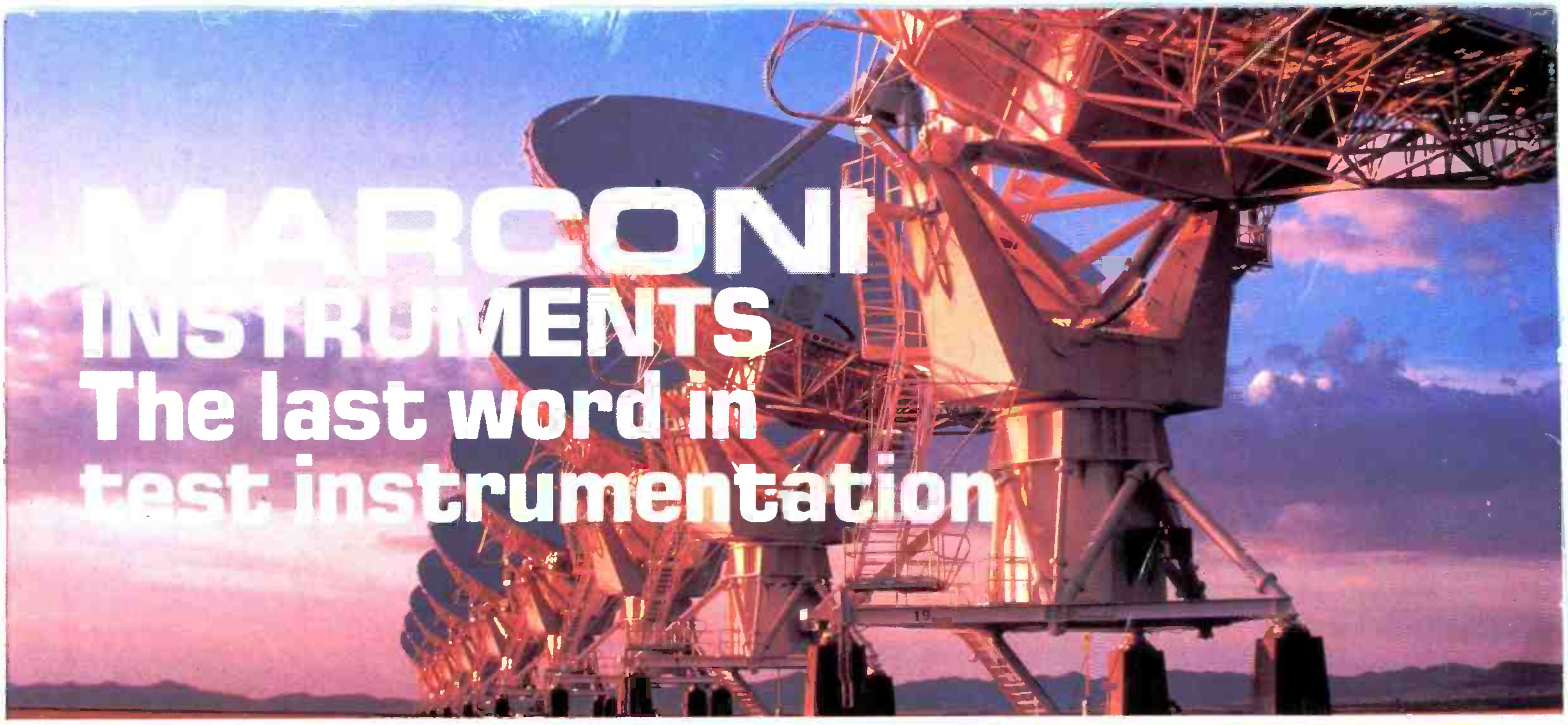

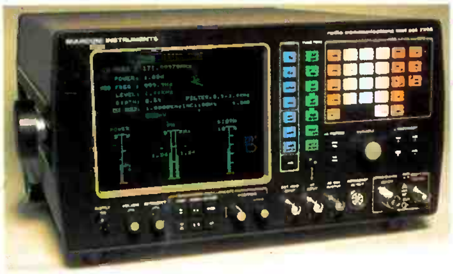

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