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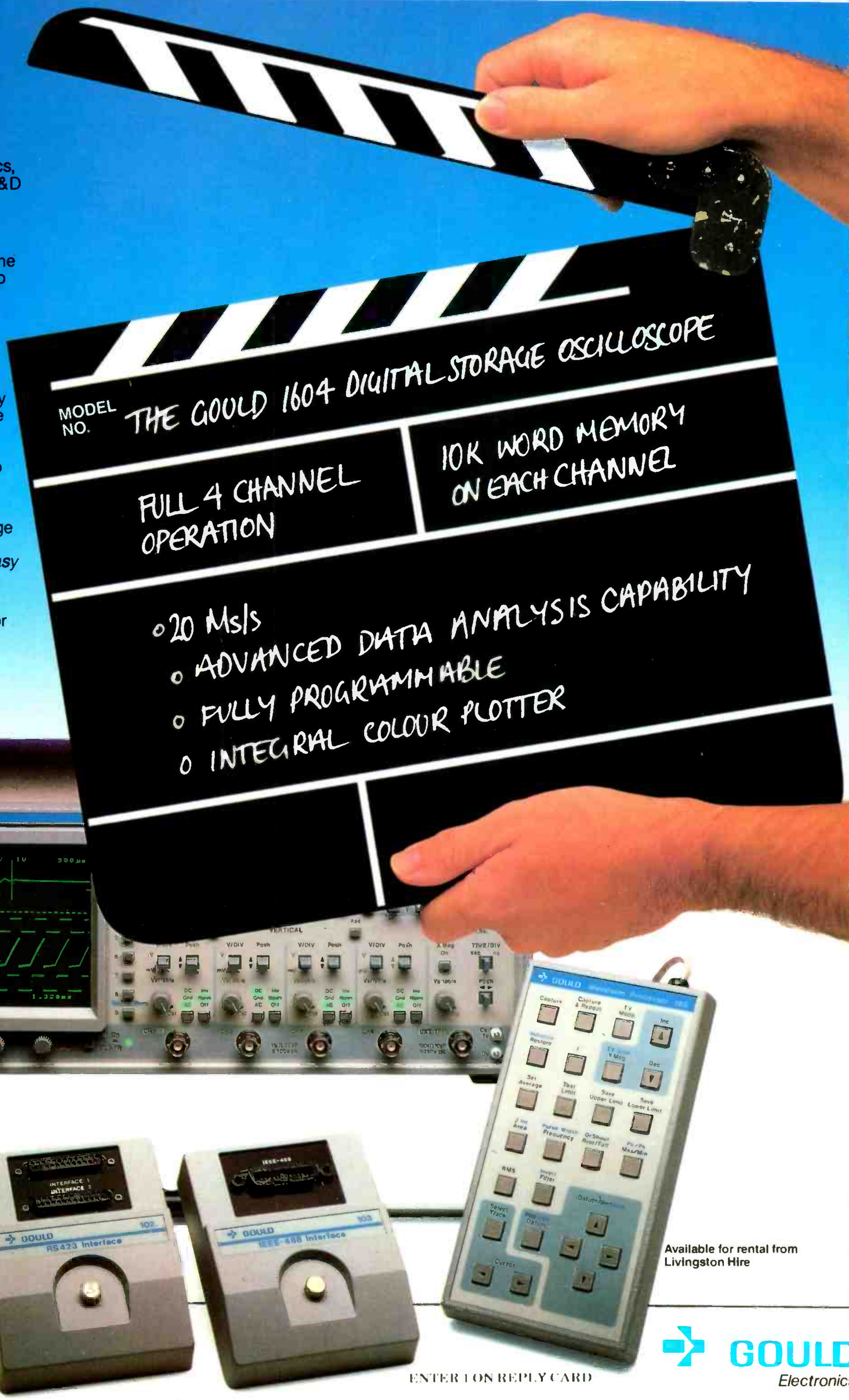

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CONTENTS

SEPTEMBER 1988 VOLUME 94 NUMBER 1631

FEATURES

COVER

High-definition television will bring to domestic viewers pictures sharper even than those they can see in the cinema (off-screen photographs by courtesy of Sony Broadcast).

EUREKA 95 – A WORLD STANDARD
845

European promoters of high-definition television prepare for a crucial demonstration
Tom Ivall

IEEE488-TO-Z80 INTERFACE
852

Dedicated instrumentation controller for the SC84 and other computers
T.J. Vellacott

PC BUS PERFORMANCE
856

Two new personal computers use entirely new bus structures.
William Nowlin

LOGIC PROBE
867

Fast pulse-detecting probe based on a p.l.d.
B.J. Frost

PIONEERS
873

Alec Reeves, inventor of p.c.m.
W.A. Atherton

MULTIPROCESSOR SYSTEMS
875

This third article examines the issues involved in linking processors together
Alan Clements

A DIMENSIONAL APPROACH TO UNIFIED THEORY
882

Dimensional relationships of common physical concepts
S.K. Chatterjee

PHILIP SMITH'S CHART – 2
887

JW supplies a user's guide
Joules Watt

STEP-UP SWITCHING REGULATOR
891

High-efficiency design for use with NiCd cells.
N.J. Chaffey and T.A. Perkins

L.F. NAVIGATION REVIVAL
897

Tracking vehicles by radio
Richard Lambley

DEPENDENT SOURCE THEOREM
900

Finding equivalent generators in a network which has no independent sources
Harry E. Stockman

PIEZOELECTRIC COAXIAL CABLE
905

Applications of a novel composite material
Peter Johnson

Loran brought up to date: a new nationwide radio position-finding system is described on page 897.

KEYBOARD DESIGN
910

Details that designers sometimes overlook
Jeff Wright

ANALOGUE CIRCUITS FOR AUTOMOTIVE USES
915

Spike-resistant chips for cars
Rocco Shah

PAN-EUROPEAN CELLULAR DEMONSTRATION
919

Digital radiotelephone success

BROADBAND INSTRUMENTATION AMPLIFIER
937

Wide bandwidth plus good c.m.r.r.
Nanno Herder

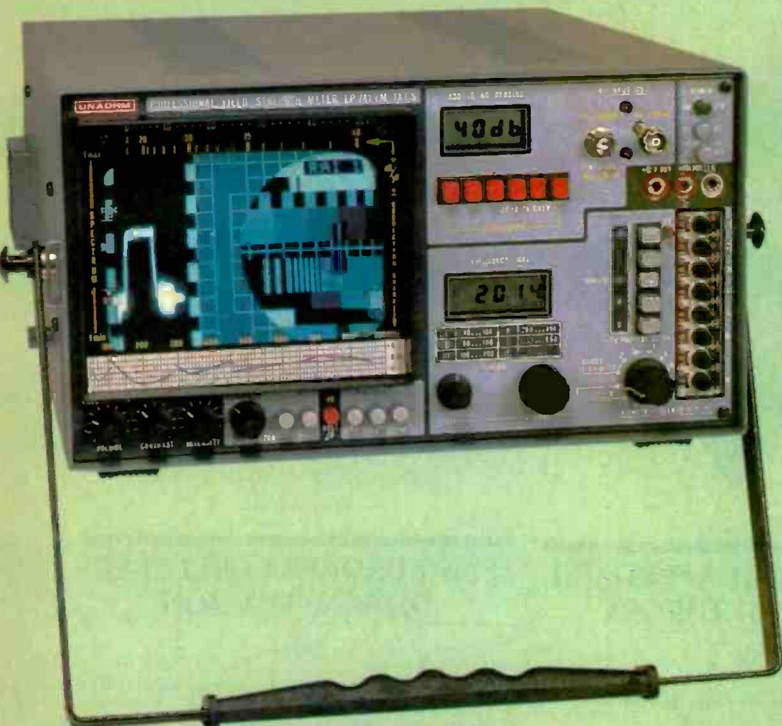
SUPERCONDUCTING FETS 850
NOVEL POWER SUPPLY 885
ASSERT COMPETITION 918
SCI-TECH '89 918
OBITUARY 918

REGULARS

COMMENT 843
EVENTS 854, 881
LETTERS 860
CIRCUIT IDEAS 864
BOOKS 869
APPLICATIONS SUMMARY 871
SATELLITE SYSTEMS 903
TELECOMMS TOPICS 908
NEW PRODUCTS 920, 927
RESEARCH NOTES 929
TELEVISION BROADCAST 932
RADIO COMMUNICATIONS 934
RADIO BROADCAST 936

TAYLOR RF/VIDEO MEASUREMENT INSTRUMENTS

MEASUREMENTS MADE EASY



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COMMENT

Predicting the unpredictable

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How technological advancements will affect the future is remarkably difficult to predict. There is no need to go back to the industrial revolution to find evidence of this statement. As many of you will remember, not too many years ago experts predicted that the country would soon be run by a big brother computer.

Were it not for microprocessors we might now have a big brother. Admittedly there are a few large central computers doing mainly specific tasks, and the day might still come when our destinies are determined by a central supercomputer, but the majority of today's processing is done locally – in offices, laboratories, shops, factories and in the home.

And, on the subject of predictions, who can say with any certainty whether computers will eventually create jobs or cause even more unemployment? Popular answers to this question are frequently evaluated from political rather than computer knowledge, which is perhaps what flawed the central-computer theory.

One of the bolder predictions made recently comes from researchers at the Georgia Institute of Technology who say that by the year 2000, operators will be instructing computers in plain language, not by entering commands on a keyboard. That in itself is not a particularly profound prediction, but researcher David Roessner goes on to make a point with much wider implications. As a result of advances in computer technology, and in particular in the computer-to-person interface, he says that we will be "thrown back on those skills that are uniquely human – skills such as knowing what questions to ask, how to interpret information, and how to judge when a computer-generated answer does not make sense."

Our schools are certainly working hard at 'computer-education', but might emphasis be turning away from *teaching* the disciplines of computer technology and programming – which is essentially problem solving – towards *training* in how to type and how to use programs such as word processors, data bases and spread sheets? One hopes not, but since it has become so clear that the health of a nation relies on the success of its industry and commerce such a situation is justifiable should you put the long-term future second to current needs.

Getting and holding a job in the future, says Roessner, will require literacy, not computer literacy. If he is right, there will be problems for everyone should we decide to train computer use rather than continue to teach problem solving using computers. Young people will leave school expecting to use their hard-earned training and be disappointed, employers will find a shortage of suitable staff, and the economy will suffer through the resulting short-fall in production.

Of course, nothing indicates that every future worker will need to be a computer programmer. It might be that our current information-technology managers and computer programmers will evolve side by side, and jobs for everyone else might suddenly appear, be created, or never have disappeared in the first place.

Two things are certain from this reminder that new technology might not produce the results that seem immediately apparent. One is that is that any child emerging from school with the ability to solve problems will make a better contribution to society than one emerging with a sound knowledge of how current computer programs work, and the other is that any unbiased prediction of the effects of new technology is better than none.

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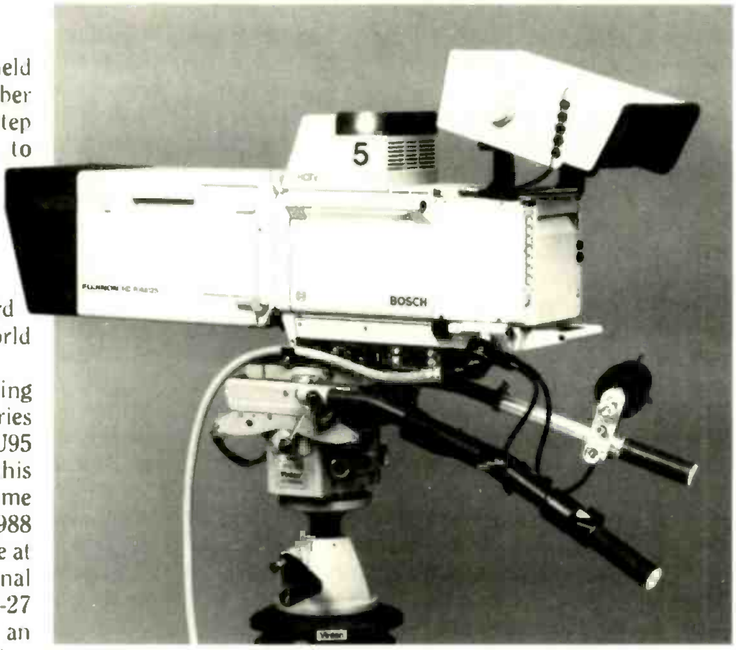
Eureka 95 – a world standard?

Research teams all over Europe are racing to make ready a crucial h.d.tv demonstration

TOM IVALL

A demonstration to be held at Brighton in September will form a significant step in the European attempt to establish a compatible high-definition television standard. It could also be crucial in an international decision, to be made eventually by the CCIR, on whether this standard will be acceptable as a world h.d.tv standard.

The demonstration is being organized by member countries responsible for the Eureka EU95 h.d.tv project[1] (an outline of this collaborative European scheme was given in the March 1988 issue, p.294). It will take place at the site of the International Broadcasting Convention, 23-27 September, but will not be an official part of the convention and will not be open to all IBC visitors. It has a limited objective: to demonstrate a working chain of hardware based on an interim h.d.tv production standard of 1250 lines, 50 fields per second and a 2:1 interlacing factor.



Bosch h.d.tv camera for Eureka 95 system (see July issue, 708-710 for a description).

This hardware is designed as if for a compatible broadcasting system – an essential feature of the European proposal. The compatibility will be with the MAC/packet d.b.s. transmissions to be started soon in Europe (e.g. in Britain from the BSB satellite now being prepared for launch). Since the MAC d.b.s. signals will be displayed through MAC decoders on existing standard PAL and SECAM television sets, the EU95 h.d.tv transmissions would therefore be compatible with these 625/50/2:1 receivers. And, of course, the h.d.tv pictures transmitted via the d.b.s. channels would also be displayed on new high-definition television sets as and when these became available.

Demonstration of the interim production standard at Brighton is described as a "limited objective" because it is only one step on the way to a complete and viable system. In the past the television production standard was the same as the transmission standard and the receiver display standard. Then standards converters working between, say 525 and 625-line systems, showed that a production standard need not, in fact, be the same as the transmission (= display) standard.

Now, digital signal processing has advanced to such an extent, and its cost reduced through v.l.s.i. devices, that all three can be different from each other where it serves a practical purpose. For example, large-area flicker, resulting from a combination of field rate and screen brightness, is exclusively a problem of the display standard. It occurs with screen areas subtending a large angle at the eye because the outer part of the retina is more sensitive to flicker than the fovea or central part. Component manufacturers are therefore now beginning to supply chip sets with digital field memories for receivers to enable incoming 50 field/s transmission standard pictures to be displayed at 100Hz field rate in order to eliminate this flicker.

HISTORICAL PERSPECTIVE

As reported in March, the Eureka 95 collaborators are proposing a single world digital production standard of 1152/50/1:1 (sequential scan) with a 16:9 aspect ratio and 1920 samples per active line for luminance (960 for colour). At Brighton they will only demonstrate an interim production standard because it is as far as they can get in a race against time. An earlier demonstration, at the 1987 Berlin radio and tv show, was little more than a statement of intent and did not include any encoding/decoding hardware. The race results from the need to meet an important deadline – the next plenary assembly of the CCIR in May 1990. As a permanent body of the ITU, the CCIR is the world organization which makes international decisions on broadcast engineering standards.

Eureka 95 made a late start in the h.d.tv stakes because the collaborative organization was only formed in 1986, immediately after the last CCIR plenary assembly held in Dubrovnik. Essentially it was a European reaction to the possibility that the NHK non-compatible 1125/60/2:1 h.d.tv standard could become a *de facto* world standard for broadcasting. This was the only working h.d.tv system offered as a candidate at Dubrovnik and was officially supported by the USA, Japan, Canada, Brazil and Chile. It includes a bandwidth-compression technique called Muse (multiple sub-Nyquist sampling encoding[2]) outlined in the December 1984 issue of *E&WW*, p.38.

Most European delegates at Dubrovnik strongly opposed this 'revolutionary' non-compatible system because they felt it would be disastrous for Europe. A major objection was the incompatible 60Hz field rate. They stressed that they wanted an 'evolutionary' approach to h.d.tv starting from the other end – the existing base of PAL and SECAM receivers in Europe. These millions of 50Hz receivers were not only a huge investment in domestic equipment which should be utilized instead of ignored: in a compatible system they would also provide an immediate audience for the first h.d.tv programmes – before new h.d. receivers became generally available – and thus give a commercial incentive to programme companies to produce material for the new medium.

As a result of this disagreement the 1986 CCIR meeting ended in a stalemate on the question of a world standard. The plenary assembly decided to defer a decision on h.d.tv. It simply issued a report, No 801, giving details of the proposed 1125/60/2:1 standard and adding a footnote expressing reservations. Even before the Dubrovnik meeting there had been discussions between like-minded European broadcasters, equipment makers and government officials on the possibility of establishing an alternative h.d.tv standard. The effect of the plenary assembly was to turn these thoughts into action.

Immediately afterwards, four European companies with interests in television broadcasting equipment and receivers got together to formulate a definite proposal for an alternative standard and the development of equipment to demonstrate it. These were Bosch (West Germany), Philips (Netherlands), Thomson (France) and Thorn-EMI (UK). To obtain EEC backing and financial support, the proposal was put to a June 1986 conference of EEC ministers concerned with the Eureka scheme, which was founded in 1985 for co-operation on advanced technology (*E&WW* April 1986, p.7). It was accepted by the Eureka ministers and given the project number EU95. A first meeting of the new h.d.tv consortium was held in October 1986 and included government officials from the principal countries concerned, France, Germany, Netherlands and UK. Later, Belgium, Italy, Sweden and Switzerland joined as secondary, or 'B' participants.

The extremely urgent research and development effort needed to catch up with the formidable NHK/Sony engineering achievement in h.d.tv – a product of some ten years' work – is being supplied by eleven teams in different countries. These are covering fundamentals and psycho-physics, production standards and conversions, studio equipment, transmission, MAC encoding/decoding, display standards, receivers, home video recorders and players, programme material, bit-rate reduction, and overall co-ordination.

CRITERIA FOR HIGH DEFINITION

A primary question that has to be considered by all these teams is: what is high-definition television supposed to be? Or, more precisely, what performance do we need from h.d.tv to justify the effort and cost of developing it? Fortunately, all countries in the world concerned with h.d.tv, regardless of support for different systems, seem to agree on this. Everyone recognizes that a large improvement in picture quality must be achieved to make it worthwhile.

CCIR report No801 formally states that, relatively to existing tv systems, h.d.tv should have twice the vertical and horizontal resolution (thus four times the picture information), with separate luminance and colour-difference signals and improved colour rendition. Also it should have pictures of wider aspect ratio. Here, everyone seems to agree that a 16:9 aspect ratio is desirable. At a given viewing distance from the screen, a wider picture than in conventional television sets makes the viewer feel more involved with the programme material, possibly because there has to be more movement of the eyes to take in all the picture content. There seems to be general accord here that a viewing distance of three times the picture height (3H) is optimum, as against the typical 6H of conventional viewing. Finally, the CCIR report specifies multi-channel high-fidelity sound.

In general the Eureka 95 project is aiming at a resolution of about 440 000 pixels in the 16:9 format (compared with about 110 000 pixels in a typical 4:3 PAL/SECAM receiver). This would be given by 900 horizontal pixels and 490 vertical pixels. Ideally the receiver display should have a screen area of about $0.8m^2$.

Another general problem already studied by the CCIR is that of finding sufficient bandwidth for world-wide h.d.tv services in the satellite broadcasting frequency allocations at present available. These allocations are at 12GHz, 23GHz, 42GHz and 85GHz. The 12GHz allocation is available for all ITU regions and is planned for analogue transmissions in 24 or 27MHz channels. It allows basebands of a maximum of 12MHz. So with h.d.tv production standards requiring initial vision bandwidths in the region of 30 to 60MHz (depending on the interlace factor, 2:1 or 1:1), considerable bandwidth compression is necessary for transmission in these r.f. channels.

More attractive is the greater bandwidth available at 22.5 – 23GHz. This 500MHz, however, is available for satellite broadcasting only in Regions 2 and 3, not Europe in Region 1. So there would have to be a new international agreement to allow it to be used world-wide. Here, estimates have been made that a possible r.f. channel bandwidth of about 40MHz would allow two h.d.tv channels per country and that signal basebands could be about 20MHz, again necessitating some degree of bandwidth compression.

In the 40.5–42.5GHz and 84–86GHz allocations, rain attenuation is a serious problem and much more development would be needed to make these two bands suitable for h.d.tv. All in all, says the CCIR, for h.d.tv on a world-wide basis there is a requirement for an all-region BSS allocation of about 500MHz, preferably not above 23GHz. The second part of the latest WARC devoted to the geostationary satellite orbit, which was started in 1985 (see December 1985 issue), is now being held in Geneva, but this is not constituted to make any substan-

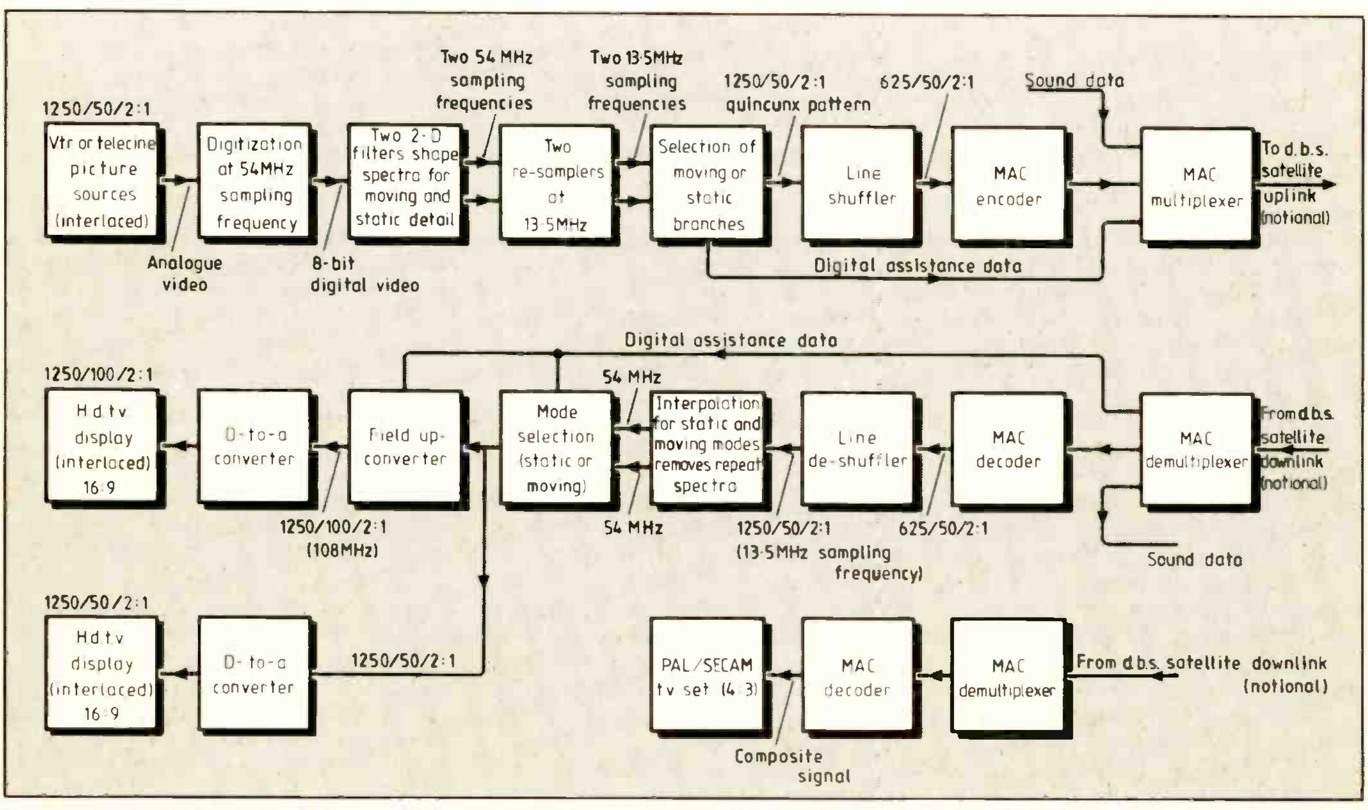


Fig.1. Simplified schematic of Eureka EU95 compatible h.d.tv encoding/decoding demonstration chain, based on interim production standard of 1250/50/2:1. Only luminance digital processing is shown.

tial changes in the d.b.s. allocations. However, the feasibility of making the 22.5 – 23GHz band into a world-wide allocation is likely to be considered at this Geneva conference.

EUREKA 95 PRODUCTION STANDARD

The equipment to be demonstrated at Brighton assumes compatible transmission in the 12GHz world-wide d.b.s. allocation. An outline of the chain of hardware based on the 1250/50/2:1 interim production standard is shown in Fig.1. For simplicity only the luminance signal processing is shown. Broadly, this chain is built around two established international broadcast engineering standards. One is the CCIR 4:2:2 digital coding standard for 625-line studio equipment, with sampling frequencies of 13.5MHz for luminance (Y) and 6.75MHz for the two colour components (U and V). All the digital signal processing is related to these sampling frequencies and has eight-bit resolution (256 quantization levels).

The second broadcast engineering standard is the MAC/packet family of transmission systems[3] adopted for d.b.s. by the EBU and recognized by the CCIR. In the Eureka 95 scheme it is being employed as a development from HD-MAC, which itself followed from the earlier extended- or E-MAC, or enhanced C-MAC proposal (see *E&WW* December 1984 p.37, and February 1986, p.7). Essentially the Eureka 95 version provides the extra vision information (pixels) needed for the 16:9 h.d.tv pictures, while allowing conventional PAL/SECAM receivers with MAC decoders to use only the information appropriate for their 4:3 pictures in a compatible fashion. Extra digital information to assist the receiver, called digital assistance data, is transmitted as well. From the EBU MAC family, Eureka 95 will be compatible with both the D-MAC standard as intended for Britain's d.b.s.[4], and the D2-MAC version, intended for cable television systems.

In studying Fig.1, some readers may be puzzled by the block marked '2-D filters' (two-dimensional filters). This term derives from the concept that television pictures are distributions of visual information in space and time. More precisely, the individual pixels in a continuing sequence of pictures can be located in relation to a three-dimension set of co-ordinates: horizontal, vertical and time.[5]

In this context, a conventional filter such as a low-pass type, whether analogue or digital, is only a one-dimensional filter. If connected in a video circuit it simply modifies the vision bandwidth and therefore, on the displayed picture, alters only the *horizontal* resolution.

A 3-D filter, which requires field delays, shapes the bandwidth horizontally, vertically and temporally, so that useful bandwidth is represented by a volume.

Thus a 2-D filter operates in any two of these three dimensions. Sampling is applicable to all three dimensions. Indeed it already exists in one dimension in conventional television – the vertical sampling of the picture by the scanning lines.

In Fig.1 a picture source working on the interim production standard generates ana-

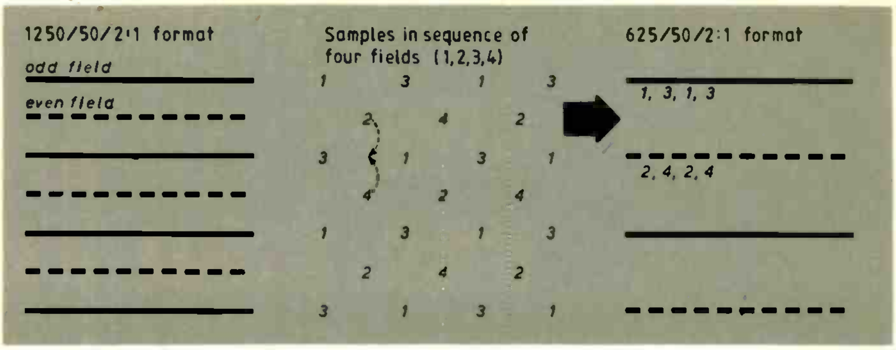


Fig.2. Line shuffling technique combines samples as shown to convert 1250/50/2:1 signal into 625/50/2:1 compatible signal. Numbers indicate both sample positions and successive fields in which these samples occur.

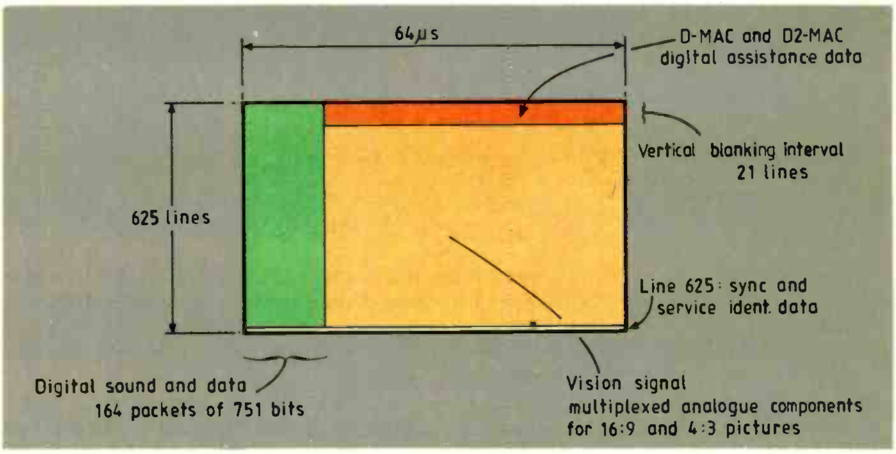


Fig.3. D-MAC format of Eureka 95 compatible h.d.tv signal (not to scale).

logue video signals in component form. This working standard was chosen because its simple relationship to the 625-line television standard allows efficient and economical conversion. At a later stage a sequential source will be introduced to give greater vertical resolution and better digital processing performance. At the demonstration, Thomson will show a 1250/50/1:1 camera as an example.

Analogue luminance signals from the source are digitized to eight-bit resolution at a sampling rate of 54MHz. This is four times the CCIR digital coding sampling rate of 13.5MHz for luminance and has been chosen because of the 4:1 bandwidth compression that follows, thus retaining the CCIR coding standard.

BANDWIDTH COMPRESSION

The next four blocks of Fig.1 are concerned with bandwidth compression and conversion to a 625-line signal format. Bandwidth compression is based on the general principle of first removing redundant visual information from the picture and then spreading selected portions of the resulting video information over an extended period of time. This follows the Hartley-Shannon theory on the maximum communications capacity of a channel in bit/s: a trade between bandwidth, time and signal/noise ratio is possible.

Here the redundant information that is discarded consists of diagonal image frequencies and components of scene movement in which the eye is not sensitive to fine detail. Two 2-D filters perform this spectrum shaping task. Their mode of operation will be described in more detail later with the aid of Fig.4, which is an elaboration of this part of Fig.1.

The reduced-bandwidth signals from the filters are then re-sampled at a lower frequency, namely the 13.5MHz CCIR digital coding frequency for luminance. What are being re-sampled here are the eight-bit representations of the signals. Re-sampling at a lower rate, called sub-sampling, has the effect of spreading the samples over a longer period of time, in this case over four fields. It is effective for bandwidth compression with stationary pictures and static parts of pictures containing movement but introduces a loss of resolution on moving parts. So the two sub-sampled signals are next passed into a section of the bandwidth-compression system that exploits the eye's insensitivity to high spatial frequencies on moving parts of the picture. The purpose of this section is to select dynamically from the two filtered inputs an optimum signal for transmission, depending on the nature of the scene content. It produces a digital assistance signal which carries instructions for controlling a decoding system in the receiver (see later).

At this point the luminance and colour components are still on the 1250/50/2:1 standard, though in sampled and digitized form. The samples of the sub-sampled signal are distributed over four fields as shown in the middle part of Fig.2. Here the positions of the samples are marked by numbers. Each number (1,2,3,4) indicates the field, in a time sequence of four, in which that particular sample has been placed by the sub-sampling process. It will be seen that the samples are arranged in a quincunx pattern (like the arrangement of five dots on one face

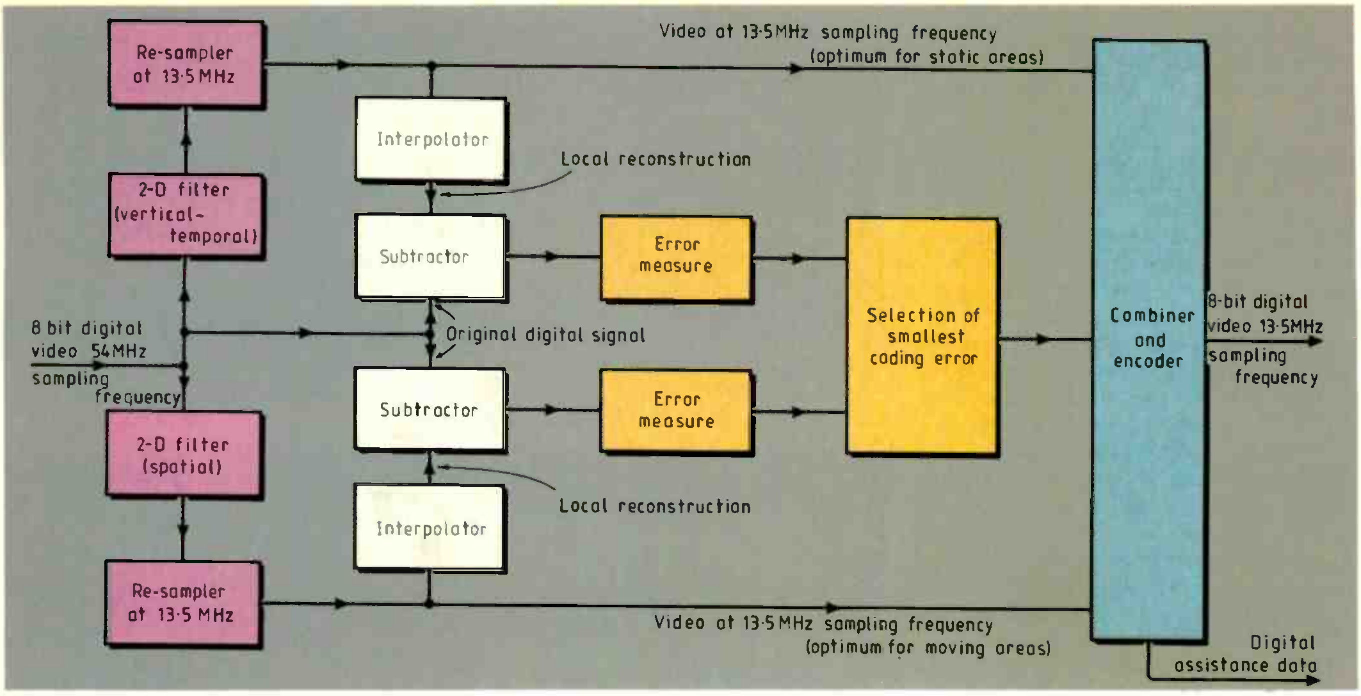


Fig.4. Motion-adaptive bandwidth-compression algorithm used in 1250/50/2:1 encoding chain. This functional diagram is a more detailed version of the third, fourth and fifth blocks of the encoding chain in Fig.1. Interpolators correspond to those in Fig.1.

of a gaming die), a result of the diagonal filtering. The process is similar to that used in the NHK Muse system.

Next, the 1250-line signal is converted into a 625-line format. This is done by a process called line shuffling: the principle is illustrated in Fig.2. Solid lines indicate one field while the broken lines indicate the next field interlaced with it. As can be seen, in a four-field sequence the line shuffler re-arranges samples from two successive lines in each field of the 1250/50/2:1 picture into one line of a 625/50/2:1 picture. Thus samples from odd-numbered fields (1,3) are transferred into one 625 field while samples from even-numbered fields (2,4) go into the next, interlaced, 625 field.

After this line shuffling, the resulting 625/50/2:1 luminance signal shown in Fig.1 passes into a MAC encoder as the Y component, along with the U and V colour components (not shown), of a complete video signal. The Y, U and V components are time compressed and arranged in time-division multiplex, all by digital signal processing. Extra picture information is, of course, generated with the wider, 16:9 h.d.tv aspect ratio relative to the standard 4:3 aspect ratio. In the high-definition MAC encoding equipment contributed by the IBA this is accommodated by time compressing the luminance by a greater amount – a factor of 2:1 (and colour components 4:1) instead of the 3:2 factor (colour components 2:1) used in a conventional D-MAC encoder.

As a result of these higher compression ratios the image frequencies of the analogue components multiplexed in the transmission signal are increased correspondingly. Consequently the high-definition MAC signal has a wider baseband width, of about 10.5MHz, than that of the conventional D-MAC signal, which is about 8.4MHz. However, this can still be accommodated in the normal d.b.s. 27MHz r.f. channel. Pre- and de-emphasis techniques are being considered to improve the signal/noise performance.

After the MAC encoding of the Y, U and V video components they and the digital sound and data packets are time-division multiplexed to produce the complete high-definition MAC waveform for modulating the transmitter. At this point the digital assistance data signal mentioned above is also included in the multiplex. This represents a data rate of about 1.1Mbit/s and is inserted in the 21 lines of vertical blanking period for D-MAC and D2-MAC compatible transmissions (Fig.3).

The receiving/decoding chain in Fig.1 is almost self-explanatory as it reverses the processes described above for the encoding/transmitting chain. Two alternative 1250-line h.d.tv displays are available, one with 50Hz field rate and the other with 100Hz field rate. Reception of the compatible signals on existing PAL/SECAM television sets is indicated at the bottom right. Here, the MAC decoder, in addition to expanding the time-compressed analogue vision components, also receives a data signal telling it what portion of the 16:9 picture to select to form the standard 4:3 PAL/SECAM picture.

MOTION-ADAPTIVE ENCODING

Returning to the bandwidth-compression part of the system, the main functions of this encoding algorithm are shown in more detail in Fig.4. It is a motion-adaptive scheme producing digital assistance signals for transmission to the receiving system.[6] The incoming eight-bit digital luminance signal with a sampling rate of 54MHz is applied to two 2-D filters for bandwidth reduction as explained above. One functions in the vertical and temporal dimensions and gives optimum performance for stationary areas while the other functions in the horizontal and vertical dimensions, or spatial domain, and gives optimum performance for moving areas. After re-sampling at 13.5MHz there are two reduced-bandwidth signals. One gives good resolution on stationary pictures but poor resolution on movement, i.e. blurring. The other gives only moderate resolution on both stationary and moving pictures.

One or other of these two signals is automatically selected for transmission – and this is the motion-adaptive part of the system. To decide which is the better at a given moment, the total picture is divided into a large number of small blocks. Within each block the system first reconstructs two displayable versions from the two re-sampled signals. This is done by the two interpolators shown in the diagram. It then compares these two local reconstructions of the block with the corresponding part of the incoming signal. This is done by the subtractors shown, which give the accumulated difference, or error, between the original and the reconstruction. The two errors are measured; and the version of the block which shows the smaller error, i.e. the better rendition of the original picture, is selected for transmission.

In stationary areas this system uses four fields of samples (Fig.2) to reconstruct an image of high spatial resolution but poor temporal resolution. In moving images it uses one field of samples to reconstruct each image, resulting in reduced spatial resolution but good temporal resolution.

If the receiver is to display optimum pictures by reconstruction from the selected, more accurate, blocks, it must be 'told' for each block which of the two 2-D filtering processes has been used in the motion-adaptive encoder. This is necessary because the receiver decoder must apply the reverse process to that of the selected 2-D filter in each case. Here the reverse process is interpolation, or post-filtering as it is sometimes called (they are functionally equivalent).

To tell the receiver which of the two

interpolators to apply to the incoming video, the encoder in Fig.4 sends a digital control signal. Called 'digital assistance' data, this control information is produced by the coding-error selection block in Fig.4. As shown in Fig.1, it is multiplexed as data in the D-MAC signal and then de-multiplexed in the receiving/decoding chain.

This digital assistance technique, originally investigated by the BBC Research Department and here adopted in the Philips encoding/decoding algorithm, has two important benefits. One is that all processing decisions are taken at the encoding end, using the high quality, full bandwidth signals available at the source, rather than at the receiver where the signals are compressed in bandwidth and may be corrupted by interference and a relatively poor signal/noise ratio. In this way the performance of the system is enhanced. The second benefit is that the highly complex and expensive signal processing hardware is concentrated at the encoding/transmitting end, so that the receiver is kept relatively simple and its cost minimized.

MEASURING SCENE MOTION

A serious limitation of this motion-adaptive bandwidth compression system as it stands is an objectionable loss of resolution on moving areas of the picture which the eye is able to follow – say a slow sweep of a person's hand. The Brighton demonstration stops short at this point and does not provides a remedy in the encoding/decoding alorithm. But the Eureka 95 development teams are now addressing this problem and hope to have overcome it by the time of the next demonstration in late 1989.

The method being adopted is to provide at the transmitting end a refined method of responding to motion. This will measure motion and supply information to the receiver that will result in improved resolution on moving areas.

Essentially the refined system will measure speed and direction of movement in the picture and will transmit this 'motion vector' information to the receiver. The measurement will be made in each of the small blocks mentioned above and the result will be sent as data to the receiver via the digital part of the Eureka 95 signal. In the receiver the motion vectors will be used to control digital processing functions which will enable moving areas to be reconstructed with the same resolution as stationary areas.

Several techniques for television motion measurement have been investigated over the years. One that looks promising at the moment is called phase correlation. Here the correlation measured is between successive images. A two-dimensional Fourier transform is performed on each image, the corresponding frequency components are multiplied together and a reverse Fourier transform is done on the resulting array. This gives a set of numbers called a 'correlation surface', which has a peak at the coordinates corresponding to the shift between the successive images. The correlation surface shows by its shape the direction and velocity of the movement responsible for the shift.

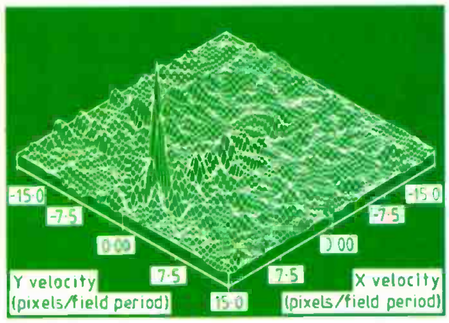


Fig.5. Correlation surface computed from successive images, as one way of deriving motion vectors (BBC Research Department). This example results from a camera pan, where the amount of displacement of the main correlation peak from the origin measures the velocity, here mainly in a horizontal direction.

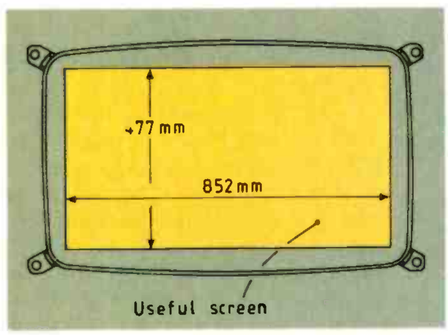


Fig.6. Screen dimensions of a new Sony Trinitron colour tube providing a display of 16:9 aspect ratio. Outside diagonal of the tube is 1048mm.

Figure 5 is an example, a correlation surface calculated from successive images obtained by panning a camera across a scene. Here, the large peak showing high correlation occurs at a certain horizontal (X) velocity, while there is virtually no vertical (Y) velocity. If there had been no movement at all (e.g. before panning) the large correlation peak would have been stationed in the middle of the surface at the origin, indicating zero horizontal and vertical velocities. In Fig.5 the amount by which the peak is displaced from the origin is a measure of the velocity of the pan.

Because only phase information is used, the process is not confused by brightness changes and also has good noise immunity. It is therefore a robust method of measurement. But as described so far it is only capable of measuring overall motion. Real television picture sequences, of course, contain a variety of different movements occurring at the same time.

The BBC Research Department has investigated by computer simulation an extension of the basic phase correlation principle that would be able to measure the motion of many separate objects in a scene[7]. In this the picture is divided into blocks of, say, 64 pixels square. Phase correlation is performed between corresponding blocks in successive pictures. This gives a number of correlation surfaces describing the movement present in different areas of the picture.

Each correlation surface is then searched to locate several dominant peaks – not just one – resulting from the motion of objects within each block. So several motion vectors are measured by each correlation process. A further stage in the method is to assign the principal motion vectors to particular areas of the picture.

Experiments have shown that the phase correlation technique does work well. The BBC says that for simple panning and one moving object, typical vector measurement accuracies of 0.05 pixel can be obtained, and 0.015 pixel by use of a windowing process. They also say that in most cases it is impossible to detect three independently moving objects. Hardware to implement the technique is being constructed.

WIDE-SCREEN DISPLAY

Whatever h.d.tv standard is eventually chosen, the spread of any new broadcasting services based upon it will depend on the availability of receivers with large, wide screens. Most demonstrations so far have used projection displays but wide-screen cathode-ray tubes are beginning to appear as well. To judge from a recently introduced Sony Trinitron tube for h.d.tv, it would seem that these can provide the required aspect ratio of 16:9 but not yet the desirable large screen area of about $0.8m^2$.

Figure 6 shows the 16:9 screen dimensions of this new tube. From these figures one can calculate that the useful screen area is about $0.35m^2$. Deflection angle is 90° and the overall length, following from this, is 798mm, while the neck diameter is 36.5mm. An anode voltage of 32kV is required. The Trinitron, of course, has a screen formed by trios of vertical phosphor stripes, with a corresponding aperture grille behind it. Across the 16:9 screen format there are 1861 phosphor-stripe R,G,B trios, while the aperture grille has a pitch of 0.45mm. The makers claim a horizontal resolution of more than 1000 lines and a screen luminance of $95cd/m^2$. A display monitor constructed with this tube operates on 1125/60/2:1 and has a video bandwidth of 30MHz.

Wide-screen tubes of this kind must obviously be bulky and heavy (here 105kg). As such they provide a strong incentive to further development of flat-screen colour displays for future h.d.tv domestic receivers. Work is continuing in this field, for example at Philips Research Laboratories.

OUTLOOK FOR EUREKA 95

The success of the Eureka 95 system in supporting a possible world h.d.tv standard will depend mainly on whether it achieves a satisfactory compromise between the twin requirements of compatibility and high quality pictures. A compromise cannot be avoided. In practice there is no such thing as perfect compatibility with no impairments whatsoever to the existing broadcast pictures on standard receivers. And in picture quality, with the practical limitation imposed by bandwidth on channel capacity, perfect definition, equalling the resolution of the human eye, is unobtainable. Two researchers examining the psycho-physical bases of h.d.tv have concluded[8] that if a television system were to be "transparent" at a viewing distance of three times the picture height it would have to operate on a standard of at least 2270/80/1:1. This is obviously not possible with existing bandwidth constraints.

Furthermore, in all practical, bandwidth-limited systems the two requirements of good compatibility and high quality pictures conflict with each other. You can improve one, but only at the expense of the other.

There are several other requirements which a h.d.tv system has to meet. It must allow satisfactory recording on video tape; simple transfer from tape to film and *vice versa*; the convenient exchange of high-definition programmes; easy conversion between the h.d.tv production standard and existing production standards; and straightforward transcoding from the h.d.tv production standard to the h.d.tv transmission standard (see The h.d.tv studio. *E&WW* July 1988, p.710).

At the present stage of Eureka 95 development there is a serious problem in obtaining good resolution on movement, as explained above, and this will have to be overcome before the system can be properly assessed as a whole. In the meantime, a belated recognition in the USA that compatibility is, after all, important has given rise to several more h.d.tv system proposals. Some of these have already been outlined in *E&WW* (see March 1988 issue, pp.226-229 and 294). Including the NHK/Sony system already mentioned, no fewer than eight h.d.tv proposals are currently being reviewed in the USA alone[9]. Clearly the Eureka project is up against a lot of competition. But the demonstration at Brighton should at least give a better idea of what chances it has of becoming internationally accepted as a basis for a world standard.

Postscript. Just before going to press, information received from the Eureka HDTV Directorate at Eindhoven suggested that the demonstration equipment at Brighton might differ in a few details from that shown in Fig.1. However, the interim production standard and the principles, parameters and techniques to be demonstrated will remain as described.

In Britain, the DTI has now increased its financial support to UK participants by £1.7 million to make a total of £4.8 million. This £1.7M will go partly to Quantel Ltd. to develop a range of h.d.tv editing and image processing equipment, and partly to Philips Research Laboratories for research into picture analysis and coding techniques.

● The 1988 International Broadcasting Convention will take place at Brighton, 23-27 September. Further information about the technical sessions, the exhibition and other aspects of the event can be obtained from the IBC Secretariat, Institution of Electrical Engineers, Savoy Place, London WC2R 0BL, telephone 01-240 1871.

The author thanks the EBU Technical Centre, the BBC Engineering Information Department and the IBA Engineering Secretariat for their valuable help in the preparation of this article.

Further reading

A useful, though not comprehensive survey of European work on h.d.tv is a collection of five papers under the heading EBU Studies on High-definition Television, reprinted from the *EBU Review (Technical)*, No219, October 1986. Mainly American h.d.tv work, with some European and Japanese, forms the entire contents of the *IEEE Trans. on Consumer Electronics*, vol. 34, No1, February 1988. Earlier papers on an international front are to be found distributed in the Proceedings of the International Broadcasting Conventions for 1982, 1984 and 1986 (IEE conference publications).

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8. I. Childs and R. Melwig. HDTV standard-setting on psycho-physical bases. *EBU Review (Technical)*, No219, October 1986.

9. R. Hopkins. Advanced television systems. *IEEE Trans. on Consumer Electronics*, vol. 34, No1, February 1988. Some of the systems described here were listed in the Television Broadcast column, *E&WW* July 1988, page 724.

Superconductive j-fets

It is broadly assumed that many semiconductor devices are suitable for use at cryogenic temperatures. Indeed, many semiconductors may work at cryogenic temperatures, but few actually offer the sensitivity available at room temperature. The junction field-effect transistor, however, shows little shift in performance over changes in temperature, and offers a unique solution for operation at cryogenic temperatures, writes Ed Oxner of Siliconix.

Most cryogenic instrumentation relies on indium-phosphide or germanium-gallium infrared sensors to monitor activity. These sensors, like the common electret sensor, present an extremely high impedance. As long as the sensors/detectors operate at high impedances, whether at cryogenic or at room temperatures, j-fets should be the first choice.

The reason why j-fets outperform bipolar transistors when input impedances are high is simple. The term noise really defines a power phenomenon, represented as E^2/R or I^2R. When j-fets are operated with a gate voltage, the noise power is reduced by resistance (E^2/R). However, for the bipolar transistor, which uses a base-drive current, the noise power is a *multiple* of this high resistance (I^2R). Hence, the j-fet easily outperforms the bipolar transistor when high-impedance sensors are involved.

Problems increase below the temperature of liquid nitrogen (77K). At 40K, a phenomenon known as (silicon) 'carrier freeze-out' halts all action of the semiconductor, whether it is a bipolar transistor or a fet. As the critical superconductivity temperature rises, transistor action returns. The extent to which it returns depends on several factors, but the most crucial appears to be related to the doping concentration.

Siliconix has responded to the current interest in the superconductivity, and is actively pursuing a low-noise development. Although already offering a commercially available j-fet, the Siliconix Si4338 (g_m=750μS, C_{gd} = 1pF, typically) that offers outstanding noise performance at 80K of 25nV/√Hz at 10Hz and of 104nV/√Hz at 1Hz, the company says it is developing a higher gain j-fet with even lower cryogenic noise.

In addition to superconductivity, there are other applicaitons for cryogenic fets, for NASA, for orbital astronomy, and for the military. All these rely on high-impedance sensors, so they must use fets to gain the advantage of increased sensitivity and dynamic range. For example, radio astronomers, who seek and send signals far into the solar system, have historically pushed the technology, seeking fets with a 1/f noise voltage of 20nV/√Hz at 10Hz at 50K. Today, they hope to halve that figure. As the noise voltage is halved, the signal/noise performance of the system is doubled. Therefore, focusing on astronomy, the limits are pushed out by offering double the sensitivity of former non-fet systems.

In electrical utility transmission lines, for example, up to 15% of the generated electric power is lost during transmission because of resistive wire losses. In fact, the US-based Pacific Gas & Electric Company is reported to lose more than $200M each year through transmission resistance. It is speculated, however, that when superconductivity becomes fully practicable the web of electrical lines will be replaced with buried tubular cryogenic dewars containing low-voltage, high-current superconductive transmission lines engulfed in liquid nitrogen. Conduction in zero-resistance superconductive transmission lines, achieved with high currents rather than high voltages, would also save energy by eliminating high-voltage corona discharge. The initial costs of such a system would be staggering, but these costs must be weighed against the improved efficiency that would result in tremendous energy savings.

Other commercial applications could also see revolutionary changes. Motors for heavy machinery that today run with large heat exchangers to limit entropy might be submersed in liquid nitrogen to eliminate the heat exchangers. Power-station chimneys and acid rain might both disappear. The electric car might become a worthy reality.

IEEE488-to-Z80 interface

A dedicated IEEE488 controller and bus buffers greatly simplify the interfacing of instruments to the SC84 and other Z80-based computers.

T.J. VELLACOTT

John Adams presented his SC84 computer design in E&WW just over four years ago. In the computer world, this is a long time and most applications for which the SC84 would have been considered ideal then are now almost universally implemented using PC-compatibles. But SC84 still has advantages over the more modern approach: in particular, it is adaptable, and facilities can easily be added on plug-in cards designed for a specific purpose, such as this IEEE488 interface.

Since the design was first published, the SC84 Z80 c.p.u. has been upgraded to the more powerful 64180, which is capable of running Z80 software. This article describes hardware, and outlines software requirements, for an IEEE488 interface based on the original Z80 SC84. It was produced for the satellite-instrument testing facility at Oxford which uses SC84s to perform relatively low-level control and data collection to reduce the processor load on a PDP11/23, which has overall control of our experiments. Some modifications may be required to adapt the interface for use with the 64180.

Only one modification to the existing set of three cards is required so the interface board is very easy to install. I wire-wrapped the prototypes, but construction is now much simpler since a p.c.b. is available (details later). For our purposes the IEEE488 socket was bolted to the end of the Eurocard away from the backplane connector, obviating the need for a flying lead connecting to a header on the card.

IEEE BACKGROUND

Originally, the IEEE488 interfacing standard came from Hewlett-Packard, which is why it is often referred to as the HPIB (Hewlett-Packard interface bus); it is also known as GPIB (general-purpose interface bus). Data passes through the interface in bit-parallel, byte-serial form to and from up to thirty slave devices, each with a unique address. One cable connects all slave devices to the controller. As a parallel printer interface, IEEE488 is usually very fast. It is becoming increasingly common to find IEEE488 interfaces on equipment including oscilloscopes and stepper-motor controllers.

The bus consists of eight data lines (DIO_{1-8}) and control/handshake lines (SRQ, ATN, EOI, DAV, NRFD, NDAC, IFC and REN). Control line DAV ('data valid') is used by the sending device to indicate that the data lines contain a valid byte. Signals NRFD ('not ready for data') and NDAC ('not data accepted') are activated by the devices for which the byte is intended until the data has been accepted and the devices are ready to receive the next byte.

Pull-down open collectors drive the interface lines so the logic is active-low. Also, a line remains low until all the collectors connected to it turn off. For this reason, the speed of transfer is determined by the slowest listening device.

Bytes sent on the data lines are either commands or data. Commands are used by the controller to order the source and destination(s) of transfer, or (quasi-asynchronously) to investigate the status of the devices on the bus.

At any moment, the controller may designate a particular device (including itself) to be a 'talker', and others as 'listeners', by sending the address of the device in the low five bits along with the appropriate command in the high three. Under this condition, all those addressed to listen receive data from the talker, and send handshaking after each byte. Similarly the controller may pass control of the whole bus to another device, but the master controller can regain it on demand.

With five bits for address, why are there only thirty-one possible addresses, rather than thirty-two? The reason is that address 31 (decimal) is used for universal negation – for example, telling address 31 to listen has the effect of making everything ignore the data (nothing can ignore commands while its interface is active).

If more than 31 devices are required, there are two choices. One is to use another complete interface (not so silly as it sounds) and the other, which involves a lot more work, and is probably only possible if building a complete system from scratch, is to use secondary addressing, which effectively divides one device into different sections.

Remaining control lines are used as follows. Attention line ATN is activated by the controller to indicate that the data lines (DIO_{1-8}) contain a command, rather than data. Service-request signal SRQ is activated by a slave device to indicate to the controller that it has a problem. In a normal response, the controller asks each device in turn (serial polling) or in groups of eight (parallel polling) which one initiated the service request. End-or-identify signal EOI is usually used to indicate the last byte of a block transfer; it is optionally sent with the last byte and can be used to simplify and speed up a command system.

Interface-clear command IFC is held active by the controller for a specific period, usually only when starting up the bus. Interfaces of slave devices on the bus are activated by the REN command. Many fuller descriptions of the IEEE488 interface standard can be found in previous articles in *E&WW* and elsewhere.

DESIGN

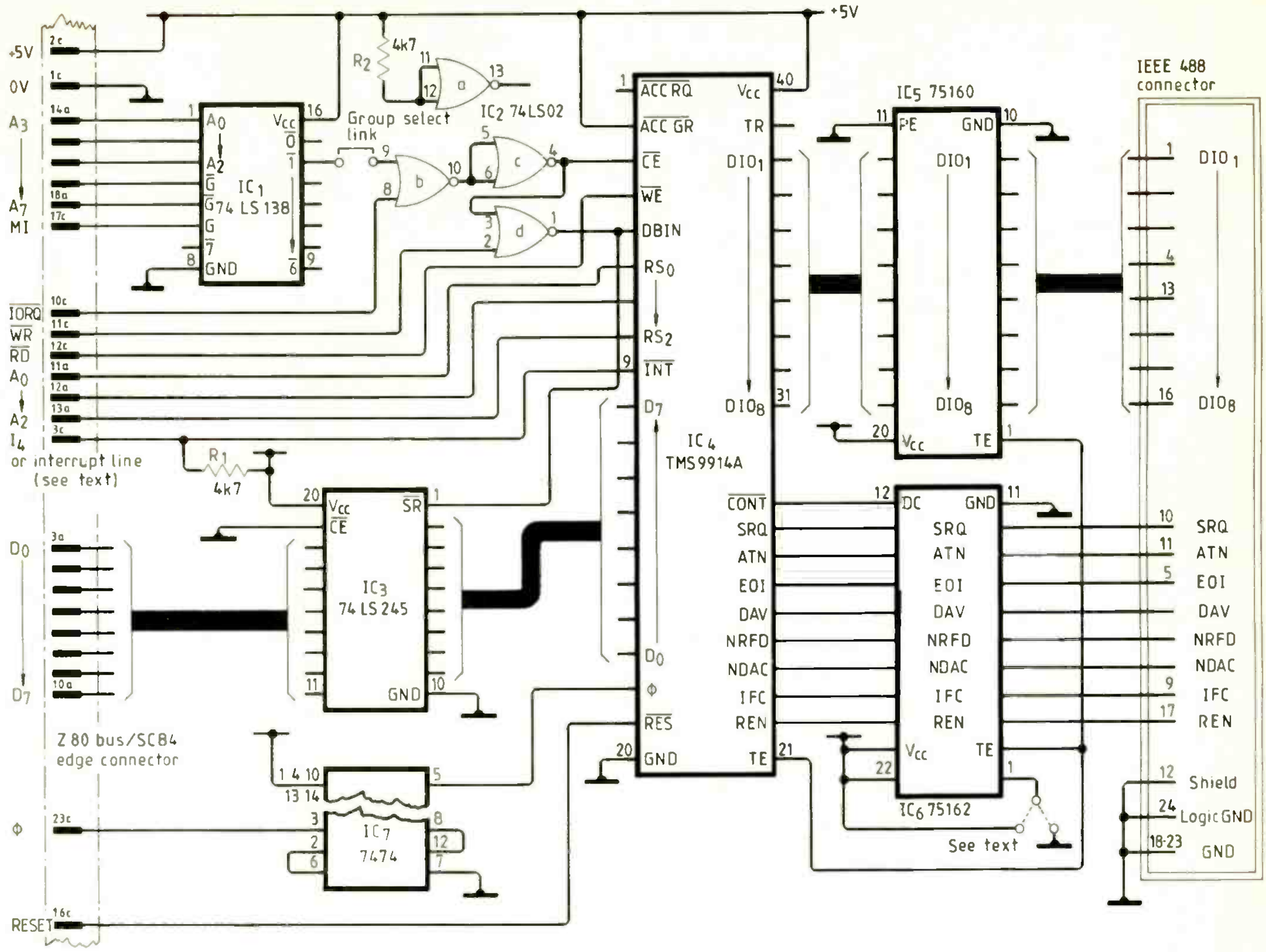
At the centre of the design is a TMS9914A, which connects to the 75160 and 75161 buffers designed specially for IEEE488 interfacing. Almost all of the IEEE488 interfacing is performed by the 9914 alone, and it has the particular advantage of being usable as a controller; other i.cs do not have this capability.

Connection of the 9914 to the Z80 bus is done by the remaining three i.cs through the SC84 backplane, buffering the bus between the 9914 and Z80 and decoding the link-selectable port-address range of the 9914. For interrupts, the 9914 has an open-collector line which in the SC84 connects to line I_4 of the serial timer and interrupt i.c. (STI) using a spare line on the SC84 backplane on the STI card. On other computers this should go to a spare interrupt line. The open-collector output is converted to a voltage level with a resistor to the positive supply rail.

Line I_4 is unused in the basic SC84, and is one of the eight lines on the STI that may be programmed either as a parallel i/o port or as a general-purpose interrupt input. Here I_4 is used as an interrupt line, and the STI registers are reprogrammed to allow interrupts from this source.

Address decoding is straightforward. There are eight registers in the 9914, the required one of which is selected by three lines, RS_{2-0}. Texas Instruments' numbering system for buses is somewhat confusing, since the least-significant bit for the register-select pins is numbered zero, while that for the data bus pins is numbered seven.

Since lines RS_{2-0} connect directly to the lowest three bits of the address bus, A_{2-0} respectively, the eight registers are mapped to eight consecutive ports in memory. Address lines A_{5-3} are sent to a 74LS138 one-of-eight decoder, the highest two, $A_{7,6}$ going to active low ENABLE inputs, and the



remaining three, A_{5-3} being used to select one of the eight output lines used to enable the 9914.

Which output line to use is chosen fairly arbitrarily. Number 1 is used here, so the registers are mapped to ports $10\text{-}17_{16}$. By changing the order of the inputs to the LS138 to any eight unused consecutive ports, the range is selectable.

An often overlooked characteristic of the Z80 is that the IORQ line not only signifies an input/output request, as its name implies, but also an interrupt acknowledgment. When IORQ is active (low), therefore, it does not necessarily imply that i/o is taking place. Whether i/o or an interrupt acknowledge is required is determined by the state of M1 which, when active (low), indicates that the c.p.u. is in the first machine cycle of an instruction (normally the op-code fetch period).

Input/output requests cannot occur during M1, so M1 being active concurrently with IORQ indicates interrupt acknowledgement, while M1 being inactive (high) designates an i/o request. This is why M1 is connected to the active-high enable input of the 74LS138. Of course, it is not a problem for computers which do not use interrupts.

Output of the 74LS138, indicating that the address bus holds an address in the range of the 9914 registers and that M1 is not active, is gated with IORQ by one gate of the 74LS02 quadruple two-input Nor package. This is inverted by a subsequent gate to give

Z80 to IEEE488 interfacing is simplified by the 9914 dedicated controller. Apart from a little control-signal gating, the remaining i.cs simply buffer the various buses.

the correct (active low) sense for the chip-enable input (pin 3) of the 9914, and this signal is also gated with the RD line from the Z80 to give an active-high DBIN signal (pin 5 of the 9914) to indicate that the Z80 wants data from the chip.

The active-high DBIN signal is also sent to the 74LS245 data buffer to indicate that it should send data from the 9914 to the Z80. Care must be taken not to allow data from a peripheral onto the data bus spuriously, as the consequences are generally more disastrous (and less difficult to trace) than a spurious write to a peripheral.

Design of the data-bus buffer is simple. Its chip-enable input is held permanently active (low) so the 9914 data inputs usually follow those of the Z80. Data is ignored by the 9914 until DBIN is high and CE are low; the decoding ensures that there are no spurious writes to the chip. When the 9914 address is selected and the RD line from the Z80 is active (low), the direction of data transfer in the buffer is reversed and output from the 9914 is connected to the bus.

Unused gates of the 74LS02 are tied to +5V through a resistor. As mentioned earlier the 75160 and 75161 buffer output of the 9914, with the control lines using the 75161, and the data lines using the 75160. Input TE, pin 1 of the both the buffers ('talk enable'), determines the sense of the flow through the buffers. A fuller implementation of the IEEE488 standard would require a 75162 instead of the 75161 to allow an overall interface controller to take precedence over temporarily-assigned controllers, but there are relatively few applications where this is necessary.

SOFTWARE

Since the IEEE488 interface is so versatile, and its applications so diverse, it is difficult to give much indication of what software to drive it entails. Consequently I have not included examples. Reference to the Texas Instruments data book on the 9914 is essential.

Under SciDOS and CP/M operating systems it is relatively easy to set up the bus for read/write transfers using the often otherwise redundant PUN: and RDR: logical devices. Where these devices have been allocated, for RS232 input and output ports, accessing the IEEE488 interface from separate programs is more tedious. It is usually better to have one block of general-purpose code used in different ways than to rewrite source code for each application.

Further complications arise when advanced features such as service requests and secondary addressing are used, but with relatively little effort the necessary information can be extracted from the Texas Instruments book. For operation of the interface from SC84, the STI data sheet will also be necessary to find out how to interrupt the main processor.

Software sets the IEEE488 address bus by writing to one of the registers in the 9914, which is why I have not included the customary dip switches. For our purpose this was more appropriate since the various SC84s could have their software exchanged to change their functions. As the address was specified in software, it moved with the function of the computer, not with the hardware.

TESTING

The easiest way to test the interface is to connect a printer with an IEEE488 interface to it. Epson provides plug-in cards for some of its models, which allow the printer to behave both as an addressed device (printing only when told to listen by the controller) and as a bus monitor, when it prints (in hexadecimal form) the contents of data lines DIO_{1-8} as each byte is transferred (slowing the bus down to do so). Each command sent is also printed in bold type, which is very useful.

Connecting other devices to the bus is then quite straightforward, but some interfaces do not seem to behave as expected, so it is as well to have tried your software with a device that is known to work and is understood.

Further reading

Adams, J.H., SC84 Microcomputer. Electronics and Wireless World, June, July, September and October 1984.

TMS9914A General Purpose Interface Bus (GPIB) Controller, Texas Instruments, Manton Lane, Bedford MK41 7PA.

Timothy Vellacott is 23 and in the second year of a Doctor of Philosophy course in the Department of Atmospheric, Oceanic and Planetary Physics at Oxford. He is involved with building part of the PMIRR satellite instrument to be flown on NASA's Mars Observer mission in 1992.

Timothy's IEEE488 interface was designed in 1985 when he was a vacation student in the Department. The satellite instrument mentioned in the article is ISAMS, a stratospheric and mesospheric sounding pressure-modulator radiometer being built by Oxford, Rutherford Appleton Laboratory and British Aerospace, and to be flown on the Upper Atmospheric Research Satellite in the early 1990's. ISAMS will measure temperature and concentrations of gases involved particularly in the chemistry of ozone on a global scale.

Eurocard p.c.bs for this design are available from Combe Martin Electronics, King Street, Combe Martin, North Devon for £9 fully inclusive (UK or overseas). The boards are single sided, silk screened and compatible with SC84's Z80 backplane.

Conferences and exhibitions

5-9 September, Oxford: Science 88. 150th annual meeting of the British Association for the Advancement of Science. Special events include exhibitions in the University and at Oxford Polytechnic, concurrent conferences organized by other learned societies, a scientific film festival, a day of debates on problems now confronting science, a family science day – and a re-enactment by BBC Television of the celebrated confrontation between Bishop Wilberforce and T.H. Huxley over evolution and the origin of Man, which took place in Oxford at the BA meeting of 1860. Among the highlights of this year's conference are a day's symposium on molecular electronics, a session on educating the engineers of tomorrow, and a lecture by Dr David Jones ("Daedalus" of the *New Scientist*), who promises to demonstrate to his audience some intriguing physical phenomena. A programme is available from the BA in London, 01-734 6010 ext 381.

6-8 September, Wembley, London: **Coil Winding** International exhibition and conference. Details from Bush Steadman and Partners, 0799-26699.

6-11 September, New Delhi: **Electronics India** 88. Details from the general manager, Trade Fair Authority of India, Pragati Maidan, New Delhi, India; telex (India) 031-61022 COMX IN.

9-11 September, Eastbourne: **Tecdoc'88**, technical documentation and communication, organized by the Society of Electronic and Radio Technicians. One of this year's themes is translating documents into other languages – 1992 is not far off. Details from Consert, 57-61 Newington Causeway, London SE1 6BL, tel. 01-403 2351.

12-15 September, University of York: IERE conference on electromagnetic compatibility **(e.m.c.)**. The conference will be preceded by a tutorial day and accompanied by an exhibition. Details from the conference secretariat on 01-240 1871.

13-15 September, Novotel, London W6: **Power UK** 88 and **Enclosures** 88 (note change of dates). Conference topics include battery technology, r.f.i./e.m.i. shielding, smart power, connection design for the enclosure industry. Contact: SCS Exhibitions Ltd at Portsmouth on 0705-665133.

13-16 September, Alexandra Palace, London: **EPoS/EFTPoS 88** – retail automation show and conference, including technical sessions. Details from RMDP Ltd in Brighton, 0273-203581/3.

14-17 September, Washington D.C.: National Association of Broadcasters' **Radio '88**. Details from NAB at 1771 N Street, N.W., Washington D.C. 20036, tel. (202) 429-5420.

19 September, London: one-day conference on digital **cordless telephones** (CT-2, telepoints etc.). Fee: £245+v.a.t. IBC Technical Services, 01-236 4080.

20-24 September, Besançon, France: international exhibition of microtechniques, **Micronora 88**, with the theme cad/cam stamping and machining. Details from French Trade Exhibitions, London, 01-225 5557.

21-25 September, Olympia, London: Personal Computer World Show. Details from Montbuild Ltd, 01-486 1951.

23-27 September, Brighton: International Broadcasting Convention (**IBC88**), with 100 technical papers covering d.b.s. and cable systems, recording, studio and o.b. equipment, measurement techniques and new services, and an exhibition supported by 200 companies from Britain and abroad. Details from IEE Conference Services on 01-240 1871 ext.222.

27-30 September, Birmingham NEC: Test + Transducer '88 exhibition and conference. Electronics in Engineering Design and Design Engineering shows. Details from Trident International Exhibitions Ltd in Tavistock, 0822-614671.

28 September, London: one-day conference, Liberalisation of European **telecommunications** – preparing for 1992. IBC Technical Services, 01-236 4080.

3-7 October, Cascais, Portugal: international conference on the theme New Directions for Unix, with tutorials and showcase. Organized by the European UNIX systems User Group, telephone (Royston, Hertfordshire) 0763 73039.

5-11 October, Cologne: photokina – world's fair of **imaging systems**. KolnMesse, Messeplatz 1, Postfach 210760, D-5000 Koln 21 (Deutz): telefax (0221) 821 2574.

4-6 October, San Diego, California: international **display research** conference, organized by IEEE Electron Devices Society and others. Details from the Advisory Group on Electron Devices, 201 Varick Street, suite 1140, New York, NY 10014.

17-19 October, IEE, Savoy Place, London: fourth international conference on **satellite** systems for mobile communications and navigation. Details from IEE Conference Services, 01-240 1871 ext. 222.

18-20 October, Brighton: Southern Electronics Show. Details from Trident International Exhibitions Ltd in Tavistock, 0822-614671.

24-28 October, Monte Carlo: international symposium on **automation**, concentrating on cell control and quality management systems for the manufacturing industries; accompanying trade exhibition. Details from ISATA in Croydon, 01-681 3069 or 01-686 1329.

26-27 October, Wembley Exhibition Hall, London: Instrumentation Wembley. Details from Trident International Exhibitions Ltd in Tavistock, 0822-614671.

1-3 November, Barbican, London: ITEX – Information Technology Exchange. New event which will display the latest commercial applications of i.t. research and development, linking Alvey, Esprit and other research programmes. Supported by DTI. Cahners Exhibitions, 01-891 5051.

3-6 November, Los Angeles. The DTI is again providing support for British companies wishing to exhibit at **AES**: details from the Sound and Communications Industries Federation in Slough, tel. 06286-67633.

14-18 November, Paris: International Exhibition for Electronic Equipment and Products, PRONIC. Details from French Trade Exhibitions, 01-225 5566.

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PC BUS PERFORMANCE NUBUS VS MICRO CHANNEL

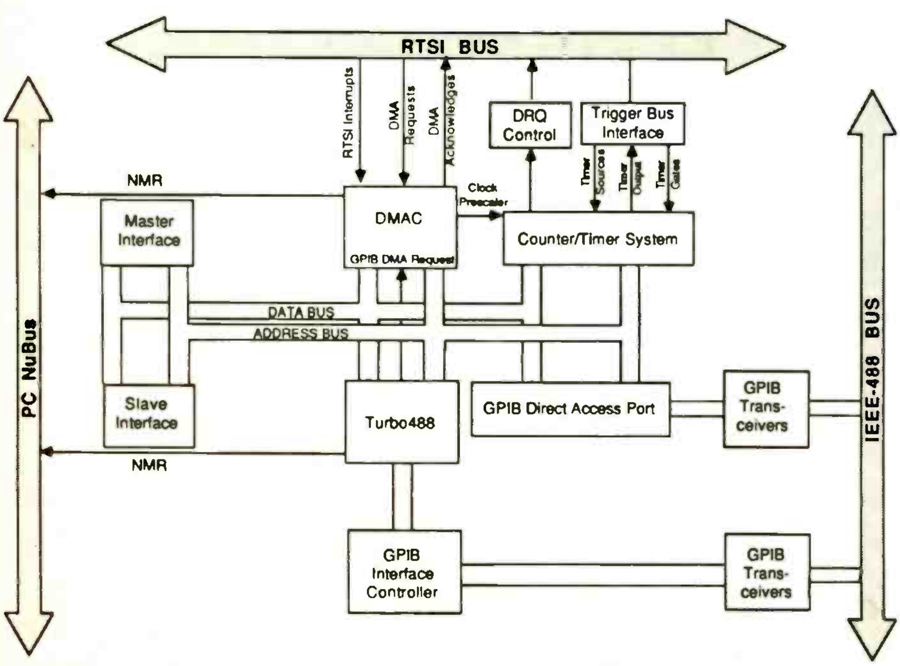
This analysis of two new personal computer bus structures includes comparative measurements based on plug-in GPIB boards.

Two new computers have been introduced recently which use entirely new bus structures for add-in cards. Apple Computer's Macintosh II uses a personal computer version of the NuBus. IBM's new Personal System/2 family uses an improved personal computer bus called the Micro Channel Architecture. This article presents a comparison of the two buses and the two computers, and includes a technical examination of certain measured system characteristics using GPIB/IEEE488 boards which have been developed for both buses.

The Apple Macintosh II and the IBM Personal System/2 computers are attracting a great deal of attention from add-in board manufacturers. The article covers some of the technical aspects of designing cards for these machines.

The Macintosh II is a 32-bit 68020-based computer which uses a personal computer version of NuBus a general-purpose 32-bit computer backplane bus conceived at MIT and developed further by Texas Instruments. At present, the IEEE P1196 committee is formalizing the NuBus specification into a form suitable for acceptance and publication.

The IBM PS/2 family currently consists of six computers, three of which use the new Micro Channel Architecture (MCA). The Micro Channel is a general-purpose computer bus which supports 8, 16, or 32 bit microprocessors, peripherals, and memory. PS/2 Models 50 and 60 are equipped with 16bit 80286s, and Models 70 & 80 use the 32bit 80386. Models 50 and 60 support the 16bit version of the MCA, and Models 70 & 80 support both 16 and 32-bit add-in cards.



Performance examples

The performance specification listed in the panel are all theoretical in nature. To determine how each bus actually performs, I examined two add-in card examples and discuss the measurements obtained.

Table 1 gives a comparison of the two computers used: a Macintosh II computer and a PS/2 Model 80. The Macintosh II is run by a 16MHz 68020 microprocessor and the Model 80 by a 16MHz 80386. The d.m.a. controller in the PS/2 runs at 8MHz, while the Mac is equipped with a National Instruments NB-DMA-8-G board containing an 82380 d.m.a. controller running at 10MHz.

TABLE 1. EXAMPLE COMPUTER SYSTEMS

	NuBus	Micro Channel
Computer	Apple Macintosh II	IBM PS/2 Model 80
Microprocessor	68020	80386
Clock speed	16 MHz	16 MHz
Card slots	6	8
Add-in card	NB-DMA-8-G	MC-GPIB
Operating syst	Macintosh	PC DOS
Wait state	100 ns	62.5 ns

The Macintosh II has six card slots, one of which is used by a display adapter and another which is occupied by the NB-DMA-8-G card. The Model 80 has eight slots, with one taken up by a disc controller and a second slot used by National Instrument's MC-GPIB card.

The Macintosh II runs the Macintosh operating system and the Model 80 runs PC DOS3.3. Slave cards on the Macintosh II can introduce wait states of 100ns each, and on the Model 80 each wait state adds an additional 62.5ns to the transfer.

The NB-DMA-8-G, in addition to its 82380 d.m.a.c. and bus master circuitry, has an IEEE488 interface which responds as a NuBus slave. The measurements described use the NB-DMA-8-G both as NuBus d.m.a. master and slave.

MC-GPIB is an IEEE488 interface for the Micro Channel. It can respond as a bus slave and also contains arbitration circuitry to allow it to be used in conjunction with the d.m.a. controller on the mother board.

Slave performance

In this example, I treat the NB-DMA-8-G and the MC-GPIB cards as bus slaves and measure some of the timing parameters which are of interest and which affect i/o performance.

A block diagram of the NB-DMA-8-G is shown alongside. For performance testing, I had the Macintosh II's 68020 execute a simple i/o write test. The test programs, shown on this page, transfer data to and from the 16×16 bit, fifo memory in the Turbo 488 integrated circuit on the card.

The same test was performed on the PS/2 Model 80 using the code shown. A block diagram of the MC-GPIB card, right, identifies the Turbo 488 and circuitry that perform slave functions which are quite similar to those on the NB-DMA-8-G.

Table 2 gives a summary of the performance obtained using the test programs and the two different systems. The fifo read and write cycle times are theoretical best-case values. Note that the NB-DMA-8-G adds 200ns to the fastest possible transfer cycle on the NuBus. This extra delay is due to fifo synchronization arbitration and access time. Similarly, the MC-GPIB adds approximately 125ns to the minimum Micro Channel cycle. These delays establish maximum theoretical transfer rates of 2.5×10^6 16-bit transfers per second (5Mbyte/s) for the NB-DMA-8-G and 2.67×10^6 16-bit transfers per second (5.3Mbyte/s) for the MC-GPIB.

TABLE 2. SLAVE TIMING PERFORMANCE

	Macintosh II and NB-DMA-8-G	PS/2 Model 80 and MC-GPIB
Type	16-bit i/o	16-bit i/o
Read cycle (min)	400 ns	375 ns
Write cycle (min) (byte/s)	400 ns	375 ns
Measured i/o read rate (byte/s)	700K	533K
Measured i/o write rate byte/s)	700K	533K
Measured interrupt latency	35 μs	7.3 μs

The actual programmed i/o rates obtained using the i/o read and write test programs are 0.7Mbyte/s for the NB-DMA-8-G and 0.533Mbyte/s for the MC-GPIB. As you can see, bus speed is of less importance in this example than microprocessor performance (execution time, program memory speed, on-chip cache, instruction set, etc).

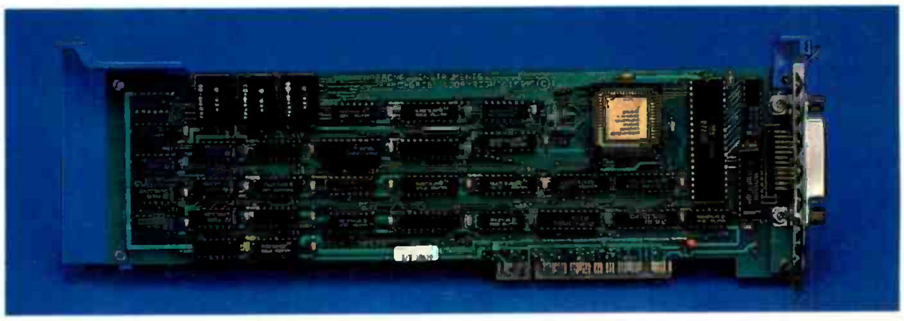
One final slave timing characteristic was measured for both systems: interrupt response time. For this test, the time between when the card generated the interrupt request on the bus to when the interrupt service routine was entered when measured.

The 35μs interrupt latency for the Macintosh II is indicative of the interrupt service queue used by the Macintosh Operating System rather than hardware performance features of the 68020. The 7μs interrupt latency for the PS/2 Model 80 is a close indicator of actual hardware performance, since no intervening interrupt service software overhead is incurred in PC DOS.

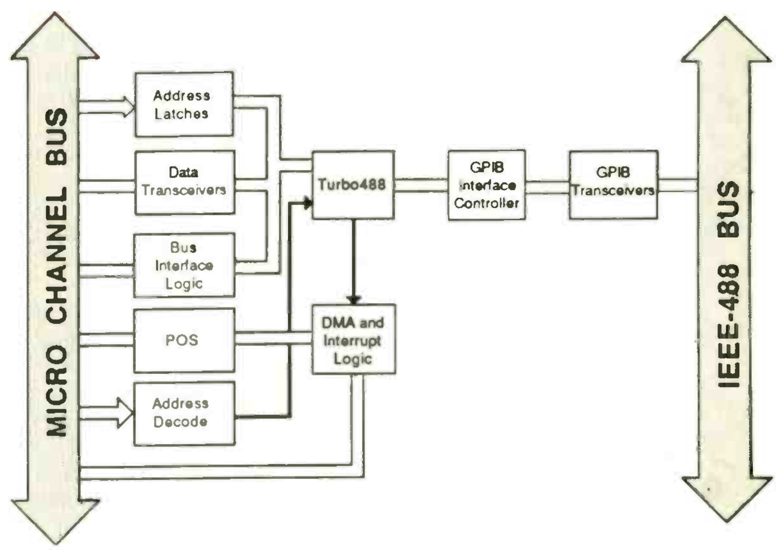
Bus master performance

To measure bus master performance and, in particular, d.m.a. performance, we use the 82380 d.m.a.c. on the NB-DMA-8-G to transfer data to and from the Macintosh II motherboard and the fifo on the card. For the Micro Channel, we use the arbitration circuitry on the MC-GPIB in conjunction with the PS/2 Model 80 d.m.a.c. to transfer data to and from the motherboard memory and the fifo on the card. The results of the test are shown in Table 3.

Burst mode fetch and deposit d.m.a. transfers were used on both machines. Transfers on the NuBus were 16 bits wide for i/o accesses (fifo reads and writes) and 32 bits wide for memory. (The 82380 automatically



The two boards and computers compared in these tests are National Instrument's MC-GPIB interface for the IBM PS/2 (above and below), and the NB-DMA-8G combined d.m.a. controller and 488 interface (page 856).



Macintosh II I/O Write Test Source Code

```
code test-write
                move.l      #$50, d1
                move.l      #fifo_addr, a1
                move.l      #buf_addr, a0
                move.l      #isr3_addr, a2
                move.l      #3, d0
loop            btst        d0, (a2)
                beq         finis
                move.w      (a0)+, (a1)
                dbne        d0, loop
finis           rts
end-code
```

Macintosh II I/O Read Test Source Code

```
code test-read
                move.l      #$50, d1
                move.l      #fifo_addr, a1
                move.l      #buf_addr, a0
                move.l      #isr3_addr, a2
                move.l      #2, d0
loop            btst        d0, (a2)
                beq         finis
                move.w      (a1), (a0)+
                dbne        d0, loop
finis           rts
end-code
```

PS/2 Model 80 I/O Write Test Source Code

```
.285c
                public _fillfifo

 TEXT           segment     byte public 'CODE'

                assume cs:_TEXT

xx              proc        near

_fillfifo:
                push        ax
                push        dx
                push        cs
                push        bx
                push        si
                mov         si, 0ff00H
                mov         bx, 0fe1aH
                mov         cx, 20H
L2:             mov         dx, bx
L1:             in          ax, dx
                test        ax, 8
                jz          L3
                mov         dx, 0fe18H
outs            dx,word ptr ds: [si]
                loop        L2
L3:             pop         si
                pop         bx
                pop         cx
                pop         dx
                pop         ax
                ret

xx              endp

 TEXT           ends
                end
```

PS/2 Model 80 I/O Read Test Source Code

```
.286c
                public _filfifo

_TEXT           segment     byte public 'CODE'

                assume cs:_TEXT

xx              proc        near

_filfifo:
                push        ax
                push        dx
                push        cs
                push        bx
                push        si
                mov         si, 0ff00H
                mov         bx, 0fe1aH
                mov         cx, 20H
L2:             mov         dx, bx
L1:             in          ax, dx
                test        ax, 4
                jz          L3
                mov         dx, 0fe18H
                insw        dx, word ptr ds: [si]
                loop        L2
L3:             pop         si
                pop         bx
                pop         cx
                pop         dx
                pop         ax
                ret

xx              endp

_TEXT           ends
                end
```

TABLE 3. BUS MASTER PERFORMANCE		
	Macintosh II and NB-DMA-8-G	PS/2 Model 80 and MC-GPIB
DMA transfer type	burst dual	burst dual
Data width	16/32	16/16
Master latency	300ns	500ns
I/O read	500 ns	750ns
I/O write	500 ns	750 ns
Memory read	1.1 μs	375 ns
Memory write	1.1μs	375 ns
Transfer rate (byte/s)	1.9M	1.8M

performs source and destination bit width adjustments. The master latency times show how long it took from the time the card requested use of the bus until the time it received bus control.

The i/o read and write times indicate the time taken to access the fifo by the d.m.a. controller. The memory read and write times show how long it took for the d.m.a. controller to access system motherboard ram. Note that it should be possible to substantially increase the performance of the Macintosh II in this example by using a high-speed ram. PC-style NuBus add-in card.

The data transfer rates are given last. The Macintosh II is able to overcome its relatively slow memory access time by transferring 32 bits as opposed to 16 bits on PS/2.

Results

Both machines provide powerful platforms for add-in i/o cards, and both have distinct advantages and disadvantages, as well as unique characteristics. Some of the features that are common to the Macintosh II and the PS/2 Model 80 are high speed, 32-bit microprocessor, memory, and bus; automatic card configuration at power on (no jumpers); powerful interrupt mechanism; and support for multiple add-in cards. Some of the dissimilar features are listed in Table 4.

TABLE 4. MACINTOSH II AND PS/2 MODEL 80 FEATURE COMPARISON	
Macintosh II	PS/2 Model 80
NuBus	Micro Channel
industry standard connectors	custom edge connector
"one" standard bus	multiple versions of bus
medium board area	small board area
synchronous bus	asynchronous bus
parallel bus arbitration	serial bus arbitration
no integral d.m.a.	integral d.m.a.
refresh circuitry on cards	refresh circuitry on
slow memory access	fast memory access

I feel that the 96-pin DIN connector used by the PC-style NuBus cards offers advantages over the edge fingers defined by the Micro Channel Architecture, primarily in terms of mechanical realiability.

The multiple versions of the Micro Channel make it more difficult to develop add-in cards that can be used on all machines and at the same time offer maximum performance. For example, if you were developing a high performance, intelligent peripheral processor card for the Micro Channel, you may be forced into developing two versions: one with a 16-bit interface and one with 32-bit interface.

The small board area available on Micro Channel cards makes development more difficult. In many cases, the developer will be forced into designs which require gate arrays or other asics and/or surface-mounted components. Both of these solutions lengthen development time and, except in very high volume cases, increase manufacturing costs.

At National Instruments, it is easier to design for the NuBus because of its synchronous nature. The separate address and data lines on the Micro Channel do not turn out to be of advantage because timing requirements force addresses to be latched much in the same way that they are latched on NuBus implementations.

Although I don't have quantitative, measured data to support this next conclusion, it is obvious that a portion of the Micro Channel bus bandwidth is utilized by the arbitration process, and that the percentage used increases as more devices contend for the bus. Unlike the Micro Channel, NuBus arbitration occurs in parallel with normal bus traffic.

For i/o intensive applications involving large blocks of data, I feel that it is essential for the computer system to provide d.m.a. transfer capability. The Macintosh II requires that this capability be provided by the add-in cards, themselves. The PS/2 uses a clever scheme which allows cards to use a d.m.a.c. on the motherboard. Unfortunately, the one on the PS/2 Model 80 is limited to 16-bit transfers. Perhaps future members of the PS/2 family will offer full 32-bit support.

The Micro Channel provides refresh support for dynamic ram. add-in cards. This eliminates the expense of refresh circuitry on each ram card. It does, however, utilize bus bandwidth (less than 5% on the PS/2 Model 80). This characteristic is probably paralleled on the NuBus, however, by increased access times during memory refresh and bus access collisions.

Accessing the Macintosh II motherboard ram from an add-in master NuBus card is agonizingly slow by today's standards. The PS/2 family offers acceptable access to its motherboard memory. Perhaps future versions of the Macintosh II will correct this deficiency.

William Nowlin is engineering vice-president with National Instruments Corporation, Austin, Texas, represented in the UK by Amplicon Electronics.

Comparative overview

The table lists some of the primary features of the PC-style NuBus and the Micro Channel bus. The NuBus is considered a synchronous bus. All bus transactions are referenced to a single, 10MHz clock signal. Transactions on the Micro Channel bus are asynchronous and are not referenced to a specific clock signal.

The 10MHz + 0.01% clock on the NuBus has an unequal duty cycle of 25:75. The Micro Channel bus provides a 14.31818MHz + 0.01% clock signal but does not use it for bus timing.

Micro Channel Architecture provides for separate memory and i/o address spaces while NuBus provides for a single address space. I/O addresses on the Micro Channel are 16bits wide, providing 64K bytes of i/o address space.

Memory addresses on the NuBus are 32-bits wide and allow up to 4Gbytes of ram or rom to be individually addressed. The 16-bit version of the Micro Channel uses a 24-bit memory address, which translates to 16Mbytes; the 32-bit version provides a full 32-bit, 4Gbyte memory address space.

Data can be transferred on the NuBus as bytes, 16-bit halfwords, or 32-bit words. The 16-bit version of the Micro Channel can transfer 8 or 16-bit data, while the 32-bit version can handle 8, 16, 24 and 32-bit data. Bit, byte, halfword, and word significance is the same on both the NuBus and the Micro Channel.

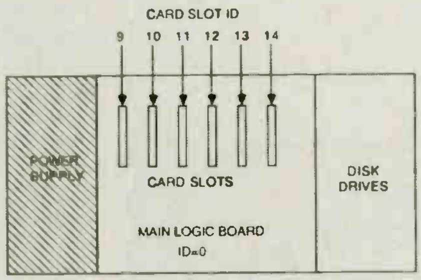
On the NuBus, cards are given 1/16th of the total 4Gbyte address space (256Mbyte). NuBus allows up to 16 cards in a system and each card is given 1/16th of the total 256M card address space (16Mbyte per card). The card automatically assumes its proper address by sampling four signals on the NuBus connector which provide a card identification code.

Micro Channel cards use the Programmable Option Select (POS) feature to determine i/o addresses. Add-in card address information is stored in a non-volatile r.a.m. available to the microprocessor. At power-on-time, the microprocessor reads the address informationi from the n.v. r.a.m. and configures each card in the system. Using the POS mechanism, add-in cards may occupy any free portion of the available memory or i/o address space.

Data transfers. A minimum single data transfer on the NuBus consists of two clock cycles (a start cycle and an acknowledge cycle, of 200ns, which translates to a 20Mbyte/s transfer rate see Tables. The Micro Channel minimum cycle is 200ns, which, for 32-bit data transfers, translates to 20Mbyte/s. The 10MHz 80286 microprocessors used in the PS/2 Models 50 and 60 support a minimum cycle of 300ns, which translates to 6.7Mbyte/s. The 16MHz 80386 Models 70 & 80 have a minimum cycle of 250ns, or 16Mbyte/s. The higher-performance 20MHz 80386 version will be able to support the full 20Mbyte/s transfer rate of the Micro Channel.

Bus masters. NuBus arbitration priority is fixed and depends on the card slot ID, with slot number 15 having the highest priority. Figure 1 shows the relationship of the NuBus slot IDs for the Macintosh II.

The Micro Channel defines 18 levels of fixed priority, see Table. The arbitration level used by an add-in card is normally controlled by a Programmable Option Select register on the card which allows a limited form of programmable priority.



DMA transfers. The Micro Channel computers are equipped with an eight-channel d.m.a. controller. Add-in cards can use the d.m.a. controller to perform data transfers using the standard Micro Channel bus arbitration mechanism. The d.m.a. controller on PS/2 Models 50 and 60 runs with a 10MHz clock, and the 16MHz Model 60 d.m.a.c. runs at 8MHz.

The Macintosh II does not provide a d.m.a. controller on the backplane. For d.m.a. comparison, we used the NB-DMA-8-G card, Fig.2. This provides the Macintosh II with a general-purpose d.m.a. controller for the PC-style NuBus in addition to a 488 bus interface. It uses an Intel 82380 controller running at 10MHz.

An analysis of the d.m.a. capabilities of the Macintosh II equipped with an NB-DMA-8-G card as compared to a 16MHz IBM PS/2 Model 80 with built-in d.m.a. controller is shown in the Table. The analysis is theoretical and assumes best-case conditions.

Each configuration can support eight independent channels. The 82380 on the NB-DMA-8-G can perform 8, 16, or 32-bit data transfers; the PS/2 Model 80 can perform 8 or 16-bit transfers. The Model 80 d.m.a.c. transfers data using a fetch and deposit technique, called flow-through or dual-addressing. The 82380 normally uses the same fetch and deposit method, but can also support single address or flyby d.m.a. transfers.

For this theoretical analysis, I assumed that the data transfers can be performed in the minimum time possible: for both Micro Channel and NuBus.

Burst capabilities allow the d.m.a.c. to keep the bus as long as necessary. Assuming that no higher-priority master is using the NuBus, we can determine the maximum transfer rate obtainable using burst mode. For the NB-DMA-8-G, this time is 600ns per 32-bit fetch and deposit cycle (6.67Mbyte/s) and 400ns per 32-bit flyby cycle (10Mbyte/s).

On the PS/2 Model 80, the memory refresh arbitration level will override any burst transfer in progress. Since a memory refresh takes place an average of once every 15.8µs, this will limit the number of 16-bit fetch and deposit transfers that can be performed during a burst to 25. Using this fact, the maximum burst data transfer rate that can be achieved is 3.1Mbyte/s.

The 82380 d.m.a.c. on the NB-DMA-8-G is equipped with a 24-bit transfer counter, allowing it to transfer a maximum of 16Mbyte/s with one d.m.a. transfer operation.

The custom d.m.a.c. on the PS/2 Model 80, and on Models 50 and 60, contains a 16-bit transfer counter, providing the ability to transfer 64K 16-bit words (128K bytes) or 64K bytes with a single d.m.a. operation.

Interrupts. The PC-style Nubus provides an interrupt request signal for slave cards called non-master requests, or NMRQ. As implemented on the Macintosh II, each card generates a separate interrupt request signal to the 68020 microprocessor on the motherboard. Each slot's interrupt has a programmable priority. Interrupts on the Macintosh II are level sensitive as opposed to edge sensitive.

The Micro Channel implements a shareable, level-sensitive, multiple-line interrupt mechanism. A total of 11 shareable interrupt lines are available on the bus. Priorities are shown in the Table.

MAIN FEATURES OF NUBUS AND MICRO CHANNEL

	NuBus	Micro Channel
Type	synchronous	asynchronous
Frequency	10 MHz	–
I/O address width	–	16 bit
Memory address width	32 bit	24/32 bit
Data width	8/16/32 bit	24/32 bit
Card addressing	Geographic slot	POS
Data address lines	Multiplexed	Separate
Multimaster	yes	yes
Bus parity	Optional	no
Number of cards	16	8

Theoretical maximum bus transfer rates

	NuBus	Micro Channel
Single cycle	20Mbyte/s	20Mbyte/s
Block	37.6Mbyte/s	–
Block size	16 (64byte)	–

Bus masters

	NuBus	Micro Channel
Number (max.)	16	16
Arbitration	Parallel	Serial
Priority	Fixed	Programmable
Fairness	Yes	Programmable

MicroChannel arbitration priority

Arb level	Assignment
–2 (highest)	Memory refresh
–1	n.m.i.
0-7	d.m.a.
8-E	Reserved
F	System microprocessor

Theoretical maximum d.m.a. transfer rates (byte/s)

	Macintosh II with NB-DMA-8-G		16MHz PS/2 Model 80
Number of channels	8	8	8
DMA transfer type	dual	single	dual
Cycle steal transfer rate	5.0M	6.7M	2.0M
Burst mode transfer rate	6.7M	10M	3.1M
Maximum transfer size	16MB	16MB	128KB

MicroChannel interrupt priorities

NMI	Parity, watchdog timer, Arbitration time-out, Channel check
IRQ 0	Timer
IRQ 1	Keyboard
IRQ 2	Cascade interrupt control–
	IRQ 8 Real time clock
	IRQ 9 Redirect cascade
	IRQ 10 Reserved
	IRQ 11 Reserved
	IRQ 12 Mouse
	IRQ 13 Math coprocessor exception
	IRQ 14 Fixed disc
	IRQ 15 Reserved
IRQ 3	Serial alternate
IRQ 4	Serial primary
IRQ 5	Reserved
IRQ 6	Diskette
IRQ 7	Parallel port

IRQ 8-15 are cascaded through IRQ 2

Mechanical comparison

	NuBus	Micro Channel
Board area	~52 in²	~35 in²
Number of i.cs (@ 0.7 in²/i.c.)	74	50
Intercard spacing	1 in	0.8 in
Component height	0.55 in	0.6 in
Connectors	96-pin DIN	Card edge

Bus connectors and signals

	NuBus	Micro Channel 16	16+VE	32	32+MMS
Total active pins	96	112	132	174	182
Digital bus signals	51	76	76	107	107
Total power	23	12	12	18	18
+5V	11	7	7	10	10
+12V	2	3	3	6	6
–12V	2	2	2	2	2
–5.2V	8	0	0	0	0
Ground	22	17	22	26	28
Other and reserved	0	7	22	23	29

FEEDBACK

Better, nicer connector

The review of 'Electronics and computer acronyms' by Phil Brown (*EWW* July) mentions that BNC (as in connector) stands for Bayonet Nut Coupling.

A more interesting version is given by Chet Heyberger and Marshall E. Pryor in 'The XYZs of using a Scope' (Tektronix, Beaverton, 1981) in which BNC means "Bayonet Neill-Concelman"; named for Paul Neill, who developed the N series connector at Bell Labs, and Carl Concelman, who developed the C series connector.

Roy Fursey,
Netherbury,
Dorset.

I am afraid I must take issue with the statement that BNC stands for Bayonet Nut Coupling (book reviews, *E&WW* July 1988). It is in fact short for Bayonet Navy Connector, being a development of the "N" or Navy type coaxial connector. SMA, SMB and SMC are variants of the Sub Miniature connector. All this information can be found in Hewlett Packard's professional r.f. testgear catalogue – which contains a great deal more very useful information (and doesn't cost £24!).

Andrew Emmerson,
Northampton.

School leavers

Mr Linsley-Hood's letter in your April issue touched a responsive chord.

In the early 'eighties I was employed by a major South African recruitment company, involved in placing technicians and engineers.

During this time we saw a number of young persons who were both "inspired and inquisitive", but lacked paper qualifications. Even in this country of (electronics) opportunity, they had difficulty finding positions commensurate with their abilities.

In the end most of them opted for the only other option, and started their own companies.

Thank you for expressing these very necessary sentiments.

Glyn S. Craig,
Microdyne c.c.,
Edenvale,
Transvaal,
South Africa.

F.m. broadcasting

Regarding the comment in Radio Broadcast in your July issue – "listeners have failed to respond to the 'listen on f.m. exhortation' " – the basic reasons for this are the design of domestic receivers (the proposed BBC receiver mentioned in the June issue would be a giant leap forward) and the programmes that are available on f.m.

The BBC must take the blame for the latter, with their policy of frequency-hopping. Imagine how long we would have been stuck with 405-line television had the same policy been applied there. You switch on BBC1 on 625 at 5p.m. on Saturday and the announcer says 'BBC1 programmes continue on 405 only; on 625 we have the third in the series "Spanish for the Hard of Hearing".

Reinforcing the 'listen on a.m.' attitude is the fact that, after twenty years, the BBC's most popular channel has no f.m. service except in the London area and the *Radio Times* lists programmes as on a.m.

What was surprising from the survey mentioned was that 40% do listen to f.m. at some time, despite all the efforts to discourage them from so doing.

S.J. Hampton,
Shoreham-by-Sea,
West Sussex.

Pseudo audio

I read with interest Mr Self's article (July) on the contemporary attitude to audio engineering and its products, and I am grateful that *EWW* has provided a forum in which this matter can be debated.

Since Mr Self invites comments, I would like to offer a few thoughts on this topic. Firstly, I am wholeheartedly in favour of his basic premise, that engineering progress must be founded on objective and reproducible measurements, and on specific technical goals. Opinions, however august their author, cannot be anything other than a possible corroboration that the technical targets sought by the engineers are correct, or an indication that the desired specification is, in some way, less than adequate.

However, the fact that the 'subjective sound' pundits ever got their foot in the door of the standards laboratory in the first place is the engineers' own fault, in that when transistor amplifiers were first introduced, as an 'improvement' on the existing valve-operated designs, they suffered from large amounts of residual crossover distortion – less than 0.1%, perhaps, at full output power, but several percent at normal listening levels. The engineers, and the manufacturers' sales blurbs, said they were excellent, but the man in the street, and his wife, thought they were nasty to listen to, as indeed they were.

We, as engineers, having tardily admitted our error in this matter, then went on to stabilize our amplifier designs, which had massive amounts of negative feedbck to improve the steady-state linearity, with dominant lag compensation, usually across the second gain stage within the overall feedback loop, because this particular technique led to the best high frequency t.h.d. figure. This led, in turn, to audibly objectionable slew-rate limiting effects, the existence of which was again overlooked in the specification, but made the amplifier sound poor, especially at higher output levels.

Once again, the man in the street noted that there were differences in sound quality between similarly specified designs, and that what we said was superb might not provide the sound quality he expected. This, and a few dozen other similar oversights gave the potential buyer of audio equipment the incentive to seek opinions based on listening trials, conducted by respected figures among the 'golden-eared' fraternity, and provided a ready market for the publishers of the magazines which catered for this area of public disquiet.

While I arrived on the transistor audio amplifier design scene rather too late to fall into the pitfall of class-B crossover distortion and I was aware enough to offer designs which were not slew-rate limited, I am sure there are other things which I did not do as well as I should, simply because I do not know sufficiently fully the performance standards I should seek to meet, or the tests which I need to apply, to disclose the faults which a careful listener with good programme material and ideal listening conditions might perceive.

Taking one specific point arising from Mr Self's article, I think he, like the audio engineering world in general, places too much reliance on steady-state tests, such as his low signal-level t.h.d. measurements on different types of capacitors, which appear to have convinced him that there are no effective performance differences between different capacitor types. This may, indeed, be perfectly true under steady-state conditions.

It is my opinion that the pursuit of steady-state linearity has now been carried to such lengths that the bulk of the residual differences between specified electrical performance and apparent sound quality lie in the – normally inadequately specified – behaviour of the audio system under discontinuous or transient signals, which make up such a large proportion of music or speech. It is in this respect that many components, particularly capacitors, exhibit a range of known and measurable defects.

With regard to the transient performance of audio equipment in general, it is certainly possible to distinguish between systems having adequately low steady-state waveform distortion, but with large differences in their response to step changes or other waveform discontinuities.

However, since these differences in transient response are seldom measured and the performance, in this respect, is sel-

FEEDBACK

dom defined, it is possible that in the eyes of the lay user the differing units will appear to be identically specified, which leads to a consequent, but disappointed, expectation of identical sound quality.

I would point, in this context, to the substantial improvements which have been made in sound quality during the development of both cassette recorders and compact disc players, as between early and later designs of the same systems, of which much of the improved performance is due to significant improvements in the accuracy of reproduction of transient-type signals rather than to any lessening of harmonic distortion.

Overall, I simply do not believe that we yet know enough about the importance, in audio terms, of some of the electrical shortcomings of components, or of the waveform distortions arising in the signal chain due to component imperfections or injudicious circuit design – which lead to effects which can be both demonstrated and measured – for us, as engineers, to be able to say that there will be no audible difference between component 'A', having one set of known defects, and component 'B' which has another, different, set, or between systems of which only some of the performance characteristics are identical.

This is not intended as a justification for high-tensile-steel control knobs or mains wiring made from single crystal copper, but as a plea that we should try to assess the significance of the electrical phenomena we do know about, and can measure, before either saying that defects due to this cause don't exist or that the effects that they do introduce must be inaudible – in view of the fact that most available programme material is already degraded.

J.L.Linsley Hood,
West Monkton,
Somerset.

Could it be that my stiff neck is due to the vigorous nodding of my head whilst reading Doug Self's article? Alas, I fear that in your august journal, his well reasoned arguments are largely directed at the converted. It is safe to assume that, had he offered it to the editorial office of any of the well-known hi-fi comics, it would have met with the enthusiasm accorded to a dead rodent.

I cannot but agree with every word, and I say this with feeling, having contributed regularly to the emerging hi-fi magazine world in the distant past, reviewing as well. But what I find much more disturbing is the steady erosion of ethical standards which the review "industry" (I use the word advisedly): the deterioration of technical competence and what appears to be covert corruption as well. Strong stuff? Yes, it is – but there is more than enough evidence of its truth.

On the question of standards, for a start: amongst those reviewers who actively lobby manufacturers and import agents for work, very few have any academic qualifications or training whatsoever; I usually refer to them as the "ex-shop assistant" brigade. From them, we cannot really expect anything other than their own concept of what is acceptable. Sadly, that tiny minority who do have an engineering background have now been fully corrupted by what I refer to as the "Emperor's clothes" syndrome. They either join the Subjectivist chorus – or lose work. Simple as that. It isn't helped, either, by university academics who lend a gloss of respectability by contributing largely unreadable treatises from their ivory towers.

We must remember, and this must not be interpreted as a justification for all this nonsense, that hi-fi is now about consumer durables, like washing powder. Change the perfume and this is the New, Improved Hi-Fi Amplifier; and a sycophantic review press obligingly dances to the industry's tune.

Ethics? Who pays for those trips to shows abroad? Not the magazine, that's for sure. Why are some advertisements refused by at least one well-known magazine, with no explanation given? Why does at least one of our leading high-quality audio manufacturers, Quad, openly discourage reviews of their products (Letters, July, *HiFi News*)? Could it be that, bearing in mind the questionable expertise of those to whom their product is entrusted, they regard a "good" review just as damaging as a "bad" one? Looking at a couple recently, a very expensive amplifier was measured as having an overload of 23dB on a CD input of 100mV sensitivity. Another, in which a CD player measured poorly, yet sounded the "best". In both cases, the reviewers had some degree of engineering qualification – yet not one word of explanation. These two examples are far from isolated. Readers of this magazine will need no explanation from me, as to the absolute failure in this instance to justify public trust.

Like Doug Self, I fear this nonsense is going to be with us a while yet. Experienced engineers will run a mile, rather than take on a review commission these days. This is not to say its end could not be hastened. Reputable manufacturers could go public and disown *all* reviews, until the magazine business puts its house in order. Those reviewers who do still enjoy some respect and are clinging to the wreckage – a mere handful, sad to say – should cease their ambivalence. Abandon all that euphemistic custard poured over a dubious product: emulate the little girl in the fairy tale and cry "But this is rubbish!". I'd like to think it was possible, but you know they have a living to earn. Meanwhile, I shall go on doing my best at the university where I teach and nip this rubbish in the bud as soon as I see it.

Reg Williamson,
Kidsgrove,
Staffordshire.

Three cheers for Doug Self and his spirited attack on the lunatic fringe of the hi-fi fraternity. More power to his elbow.

I would like him to know that there are plenty of us out here who are strictly amateurs so far as audio engineering and hi-fi are concerned, but who are nonetheless enthusiasts and who have some sort of rigorous scientific training, who find it impossible to swallow some of the nonsense currently propounded.

I, for one, believe the following (amongst other things – the list is purely representative, but one could go on and on):

(i) any subjective audible difference between, say, amplifiers, which can be shown to exist by means of a statistically well-controlled double-blind trial, can be explained in terms of measurement and current scientific knowledge;

(ii) it is possible to make one's own perfectly competent if modestly powered amplifier, whose performance need not sensibly to be improved any further, for less than £150;

(iii) loudspeaker cables have a small resistance, even smaller reactance, and that is the end of it – discussions of skin-depth, or worse, transmission lines, are ludicrous at audio frequencies;

(iv) differences between electro-mechanical transducers, and recording techniques (microphone placement etc.) *far* outweigh anything else in subjective terms.

All this seems really very obvious, and yet such is the current seizure of the high ground by the subjective extremists, that I, an amateur at that, feel obliged to state it. Can I put in a plea for people to stand up and say so if they honestly can't tell the difference between amplifier A or B, and not be intimidated into thinking that they have got cloth ears, rather than golden ones. Let us have the courage to shout "The king isn't wearing any clothes!".

John Howarth,
Hull,
Humberside.

It was with some interest and relief that I read the article by D.R.G.Self. As a professional engineer with an interest in high-quality sound reproduction, I have always thought of subjectivism as with little technical foundation and even less common sense.

I would not, however, have been moved to put pen to paper were it not for an article published in the June 1988 edition of *Hi-Fi Answers*. The item entitled 'Free of charge' in my view transcends by orders of magnitude any other writings on subjective

FEEDBACK

audio. In it the author (Mr J.Hughes) puts forward the theories of a Mr P.Belt claiming that the sound of your hi-fi is affected by such perverse things as the number of CDs on your shelf, your wristwatch and even whether your sofa has three or four legs, etc.

Much more worrying is the theory that all unused mains powered appliances in the home must be "neutralised" by shorting the live and neutral pins of the mains plug with a piece of wire and crocodile clips. Although the author does state that appliances must be unplugged, the implications for safety in the home are clearly worrying if readers believe the rest of the article. After telephoning the editorial department of *Hi-Fi Answers* to check if the article was genuine (which it was) I have written to both the magazine and the publishing company to complain. If, as Mr Belt claims, all items in the listening room that carry a static/electromagnetic charge should be neutralized, perhaps the listener should retire to another part of the house whenever the hi-fi is operating, as he/she could be carrying a large static charge and is definitely a source of electromagnetic interference!

In conclusion, subjectivism in the area of hi-fi has now moved way beyond the realm of good sense and one wonders where it can possibly go from here.

S.J. Shorey,
Dartford,
Kent.

Diagrams, please

I am writing on behalf of the Calderdale Business and Innovation Centre (CBIC) with a special request to your readers.

CBIC is a member of a European network of centres set up to help small companies in all aspects of their business development. In particular we deliberately encourage such companies to use modern technology to their advantage. As part of our work we are planning to stage several events and seminars for companies in the Yorkshire and Humberside area. We also take part in events which bring together other members from Europe. At present I am preparing a programme which will (hopefully) demonstrate the changes in electronic technology from the turn of the century through to the present day. The concept is to illustrate, by means of a series of circuit diagrams, not only how the technology has changed but how the "technological information" has changed, i.e. the way the presentation of circuit diagrams as well as the information content therein has changed. The period 1908 to 1988 in 10 year segments has been chosen to illustrate this theme.

I am therefore requesting any of your readers who has, or can get, access to circuit diagrams from these years if they would be so kind as to send me a copy. I am sure the engineers working for the larger corporations would be willing to dig amongst their archive material to find a good example of their past work. These diagrams need not be overly complex, indeed simplicity is probably a more effective way of getting our message across.

Any contributions to this programme would be gratefully accepted and of course your name and company would be acknowledged in the final presentation.

Thanking you in anticipation.

Bill Herdman,
Dean Clough,
Halifax HX3 5AX
West Yorkshire

Wagner, Debussy and electromagnetism

I have read the letter by T.R. Boag in the July issue of *EWW*, concerning the constant k_e in $F = k_e q_1 q_2 / r^2$, the expression linking the magnitudes of the force F between charges q_1 and q_2 separated by a distance r, and I am at a loss to understand his difficulty. The constant is usually written as $1/4\pi e_0$ and has the value 9×10^9 Nm^2/C^2 where F is in newtons, q_1 and q_2 in coulombs and r in metres. This number is easy to remember and is wrong by about 0.1%.

In my experience, e_0 occurs by itself far more frequently than $1/4\pi e_0$; hence I would not like to be writing $1/4\pi k_e$ whenever I meant the constant represented by e_0 if I were constrained to be using standard notation. If Mr Boag wants another symbol as standard, I suggest he advocates something looking vaguely like e_0, as is the case with Planck's constants h and $\hbar$ = h/2.

Finally, the equation

$$F = \frac{1}{4\pi e_0} \cdot \frac{q_1 q_2}{r^2}$$

expresses a relationship between pure numbers. A mathematician would not accept, for example, an answer F = 10 newtons – he would insist that the force is F newtons, the distance apart is r metres, etc., ensuring the quantities are pure numbers and giving the answer F = 10. Given this, I do not understand what Mr Boag is trying to do at the end of his letter by dividing the magnitudes of a charge by a coulomb, of a distance by a metre, and so on. I suggest he consults the maths department of his university for help.

Peter F. Vaughan,
Coutant Electronics Ltd,
Ilfracombe,
Devon.

T R Boag's vision in the July letters of a madman wandering about at a Royal Society Soirée, and introducing himself to all and sundry as 'the Coulomb Constant', is perhaps even more appropriate than he realises. In the original absolute version of the electrostatic units there is no dimensional constant in the Coulomb equation, since the equation itself defines the unit of electrical charge in terms of purely mechanical quantities. Instead there is a purely numerical factor, which is specified in defining a particular absolute system. The symmetry of the force law demands that, if charge is to be given an electrical dimension, then not one but two equal dimensioned constants must be introduced, one associated with each charge in the equation, i.e. that Coulomb's law must be written

$$F = \frac{a_0}{r^2} \frac{q_1}{\sqrt{k}} \frac{q_2}{\sqrt{k}}$$

where a_0/k is equal to $1/4\pi e_0$. If the consequences of this split are systematically followed through, and the fact that some over-familiar equations were originally derived in the Absolute Electrostatic System and contain suppressed dimensional factors is not forgotten, it can be shown that **E** and **D** have the same dimensions, and that at any point in a vacuum both take the same value.

The usual introductions of SI units fail to take account of these suppressed dimensional factors, and introduce some legerdemain into the handling of Gauss's theorem, errors which lead to a number of unexpected dimensional distinctions. Thus **E** and **D** are assigned different dimensions, and take different values at the same point in free space. This result, which physicists of the generation of Jeans and Eddington would for good physical reasons have rejected out of hand, leads to the mystic notion of the 'impedance of free space'.

The logical structure of the SI electrical units is sound enough, and their utility for practical purposes is unquestionable. However the expedients adopted in deriving them created a single 'Coulomb Constant' suffering from incurable schizophrenia, which imposes a heavy burden on anyone trying to understand rather than merely to use electromagnetism. Nevertheless I believe that this burden can be relieved by changes falling well short of complete destruction of the SI Valhalla for practical units.

C.F. Coleman,
Grove,
Oxfordshire.

B3 =/A4 * A3 * /A2 + /A4 ;increment
* A3 * /A1 + /A4 * A3 bit3
* /A0 + /A4 * A3 *

Centre for Development of Telematics
Bangalore
India

HLLLL	HLLLH	L	L	L	;	17	;Loop
HLLLH	HLLHL	L	L	L	;	18	;here
HLLHL	HLLHH	L	L	L	;	19	;until reset

CIRCUIT IDEAS

FM quadrature i.c. works as a p.l.l. detector

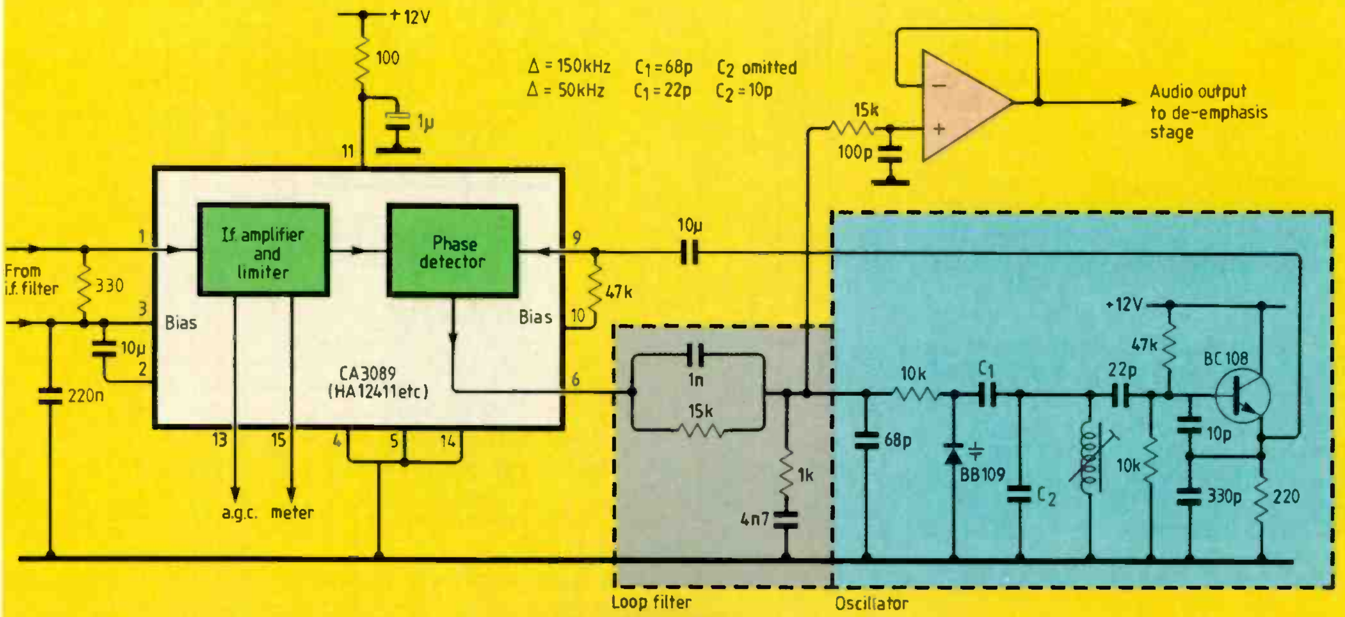
Normally, the CA3089 and its many derivatives are used as quadrature f.m. detectors, and work well where distortion is the primary design criterion. In some applications, however, noise and threshold performance are more important. This idea was designed for demodulation of weak wideband audio subcarriers on satellite tv broadcasts, but with modified values, it may be useful for n.b.f.m.

Inside the chip are a limiting amplifier and phase detector, so by adding an external v.c.o. and loop filter a phase-locked-loop demodulator can be realized.

In the circuit shown, i.f. input is connected as usual so the a.g.c. and signal-level outputs function normally. One input of the phase detector connects internally to the i.f.; the other input comes from the external v.c.o. Control voltage for the v.c.o. is provided by the 'audio output' through the loop filter. With values shown, the simple Colpitts voltage-controlled oscillator operates around the i.f. of 10.7MHz.

Values of $C_{1,2}$ were determined empirically for various frequency deviations and the loop filter was optimized for high-fidelity music. Threshold performance is considerably better than the quadrature detector, but of course distortion is much greater.

M.L. Christieson
Crowborough
East Sussex

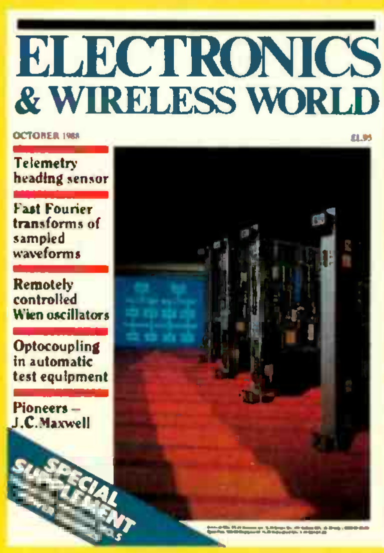


NEXT MONTH

Magnetic heading sensor. Using a pendulous flux valve detector to obtain a direct-current heading signal for airborne telemetry. The device is compact, can be remotely sited and is free from e.m.i. emissions.

Fast Fourier transforms of sampled signals. A procedure to enable the accurate determination of unknown frequencies. The author suggests that the f.f.t. algorithm does not require a repeating waveform and that the waveform in the window is "considered" in isolation.

Remotely controlled Wien oscillators. A novel Wien-bridge oscillator design using analogue switches and photoconductive cells to provide a coverage of 10Hz to 1.3MHz.



Interfacing and signal processing with C. Programming in C has many advantages; this article describes how to exploit the language in interfacing a microcomputer to the outside world.

Butterworth low-pass filter with equalization. Kamil Kraus shows that a low-pass Butterworth with equalization leads easily towards the implementation of a higher-order crossover filter.

Bi-directional opto-coupling. If you need to avoid trouble with earthing and noise, opto-coupling could be the answer. But if there is a computer and a text fixture at each end, it might not be easy; R.A. Beck shows the way.

Fast logic probe

Putting the logic of a logic probe into a p.l.d. results in a fast and versatile unit no larger than much simpler designs.

B.J. FROST

Recently, in a popular compendium of electronic circuits I found no fewer than 24 logic-probe circuits. With so many logic-probe designs around, I feel that I must first justify my version. Its main feature is that it captures pulses too short to display on an oscilloscope. Sometimes simply connecting the capacitance of an oscilloscope probe removes erroneous pulses and causes a faulty circuit to work perfectly – until the oscilloscope is removed. Being built around a programmable-logic device, the probe is small and simple, yet it includes pulse-analysis features.

Two types of pulse that I frequently encounter are problematical enough to justify the probe's pulse-detection facility. They are glitches, i.e. pulses that cause erroneous circuit operation, and pulses such as processor chip-select signals. Neither type of pulse is easily made repetitive, and although processor strobes can be made repetitive by suitable programming, some means of detecting these as single events certainly justifies adding to the logic-probe circuitry.

A major feature of the probe is its ability to classify pulse widths into several bands; the probe differentiates between fast glitches, typical processor strobes and strobes that are too long to be valid. Of these pulses the glitch is the most important since the probe must illustrate the presence of pulses that affect present-day advanced logic such as 74F and 74AC series.

Most logic probes have a pulse-indication facility based on either a monostable multivibrator or pulse-stretching principle. If only edge indication is required, a 74F or 74AC bistable i.c. with a delayed reset provides about the fastest detector. This simplicity diminishes though when detection from any input edge is required.

Any circuitry that responds to both edges must preserve the bandwidth needed for glitch-detection. When the basic logic-probe level-detecting circuitry is added to the pulse-detection circuits, it becomes difficult to accommodate the number of chips required inside a reasonably-sized case. It is not surprising that simple transistor-based probes are so popular.

Each probe function requires only simple logic, but brought together, these functions represent an untidy mixture of gates and inverters. This mixture is ideal for implementing in programmable logic. My probe design has a single programmable-logic array providing the logic-probe functions and pulse-analysis facilities with few additional components.

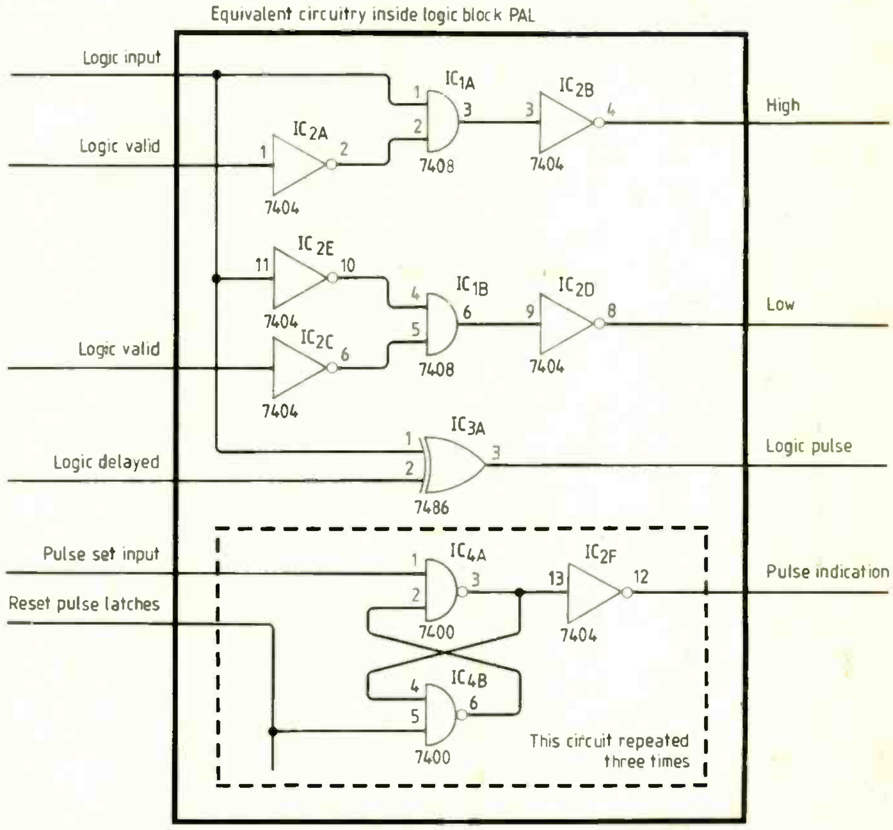


Fig. 1. Logic of the logic probe is programmed into a pal to save space.

Probe circuitry falls into two sections, namely the logic-state indicator and the pulse analyser. Circuitry shown in Fig. 1 and the peripheral components of Fig. 2 will give you an insight into the operation of each section. Logic-state indication is simply a matter of determining whether the probe input is high, low or, with the aid of a window comparator, open circuit. Leds indicating the logic state are driven directly.

Being based on a set-reset bistable device, the pulse analyser is almost as straightforward. Probe input passes through an exclusive-Or differentiator which produces a low-going transition on any probe input transition. This output feeds directly to the first set-reset bistable device which is immediately set on the shortest input pulse and so provides glitch detection.

Four more set-reset bistable devices are fed with the differentiator output but via increasing CR time-constants, such that only pulses that exceed each time-constant will set the corresponding bistable device and illuminate its led. The glitch bistable device will always be set on any pulse and is used together with a reset time constant to clear all the bistable devices after a predetermined display period.

PROGRAMMING THE PLD

Other articles have described the principles behind programmable gate arrays so I will not give the full programming process. List 1, produced using a simple text editor, is passed through a proprietary logic-compiler program and a programming file is produced for sending to a device programmer.

Advantages of this method of logic implementation are apparent from List 1, where you can see that the device inputs and outputs are declared first with a pin name assigned to a pin number in quite arbitrary order and with a polarity that is indicated by an exclamation mark. Thus pin 1 is the logic-probe input, true high, and pin 2 the feed from the window-comparator circuitry, but true low. The two leds indicating the logic state connect to output pins 12 and 19,

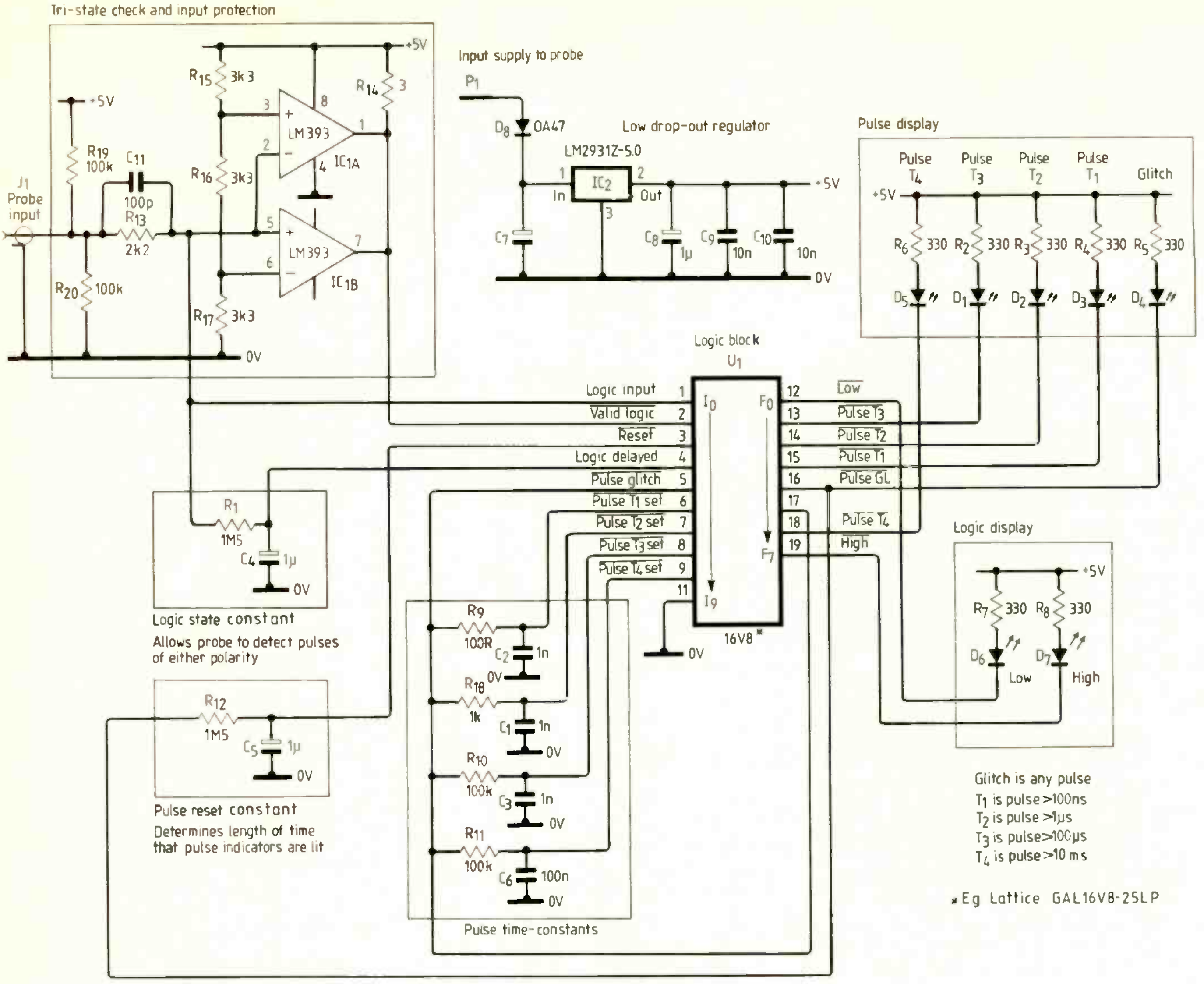


Fig. 2. These simple interface circuits connect to the pal to form the complete logic probe.

which are both true low, and the equations that relate their indication to the input states are:

/* drive HL display leds directly from logic input */
high__led = logic__input & logic__valid;
low__led = !logic__input & logic__valid;

An ampersand indicates the logic And function and an exclamation mark indicates inversion. Thus the 'high__led' pin is true (pin 19 goes low) when the 'logic__input' pin is true (i.e. pin 1 is high) And the 'logic__valid' pin is true (pin 2 low). Compare this with the logic-gate equivalent circuit of Fig. 1 and the similarities should be clear.

This principle can be used to synthesize any logic function and the bistable devices are constructed in a similar way, but need slightly more explanation. When seen on a circuit diagram a set-reset bistable device is often drawn showing a cross-coupled gate pair which conveys both the essential symmetry and the circuit connections. Some drawings do not, or cannot illustrate a gate pair in this way and place one gate followed by another with correct connectivity but with a more hidden actual function.

The logic equation for implementing such a bistable device tends to look like this:

/* latch any pulse at all */
pulse__G = (pulse__G & !reset__pulse) # pulse__G__set;

Here, the output pin of the bistable device ('pulse__G') appears on both sides of the equation, indicating its latching capability. The hash sign represents the logical Or symbol, and the equation output must become true if the input pin 'pulse__G__set' becomes true, irrespective of the state of the output; this is the SET action. Presence of a true 'reset__pulse' causes the expression '!reset__pulse' to become false and any self-latching cannot be maintained; this is the RESET action. This equation is directly equivalent to a cross-coupled Nand-gate pair and displays exactly the same instability of output when both input lines are simultaneously low.

As with any program listing these equations and pin definitions are easily changed without changes to hardware, and it is this flexibility that makes pal devices so attractive. Another advantage of this logic definition is that the logic compiler used to translate these equations into device data also allows a file of test highs and lows to be hypothetically placed on the device input pins and a print-out of the effect on the output pins to be obtained prior to programming the device. Such simulation provides a good chance of first-time success.

Implementing discrete logic with pal devices is an interesting and rewarding subject. A useful publication containing data and applications information is the AMD Programmable logic handbook, available free to designers.

A fast mos version of the popular 16L8 pal providing up to 18 inputs or 8 outputs is used here. Its mos inputs provide little loading to the probe tip and allow convenient CR network component values; its high speed provides pulse detection down to single nanosecond figures.

List 1. These equations, representing the logic within the logic probe, are used to produce the fuse plot for the programmable logic device.

```
/**            Inputs              **/
/**________________________________**/
Pin 1 = logic_input;           /* high is high, low is low */
Pin 2 = !logic_valid;          /* low if a valid logic level */
Pin 3 = !reset_pulse;          /* true to reset the pulse capture */
Pin 4 = logic_delayed;         /* delayed i/p provides auto pulse info */
Pin 5 = !pulse_G_set;          /* set pulse glitch latch */
Pin 6 = !pulse_t1_set;         /* set pulse t1 latch */
Pin 7 = !pulse_t2_set;         /* set pulse t2 latch */
Pin 8 = !pulse_t3_set;         /* set pulse t1 latch */
Pin 9 = !pulse_t4_set;         /* set pulse t2 latch */

/**            Outputs             **/
/**________________________________**/
Pin 19 = !high_led;            /* high display led */
Pin 12 = !low led;             /* low display led */
Pin 17 = !logic_pulse;         /* pulse circuit drive */
Pin 16 = pulse_G;              /* low if pulse at all */
Pin 15 = !pulse_t1;            /* low if pulse >t1 */
Pin 14 = !pulse_t2;            /* low if pulse >t2 */
Pin 13 = !pulse_t3;            /* low if pulse >t3 */
Pin 18 = !pulse_t4;            /* low if pulse >t4 */

/**      Logic      Equations      **/
/**________________________________**/
/* drive HL display leds directly from logic input */
high_led  = logic_input & logic_valid;
low_led   = !logic_input & logic_valid;
/* generate pulse drive from exclusive-Or of input and delayed input */
logic pulse = (logic_input & !logic_delayed)
            # (!logic_input & logic_delayed);
/* latch any pulse at all */
pulse_G   = (pulse_G & !reset_pulse) # pulse_G_set;
/* latch any pulse >t1 */
pulse_t1  = (pulse_t1 & !reset_pulse) # pulse_t1_set;
/* latch any pulse >t2 */
pulse_t2  = (pulse_t2 & !reset_pulse) # pulse_t2_set;
/* latch any pulse >t3 */
pulse_t3  = (pulse_t3 & !reset_pulse) # pulse_t3_set;
/* latch any pulse >t4 */
pulse_t4  = (pulse_t4 & !reset_pulse) # pulse_t4_set;
```

HARDWARE DETAILS

All of the circuitry can be built into a probe case like the one available from RS and other suppliers, and is easily accommodated on the piece of perforated board that comes with the case. The leds can be glued into small holes drilled in the case in groups of two (for the state indicators) and five (for the pulse display). All components are easily obtainable except for the pals; I will be happy to supply these for readers without programming facilities (details later).

A small amount of power supply circuitry is shown in the diagram. Any 5V logic supply could be used to power the probe directly but to ensure that it does not suffer damage, the supply circuitry shown should be included. It consists of a low voltage-drop regulator which only loses about 0.2V at full current and a germanium diode to provide reverse-voltage protection.

Probe input thresholds remain at ⅓ and ⅔ of 5V whatever the supply voltage, but supplies above 8V should not be used for extended periods. Do not omit the 1uF decoupling capacitors on both sides of the regulator. Due to their current-mode output, low-dropout regulators are prone to instability if the required decoupling capacitances are not present.

For the best glitch-catching performance, ensure that the shortest possible ground wire connects the probe circuit to the circuit under test. This connection performs the same function as the ground clip on an oscilloscope probe and has the same characteristics; i.e. it can be ignored for general, uncritical checks, but if working with narrow pulses with wide bandwidth it is essential. Remember that all common logic families except 4000 series c-mos have an edge rate-of-change that is equivalent to bandwidths in excess of 100MHz.

A programmed pal for this design can be obtained by sending £9.99 to Dorset Design and Developments at 8 Robinswood Drive, Ferndown, Dorset BH22 9RZ. This price includes postage and packing.

Brian Frost is with Dorset Design and Developments

BOOKS

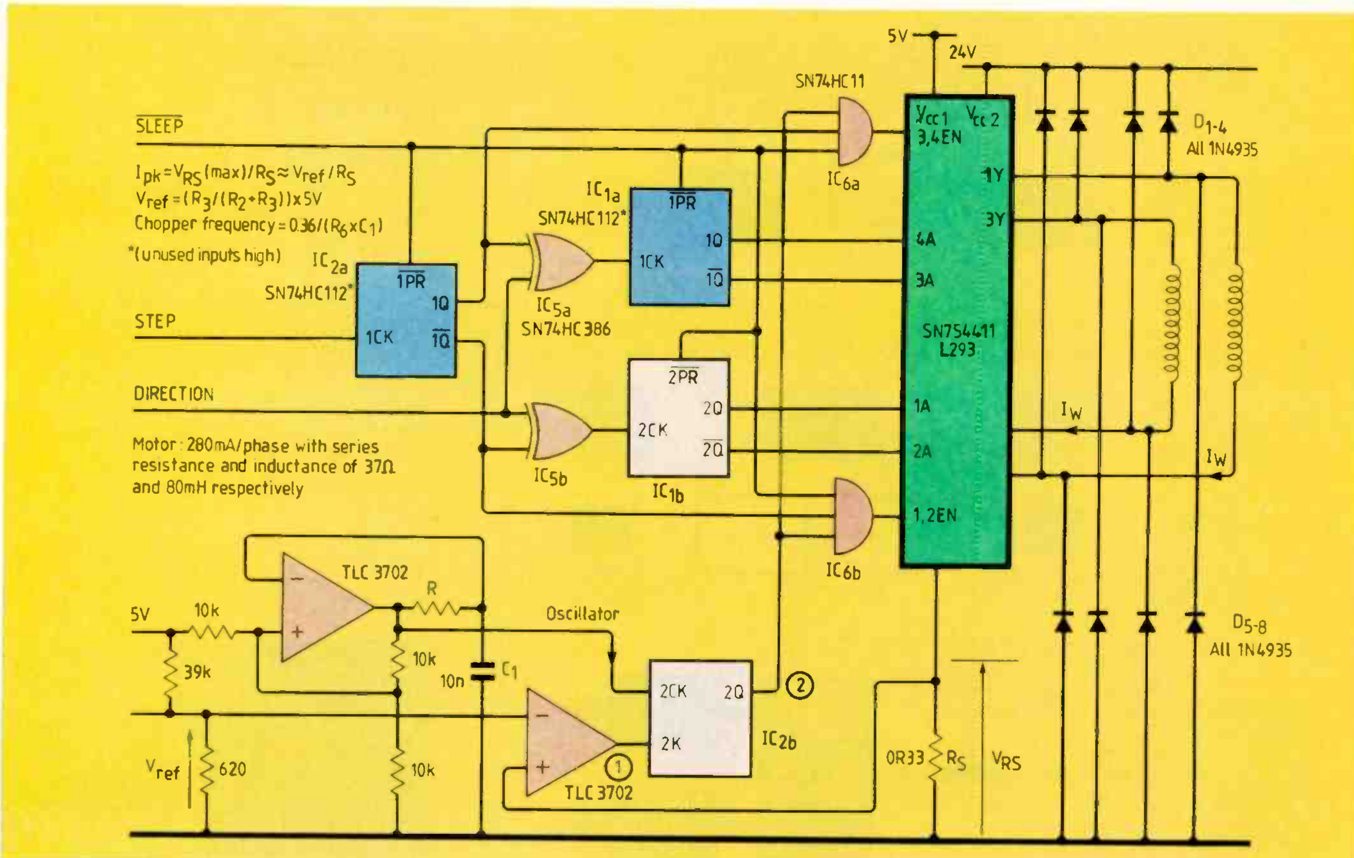
Circuits, signals and devices by Michael Julian (of Bristol Polytechnic). Longman Scientific and Technical, £14.95. Well-filled textbook on electronic engineering for first and second year degree and diploma students, designed to meet the need of readers approaching these topics for the first time although not geared to any particular syllabus. The author's treatment is primarily descriptive, but he supplies extensive mathematical support as well. Text is comfortably set out with many diagrams. An attractive feature is the statement of learning objectives which appears at the start of each chapter and the list of key points to remember at the end. Soft covers, 515 pages.

Programming Windows: the Microsoft guide to programming for the MS-DOS presentation manager. Windows 2.0 and Windows/386, by Charles Petzold. Microsoft Press (Penguin Books). £22.95. Weighty technical manual for the C programmer, providing detailed coverage of all aspects of Windows in comprehensible form. Section headings include basic concepts (creating and displaying windows), getting input (from keyboard, mouse and timer), using resources (memory management, icons, cursors, menus, dialogue boxes), the graphics device interface (bitmaps, metafiles, printers and fonts), data exchange and links. Soft covers, 852 pages.

The programmer's PC sourcebook by Thom Hogan. Microsoft Press (Penguin Books). £22.95. Excellent all-in-one reference work for the PC user, covering chips and hardware, interfaces, DOS commands and utilities, disc usage, function calls and support tables, interrupts, mice, extended memory (Lotus-Intel-Microsoft) support, and Microsoft Windows. The information is extensively indexed and cross-referenced; details of sources are given throughout. Soft covers, 525 pages approximately A4 size.

The early British radio industry by Rowland F. Pocock. Manchester University Press. £27.50. Early means pre-1900, the era when the main customers for radio equipment were Europe's navies. The author, tracing the development of the infant art and the government response to it (the British Government's, mainly), provides a political and economic history rather than a technical one: no diagrams or photographs illustrate his text. Did you know that Britain's industrial decline was recognized as long ago as 1867, and was even then being attributed to a failure to encourage scientific and technical education? Those who ignore the lessons of history are doomed to relive them. Hard covers, 184 pages.

APPLICATIONS SUMMARY

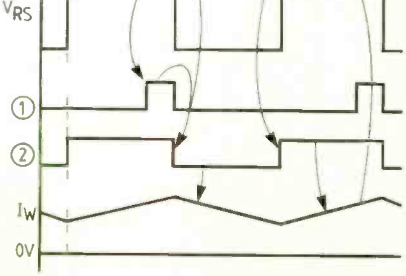


Constant-current stepping-motor drive

A brief stepping-motor overview, a circuit for normal and half-step motor control, and this constant-current driver circuit are contained in the application brief for TI's SN754411/L293 stepping motor controller/drivers.

Motor-winding LR time-constant causes motor current to respond slowly to stepped inputs. Consequently, during high-speed operation, motor speed may never reach its rated value. This chopping circuit allows the motor be be operated from a high-voltage supply, so a faster current increase is possible.

Audible motor noise is avoided by correct choice of frequency-determining components R and C (20kHz). Peak motor current is set by V_{REF} and R_S.



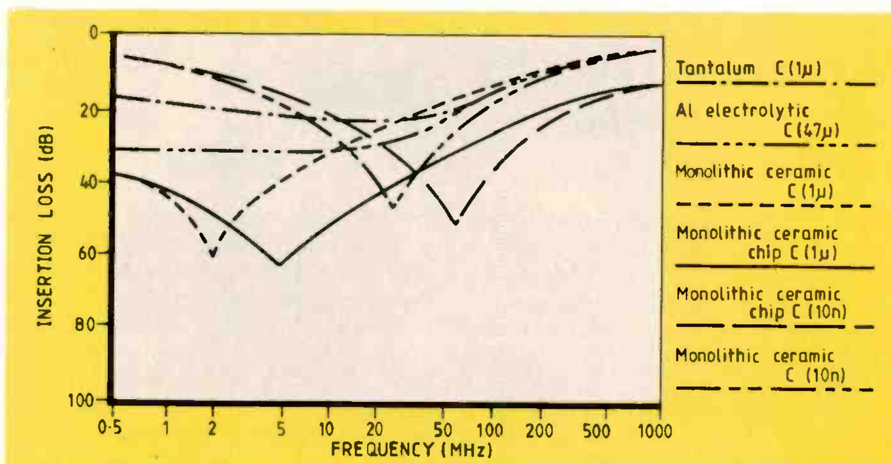
EMI suppression

Residual inductance in a capacitor, which depends on electrode construction and lead lengths, combines with the capacitance to form a resonant network. In e.m.i. suppression applications, this resonant point can significantly reduce the capacitor's effectiveness.

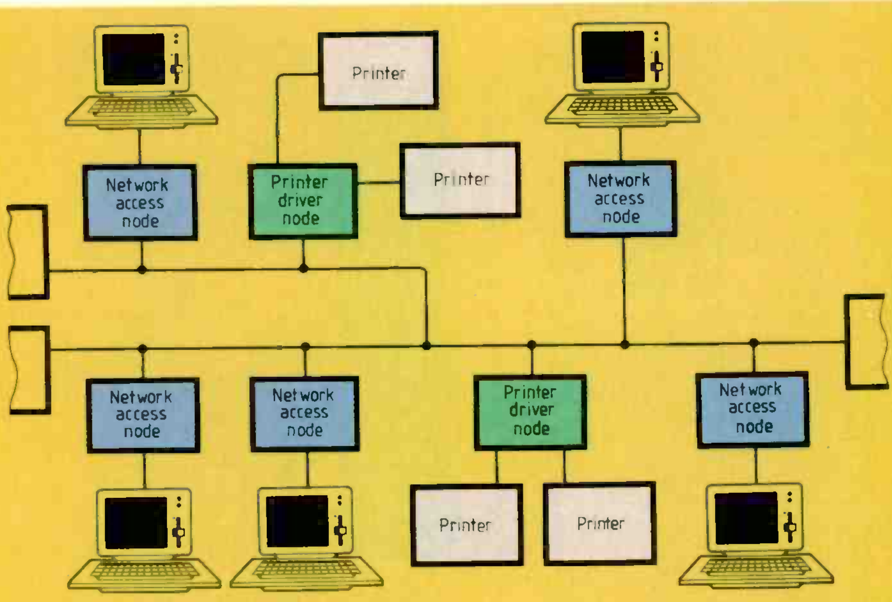
These illustrations, from Murata's "EMI countermeasure" guide, give residual inductance values and insertion losses of typical two-terminal capacitors.

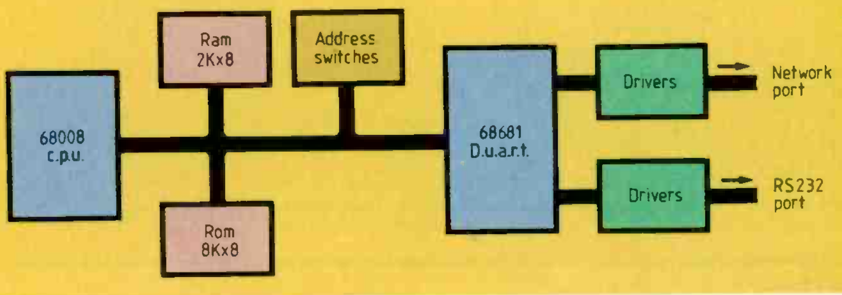
For a publication of its size, the guide does not contain much text, but it is well provided with large illustrations. It presents a summary of the fundamentals of e.m.i. suppression techniques and explains the advantages of three-terminal capacitors. Data sheets for many of the company's suppression devices are included.

Capacitor type	Capacitance (µF)	Series inductance (nH)
Leaded monolithic ceramic	0.01	5
Leaded monolithic ceramic	1	6
Leaded disc ceramic	0.0022	4.5
Polyethylene terephthalate film	0.03	9
Mica	0.01	52
Polystyrene film	0.001	12
Polystyrene film	0.1	100
Solid tantalum	16	5
Aluminium electrolytic for r.f. use	470	13
Aluminium electrolytic	470	130



APPLICATIONS SUMMARY





Small-area networking

Hardware for a simple small-area network can consist of little more than a number of universal asynchronous receiver/transmitters capable of operating in 'multi-drop' mode. Such a network is the subject of note AN990 from Motorola, entitled "A small-area network using the MC68681 duart."

In multi-drop mode the serial frame bit, normally used for parity checking, signals an address when high, or data when low. This feature allows a number of terminals with receiver/transmitters to be linked serially to the same controller and individually written to. With a simple polling mechanism, the terminal controller can also determine whether individual terminals have information to send back to it.

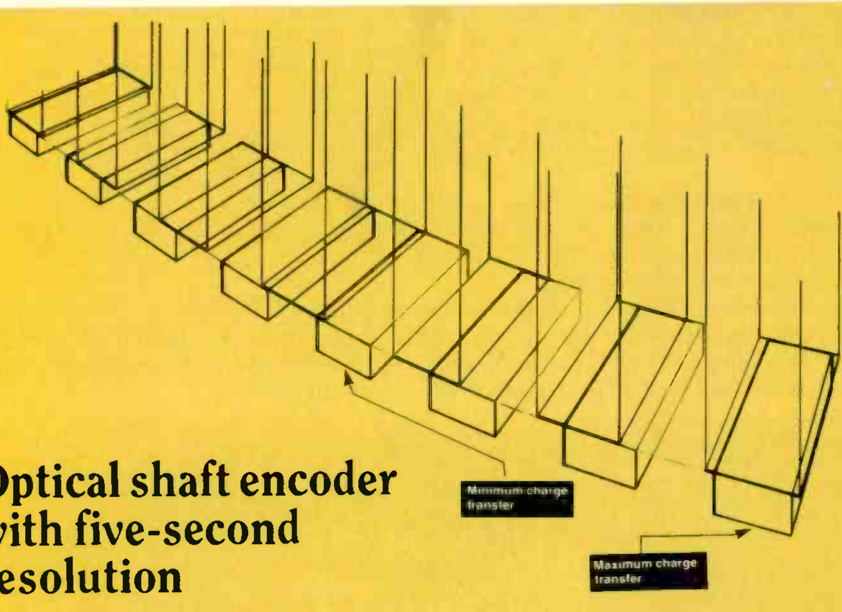
Addresses

Motorola
St Martin's Way, Cambridge Rd
Bedford MK42 0LF
0234 47188

Muirhead Vactric
38 Croydon Rd, Beckenham
Kent BR3 4BE
01 650 4888

Texas Instruments
Technical Enquiry Service
Manton Lane, Bedford MK41 7PA
0234 223000

Murata Electronics
5 Armstrong Mall
Southwood
Farnborough, Hampshire GU14 0NR
0252 523232

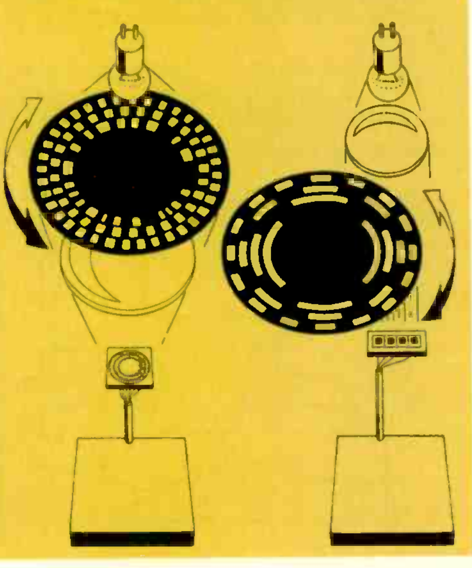


Optical shaft encoder with five-second resolution

Normal rotation encoders rely on sensing radial coded slots or holes on a disc. In contrast, a new encoder technique developed by Muirhead Vactric involves charge-coupled sensors arranged in a ring so that sensing over the whole disc surface is possible.

Resolution is further increased by taking advantage of the c.c.d's analogue sensing nature. The results, described in a brief brochure called "The Microgon Encoder", is a 38mm rotary position encoder with a resolution of 4.94 arc seconds (the first units should be available early in 1989).

On the encoder disc are two concentric tracks – a pseudo-random binary track and a bar track – which form the moiré fringes by interacting with the c.c.d. elements. The light source is pulsed to form instantaneous pattern images on the c.c.d., resulting in a set of charges within the cells. These represent the position of the pattern, and its corresponding moiré fringes. The c.c.d. correlates the pattern position with a predetermined reference position on the disc.



Pioneers

21. Alec H. Reeves, 1902-1971: inventor of pulse-code modulation.

W.A. ATHERTON

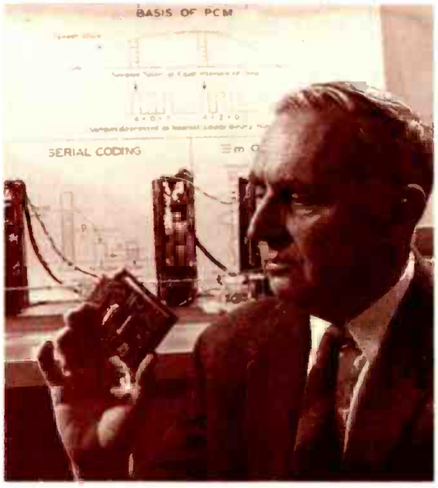
Tune in or fade out: that was the advice given by Alec Reeves in 1971 to engineers and managers to help them face the next fifty years of electronics. Reeves himself was a man highly tuned to his subject. He was the inventor of pulse-code modulation and conceived the idea of the wartime Oboe precision navigation system. His keen sense of the way ahead for telecommunications was evident again in 1960 when he led a team on a then futuristic project to achieve communication using optical waves. The advent of lasers and fibre-optic cables eventually made that possible. C.K. Kao, the father of fibre-optic cables, was employed at the same laboratories and has recalled the inspiration of working among men such as Reeves (see Pioneers 16, *Electronics & Wireless World* April 1988).

For that next half century Reeves foresaw personal global telephone numbers which would go with you anywhere in the world, and 700-line opto-electronic picturephones in colour and with stereo sound. For mass storage he suggested 10^{12} bits per cubic centimetre as an achievable long-term target. That would enable an hour of colour television programmes to be stored in a cubic centimetre of material. The ultimate would be one bit per atom, and there are around 10^{23} atoms per cubic centimetre in a solid. Generally what was needed to face the next half century, Reeves suggested, was a revolution in thought.

Pulse-code modulation is one of the foundation stones of modern telephony. It has especially good immunity to noise and has been used to transmit pictures and data from space. The first American photographs from Mars came via a p.c.m. system. Reeves's patent was filed in Paris on 3 October, 1938, though he had conceived the idea the previous year. As you read this, p.c.m. is 50 years old.

It may seem strange that a British inventor filed his invention in France but the explanation is simple enough. At the time he was working in Paris at the laboratories of the International Telegraph and Telephone Corporation (ITT).

Alec Harley Reeves was born at Redhill in Surrey, on 10 March, 1902. He graduated from Imperial College, London, in 1921 and two years later joined the International Western Electric Company. This was part of ITT and the forerunner of Standard Telephones and Cables (STC) and its laboratories, STL. There he worked on the first commercial transatlantic radio telephone circuit and was one of the first to use the Eccles-Jordan bistable flip-flop to build digital timing and counting circuits. In 1927 ITT opened new laboratories in Paris to which Reeves was transferred. There he stayed until the German takeover in 1940.



Alec Reeves at the age of 63, holding a circuit board from a demonstration model of a p.c.m. system (by courtesy of STC Technology Ltd).

P.C.M.

In Paris the ITT group was looking at ways of using the s.h.f. and u.h.f. bands for radio telephony links. The main problem was noise. Ever since A.G. Bell's invention of "speech-shaped current" the telephone had used analogue circuitry. Frequency-division multiplexing had made multiple channel transmissions possible. But to Reeves, telegraph-style pulse techniques, used with time-division multiplexing, seemed an attractive alternative to analogue methods. Pulse-amplitude modulation was tried and found to work, but the varying amplitudes of the pulses suffered from noise as badly as did analogue techniques.

In 1937 Alec Reeves came to the conclusion that what was needed was a return to the fixed amplitude pulses of telegraphy. They had great tolerance to noise since they were either there or not there. Digital telephony became his target.

Today's preoccupation with digital techniques makes it hard for us to imagine the mental struggles that such ideas posed fifty years ago. Reeves first tried using the width of the pulses to represent the amplitude of the signal (Fig.1). This is now known as pulse-width modulation (p.w.m.) He soon realised that the width could be represented by short pulses for the leading and trailing edge, or better still, by just one short fixed-duration pulse whose position relative to a fixed time represented the amplitude of the signal at that instant (Fig.1). This technique, known as pulse-time modulation or pulse-position modulation, was used in many early s.h.f. radio links.

Pulse-time modulation was an important invention but it did not solve the original problem since noise could affect the position of the pulses and so produce distortions. These effects would be cumulative if passed through many repeaters. Reeves still wanted to approach the telegraph situation where only the presence or absence of pulses mattered: for that he needed not only to sample the signal but also to convert the amplitudes of the samples into some sort of telegraph. To do this he needed analogue-to-digital and digital-to-analogue converters.

He now fell back on his earlier work at designing counting and timer circuits using the Eccles-Jordan bistable. These he combined with pulse-time modulation (p.t.m.). By converting the analogue signal to p.t.m. and measuring the time intervals with his counter he designed an analogue-to-digital converter. Similarly he showed how to convert back from digital to analogue[1]. In his 1938 patent Reeves suggested a sampling frequency of 8kHz (twice the baseband frequency of 4kHz) and 32 amplitude steps (2^5).

P.c.m. did all that Reeves had asked of it except for one thing: it was difficult to achieve with the technology of the day. Widespread implementation had to await the era of cheap transistors and integrated circuits. By that time the STC patents had expired and STC made no money from them[2]. After the war p.c.m. was developed in a number of centres, especially at Bell Laboratories where its feasibility was proved in 1947-1948 by a team led by the famous Harold S. Black, inventor of the negative-feedback amplifier.

OBOE

In 1940 Alec Reeves fled from France leaving his belongings behind – although, I am told, a suitcase was returned thanks to help given by "a man he met in a pub". He joined the Royal Aircraft Establishment at Farnborough but was transferred to the Telecommunications Research Establishment then located at Swanage. There he was in charge of a number of groups of which one, Group 17A, had the task of developing a new long-range blind bombing system conceived by Reeves and code-named Oboe. By now he had laid aside previous qualms about working on offensive systems. The operational system was worked out by F.E. Jones in discussion with Reeves in April-May 1941 but the principles came from Reeves. Airborne trials began in September, a remarkable tribute to the small team which had produced all the equipment[3].

An enormous amount of work and resources were needed to develop and use Oboe even though its principle was remarkably simple. Oboe relieved the bomber crew of the responsibility of deciding when to release the bombs and gave that job to ground-based radar operators hundreds of miles away from the action. The entire system relied on very accurate distance measurement of the aircraft by two widely-separated radar stations and on knowing the exact range of the target from the two stations. This latter requirement necessitated the accurate alignment of the Ordnance Survey with the continent of Europe – whilst the war was raging. A raid on Florennes in Belgium (described by R.V. Jones in his book Most Secret War) helped check this alignment.

Oboe made use of the fact that British radar could make range measurements better than it could make directional ones. As the bomber neared its target it flew on a circular course at a fixed distance from radar station A (Fig.2): this would ensure that it passed over the target, or rather just short of it to allow for the tangential motion of the falling bombs, which were usually dropped from 30 000 feet. Signals from station A told the pilot whether he was on track or to the left or right of it. A second radar station, B, also tracked the bomber: when this was at the correct range from the station the signal was given to release the bombs.

Oboe was tested over bombing ranges in Wales and near Stranraer, the latter some 250 miles from the radar stations. Practice bombs dropped by Mosquito aircraft from 30 000 feet gave an average radial error of 150 yards.[3]

The first Oboe-controlled sortie against enemy targets took place on 20 December, 1942. By the end of the war the RAF had flown about 10 000 Oboe-controlled raids which had marked the targets for nearly 120 000 bombers. The US Air Force had also used Oboe on more than 1600 missions. Air

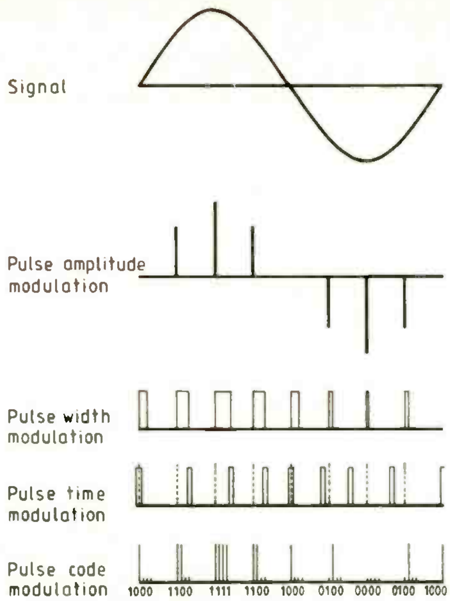


Fig.1. The path to pulse-code modulation. Over a couple of years in the late 1930s Reeves progressed towards digital telephony by a series of steps including modulating the amplitude, the width, and then the position (timing) of pulses. Finally, in p.c.m., only the presence or absence of pulses mattered.

"If I could find the man responsible for this fantastic Oboe I would sack him..."

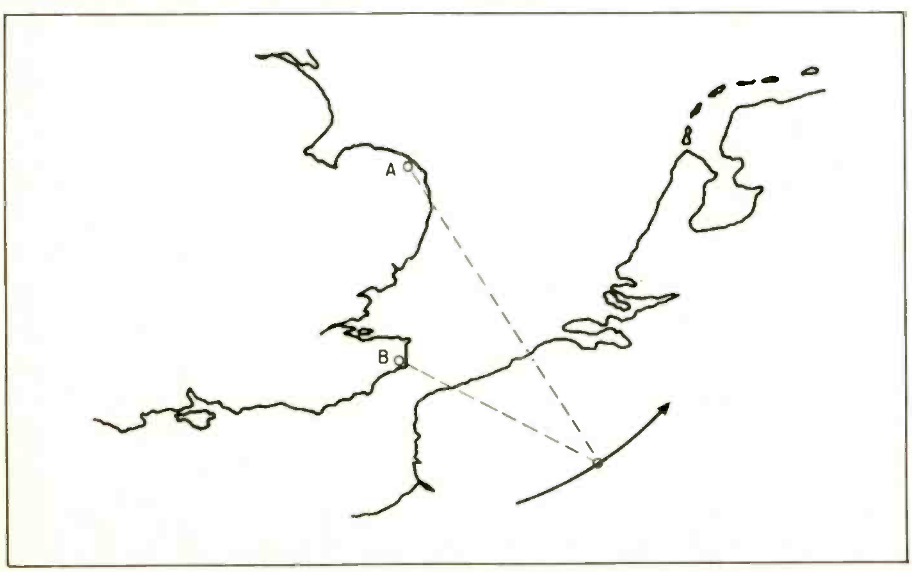


Fig.2. Oboe. By means of a transponder in the aircraft, radar stations A and B could both monitor accurately the distance from them to the bomber. Flying along a curve centred on A, the bomber released its bombs when instructed to by station B. For the Florennes raid in December 1942 station A was at Trimingham and B at Walmer.

Marshal "Bomber" Harris later wrote, "Bomber Command's main offensive began at a precise moment – the moment of the first major attack on an objective in Germany by means of Oboe". It was a far cry from a comment in one headquarters file written at the time when the principles of Reeves's idea was being considered. Perhaps worried by the transponder needed in the aircraft, whose transmissions could be detected by the enemy, a Government scientist wrote of Oboe, "If I had the power I would discover the man responsible... and sack him so that he would no longer waste not only his time and effort but ours also by his vain imaginings"[4]. Instead of being sacked, Reeves was honoured with the OBE in 1945 for conceiving the most precise bombing system of the war.

SAINTLY

After the war Reeves rejoined STL where he stayed until his retirement in 1970. After that he formed his own consultancy and performed work on optical communication systems for the British Post Office until his death on 13 October, 1971 at Harlow in Essex. He had no next of kin. As well as his two main claims to fame, p.c.m. and Oboe, he held about 100 patents and had worked on the first short-wave radio telephone link between Spain and South America.

Reeves has been described as "saintly". It is a poetic description and one which does not spring easily to the lips of engineers when describing colleagues. Professor K.W. Cattermole has written that anyone who knew him would remember his kindness and generosity, his charitable work, personal integrity and sincerity. He devoted time, money and emotional commitment to helping rehabilitate young delinquents back into the community and bore the breaking of trust with the faith that "the right thing to do was the right thing to do". He was a keen mountaineer and encouraged a love for sport in young people, and did not mind recalling being beaten at discus-throwing by a 12-year-old girl.

He received many honours besides his OBE: a CBE, honours from the American IEEE and the Franklin Institute, and a trophy and cheque from ITT. The most unusual one however was a British postage stamp and first-day cover issued in 1969 which commemorated one of the most important inventions in modern telecommunications – pulse-code modulation.

References

1. K.W. Cattermole, *Proc. IEE*, vol.126, 889-892, September 1979.
2. P. Young, Power of speech: a history of STC, Allen & Unwin, London.
3. F.E. Jones, unpublished paper (by courtesy of STC).
4. R.V. Jones, Most secret war, Hamish Hamilton, London, 1978.

Next in this series of pioneers of electrical communication: James Clerk Maxwell – A British scientist second only to Newton.

Tony Atherton works at the IBA Harman Engineering Training College, Seaton, Devon.

Multiprocessor systems

In this third article, Alan Clements looks at how microprocessors communicate with each other.

Up to now I have been looking at the topology of multiprocessor systems with little or no consideration of the actual connections between the processors. Here I describe some of the ways in which processors are linked together and examine the various issues involved in linking them.

COUPLING

Possibly more than any other factor, the required degree of coupling between processors in a multiprocessor system determines how the processors are to be linked. A tightly-coupled multiprocessor system passes data between processors either by means of shared memory or by allowing one processor to access the other processor's data, address and control buses directly.

When shared memory, sometimes called dual-port ram, is employed to couple processors, a block of read/write memory is arranged to be common to both processors. One processor writes data to the block and the other reads that data. Data can be transferred as fast as each processor can execute a memory access. Later I will look at the design of dual-port ram and the problem arising when both processors try to access the same block of memory simultaneously.

The degree of coupling between processors is expressed in terms of two parameters: the transmission bandwidth, and the latency of the interprocessor link. Transmission bandwidth is defined as the rate at which data is moved between processors and is expressed in bits per second. For example, if a 68000 writes a byte of data to an 8bit parallel port every 4μs, the bandwidth of the link is 8bit/4μs or 2Mbit/s. However, if a 16bit port is used to move words at the same rate, the bandwidth rises to 4Mbit/s.

Latency of an interprocessor link is defined as the time required to initiate a data transfer.

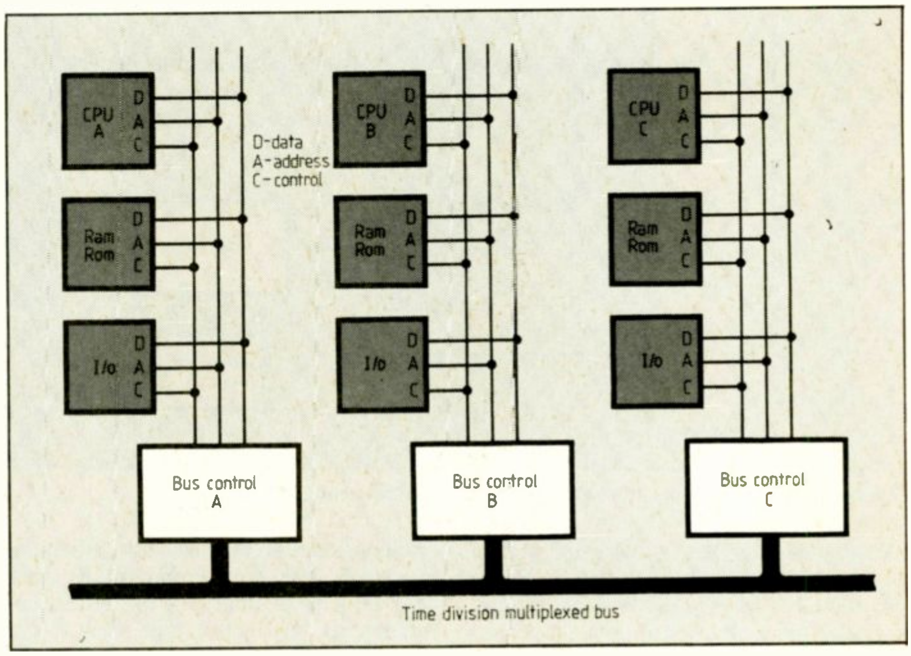


Fig.1. Processors linked by a shared bus.

That is, latency is the time that elapses between a processor requesting a data transfer and the time at which the transfer actually takes place. A high degree of coupling is associated with large transmission bandwidths and low latencies. As you might expect, tightly-coupled microprocessor systems need more complex hardware than loosely-coupled systems.

The way in which processors are linked can be listed in order of their degree of coupling as follows:

- Serial data link
- Parallel data link
- Parallel data link with fifo buffers between processors
- DMA channel
- Shared bus
- Shared common memory

Here, I will describe only interprocessor links involving shared memory or buses.

SHARED BUS

One of the most popular ways of tightly-coupling processors is to permit two or more processors to share the same bus in an arrangement of time-division multiplexing. That is, the bus is allocated to a processor only for a fraction of the available time.

It is possible for more than two processors

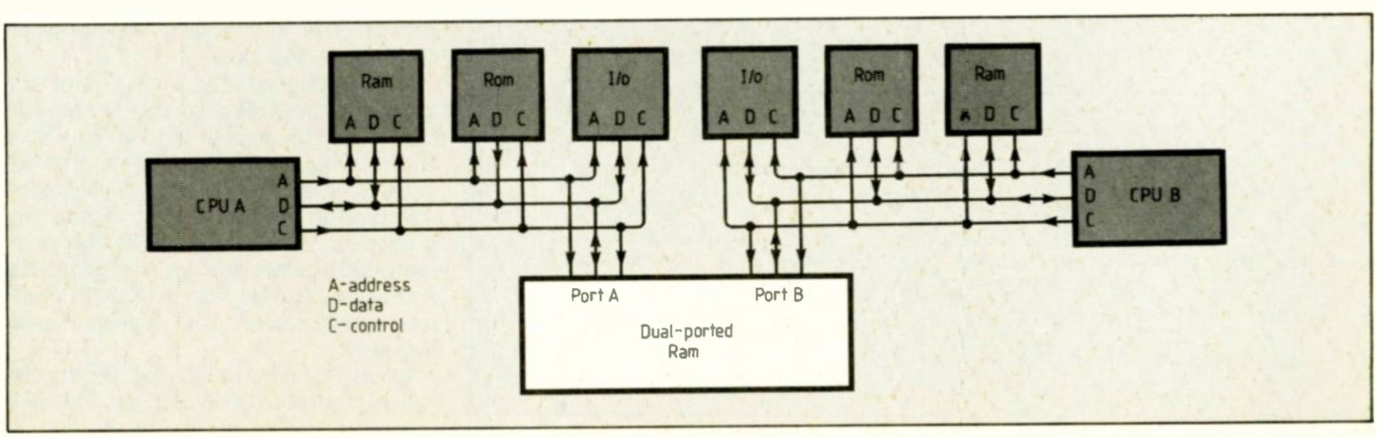


Fig.2. Processors linked by a block of shared memory common to both processors.

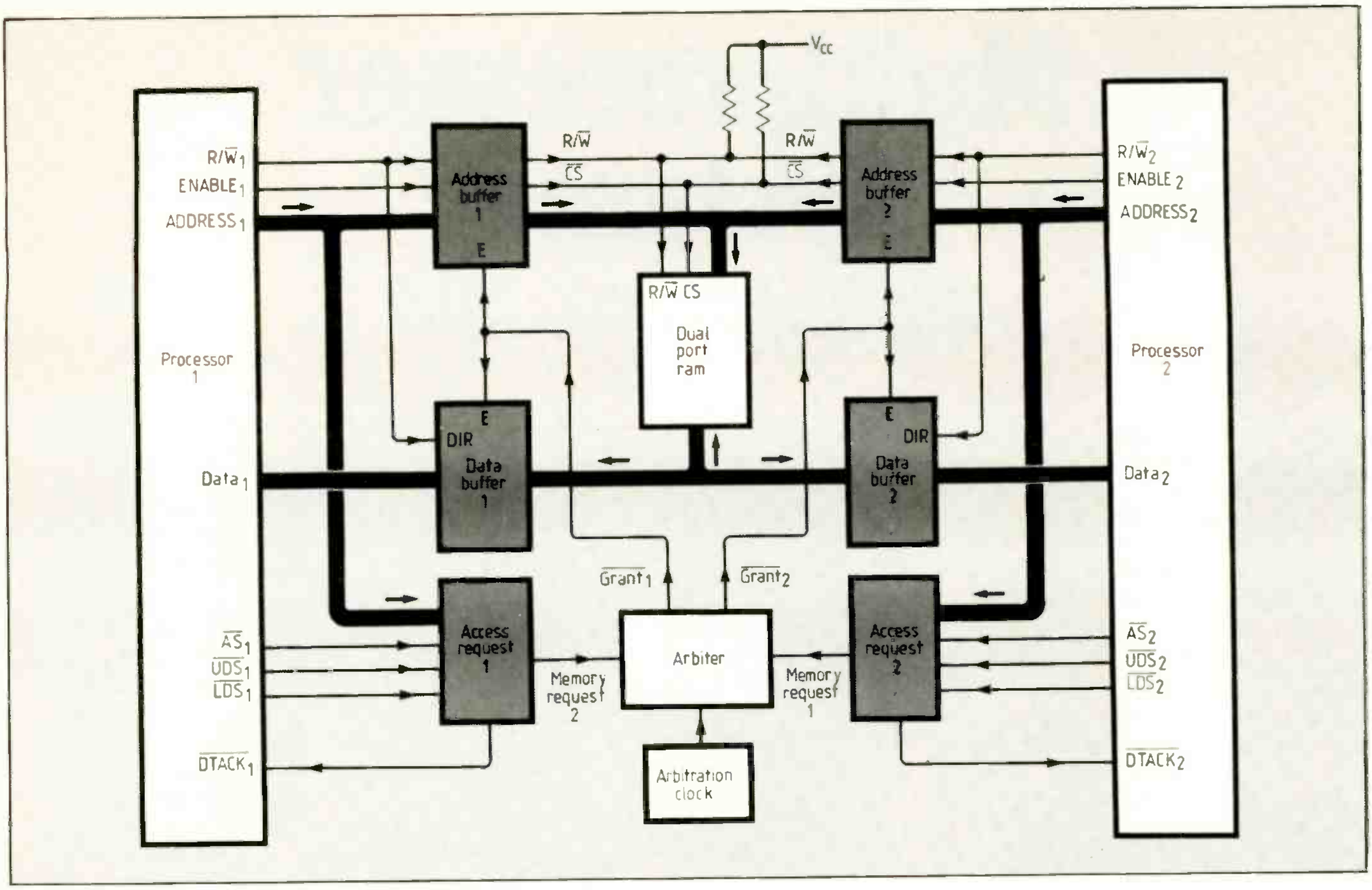


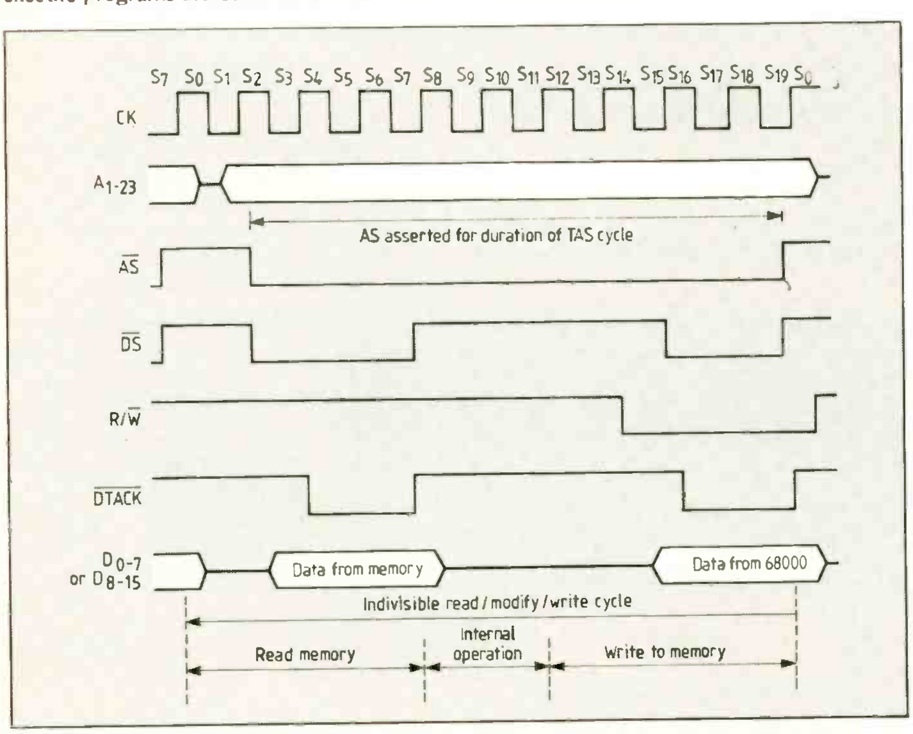
Fig.3. Structure of a shared memory common to two processors.

to share the same bus, allowing the general bus topology to be realized; this is why the shared bus is so popular. It should be immediately apparent that if a number of processors do try to access the common bus all the time, the throughput of the individual processors will be very low.

Figure 1 shows how a shared bus system is arranged. Each of the three processors, A, B and C, has its own local buses through which it accesses its own local memory and, possibly, i/o ports. For much of the time, the processors execute programs stored in their local memory and operate on their own data. When one processor wishes to communicate with another, it takes control of the system bus through its bus-control unit. Now it can access the resources of another processor by controlling the system bus.

When I introduce the VMEbus in a later article, you will see how the 68000 bus control facilities (BR, BR and BGACK) simplify the design of multiprocessor systems.

Fig.4. Timing of an indivisible test and set (TAS) instruction.



SHARED MEMORY

In the final method of linking two processors a block of memory common to both processors is used. As I have already stated, common memory is often called dual-ported ram, Fig.2. It is, in fact, possible to have n-ported ram that is shared between n processors. Because multiprocessor systems based on shared memory have very low latencies due to their tight coupling, I will discuss the design of multiprocessor systems with shared memory in more detail.

DESIGNING MULTIPROCESSORS WITH SHARED MEMORY

In the example of Fig.2, the two processors have entirely separate buses together with their own local memory and i/o resources as appropriate. However, each processor is also able to read from or write to a block of dual-ported memory common to both their address spaces. Figure 3 provides further details of the arrangement of this memory. For the sake of simplicity, byte-selection details are not included.

Each processor in Fig.3 has its own data and address bus buffered on to the dual-port ram buses by means of two pairs of three-state buffers. Processor 1 accesses the dual-ported memory when ENABLE1 is asserted and processor 2 accesses the dual-port ram when ENABLE2 is asserted. As the outputs of the buffers are connected together, only one set of buffers at a time may be enabled. Therefore, both processors cannot access the memory simultaneously.

Inputs CS and R/W to the dual ram are also buffered by three-state bus drivers. However, in this case it is necessary to pull up both CS and R/W when neither processor is accessing the bus, in order to avoid spurious memory accesses.

ARBITRATION

So far so good. The real problem in designing a shared memory system lies in the selection of a suitable mechanism by which a processor is granted access to the shared memory. Each processor in Fig.3 may attempt to access the dual-port ram by asserting its AS, UDS and LDS lines and by placing the appropriate address on A_{1-23}.

Access requests from both processors are fed to an arbiter circuit to decide which processor will be granted access to the shared memory block. Some arbiters have a clock input (not necessarily the system clock) that determines the points at which the request inputs are sampled. That is, the requests are sampled periodically by a sampling clock. This clock has important implications for the reliability of the system as you shall soon see.

If one processor requests the memory and the other does not, the requesting processor is granted access. Equally, once a processor has been granted access, the other is locked out and must wait until the memory becomes free. When both processors request a memory access almost simultaneously, the arbiter must decide which processor may proceed and which must wait.

The arbiter is an interesting device, not least because it is impossible to design a

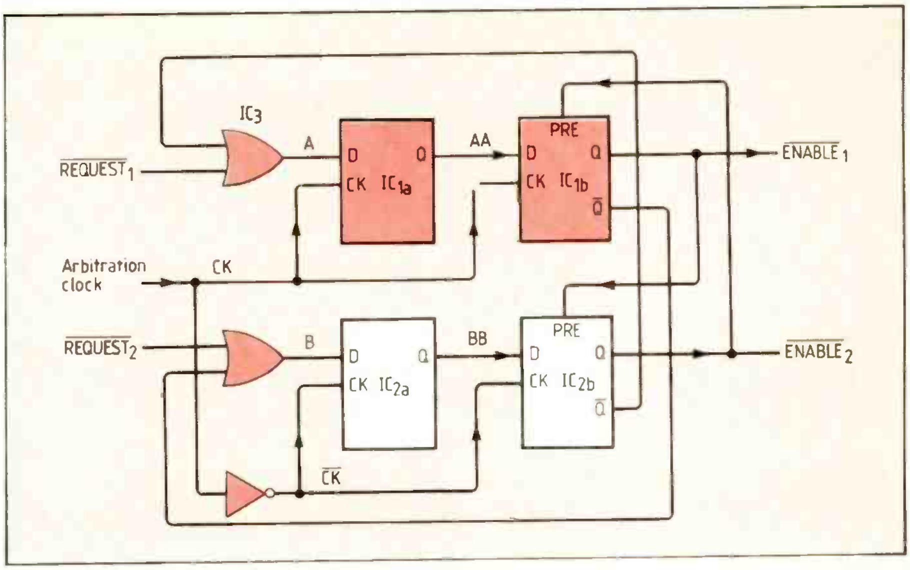
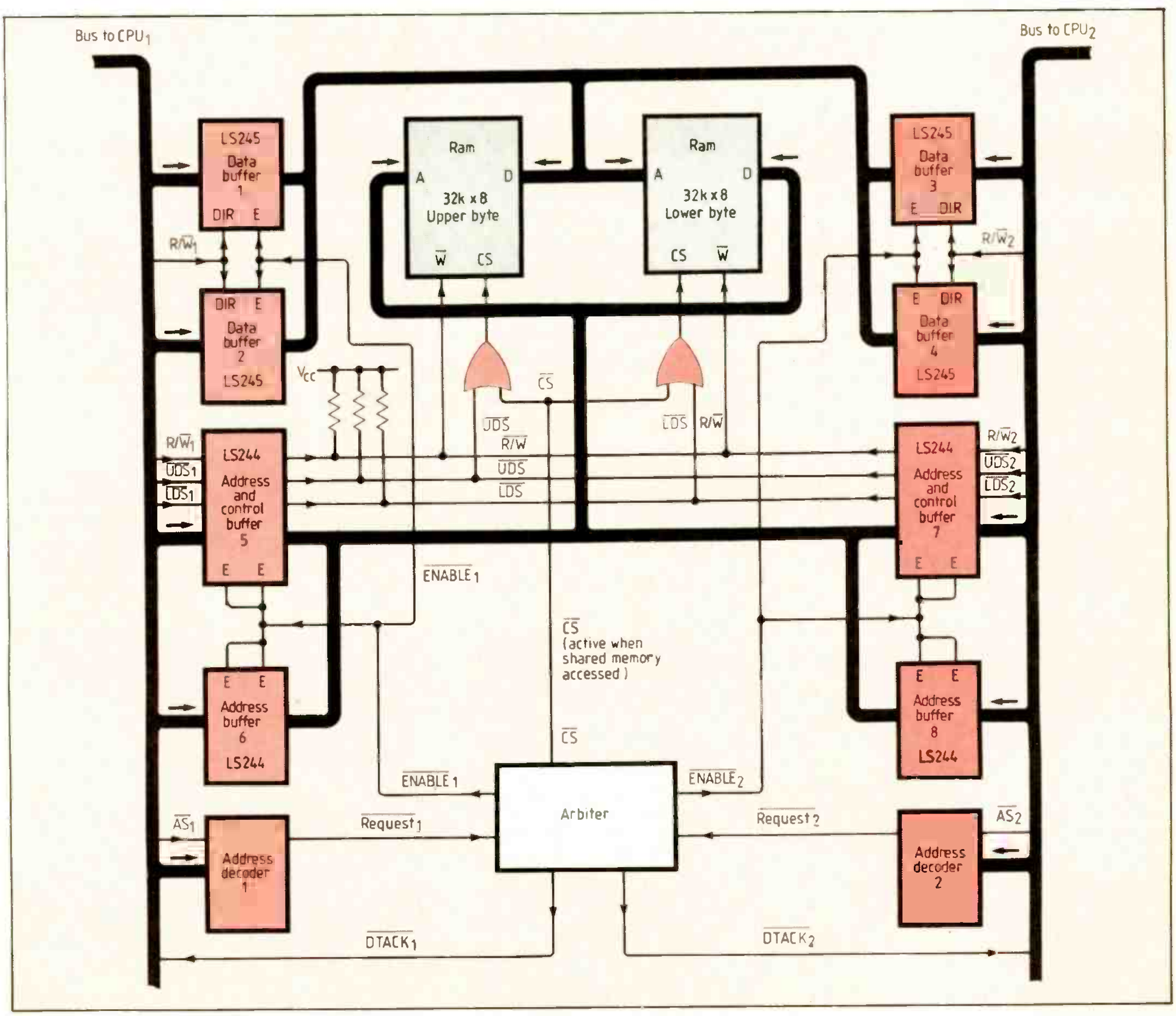


Fig.6. Circuit diagram of a two-input asynchronous arbiter taken from a Motorola application note. Latches $IC_{1a,b}$ are driven by a non-inverted clock signal and latches $IC_{2a,b}$ by an inverted clock to ensure that $REQUEST_1$ and $REQUEST_2$ are not sampled at the same time.

Fig.5. Arrangement of dual-ported ram in a multiprocessor system.



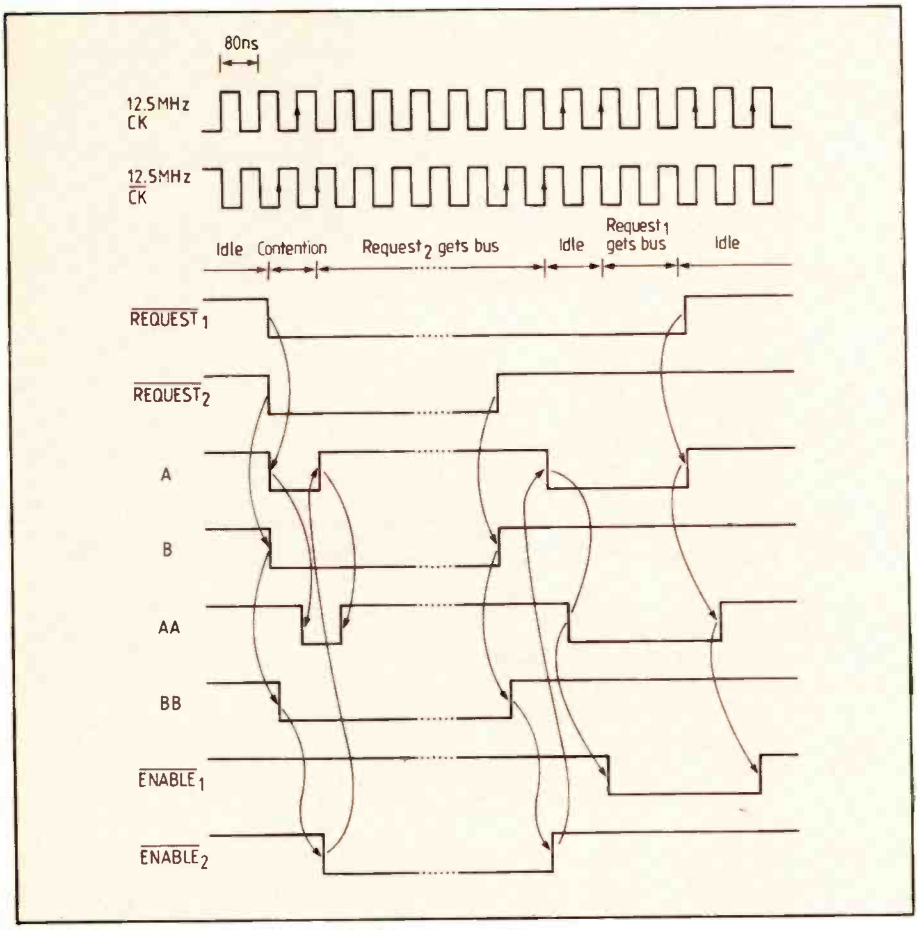


Fig.7. Timing of a dual-ported ram arbiter.

perfect arbiter. It is an asynchronous device because a processor may request a memory access at any instant if its clock is independent of the arbiter's clock. Therefore, there is a finite probability that a processor may request access at the exact moment (in practice a finite sampling window) that the arbiter is making a decision. In this case, the state of the system is undefined.

No matter how well an arbiter is designed, the problem of a simultaneous access request and sampling clock edge can never be eliminated. Simultaneous changes at a bistable device's data and clock inputs are called metastability. It is possible however to reduce the problem to acceptable limits. For example, an arbiter may be designed that fails once every, say, fifty years. A mean time between failure of 50 years represents, of course, a high degree of reliability by everyday standards. Note that a failure due to a metastability problem is a soft failure.

Another problem associated with shared memory, common to almost all forms of multiprocessor systems, is in ensuring reliable communication between the processors via the shared memory. For example, suppose that processor A writes a block of data to the dual-port memory for processor B to read. Processor A will want exclusive use of the shared memory for the entire duration of this operation. Since processor A cannot lock out processor B by a hardware technique, it is necessary for A to pass a message to B, indicating to it that it wishes to have sole access to the memory.

Typically a flag bit, called a semaphore, forms one of the memory locations and, when set, indicates to a processor that the memory is in use by another processor and is therefore unavailable.

In order for processor A to take control of the shared memory, it first reads the semaphore. Remember that both processors can physically access memory, subject only to the state of the arbiter. If the semaphore is set, processor A must wait, since B is already using the memory. If the semaphore is clear, processor A may take control of the shared memory by setting the semaphore and thereby locking out B.

Simple? Well, not really. Assume that processor A reads the semaphore and finds it clear. Processor A will then perform a write operation to set the semaphore and to gain possession of the shared memory. Now suppose that at an infinitesimally small period after processor A requests the memory, processor B does the same. Processor B will read the semaphore after A has read it and it too will set the semaphore; each will think that it has sole possession of the shared memory.

The above is not a theoretical, abstract or irrelevant problem. It has serious consequences in multiprocessor systems. For example, in a geographically distributed system a travel agent may aks for a seat on a certain flight. The computer system interrogates the data base and finds, say, a single seat free, which the client then books. But suppose that in another town a second client also requests a seat on the same flight. He or she may be told that the flight is free because the first client has not yet booked the seat. The outcome is that the seat becomes double-booked.

Fortunately, most data bases have software that avoids this dilemma. Once a client has asked if a seat is available, that section of the data base cannot be read by another user until the original transaction is fully completed.

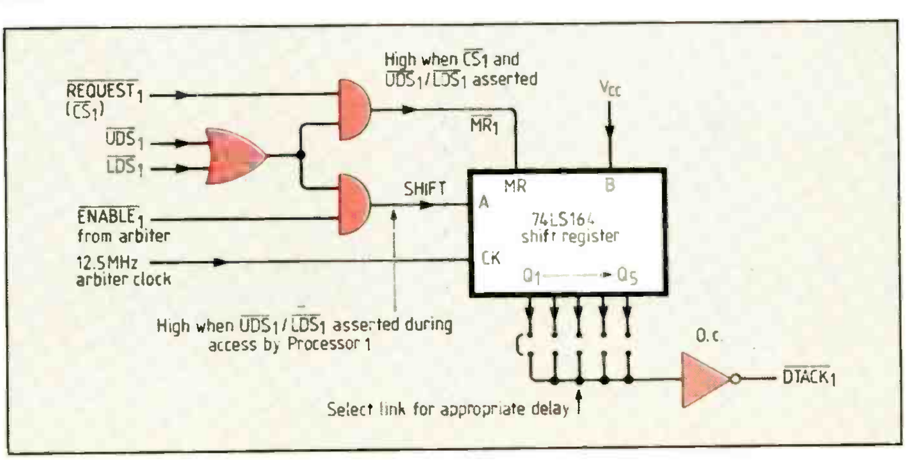
The 68000 microprocessor has a test-and-set instruction, TAS, designed specially for multiprocessor applications. A TAS <effective address> instruction reads the contents of the specified effective address and, if clear, sets the least-significant bit of the byte tested in one indivisible operation. That is, it does not release the memory between the action of reading the semaphore and that of setting it. The action carried out by a TAS instruction is called an indivisible read, modify and write operation.

Figure 4 provides the timing diagram of a TAS instruction, which lasts a minimum of 20 clock states and includes a conventional write access followed by a conventional read access. Like any other memory access, both read and write operations can be extended by delaying data-transfer acknowledge signal DTACK as required. However, unlike other read-followed-by-write cycles, the address strobe is not negated between the read and the write accesses. Therefore, in any multiprocessor system using shared memory, the arbiter must be arranged so that it will never recind a processor's access to the shared memory while its address strobe is asserted.

MEMORY ARBITRATION

An arrangement of a practical dual-port ram with 64Kbyte of shared memory is given in Fig.5. Two 32K-by-8bit i.cs provide the 32K words of shared memory and eight bus drivers form the electrical interface between the ram and processor 1 or processor 2. Processor data

Fig.8. Generating DTACK in a dual-ported ram.



lines are buffered by 74LS245 bidirectional transceivers, whose data direction inputs are controlled by the R/W signal from the processor bus to which they are connected. The data buffers are enabled by ENABLE$_1$ when processor 1 has access to the memory and by ENABLE$_2$ when processor 2 has access.

Address lines A_{1-15} from processor 1 are buffered by two 74LS244 octal three-state bus drivers enabled by ENABLE$_1$. Lines A_{1-15} from processor 2 are similarly buffered and enabled by ENABLE$_2$.

Three 74LS244 three-state buffers are required to buffer the 15 address lines and the R/W, UDS and LDS control lines from the processors. Each of these three lines is pulled up to a logical one state (on the ram side of the buffers) by resistors, to avoid accessing the ram when neither ENABLE$_1$ nor ENABLE$_2$ is asserted.

Two Or gates (And gates in negative logic terms) permit the processors to perform byte or word accesses to the ram. These gate upper data strobe UDS with CS from the arbiter to select the upper byte, and LDS with CS to select the lower byte.

Address decoders 1 and 2 are driven from processor 1 and processor 2 address buses respectively. Each decoder is enabled by its own processor's address strobe. For example, if processor 1 requests a memory access by addressing the 32K block selected by address decoder 1, the decoder output REQUEST$_1$ is asserted. Assuming processor 2 does not require the bus, the arbiter asserts ENABLE$_1$ and buffers 1, 2, 5 and 6 are enabled. This permits processor 1 to access the memory exactly as in any other access to static ram. Note that CS from the arbiter is asserted to enable the ram, if either ENABLE$_1$ or ENABLE$_2$ is asserted. Should processor 2 request the ram, the action is identical to that above, except that buffers 3, 4, 7 and 8 are enabled by ENABLE$_2$.

Figure 6 is an example of an arbiter for dual-ported ram, taken from Motorola application note AN881. Each processor employs its address bus together with AS and strobes UDS/LDS to produce a memory access request whenever it wishes to write to or read from the shared memory. Memory request signals REQUEST$_1$ and REQUEST$_2$ are sampled by two positive-edge triggered latches. The latch to be clocked first locks out the other latch, so that the latter cannot respond to a request at its input. The secret of the arbiter is its use of an antiphase clock to provide different sampling points for the request inputs.

Timing for the case in which both processors request the bus simultaneously is shown in Fig.7. As you can see, processor 2 wins the request and processor 1 must wait until processor 2 has relinquished the bus. That is, processor 1 does not have to try again, it simply waits for the memory to become free. Processor 1 determines that the bus is once more free by the eventual assertion of its data-transfer acknowledge signal.

Initially, the arbiter is in an idle state with both request inputs inactive-high. Therefore, both D inputs to latches $IC_{1a,2a}$ are high and in a steady state condition. Outputs AA, BB, ENABLE$_1$ and ENABLE$_2$ are all high.

Suppose that REQUEST$_1$ and REQUEST$_2$ are asserted almost simultaneously when the clock is in a high state. This results in the outputs of both Or gates (A and B) going low simultaneously. The cross-coupled feedback inputs to the Or gates (ENABLE$_1$ and ENABLE$_2$) are currently both low.

On the next rising edge of the clock, the Q output of latch IC_{1a} (i.e. AA) and the Q output of latch IC_{2a} (i.e. BB) both go low. However, as latch IC_{2a} sees a rising edge clock first, its Q output goes low one half a clock cycles (40ns) before latch IC_1's output also goes low.

Earlier, I said that when a latch is clocked at the moment its input is changing, it goes into a metastable state in which its Q output is indeterminate. The metastable state can last for up to about 75ns before the output of the latch settles into one state or the other. For this reason a second pair of latches is used to sample data at the input latches after a period of 80ns.

Thus, 80ns (one clock cycle) after REQUEST$_2$ has been latched and output BB forced low, the output of latch IC_{2b}, ENABLE$_2$ goes low. Its complement, ENABLE$_2$, is fed back to Or gate IC_3, forcing input A high. After a clock cycle AA also goes high. Because ENABLE$_2$ is connected to latch IC_{1b}'s active-low preset input, latch IC_{1b}

Fig.9. Timing of DTACK during execution of a TAS instruction.

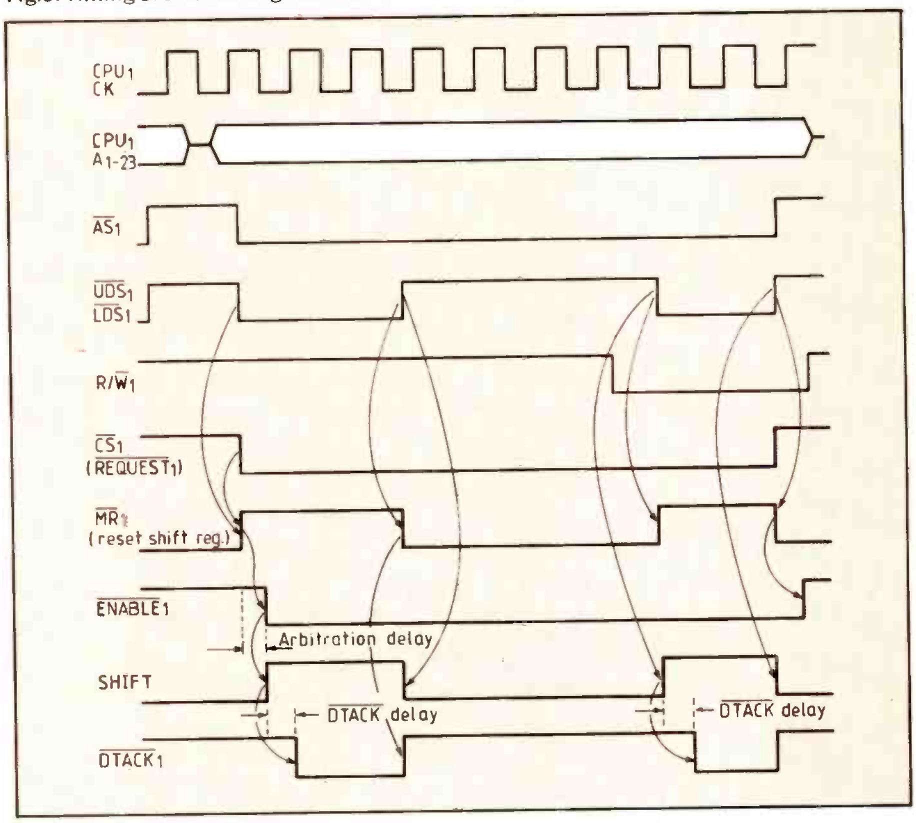
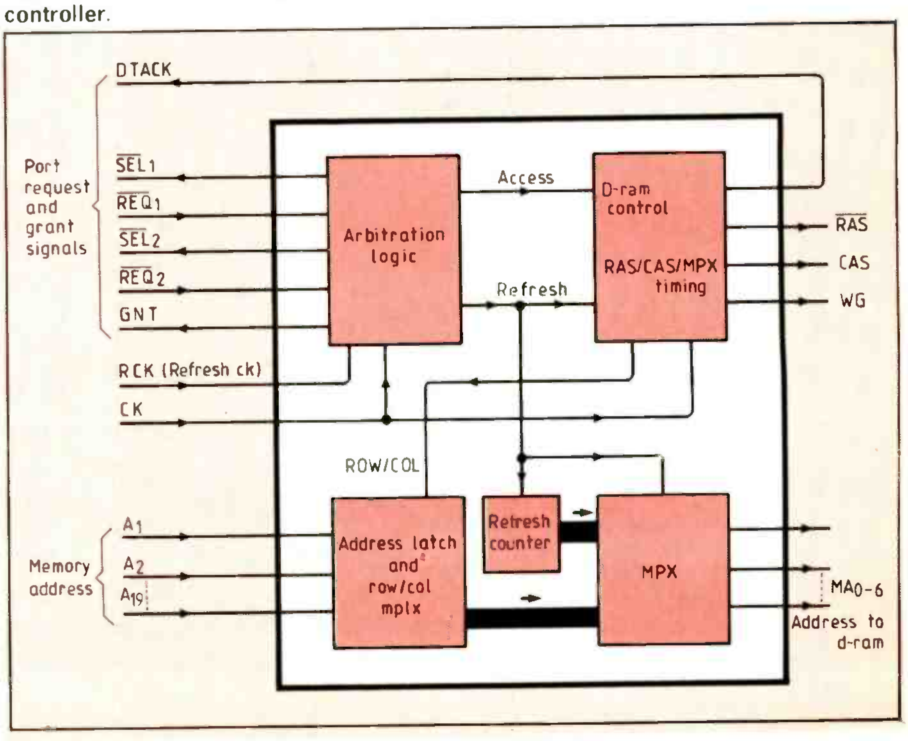


Fig.10. both arbitration logic and memory refreshing are provided by the 74LS764 controller.



is held in a high state.

At this point, ENABLE$_1$ is negated and ENABLE$_2$ asserted, permitting processor 2 to access the bus. The access is completed by the generation of a DTACK$_1$ (described later) and by the negation by processor 2 of its AS and UDS/LDS outputs.

When processor 1 relinquishes the memory, REQUEST$_2$ becomes inactive-high, causing first B, then BB and finally ENABLE$_2$ to be negated as the change ripples through the arbiter. Once ENABLE$_2$ is high, ENABLE$_2$ goes low, causing the output of Or gate IC$_3$ (i.e. A) to go low. This is clocked through IC$_{1a,b}$ to force ENABLE$_1$ low and therefore permit processor 1 to access the memory. Of course, once ENABLE$_1$ is asserted, and assertion of REQUEST$_2$ is ignored.

The remaining aspect of the dual-ported ram to be considered is the generation of DTACK$_1$ and DTACK$_2$ by the arbiter. Many circuits which produce a DTACK response to the assertion of the processor's address strobe following a valid address would not be suitable for a dual-ported ram. A glance at Fig.4, the timing diagram of a TAS instruction, reveals the difficulty unique to TAS. This is the only instruction that requires two handshake cycles (one to acknowledge the read cycle and one to acknowledge the write cycle) while AS is continually asserted.

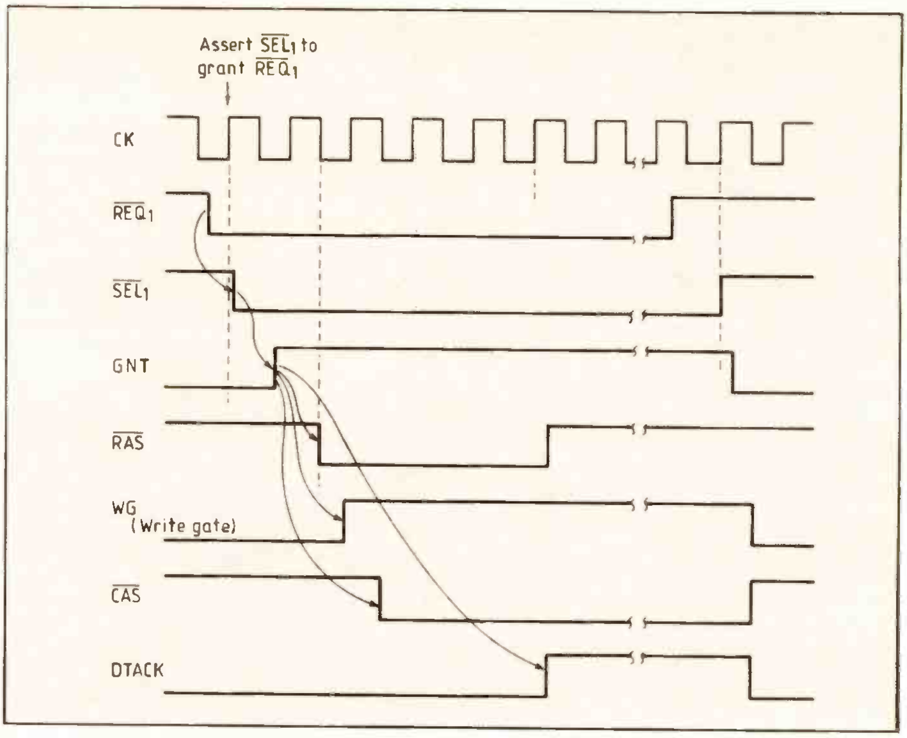


Fig.11. Timing of the LS764 arbitration sequence.

Fig.12. Dual 68000 system using a 74LS764 controller.

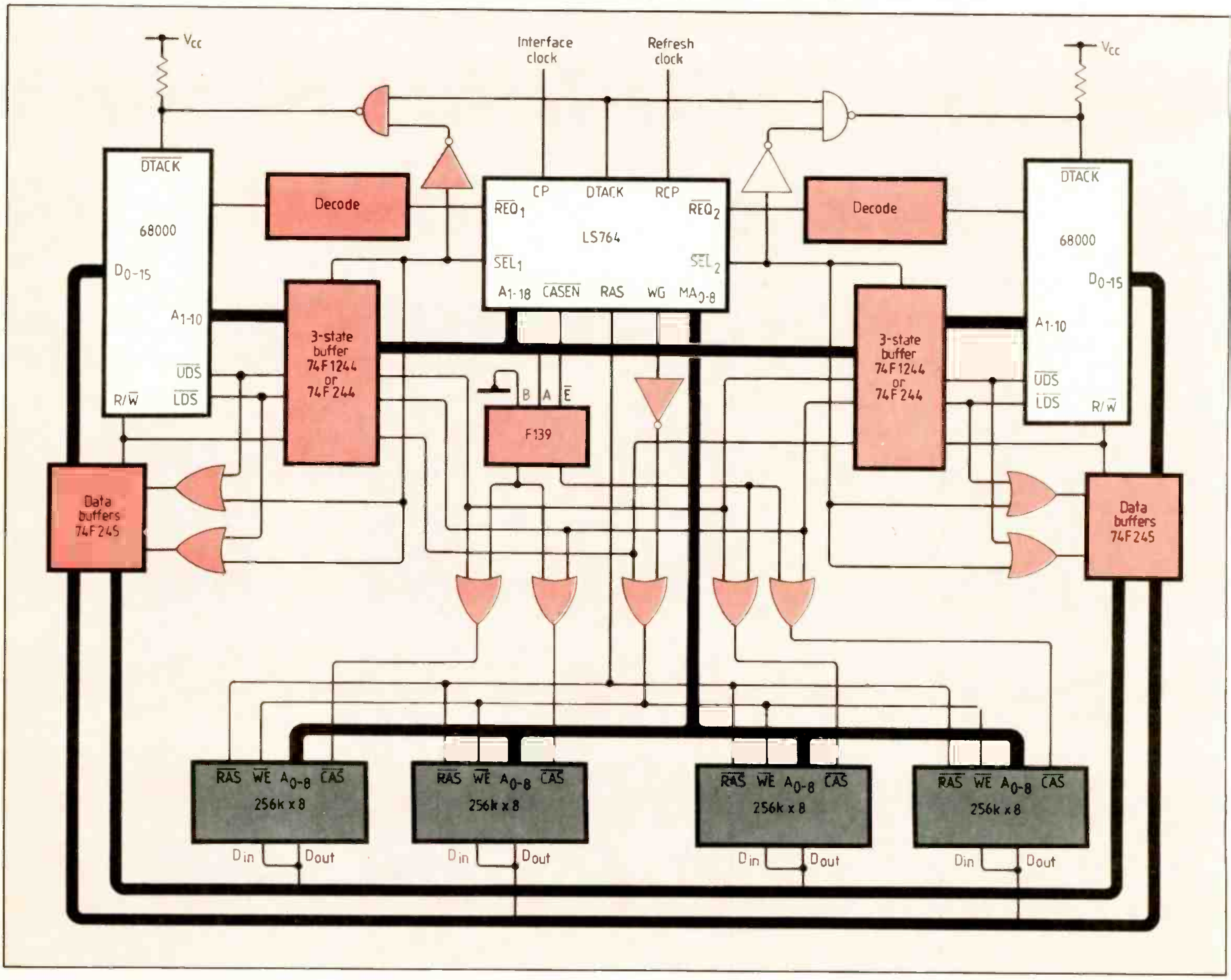


Figure 8 shows how DTACK$_1$ for processor 1 is generated from UDS$_1$ (or LDS$_1$), REQUEST$_1$, and ENABLE$_1$ from the arbiter. Basically, DTACK$_1$ is generated in the normal fashion by holding a shift register (74LS164) in a clear state whenever REQUEST$_1$ (i.e. CS$_1$) is inactive-high, and then using the shift register to shift a clock pulse along when it is enabled. In this case, the shift register is also reset when UDS$_1$ and LDS$_1$ are negated. Consequently, the circuit generates the two consecutive DTACK$_1$'s required during a TAS operation. Figure 9 provides a timing diagram for the DTACK generator. Note that DTACK$_2$ is produced in an identical way, except that the shift clock is derived from the complement of the arbiter clock.

Now the hardware design of a dual-ported ram is complete. In use it may be accessed by a processor as follows:

```
Shared-   EQU    $F00000     Location of
memory                       memory
                             block
Sem       DS.W   1           First word=
                             semaphore
          .
          .
          .
          LEA    Semi,(A0)   Point to
                             semaphore
Wait      TAS    (A0)        Test and set
                             semaphore
          BMI    Wait        Repeat until
                             semaphore
                             set
          .                 }
          .                 } Critical
          .                 } section
          CLR.B  (A0)        Clear
                             semaphore
```

The address of the semaphore is loaded into A0 and the TAS/BMI loop repeated until the semaphore is found to have its seventh bit clear (i.e. BMI WAIT not taken). When bit seven of the semaphore is clear it is set by the TAS to enable the processor to take control of the shared memory.

The next part of the program is called the critical section because it is the region that must be executed to completion without any other processor accessing its data. Once the critical section has been completed, the shared memory is de-allocated by CLR.B (A0) which resets the semaphore.

DYNAMIC RAM CONTROL

Both arbitration logic for dual-port memory and the controller and interface to a block of dynamic ram are included in the 74LS764 dynamic-ram controller, Fig.10.

Request signals REQ$_1$ and REQ$_2$ are the access-request inputs from ports 1 and 2, and SEL$_1$ and SEL$_2$ are the corresponding access-grant outputs. All other inputs and outputs are largely self explanatory. Typical timing of an access by processor 1 is shown in Fig.11 and a circuit diagram of a dual 68000 system based on the 74LS764 is shown in Fig.12.

A microprocessor requests access to the dynamic ram by asserting the appropriate REQ input. If a dynamic-ram refresh cycle is not in progress and the other request input is not active, the SEL output corresponding to the active REQ will go low to indicate that the access will be granted. Output GNT then goes high and its low-to-high transition indicates that a memory cycle is about to begin.

If an access or refresh cycle is in process and the other processor has not requested access by asserting its REQ signal, the SEL output corresponding to the active REQ will go low to indicate that access will be granted. However, GNT will not go high until the current cycle has been completed. After completion of the current cycle, GNT will automatically be asserted high.

If access to the dynamic ram is requested by both processors, the initial arbitration phase determines which processor is to gain access to the memory by asserting the appropriate SEL output. This arbitration takes place irrespective of whether or not a refresh cycle is in progress at the time the access is requested. Request contention is arbitrated, as discussed earlier, by sampling the REQ inputs on opposing phases of the arbitrer's clock.

When GNT becomes active-high, address inputs A_{1-18} are latched by the 74LS764 and the A_{1-9} signals propagated to the MA_{0-8} row-address outputs. One half clock cycle later, column-address inputs on A_{10-18} are propagated to MA_{0-8} and the active-high column-address strobe, CAS, asserted. Once CAS is asserted, the controller will wait three clock cycles before negating RAS, making it four clock cycles in duration.

As RAS is negated, the DTACK output becomes active-high to indicate that data on the dynamic-ram data lines is valid (or that the proper access time has been met). All controller outputs are held in their final state until the processor accessing the dynamic ram negates its REQ signal. When the request is negated, all controller outputs assume their inactive states and any impending refresh cycles are serviced.

A refresh cycle is triggered by internally generated refresh requests. The refresh clock is divided by 64 to produce periodic refresh cycles and then arbitrated with the SEL outputs in the second stage of arbitration.

Refresh cycles always take priority over processor accesses. At the start of a refresh cycle, the 9bit refresh address is placed on MA_{0-8} for a half clock cycle and then RAS is asserted for four clock cycles, followed by three inactive-high cycles. The inactive-high period of RAS allows time for the dynamic ram precharge period.

I introduce VMEbus and look at some of the special-purpose i.cs that simplify interfacing 68000s to VMEbus in the final section of this series.

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Conferences and Exhibitions

8-12 November, Munich: **Electronica 88**, 13th international trade fair for components and assemblies in electronics. Associated conferences include sessions on quality assurance, component testing techniques and sensor elements for mass-market products. Organizer: Munchener Messe- und Ausstellungsgesellschaft mbH, Messegelande, Postfach 12 10 09, D-8000 Munchen 12, tel. (89) 51 07-0.

22-24 November, IEE, Savoy Place, London: fourth international conference on electrical **safety** in hazardous areas. An accompanying exhibition is planned. Details from the conference secretariat, IEE Conference Services, 01-240 1871 ext. 222.

25-27 November, Windermere: Institute of Acoustics 1988 autumn conference on **noise** in and around buildings. Institute of Acoustics, 25 Chambers Street, Edinburgh EH1 1HU.

20-22 December, University of Nottingham: Institute of Physics annual solid-state physics conference. Details from the IoP in London, 01-235 6111.

23-26 January, 1989, Bahrain: Middle East Electronic Communications Show and Conference, incorporating the Middle East Commputer Show. Contact: Overseas Exhibition Services Ltd in London, 01-486 1951.

23-26 January, 1989, Bahrain: Middle East Electronic Communications Show and Conference, incorporating the Middle East Computer Show. Contact: Overseas Exhibition Services Ltd in London, 01-486 1951.

25-26 January, 1989, Fleming Park, Eastleigh: **Instrumentation** Southampton. Details from Trident International Exhibitions Ltd in Tavistock, 0822-614671. Further dates in 1989 for exhibitions in this series are 22-23 February at the Harrogate Exhibition Centre, 21-22 March at Filton, Bristol, and 14-15 June at The Forum, Livingston.

7-9 February, 1989, Wembley, London: surface mount and related technologies exhibition and conference, **Smartex**. Details from MGB Exhibition Ltd, 01-302 8585. Prospective authors of conference papers should submit a 200-word synopsis to the chairman of the technical committee, Smart Group, 3 Lattimore Road, Wheathampstead, Hertfordshire AL4 8QF.

20-23 February, 1989, Genoa, Italy: European Advanced Manufacturing Systems Exhibition and Conference. Cahners Exhibitions, 01-891 5051.

21-24 February, 1989, Birmingham NEC: *Which Computer?* Show. Cahners Exhibitions, 01-891 5051.

6-9 March, 1989, Swiss Federal Institute of Technology, Zurich: 8th international Zurich symposium and technical exhibition on electromagnetic compatibility. Details from EMC Symposium Zurich, ETH Zentrum – KT, 8092 Zürich; tel. (Switzerland) 01-256 2790/2788.

A dimensional approach to a unified theory

Dimensional relationships of common physical concepts.

S.K. CHATTERJEE, M.A.

It is possible to reduce the conventional dimensional expressions, in terms of length, time and mass (inertia) or force, to terms containing length and time only. Some advantages accrue and tabulating the resulting expressions in the way shown in Table 1 clarifies relationships previously obscured by the complexity of a three-dimensional format.

The chart does not show all the many scientific concepts now in use, since it is intended primarily to be introductory and indicative; but it will, I hope, interest those familiar with the dimensional techniques now increasingly being used.

It is obvious that all the non-dimensional parameters and numbers, such as Reynolds, Froude, Densitometric Froude, Richardson, etc., are merely ratios of the values tabulated and that they are finite in number, for practical purposes. Although the tabulation can extend to infinity, the concepts susceptible to measurement are confined to the first six powers on each axis.

What is perhaps not so obvious is that the table also shows the *laws* or *rules* of Nature and their relationships as interlinked by Newtonian calculus. One can make several deductions from the tabular array, but it is enough to point out here that it might have been preferable for scientists to use a natural unit of measurement based on Napierian e, π and a representative velocity such as c or, more accurately, the constant for the ratio of length to time for the particular case; and in general in the study and measurement of natural phenomena.

The Michelson-Morley experiment, and subsequent endeavours to establish the velocity of light and other forms of electromagnetic radiation, are open to another interpretation – that of establishing a ratio of length to time in this universe. In this paper the meaning of these experiments is to be taken as establishing the connection of the dimension length to that of time in an absolute sense, instead of its being measured in units familiar to the scientist. Those units are arbitrary, despite the attempts of Wren and the Abbé Piccard in 1670 AD to relate the unit of length to the unit of time by the beating of a pendulum in a gravitational field. That these experiments, such as the Michelson-Morley, have also established that the value so obtained is a physical constant of the universe is accepted.

The expressions for Newton's Law P = mf and Einstein's Law $E = mc^2$ can be expressed as $P = m\mathbf{L}/\mathbf{T}^2$ and $E = m\mathbf{L}^2/\mathbf{T}^2$ and, substituting $m = \mathbf{L}^3/\mathbf{T}^2$, we obtain for these two laws

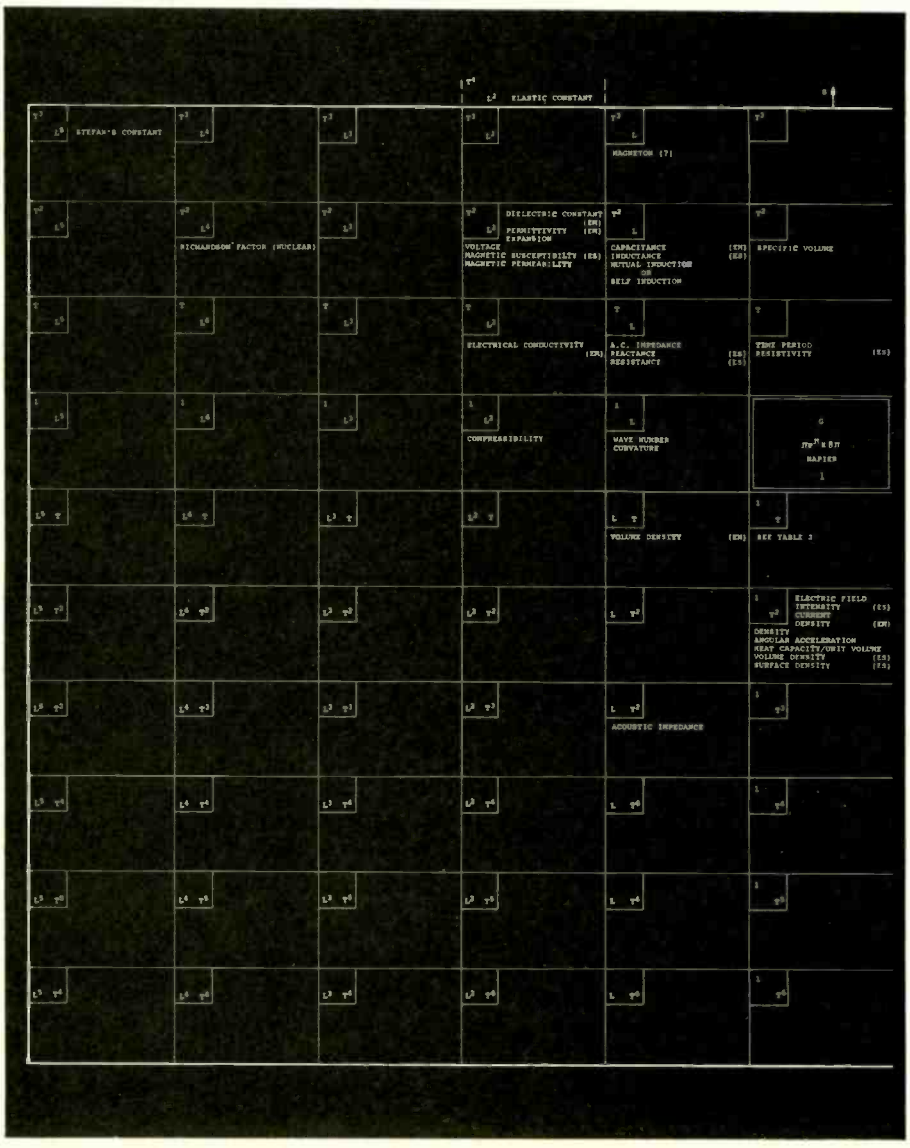
$$P = \frac{L^3}{T^2} \times \frac{L}{T^2} = \frac{L^4}{T^4}$$

and

$$E = \frac{L^3}{T^2} \times \frac{L^2}{T^2} = \frac{L^5}{T^4}$$

The expression for $m = \mathbf{L}^3/\mathbf{T}^2$ is derived by Clerk Maxwell[1] as follows. If (as in the metric system[2]) the unit of mass is defined by its attractive power, the acceleration of a mass m at a distance r is by Newton's Law m/r^2. Suppose this attraction to act for a very small interval of time t on a body originally at rest, and to cause it to describe an interval of space s, then by the formula of Galileo

$$s = \frac{1}{2} ft^2 = \frac{1}{2} \frac{m}{r^2} t^2$$



whence

$$m = \frac{2r^2 s}{t^2}, \text{ i.e. } \mathbf{M} = \frac{\mathbf{L}^3}{\mathbf{T}^2},$$

that is, volume ($\mathbf{L}^3$) and density ($1/\mathbf{T}^2$) conjointly, which is in line with Newton's definition for mass ("*Quantitas materiae est mesora ejusdam orta ex ilius densitae et magnitudine conjunctem*") in his Proposition 1 in ref.[3] (see also p.5 in ref.[1]). In practical units Heisenberg[4] confirms this when he takes the measured values of Planck's constant and the velocity of light, assumes a length of roughly 10^{-13}cm, and forms an expression which in its dimension corresponds to a mass, its value being of the order of magnitude of the masses of the elementary particles. In dimensional terms this becomes

velocity of light	cm/s	$\mathbf{L/T}$
Planck's Constant	erg/s	$\mathbf{L}^5/\mathbf{T}^3$
length	cm	$\mathbf{L}$

whence

$$\left(\frac{\mathbf{L}^5}{\mathbf{T}^3}\right) \Big/ \left(\frac{\mathbf{L}}{\mathbf{T}} \times \mathbf{L}\right) = \frac{\mathbf{L}^3}{\mathbf{T}^2}.$$

In these circumstances where mass has the dimensions of $\mathbf{L}^3/\mathbf{T}^2$ the Gravitational Constant G is non-dimensional, since[5]:

$$P = G\frac{mm'}{r^2} = G\left(\frac{\mathbf{L}^3}{\mathbf{T}^2} \times \frac{\mathbf{L}^3}{\mathbf{T}^2}\right) \Big/ \mathbf{L}^2$$

$$= G\left(\frac{\mathbf{L}^6}{\mathbf{T}^4}\right) \Big/ \mathbf{L}^2 = G\frac{\mathbf{L}^4}{\mathbf{T}^4}$$

but

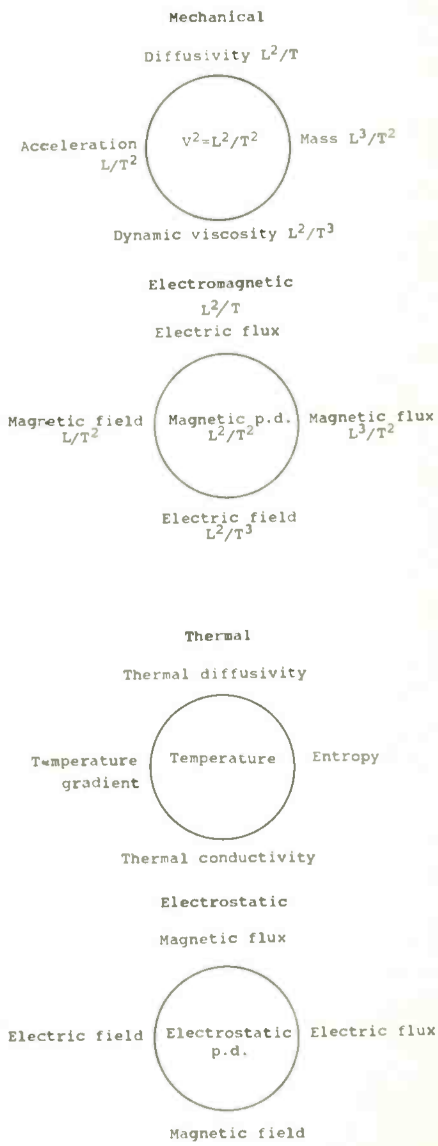
$$P = \mathbf{M} \times \frac{\mathbf{L}}{\mathbf{T}^2} = \left(\frac{\mathbf{L}^3}{\mathbf{T}^2}\right) \times \left(\frac{\mathbf{L}}{\mathbf{T}^2}\right) = \frac{\mathbf{L}^4}{\mathbf{T}^4}$$

hence G = 1 (non-dimensional). Alternatively, GM = cm^3/s^2, but $\mathbf{M} = m = \mathbf{L}^3/\mathbf{T}^2$, so again G = 1.

Although Heisenberg believed at least three fundamental constants were necessary to determine the masses and the other properties of elementary particles (e.g. atomic nuclei of the lighter elements) it is only necessary, as will be shown later, to have two –

	SYSTEM				
	MECHANICAL	THERMODYNAMIC	ELECTROSTATIC	ELECTROMAGNETIC	NUCLEAR ATOMIC
L^3/T^2	MASS INERTIA	ENTROPY THERMAL CAPACITY BOLTZMANN'S CONSTANT	CHARGE ELECTRIC FLUX QUANTITY OF ELECTRICITY	POLE STRENGTH MAGNETIC FLUX	
L/T^2	ACCELERATION	TEMPERATURE GRADIENT	ELECTRIC INTENSITY FIELD DISPLACEMENT INDUCTANCE	MAGNETIC FIELD INDUCTION INTENSITY	
L^2/T	KINEMATIC VISCOSITY DIFFUSIVITY CIRCULATION	THERMAL DIFFUSIVITY	MAGNETIC FLUX POLE STRENGTH	CHARGE RESISTIVITY ELECTRIC FLUX QUANTITY OF ELECTRICITY	DIFFUSION COEFFICIENT ELECTRON MOBILITY ION MOBILITY CHARGED-PARTICLE MOBILITY
$1/T$	ANGULAR VELOCITY VORTICITY FREQUENCY		ELECTRIC CONDUCTIVITY MAGNETIC INDUCTION MAGNETIC POLE STRENGTH	ELECTRIC DISPLACEMENT ELECTRIC INDUCTION SURFACE DENSITY	

$T^3 L$	$T^3 L^2$	$T^3 L^3$	$T^3 L^4$	$T^3 L^5$	$T^3 L^6$
$T^2 L$	$T^2 L^2$	$T^2 L^3$	$T^2 L^4$	$T^2 L^5$	$T^2 L^6$
$T L$	$T L^2$	$T L^3$	$T L^4$	$T L^5$	$T L^6$
L LENGTH SELF INDUCTION (EM) INDUCTANCE (EM) CAPACITANCE (ES)	L^2 AREA	L^3 VOLUME	L^4 SECTION MODULUS	L^5	L^6
L/T VELOCITY MAGNETIC INDUCTION (ES) A.C. IMPEDANCE REACTANCE (EM) RESISTANCE (EM)	L^2/T KEPLER BROWNIAN MOTION SEE TABLE 1	L^3/T RECOMBINATION COEFFICIENT MAGNETIC MOMENT	L^4/T	L^5/T	L^6/T
L/T^2 SEE TABLE 3	L^2/T^2 GALILEO TEMPERATURE (LATENT HEAT) MAGNETIC P.D. (EM) DIFFERENCE OF POTENTIAL (ES) CURRENT (EM) ELECTRIC FIELD INTENSITY (EM)	L^3/T^2 CONSERVATION OF MASS BOLTZMANN CONSTANT KEPLER SEE TABLE 2	L^4/T^2 MAGNETIC MOMENT (EM)	L^5/T^2 MOMENT OF INERTIA	L^6/T^2
L/T^3 CURRENT DENSITY (ES)	L^2/T^3 ELECTRIC FIELD (EM) ELECTRIC INTENSITY (EM) THERMAL CONDUCTIVITY MAGNETIC FIELD (ES) MAGNETIC INTENSITY (ES) VISCOSITY	L^3/T^3 E.M.F. (EM) ELECTRIC P.D. (EM) VOLTAGE (P.D.) (EM) CURRENT (ES) MAGNETIC POLE STRENGTH (EM)	L^4/T^3 MOMENTUM IMPULSE FLUIDITY	L^5/T^3 PLANCK'S CONSTANT MOMENT OF MOMENTUM ANGULAR MOMENTUM ACTION	L^6/T^3
L/T^4 SPECIFIC WEIGHT	L^2/T^4 STRESS INTENSITY RIGIDITY MODULUS ELASTIC MODULUS TENACITY PRESSURE/UNIT AREA	L^3/T^4 FLUIDITY SURFACE TENSION CAPILLARY CONSTANT	L^4/T^4 NEWTON FORCE	L^5/T^4 EINSTEIN COUPLE FORCE MOMENT TORQUE WORK ENERGY ENTHALPY HEAT CONTENT	L^6/T^4
L/T^5	L^2/T^5	L^3/T^5	L^4/T^5	L^5/T^5 POWER	L^6/T^5
L/T^6	L^2/T^6	L^3/T^6	L^4/T^6	L^5/T^6	L^6/T^6



namely length and time, and their ratio.

So far I have dealt with the dimensions of mechanical quantities, and it must be stressed that only those properties susceptible to measurement are being investigated. Other meanings of the word *dimension* are not applicable to this enquiry.

The dimensions of entropy, the heat weight of Zeuner (defined as $\partial Q/\theta$)[6], are derived from the equation $(\partial Q/\theta) \times \theta$ = work done or energy, where ∂Q is the quantity of heat, whereas those of temperature θ are derived from $PV = mR\theta$ where P is pressure, V volume, and R is the Universal Gas Constant (a pure number). Thus using $P = (\mathbf{L}^4/\mathbf{T}^4) \times 1/\mathbf{L}^2$, $V = \mathbf{L}^3$, $m = \mathbf{L}^3/\mathbf{T}^2$, $R = 1$, gives $\theta = \mathbf{L}^2/\mathbf{T}^2$, and entropy $= \mathbf{L}^3/\mathbf{T}^2$. These are then substituted in the dimensions for thermodynamic concepts.

Since electrostatic permittivity μ and magnetic permeability ϵ are essentially of the same kind or quality, and $\mu\ \epsilon = 1/c^2$, it is reasonable to substitute $\mu = 1/c$ and $\epsilon = 1/c$ in the electrical entities.

There remains one more step before I can establish that Table 1 shows the interconnections of the entities by means of the Calculus of Newton. Consider the volume of a sphere $4/3\pi\, r^3$, and its surface area $4\pi\, r^2$. One can see, by extending these two expressions backwards and forwards that we have an infinite sequence

$$8\pi \quad 8\pi r \quad 4\pi r^2 \quad \frac{4}{3}\pi r^3 \quad \frac{1}{3}\pi r^4 \qquad \ldots$$

or

$$\frac{8\pi}{1} \ \frac{8\pi r}{1} \ \frac{8\pi r^2}{1.2} \ \frac{8\pi r^3}{1.2.3} \ \frac{8\pi r^4}{1.2.3.4} \cdots \frac{8\pi r^n}{n!} \cdots$$

of terms found in the expansion of the exponential expression $8\,\pi\, e^r$ or $8\,\pi \exp(r)$, i.e. $8\,\pi \exp(\mathbf{L})$. Thus, on the horizontal axis in Table 1, there is shown

$$\mathbf{L} \ \mathbf{L}^2 \ \mathbf{L}^3 \ \mathbf{L}^4 \ \ldots \ \mathbf{L}^\infty$$

as a shorthand for the terms $8\,\pi\, \mathbf{L}^n/n!$ $n = 1,2,\ldots+\infty$.

On the vertical axis of Table 1 there is similarly shown

$$\frac{1}{\mathbf{T}} \ \frac{1}{\mathbf{T}^2} \ \frac{1}{\mathbf{T}^3} \ \frac{1}{\mathbf{T}^4} \cdots \frac{1}{\mathbf{T}^\infty}$$

The inverses of these **L** and **T** terms are also shown and yield Table 1 divided into quadrants indexed by $\mathbf{L}^n$, $1/\mathbf{L}^n$, $\mathbf{T}^n$, $1/\mathbf{T}^n$. Into this table can be inserted all the modified dimensional expressions in terms of **L**, **T**, and their ratio c, and the permutations and combinations of these expressions which for most practical entities seem to be confined to the first six or eight powers.

An additional analogy which bears on the interpretation of the tabulations is the Column Analogy of Professor Hardy Cross[7] where it is the mathematical identity between the moments produced by continuity in a beam, bent or arch, and the fibre stress in an eccentrically loaded short column; this has the dimension $\mathbf{L}/\mathbf{T}^4$.

Similarly, the equations of Poisson and Laplace have applications in several branches of physics due to their dimensional identity in each of the disciplines. They are equations of energy and have dimensionality $\mathbf{L}^5/\mathbf{T}^4$.

Thus the *laws* (e.g. Newton's) or *rules* (e.g. Column Analogy) are shown in generalized dimensional form in Table 1 – which is to be understood as one entity embracing all others which are manifested as Hilbert geometries in space and time.

From the time of Newton, for whom the Book of Nature was written not in mathematical symbols but in the form of a cryptogram, and of Boole, who believed that dynamical and other actions seemed not only to be measurable in themselves but also to be connected to each other, even to the extent of mutual convertibility, it is perhaps only now that it is possible to display – through tabulation in terms of **L**, **T** and c – the fundamentally abstract nature of the entities of science in the form of Hilbert spaces of many dimensions. As a consequence, one obtains a consistent theory applicable to the very large and the very small, uniting the many concepts susceptible to measurement by a dimensional approach to a unified theory.

Omitted so far are Planck's large numbers for **L**, **T** and **M**, which relate all three entities through Planck's Constant, the velocity of light and the gravitational constant, in numerical terms measured in the c.g.s. system, as a further confirmation.

There are, I believe, a number of other expressions which are relevant to the understanding of a unified theory based on dimensions, and the ones which spring to mind most readily arise in Heaviside's Impulse Theory and his fascination with the special case of Euler's Integral:

$$-\int_0^x \frac{x^6}{6!} e^{-x} dx$$

$$= e^{-x}$$

$$\left[\frac{x^6}{6!} + \frac{x^5}{5!} + \frac{x^4}{4!} + \frac{x^3}{3!} + \frac{x^2}{2!} + x + 1 \right]$$

$$= -1.$$

Heaviside's final (unpublished) researches[8] led him to formulate a unified field theory in which electromagnetism is co-related with mass properties and in which there is a reciprocal relationship between radiation and matter. This is a somewhat similar idea to Professor Jennison's model [9] of an electron as a phase-locked cavity: mass equals a volume ($\mathbf{L}^3$) and two frequencies $1/\mathbf{T}_{magnetic}$ and $1/\mathbf{T}_{electric}$. Of equal interest is Euler's Gamma Integral and its relation to the Logarithmic Spiral, the Golden Section and the Fibonacci Series.

There is one more relationship which is pertinent to this discussion, and which is as follows:

$G = 1$,
NEWTON

$G = K = kc^2/8\pi$,
EINSTEIN [10]

and hence

$k = 1/c^2 = \mu\epsilon$
CLERK MAXWELL

and is the result of G being 1, i.e. non-dimensional. This indicates that instead of writing $E = mc^2$ one should now write

$$E = \frac{m}{\mu\epsilon}.$$

As $\mu\epsilon$ depends on the physical characteristics of the media, it is more accurate for experiments carried out under terrestrial conditions to calculate the value of the masses of the elementary particles using these values rather than the constant c, that is, $m = E\,\mu\epsilon$ rather than $m = E/c^2$.

Table 1 of the unified theory extends to plus and minus infinity. It still has many gaps such as the entities of chemical, biological and social sciences. However, provided that these can be expressed in terms of dimensional equations including, if unbalanced, one or more constants, the values of which are determined by dividing one side into the other, it will be found that these constants either turn out to be non-dimensional numbers or to have dimensions in terms of **L**, **T** or c, which are then substituted into the original equations to give a dimensionally homogeneous expression. In many problems the time element ($1/\mathbf{T}^n$) can be disregarded, but it becomes significant in studies of the very large (cosmology) and the very small (nuclear physics), and in problems involving frequency.

I now express my great appreciation to Dr John Amson and Dr Christine Crow for its help, to St Andrews University for the use of its libraries, and to the members of ANPA for their courteous and critical appreciation of the views now made public.

Symbols used

dimensional		**variables**		**standard**	
M	Mass	m	mass	θ	temperature
L	Length	r,s	length	μ	magnetic permeability
T	Time	t	time	ϵ	electrical permittivity
		f	acceleration	G,K	Universal Gravitation Constant
		c,v	velocity	k	Einstein constant
		Q	heat	R	Universal Gas Constant
		P	pressure		
		V	volume		

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APPENDIX A – PROPOSITIONS

1: THAT the ratio measured as the velocity of light, c, can be interpreted as a ratio of dimensions L = Length and T = Time in the study of natural phenomena, and that 'c' is THE basic physical constant.
2: THAT the dimensions of physical entities can be expressed in terms of a representative length L and/or a representative time T.
3: THAT these concepts so expressed can be tabulated as shown in Table 1.
4: THAT the tabulation indicates that the entities are connected by a calculus (of Newton) and can be split to form entities of a lower order: for example:

$$\frac{L^4}{T^4} = \frac{L^3}{T^2} \times \frac{L}{T^2} \text{ or } \frac{L^3}{T^2} \times \frac{L}{T} \times \frac{1}{T}$$

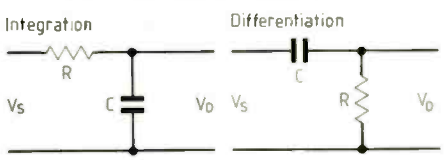
5: THAT each concept so defined exists in a space-time of a multi-dimensional geometry consisting of scalars, vectors, quarternions (Hilbert spaces, in general). For example: (a) mass exists in a space consisting of three dimensions of length and two dimensions of time (or frequency = 1/T):
(b) the quantum of action L^5/T^3 exists in a space with five dimensions of length and three of time, being the time integral of energy $\int E\,dt$.
6: THAT each of the geometries is conservative, e.g. exhibits conservation of mass, or of power, or of energy; but that interchange occurs in physical systems.
7: THAT Table 1 provides a metric for an aether in which all the entities operate.
8: THAT throughout the tabulation there are time and length integrals and differentials connecting the concepts, and that these operate in general from minus infinity to plus infinity.
9: THAT is c is a constant, then L/T is constant. (Thus, if L increases, then T must increase to preserve the constant ratio. When T increases, 1/T decreases in numerical terms. Therefore the greater the distance over which L is measured, 1/T (i.e. frequency) diminishes. Thus there is a shift to the red in the observed spectrum which cannot be equated to a velocity of recession as in the Doppler Effect).

APPENDIX B – SIMILAR OPERATIONS

Operation =	Integration	Differentiation
Mathematical	$\int \frac{L}{T}\,dx$	$\frac{L}{T}\frac{\partial}{\partial x}$
Electrical ★	$V_o = -\frac{1}{-CR}\int V_s\,dt$	$V_o = -CR\frac{\partial V}{\partial t}$
Mechanical	Babbage	Babbage
Unified Theory	× L or × T	× 1/T or × 1/L

N.B. $\frac{L}{T}$ = C and x = L or T

★ Equivalent electrical circuits



Examples

$$\int P\,dL = \frac{L^4}{T^4} \times L = \frac{L^5}{T^4} = \text{energy or work done.}$$

$$P\frac{\partial}{\partial L} = \frac{L^4}{T^4} \times \frac{1}{L} = \frac{L^3}{T^4} = \text{impulse or momentum.}$$

$$\int E\,dT = \frac{L^5}{T^4} \times T = \frac{L^5}{T^3} = \text{Planck's constant.}$$

$$E\frac{\partial}{\partial T} = \frac{L^5}{T^4} \times \frac{1}{T} = \frac{L^5}{T^5} = \text{power.}$$

N.B. The quantities on the right-hand-sides are constant or conservative in any closed system.

The equation of conservation of mass (sometimes called the convection-diffusion equation) may be written as

$$\frac{\partial}{\partial t}\left(AC\right) = m + \left[\frac{\partial}{\partial x}\, DA\frac{\partial C}{\partial x}\right] - \left[\frac{\partial}{\partial x}(AVC)\right]$$

(α) (△) (β) (γ)

where

$A \equiv L^2$ ...area; $C \equiv \frac{L}{T} = V$...velocity;

$m \equiv \frac{L^3}{T^2}$ ...mass; $D \equiv \frac{L^2}{T}$...diffusion

Then:

$$(\alpha) = \frac{\partial}{\partial t}\left(AC\right) = \frac{L^2}{1} \times \frac{L}{T} \times \frac{1}{T} = \frac{L^3}{T^2} = m \quad \text{i.e.}(\triangle)$$

$$(\beta) = \frac{\partial}{\partial x}(DA\frac{\partial C}{\partial x}) = \frac{L^2}{1} \times \frac{L^2}{T} \times \frac{L^2}{1} \times \frac{1}{T} = m^*$$

$$(\gamma) = \frac{\partial}{\partial x}\left(AVC\right) = \frac{1}{L} \times \frac{L^2}{1} \times \frac{L}{T} \times \frac{L}{T} = m$$

$$^*\text{n.b. } \frac{\partial C}{\partial x} = \frac{\partial L/T}{\partial L} = \frac{1}{T}$$

If the substance is decaying at the rate K, proportional to its concentration, then KAC is added to the right-hand of the equation, i.e.

$$KAC = \frac{L^3}{T^2} = \frac{K}{1} \times \frac{L^2}{1} \times \frac{L}{T} \quad \text{i.e. } K = \frac{1}{T}$$

If there are two flows in opposite directions then

$$U = U_1 \pm \frac{Q}{A},$$

where U_1 is the main flow, and A is the cross-section under review. The corresponding equation for conservation of volume, i.e. L^3, is then

$$\frac{\partial A}{\partial t} \pm \frac{\partial}{\partial x}\left(AU_1\right) = 0;$$

i.e. constant diffusion/concentration

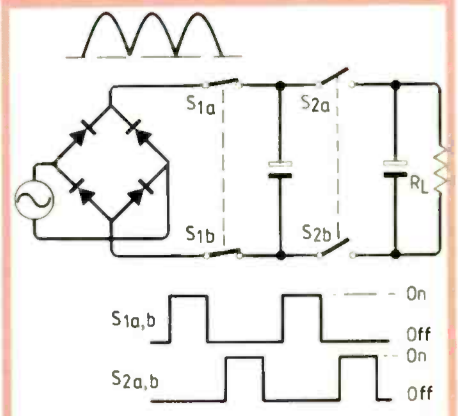
$$\left(\frac{L^2}{T}\right).$$

Novel power supply needs sponsorship

By switching capacitors using mosfets it is possible to build a power supply that is 'isolated' from the mains, yet does not need a transformer. Transferring charges via switches is not a new method of providing isolation – take the flying capacitor for example – but applying the approach to power-supply design probably is new.

Aubrey Sandman, who has applied for a patent for the charge-transfer supply, says that switching-capacitors will simplify p.s.u. design and result in lighter products. And, if his assumptions are correct, the theory could also result in efficiencies approaching those obtained from switch-mode supplies, but without the same r.f.i. problems.

Mains 'isolation' provided by the circuit is not what most people would envisage as isolation, hence the inverted commas. By isolation, Aubrey means that the positive and negative rails of the supply are always isolated from the mains by a power mosfet in its off state. As a result, either the positive or negative sides of the supply could potentially be connected to earth without causing current in the neutral line.



He argues that by including protection circuits, such as crowbars, the switching-capacitor supply could be as safe as a conventional isolating supply. We pointed out that BS has difficulties with the opto-isolator, which puts a piece of plastic between the mains and the user, so it would certainly find a semiconductor isolator hard to accept. Remaining optimistic, Aubrey said "I'll have to have a chat with BS".

Although Aubrey has a working circuit, he still has one or two problems to sort out. For example, to get the best results the power mosfet pairs need to operate as close as possible to their safe-operating limits throughout the entire capacitor-charging cycle, providing a few milliamps while their drain-source voltages are high and a few amps when their capacitor is almost fully charged. He says that he has this problem almost solved.

Another problem is that d.c. output from the circuit is at 300V. On paper, Aubrey's solution to this problem looks interesting, but he has yet to work out the practical details. To develop his ideas further, he needs sponsorship. Is anyone interested? If so, telephone 01 608 1282.

Philip Smith's chart

Having described the Smith chart in detail in the first part of this article in August, JW concludes by giving some examples of its usage

JOULES WATT

Last month, I traced the development of the Smith chart and showed how it is applied to the presentation of transmission-line impedance problems in a visual manner, although it has many uses in stability, matching and related problems in other types of circuit. Now, we can have a look at a few examples of the chart in impedance plotting and stub matching.

EXAMPLES

You should find plotting impedances straightforward. For example, the impedance z_L of a certain radio aerial might vary with frequency according to Table 1. An impedance plot crossing the real axis of the Smith chart shows where your resonances are. In this example, label the resonant frequency "1" on the aerial impedance plot, Fig.11. We have *normalized* values again – this time with respect to frequency. If you now connect an inductance with normalized reactance j1.4 at f = 1, in series with the aerial, the new impedance plot, z_L' on the chart, shows resonance lowered to about 0.875f. If you draw a maximum tolerable s.w.r. circle on the chart, you get the bandwidth over which this aerial will operate for the condition before you connected the series inductor, as well as that after.

The next example shows how a shift in position along a transmission line changes the impedance. Suppose you have a z_L of 1.8 – j0.5 and you want to know the impedance at a point 1.1 back along the line. Enter the chart at this point in Fig.12. By the way, the angle from the entered point to either the 0 or ∞ position in the direction towards the generator defines the *electrical length* of the termination. This length gets you to a point of pure resistance, either the high value (choose ∞) or the low one (choose 0). I have chosen the open line, so the length is 0.28. The "S = 2" circle upon which z_L sits, shows the v.s.w.r. on the line. Move round the chart a further 1.1 towards the generator. The impedance locus moves along the S circle to position z_{in}. Read off the impedance as 0.72 – j0.53 which, on a 50Ω system, would be (36 – j26.5) ohms.

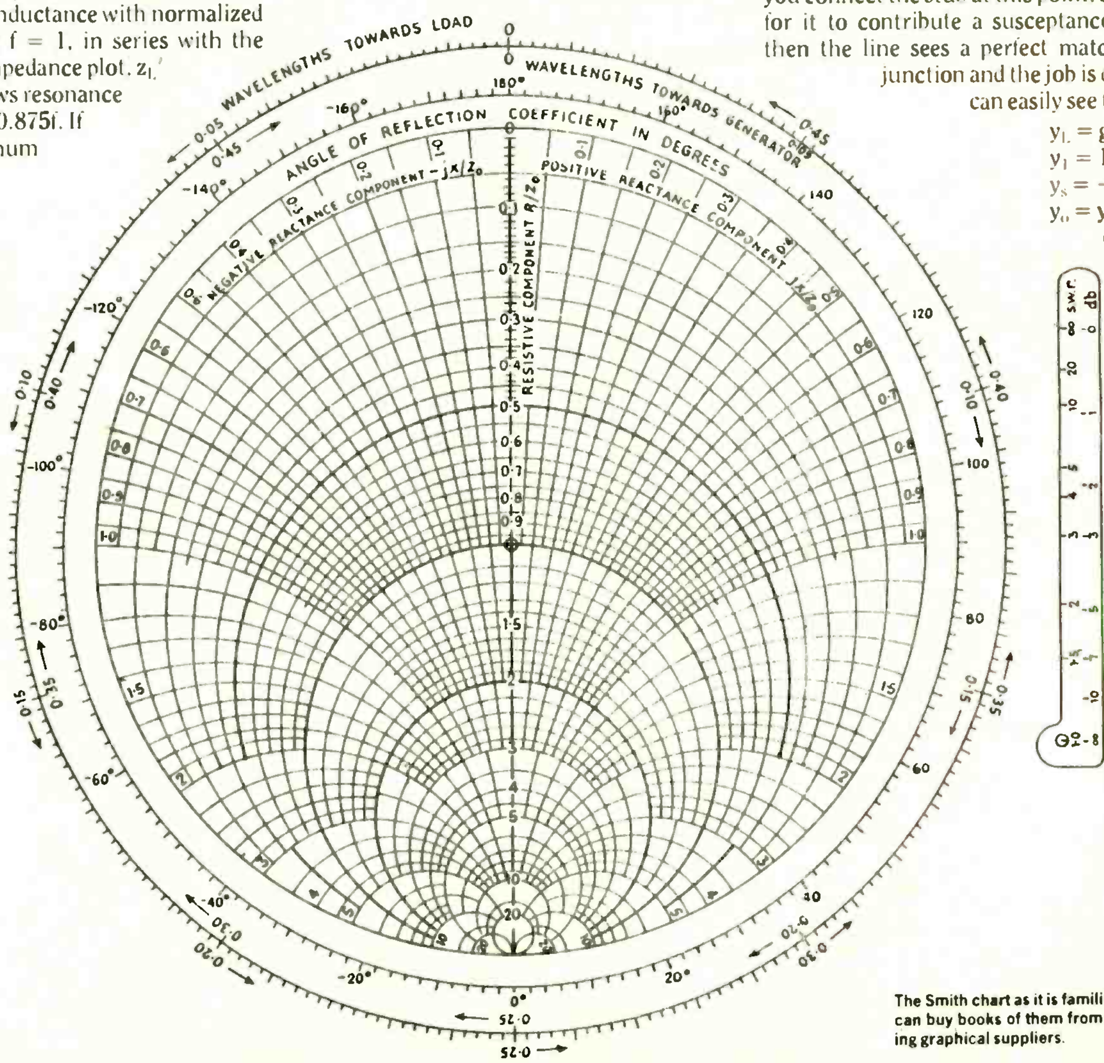
Now have a go at *stub matching*. A single short-circuited transmission-line stub possesses two variables – its length and where you have connected it across the line. Both parts of the admittance, the real and the imaginary, come under control because of this. In particular, you can adjust the real part to 1 and eliminate the imaginary part altogether. *Across* the line is the operative word. It indicates that we should work in terms of *admittance*, and that is how the chart should be interpreted now. I have left this example as the general case; see Fig.13. Enter the chart at y_L. Immediately, you have the electrical length of y_L and the v.s.w.r. on the line, if you want them. As you move back along the line towards the generator, eventually you will strike the circumference of the g = 1 circle. At this point $y_1 = 1 + jb$. If you connect the stub at this point, arranging for it to contribute a susceptance of – jb, then the line sees a perfect match at this junction and the job is done. You can easily see this form.

$y_L = g_L + jb_L$

$y_1 = 1 + j_1$

$y_s = -jb_1$

$y_o = y_1 + y_s = 1$ (matched)



The Smith chart as it is familiarly seen. You can buy books of them from the engineering graphical suppliers.

Table 1. A typical list of impedance values with frequency for a microwave aerial.

f/f_o	Z_L	X_L	Z_L
0.8	0.80 – j1.6	j1.12	0.80 – j0.48
0.9	0.90 – j	j1.26	0.90 + j0.26
1.0	1.20 + j0.0	j1.40	1.20 + j0.40
1.1	1.50 + j	j1.54	1.50 + j2.54
1.2	2.20 + j1.7	j1.68	2.20 + j3.38
f_o = 1 GHz L = 11.2 nH			

You will not find sliding a stub up and down coaxial transmission lines very easy. A standard method to overcome this problem uses two variable short-circuit stubs at fixed positions on the line, as Fig. 14 shows.

A number of people beginning the use of the Smith chart find the treatment of this double stub difficult to visualize (geometry again?), but following it through the illustrates the usefulness of the chart very well. Moving towards the generator through the distance d_1 transforms the admittance of the load, y_L, to some value y_1 across 1 – 1: see Fig. 14 inset. Stub No 1 adjusts y_1 so that, at a further distance d_2 back along the line, an admittance value y_2 appears across 2 – 2 with a normalized real part equal to 1. Therefore at 2 – 2, $y_2 = 1 + jb_2$ so that stub No 2 has the duty of adding susceptance $-jb_2$ there, so tuning out the $+jb_2$ to leave a matched line.

We do not yet know the value of b_2, but whatever it is, y_2 at 2 – 2 sits somewhere on the "g = 1" circle of the chart. To arrive forward at position 1 – 1, the whole of the "1" circle has to move round the chart toward the *load* through the distance d_2 in wavelengths, carrying all its circumferential points – including the unknown point relevant to the problem. At this stage you can see how much susceptance stub 1 has to add across 1 – 1 to move the admittance y_1 along a constant conductance circle to get on to the shifted "g = 1" circle. This move arrives at and identifies the relevant point. (There might be two points. How would you interpret the other one? On the other hand, suppose the move along the constant conductance circle failed to intersect the shifted "1" circle at all. How would you handle that?)

Notionally, you now journey back along the transmission line to position 2 – 2 carrying the known point back to the normal "g = 1" circle position. Stub 2 tunes out the remaining susceptance, as already mentioned, and this final move takes the point into the centre of the chart. In other words, you have matched the line.

The Smith chart, then, after a little practice, answers questions about impedance very quickly and with engineering accuracy. I hope you now agree that it forms one of those 'analogue' applications that come through the 'digital' revolution undiminished – in fact enhanced, as its regular appearance on computer v.d.us testifies.

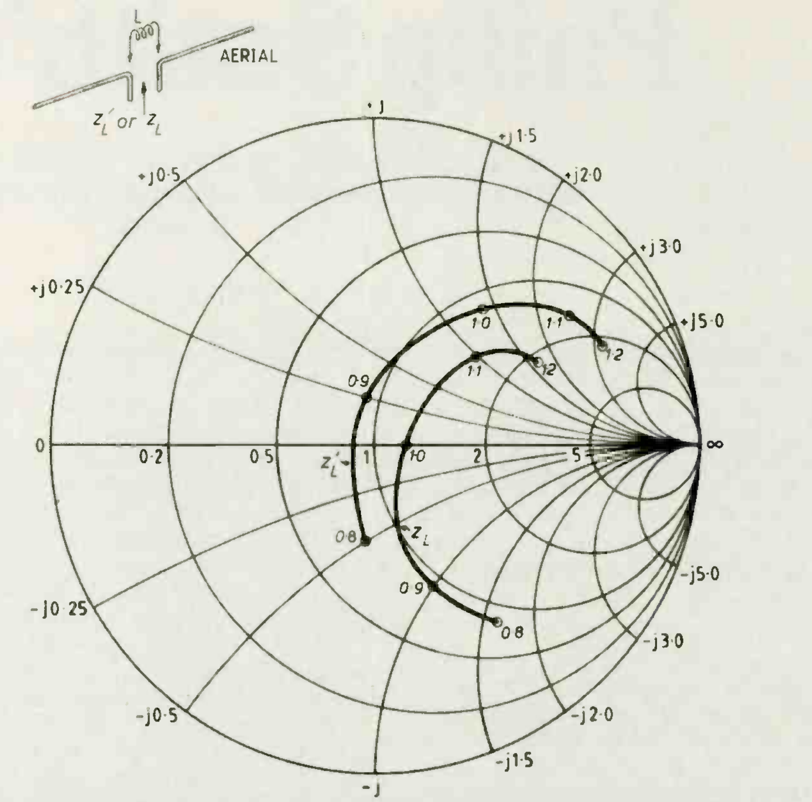


Fig.11. The Smith chart allows the locus plots of impedances and admittances over wide bandwidths; the effect of changes can be instantly observed (especially with automatic plotting equipment, see last month's bibliography).

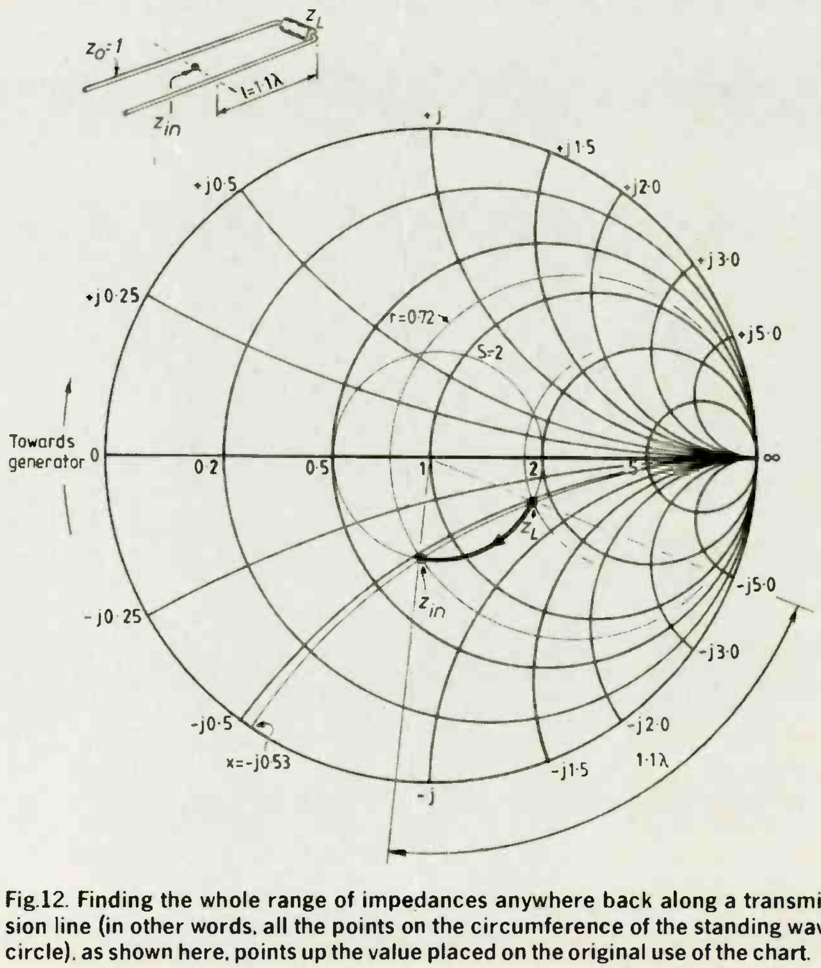


Fig.12. Finding the whole range of impedances anywhere back along a transmission line (in other words, all the points on the circumference of the standing wave circle), as shown here, points up the value placed on the original use of the chart.

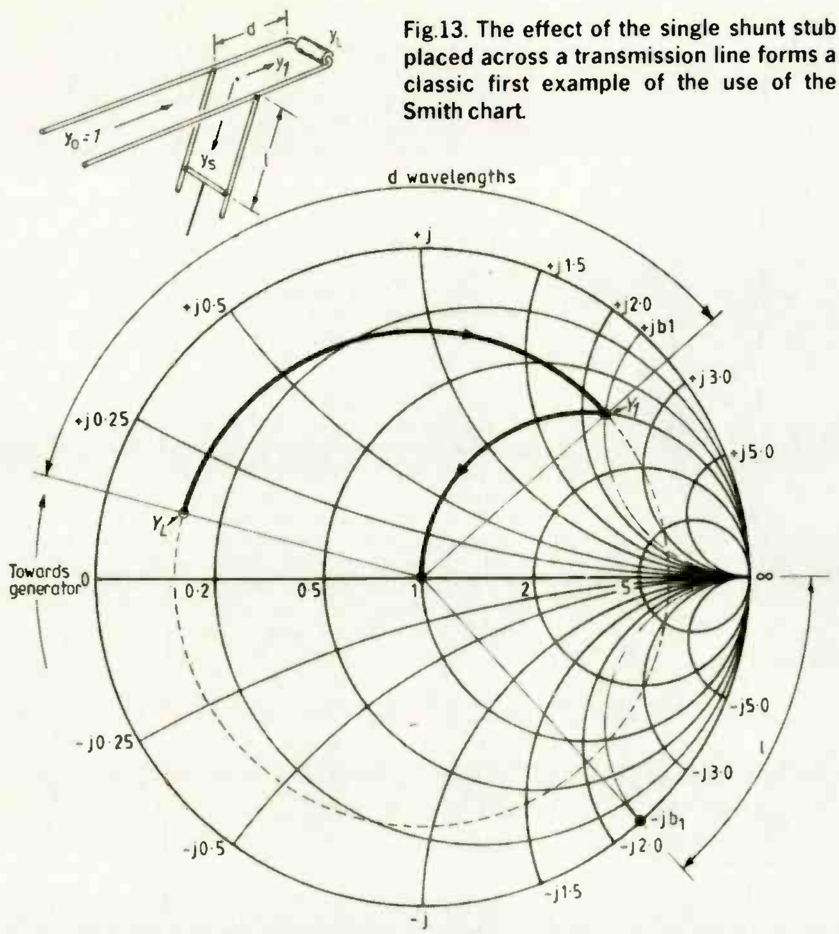


Fig.13. The effect of the single shunt stub placed across a transmission line forms a classic first example of the use of the Smith chart.

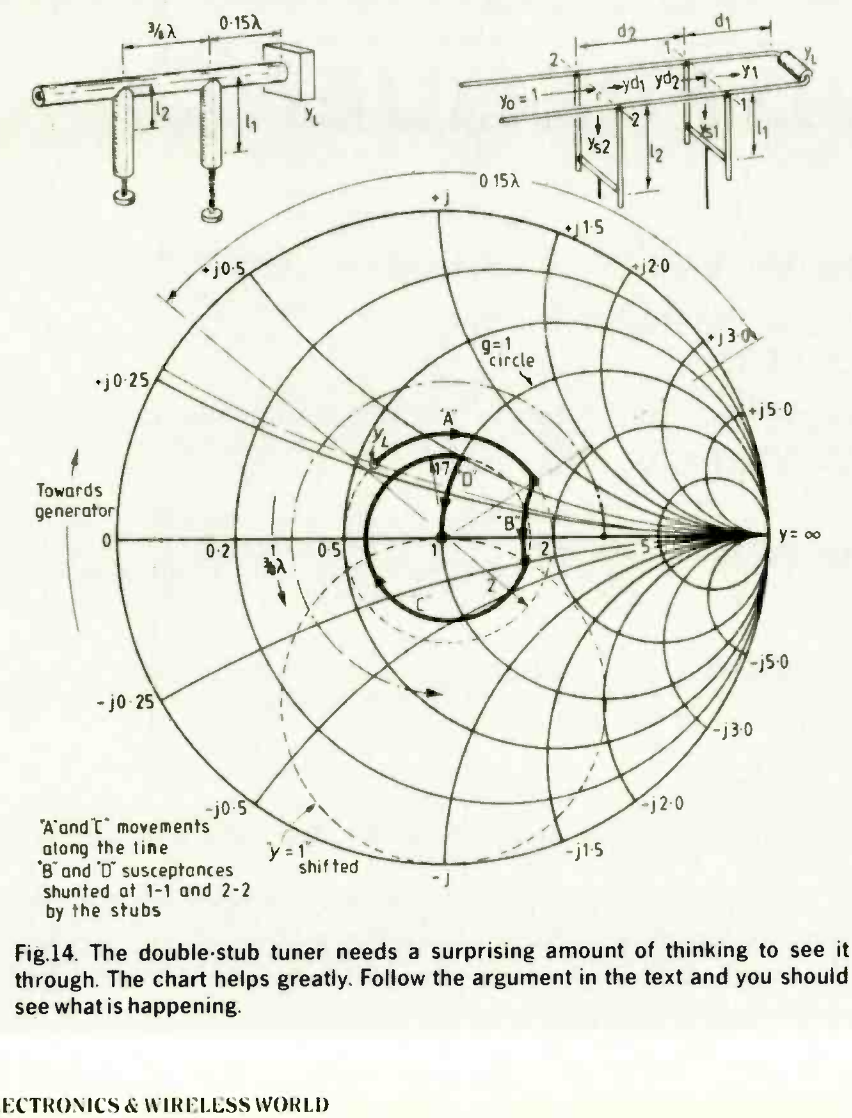


Fig.14. The double-stub tuner needs a surprising amount of thinking to see it through. The chart helps greatly. Follow the argument in the text and you should see what is happening.

Seminars, training courses

20-23 September. University of Southampton Microelectronics Centre. Practical course on circuits and systems in **silicon.** Contact the conference office at Sira Ltd. 01-647 2636.

18 October. Chislehurst, Kent. Tutorial on adaptive and self-tuning **controllers:** principles and limitations of conventional p.i.d. loop controllers. Sira Ltd. 01-647 2636.

27-28 September. University of Essex, Colchester: **STEbus** applications seminar and trade exhibition, organized by the STE Manufacturers and Users Group. Topics include networking, multiprocessing, rom-based target systems, datacomms, system development using intelligent slaves. Details from STEM on 07357-4976 (fax 5155) or at P.O. Box 149, Reading, Berkshire RG6 3HB.

Among the summer events organized by the Institute of Electrical Engineers are **vacation schools** on switching and signalling in telecommunications networks (4-9 September, Birmingham): measurement technology, d.c. to v.h.f. (4-10 September, Birmingham); telecommunication network design and performance evaluation (11-16 September, Glasgow): electromedical technology (18-24 September, Canterbury). A school on plasma processing of semiconductor materials is being arranged for December. Details from the IEE in London, 01-240 1871.

A series of one-day workshops on **p.c.b. design tools** is being staged at Cambridge by Hi-Tek CAE. Dates this year are 22 September, 20 October, 24 November and 15 December. Fee is £200. Hi-Tek CAE, Ditton Walk, Cambridge CB5 8QD, tel. 0223-213333.

Commercial courses covering a wide range of subjects including artificial intelligence, supercomputers, digital processing, communications and technology management are organized by Integrated Computer Systems. Fee for each two-day course is £250. Details from ICS Publishing Company on 0372-379211.

European Silicon Structures offers courses on **custom silicon design** at is own premises or the customer's. Details from ES2 at Bracknell on 0344-525252.

Force Computers, which specializes in **VMEbus** products, has produced a brochure describing its training courses and seminars. Contact Force Computers (UK) Ltd, 1 Holly Court, 3 Tring Road, Wendover, Buckinghamshire HP22 6PE, tel. 0296 625456.

EVENTS

14-16 March, 1989. Birmingham NEC: Internepcon, Semiconductor International. Special topics are hybrid manufacture, p.c.b. sub-contracting, and custom silicon. Both exhibitions will be accompanied by conferences. Details from Cahners Exhibitions in Twickenham on 01-891 5051.

16-17 March, 1989. Olympia, London: **Cable & Satellite** 89 exhibition and conference. The exhibition continues for a further two days during which it is open to the general public. Details from Montbuild Ltd, 01-486 1951.

17-19 March, 1989. Brighton: Defence **Oceanology** International 89, embracing technology from sub-sea to satellite. Spearhead Exhibitions, 01-549 5831.

5-6 April, 1989. London: fifth International **Logistics** Conference, organized by the Society of Logistics Engineers. Details from Consert, 57-61 Newington Causeway, London SE1 6BL, tel. 01-403 2351.

Step-up switching regulator

An f.m. switching regulator producing 44V from seven NiCd cells at an efficiency of over 90% for currents of 1.5 to 60mA

N.J. CHAFFEY and T.A.PERKINS

Many of the portable stimulation controllers produced by the MRC Neurological Prosthesis Unit require a supply of between 25 and 44 V. To save on the number of cells in the battery, flywheel-type, step-up switching regulators have been used for most of our stimulation controllers designed in the last two years.

We found that commercial switching-regulator control i.cs were disappointing – particularly in stability, efficiency, quiescent current and the large number of outlying components needed. For scarcely any more components a much more predictable and efficient voltage converter may be based on standard op-amps or comparators. The f.m. switching regulator described here is designed to produce about 44 V ± 1V from a 7.5 to 10 V battery (seven NiCd cells, giving 8.5 V for most of the discharge curve) whilst maintaining an efficiency of over 90% for loads from 1.5 to 60 mA. Useful efficiency (80+ %) is maintained down to only 400 μA load – a dynamic range of 150:1, which is due to the low quiescent current of 368 μA for 8.50 V input. Since very little has been published on switchers for use below 5 W and as 80% seems generally accepted as "good" efficiency – usually quoted at full load with a load-current dynamic range of about 5 : 1 – we thought our design might be useful to others. Output voltage can readily be altered by changing the ratio of a potential divider. Best of all, the design is simple and can be made compactly, most of the components being available in surface-mount versions.

The circuit shown in Figure 1 consists of four main parts: the parametric feedback circuit which sets the output voltage; oscillator; the flywheel voltage converter; and a low-battery-voltage cut-off.

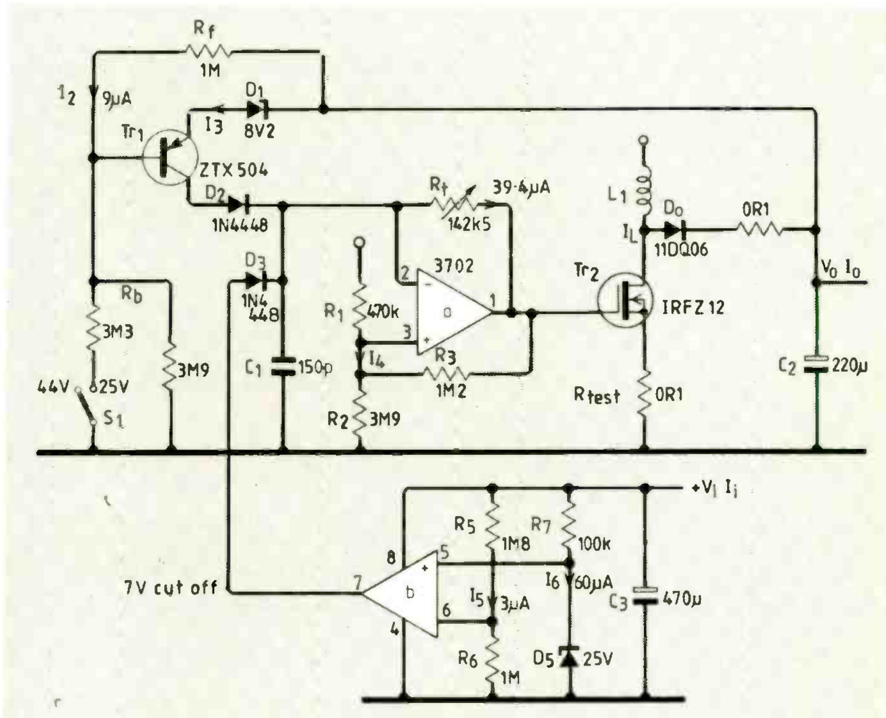


Fig.1. Switching-regulator circuit diagram.

THE FLYWHEEL CONVERTER

Taking the flywheel converter first, there are three phases of operation. Initially the inductor is charged from the input supply; in the second phase it is discharged to the output; and in the final phase it is essentially disconnected.

Charging the inductor. In the first phase, when the mosfet Tr_2 is turned on, energy E_L is stored in the choke. Presuming that the current rises linearly with time (true for a constant inductance with no series resistance), E_L is given by

$$E_L = L I_L^2/2 = V_i I_m T_c \quad (1)$$

Where L is the inductance of the choke. I_L is the peak current in it. I_m is its mean current averaged over the whole cycle of period T_c and V_i is the input supply voltage.

I_L can be obtained from:

$$I_L = V_i T_i/L = 2 I_m T_c/T_i \quad (2)$$

T_i being the input pulse width. L is related to the number of turns N in the inductor

$$L = A_L N^2 \quad (3)$$

where A_L is taken from manufacturer's data. From equation (3), equation (2) may be rewritten

$$I_L = V_i T_i/(A_L N^2) \quad (4)$$

and hence

$$E_L = V_i^2 T_i^2/2 A_L N^2. \quad (5)$$

By definition

$$V_i I_i = \eta V_o I_o/100 \quad (6)$$

where η is percentage overall efficiency, V_o the output voltage, I_o the output current, and I_i the mean input current (including that of the converter control circuit). At full load in this design, the control circuit current I_c is quite insignificant (about 0.1% of I_m – see Tables 1 and 2). I_i may then be taken as the same as I_m and the overall efficiency the same as the converter efficiency η_c.

By using equations (1), (5) and (6) and crudely approximating η = 100%, a rough calculation can now be carried out. Suppose V_i = 8.5 V, A_L = 250 nH, N = 35, T_i = 35μs (keeping it simple), V_o = 44 V and I_o = 60 mA: then E_L = 144 μJ and T_c turns out at 55μs. Note designs with $T_c < T_i$ are not feasible! For Fig. 2, the situation is T_i =

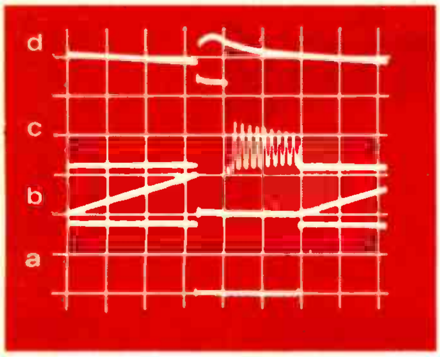


Fig. 2. Operation at 8.50 V_i, 43.5 V_o, 727 ohm load : η = 93%. (a) oscillator output at 5V/div; (b) choke charge current at 1 A/div; (c) Tr_2 drain/choke at 20 V/div; (d) V_o at 0.1 V/div.

33.5μs, T_c = 59.5μs, V_o = 43.5 V and η = 93%. Table 1 summarizes key data for the flywheel converter, along with the required formulae. To simplify assembly of the pot core, the adjuster was omitted; a 6% inductance reduction can be expected for this.

Saturation. The usual relationship between the voltage across a coil and the rate of change of magnetic flux linking the turns of that coil may be written for our purpose (bearing in mind the flux is initially zero)

$$B = V_i T_i/(AN) \qquad (7)$$

where B is the flux density and A the effective cross-sectional area of the core. If the pulse width T_i exceeds the time T_s at which the flux density reaches saturation both magnetic hysteresis losses and current increase rapidly. Using the 'rough' example quoted above, a peak flux density estimate of 340 m Tesla is obtained, which seems safe compared with the manufacturer's saturation flux density value of 390 m Tesla (see again Table 1). This last figure, however, is for a uniform toroidal core. For a pot core of non-uniform cross-section, it may be more pertinent to substitute the minimum cross-section A_m (if known) for A in equation (7). Where the ferrite data is not available, a more conservative limit of 300 m Tesla is probably safe (cf K.L. Smith, 1985[4]).

With V_i = 10 V, Fig.3 illustrates the start of saturation where the current changes slope dramatically upwards after 29μs, some 10% before the end of the input pulse. Fortunately the reduction in efficiency from 93% to 92% is acceptably small. However, if

Table 1: choke :14mm × 8mm N48 pot core) and switch (IRFZ12)

PARAMETER	SOURCE/FORMULA	THEORY	SOURCE/FORMULA	MEASURED
nominal A_L/u_r	Data Book[1]	250nH/159		
nominal A_R	Data Book[1]	115 μΩ		
N turns 0.375 mm Cu wire		35		
L zero bias inductance	$L = A_L N^2$	306.25 μH	no adjuster-6%	284 μH
R_c coil resistance	$R_c = A_R N^2$	0.14 Ω		0.2 Ω
I_m mean coil current			**	329 mA
E_L energy per cycle	* $V_i^2 T_i^2/(2A_L N^2)$	144 μJ	** $V_i I_m T_c$	166 μJ
I_L peak coil current	* $V_i T_i/(A_L N^2)$	0.97A	** $2I_m T_c/T_i$	1.17 A
L_{dc} d.c.-biased inductance			** $V_i T_i/I_L$	244 μH
l magnetic path length	Data[1]	20 mm		
A cross sectional area	Data[1]	25 mm^2		
A_m minimum cross section	Data[1]	19 mm^2		
B mean flux density @ I_L	* $V_i T_i/(AN)$	340 mTesla	** $V_i T_i/(AN)$	325 mTesla
B_s maximum flux density	Data[2]	390 mTesla	*** $V_i T_s/(A_m N)$	436 mTesla
I_{sat} saturation current			*** $V_i T_s/L_{dc}$	1.19 A
max. V_{ds} for IRFZ12	Data Sheet[3]	50 V		
R_{dson} for IRFZ12	Data[3] @ 10 V_{gs}	0.2ohm Typ	@ 8.5 V_{gs}	0.2 Ω
C_{oss} output capacitance	Data[3] @ 8.5V_{ds}	240 pF	$1/(4\pi^2 f^2 L) = C_p$	309 pF
V_R ripple voltage pk-pk	$E_L/V_o C_o + I_L$(e.s.r.)	15 mV + ?	**50 mΩ esr	75 mV
R_{son} series res. Tr_2 on	$R_c + R_{dson} + R_{test}$	0.5 ohm	0.1Ω wiring!	0.6 Ω
R_{soff} series res. Tr_2 off	$R_{son} - R_{dson} - R_{test}$	0.3 ohm		

Notes 1, 2 and 3: see references.
* Rough estimate based on: V_i = 8.5V, V_o = 44V, I_o = 60mA, T_i = 35μs, nominal A_L and η = 100%, then T_c = 55 μs
**Conditions: V_i = 8.5V, V_o = 43.5V, I_o = 60mA, T_i = 33.5μs, then η = 93% and T_c = 59.5μs
***Based on: V_i = 10V, L_{dc} = 244μH and see Fig. 3 for T_s = 29μs; η = 92%

Table 2: oscillator, regulation and low-voltage cut-off

PARAMETER	DATA USED & (EQUATION)	VALUE
τ time constant	$R_t C_t$, 142.5 kohm & 150 pF (Fig.1)	21.38 μs
V_{lt} lower trip point	Fig.1 & (15) → 0.661V_i · V_i = 8.5V →	5.62 V
V_{ut} upper trip point	Fig.1 & (16) → 0.920V_i · V_i = 8.5V →	7.82 V
delay correction for V_{ut}	t = 2.5μs, T = 21.38μs, $V_{ro} = V_i - V_{ut}$ & (17)	0.071V_i
V_{ut}' corrected V_{ut}	V_i − 0.071V_i	0.929V_i
time from V_{ut}' to V_{lt}	* $V_{ro} = V_{ut}'$, $V_{rt} = V_{lt}$ & (18)	0.340τ
Tr_1 oscillator output low	* τ = 21.38μs & (0.340τ + 2.5μs)	9.8 μs
V_{lt}' corrected V_{lt}	* t = 2.5μs, τ21.38μs, $V_{ro} = V_{lt}$ & (17)	0.588V_i
time from V_{lt}' to V_{ut}	* $V_{ro} = V_i - V_{lt}'$, $V_{rt} = V_i - V_{ut}$ & (18)	1.642τ
T_h oscillator output high	* τ = 21.38μs & (1.642τ + 2.5μs)	37.6 μs
T_{cf} oscillation period	* $T_h + T_l$	47.4 μs
expected mark: space ratio	T_h/T_l	3.84:1
measured T_l	* Tr_2 drain disconnected, V_i = 8.5V	9.5 μs
measured T_h	* Tr_2 drain disconnected, V_i = 8.5V	37.7 μs
measured T_{cf}	* Tr_2 drain disconnected, V_i = 8.5V	47.2 μs
I_{fo} measured supply current	* Tr_2 drain disconnected, V_i = 8.5V	373 μA
I_s static current	Fig.1: $I_4 + I_5 + I_6 + I_C$	91 μA
I_{fd} free osc. dynam. current	* Tr_2 drain disconnected: V_i = 8.5V, $I_{fo} - I_s$	282 μA
I_{dl} dynamic current, I_o = 60mA	V_o = 43.5V & V_i = 8.5V : I_{fd}(47.2/59.5)	224 μA
I_c control circuit current	I_o = 60mA, V_o = 43.5V & V_i = 8.5V: $I_s + I_{dl}$	315 μA
V_{set} set voltage – high	Fig.1, V_{be} = 0.6, S1 open, h_{fe} = 150 & (19)	44.1V
V_{set} set voltage – low	Fig.1, V_{be} = 0.6,S1 closed, h_{fe} = 150 & (19)	25.0V
V_o measured output voltage	V_{set} = 44.1V, I_o = 0 – 60mA & V_i = 7.5 – 10.0V	42.7 – 44.7V
V_o measured output voltage	V_{set} = 25.0V, I_o = 0 – 34mA & V_i = 7.5 – 10.0V	24.2 – 24.6V
V_{cut} low battery cut-off	Fig.1 & (20)	7.0 V

* As free-running oscillator, n.b. timing independent of V_i

much greater than 10% of the pulse is in saturation, the efficiency falls alarmingly! As shown in Table 1, equation (7), with T_s also substituted for T_i, then yields a maximum flux density for Fig.3 of 436 m Tesla, agreeing with the manufacturer's value to within 12%.

It should be noted that as the coil current approaches the saturation current I_{sat}, the inductance is not constant. For I_L just short of I_{sat}, Table 1 shows the inductance L_{dc} is some 14% less than that without d.c. bias. A by-product of this inductance reduction is that the energy E_L is correspondingly increased, equation (1) still applying if L_{dc} is substituted for L and 2 $I_m T_c/T_i$ for I_L.

From equations (2), (4) and (5), it may be seen that to vary N while maintaining the same power (hence holding I_m and I_o constant too), the timings T_i and T_c should both be kept proportional to N^2 and then equation (7) may be rewritten

$$B \propto N/A \text{ when } T_c \propto T_i \propto N^2, \qquad (8)$$

I_L and V_i constant.

Thus, if saturation is a problem, the flux density may be reduced for the same power by lowering N and reducing the timing periods as N^2.

This approach is limited by the speed of the control circuitry. Conversely if no reduction in inductance is detected, N may be increased to take advantage of the reduction in quiescent current possible with slower control circuitry. Alternatively, a smaller pot core may be used in this case.

Discharge phase. When Tr_2 is turned off, the choke current continues to flow (i.e. it flywheels), discharging the stored energy through the only pathway available – via the diode D_4 to the output capacitor C_2 at the output voltage V_o. In this phase of the cycle,

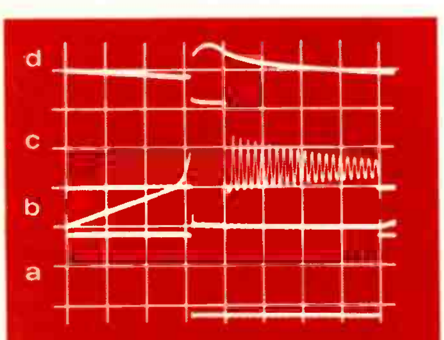


Fig.3. Operation at 10.0 V_i, 44.1 V_o, 727 ohm load: η = 92% (a), (b), (c), (d) as for Fig.2.

the step-up voltage V_{su} is across the inductor in such a direction as to reduce its current to zero in time T_d

$$T_d = V_i T_r / V_{su} \qquad (9)$$

where

$$V_{su} = V_o + V_d - V_i \qquad (10)$$

V_d being the forward bias voltage of the diode D_1. For Fig.4 a 0.1 ohm resistor was temporarily placed in series with D_1 and a pair of differential probes connected across it to show the discharge current. Superimposed on this is the charge current waveform derived from the voltage on the 0.1 ohm resistor in series with Tr_2's source, giving a good illustration of how closely equivalent are the peaks of the charge and discharge currents in the choke and how close to linear are the slopes for these currents. Taking V_d as 0.4 V for a Schottky diode, equations (9) and (10) indicate a T_d value for Fig.2 of 8.2μs, some 7.7μs being observed.

Ripple. It may be shown that the peak-to-peak capacitative ripple voltage V_c in capacitance C_o may be approximated as

$$V_c \simeq E_L / V_o C_o \qquad (11)$$

by presuming that the entire energy E_L is delivered to C_o in negligible time, and by equating energies before and after the choke discharge. At the low operating frequency here (< 20 kHz) the action of the capacitor's effective series inductance (e.s.l.) may be ignored. The total ripple V_R may then be estimated by adding in the contribution due to a presumed peak discharge current I_L through the capacitor's effective series resistance (e.s.r.)

$$V_R \simeq E_L / V_o C_o + I_L (\text{e.s.r.}). \qquad (12)$$

Unfortunately it may not be easy to predict the e.s.r. value prior to using the component. As shown in Table 1, an e.s.r. estimate of 50 mΩ accounts for most of the 75 mV p-p ripple seen in Fig.2. The value of C_o may seem unnecessarily large, but is required in our case to cope with the heavily pulsatile load of a stimulation controller as well as to reduce e.s.r.

Final phase. The inductor has across it parallel capacitance C_p made up of the output capacitance C_{oss} of the mosfet, the reverse capitance of D_1, the self capacitance of the coil, etc. It is, therefore, a parallel tuned circuit, one end of which is permanently connected to the input supply V_i. At the end of the discharge phase, the choke has no current but still has voltage V_{su} across it, kicking it into a damped oscillation centred on V_i. Here, as $V_{su} > V_i$, the first downstroke of this ringing is caught at ground by the integral diode in Tr_2 (restoring a tiny amount of charge to the input supply). Thereafter, ringing proceeds with a peak-to-peak swing of about $2V_i$, gradually decaying away. The frequency f of this ringing (537.5 kHz for Fig.2) provides the value of C_p by

$$C_p = 1/4\pi^2 f^2 L) \qquad (13)$$

Here, Table 1 shows that C_{oss} constitutes the overwhelming bulk of C_p. The energy needed to charge C_p with voltage V_{su} is

$$E_{cp} = C_p V_{su}^2/2. \qquad (14)$$

For Fig.2, E_{cp} is 0.2 μJ, which is negligible compared with the E_L value of 166 μJ but provides a warning of possible significant loss at higher operating frequencies.

THE OSCILLATOR

The relaxation oscillator in Fig.1 is built around one of the two comparators in a TLC 3702. This c-mos i.c. typically has quiescent current consumption of 11μA per comparator and 2.5 μs switching delay for 5 mV overdrive at its input. The push-pull outputs which swing fully rail-to-rail make it ideal for driving the mosfet Tr_2. Ignoring for the moment the switching delay, the capacitor C_t should be charged and discharged via R_t between a lower trip point V_{lt} and an upper trip point V_{ut} given by

$$V_{lt} = R_2 R_3 V_i/(R_1 R_2 + R_1 R_3 + R_2 R_3) \qquad (15)$$

and

$$V_{ut} = (R_1 R_2 + R_2 R_3) V_i/(R_1 R_2 + R_1 R_3 + R_2 R_3) \qquad (16)$$

The voltage on C_t may be obtained from

$$V_{rt} = V_{ro} e^{-t/\tau}, \quad \tau = R_t C_t \qquad (17)$$

where V_{rt} is the voltage across R_t at time t and V_{ro} is the initial voltage across R_t. Conversely, the time taken to reach voltage V_{rt} is given by:

$$t = \tau \ln (V_{ro}/V_{rt}). \qquad (18)$$

Using equation (17), Table 2 shows how the trip points are affected by the switching delay and hence, using equation (18), how the high and low output times may be obtained for the free running oscillator. Agreement between the theoretical and measured periods is within 0.3 μs.

The mark:space ratio for the free-running oscillator was chosen to be about 4 : 1, virtually as high as is practicable with this circuit. The intention was to maximize the E_L available per cycle (hence making regulation easier) and also to minimize the I_L required for a given power level so as to reduce resistive (i.e. I^2R) losses.

REGULATION

The parametric feedback circuit of Fig.1 limits V_o by turning on Tr_1, hence forcing the oscillator and Tr_2 off, whenever V_o exceeds V_{set} which is given by:

$$V_{set} = (R_f + R_h)(V_z + V_{be})/R_f + R_h I_3/h_{fe} \qquad (19)$$

where V_z is the zener voltage and V_{be} is the base bias voltage of Tr_1, h_{fe} its current gain and I_3 its collector current when turned on.

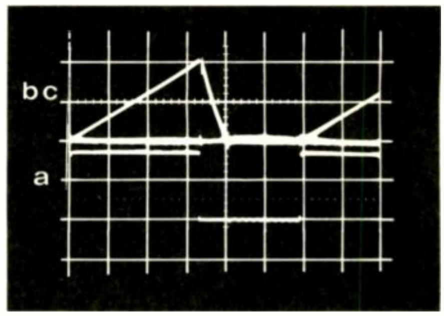


Fig.4. Choke charge and discharge currents (a) oscillator output/at 5 V/div; (b) choke charge current at 0.5 A/div; (c) choke discharge current at 0.5 A/div.

The I_3 term may be ignored in a rough estimate. When the load current I_o discharges C_o below V_o, Tr_1 is turned off, allowing a high pulse from the oscillator to deliver energy E_L to C_o after the end of that pulse. In equilibrium, pulses are permitted just often enough (f.m. control) to maintain V_o oscillating around V_{set}. Fig.5 illustrates the off-load condition where only the internal load of the parametric feedback circuit itself applies. For all but about 200 μs out of the 52 ms final phase of the cycle, V_o is such that Tr_1 supplies only sufficient current through R_t to hold C_t just above V_{lt}, keeping Tr_2 off as long as necessary. Wasted current is minimal, a powerful demonstration of the intelligence of negative feedback.

In practice, Tr_1 does not turn off instantly as V_o falls below V_{set} and the residual current slightly shortens the choke charge pulse T_r. The speed with which Tr_1 turns off is directly related to the speed with which V_o falls between choke discharges, i.e. I_o. Thus it may be reasonable to expect pulse width to decrease linearly with decreasing I_o (see Fig.6 for measurements). Although this pulse width modulation causes the inconvenience of making pulse-width prediction more involved, it does have the considerable advantage of extending the dynamic range of the regulator. Rapid optimization of timing may be carried out by setting V_i to its minimum value, monitoring V_o at high setting off load, then applying the maximum I_o and varying R_t till the drop in V_o is acceptable. A check should be made at maximum V_i that the off load V_o is still sufficiently restrained and that the core is not then excessively saturated with maximum I_o (see again Fig.3). Table 2 shows the

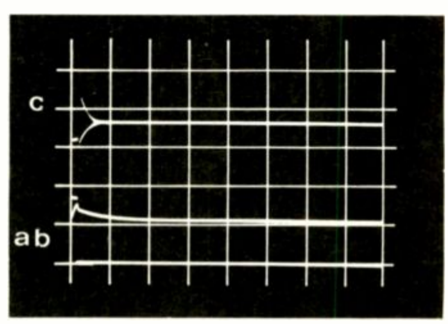


Fig.5. Operation of parametric feedback at 8.50 V_i, off load: T_c = 52 ms. (a) oscillator output at 5 V/div; (b) C_t/R_t at 5 V/div. N.B. trip point at 5.6 V; (c) Tr_2 drain/choke at 20 V/div.

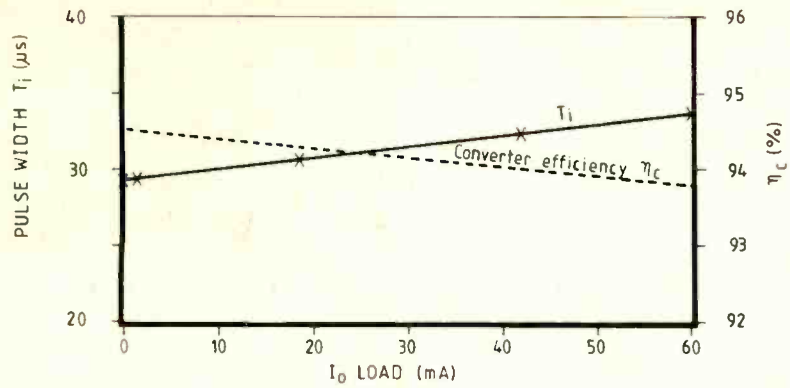


Fig.6. Pulse width T_i and voltage converter efficiency η_c for 8.5 V_i to 44 V_o conversion – versus load current.

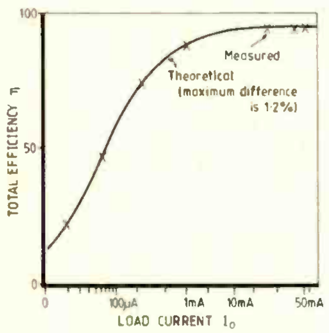


Fig.7. Total efficiency η for 8..5 V_i to 44 V_o conversion – versus load current.

measured range of V_o for both the 44 V and the 25 V settings. While regulation at the higher voltage is merely adequate for our purposes, that at the lower voltage is relatively much better because of the lower power required. Fig.6 shows a line for pulse width T_i versus I_o for $V_i = 8.5$ V and the 44 V setting, this line being linearly interpolated from measurements at the four points V_i = 7.5 V and 10.0 V with I_o = 0 and 60 mA. Agreement between the line and the points measured at $V_i = 8.5$ V is within 0.2 µs.

LOW VOLTAGE CUT-OUT

The fourth section of the regulator is almost self explanatory. When V_i is below V_{cut}, the comparator output is high and, being wire-Ored via a diode to the same input to the oscillator as for the parametric feedback, forces the oscillator off. V_{cut} is given by

$$V_{cut} = 2.5\,(R_5 + R_6)/R_6. \qquad (20)$$

As well as protecting a flat battery from large currents, this circuit also ensures that, at power on, Tr_2 is held off until V_i is high enough to ensure proper operation of the regulator. Consequently, the circuit may be switched on at the 44 V setting with maximum load with equanimity (power on settling time is then 140 ms).

LOSS ANALYSIS

Presuming that the choke current I increases linearly on charge, the energy E_{Ron} dissipated in the total resistance R_{son} in series with the inductance is given by

$$E_{Ron} = \int_0^{T_i} I^2 R_{son}\,dt = I_L^{\,2} R_{son} T_i/3. \quad (21)$$

Hence from equations (1) and (21) the percentage P_{Ron} of the input energy E_L lost in R_{son} is

$$P_{Ron} = 200\,R_{son}\,T_i/3L. \qquad (22)$$

During the choke discharge, Tr_2 does not contribute to the series resistance, so a lower value R_{soff} applies. Thus from equations (9), (10) and (22) and presuming P_{Ron} is small, the percentage P_{Roff} of E_L lost in R_{soff} is, to a first approximation

$$P_{Roff} \simeq 200\,R_{soff}\,T_i\,V_i/[3L\,(V_o + V_d - V_i)]. \qquad (23)$$

The percentage P_d lost in the flywheel diode D_o may be written as

$$P_d = 100\,V_d/V_o \qquad (24)$$

Assuming all these losses are small they may be combined by the Binomial Theorem to give a simple estimate of converter efficiency η_c

$$\eta_c = 100 - P_{Ron} - P_{Roff} - P_d \qquad (25)$$

If the coil is tightly and evenly layer-wound and the enamelled copper wire diameter and N are chosen so as to exactly fill the bobbin, then the coil resistance R_c can be obtained from

$$R_c \simeq A_R N^2 \qquad (26)$$

where A_R is a constant given by the manufacturer. In practice, although equation (26) is a useful guide, not all the above conditions apply and R_c is consequently rather higher (see Table 1). R_{son} may be written as

$$R_{son} = R_c + R_{dson} + R_{test} + R_w \qquad (27)$$

where R_w is the wiring and connection resistance which is not negligible unless great care is taken with the circuit layout. In a production circuit, R_{test} would be omitted. As P_{Roff} is much smaller than P_{Ron}, a rough estimate for R_{soff} is sufficient (see again Table 1). Using equations (22) to (25) and the T_i values indicated by the solid line in Fig.6, η_c may now be obtained for 44 V output with 8.5 V input as shown by the dotted line in that figure. For instance, the off load η_c estimate is 94.5% and that at full load 93.8%.

In Fig.1, the current values indicated by arrows apply for $V_i = 8.5$ V, $V_o = 44$ V and for the oscillator being just held off by Tr_1. In this circumstance, the internal load current I_{oi} drawn from V_o by the parametric feedback circuit is

$$I_{oi} = I_2 + I_3 = V_o/(R_f + R_b) + V_{li}/R_t. \; (28)$$

The consequent input current I_{ii} necessary to maintain I_{oi} is:

$$I_{ii} = V_o\,I_{oi}/V_i\eta_c \qquad (29)$$

which for the above conditions comes to 265 µA.

The remainder of the control circuitry in these circumstances consumes a static current I_s of 91 µA (see Table 2). The total quiescent current I_q can then be estimated from

$$I_q = I_s + I_{ii} \qquad (30)$$

which here amounts to 356µA. This theoretical value is just 12µA short of the measured quiescent current. The total input current I_i for any external load current I_o can now be confidently predicted by

$$I_i = V_o\,(I_o + I_{oi})/V_i\eta_c + I_s \qquad (31)$$

and hence the overall efficiency η by equation (6).

The resulting efficiency curve for I_o from 20µA to 60 mA is shown in Fig.7, together with seven measured points which agree with the theoretical curve to within 1.2%.

It would appear that other losses are negligibly small.

DESIGN PROCEDURES

The design procedure may be summarized as firstly finding an E_L such that $T_c > T_{cf}$ (equations (1), (5) and (6) and Table 2). Secondly equations (7) and (8) are used so that saturation is avoided. Note the full-load T_i in this design is about 10% less than that of the free oscillator's T_b. Once the timing is known, efficiency may be predicted by equations (22) to (31).

Having obtained the appropriate values for the parametric feedback components from the intended V_o and equation (19), the regulator's performance may then be tested in practice. Finally, it should be noted that this circuit is tolerant of considerable component variation. Hence a wide range of input and output voltage and current is possible.

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Acknowledgement

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N.J.Chaffey, Ph.D. and T.A.Perkins, M.Sc. are both at the Medical Research Council's Neurological Prosthess Unit.

L.f. navigation revival

Britain's first new long-wave radio network for decades is being set up by a Swindon company, Datatrak. It forms one half of a system for tracking vehicles on the move.

RICHARD LAMBLEY

For a fleet operator, knowing each vehicle's exact location provides a worthwhile boost to efficiency. At the very least it can help improve scheduling. But with valuable cargoes such as cash or bullion, or tobacco or spirits, the information could reassure you that a load was safely on it way; or it might warn you that hi-jackers were at work.

Datatrak's system is centred on a small electronic module carried by each vehicle. Using positional information obtained by monitoring Datatrak's l.f. signals, this unit determines its exact location and reports it automatically by radio to a monitoring point. Any v.h.f. or u.h.f. radio link is suitable (including the new Band III trunked systems), though the company offers its own dedicated data network: this can handle some 2000 vehicles on a single radio channel. For dealing with the flow of position reports Datatrak offers a bureau service, operated by Securicor (which is one of its parent companies – the other is the George Wimpey group, whose interests in offshore surveying were the source of much of the radionavigation expertise behind the system). At the bureau, information is collated and sent out to individual customers via modems and telephone lines.

For land vehicles, an l.f. radiopositioning system offers important advantages over the satellite systems increasingly being used in the air and at sea. To obtain a fix from the GPS satellites, it is necessary to have a path to three of them – and that is difficult to arrange in city streets overshadowed by tall office buildings. Besides, hardware for an l.f. system is much cheaper.

Since last November the system has been running in the London area, though Datatrak is now expanding it to cover the entire country. Eventually the long-wave network will comprise 18 sites in a grid layout: stations covering the south-east are at Heathrow Airport to the west of London, Romney Marshes, Selsey Bill, Kineton (near Stratford-upon-Avon) and St Neots. Power level in each case is about 1.5kW delivered to the antenna, though it is difficult at such frequencies to achieve a radiation efficiency better than about 20 per cent.

These stations, operating in the 135-145kHz region, are organized in groups of eight: each transmits in turn, sending a pair of frequencies within its time-slot. A complete sequence of transmissions, the primary navigation cycle, occupies 1.68 seconds. Time-slots for a further eight stations are interleaved between the first set.

On the vehicle, the receiver module looks for the six strongest signals and then computes its position by measuring the transmission path delays. With three signals, it can get a rough fix; with six, the intersecting lines box it in more closely and the fix becomes highly reliable. A status signal from the unit indicates the degree of confidence. An output, in the form of map grid coordinates, is available from the unit on a V.24

One of Datatrak's l.f. antennas: the complete l.f. chain will consist of 18 stations.

The vehicle-mounted module is fully automatic. A 68008 processor computes the vehicle's position by reference to the l.f. signals.

serial port for users who wish to take it no further.

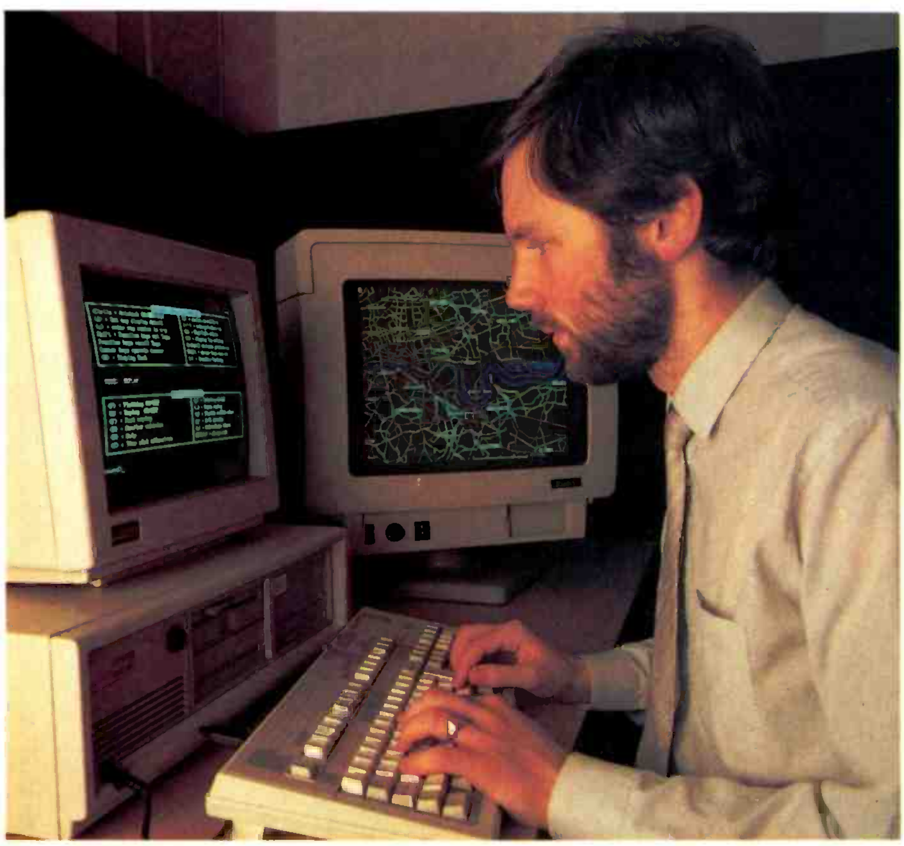
A special feature of the Datatrak system is that the pairs of l.f. signals are frequency-modulated slightly: the complex signal which results can yield a much greater positional accuracy than was possible with earlier systems. A fix can be to within 50 or even 10 metres. In additional, the receiver can initialize itself from cold anywhere – every fix is an absolute one.

For relaying data back from the vehicle, Datatrak has two frequencies in the 170MHz region and a network of 25 base stations, mainly at IBA sites. Expansion outside the south-east will entail a move to u.h.f. channels around 400MHz. Each vehicle has its own pre-programmed time-slot, synchronized by the l.f. navigation signal, during which it sends a 30ms burst of data containing its position, status, direction and speed. Direction and speed (accuracy is to within five miles per hour) are obtained by comparing the two most recent fixes. Some 150-160 base stations will be needed to cover the whole country, each linked by private lines to a data centre and interconnected to allow roaming. In England there will be four data centres, in London, Loughborough, Swindon and Leeds.

How often your vehicle transmits a fix depends to some extent on what you are willing to pay: for a bullion van, a fix every few seconds might be needed, since any deviation from its planned route could mean trouble. With other types of vehicle, a fix every minute would be enough. Datatrak's full service includes the use of an emergency alarm: when the driver hits the button, the system reports it immediately and the vehicle continues to transmit its position every four seconds until the emergency is over.

One early customer for the system is Cellnet, which will use the system for compiling field-strength maps for its cellular radiotelephone network. Measuring vehicles will be able to log signal measurements direct to tape or disc together with their exact location, cutting out a lot of tedious manual data entry. Another user could be London Regional Transport, which has been investigating the system's potential for helping to reschedule buses caught in traffic jams.

The vehicle-mounted unit for Datatrak costs just over £1000; and the running cost, including the bureau service, is about £85 per month. Further details from Datatrak Ltd, Hargreaves Road, Groundwell Industrial Estate, Swindon, Wiltshire SN2 5AZ; tel. 0793-722549.



Left: top-of-the-range display is a high-resolution colour screen on which each vehicle's position is re-plotted every few moments. Advanced software will make it possible for a warning to be given automatically if a van deviates from its planned route. Less ambitious users can opt for a simple telex-style printer instead.

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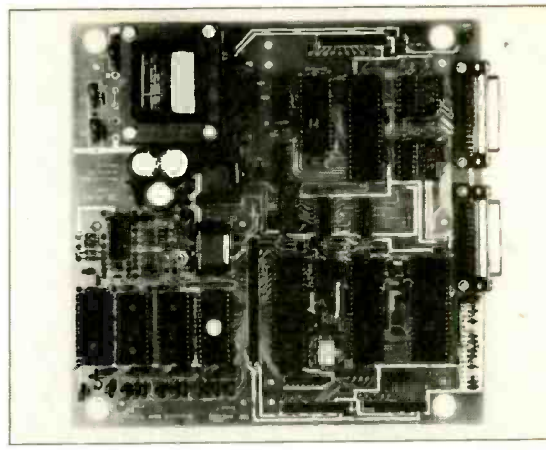

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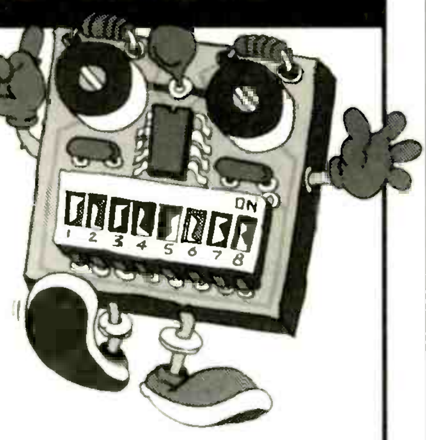

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Dependent source theorem

Finding equivalent generators in a network which has no independent sources.

HARRY E. STOCKMAN

Many of today's networks contain dependent sources only, in fact the majority of the semiconductor-equivalent networks belong to this group. While the Thévenin-Norton theorem readily yields equivalent generators when the network contains at least one independent source, it fails when the network is free of such sources. Still, we wish to be able to construct equivalent generators in all cases: methods to obtain such generators are discussed in the following. Although the network is put in the handy configuration of a generator, in reality it remains passive, with its "source" controlled by a current or a voltage outside the port. The dependent sources we are concerned with presently are of the basic kind ke(s) and ki(s).

A simple example of a network which contains a dependent source only is shown by the one to the right of the port in Fig. 1(a), and this network might well represent a transistor. One method to construct an equivalent generator is that of the Source Transformation Theorem, in which we collapse the given network in steps from right to left, thus ultimately obtaining a series-form generator and a parallel-form generator like the ones shown in Fig. 1 (b) and (c). Such equivalent generators, however, are never independent of the driving network on the other side of the port, and we must consult the equations for the entire system when we wish to switch variables, for example to make the source a function of e instead of i. Since the driving voltage and current are the same before and after the transformation, we may express the equivalent source as a function of either.

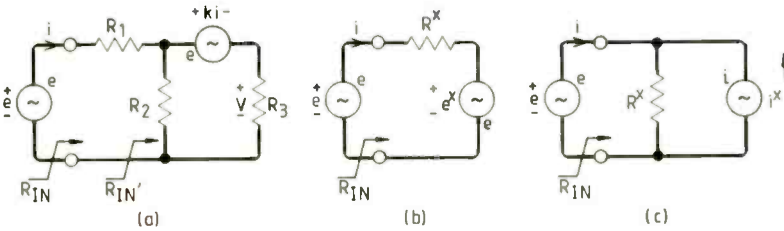
Another method is contributed by the Dependent Source Equivalent-Generator Theorem, which makes the segregated "dead" network alive by prescribing that the source retains the initial value it has in the given network. This means that we determine the value of i in the given total network, and then treat ki as an independent source when determining the open-port voltage and the closed-port current. Expressing the equivalent sources e^x and i^x as current sources, we find, with $R_{23}=R_2+R_3$ and $R_1R_2+R_1R_3+R_2R_3=A$,

$$e^x = k R_2 i/R_{23} \quad (1)$$
$$i^x = k R_2 i/A \quad (2)$$
$$R^x = A/R_{23} \quad (3)$$

We note that the relationship $e^x/i^x = R^x$, typical for the Thévenin-Norton theorem, also holds for this theorem.

We may use either equivalent generator to calculate quantities such as R_{IN} and v/e, obtaining

$$R_{IN}=(A+kR_2)/R_{23} \quad (4)$$
$$v/e=R_3(R_2-k)/(A+kR_2) \quad (5)$$



A most direct way of obtaining R_{IN} from the constructed generator in Fig. 1(b) is to apply the Compensation Theorem, change e^x into a resistance and then just sum the two resistances.

There exists a short-cut to the determination of input and output impedance, contributed by the Port Immittance Theorem, assuming, however, that the transfer function is known, and in this case it is given by (5). The theorem states that the denominator of (5), set to zero, contains both the input and the output impedances. It states that the input impedance is the negative of R_1, thus $-R_1 = R_{IN}$ and that the negative of R_3 is the output impedance, thus $-R_3 = R_{OUT}$. Whenever the proper transfer function is known, this theorem saves time. To find R_{IN} we must add R_1 to R_{IN}'. We find for R_{OUT}:

$$-R_3=R_{OUT}=(R_1+k)R_2/R_{12}. \quad (6)$$

If the transfer function is not known, we may still use the indicated short-cut by introducing $-R_{IN}$ in the given network as a replacement for e and R_1 and, in a subsequent operation, $-R_{OUT}$ as a replacement for R_3. An analysis of the network yields the formulas for R_{IN} and R_{OUT}. This is in accordance with the Theorem, which is a collateral to the Tellegen theorem, and the proof rests with the Tellegen theorem. As we replace e and R_1 by $-R_{IN}$, we cut off the signal supply to the network under investigation, but at the same time we introduce a negative resistance, and indeed one that equals the positive resistance it "sees". Accordingly, we create instability and thus the currents and voltages we need to analyze the network.

The Dependent Source Equivalent Generator Theorem has the following formulation:

A linear network with dependent sources only, provided with an accessible port for a driving generator, may at this port be replaced by a generator impedance in series with the open-port voltage or in parallel with the closed-port current, respective voltage and current appearing with the initial values they have in the given network, and the generator impedance being the port looking-in impedance when all sources are removed.

The driving network may be represented by a series-form or parallel-form generator, and may consist merely of the source to such a generator, as is the case in Fig. 1(a). Additional network theorems are listed in the reference.

Reference

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Dr Stockman was born in Sweden. He received his M.S. degree from the Royal Institute of Technology in 1938, continuing as Assistant Professor of Radio Engineering at the Institute. During the Finnish-Russian war, he served as a radio adviser and was awarded the Liberty Cross by Field Marshal Mannerheim. In 1941, Dr Stockman went to the United States on a Ford Fellowship and gained a S.D. from Harvard. He eventually became Head of the USAF Communications Laboratory and later formed his own company, Sercolab, in the electronics education field.

SATELLITE SYSTEMS

Geostationary loops?

A novel idea to solve the problem of congestion in the geostationary orbit is the geostationary loop. It doesn't use the conventional Clarke orbit at all but has three satellites moving in three elliptical orbits as shown in Fig. 1(a). The orbital planes are angularly spaced by 120° from each other. The orbital elements are chosen so that the three satellites follow each other in the same track in a co-ordinate system rotating with the Earth, as shown in Fig. 1(b).

As a result of this arrangement there are two small geostationary loops, 180° apart, positioned above particular points on the Earth's surface. Observers on the Earth would 'see' a satellite in each loop, moving round it in eight hours. There would be a satellite in each loop at all times: as one satellite leaves a loop, the next satellite in the sequence of three enters it. They pass in and out of the intersection points seen in Fig. 1(b).

As mentioned briefly in our May issue report on an IEE discussion on the geostationary orbit (p.489), this proposal comes from Germany and has been put to the European Space Agency. It is the joint work of three West German organizations: the aerospace company MBB/ERNO, the communications engineering firm ANT Nachrichtentechnik, and the country's central aerospace research and development body DFVLR. They have called the system Loopus (geostationary loops in orbit occupied by unstationary satellites).

For each of the elliptical orbits in Fig. 1(a), the orbital elements (defined in the November 1987 issue, p.1158) are as follows. Apogee is 39 117km, perigee is 1 238km and inclination is 63.4°. The semi-major axis of the ellipse is a distance of 26 585.7km while the eccentricity is 0.7132 and the argument of perigee is 90°. In this path each satellite has an orbital period of 11 hours, 57 minutes, 47 seconds (there's German precision for you!). One version of this system would produce geostationary loops above Europe at 10°E and above the Pacific Ocean at 170°W. Both loops would be at latitudes between 45°N and 63.4°N.

As a means of providing satcom services the Loopus system has been designed to meet two main requirements. One is to give global coverage for the maritime mobile satellite service – that is, coverage of areas on Earth where ground stations can see the appropriate satellite at a minimum elevation of 5°. The other requirement is to provide spot beam coverage for the fixed satellite service (FSS). Here the comsat beams would give five spots on the Earth's surface, four with a diameter of about 3000km each and one with a diameter of about 1000km. All the spot-beam footprints provided by one such Loopus would be in the northern hemisphere, but it would be possible to have another, similar, independent system serving the southern hemisphere as well.

One problem that had to be considered in devising this unusual technique is that the coverage areas change as each satellite moves round its geostationary loop. This is because of the varying distance and angle of the spacecraft relative to a given point on the Earth.

The coverage areas are defined as those areas in which the power flux density on Earth, during the entire passage of the spacecraft from the intersection to the top of the loop and back again, corresponds to at least the p.f.d. generated at the top of the loop at the 3dB contour. A study has shown that by taking the p.f.d. as a basis for determining the periphery of the coverage area, the changes in path attenuation are more or less compensated by changes in the satellite antenna gain which affect the edges of the coverage area. So the size of these areas remains practically constant and only minor deformations occur as a result of changes in the satellite's angle relative to the Earth.

Another problem arising from the varying position of each comsat as it travels round the geostationary loop is that it affects the parameters of the radio link between Earth and space. As a result, various compensation techniques have to be introduced – especially, for example, for the change in received carrier frequency caused by the Doppler effect. Further complications are made necessary by the fact that in each geostationary loop the communication task has to be handed on, every eight hours, from one satellite to the next.

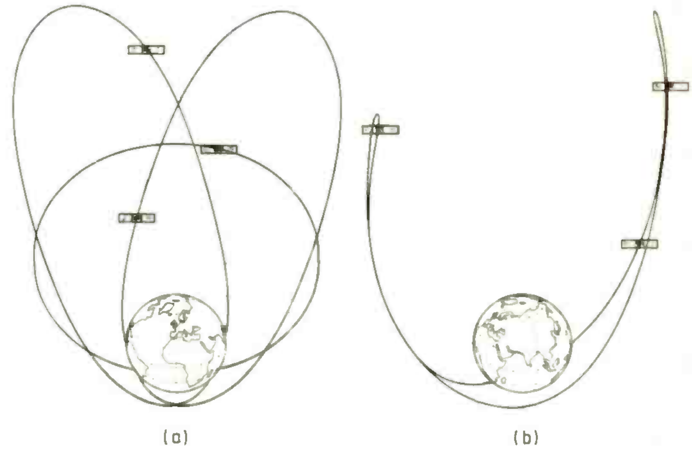

Fig.1. Loopus system using three satellites to form two geostationary loops: (a) three elliptical orbits as seen by a fixed observer; (b) the satellites' track as seen from within a frame of co-ordinates rotating with the Earth. A second, independent, 'upside down' system could be used as well, to give good coverage in the southern hemisphere.

All these difficulties have been looked into by the originators of the Loopus scheme and solutions have been proposed. It remains to be seen whether these inevitable complexities are justified by the benefits offered by the system. Apart from the relieving pressure on the limited resource of the geostationary orbit, the Loopus system would also provide two other benefits. It would give better coverage of polar regions than the g.s.o. does and would allow single-hop connections between Earth stations on opposite sides of the world provided these were in the same hemisphere.

New amateur radio satellite

One of the three spacecraft launched simultaneously on the first flight of the new Ariane-4 rocket was a further communications satellite for radio amateurs, Amsat IIIC. It becomes the latest member of the well known Oscar series (orbiting satellites carrying amateur radio) and will be known as Oscar 13.

The new Oscar was built by Amsat-Germany under the international programme run by the Amsat organization. It is a 150kg spin-stabilized space-craft shaped like a solid three-pointed star (pictured overleaf), with solar arrays fixed on the six edges of the points of the star. Like all others in the series, Oscar 13 is basically an educational aid, allowing amateur radio communication over much greater distances than would normally be possible in the v.h.f. and u.h.f. bands used.

There are four transponders in the spacecraft. One, with 435.5MHz uplink and 145.9MHz downlink, has a bandwidth of 150kHz. The second has a 1269.45MHz uplink and a 436.85MHz downlink, with a bandwidth of 250kHz. The third transponder operates on a 144.45MHz uplink and a 435.95MHz downlink, while the fourth uses a 435.6MHz uplink and a 2400.7MHz downlink. A digital communications experiment is included in the last-mentioned transponder. The antennas are a mixture of v.h.f. rod, u.h.f. dipole and helical types.

Because most of the world's radio amateurs live in the northern hemisphere between the latitudes 30° and 60°, satellites in the third Amsat generation have been put in orbits designed to be the most useful for these regions. Amsat IIIC/Oscar 13, as the third member of this third generation, carries on this policy and has an elliptical orbit which gives much better coverage of these northern regions than

SATELLITE SYSTEMS

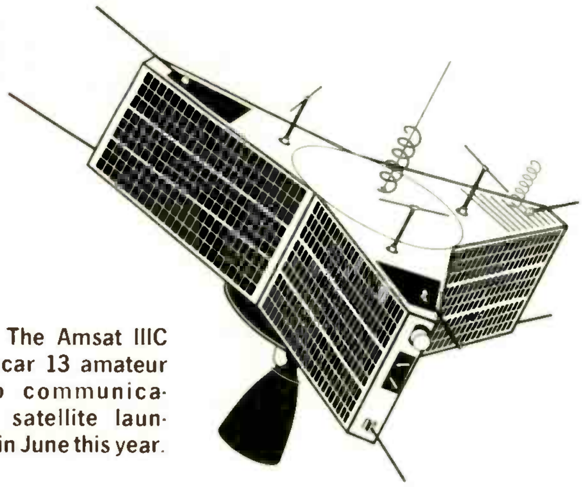

Fig.2. The Amsat IIIC or Oscar 13 amateur radio communications satellite launched in June this year.

would be possible from, say a geostationary one. This elliptical orbit has an apogee of 36 000km, a perigee of 1500km, an inclination of 57° and an orbital period of about 11 hours. Immediately after launch from Kourou, French Guiana, the satellite was placed in a transfer orbit with an inclination of 10° and was subsequently moved into the final elliptical orbit by the reaction-propulsion motor mentioned above.

The Oscar series started in December 1961 with a spacecraft carrying just a simple 145MHz beacon transmitter. Later satellites introduced transponders and became progressively more sophisticated in spite of cost constraints. Britain's contribution so far to the international amateur programme is the University of Surrey's UoSat-1, called Oscar 9 and launched in October 1981, and UoSat-2, called Oscar 11 and launched in March 1984. The new Oscar 13 is an improved version of Oscar 10, which was built by Amsat-Germany and launched in June 1983.

Space station agreed

Elaborate radio communications between space and ground will be needed when the Western world's permanently-manned space station eventually goes into operation, possibly in the 1990s. This will be a very large artificial satellite, orbiting the Earth at a low altitude of 450km and an inclination of 28°.

As a proposal it has been discussed and argued over for several years, but now seems more likely to go ahead as a definite project. After two years of negotiations, a basis for international co-operation on design, development, manufacture and operation has been agreed between the four main partners: USA, Europe, Canada and Japan. NASA will be responsible for the American work and ESA, representing eight member states, for the European contribution.

The USA will provide the overall space station framework: operating sub-systems including life support and 75 kilowatts of power: laboratory and living quarters: and an unmanned free-flying platform that will be placed in polar orbit for Earth observation.

Canada will provide a mobile servicing system to be used in conjunction with the assembly, maintenance and servicing of parts of the space station. Japan will contribute an 'experiment module', which is a permanently attached pressurized laboratory. ESA, through the associated Columbus programme, will provide a pressurized laboratory module permanently attached to the manned base: an unmanned free-flying polar platform to work in conjunction with the US polar platform; and a 'man-tended free flyer' to be serviced at the manned base.

Some time ago there was a sharp rift between the Americans, who seemed to want to use the space station partly for military purposes, and the Europeans, who were firmly opposed to this. In recent statements NASA describes the project as a "civil" space station while ESA goes further and adds the words "for peaceful purposes".

New satcoms operator

The first private company to own and operate an international satcoms service outside of the official Intelsat, Eutelsat and Intersputnik organizations is the US firm Pan American Satellite, a subsidiary of Alpha Lyracom of Greenwich, Connecticut. It owns a single spacecraft, the PAS-1 comsat, which was launched by the first Ariane-4 rocket along with Amsat IIIC (see report elsewhere) and Meteosat P2 (January issue p.58). From its geostationary slot of 45°W, PAS-1 will be able to relay international traffic between Europe and USA and between Latin America and the USA, as well as covering the Caribbean area.

Although providing an international service, Pan American Satellite will not be competing directly with the main world organizations in public telecommunications. The company will be concerned principally with private business satellite communications and will not link into public telephone networks. In the UK, uplinks to PAS-1 will be provided by British Telecom. However, the comsat is also likely to be assisting with national services for Latin American countries which might otherwise be unable to afford them.

In engineering design PAS-1 is fairly conventional, being a modified version of a standard RCA Astro-Electronics Series 3000 satellite. It has 24 transponders and operates in the C and Ku bands, normally working to small and inexpensive Earth terminal antennas.

• The three satellites launched on the first Ariane-4 flight on 15 June had a combined mass of 3513kg. As already reported in the July issue, the Ariane-4 design, which is much more powerful than the preceding Ariane-3, allows various combinations of engines and boosters to be used to suit different loads. In this case the 44LP version was employed, with two liquid and two solid propellant boosters. The third stage of this rocket was first injected into a transfer orbit with an apogee of 36 359km, a perigee of 221km and an inclination of 10°. Subsequently the three satellites propelled themselves into their respective final orbits as stated elsewhere.

A further success for the Ariane – 3 space vehicle came on 22 July, with the launch of the Indian satellite Insat 1C (see January issue, page 57) and the last of the five European Communications Satellites. When commissioned, ECS-5 will be renamed Eutelsat 1-F5 and will provide a range of telecommunications services to Europe including telephony, business services, and radio and television distribution. ECS-5 will replace Eutelsat 1-F1, which will then be available to carry new services in addition to acting as an in-orbit spare. ECS-5 is one of the three Eutelsat craft built by British Aerospace.

Intelsat VII transponders

The new Intelsat VII series of comsats announced last year (December 1987 issue, p.1232) will each carry 36 transponders. For C band there will be sixteen 72MHz and ten 36MHz transponders. For Ku band communications the spacecraft will provide six 72MHz and four 112MHz transponders.

These high-power satellites will allow the use of smaller Earth station antennas and will replace the present Intelsat V-A comsats at the end of their life in the Pacific Ocean region. They will have the ability to switch C band capacity between the eastern and western hemispheres and will give simultaneous Ku band coverage of three regions in the Pacific area which can be altered while the spacecraft are in orbit. Later on, The first two spacecraft are expected to be launched in mid-1992 or early 1993.

• The penultimate Intelsat V-A spacecraft, F-13, was successfully launched on an Ariane-2 rocket in May this year and is stationed at 53°W.. The last in this series, F-15, is due to go up in January 1989 (the F-14 having been launched out of sequence).

Satellite Systems is written by Tom Ivall.

Piezoelectric coaxial cable

Novel packaging should make piezo-rubber more usable

PETER JOHNSON

Most applications which require a piezoelectric transducer, for example underwater hydrophones or pressure sensors, use a ceramic material called PZT, (lead zirconium titanate). When subjected to a mechanical strain, this produces a voltage of the order of 3μV/Pa – a usefully high value that requires nothing more sophisticated than a charge amplifier to buffer the extremely high source impedance of this capacitive transducer to an analogue signal-conditioning circuit, Fig.1.

PZT has many advantages: it is chemically inert, it has a reasonably high sensitivity and it can be used over a very wide range of pressures without serious non-linearity. There are no problems in making this ceramic in almost any shape or thickness at relatively low cost.

The biggest drawback of the material is its mechanical fragility: like all ceramics, PZT is brittle and must not be subjected to impact or excessive flexure. In underwater hydrophone design, where maximum sensitivity is obtained by using a very long transducer assembly, mechanical flexibility is essential, so a large number of PZT elements are linked electrically within a long PVC tube. This tube may be filled with an insulating oil to obtain the required overall specific gravity and minimize the support needed for the hydrophone in the water.

Such a hydrophone incorporates a great many lengths of wire and soldered joints which will be subjected to considerable whiplash if used at sea – a labour-intensive and potentially unreliable technique.

The technical ceramics division of NTK, one of the world's largest spark plug manufacturers, supplies PZT transducers to oceanographic hydrophone constructors. In a paper presented to the 7th Symposium on Ultrasonic Electronics in Kyoto (piezoelectric transducers are widely used at ultrasound frequencies), four NTK researchers presented a paper describing a new composite material consisting of fine particles of piezoelectric ceramic material embedded in a synthetic rubber, Chlorobren.

By attaching flexible electrodes made from carbon-loaded Chlorobren, the researchers were able to show that this composite has excellent piezoelectric properties, but is completely flexible. Further, the rubber used has good acoustic coupling properties for signals in sea water, because the speed of sound in both media is similar.

This table gives some of the relevant properties of piezoelectric rubber compared with PZT and PVDF (polyvinylidine difluoride, a synthetic rubber with inherent piezoelectric properties).

Note that both the new composite and PVDF

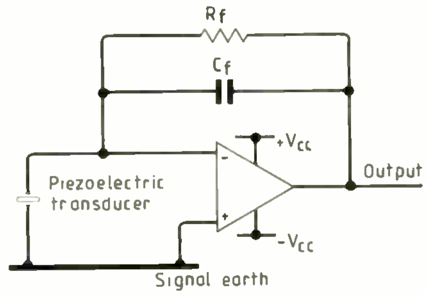

Fig.1. Lead-zirconium-titanate is easy to use as a pressure transducer. It has a relatively high voltage output and needs only a charge amplifier like this one to produce a signal suitable for feeding to analogue signal-conditioning circuits. Resitor R_f would typically be around 20MΩ given an LM308.

	Piezo rubber	PVDF	PZT-4	
Density	4.8	1.78	7.5	tonne/m³
Speed of sound	1.33-1.6	0.9-1.8	3.3	km/sec
Dielectric constant	30	8-11.5	1475	at 1kHz
Sensitivity (g_{33})	150	83-282	2.6	mV.m/N

have similar sensitivities; however, since the voltage generated by a piezoelectric transducer is given by:

$$V_o = gtP$$

where P is the pressure applied, g is sensitivity and t is thickness of the transducer in the direction of the pressure, electrical output of a piezo-rubber device can be made greater than that of a PVDF transducer by increasing the thickness; PVDF is not easy to manufacture except in thin sheets.

Underwater hydrophones are typically used in sonar systems to monitor the return pulse of acoustic energy reflected from the seabed or other submerged object. This is a sharp-edged pulse when transmitted, but will normally show "clutter" after reflection which gives the experienced sonar operator some indication of the type of surface from which it was reflected.

With a PZT transducer, which has a very low damping factor, this characteristic shape is masked by the ringing of the transducer element itself, Fig 2(b). The rubber matrix material of the new composite imparts a much larger damping factor to the hydrophone, greatly reducing ringing, Fig. 2(a). PVDF, a ferroelectric material, also exhibits ringing oscillations when used to detect a single ultrasonic pulse.

PIEZOELECTRIC CABLE

Flexible materials are not easy to make contact with, especially unsolderable sub-

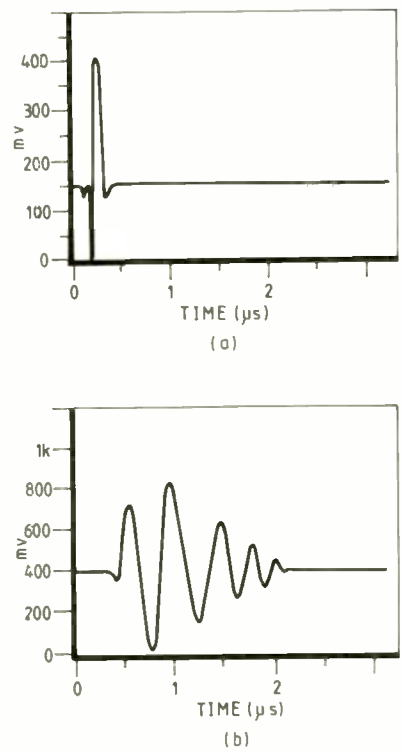

Fig.2. Piezo-rubber (a) and PZT (b) transient responses. Amplitudes are not directly comparable due to different thicknesses of transducer.

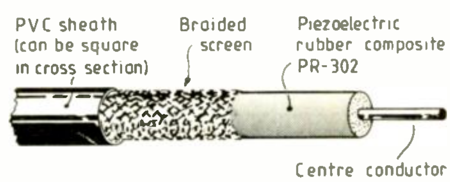

Fig.3. Piezoelectric coaxial cable is similar in appearance to ordinary 50Ω coaxial cable.

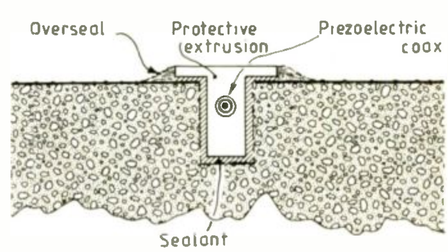

Fig.4. Piezoelectric coaxial cable used as a vehicle sensor requires a protective extrusion, but it has a longer life than electrical contact strips. Compared with electromagnetic sensors, a piezoelectric cable sensor detects smaller vehicles and is easier to install.

stances like piezo-rubber. In existing applications of this still new material, the active element is sandwiched between layers of conductive rubber of similar elasticity; contact is then made to the conductive rubber by means of beryllium-copper leaf springs.

Clearly, this is an inconvenient method of connection, so NTK investigated more versatile techniques which did not require the mechanical precision of earlier methods such as the one described. The result of this effort was a coaxial cable, similar in appearance to normal 50Ω coaxial cable, but with the insulating layer between the screen and centre conductor made of a piezoelectric rubber composite designated PR-302, Fig.3. This cable can be made in continuous lengths of up to 20m and is compatible with soldering or with standard coaxial plugs, making it much easier to use.

Electrical properties of this cable are as detailed in the table above.

APPLICATIONS OF PIEZOELECTRIC COAXIAL CABLE

This form of the material has only been in production for a short time, so there are, for instance, no hydrophone applications so far. However, the cable has been used in Japan as a non-contact self-screening pickup for an electric guitar, and research is being carried out into its incorporation into a blood-pressure/pulse-rate monitor.

As a vehicle sensor for traffic lights, the cable was found to perform well because of its resilience and high sensitivity. Such sensors receive severe battering so the cable was protected by embedding it in tough synthetic rubber extrusion, shown in Fig.4. Compared with vehicle sensors relying on electrical contact strips, this method has a longer life and is insensitive to the ingress of rainwater.

Electromagnetic sensing systems – the most popular alternative – are reliable but have problems detecting cyclists and moped riders, and require a large area of the road surface to be removed for installation. The piezoelectric cable sensor needs only a narrow transverse trench to be excavated by pneumatic tool.

Piezoelectric coaxial cable is still, to some extent, an interesting solution looking for a problem. It is here, in an easily-used form, and available off-the-shelf to the development engineer. It remains to be seen what the ingenuity of R&D engineers will make of it.

Further reading

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RY Ting, *Ferroelectrics Vol.67 p.143, 1986.*

H. Ohigashi, K. Koga, M. Suzuki *et al. Ferroelectrics Vol.60 p.263, 1984.*

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Towards ISDN – 2

Adrian Morant continues his introduction to integrated services digital networks.

ISDN basic access consists of two 64kbit/s B channels for user information together with a 16kbit/s D channel. While the former are circuit-switched, the latter is a packet-orientated channel whose main purpose is to exchange signalling between terminal equipments and the local exchange.

Under normal circumstances, when used for voice, once the call has been set up the D channel is free until the call is to be terminated. For this reason, while the basic access consists of 2B+D, at the next level in the hierarchy (primary rate access or PRA) there is only one D channel with either 30 or 23 B channels. This depends, respectively, on whether the system is operating to the CCITT or the American "Bell" standard: the former uses a 2Mbit/s transmission channel while the other uses 1.544Mbit/s.

From this it can be seen readily that a D channel is shared between a number of B channels. This is a "common channel," and the signalling it carries is therefore common channel signalling. It forms an essential part of the network and provides control and supervisory information regarding the routing and setting-up of a call as well as status information. Consequently, when attempting to initiate an ISDN call, the calling terminal will use the signalling channel to make its request and will use the CCITT Common Channel Signalling System No.7 – often just referred to as C7. Not only must this request cite the number of the party being called, it must include a variety of other information. For example, if the proposed call is just voice from one digital telephone to another, only one 64kbit/s B channel would be needed. If, on the other hand, the required call was between two combined voice and data terminals, two B channels would be required spanning the entire end-to-end path. Different devices require different network resources: the calling party must therefore initiate negotiations to ensure that it will obtain the necessary channel capacity.

OSI Protocols

The D channel signalling protocol consists of Layers 1 to 3 in the ISO Open Systems Interconnection (OSI) Reference Model. In Layer 1, the electrical and physical characterstics of the S interface are defined. In addition, a multiple access mechanism is specified which allows the D channel to be used by a number of terminals.

Layer 2 of the D channel protocol (LAP D) can be considered to be an adaption of the LAP B procedure defined in CCITT recommendation X.25 to the specific needs of ISDN basic access. Owing to the bus structure of the S interface, LAP D has to support multiple simultaneous Layer 2 connections. Additionally, LAP D enables the higher layers to broadcast a message to all terminals connected to the S bus.

Layer 3 defines procedures for controlling the supplementary service facilities as well as signalling procedures for the basic call handling, e.g. call establishment and release for B channel connections.

Were the D channel used only for signalling it would frequently be idle. Consequently it can also be used for the transmission of packets of data. The transmission of data by packet switching makes for far more efficient use of resources. Instead of a circuit being allocated and held exclusively during a message transfer it can be time-shared between many.

Access to a packet network is via a packet assembler/disassembler (PAD): this is reached at present via the public switched telephone network, but in due course it will be via the ISDN. Initially it will use a B channel – being analogous to a PSTN voice channel – but eventually the D channel will be employed. This will mean a more efficient use of resources. After all, the D channel is transparent to the packets being sent and is not concerned with their content. It will transfer them as required irrespective of whether they are signalling information or actual user data.

In packet switching the message is transmitted as a series of discrete blocks or packets. In addition to the data itself, each packet must contain address information to indicate its source and destination. It must also include a sequence number to enable the received message to be re-assembled correctly. This is analogous to a series of postcards which each contain part of an entire message. By marking them with a serial (or sequence) number it is possible to ensure that they are in order and so determine whether any have been lost in the post. Should this occur, the recipient would request the sender to repeat the lost information.

Whereas in circuit switching a path through the network is "transparent" to the user once a call has been set up, in packet switching the network must supervise the whole operation.

To send a message from a character-orientated terminal, such as a teletype or a dumb v.d.u., it is necessary to dial in to a PAD and then log-on with one's Network User Identification (NUI) and password. The PAD maintains control and integrity of individual messages and integrates them with others which are also within the system. Having obtained access to the network, the user specifies a destination address for the message and then inputs the message. The PAD takes the message and breaks it into a series of data packets. To each of these packets it adds framing information and then the whole packet is launched into the network. Both header and data portion of the packet have a checkword attached, to enable the integrity of each packet (and thus of the entire message) to be verified on receipt. Should an error be detected the receiving end will request re-transmission.

Skyphone takes to the air

Europe's first public satellite telephone call from an aircraft has been carried out by Racal and British Telecom International. The test link-up took place between Racal's company Jetstream aircraft and BTI's satellite Earth station at Goonhilly in Cornwall.

The in-flight tests are paving the way for a trial commercial service for passengers travelling on British Airways Boeing 747 transatlantic aircraft later this year. This will be followed by a regular manually-connected telephone service and subsequently by a full commercial direct-dial Skyphone service available to all airlines by mid-1989.

Using the Inmarsat satellite network, Skyphone will offer passengers a direct-dial telephone service to 185 countries worldwide, as well as facilities for the transmission of aircraft operational telephone and data traffic.

The equipment is designed to operate to Inmarsat specifications in the 1.5-1.6GHz L band. The low noise amplifier is housed in a small package to permit mounting on the inside of the aircraft skin close to the receiving antenna. It has sufficient gain to allow inexpensive and long cable runs to the radio frequency/intermediate frequency unit mounted in the aircraft equipment racks, without impairing receiver noise figure. L.n.a. noise figure, including losses from pre-l.n.a. filters, is lower than 2.5dB even at aircraft skin temperatures of +70°C.

Research into personal communication

The Government has announced the eighth 'Link' programme, which aims to stimulate the pre-competitive research towards a new, higher capacity, third generation personal communications system. Its contribution to the three-year Personal Communications Programme is £6.35 million – £3.35M from the DTI and £3M from SERC.

TELECOMMS TOPICS

Companies which have indicated that they would like to be involved in this programme include Aerial Facilities, Autophon, British Aerospace, BT Research Laboratories, GEC, Marconi, Philips, Plessey Research, Racal, STC and Thorn EMI. Interested academic institutions include the following universities: Aston, Bangor, Bradford, Bristol, City, Heriot-Watt, Leeds, Liverpool, Southampton, Surrey, Swansea and York.

Lord Young, Trade and Industry Secretary, speaking in the House of Lords, said: "The need for the programme is prompted by the convergence of telecommunications and radio technologies, which is generating a new industry of personal communications. The number of subscribers is increasing, with greater demand for accessibility both indoors and outdoors – whether stationary or mobile – and internationally.

"There is therefore a need to extend the range of services available and to integrate private mobile, cellular and satellite mobile systems. Much basic work needs to be done to achieve this. It will be a key technological development for the 1990s."

Flexible Access Systems

STC has been appointed one of the suppliers for the nationwide extension of British Telecom's Flexible Access Systems (FAS), for completion by the middle of 1991. STC expects to receive orders in excess of £100 million.

FAS is based on the use of optical fibres rather than copper cable connections to business customers. This will allow large numbers of private circuits to be provided, and the evolution to wide bandwidth services such as video conferencing in the future. At the customer's end, a multiplexer connects the various circuits on to the fibre. These multiplexers are controlled by network management software which enables the mixture of connections to be varied to service customers' changing needs and to provide connection to any other location required.

The first Flexible Access Systems have been successfully deployed in the City of London Fibre Network, for which STC was the prime contractor, and STC is also supplying equipment for part of British Telecom's London Docklands project.

STC claims to have been the first company to appreciate the strategic possibilities of distributing intelligence in the network.

Flexible Access Systems will extend to local communications the benefits of the major modernization programme that British Telecom has been undertaking in the trunk network. STC and its partner Northern Telecom have established a 200-strong team to work on the developments and products required. This team is deployed in the UK and North America.

STC and NT are also jointly working on the extension of optical fibres to small businesses and residential customers to provide high quality telephony services, and the future possibility of television-based services. Another joint programme on synchronous multiplexers and switches will allow circuits of any bandwidth to be carried efficiently around the whole network.

Payphones up the Canyon

Visitors to the Grand Canyon can now dial home from remote areas of the park following an agreement between US West Inc. in Arizona and the British company GPT Telecoms Products.

Under the agreement, GPT has installed the first phase of intelligent payphones throughout the Grand Canyon National Park. These payphones connect to a variety of transmission lines and carriers.

GPT payphones generate coin accounting reports and they diagnose malfunctions and attempt to clear them. With the help of a dot-matrix display and voice chip, the telephones also communicate in two languages, which will help some of the thousands of international tourists who visit the park each year.

"We are currently investigating ways to extend even more services to communication points such as the Grand Canyon", said Peter Brown, managing director of GPT Telecoms Products. "We can foresee the time when we will be providing direct international dialling."

Third World Telecoms

By the first anniversary of the start of its field activities, the Centre for Telecommunications Development (CTD), established in 1985 by the ITU Administrative Council in Geneva, had received some 40 requests for assistance from developing countries.

As the Centre employs only a small core staff at its headquarters, the major part of its work in the field has so far been carried out by experts and consultants whose services were obtained by a combination of cash contributions and support in kind.

CTD's work is in preparing preliminary documentation for rural telecommunications projects in several developing countries and of telecommunication development master plans in others, including some regional projects. This groundwork will enable the countries to submit telecommunication projects for financing. Some of the countries concerned are Burma, Gambia, Tanzania, Somalia, Egypt, Nepal, Malta, the Yemen Arab Republic, and People's Democratic Republic of Yemen.

The Centre relies entirely on voluntary contributions from both the private and public sectors in the developing and in the industrialized parts of the world which stand to benefit from the Centre's activities. To date, pledges amounting to about Sw. Fr. 5 million (very little in view of the huge task) are 60% in cash and 40% in kind for the current year 1988, broadly distributed as follows: 45% from industry, 45% from administrations and the rest from development finance agencies. Several development finance institutions, as well as developing countries themselves, have so far responded favourably.

Twelve missions have been carried out so far and six more (to Bolivia, Chile, China, Iran, Mozambique, Nigeria) are scheduled during 1988. It is expected that these missions will lead to additional requests for projects and specific assistance.

Telecomms Topics is compiled by Adrian Morant.

Keyboard design

Finer details of keyboard and keypad design are often overlooked by design engineers.

JEFF WRIGHT

There are hundreds of keyboard applications, not only in computers, but also in typewriters, telephones, remote controllers, washing machines, microwave ovens etc. In many of these applications a single-chip microcomputer, or controller, reads the keys and acts on the data entered so a good understanding of keyboard-to-microcomputer software and hardware interface techniques is essential for anyone involved with keyboard design.

There are two main types of microcomputer-based keyboards. In the first type, found for example in telephone and washing machine controllers, keyboard reading is only a part of the microcomputer's function. Alternatively more complex systems, such as computers and typewriters, often have a dedicated microcomputer controlling only the keyboard. These applications might seem quite distinct but the software and hardware techniques for any size of keyboard are similar.

KEYBOARD TYPES

There are several different keyboard configurations, each with its advantages and disadvantages. The simplest type of controller-based keyboard has one key which is assigned to each line of an input port, Fig.1. Keys can be read very quickly using this method, and the software needed is trivial, but it can only be used where there are many spare input lines. Direct key reading is therefore restricted to small keypad applications.

Much more common is the matrix keyboard where the keys are arranged in rows and columns. This method makes much more efficient use of the microcomputer's input/output lines, but it requires more complex software for scanning the matrix. Scanning is normally accomplished by producing an output pulse on one column at a time and reading in all the rows to determine whether a key in that column has been pressed. For a given number of i/o lines, the number of keys in the matrix is maximized by arranged it as a square; for example an 8×8 matrix reads 64 keys whereas a 4×12 matrix reads only 48.

Roll-over of a keyboard is defined as the number of keys which can be pressed at any one time and still be individually recognized; if all keys can be pressed at once and recognized the keyboard is said to have n-key roll-over. This is the most desirable solution but is more expensive than simpler matrices for reasons explained later.

Figure 2 shows a basic 4×4 resistive matrix. In the case of a resistive matrix each key has a contact resistance of the order of 50Ω when pressed and a potential divider effect is thus produced. This matrix is said to have two-key roll over because if any three keys in the corners of the an imaginary square or rectangle are pressed then the key in the fourth corner will appear closed as well (a ghost key) and it is impossible to tell which three keys are actually pressed. Therefore the maximum number of keys that can be pressed without confusion is two.

Although this matrix is defined as having two-key roll-over it would be more accurate to say that it had a minimum of two-key roll-over as often many more keys can be pressed before a ghost key is produced. For example, all keys on one row can be pressed at the same time and still be successfully detected. It can therefore be advantageous when designing a keyboard of this type to make the matrix as rectangular as possible with the maximum number of output scan lines and also to arrange the layout so that the keys which are most commonly pressed together are on the same row.

A drawback of making the matrix rectangular is that more i/o lines are required for the same number of keys, but for many applications the gains obtained make the extra lines worthwhile.

Another enhancement which can be made to the basic matrix is to give important keys, such as 'shift' on a computer keyboard, their own input line. This then gives the two-key roll-over minimum and additional special keys.

Software for this matrix is actually the most complex since to ensure correct operation, ghost keys have to be detected. Also, i/o switching is needed to scan the matrix to avoid contention caused by a scan pulse of one logic level being connected via pressed keys to another pin outputting the opposite logic level. This latter point also means that pull-up resistors are required on both sides of the matrix as shown to avoid floating inputs (these pull-up resistors also act as current limiters).

When a ghost key is detected the keyboard is locked to prevent the false key from being processed, but the designer then has an option as to when to allow processing to begin again. One option is to start processing keys once the ghost key has been released but this can lead to key strokes being missed – a problem for the fast typist who may frequently have several keys pressed together momentarily. The safest option is to delay processing until all keys are released – a warning of the delay could be given to the user if desired.

This basic matrix is used extensively in low-cost computer keyboards, terminals and many keypad type data-entry systems where multiple-key presses are uncommon. Try

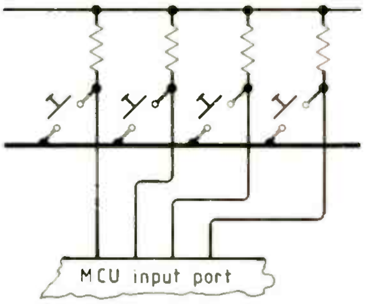


Fig.1. Using one controller input for each key results in fast key-press reading and very simple software, but this does not make efficient use of controller lines.

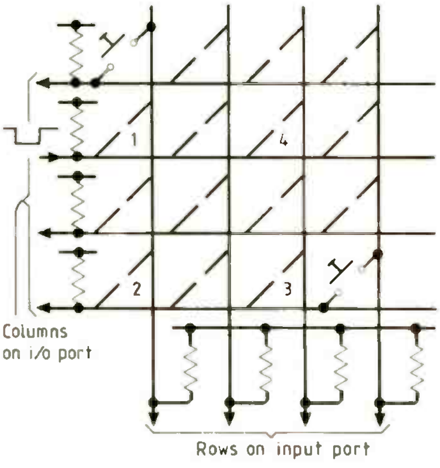


Fig.2. Arranging keys in a matrix make more efficient use of controller ports – only 8 lines are needed to read 16 keys. This produces two-key roll-over since pressing more than two keys at once can result in an erroneous reading e.g. press 1,2,3 and 4 appears as a ghost key.

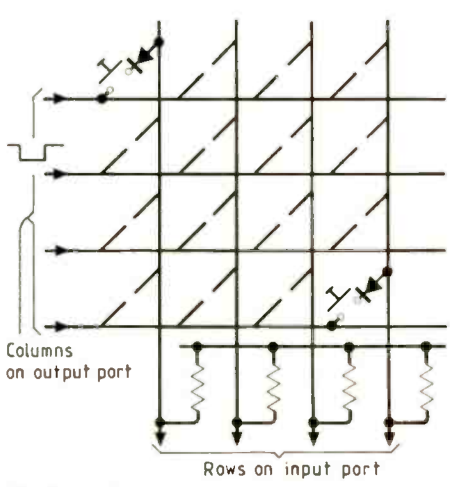


Fig.3. Adding diodes to the matrix stops keys interfering with each other, producing n-key roll-over.

your PC keyboard for quality: some don't even have ghost detection so that by pressing a certain three keys you get four characters on the screen!

N-KEY ROLL OVER

In higher quality computer keyboards and in applications where a large number of multiple-key entries are required, an n-key roll-over matrix is used. There are two popular methods of achieving an n-key matrix but both are more expensive to manufacture than the basic matrix type.

The first and most common method is to add diodes to the basic matrix, Fig.3. These diodes prevent any one key from interfering with another, thus producing n-key rollover. Voltage drop across the diodes is an important hardware constraint when designing a matrix of this type since it can cause violation of the controller port input thresholds. Excessive voltage drop can normally be avoided by choosing the correct value of pull-up (current-limiting) resistor but in low voltage applications it can be more of a problem.

The second main type of n-key roll-over matrix has capacitive keys Fig.4. This configuration gives n-key roll-over without the cost of the diodes but with the additional cost of comparators. Each key forms the plates of a capacitor and when the key is pressed the plates move closer, increasing the capacitance and allowing a short low-voltage pulse to reach the comparator input. Impedance of the other scan lines and the number of keys pressed also affects the level of this pulse. Pressing a ghost key produces three capacitors in series, which reduces the effective capacitance, thus degrading the pulse which would appear as the fourth key signal.

When a key is pressed the comparator restores the incoming differentiated signal to a true logic level, so producing an output pulse which is detected by the controller. Since this pulse is normally shorter than the scan pulse, care has to be taken in the software not to miss any keys by reading too late. Also, the comparator reference must be set up carefully so that the low-amplitude signal can be detected reliably, and the biasing circuit's impedance should be large so that the time constant for the key press is long enough to produce an acceptable pulse length for detection.

With both these n-key matrices the software is simpler than in the previous two-key roll-over case, since the scan lines can remain as outputs all the time and ghost-key detection is not required. They also avoid the requirement for pull-up resistors on the output scan lines – a minor cost saving.

KEY BOUNCE

In all keyboard types there is another vitally important criteria – key bounce. Keyboards can often be installed in very noisy environments and the scanning of a large keyboard with long p.c.b. tracks can produce its own noise and cross-talk problems. For these reasons p.c.b. layout and software debouncing must be handled carefully.

One common method of debouncing is to

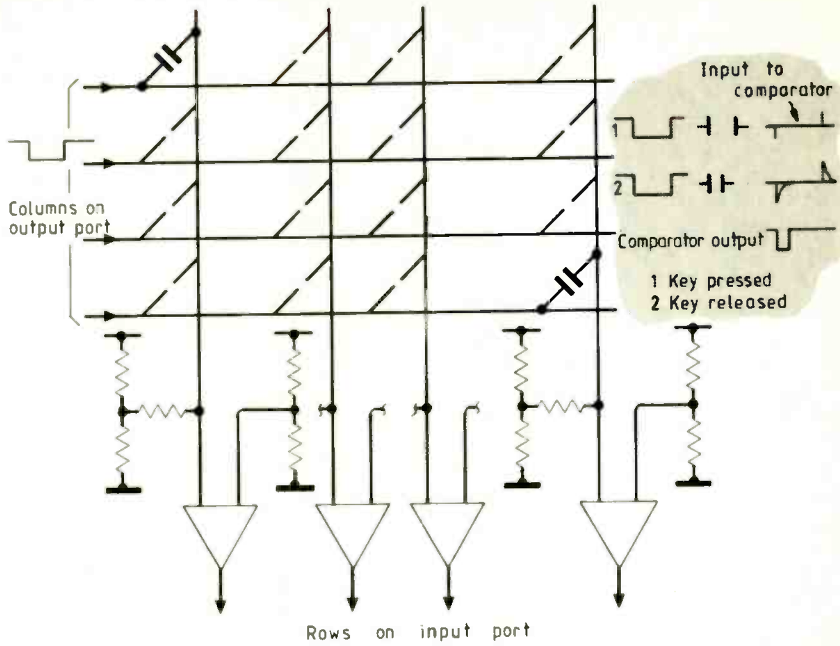


Fig.4. Capacitive keys and comparators produce n-key roll-over without the use of diodes.

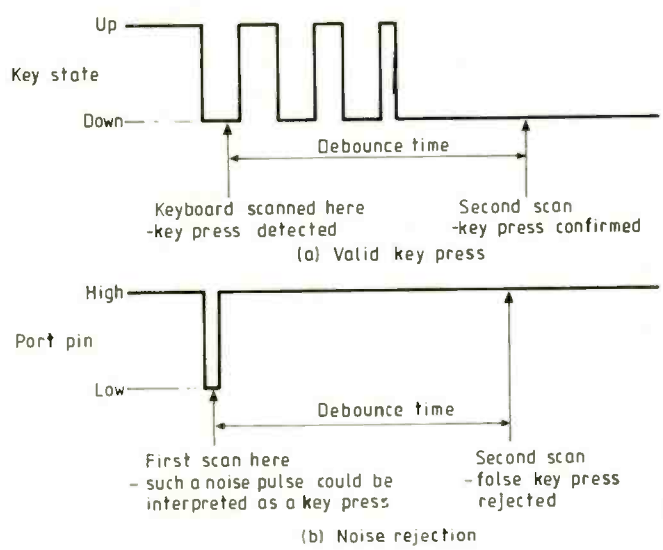


Fig.5. Contact bounce problems are commonly solved by reading a key's state twice in quick succession and comparing the readings.

FEATURES IMPORTANT TO KEYBOARD DESIGNERS

– Bidirectional i/o lines are suitable for both two-key and n-key roll-over type keyboards and available in numbers sufficient for any application from 4×4 matrix to a 120 key or larger designs. Selectable pull-up/down resistors on some devices are an added bonus.
– Timers can be used to determine a fixed polling rate or, in the case of a computer keyboard, used to provide timing for the auto-repeat feature. Timers can also be used for the data transmission.
– High current ports are a prime requirements for many control applications. On computer keyboards they can be used to directly drive leds which are often required to indicate the state of certain keys such as the lock for capital letters. Two bits can also be used for serial line driving.
– Low power consumption modes and wake up features are important for portable applications such as remote control, telephones and portable computers.
– Serial Interfaces can be used for the serial link between keyboard and computer or to incorporate a magnetic card reader or mouse.
– Large ram holds matrix images for debouncing and forms buffers to hold characters to be sent when required.
– On board eerom could be used to provide user programmable function keys on a computer keyboard independent of the actual computer. Only an additional program key on the keyboard would be required.

read a column, store it, and then read the column again, after the anticipated bounce time, Fig.5. When the column is read for the second time it is compared with the first result and if there are any differences then those keys are considered to be in the unpresssed state. A genuine key press will be detected on subsequent scans.

The problem with this method when applied to large keyboards is that the accumulated debounce times from each column check can produce an unacceptably slow scan rate. A simple way around this problem is to scan the entire matrix in one go, storing it in ram. After the debounce time the matrix is scanned again with each column being compared to its stored image as before. This can use a lot of ram depending on the size of the matrix and so a compromise between scan rate and ram usage can be obtained by debouncing the matrix in sections.

Up to now it has been assumed that the keyboard will process any key that is found to be pressed, but on some keyboards a key is only processed when it has changed state so that no repetition takes place. Alternatively some computer keyboard protocols send a key break code when the key is released.

Both of these situations complicate the debounce and key-handling software since an image of the entire matrix has to be maintained in ram so that the present state of the keys can be compared with that obtained on the previous scan. Figure 6 shows the actions taken by a computer keyboard depending on the type of operation and the states of the keys.

With complex keyboards a good method of debouncing is to keep a new and an old image of the keyboard in memory (called, say, NEWBUF and OLDBUF). Then in the scan routine the entire keyboard is read into NEWBUF and after a desired debouncing time the matrix is scanned for a second time. On the second scan, as each column it is read and compared with the first scan result. If any of the keys have changed state they are considered to have bounced and the old value of that key is extracted from OLDBUF and inserted into NEWBUF. In this way only key states which are valid for the two scans are accepted. Later in the program NEWBUF and OLDBUF are compared, the valid key changes are processed, and OLDBUF is updated ready for the next scan (details later).

Keyboard type	Old key state	New key state	Action taken
Simple auto repeat	X	On	Send key code
	X	Off	Do nothing
Non auto repeat	Off	Off	Do nothing
	Off	On	Send key code
	On	X	Do nothing
Complex auto repeat	Off	Off	Do nothing
	Off	On	Send key code
	On	On	Auto repeat
	On	Off	Send break code

Fig.6. Software in controller-based keyboards can produce three different types of operation.

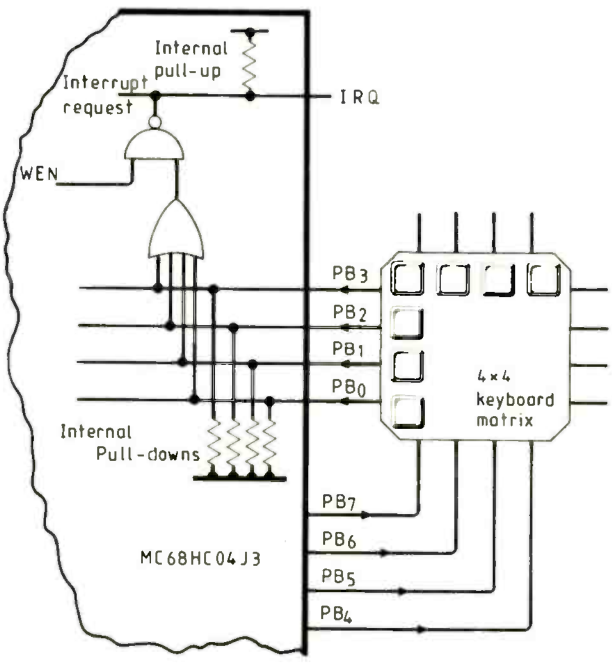


Fig.7. A dedicated controller as opposed to a microprocessor simplifies keyboard design since it has i/o lines that can be connected directly to the keys. Some controllers also have internal pull-up or pull-down resistors and internal logic that produces an interrupt when a change of i/o line state is detected.

CHOOSING A CONTROLLER

In most control-type applications the choice of microcontroller will depend largely on the other functions that the device has to perform, with the keyboard being a secondary consideration. Despite this there are a number of features available on some devices which can be a great help to the designer.

Shown in Fig.7 is the MC68HC04J3, which has two features which make it particularly suited to control applications incorporating small keyboards. The first of these is the option of internal pull-down devices on all or some of the port pins, and the second is a wired-Or interrupt option. This software controlled feature allows the device to be brought out of its low-power WAIT and STOP modes or to be interrupted from run mode when a key is pressed, thus eliminating the need for continuous polling.

Quite often there are not enough i/o lines on the controller chosen to handle all the control functions plus a keyboard, but there are ways round this problem by sharing or expanding input/output pins. In Fig.8(a), for example the MC6805 forming a tv controller does not have enough i/o lines to drive both the display and keyboard, and cost prevents the use of an external display driver. The solution to this problem is to multiplex the two functions on the one i/o port. Three port lines A_{0-2} disable the display while the keyboard is scanned and the high-value resistors are to prevent shorts between segments caused by pressed keys.

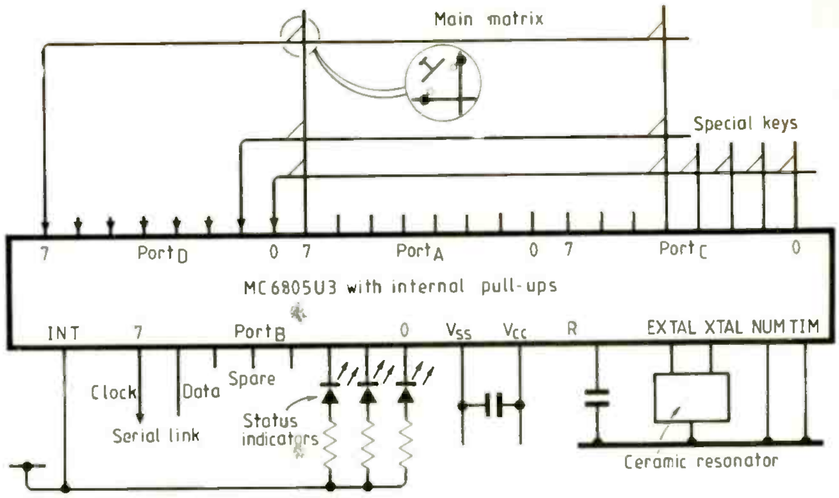
Figure 8(b) shows a situation where a low-cost controller is being used to scan a full computer keyboard. Again, this part does not have sufficient i/o lines to scan the keyboard and so an analogue multiplexer is used to compensate. Note the dual use of the multiplexer address lines as inputs for special keys that need n-key operation.

Mass produced computer keyboards need to be made as cheaply as possible. It could be argued that a computer keyboard with its own intelligence is not justifiable, but designing a keyboard with its own processor brings several advantages.

In systems with a separate keyboard a serial link between the processors improves reliability and saves on cable cost and bulk. A separate processor also allows data to be input independent of the main processor – a buffer in the internal ram of the keyboard controller can store key inputs to be transmitted to the main processor when it is free. On power-up an independent keyboard processor can perform checks on the keyboard to detect stuck keys, etc., while the main processor checks out the rest of the system.

In the past it was common to find microcomputers with external memory in computer keyboards but today the single-chip microcomputer is almost universal in new designs due to its inherent cost advantages in control applications. A list of features found on various controllers which are of

Fig.9. Most of the design work for a PC-compatible keyboard using a controller is done by the software writer.



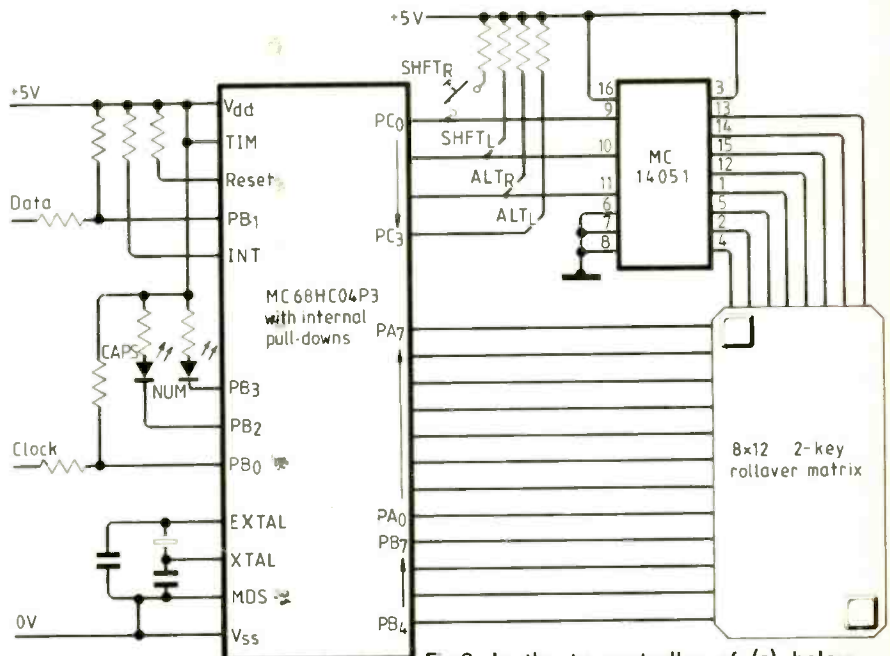
use to the keyboard designer is shown in the panel; some of them apply only to computer type keyboards, others to any type.

DESIGN EXAMPLE

This example forms the basis of a PC-compatible keyboard and has been chosen because it demonstrates most of the principles described previously. Figure 9 shows the keyboard implemented using a low-cost MC6805U3 with mask-selectable pull-up resistors on all ports. It has 100 keys arranged as an 8×12 two-key roll-over matrix plus four special keys, it also incorporates status leds and a serial link to send characters to the main computer. Software shown in List 1 is 6805 assembly language for scanning an 8×8 section of the matrix: this allows the principles to be shown clearly while keeping the software to a minimum. Note that wherever possible the number of row inputs to the controller should be kept to a multiple of four as this simplifies the scan software considerably.

The ram required for these routines consists of two buffers used to hold images of the matrix. Each has the same number of bytes as there are columns in the matrix plus one status register and two temporary storage bytes.

At the start of the program would be an initialization routine that sets up the ports



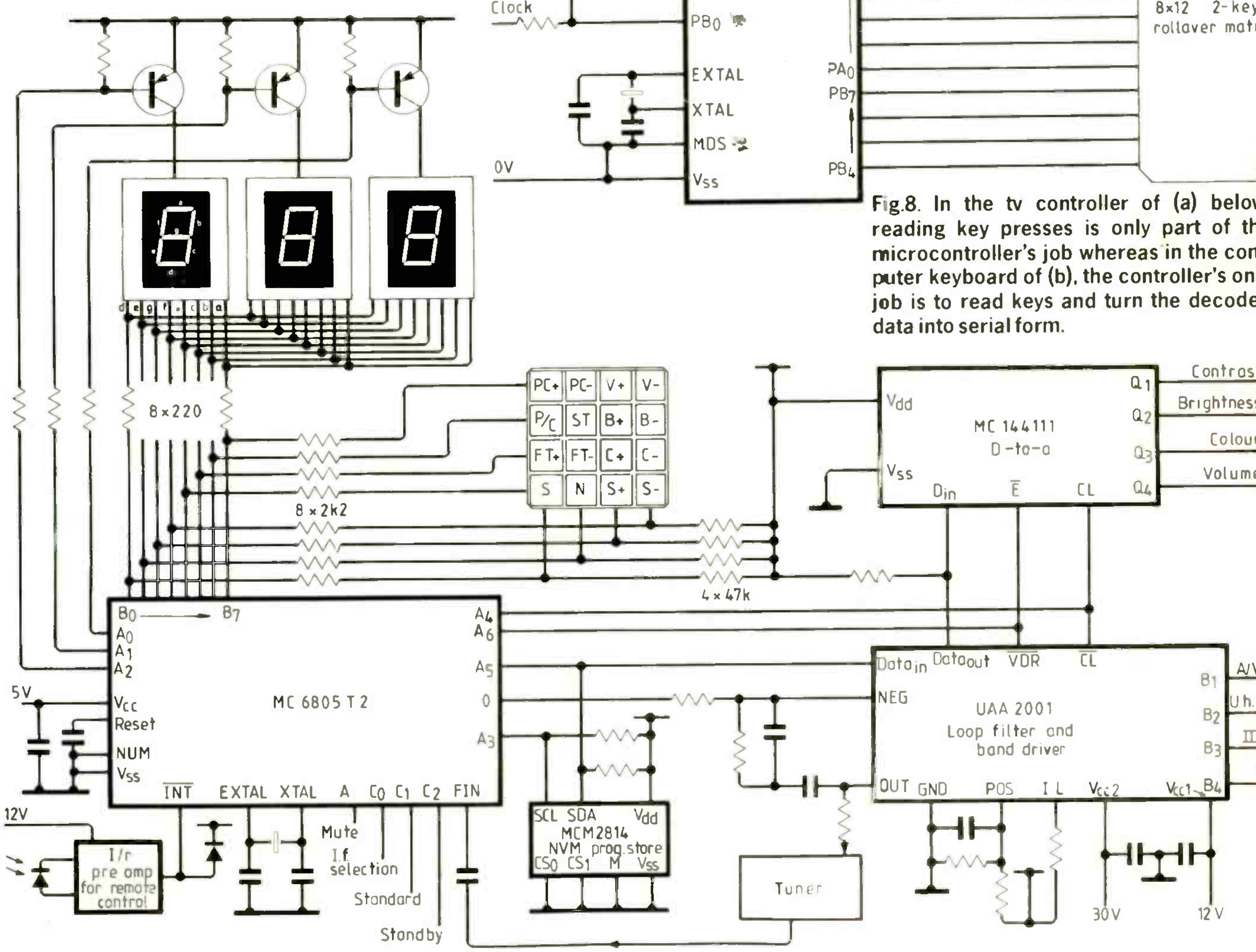


Fig.8. In the tv controller of (a) below, reading key presses is only part of the microcontroller's job whereas in the computer keyboard of (b), the controller's only job is to read keys and turn the decoded data into serial form.

and buffers, etc. This section is not shown here as the software is trivial and controller dependent. The main loop of the program consists of a scanning subroutine, SCANKBD, a ghost detect subroutine, CHKGHOST, and a routine, SENDKEY, that decodes the key changes and sends the data to the computer, updating the OLDBUF in the process. This last routine is only shown in skeleton form as it is unimportant for this example.

Routine SCANKBD scans the matrix twice using i/o switching and also detects and corrects bounce. It begins by setting a flag to identify which scan pass is being executed. Port A data register is cleared as is TEMP1 which is used as an image for Port A data-direction register DDRA (this is necessary since certain commands cannot be executed on the port data-direction registers).

Bit0 of TEMP1 is set and the byte is written to DDRA forcing port A bit0 to output a low; column 0 of the keyboard matrix is then read in vai Port D in the subroutine READCOL. Value TEMP1 is then shifted left and if it has not overflowed then it is written to DDRA thus shifting the scan pulse to the next bit of Port A, this continues until TEMP1 overflows. After the scan the loop flag is tested to see if it is the first or second scan that has been completed. If it is the second then the scan routine is exited; otherwise the loop flag is toggled, the required debounce delay executed and the keyboard scanned for a second time.

During the first scan the subroutine READCOL simply reads the column in via Port D, stores it in NEWBUF and increments the buffer pointer. In the second scan however READCOL is a little more complex as it checks for key bounce. As each column is read an exclusive-Or operation is performed with it and the result from the first scan to see if any changes indicating possible bounce have occured. If there are changes then the result of the exclusive-Or operation is used as a mask to replace the "bouncing" keys with their previous state (held in OLDBUF).

If a valid key state is wrongly interpreted as bounce it will be picked up next time round the main loop. Note that if an n-key roll-over matrix were used instead of the one shown then SCANKBD could be simplified, as shown at the end of the software listing, since no i/o switching would be required.

Also of interest is the ghost checking routine CHKGHOST (not required for n-key roll-over matrices). The detection technique used relies on the fact that when a ghost key is produced there will always be two columns which show two or more keys pressed in the same row positions. Thus if two columns are equal and contain more than one key press then a ghost-key exists.

Each column in the matrix image NEWBUF is only compared with those residing above it in memory to avoid time-wasting duplicate comparisons. Temporary register TEMP1 stores the contents of the column that is being compared to the others and TEMP holds the pointer value for the same column. As discussed earlier, once the ghost flag has been set it is only cleared when all keys are released (not just the one causing the ghost).

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List 1. Example software in 6805 assembly language for scanning 8×8 rows of the PC-compatible keyboard.

```
          ORG   RAMBSE
NEWBUF    RMB   COLS           New and Old matrix image
                               buffers
ENDBUF    EQU   *              1 byte in each for each
                               column
OLDBUF    RMB   COLS
FLAG      RMB   1              Status register
TEMP      RMB   1              2 temporary storage
                               registers
TEMP1     RMB   1

          ORG   ROMBSE
RESET     EQU   *
          JSR   INIT           Set up ports, initialise
                               buffer and status reg etc.
MAINLOOP  EQU   *
          JSR   SCANKBD        Go scan keyboard twice &
                               store in ram.
          JSR   CHKGHOST       Check image in ram for
                               Ghost keys –
          BRSET GHOST.FLAG,    if detected then wait for
                MAINLOOP       keys to be released.
          JSR   SENDKEY        Go and process any valid
                               key changes.
          BRA   MAINLOOP
NXTCMP    LDX   TEMP
          INX                  Check if we have
          CPX   #ENDBUF        compared every column
          BLO   STOREX         to every other – If not,
                               update pointer and do
                               loop again.
          LDA   TEMP1
          INCA                 If all keys are released
          BNE   GHOSTEX        then TEMP1 should
                               contain FF –
ALLOFF    BCLR  GHOST.FLAG     So clear ghost flag.
GHOSTEX   RTS

SENDKEY   EQU   *
TSTCNG    JSR   TSTCHNG        Look for differences
          BNE   SENDKY         between NEWBUF &
                               OLDBUF. If none found
                               return with Z = 1.
          RTS                  No key changes to
                               process so return.
SENDKY    JSR   TSTKEY         Process each key change
*                              in this column and update
                               OLDBUF with its new state.
          BRA   TSTCNG         Look for next column with
                               a change in it.

Modified scan routine for an N-Key rollover matrix

SCANKBD   EQU   *
          BSET  LOOPFLG.FLAG
          LOA   #$FF
          STA   PORTA          Set portA all output high.
SCAN      CLX
          BCLR  0.PORTA        Pull first scan line low.
SCANA     BSR   READCOL        As before with 2 key roll-
                               over version.
          LSL   PORTA          Move scan pulse to next
                               column.
          BCS   SCANA          If not all done yet then
                               continue.
          BRCLR LOOPFLG.FLAG   Rest same as for 2 key
                OKRTN          rollover version.
          BCLR  LOOPFLG.FLAG
          BSR   DEBNCE
          BRA   SCAN
OKRTN     RTS
SCANKBD   EQU   *
          BSET  LOOPLG.FLAG    Initialise loop flag.
SCAN      CLRX
          STX   PORTA          Clear data register and
          STX   TEMP1          Data Direction image
                               register.
          BSET  0.TEMP1
SCANA     LDA   TEMP1          Switch selected column to
          STA   DDRA           output so producing a low
                               scan pulse.
          BSR   READCOL        Now read in that column.
          LSL   TEMP1          Move scan pulse to next
                               column.
          BCC   SCANA          If not all done yet then
          CLRA                 continue else return all
                               lines to input.
          STA   DDRA
          BRCLR LOOPFLG.FLAG   If 2 scans complete then
                OKRTN          return.
          BCLR  LOOPFLG.FLAG   Clear loop flag.
          BSR   DEBNCE         Wait for desired debounce
          BRA   SCAN           time then scan keyboard a
                               second time.
OKRTN     RTS

READCOL   EQU   *
          LDA   PORTD          Read selected column.
          BRCLR LOOPFLG.FLAG   If second scan then go
                VERIFY         check for bounce, other-
          STA   NEWBUF.X       wise store column.
COLINC    INCX                 Increment the buffer
                               pointer.
          RTS

VERIFY    EOR   NEWBUF.X       Compare with first scan
          BEQ   COLINC         value – if no differences
                               (bounce) then return,
          STA   TEMP
          COMA                 otherwise manipulate
          AND   NEWBUF.X       scan results with old value
          STA   NEWBUF.X       so that only key changes
          LDA   OLDBUF.X       that were valid for both
                               scans are included, the
                               others are returned to
                               their old value.
          AND   TEMP
          ORA   NEWBUF.X       Equation for NEWBUF is:
          STA   NEWBUF.X
          BRA   COLINC         (SCAN1 EOR SCAN2).
                               OLO BUF + (SCAN1 EOR
                               SCAN2).SCAN1
CHKGHOST  EQU   *              Look for Ghost keys in
          LDX   #NEWBUF        matrix image stored in
                               NEWBUF.
          LDA   #$FF           Initialise pointer and
                               temporary register.
          STA   TEMP1
STOREX    STX   TEMP           Store latest pointer value.
          LOA   ,X             Get associated byte from
                               NEWBUF.
          CMP   #$FF           If no keys pressed in that
          BEQ   NXTCMP         column then try the next
          STA   TEMP1          one else store it.
INCRX     INX
          CPX   #ENDBUF        If end of table reached
          BEQ   NXTCMP         then go compare next
                               column with all those
                               above it.
          LDA   ,X             Get a column from buffer
          CMP   TEMP1          and compare it with the
          BNE   INCRX          stored one – If not equal
                               try next column.
          SEC                  Bytes are equal-possible
                               ghost, set carry for test.
ROTA      RORA
          BCS   ROTA
          CMP   #$FF           Have got the 1st 0 in carry
                               so if acc now not = FF
          BEQ   INCRX          then there must have been
          BSET  GHOST.FLAG     more than 1 key in the
          RTS                  same position in 2
                               columns and so a Ghost
                               situation – set flag and
                               return.
```

Analogue circuits for automotive uses

These i.cs, designed to survive the harsh operating conditions found in motor vehicles, can provide substantial cost savings.

ROCCO SHAH

With the increasing use of microprocessors for engine control, transmission control, anti-lock braking and multiplex load control the need has arisen for interface and power switching circuits for interfacing from logic level or analogue signals to high current, high voltage loads.

Development of these circuits has been mainly driven by the search for improvement of total system performance, protection against the harsh automotive environment, minimum component count and hence lower module costs.

Several environmental factors must be considered in the selection of automotive devices.

TABLE 1. – TYPICAL TRANSIENTS ENCOUNTERED IN THE AUTOMOTIVE ENVIRONMENT.

Length of transient	Cause	Voltage	Energy capability	Occurrence
Steady state	Failed voltage regulator	+18V		Infrequent
5 minutes	Booster starts with 24V battery	24V		Infrequent
4.5—100ms	Disconnection of battery during high charging rates	≤125V	≈10J	Infrequent
≤0.32s	Inductive load switching	−300V to +80V	<1J	Often
≤0.20s	Alternator field decay	−100V to −40V	<1J	Each turn-off
90ms	Ignition pulse – disconnected battery	≤75V	<0.5J	≤500Hz, several times in vehicle life
1.0ms	Mutual coupling in wiring harness	≤200V	<1J	Often
15μs	Normal ignition pulse	3V	<0.001J	≤500Hz continuous
	Accessory noise	≤1.5V		50Hz to 10kHz
	Transceiver feedback	20mV		R.f.

TEMPERATURE

Passenger compartment electronics have a more limited range requirement of −40°C to +85°C, whilst under-bonnet electronics must withstand −40°C to +125°C or even higher. Remember that the junction temperature will be above ambient, hence the trend to the lower power dissipation technologies such as high-speed c-mos, where the junction-to-ambient temperature differential is generally lower.

SUPPLY VOLTAGES

For passenger cars the normal battery voltage is +12V, although +24V systems may be introduced in the future. Unfortunately this 12V is not constant: essential systems have to operate at 6V, the low point reached during cranking. Once the engine is started, the charging voltage at the battery may reach +16V. With the battery disconnected, the alternator will probably produce a continuous +18V; and during a two-battery jump start +24V is applied. Not only must integrated circuits protect themselves, they are now expected to protect their loads from damage also.

TRANSIENT VOLTAGES

Transients can appear on any line, with various voltages and durations: the probability of each varies (Table 1). This hazard is much more difficult to assess but nevertheless has to be taken into account if anything other than a worst possible case design (which is not necessarily the most economical) is required.

Designing for transient survival probably causes as many problems as any other aspect, and reliable data can be difficult to come by. The load dump transient often quoted is actually a worst case. It occurs when a battery so flat as to be effectively a short circuit is disconnected whilst being charged by an alternator driven by an engine at maximum engine speed. It can be more cost-effective for a car manufacturer to choose lower load dump criteria based on his experience. He could then save money on all units, but would trade this off against the increased claims that resulted.

The car manufacturer may well decide that central transient suppression at the alternator is more cost-effective than a higher degree of protection at each and every unit – particularly as these proliferate.

IGNITION INTERFACE CIRCUITS

Basic building blocks for the interface circuits are power supply regulator, reset generator with over-voltage protection, coil driver outputs and sensor input circuit.

Figure 1 shows a simplified diagram of an ignition injection system based on the MC68HC05-B6 or MC68HC11, interface circuit UAA1550, the microprocessor input protection circuit TCF6000 (Fig.3) and the high voltage Darlington BU323.

The power supply regulator provides an output of 5.1V +3% and current capability of 400mA, adequate for the microprocessor plus other peripheral circuits. Its design enables it to cope with the voltage range and noise level of the vehicle's battery supply.

The reset generator provides a reset signal to the microprocessor if the regulator output falls to 7% below normal level. In the event of broken spark plugs or leads, the over-voltage protection circuit provides protection to the Darlington. The coil driver output stage has outputs for two coils with steering logic and constant current logic.

Finally, the sensor input circuit has been designed for either variable reluctance or Hall-effect sensors, both of which are popular for speed/position sensing.

In the system shown, the interface regulator provides a regulated output with a battery voltage down to 6V. The diode provides protection against reverse battery, and, in association with a capacitor, ensures an uninterrupted supply during negative transients.

PRESSURE SENSOR AMPLIFER

Load sensing is normally effected by measuring absolute pressure. Most measuring devices suitable for automotive use produce an analogue voltage output.

Figure 2 shows a manifold pressure measuring system with a semiconductor piezoelectric device MPX100 and a dedicated low power dual operational amplifier. The operational amplifier has been designed for an output voltage swing from 0V to V_{cc}, a low offset voltage (2mV), a large current drive capability and an operating temperature range of −40 to +125°C.

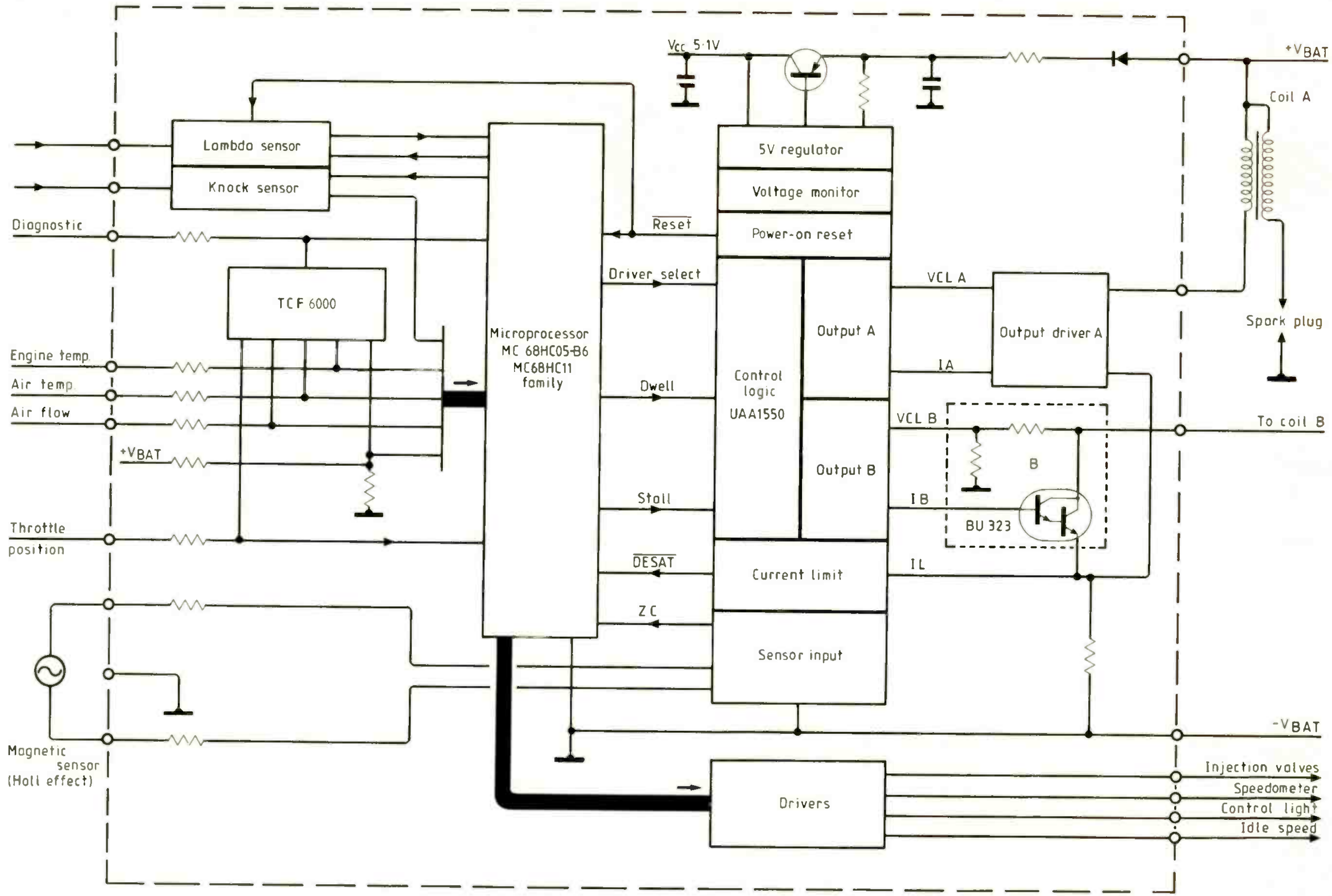


Fig.1. Ignition and injection module with dual-coil output, based an eight-bit microprocessor (simplified).

MICROCOMPUTER INPUT PROTECTION NETWORK

Normally mos and bipolar circuits are sensitive to negative and positive voltage spikes, and so care has to be taken to ensure that voltage transients do not reach the microcomputer's i/o pins.

Conventional protection units consist of diode resistor networks which do not in general meet the specification over the whole temperature range.

Figure 3 shows one of the six input protection circuits developed as an integrated circuit, TCF6000, and capable of sinking 10mA at +5.75V and −0.3V. This peripheral clamping array has been optimized for microprocessor-based automotive systems requiring minimal component count and low board space. Figure 4 shows a typical ignition system protected in this way.

DATA CONVERSION CIRCUIT

In several automotive systems, independent a-to-d converters are used for converting analogue signals from the sensors (such as lambda [oxygen], knock, load and temperature) to provide digital inputs to the microprocessor.

A low cost c-mos eight-bit a-to-d converter MC145040, with serial interface parts to provide communication with microprocessors, operates from a single power supply and gives a maximum non-linearity of ±½ l.s.b.

The device provides a successive approximation conversion time of 10 microseconds, has 11 analogue input channels with internal sample and hold, and has separate reference voltage and analogue ground pins for noise immunity.

HIGH SIDE DRIVER SWITCH

In engine and multiplex control modules, high-side driver switches are increasingly used to drive loads from the positive side of the power supply.

The main advantages of high-side switches are corrosion resistance and protection against accidental short-circuits during module inspection or repair.

Figure 5 shows a high-side driver switch, MC3399T, fabricated in a power BiMOS process which combines the best features of bipolar and mos technologies. The device has been designed to drive low current loads directly and for intelligent control of low-power relays or solenoid valves. Its output is controlled by t.t.l.-compatible enable pin. In the on state, the device exhibits very low saturation voltage (400mV typical) for load currents in excess of 750mA.

The device also protects the load from positive- or negative-going high voltage transients (±100V). With its current limiting and thermal shutdown, it can drive all kinds of loads including inductive ones over a wide temperature range (−40 to +125°C).

DASHBOARD DISPLAY

Independent display drivers are still used in low cost microprocessor-based dashboard

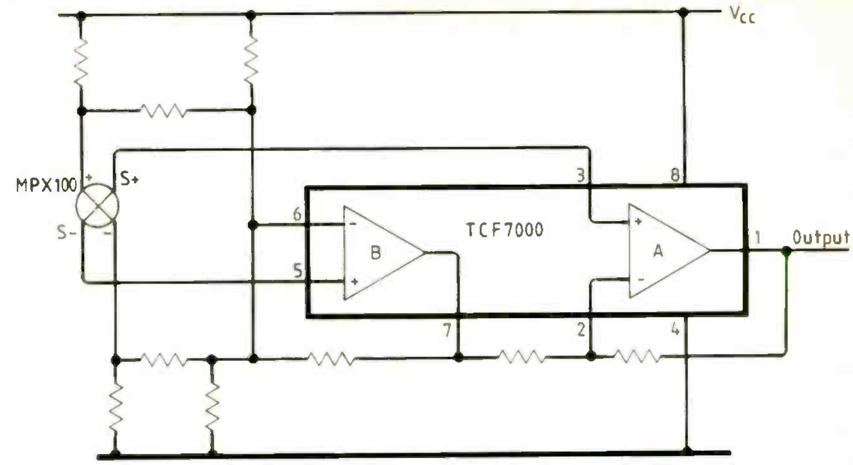


Fig.2. Manifold pressure-measuring system based on a special-purpose dual op-amp.

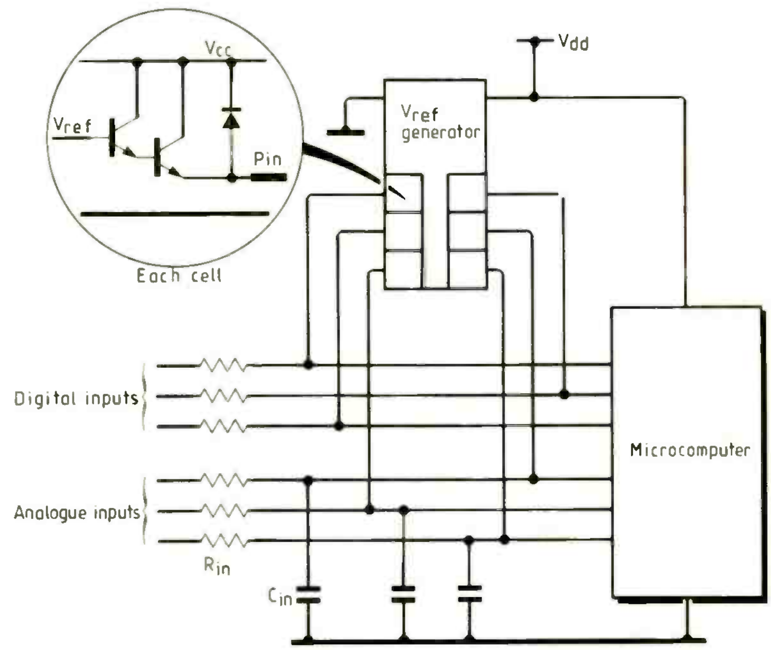


Fig.3. Both mos and bipolar inputs in motor vehicle systems need to be guarded against transients: the TCF6000 is made up of six protection networks.

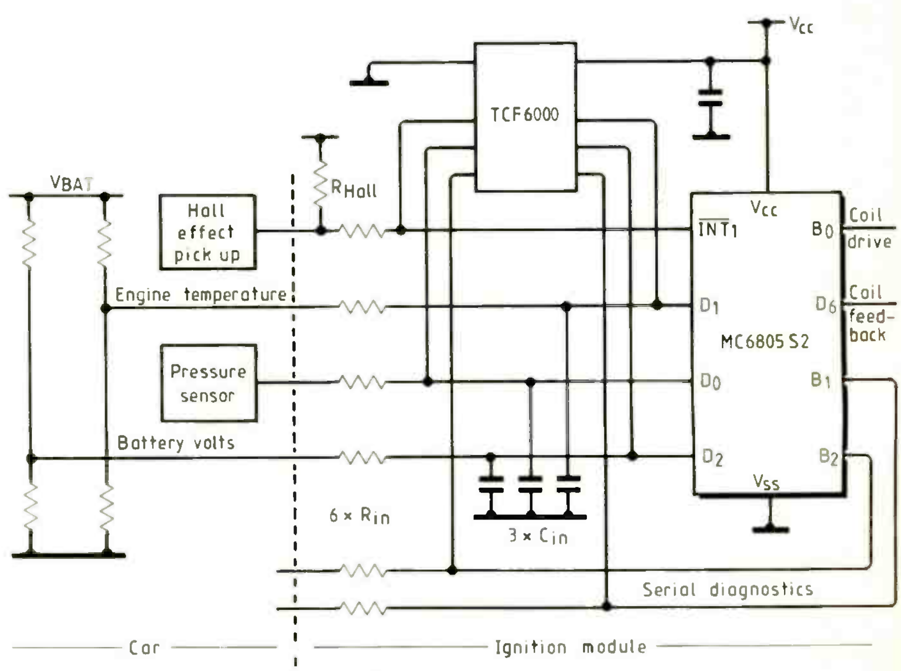


Fig.4. Using the TCF6000 to protect a microcontroller's i/o pins.

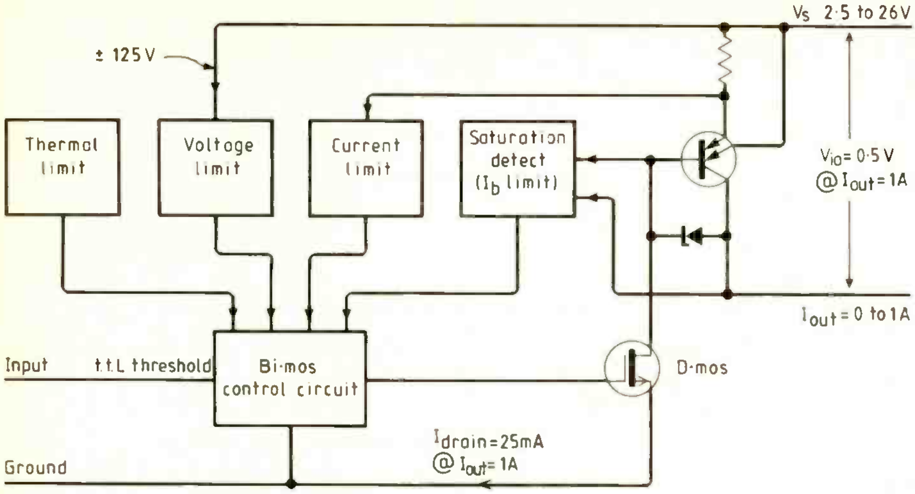


Fig.5. Driver switch based on hybrid bipolar-mos technology.

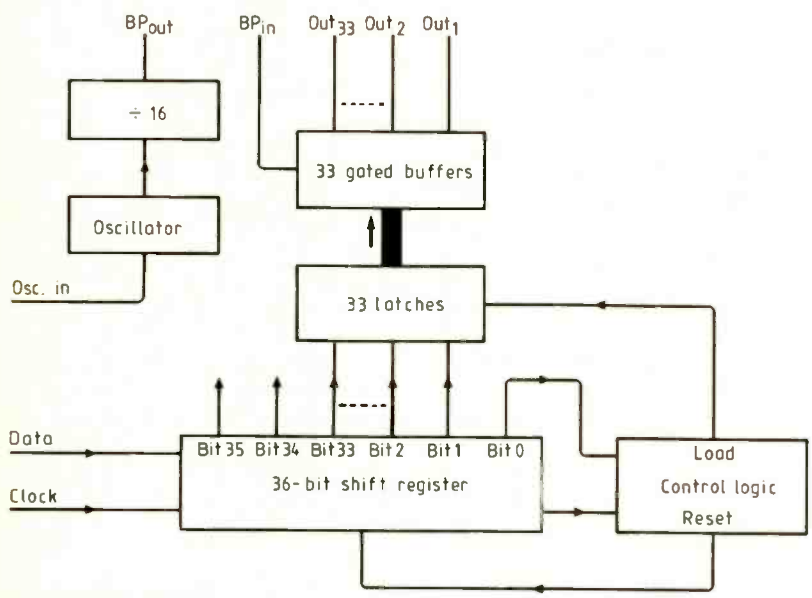


Fig.6. Low-power driver for liquid-crystal displays on the dashboard. Data input is in serial form.

systems because they allow flexibility and free the microprocessor for other tasks.

Liquid crystal displays, as used for clocks, trip meters, information, climate control systems etc., need low-power display drivers, capable of handling several l.c.d. segments per package.

Figure 6 shows a low-cost c-mos display driver for automotive dashboard applications. It consists of a 36-stage shift register with 33 latches and output buffers, which may drive up to 33 non-multiplexed l.c.d. segments per package. Devices may be paralleled to increase the number of segments per package with minimal interfacing between the display and data source.

Further reading

Microprocessor-controlled engine management, by Pat Jordan. *Electronics & Wireless World*. September 1987, p.876.

Advanced engine management systems, by Pat Jordan. *Electronics & Wireless World*. December 1987, p.1225.

Rocco Shah is in product marketing at Motorola Semiconductors S.A., Toulouse, France.

Radio-nav pioneer

Harvey Schwarz, joint developer with W.O'Brien of the Decca Navigator system, has died.

He came from the American mid-West and worked at GEC on the development of radio reception, arriving in England in 1932 where he went to Decca. As chief engineer, he was responsible for the development of the radio navigation system, spending some of his time in California working with O'Brien and much of the rest persuading the Admiralty that his system was worthy of their attention. Fortunately, he was sufficiently persuasive and it was adopted in time to be used in the invasion of France in 1944.

After the war he turned his attentioin to Decca's new long-playing records. He leaves a widow, who was also involved in the development of the Decca Navigator.

ASSERT competition

All the entries for our 1988 writing competition are now in and are being read by the judges. This is no light task and will take some time to get through, but we will be as quick about it as possible. Results will be announced in a couple of months.

The first impression is that the quality of entries is good, so that a number will eventually be seen in print after the competition is over.

SCITECH 89

The British Science and Technology Trust has accepted an offer from SCS Exhibitions Ltd to stage SCITECH 89 at Alexandra Palace and Park from 17 to 21 May, 1989. The organizers intend that the exhibition shall be housed in the new location each May.

Invitations to exhibit are to be restricted to science-based, British companies or those foreign companies which carry out a major part of their research and development in Britain.

The organizers will allocate free space to a limited number of schools, universities and hospitals to allow them to show their scientific and technical development.

Enquiries should be made to SCS Exhibitions Limited, 212 London Road, North End, Portsmouth, Hampshire PO2 9JE.

Professor Paul Cook of BSTT talking to science students

Pan-European cellular demonstration

This equipment has proved that Europe's new cellular telephone system is workable: now the task is to miniaturize it. The complex digital speech coding will result in a spectral efficiency three times better than that of Britain's present cellular networks. Some 17 countries are already involved in the project. By 1999, the system is expected to cover a population of 300M and to have 9M subscribers.

Research teams at Plessey and Racal give themselves until 1991 to shrink this equipment into a telephone handset. Inside the 19-inch rack in the photograph is the digital part of a mobile telephone for GSM, Europe's second-generation cellular telephone system. GSM (standing for Groupe Speciale Mobile, a standards-making committee of the European PTTs) is a 900MHz system which will use digital speech encoding to achieve about three times the spectrum efficiency possible with the present-day analogue networks.

The core of the first GSM network has now been ordered by Racal-Vodafone. Equipment to be supplied by Orbitel, the manufacturer owned jointly by Racal and Plessey, will serve 60 000 subscribers in London and the south-east of England. Work on installing it is expected to begin in 1990, to provide an initial service in June 1991. Vodafone has ordered a second system, from Ericsson Radio Systems, to serve the Midlands and North. Eventually GSM will become the largest single-standard mobile telephone system in the world, with 17 networks all over Europe. Some 9M subscribers are expected to be on it by 1999.

The prototype seen here, built by Plessey staff at Roke Manor and demonstrated in London in July, contains most of the features of a GSM mobile unit. Missing were the frequency-hopping capability, which will enable the system to live with interference, and the long-term predictor section of the digital voice coder.

At the distant end of the radio link was a roving light van, fitted with broadly similar equipment though cast paradoxically in the role of a base station. A call put through by Orbitel's technical director, Dr David Balston, to Bernard Mallinder of GSM's Permanent Nucleus in Paris, was clear and free from interference – though troubled at first by delayed echoes returned through a public address system at the Paris end. This call was coupled at the van to the Vodafone cellular network and was thence routed over ordinary international lines.

In an operational system, each GSM radio channel would be time-shared by up to eight conversations, giving a total data rate of 270kbit/s. The speech rate leaving the voice coder (top shelf of the demonstration unit) is about 13kbit/s per channel, but to this channel codec adds error-protection and control data. Because of bandwidth compression, the speech quality sounded distinctly gritty; but according to Orbitel the long-term predictor will improve it to the point where it hardly differs from the average analogue cellular quality. The coder is designed to accept a bit error rate of 1 in 100 on speech, but the system could manage 9.6kbit/s of data with a b.e.r. of 10^{-5}. Propagation delay through the system can be up to 90ms.

A crucial feature of GSM radiotelephones will be the equalizer (bottom shelf of the cabinet). By means of advanced digital signal processing techniques, this extracts the wanted signal from the mass of multi-path reflections which are inevitable at u.h.f. in a city. With the aid of the equalizer, the digital telephone gives acceptable reception with a carrier-to-noise ratio of 12dB: analogue cellular needs 30-35dB. Improvements in equalizer design could enhance performance still further, and would of course enable the networks to pack more paying customers on to the same frequencies.

On the centre shelf of the unit is the channel codec, which handles the complex signalling procedure between base station and mobile. The 900MHz r.f. unit, running about 5W, is in a separate cabinet on the top. Frequencies used for the demonstration were in the band reserved for GSM – 955MHz mobile-to-base and 910MHz coming back.

Work is now in hand to design the all-important v.l.s.i. chips for the voice codec, channel codec and equalizer, each likely to be the equivalent of about 600 000 transistors. One potential hitch is that GSM is still struggling to agree on the details of a common radio interface standard; but if no agreement can be reached, Orbitel and its associated companies are prepared to go ahead with their own joint standard.

Base station hardware for both Vodafone GSM systems will include Matra designs already in use in the French Radiocom 2000 mobile telephone network. Switching will be based on the Ericsson AXE-10 exchange.

Further details from Orbitel Mobile Communications Ltd, Keytech Centre, Ashwood Way, Basingstoke RG23 8BG.

NEW PRODUCTS

Fault finding in i.cs

Fast repair at component level in production or field service is possible using the diagnostic information obtained from the DIT-24XP digital i.c. test system.

Thurlby Electronics' device can detect manufacturing defects such as dry joints and faulty i.cs, identify unknown i.cs; and test i.cs in-circuit using a self-contained library. Operation is simple: a test clip is connected to each i.c., the i.c. number keyed in, and after pressing the test key the results are displayed on the monitor. The normal library covers t.t.l. c-mos memory and interface devices. Standard interfaces are provided for RS232. Centronics type printer and an external keyboard. Thurlby Electronics Ltd, New Road, St. Ives, Huntingdon, Cambs PE17 4BG. Tel: 0480 63570.

Cursor measurement of waveform

A cursor measurement system on the Hitachi V1100A, 100MHz readout oscilloscope allows easy measurement of voltage, time, frequency, phase difference and ratio.

The results are numerically displayed on the screen to eliminate the errors associated with visual interpretation of waveform parameters. There are four channels with varying sensitivities on the unit, which is available from Thurlby Electronics. A signal delay line permits viewing of the leading edge of the displayed waveform on an 8×10cm display with autofocus. Thurlby Electronics Ltd, New Road, St. Ives, Huntingdon, Cambs. PE17 4BG. Tel: 0480 63570.

Programmable display module

A programmable vacuum fluorescent display has been introduced by Pulseview.

The PVFM 35-05-20 can be pre-programmed with up to 32 fixed messages or 24 fixed and 4 moving messages; either by the manufacturer or by the user with a standard eeprom programmer. The device provides a single row of twenty characters each comprising a 5×7 dot matrix, and each 5mm in height. The module measures 128×34.5mm. Pulseview Ltd, Unit 1 & 2, Suffolk Way, Drayton Road, Abingdon, Oxon OX14 5JY.

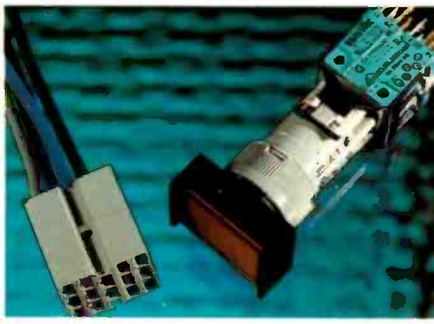
Inductive proximity sensors

Contact-free detection of metal objects in industrial automation applications is offered by Kuhnke's new inductive proximity sensors. With 8 switching distances between 1 and 15mm, the series has bounce free switching with a typical repeatability of 2%. The switches are capable of operating from either 10-30V d.c. or 80-250V a.c. H. Kuhnke Ltd, Lane End Industrial Estate, Lane End, High Wycombe, Bucks HP14 3JG. Tel: 0494 882829.

Colour graphics

Single-board layout, smooth hardware scroll, flash facility, 2MHz operation and a Centronics printer port are among the advantages claimed for the CU-Graph II colour graphics controller.

Compatible with its predecessor, it is designed by Control Universal for use with EuroBEEB, the BBC Basic-based single-board computer. Three versions of the controller are available: colour and monochrome each with a Centronics printer port; and a low-cost monochrome without the printer port. Control Universal Ltd, 137 Ditton Walk, Cambridge CB5 8QF. Tel: 0223 244448.



Multi-pin connection with no soldering

Highland Electronics' Swisstac range of front-panel components including switches, pushbuttons and lamps can be easily installed and replaced using a new multi-pin plug assembly.

All the wires are pre-assembled into a three-element contact block which includes up to 14 flat connectors. The connector assembly is plugged onto the rear contacts of the switch unit with no need for soldering. Each flat connector measures 2.8×0.5mm including catch and is tin-coated. Highland Electronics Ltd, Albert Drive, Burgess Hill, West Sussex RH15 9TN. Tel: 04446 45021.

Complete p.c.b. design system

The entire design process of p.c.bs from schematic generation through to board artwork can be automated with Project p.c.b.

This software system is designed to be easy to learn and to use. A mouse is used to select menu options, draw lines, define symbols and enter parts locations. Screen windowing helps to speed progress through the package without long delays or indirect input sequencies. Clwyd Technology has offered to refund the purchase price to any customer not satisfied with the package within 28 days. Clwyd Technology Ltd, 99 Leman Street, London E1 8YE. Tel: 01-480 5447.

Small surge arrester stops big surges

An inert gas-filled cylindrical surge arrester measuring only 5×5mm is capable of diverting a surge current of up to 2.5kA and an alternating current of up to 2.5A. Typical applications for the unit designed by Siemens are the highly concentrated main distribution frames for telephone lines. Siemens Ltd, Siemens House, Windmill Road, Sunbury-on-Thames, Middlesex TW16 7HS.

NEW PRODUCTS

Digital storage oscilloscope

Sampling rates of 100M samples/sec can be achieved simultaneously on the two channels of Hitachi Denshi's digital storage oscilloscope.

The unit has a memory capacity of 4000 words/channel and two 4000 word save memories relative to channel 1 which has energy back-up to hold data for 72 hours. It can handle four samples/period that enable storage of single shot phenomena at 13.5MHz or 25MHz on one or two channels.

Three different modes – envelope, averaging and roll – allow detailed analysis of waveform. The VC6265 has as standard: plotter output; GPIB (binary or BSC II) for computer data input/output; and analogue output for a chart recorder. Hitachi Denshi (UK) Ltd 13-14 Garrick Industrial Centre, Garrick Road, Hendon, London NW9 9AP. Tel: 01-202 4311.

Low-consumption power supply i.c.

A c-mos chip that can supply telephony equipment with 40V to the four-wire network termination in accordance with CCITT (S interface) recommendations consumes less than 10mW.

This chip has been designed by Siemens to replace discrete power supply circuits and is suitable for voice terminals which are line-fed and require an internal regulated voltage of 5V. It is also suitable for terminals that operate in emergency power conditions, for example, after an a.c. power failure. Siemens Ltd, Siemens House, Windmill Road, Sunbury-on-Thames, Middlesex TW16 7HS. Tel: 0932 752323.

Fast digitizing oscilloscope

Philips has announced its fastest oscilloscope, the PM3340, with full 2GHz bandwidth and triggering, post-capture waveform processing, sensitivity down to 1mV/div and a dynamic range of 125 to 1.

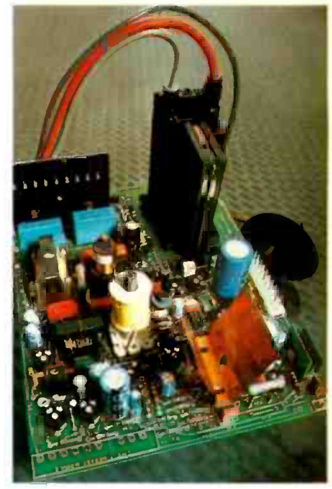
The PM3340 uses the principle of sequential sampling which allows faster signal build-up than is possible with random sampling at u.h.f. frequencies. The oscilloscope has four memories in which the waveforms can be subjected to processing and automatic measurements. Operation is simple through on-screen menus and soft keys plus auto set. Up to eight signals can be stored and comparative measurements performed easily with on-screen annotation. Philips Test and Measurement, Colonial Way, Watford, Herts WD2 4TT. Tel: 0923 240511.

Increased data capture on logic analyser

Data-capture capabilities have been increased with the introduction of a logic-analyser system which makes use of a high-speed dram module.

The K450M system provides up to 10Mbit of data capture on each of its 64 logic-analyser channels at speeds of up to 50MHz and is front panel configurable up to 40Mbit per channel of data capture across 16 channels at 200MHz. Gould Electronics claims that the instrument has up to 4000 times more full-speed data capture memory than any other logic analyser on the market.

It is supplied complete in a 48in rolling cabinet, which contains the logic analyser with dual disc drives for storage, the memory module, and the PC/AT compatible chassis with 80Mbyte hard disc. The PC colour screen and keyboard may be placed on top of a convenient work surface. Gould Electronics Ltd, Instrument Systems, Roebuck Road, Hainault, Ilford, Essex IG6 3UE. Tel: 01-500 1000.



Colour display modules

Colour display modules offering a choice of user-selectable line rates from 15 to 35kHz, combined with high performance video inputs are available from Nevin Developments.

The units measure 183×142×120mm and the complete scan electronics, including the line transformers are mounted on a single p.c.b. for ease of installation. User controls include: height; width; horizontal phase and frequency; vertical shift and frequency; linearity; brightness; and contrast. Nevin Developments Ltd, Charlton Road, Andover, Hants SP10 3JL. Tel: 0264 332122.

Microwave modulation analysis

More accurate analysis of complex microwave modulation is possible with Hewlett-Packard's HP 8981A vector modulation analyser.

It adds a broadband, coherent I/Q demodulator, covering the 50 to 200MHz intermediate frequencies and carrier range, to the HP 8980A vector analyser introduced in 1987, which provides time, vector and constellation analysis modes. The additional front-end vector demodulator processes a 35MHz I/Q bandwidth (for up to 70MHz channel measurement). External filter ports are available for use with 200MHz channel measurements.

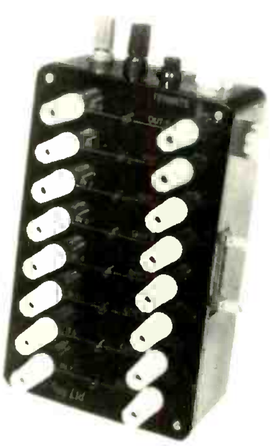
After digitally processing the signal the analyser displays constellation parameters, quadrature error, I/Q imbalance and d.c. offsets in visual as well as digitally annotated form. Hewlett-Packard Ltd, Eskdale Road, Winnersh Triangle, Wokingham, Berks RG11 5DZ. Tel: 0734 696622.

NEW PRODUCTS

Real-time control for BBC microcomputer

A real-time control interface for the BBC microcomputer has been designed with schools, laboratories and home users in mind.

The Termite interface from Paul Fray provides eight terminals, independently programmable to any combination of i/o, and it connects directly to the user port of any model BBC computer. It is powered either directly from the BBC or an external power supply and can be used to drive motors, relays, detect sensors or simply light up bulbs. Paul Fray Ltd, Willowcroft, Histon Road, Cambridge CB4 3JD. Tel: 0223 66529.



Signal analyser allows custom-measurement

Many test and automation features that traditionally have required the use of an external computer are included in the Hewlett-Packard two-channel dynamic signal analyser.

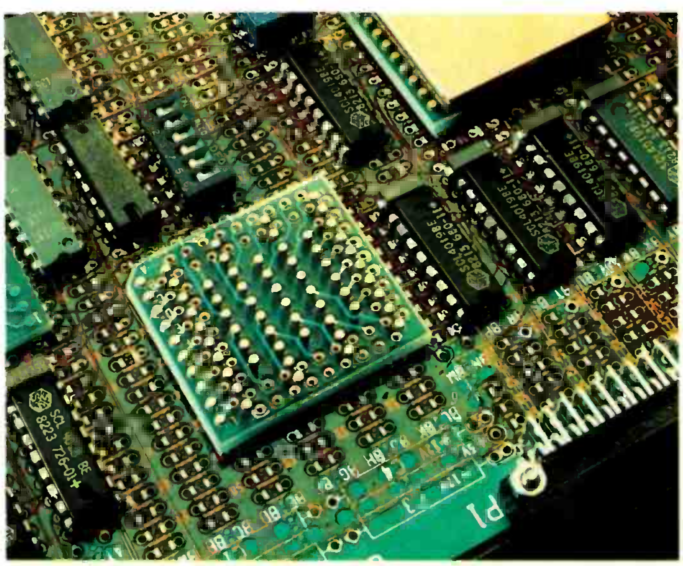
The HP 35660A fast Fourier transform-based analyser has applications in electronics, mechanical testing, acoustics and other low-frequency areas in both production/process and r. and d. environments. It provides spectrum analysis from zero to 102.4kHz and network analysis from zero to 51.2kHz.

Using HP Instrument Basic which runs inside the analyser without the need for an external computer, test sequences are simplified. Advanced users can create custom algorithms and result formats to provide answers not directly available from the standard analyser. Hewlett Packard Ltd, Eskdale Road, Winnersh Triangle, Wokingham, Berks RG11 5DZ. Tel: 0734 696622.

Verbal communication between man and machine

Verbal command and response between user and personal, micro, mini or mainframe computers is achieved by the Verbex 5000 voice i/o system.

The system from Decade Computers uses a two-way serial connection at up to 19 000baud through a standard RS232-C port on the host computer. The speech recognition technology allows a continuous flow of verbal input at natural human speeds, regardless of language or dialect. Voice cartridges can be easily changed by front loading. Decade Computers Ltd, Ringway House, Kelvin Road, Newbury, Berks RG13 2BD.



Prototype p.c.b. is also production board

Transition from a prototype p.c.b. to a final production board has been made easy by the introduction of Augat's Unilayer II board modules. These have a high-density, plated-through hole pattern on a grid of standard pitch. Supply and ground buses are already etched on either side of the board and, for prototyping, it is fitted with wire-wrap pins.

For production, the same pattern of module is used by the wire wrapping is replaced by soldered wires produced by the Unilayer II wiring system to give high-density layers. Insulated wires allow signals to cross and provide the shortest paths. Each layer is soldered to the plated holes and then bonded to the board with adhesive. A finished board may have six or more layers. Boards used with the system are available in all the popular formats for use in P.Cs, VMEbus and other systems.

Augat manufactures the modules from the prototypes and says that its service is much faster than conventional multi-layer boards. Augat Ltd, Sunrise Parkway, Linford Wood East, Milton Keynes MK14 6LF. Tel: 0908 676655.

Power transistor modules

Separate driver stages in a.c. and d.c. motor controllers, power supplies, converters and other industrial equipment are not needed with the new range of power transistor modules from Mitsubishi Semiconductors.

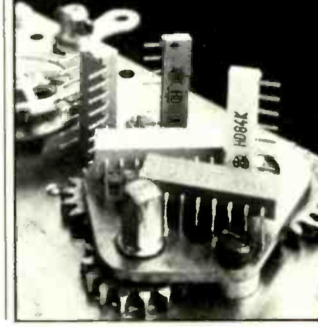
These high-gain versions of the QM series consist of six pack configurations for three-phase bridges as well as dual driver stages. Voltage ratings are 600 or 1000V, and current ratings range from 10 to 200A. Mitsubishi Semiconductors, Mitsubishi Electric UK Ltd, Electronics Division, Travellers Lane, Hatfield, Herts AL10 8XB. Tel: 07072 76100.

Diode arrays reduce assembly time

Where large numbers of diodes need incorporating on densely packed p.c.bs, assembly time can be reduced using Iskra's sil or dil diode arrays.

The dual in-line arrays are housed in standard 16-pin plastic packages sealed in flame-retardant epoxy resin. Each pack contains eight independent 1N4148 epitaxial signal diodes or the BZY 88 range of diffused junction zeners.

Single in-line networks consist of either common-anode or common-cathode 1N4000 series diode chips which are bonded on to a ceramic substrate. The lead-outs are on a standard 0.1in pitch for compatibility. Iskra Ltd, Redlands, Coulsdon, Surrey CR3 2HT. Tel. 01-668 7141.



NEW PRODUCTS

Multicore cable analyser

The latest industry requirements for testing cables up to 1000V d.c. are met in the upgraded multicore cable analyser available from Cable Check Systems.

The analyser can be used for a complete serviceability test on multicore cables on or off site. Results are displayed digitally, along with core numbers for easy identification. A hard copy of fault locations and test acceptance levels can be obtained using the integral printer. Cable Check Systems, 18 Quay Lane, Gosport, Hampshire PO12 4LJ. Tel: 0705 528396.

Digital wattmeter

A high resolution digital wattmeter manufactured by Infratek is suited to the measurement and analysis of distorted waveforms.

The single phase 103A available from Lyons Instruments features a wide frequency range from d.c. to 100kHz, voltage ranges to 1000V and current to 50A without external accessories. Power ranges are from 9mW to 50kW and the unit has a six-digit display with a basic accuracy of 0.3%. Lyons Instruments Ltd, Hoddesdon, Herts. Tel: 0992 467161.

Power supply units

The first of a series of compact, o.e.m. power supply units capable of delivering up to 1500W d.c. output has been introduced by Weir Electronics.

The series, based on an advanced switched-mode regulator, is to include single output and multiple output configurations to meet industry requirements. All models are housed in a metal enclosure measuring 279×203×127mm with an integral cooling fan.

Now available is the SMM 1500 00 00 which has five output rails. The combined load rating is 500W but if higher power levels are required the units can be connected in parallel to provide outputs as high as 3kW. Weir Electronics Ltd, Durban Road, Bognor Regis, Sussex PO22 9RW. Tel: 0243 865991.

Real-time video digitization

The IBM PC is turned into an image processing workstation using a hardware and software package called PCVisionplus Frame Grabber.

The package from Amplicon Electronics is composed of four major sections: video source interface; frame memory; display logic and host computer interface. It occupies only a single expansion slot in the PC and features an eight bit a-to-d for 256 grey levels/pixel; advanced phase-lock for stable synchronization with v.c.rs; programmable gain and offset and a 1024×512×8 bit frame memory stores multiple images. Amplicon Electronics Ltd, Richmond Road, Brighton, East Sussex BN2 3RL. Tel: 0273 608331.

Probe identifies metals

Identification of the carbon content in ferromagnetic steels, the chromium content in stainless steels, the alloying elements in carbide tool alloys and the amount of retained austenite in austempered ductile iron can be carried out simply using the Metal Analyser available form Kontron Electronics.

The analyser's probe is placed against the material under investigation and the metallurgical characteristics are identified by sensing the electrical effects produced in the probe. Changes of inductance and the inductance-to-resistance ratio of the sensing coil are all measured. Kontron Electronics Ltd, Blackmoor Lane, Croxley Centre, Watford, Herts WD1 8XQ. Tel: 0923 45991.

Four-channel oscilloscope

The simultaneous observation of multiple signals is possible using the Grundig MO 100 four-channel 100MHz oscilloscope available from Instrumex.

The trigger level position on the screen is shown by a cursor and can be selected to trigger from a specific point. An automatic time-range switch selects the appropriate time base for the signal to be measured. A seven segment led digitally displays the time range. The conventional stepping switch for setting the time sweep is replaced by a potentiometer. Instrumex Ltd, Dorcan House, Meadfield Road, Langley, Berkshire SL3 8AL. Tel: 0753 44878.

Electronic key for security

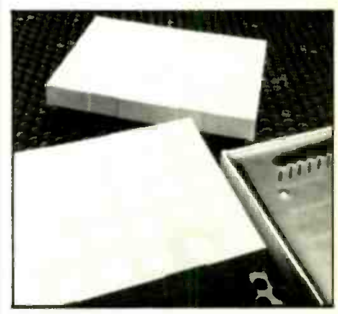
An electronic key has been designed by Dallas Semiconductor as part of a range of miniature security systems for software and other data.

Constructed to be carried around in the pocket, the device stores 64 bits of user-definable identification code and a 64 bit security match code which protects 128 bits of read/write non-volatile memory. The identification and security match codes are programmed into the key after which it follows a special procedure with a serial format to retrieve or update data. Dialogue Distribution Ltd, Wicat House, 403

Stacking dot matrix display

A two colour 101mm dot matrix display element designed for easy p.c.b. mounting is stackable both vertically and horizontally to form large alphanumeric displays.

The LTP-4357AA 5×7 dot single-plane device is intended for applications such as computer-controlled message boards. It



incorporates green gallium phosphide and orange gallium arsenide phosphate elements on a transparent substrate. The elements have individual pins for each colour, producing 28 pins on the rear face of the package. The light output ensures that either colour is visible in normal artificial lighting conditions. Selectronic Ltd, The Old Stables, 46 Market Square, Whitney, Oxon OX8 6AL. Tel: 0993 73888.

Flat electrolytic capacitors

Half-size versions of the Petchacon range of thin electrolytic capacitors have been introduced by ECC Electronics. The 7mm thick devices are suited to applications where height is restricted. They are available with capacitances ranging from 180 to 15 000μF ECC Electronics (UK) Ltd, 9 Blenheim Road, High Wycombe, Bucks HP12 3RT. Tel: 0494 450716.

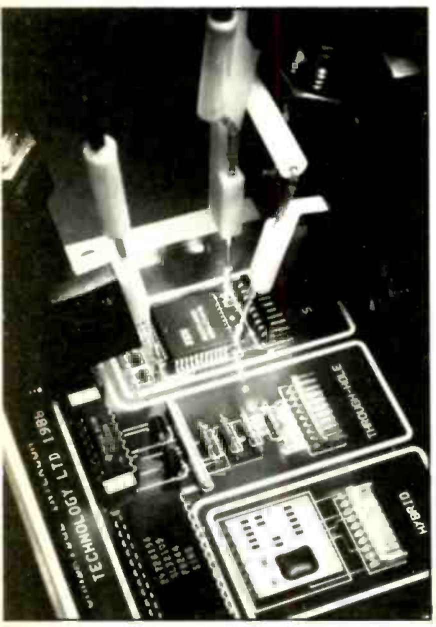
NEW PRODUCTS

Fixtureless test system

An in-circuit test system called the Takaya APT-2200N uses three moving probes and functions as an impedance signature analyser to perform tests on a loaded board.

Contax supplies the fine-tipped probes for contact spacings down to 0.1mm, so the latest surface mount and hybrid devices can be tested on a non-fixed test bed. Also the probes have a height clearance of 15mm allowing either side of a loaded board to be probed.

Board sizes up to 400×350mm can be handled and each test takes about 0.5s, making the system suitable for low volume production. Using bar coding techniques, test programs are called off disc or from another computer station as each board arrives at the test station. Contax, 362 Spring Road, Sholing, Southampton SO2 7PB. Tel: 0703 434141.



Improved reception for shortwave listeners

Listeners will appreciate the improved quality of the reception of the BBC World Service using the Liniplex F2 receiver.

This receiver system, available from Phase Track, is based on receivers supplied for off air broadcast relays to BFBS in the Falklands, Belize, Gibraltar, Cyprus, Hong Kong and Nepal. Now a synthesizer covering 2-22MHz is offered in addition to the standard eight preset frequencies, which are chosen according to the user's location.

A linear phase-locked fully automatic synchronous demodulator reduces the effects of fading and interference. Total frequency range available is from 0.15 to 26.1MHz. Phase Track Ltd, 16 Britten Road, The Robert Cort Industrial Estate, (Elgar Road), Reading RG2 0AU. Tel: 0734 752666.

Television and video testing

Trouble-shooting and testing of television, monitors and video equipment are easily carried out using the Philips PM5514 and PM5514V colour pattern generators.

The MP5514 is intended for monochrome and colour television testing and the PM5514V with CVBS and RGB outputs meets the requirement of the video equipment and computer monitor markets.

Available from Instrumex, both offer a choice of over 70 colour patterns and combinations which are selected using push-buttons on the display panel. Sound modulation is also provided, with a choice of internal and external modulation modes and a switchable carrier signal. Instrumex (UK), Dorcan House, Meadfield Road, Langley, Berks SL3 8AL. Tel: 0753 44878.

Modular logic analyser has 112 channels

A multi-level conditional trigger-trace sequencer controls the 112 channels of timing and state analysis on the Thandar TA3000 modular logic analyser.

Complex acquisitions can be set up rapidly using the soft-key guided menus and displays. Instrumex supply the analyser which has a general purpose computer with a CP/M Plus operating system, 1.4Mbyte of storage on dual floppy disc drives, qwerty keyboard and full IEEE-488, RS232 and Centronics communications capability as standard. Instrument Rentals (UK) Ltd, Dorcan House, Meadfield Road, Langley, Berks SL3 8AL.

Input switches for p.c.b. mounting

A range of input switches designed for mounting on to p.c.bs is available from Highland Electronics.

The polyester switches can be illuminated with a choice of coloured leds, 3mm in diameter. Key caps are available in ten colours and have either a pulse or latching function: they are pushed on to the switch as a module. There is a single break, self-cleaning, snap-action switching element and the contacts are gold plated to give a mechanical life of 5×10^6 operations. Highland Electronics Ltd, Albert Drive, Burgess Hill, West Sussex RH15 9TN. Tel: 04446 45021.

One GAL replaces 21 pals

Twenty-one different 20-pin pal devices can be replaced by one of Thomson Microelectronics 16V8 series of Generic Array Logic devices supplied by ITT Multicomponents.

The series uses a floating gate concept which means the user can electrically erase and reprogram the devices several times. Other features of the 16V8 include an active supply current of 90mA (compared with 180mA for pals); an i/o propagation delay time of 15-20ns and a 5V operating voltage.

The GALs have logic copying and bulk erase facilities and a 64 bit register which can be programmed to contain user defined data. They use ABEL and CUPL compilers both of which run on the IBM PC and compatibles. The series is available in dual in-line plastic packages. ITT MULTIcomponents Ltd, 346 Edinburgh Avenue, Slough, Berks SL1 4TU. Tel: 0753 824131.

Two-wire pressure transmitter

Excitation voltage and current output are transmitted over the same pair of wires in the model BL flush diaphragm pressure transmitter.

Control Transducers offers the unit in various pressure ranges from 0.35 to 1400 bar. Overload is two times rated pressure without damage and five times without bursting. Excluding the connector, the unit measures 24×98mm and is suitable for applications where ease of cleaning and sterilization are important, such as film processing and the food and drink industry. Control Transducers, North Lodge, 25 Kimbolton Road, Bedford MK40 2NY. Tel: 0234 217704.

COUNTERS & OSCILLATORS

COUNTERS MET100/600/1000/1500
8 digit 0.5" LED. 5Hz up to 100/600/1000/1500MHz. Resolves 0.1Hz. Sensitivity 5mV up to 10MHz. Low pass filter. Mains/rechargeable battery powered.

LEVELL RC OSCILLATORS TG152D/DM
3Hz-300kHz. 5 ranges, acc 2% + 0.1Hz up to 100kHz, 3% at 300kHz. Sine or square <200μV to 2.5Vrms. Distn. <0.2% 50Hz-50kHz. **TG152DM** has an output meter.

LEVELL RC OSCILLATORS TG200D/DMP
1Hz-1MHz. 12 ranges, acc 1.5% + 0.01Hz to 100kHz, 2% at 1MHz. Sine or square outputs <200μV-7Vrms. Distortion <0.05% 50Hz-15kHz. Sync output >1V. **TG200DMP** has output meter and fine frequency control.

LEVELL FUNCTION GENERATORS TG302/3
0.02Hz-2MHz in 7 ranges. Sine, square, triangle, pulse and ramp 20mV to 20Vpp from 50Ω. DC offset 0/±10V. TTL output. **TG303** also has a CMOS output and 6 digit 10MHz counter with INT/EXT switch.

TEST METERS

LEVELL AC MICROVOLTMETER TM3B
16 ranges 15μVfs/500Vfs, accuracy 1% + 1%fs + 1μV. −20dB/+6dB scale. ±3dB 1Hz-3MHz. 150mVfs output.

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HC5040T	£32
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16 LF ranges as TM3B + 8 HF ranges 1mVfs/3Vfs, accuracy 4% + 1%fs at 30MHz. ±3dB 300kHz-400MHz.

HC DIGITAL MULTIMETERS HC5040/5040T
3½ digit 12.7mm LCD. Up to 1kVdc, 750Vac, 10A, 20MΩ. Resolution 100μV, 100nA, 10mΩ (**5040T**: 100mΩ). Buzzer. dcV 0.25%. Battery life 2000hrs. **5040T**: has a TR test.

HC DIGITAL MULTIMETER HC4510
4½ digit 11mm LCD. Up to 1kVdc, 750Vac, 10A, 20MΩ. Resoln. 10μV, 100nA, 10mΩ. Buzzer. dcV 0.05%.

LEVELL DIGITAL CAPACITANCE METER 7705
0.1pF-2000μF, acc 0.5%. 3½ digit 12.7mm LCD.

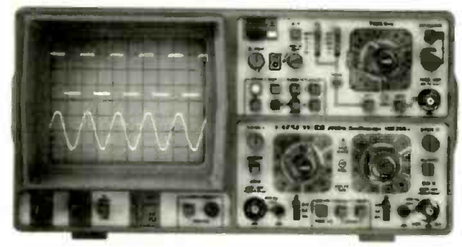
LEVELL INSULATION TESTER TM14
Log scale covers 6 decades 10MΩ-10TΩ at 250V, 500V, 750V, 1kV; 1M-1TΩ at 25V-100V; 100k-100GΩ at 2.5V-10V; 10k-10GΩ at 1V. Current 100pA-100μA.

OSCILLOSCOPES

CROTECH SINGLE TRACE 20MHz 3031/36
2mV-10V/div. 40ns-0.2s/div. Cal 0.2V. Component test. **3031**: CRT 1.5kV 5x7cm. **3036**: CRT 1.8kV 8x10cm.

HAMEG DUAL TRACE 20MHz (@2mV) HM203-6
2mV-20V/cm. Ch2±Ch1. X-Y. Cal 0.2V/2V 1kHz sq. 20ns-0.2s/cm. Auto, normal or TV trig. Component test.

HAMEG DIGITAL STORAGE 20MHz HM205-2
2mV-20V/cm. Ch1±Ch2. Single shot and X-Y modes. 20ns-0.2s/cm. Auto, normal or TV trig. Component test. Cal 0.2V/2V 1kHz. 5MHz sampling. Two 1K memories. Dot Joining feature. Y out. CRT 2kV 8x10cm.



HITACHI DUAL 20MHz V212/222/223
1mV-12V/cm. 20MHz at 5mV. Ch1±Ch2. X-Y. Ch1 output. 100ns-0.5s/cm. Auto, normal or TV trigger. Cal 0.5V 1kHz square. Z input. CRT 2kV 8x10cm.
V222: Plus DC offset and alternate magnify function.
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Racal RA17L Communications Receivers. 500KC/S to 30MC/S in 30 bands 1MC/S wide from £175. All receivers are air tested and calibrated in our workshop supplied with dust cover operation instructions circuit in fair used condition – **Racal Ancillary Units** for all receivers mostly always in stock – **Don 10 Telephone Cable** ½ mile canvas containers or wooden drum new from £20 – **Army Whip Aerials** screw type F sections and bases large qty available now P.O.R. – **Test Equipment** we hold a large stock of modern and old equipment. **RF and AF Signal Generators** – **Spectrum Analysers** – **Counters** – **Power Supplies** – **Oscilloscopes** – **Chart Recorders** all speeds single to multipen – **XY Plotters A4 A3** – **Racal Modern Encryption Equipment** – **Racal Modern Morse Readers and Senders** – **Clark Air Operated Heavy Duty Masts P.O.R.** All items are bought direct from H M Government being surplus equipment price is ex-works. S.A.E. for enquiries. Phone for appointment for demonstration of any items, also availability or price change V.A.T. and carriage extra.

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NEW PRODUCTS

Desk-top flatbed plotter

A high level of accuracy in photo-plotting is brought to PC CAD users by the compact Flashscan flatbed plotter.

Measuring only 16 by 20in, it is made in Switzerland by Patek Philippe and marketed in the UK by Kontron Electronics. It uses a firmware-controlled variable-aperture system which projects images onto a film. These images create pads from 0.12 to 2.54mm with 135 steps in between. The pads are used to create lines of any width as well as user-defined graphic symbols. Kontron Electronics Ltd, Blackmoor Lane, Croxley Centre, Watford, Herts WD1 8XQ. Tel: 0923 45991.

Compact mosfet modules

International Rectifier's new CPX200 series 250 and 500V H-bridge modules replace four TO-220 devices with a single in-line nine-pin moulded package.

Designed for high-density p.c.b. applications including medium/high power supplies, u.p.s. systems, high voltage motor drive systems, and servo amplifiers the fully isolated package measures only 0.2in thick by 0.75in high. It can be mounted directly on to the chassis or heatsink. International Rectifier, Hurst Green, Oxted, Surrey RH8 9BB. Tel: 0883 713215.

Memory gets battery back-up

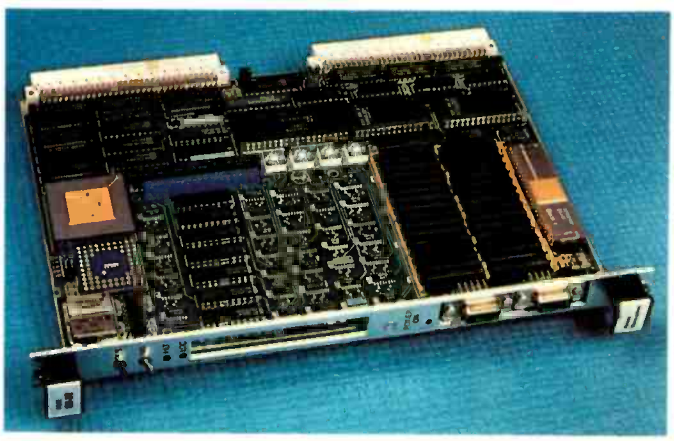
The memory in Instrumatic's ICD emulators can be protected by a battery back-up to overcome problems associated with memory volatility.

The incoming memory V_{CC} is monitored and if an out-of-tolerance condition occurs a lithium power source is automatically switched on and write protection is unconditionally enabled to prevent corruption of data. The battery back-up memory option supports standard ZAX memory of 128K or extended memory board of 512K. Instrumatic UK Ltd, First Avenue, Globe Park, Marlow, Bucks SL7 1YA. Tel: 06284 76741.

Compact instrumentation recorder

Up to 24 channels are available in the V-Store portable video cassette instrumentation recorder. Racal Recorders claims this instrument is the most compact recorder of its type.

Recording signals from all types of sensors with electrical output from d.c. to 100kHz, the unit is ideal for use in medical, military, automotive and general industrial research including vibration, noise and performance monitoring. The recorder is simple to operate, uses easily available VHS tapes and has a high-contrast electroluminescent display screen with associated soft keys. Racal Recorders Ltd, Hardley Industrial Estate, Hythe, Southampton, Hants SO4 6ZH. Tel: 0703 843265.



68030 computer

Existing systems can be updated with the Plessey Microsystems PME 68-32, a single-board computer which is optimized for disc-based, single and multimaster system architectures that run on Unix 5.3.

It is suited to real-time applications with multi-processor support. The board is based on the 68030 processor and gives about two to three times the performance of previous 68020-based products. Clock speed ranges from 16 to 33MHz. The system has a 4Mbyte dram which is dual ported, giving fast access from the processor and VMEbus. The memory is able to support the cache burst fill of the 68030 processor, giving up to a 15% improvement over cards not having it. Hi-Tek Electronics, Ditton Walk, Cambridge CB5 8QD. Tel: 0223 213333.

Sustained performance at 20mips

A continuous operating rate of 20mips with a 25MHz clock rate is offered by the LR3000, LSI Logic's latest 32 bit hc-mos risc microprocessor chip set.

The chip set consists of the LR3000 c.p.u., LR3010 floating point accelerator, and LR3020 write buffer. The c.p.u. includes a high-speed arithmetic unit and co-processor interface. It contains a 64 entry translation look-aside buffer, support 512Kbytes of cache memory which only requires medium performance s.rams. Binary compatibility with existing R2000 software is maintained. LSI Logic Ltd, Grenville Place, The Ring, Bracknell, Berks RG12 1BP. Tel: 0344 426544.

Fast i.c. design

Engineers can specify i.c. designs in an easy-to-use high-level language, simplifying the design process and reducing the chance for error with VLSI Technology's enhanced state-machine compiler.

This version offers the user fast compilation, automatic state assignment, readable output information, and an improved system of control over fan-out that prevents signals from being overloaded. The company claims that in less than a day a designer can enter a complex design by simply writing a few dozen lines of instructions at an engineering workstation. Using traditional design methods, the same design would have taken weeks of development. VLSI Technology Ltd, 486/488 Midsummer Boulevard, Saxon Gate West, Central Milton Keynes MK9 2EQ. Tel: 0908 667595.

Plug-in terminal blocks

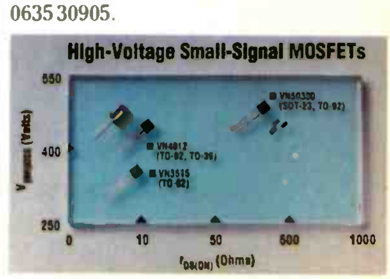
Modular terminal blocks that can be built up to any number of terminations have been introduced by IMO Electronics.

The 20.900 Series has two- and three-way modules in horizontal and vertical plug-in units for attachment to on-board soldered pin connectors. To prevent incorrect connection without losing a pole a tiny key is inserted into the block. This avoids the need for blank terminals or end cheeks to achieve polarization. IMO Electronics Ltd, 1000 North Circular Road, Staples Corner, London NW2 7JP. Tel: 01 452 6444.

High-voltage mosfets

There are three new high-voltage n-channel mosfets specifically tailored with on-resistance ratings that support the requirements of test equipment and telecommunications.

Siliconix claims the VN50300, which is an ideal voltage-spike protector, is the first 500V device available in the SOT-23 surface-mount package. The other two devices are 400 and 350V models providing high-voltage, low on-resistance operation in systems using low-level power supplies or c-mos logic. Siliconix Ltd, 3 London Road, Newbury, Berks RG13 1JL. Tel: 0635 30905.



RESEARCH NOTES

Space-age vision aid

Researchers at NASA and at the Johns Hopkins Wilmer Eye Institute are to adapt a vision system designed originally for space robots to restore sight to the almost-blind. It's essentially a portable closed-circuit television system that will produce bright pictures directly in front of the eyes via what looks like wrap-round sunglasses. Instead of lenses, the sections covering the eyes will actually be small flat tv screens that the person will look *at* rather than look through.

What's even more ingenious than the display system is the camera system to pick up images of the outside world. Obviously no normal person would want to walk around with a standard tv camera mounted on a hat, and so a method had to be devised of disguising this inevitably bulky item. The answer researchers have come up with is to use tiny lenses and bundles of optical fibres embedded in each side of the spectacle frame where the front and ear pieces join. Light is then conveyed along the fibres to a c.c.d. camera in a pack worn on the hip or shoulder.

NASA's existing black-and-white version designed for remote handling applications in space will form the basis of the new vision aid. But before it can be of practical use for handicapped people on Earth the system will have to be converted to full colour and also made capable of a degree of video processing.

The team emphasizes that the portable vision aid is not intended to restore totally lost vision nor to correct the many optical defects that are more-or-less adequately dealt with by spectacles. The main function is to provide an increase in sensitivity for those who are almost blind. It's therefore a sort of picture amplifier.

Dr Robert Masoff, a researcher at the Johns Hopkins Wilmer Eye Institute says the new device should be able to help an estimated 2.5 million people in the USA alone. It won't however, only help those who have low visual sensitivity. Because of the video processing capability, it will be possible to enhance contrast or to accentuate edge effects or even introduce false colour to help those with specific forms of colour blindness.

The whole project, lasting five years and costing £11 million should, say its developers, lead to a practical device that is affordable by elderly people on fixed incomes. In more concrete terms they talk in terms of the cost of two colour television sets.

Memories that last for ever?

New memory chips being developed by various US companies could largely supersede eproms. That's the view of some experts watching the emergence of experimental memories based on the ferroelectric effect. This is a property whereby certain crystalline materials such as lead zirconate titanate become polarized when subject to an externally-applied field. This polarization is non-volatile, but can be reversed by the application of a field of opposite polarity. In practice, ferroelectric materials behave rather like bistable capacitors with zero leakage. The only problems in developing a practical application for such seemingly ideal materials has been the slow 'write' speed and the rather indefinite polarization threshold.

Research into new and as-yet secret materials is now coming up with some highly promising prototype rams offering high read/write speeds and non-volatility. Raintron Corporation, one of the companies concerned, predicts that data stored in some of its chips will remain uncorrupted for 100 years or more.

As well as developing new materials, one of the important goals of research into ferroelectric rams has involved finding ways of integrating such materials into the memory circuits of existing technology. Here different researchers adopt different approaches, some favouring direct substitution of conventional capacitor elements, others use the ferroelectric material as a 'power-down' memory backup.

Either way, it looks as if it's just a matter of time before chips appear on the market that are much faster than today's eproms and which can tolerate many more write cycles before they wear out. It also appears that a ferroelectric memory is radiation-hard, which will give it instant applications in space as well as the nuclear industry and military projects.

Electronic speech therapy

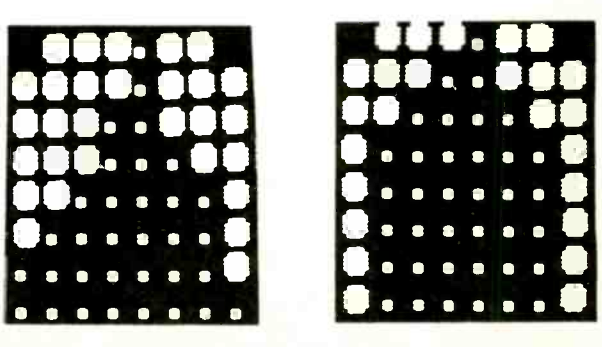
Significant advances in the use of a computer-based technique to aid speech therapy were described at the first National Symposium on the Clinical Applications of Electropalatography in Reading.

The symposium reviewed the work of 28 speech therapists and experimental phoneticians who use a technique called electropalatography (EPG), whereby an artifical palate with 62 electrodes is placed in the mouth and the contact of the tongue with the matrix of electrodes is recorded on a personal computer and displayed on the screen. The EPG system gives access to detailed and previously unobtainable information about tongue position on the roof of the mouth.

In speech therapy, a patient's abnormal pattern of tongue contact can be displayed alongside a model pattern which the therapist has produced using a separate EPG palate. This visual feedback therapy technique has been found to be particularly effective for children with developmental speech disorders, for those with cleft palate, and for stroke patients who have been left with speech problems.

An improved version of the EPG has resulted from progress made recently by a team comprising researchers from the IBM UK scientific centre in Winchester and from the department of linguistic science at Reading University.

Dr Bill Hardcastle, Reader in Linguistic Science at Reading University, told the symposium that advances in the EPG system mean that it is now a viable and proven technique for both therapy and speech research. EPG records have shown that individual speech sounds such as 't', 'k' and 's' have specific tongue contact patterns and that these patterns can change in predictable ways depending on a number of factors like how fast the person is speaking, and which sounds precede or follow, and so on. By comparing these patterns with those produced by a speaker with a speech disorder, the clinician is able to pin-point the nature of the errors more precisely than by using traditional procedures. The extra precision in diagnosis means that the clinician can now not only plan more efficient therapy but can also often gain valuable pointers as to the underlying cause of the disorder.



Wrong (left) and right: visual feedback from tongue and palate.

Computer biology?

Further evidence that today's sequential von Neumann computer architecture may be on the way out comes from the relatively recent re-emergence of interest in neural networks – attempts to model electronically the behaviour of neurons, or nerve cells in the brain. Part of the aim is to try and gain insight into how the human 'computer', based on an incredibly slow logic element, can outperform machines at so many complex tasks. In fact, the more complex the task, the greater the brain's advantage. Try getting a machine to recognize someone it hasn't seen for 20 years!

One of the fascinating aspects

RESEARCH NOTES

of neural networks is their unpredictability. Based as they usually are on thousands of interlinked processors, they aren't always susceptible to being analysed by conventional Boolean algebra. In fact neural networks – like their biological counterparts – are self-programmed to the extent that they can sometimes learn new and unsuspected tricks. All one has to do, it seems, is teach the machine by its own mistakes.

A recent example of this approach was an attempt by researchers at MIT and the University of California to build a neural network capable of imitating the brain's ability to locate objects in space. The network consisted of three layers of processors, one to accept input data, an uncommitted middle layer and an output layer to assemble the answers. Input data consisted of electronic analogues of eye position and visual field and, initially, the network was 'told' what it was looking at, i.e. what 'answer' to expect. After about 1000 trial runs, the network had 'learned' to recognize and locate some remarkably complex shapes.

Another intriguing aspect of these neural networks is their theoretical basis.

As I mentioned earlier, they don't readily yield to conventional mathematical analysis. Their properties do, however, show striking similarities to those of the materials that comprise biological brains. And just as bulk properties of matter such as temperature or pressure can be deduced from molecular behaviour, the behaviour of neural networks can sometimes be deduced from the way the individual constituent processors interact.

If all this seems a flight of journalistic neuronal fancy, consider one of the more advanced developments in the USA, a 'biological' computer at Carnegie-Mellon University. Not only does it outperform sequential processors at a variety of tasks, its behaviour can to some extent be predicted by the principles of thermodynamics! Tomorrow's programmers, it seems, will have to forget all they ever learned of high-level languages and take a few lessons in biophysics.

Enter the electronic dentist

An unexpected and unwelcome visit to the dentist recently prompted me to take a closer look at what seemed at first sight to be an excellent d.i.y. method of spotting rotten teeth.

Studies at three U.K. dental colleges (*Br. Dent. J.* vol 164 No 8) have shown that simple resistance measurements can spot early caries in 85% of cases.

Research over 30 years ago showed that, when dried with a blast of air, a sound tooth exhibits a tip-to-gum resistance of greater than 600kΩ. Under similar conditions, a tooth with pits or fissures is likely to read less than 250kΩ. But because lots of well-established methods of spotting dental caries already exist, the plug-in approach has never really caught on.

There is, moreover, a real problem with it: electronic testers have often given low readings on teeth that appear perfectly sound. In fact three out of every four teeth fall into this category. A dentist can't just start drilling and filling every tooth that appears normal but measures less than 250kΩ.

What this latest study did was to apply the technique prospectively to patients due to have apparently sound teeth extracted for cosmetic reasons. Fifty teeth were measured *in vivo* and also inspected in the normal way. After extraction the same teeth were sliced up and subject to detailed microscopic examination.

Result? Six were bad according to the dentists, 28 according to the electronics and 37 in actual fact. The electronic technique therefore appears much more likely to spot early decay than standard dental techniques. It also generates relatively few false positives. But as the authors point out, this doesn't mean dentists are doing a bad job. Not many of the electronically identified cases of decay would yet be ready for filling. Nevertheless the now-validated technique offers great potential for catching early decay and treating it in other ways. But before you start trying to eat a set of Avo probes, I should point out that for accurate results the probe needs to be provided with a coaxial blast of dry air – a bit like a miniature MIG welder. Without that essential item the results are likely to send you rushing off prematurely to the nearest false teeth suppliers!

Smashing space particles

Physicists at the Los Alamos National Laboratory have used a Van de Graaff generator to accelerate particles of iron 10^{-6}m in diameter up to velocities of 10^5m/s, a hundred times faster than a high-velocity bullet. The idea is to simulate what happens when a spacecraft is hit by showers of micrometeorites.

When we think of collision damage, most of us think more naturally of cars, aeroplanes or perhaps missiles. But out in space these macro-scale collisions aren't always the best models, nor are they necessarily a good basis from which to extrapolate. Free from atmospheric drag, space dust can reach truly enormous velocities, accelerated by the gravitational and electrical fields of the solar system.

Any O-level physics student knows that, in terms of damage caused, the size and velocity of a projectile are in no way equivalent. If you double the size of a colliding particle then it has double the inertia and causes roughly double the damage. On the other hand if you double the velocity of a given object it has the potential to inflict four times the damage. So even a particle the size of fine smoke can be lethal if it's travelling fast enough.

But in devising their latest experiments to accelerate smoke-sized particles of iron, the Los Alamos team were well aware that you can't just use O-level equations to extrapolate to the conditions found in space. A one-micron-sized particle travelling at 10^8m/s will, for example, vaporize a target up to 1000 times its own weight. So it's scarcely just an extension of what happens every day on the M25!

By observing exactly what does happen under these extreme conditions, the physicists hope to develop mathematical models to predict in detail the processes of melting and vaporization that take place. Prior to the construction of their 140 ton Van de Graaff machine, which has an energy level of 8MeV, the basic data was simply not available.

Although there is obviously a military interest in how to 'harden' spacecraft against the effects of natural micrometeorites, this latest work is definitely not the beginning of a new type of beam weapon. Particles travelling at 10^5m/s can survive only in the vacuum of space. And as far as the prospect of putting a particle accelerator in orbit, the Los Alamos team question the desirability of launching a 140 ton gun that fires nothing but a puff of smoke!

Bog standard

In this enlightened age of sexual equality there are some things that obstinately refuse to be equalized. A statistical survey undertaken by the Engineering Department at Cornell University has revealed an important discrepancy between the relative time men and women spend in their respective 'rest rooms'. Researcher Anh Tran, who lurked for hours with a stopwatch outside motorway loos in Washington State, says that men, on average, take 45 seconds (standard deviation 3.73) to use the facilities while women take 79s (s.d. 4.47). A university spokesman described this as 'significant'.

Tran has developed a simple computer program to make it easier for architects and designers to calculate the most appropriate ratio of male and female excretory facilities in any given area. The program runs on an Apple Macintosh and needs to be supplied with only the bare minimum of data.

One immediate conclusion is the need, in most situations, to alter the generally-accepted 50:50 ratio to something nearer 60:40 in favour of the ladies. Roll on the paperless office.

Research Notes is written by John Wilson of the BBC External Services science unit at Bush House, London.

TELEVISION BROADCAST

A licence to lose money?

Among all the media hype surrounding d.b.s. from Astra and the BSB satellite, it is easy to forget the extent to which, only a few years ago, we were all being similarly persuaded of the wonders and imminent coming of the wired city with its wideband interactive electronic grid. There were endless articles and programmes about Warner's QUBE system. Far fewer marked its demise after a few years when Warner found they could not provide enough popular programming, while subscribers found the control pad too complex and did not take kindly to the pay-per-view concept rather than the monthly subscription basis of most American cable networks. Furthermore the scrambling-descrambling system degraded the picture quality to a noticeable degree.

Similarly, the INDAX system run by Cox Cable in San Diego, offering banking, shopping and pay-per-view facilities, was unable to convince many viewers that its programmes justified the expensive converter boxes.

Nevertheless, less ambitious forms of interactive cable are again expanding in the USA, most of the "return" paths using the normal telephone network or working on a store-and-forward basis rather than instantaneous service. Some 16 million homes were connected to such systems at the beginning of the year, but the full potential of the electronic grid seems as far away as ever. Even the efforts of American cable companies to provide data links for urban business users have so far failed to produce the predicted revenues.

The success of any television channel or video system depends in the long term on providing programmes capable of attracting and satisfying large numbers of viewers as well as being relatively cheap and easy to use. Provided that it is easy to operate, technology appears to play only a minor role. The Government's suggestion (since withdrawn) of changing BBC2 and Channel Four Television into satellite subscription services, while filling terrestrial channels flew deregulated, competing advertisement and sponsor funded channels flew in the face of American experience — and was a sure way to lower the quality of British television. More choice does not necessarily mean worse "free" programmes — but I would not bet on that!

The efforts over the past decade of Australian and Australian-born media moguls to move into UK commercial broadcasting have been paralleled by their efforts to provide services in the Pacific islands. The Niugini Television Network in Papua, New Guinea, set up by the Parry Corporation at a cost of $A 9M closed down after four months as a non-viable operation. The Packer Group, taken over by Alan Bond, won the right to set up a service in Fiji in the face of stiff competition. This was due to start late last year but was cancelled following the military coup on the island. Now TV New Zealand is anxious to establish a Pacific regional service centred on Fiji, but finds that the Bond Group retains exclusive rights for twelve years.

US mast tragedy

Failures of very high television masts are fortunately rare in Europe and when they have occurred have usually not resulted in casualties. The American experience seems less happy.

Early in June a tragic accident brought down the new 610 metre triangular lattice mast of KTVO, Kirksville, north-east Missouri, resulting in the death of three erectors who were fitting new bracing rods at a height of 146m.

The £1.1M mast, one of a number of American television masts reaching the maximum height permitted by the FCC, was comparatively lightly loaded. It carried two circularly-polarized antennas for the 100kW transmitters, some microwave dishes and an f.m. radio antenna. It served viewers in parts of Missouri, Illinois and Iowa. Services were restored on the earlier, lower mast which had not yet been dismantled.

Soon after the new mast was commissioned in September 1987, cracks were found in two bracing rods. After further cracks were detected, the decision was taken to replace all 1130 rods. It was during this work that a sudden slippage of the chain winch used to provide temporary bracing caused the mast to twist and begin to collapse. Two of the riggers were crushed beneath the top 464m section of mast as it fell to the ground, becoming embedded to a depth of up to 5m. The third man jumped to his death from the work-basket.

A detailed report in *New Civil Engineer* (June 9) by Simon Montagu notes that "the frequent collapse of US masts during maintenance or because of icing has in the past failed to raise the self-governing association EIA to action". He forecasts that lessons from the collapse of the KTVO mast seem unlikely to be passed on to the US engineering fraternity.

Four-bit digital audio

With linear p.c.m. coding, 14 bits with 32kHz sampling of a 15kHz audio channel results in a bit-rate of 448kbit/s. With d.p.c.m. coding this reduces to 256kbit/s. Delta modulation with adaptive pre-emphasis brings the rate down to 203kbit/s. In practice the CD stereo data rate is about 1.4Mb/s. Nicam companding to 10 bits provides a stereo bit-rate of 728kbit/s. As noted in the February "Radio Broadcast" column, the Thomson Group has developed in Germany a form of adaptive transform coding providing a stereo data rate of 256kbit/s.

S.M.F. Smyth and J.V. McCanny of Queen's University, Belfast are making strong claims (*Electronics Letters*, 14 April, 493-5) for four-bit a.d.p.c.m. coding to give a bit rate of 128kbit/s for a 15kHz channel directly applicable to the European ISDN telecommunications hierarchy. They claim the results they have achieved are of major importance not only for ISDN and broadcasting, but also for other digital audio technology including CD records and digital audio tape.

Their coder consists of a two-band quadrature mirror filter bank incorporating backward adaptive prediction and quantization in each sub-band. The audio signals are sampled at 32kHz and each 16-bit sample is filtered into two frequency bands, coded to four bits for transmission. Work is also in progress to implement this music coder in real time. It has already been shown that a full duplex implementation is possible on a single 100 nanosecond fixed-point d.s.p.

The authors claim that their results clearly demonstrate the very high coding efficiency of sub-band a.d.p.c.m. when compared with digitally companded and a.d.m. schemes applied to high-fidelity music. They write: "We believe these findings are very significant and represent a major advance in digital audio technology, having immediate implications for ISDN, broadcasting and d.b.s. digital audio distribution ... In addition a.d.p.c.m. is known to offer bit error immunity down to 1 in 10^3 without any form of protection or concealment, four or five orders of magnitude better than most p.c.m.-based systems ... we seriously question the continuing viability of p.c.m. as a reliable and economic means of storing or transmitting high-quality digital audio".

The *Electronics Letters* report includes details of subjective listening tests which appear to show that music recovered from the four-bit coding is essentially indistinguishable from the original material. It would be interesting to see independent tests carried out, preferably based on the EBU test record (see "Radio Broadcast", page 936) on both the Thomson 256kbit/s stereo system and this latest contender. While the lower bit rates would be attractive for audio contribution and distribution networks, one wonders what the reaction would be to any suggestion at this late stage of changing existing standards for d.b.s. or terrestrial broadcasting! Already the Nicam 728 system is under threat from Rupert Murdoch's PAL plans for his Astra channels.

Television Broadcast is written by Pat Hawker.

RADIO COMMUNICATIONS

Coping with e.m.c.?

An open day at the DTI's Kenley Radio Technology Laboratories near Whyteleafe, Surrey, revealed measurement facilities capable of providing accurate type-approval checks and meeting all current and proposed e.m.c. radiation and immunity test needs. The facilities, now being offered on a commercial basis to industry for the pre-testing of equipment, are seen as an essential requirement when the European Community EMC Directive is finally approved. (The draft is still being revised and it now looks unlikely that the Council's common position can be reached until at least September.) UK legislation will also be necessary if certain British Standards are to become enforceable. While Kenley is ready, the DTI has been one of the principal objectors to some clauses of the draft Directive, arguing *inter alia* that it cannot be enforced on all apparatus in the absence of national standards.

Yet as one of the Kenley demonstrations showed clearly, home computers currently on the UK market are failing by a wide margin to meet the still unenforceable BS6527:1984 covering radiation from information technology equipment. A popular computer was shown producing 40dB(μV) radiation at 128MHz, 10dB above the BS6527 limit, measured under the specified conditions.

RTL's facilities, covering 9kHz to 22GHz, lean heavily on Hewlett Packard and Rohde & Schwarz spectrum analysers and measuring receivers. Chase Electronics assisted with a demonstration of V-network and clamp techniques for measurement of cable-conducted emissions, showing clearly the wide spectrum of emissions from a switch-mode power supply. Plessey Assessment Services collaborated in a demonstration of electrostatic discharge testing in accordance with BS5967 Pt 5. Fundamental and harmonic radiation from microwave ovens (potentially a source of interference to 12GHz d.b.s. reception) is measured in a reverberation chamber with rotating vane, although RTL is not responsible for investigating the possible health hazards that could arise from defective door seals in old ovens.

Immunity testing of television receivers and other appliances is carried out with a large t.e.m. cell; although with no v.h.f. television in the UK, it seems odd that this is suitable for a source only up to 150MHz. A large environmental test chamber is used for bulky equipment such as marine m.f./h.f. transmitters. Case radiation from transceivers can be measured down to a nanowatt to 4GHz by substitution methods using a large corner reflector to minimize the effects of wall reflections etc. Receiver oscillator radiation from mobile and c.b. transceivers can be checked over the range 100kHz to 2GHz to determine that this does not exceed 2nW below 1GHz (20nW above 1GHz).

Kenley is also the base for the new Radio Investigation Service mobile laboratory, covering 9kHz to 40GHz and fitted with two pneumatic masts, one of which can extend up to 28m. There is a quiet-running on-board 3.5kW generator. Used to back-up the RIS field teams, particularly for the investigation of industrial and radar interference, it surely represents good value at the standard RIS rate of £41 per engineer per hour.

Essentially, Kenley remains a precision measurement laboratory rather than an e.m.c. design advice centre. But what may be needed most by small electrical and electronic appliance makers, when finally the EMC Directive and new UK legislation come into force, will be expert advice at an early design stage. The open day left one wondering whether Kenley is yet set up to meet this requirement, which calls for e.m.c. design specialists rather than precision instruments.

DTI has recently introduced new type-approval testing procedures for land-mobile radio equipment. Type approval testing of MPT1300 series specifications can also be carried out by ERA Technology at Leatherhead; Plessey Technology Services at Fareham; and RFI Ltd at Basingstoke. DTI is introducing charges for all type approval testing at Kenley at rates subject to contract.

Superconducting dipoles

Theoretically, an electrically very short dipole antenna element could be as efficient as a resonant half-wave element. In practice, this cannot be achieved since there are always high r.f. ohmic losses in the element and matching network relative to the radiation resistance, which falls well below 1Ω for an electrically very short element. Clearly, a short element and associated matching lines without measurable r.f. ohmic resistance would greatly improve the efficiency.

A team at the University of Birmingham supported by ICI technologists has reported achieving a gain at 550MHz of 10.56dB (as against a comparable copper wire dipole) by using one of the new "rare earth" superconducting ceramics: (*Electronics Letters*, 14 April, 1988, 460-1).

At room temperature the radiation resistance of the test antenna was 0.26Ω and the loss resistance 3.5Ω. When the copper element was reduced to the temperature of liquid nitrogen, without of course superconducting, a gain of 6dB was achieved.

Rising above the waves

Although e.l.f. waves can penetrate to a considerable depth under the surface of the sea, they provide only a one-way radio link with submarines and then only at an extremely low data rate. For two-way communications, submarines still depend on raising an antenna above the waves. Yet, today, as A.J. Meaden points out in *PESL New Technology* (Spring 1988): "The strategic importance now assumed by nuclear-powered submarines, particularly of the ballistic missile-armed type, has placed them in a role where an individual vessel can have international impact undreamt of at the end of the second world war. It follows that the ability to communicate with these submarines at virtually any moment during the day or night is completely essential to their operation."

As the events surrounding the sinking of the *Belgrano* in 1982 showed, radio communication with submarines is still often only intermittently successful. A.J. Meaden notes that communication depends on either a buoyant antenna tower towed behind a deeply-submerged vessel, with problems of manoeuvrability and recovery, or with a mast-mounted antenna raised from the bridge-fin when the vessel is at periscope depth.

Plessey has developed a new integrated communications mast, MoD designation AJU, which is free-flooded and of glass-reinforced-plastics construction. Unlike earlier designs, it does not penetrate the hull and has a faired profile that overcomes lateral vibration due to shedding of Karmon vortices. It can carry m.f., h.f., v.h.f., u.h.f. and satellite navigation and satellite communication antennas. Two-band radar-absorbent material tuned to anticipated "enemy" frequencies has resulted from collaboration with Plessey Microwave Materials, Towcester. The u.h.f./D.-band antenna comprises a conical log spiral design at the top of the mast with a broadband dipole for line-of-sight, low-angle radiation along the axis of the cone. An h.f. whip antenna extends above the mast when required.

RSGB's 75th anniversary

By the time these notes appear, the 75th anniversary of the founding by four pre-first world war experimental amateurs of the Wireless Society of London (it became the Radio Society of Great Britain in November 1922) will have been duly celebrated by a series of events starting with a three-day convention at NEC in Birmingham, opened by the society's patron, Prince Philip, Duke of Edinburgh. This year, even the society's annual general meeting, until now always held in London, may depart the capital – perhaps a sign that the amateur radio movement, with its need to regain the interest of the younger generations, is finding it increasingly difficult to decide where its future lies.

Radio Communications is written by Pat Hawker.

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RADIO BROADCAST

A.m. stereo: what went wrong?

Robert Streeter, who developed the Magnavox medium-wave stereo system, has commented in *IEEE Spectrum* (June 1988) on the reports that a.m. stereo in the USA is in the doldrums, with little interest being shown by the vast majority of listeners ("Radio broadcast", July 1988). The Magnavox AM-OM system was initially selected by the FCC in 1980 as the American standard; but, following strong opposition from the other contenders, the ruling was withdrawn and in 1982 it was announced that the choice would be left to the marketplace.

Streeter writes: "If all interested parties had settled down to producing an a.m. stereo system in 1980, then a.m. broadcasting would have had a much better chance to be equal to f.m. stereo in the ears of the listening public before its fall to near oblivion."

He contends that none of the a.m. stereo systems authorized by the FCC in 1982 is flawless but that the same could be said of NTSC colour television or f.m. pilot-tone stereo — "Yet these other systems have served the consumer well and have made a great deal of money for manufacturers ... There are ways to hide the flaws in each of the a.m. stereo systems sufficiently to prevent the consumer from being annoyed."

The National AM Stereophonic Radio Committee was set up in 1975 charged with assessing possible systems. Ever since then the technology has been surrounded by controversy, with some proponents strongly criticising rival systems, often with legal action threatened or initiated. Of the four systems authorized by the FCC in 1982 — Magnavox AM-OM, Motorola C-QUAM, Harris V-CPM and Kahn/Hazeltine i.s.b. — only C-QUAM and i.s.b. remain in contention in an atmosphere of fading interest.

As the time approaches for the extension of the North American broadcast band from 1605 to 1700kHz, H. Dickson Norman, chairman of Global Radio Corporation (NDXE) of Opelika, Alabama, who for some years has been endeavouring to set up an international h.f. service with a.m.-stereo, has now proposed to the FCC that clear-channel frequencies in the extended m.f. band be allotted to his company for the establishment of a "super-power, a.m.-stereo, national direct broadcast service" covering continental USA, Alaska and Hawaii. Traditionally, the FCC has always limited transmitter ownership so that the main domestic radio networks are built around chains of "affiliate" stations. Power has been limited, even for the so-called "clear channels", to a maximum of 50kW. The ambitious Global plan calls for chains of synchronized transmitters at powers up to one megawatt. Programmes would be to a news and information format, funded by advertising. It remains to be seen whether FCC will respond favourably to Global's proposals for a first "national" channel.

EBU CD test record

For many years both SMPTE and EBU have produced sets of colour slides carefully selected to provide very critical tests of television systems. Such slides played an important role in the comparison of colour encoding techniques and later in devising the digital standards.

The EBU's *ad hoc* Group V3/SQAM has now produced a Compact Disc record containing 60 minutes of material for the subjective assessment of both analogue and digital audio systems. The 70 segments intended for use in accordance with the procedures detailed in CCIR Recommendation 562 comprise: alignment signals, artificial signals; 36 segments of single instruments; vocal segments with and without orchestral accompaniment; solo instruments with orchestra; orchestral and pop music segments.

The EBU committee believes that subjective listening tests are often essential when assessing high-quality audio systems and that the choice of test sequences profoundly affects the result. It contends that only if the same test sequences are used can different listening tests be compared meaningfully. The EBU record contains sequences selected to reveal a variety of defects. The recording was made directly in digital form using a Sony PCM1630 coder and VO5080 U-matic recorder.

CD life span?

It has been the claim of the recording industry that CD records not only provide near-immaculate sound quality but, having no physical contact with the laser, will last indefinitely without degradation. However, there have been rumours that a few optical discs have appeared to degrade rapidly, due to what has been called "laser rot" — a misleading term, since the problem seems to arise from exposure of the aluminium layer to the air as a result of defective application of the protective lacquer.

A more serious allegation was sprung on the public in *The Guardian* (June 29) suggesting that a significant proportion of existing discs can be expected to fail in eight to ten years time as a result of contamination of the lacquer by the ink used to print the "labels", leading to pin holes and consequent oxidation of the aluminium surface. Sony and Philips, who receive royalties on all CD records, insist that no problems are likely to arise with records made correctly to the agreed specification. While there is clearly the noise of commercial axes being ground within the industry, with Nimbus claiming that accelerated life-tests have indicated that there could be a problem, those who have built up a library of CD records must be counting the years with some anxiety.

Digital audio tape (DAT) may not be an answer since Rafail Sandu, chief engineer of the OIRT Technical Centre in Prague, recently wrote of digital audio: "Certain aspects require further study... It is still not known what causes partial signal dropouts in magnetic tapes used after a storage time of several months".

The French consultant engineer Marc Chauvierre, who has worked in television since 1930, has discussed the futuristic possibility of a sound and image recording system entirely free of electromagnetic elements (*IEEE Trans. on Consumer Electronics*, May 1988, 298-301). He dismisses the solution of electronic memory because of the difficulties of congestion of the memory, its connections to the reading device and the prohibitive costs of manufacture. His proposed solution adopts the principle of analogue modulation, after conversion to digital form, photographically recorded as a matrix on a square or rectangular film or transparency.

He recognizes that the practical implementation of such a system for more than a few seconds of audio signals depends on reducing the size of the picture element (pixel) from the fraction of a millimetre possible today to only a few microns. He comments: "This would seem utopian today, but tomorrow...?"

Solar radio set-back

Lack of help from specialized plastics firms, which are often associated with battery manufacturers, is blamed by UNESCO for the problems experienced in developing a low-cost radio receiver powered from the sun and suitable for manufacture and sale in Third World countries. The UK withdrew from UNESCO in 1985.

UNESCO has spent about $25 000 in developing the prototype of a simple receiver intended to be retailed at less than $20. AEG of West Germany, with a factory in China, has developed a suitable polycrystalline silicon solar array. Porsche agreed to design a special plastics cabinet for $5000 but UNESCO has been unable to find a specialist manufacturer willing to produce a production mould for the cabinet within its budget. The organization claims that Siemens was "not interested". Alcatel, the French multinational company which now owns ITT, Telefunken and Schaub Lorenz, did not respond. Thomson wanted $1 million.

In recent years UNESCO has pioneered solar-powered 10 watt v.h.f./f.m. transmitters for Kenya, Burundi, Sri Lanka, Togo and Ghana.

Radio Broadcast is written by Pat Hawker.

Broadband instrumentation amplifier

This design avoids the compromise between c.m.r.r. and bandwidth that characterizes conventional instrumentation amplifiers made from op-amps.

NANNO HERDER

Instrumentation amplifiers made from op-amps generally consist of an input-buffer pair followed by a differential amplifier stage. Fig.1.

It is rather difficult to realize a differential amplifier with a high rejection factor for common-mode signals combined with a wide frequency range, mainly due to the op-amp's non-symmetrical structure. Therefore, it is desirable to make use of an input-buffer pair which already has a high common-mode rejection ratio. However, a common-mode component always remains equal to that at the input $[(V_1+V_2)/2$, Fig.1]. So a high c.m.r.r. calls for a high differential gain of the buffer ($a \gg 1$), but with the drawback of a reduced bandwidth.

This common-mode component is greatly reduced in the new circuit of Fig.2. Op-amp IC_3 provides a large amount of feedback for common-mode signals in the buffer stage. In this way a high rejection factor can be obtained with low gain, maintaining a high bandwidth. Output of each of the two buffers consists primarily of the difference of the inputs; as a result the following differential amplifier is less critical.

Amplifier IC_3, whose non-inverting input can be considered as a virtual earth, forces the sum of the buffer-outputs to zero. It can be shown that with unequal R_3 resistors the common-mode component at the output of the buffers remains low, even in the extreme case that one R_3 is removed. However, the non-symmetrical structure of the circuit then leads to a reduced c.m.r.r. at higher frequencies.

Despite having more components, the circuit needs no extra adjustments for a good balance, and the two additional resistors, R_3, do not need very careful matching. Addition of IC_3 does not degrade noise performance nor does it increase offset errors. Care must be taken to guarantee the stability of the circuit.

Circuits have been built using NE5534 op-amps which have high output drive capability, low noise and high open-loop bandwidth. The latter feature is desirable for a good high-frequency common-mode rejection figure. In the practical circuit, IC_3 needed a stability capacitor (with $a=1$). With careful circuit-board lay-out and power-supply decoupling, a c.m.r.r. of 100dB at 100Hz and 80dB at 50kHz and a bandwidth of 1MHz is obtainable.

I recommend the use of low-valued resistors (<1kΩ) to reduce balance errors due to stray capacitances and to maintain a low noise level. The new buffer circuit can also be used as a precision balanced driver, e.g. for audio purposes. With one grounded input, two 180° out of phase signals can be obtained from the outputs of the buffers.

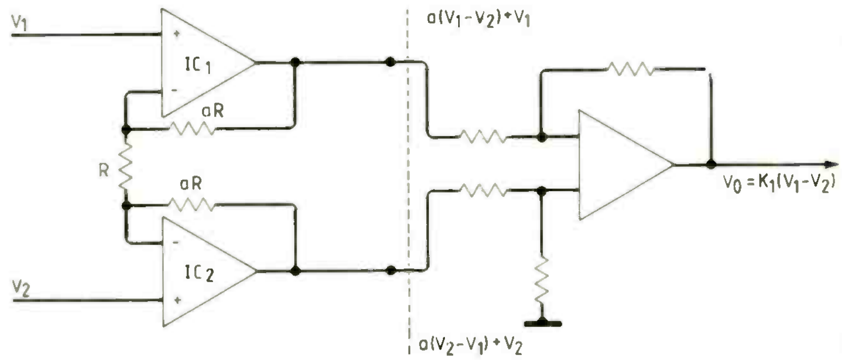

Fig.1. Conventional instrumentation amplifiers made from op-amps usually consist of an input buffer pair followed by a differential stage.

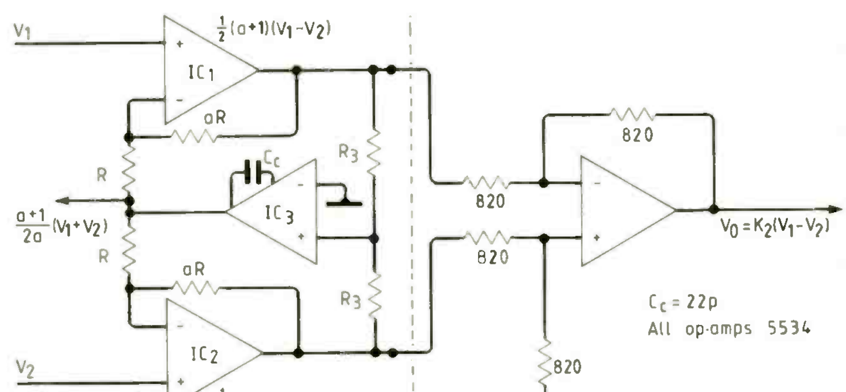

Fig.2. Adding an op-amp to the conventional instrumentation amplifier configuration provides a high common-mode rejection ratio over a wide frequency range. Output of IC_3 is proportional to the common-mode component at the input and can be used for an overrange indication.

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INDEX TO ADVERTISERS

Appointments Vacant Advertisements appear on pages 836-839

	PAGE
Aircastle Products	925
Airlink Transformers	870
Cambridge Kits	902
Cavendish Automation	931
Chemtronics UK	851
Colomor Electronics	925
Communique	925
Computer Appreciation	944
Dataman Designs	OBC
Display Electronics	935
Engineering solutions	873
European Electronic Systems	890
Field Electric	901
Gould Electronics	IFC
Hameg	890
Harrison Electronics	870
Hart Electronic Kits	931
Henrys Audio Electronics	895
Icom (UK) Limited	931
John's Radio	926
Kestrel Electronic Components	873
LJ Electronics	870
Langrex Supplies	895
Levell Electronics	926
Livingston Hire	896
M & B Radio (Leeds)	901
M A Instruments	902
M Q P Electronics	886
Number One Systems	902
Omega Dynamics	863
Private Mobile Rentals	899
R Henson	926
Ralfe Electronics	886
Raycom Communications Systems	896
Sherwood Data Systems	899
Slee Electro Products	899
Stewart of Reading	886
Strumech Engineering	896
Superkit Electronics Inc	895
Surrey Electronics	928
Taylor Bros. (Oldham)	842/IBC
Technomatic	938/939
Tektite	901
Thandar Electronics	851
Those Engineers	928
Thurlby Electronics	928
Webster Electronics	851

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