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Arms and the man

A great many words have been written in the last year or two on the amorality and expediency of engineering. On the one hand, some engineers have come to believe that the responsibility for rendering the bellicose ambitions of political leaders capable of realisation lies squarely with the designers and makers of lethal hardware—engineers themselves. If it were not for the complaisance of engineers, they say, the means to wage war in the modern manner would not exist.

Those who do not embrace this belief (or who choose to disregard its implications) point out that if "defence systems"—a weaselled expression, referring to all military equipment, including that which by no stretch of the imagination can be seen in a posture of defence—were not available, then one "side" would subdue the other and impose its own ideology on the defeated. The solution to this problem, the holders of this view assert, is for each camp to arm itself to the teeth at an ever-increasing rate, threaten to irradiate the planet if provoked, but only to do so if the other side does it first. The unspeakable, imperishable folly of such an attitude is almost too obvious to warrant argument: its holders would scarcely deny that this method of preserving life and liberty is hardly compatible with the pursuit of happiness.

It is perfectly true, as apologists for the arms race often point out, that some of the effects of the insane compulsion to accumulate weapons are not at all as unenviable as their raisons d'être. "Spin-off" has provided most of the advances in, for example, electronics in the last few decades. Innovation and development are accelerating at such a rate that it is barely possible to see five years into the future, assuming there is one. But to what effect? After the expenditure of so much effort over so many years, with neither East or West yet persuaded that an unstable equilibrium is a poor way to avoid catastrophic failure, are we being asked to believe that the possession of home computers, video games and digital wrist-watches makes the whole thing worth while?

Some of the greatest scientists and engineers in the world, in both East and West, have laboured their entire working lives to produce lethal machinery, the whole point of which is that it shall never be used. Hospitals, schools, universities are closed or run down so that more weapons can be bought or made and the only benefits in our own field that we have to show for all this misdirection of effort and resources are a few gadgets. Admittedly, communications have improved immeasurably in response to the stimulus of military requirement, but a good deal of the improvement is taken up by the provision of entertainment.

It is a specious argument, which takes no account of the time scale involved: even in the absence of military urgency, the "improvements" and engineering advances would most probably occur in their own good time, and who is to say that sooner is better than later when the pace of progress outstrips our understanding of it?

Much that has been written on this theme has not dwelt on the inconveniently large question of waste. Materials, the efforts of gifted men and women, irreplaceable earth resources, time and the wealth of nations are all squandered to produce equipment which, if employed in the manner for which it was designed, would have failed in its purpose. And this while millions of people in all continents are deprived of the simplest staples of life.

The contrast between profligacy in the highly developed and primitive in the primitive is too stark for us to contemplate the continuation of useless armed posturing into the indefinite future: for that is the outcome—either a sudden and complete end to humanity or an interminable attitude of menace between East and West. "Scientific American" has pointed out that there are now more than three TNT—equivalent tons of nuclear explosive for every single person on earth. It has been said before on this page, and it will bear repeating, that engineers in all the developed countries have made the confrontation possible. It is therefore engineers who are in the best position to bring it to an end, by simply refusing to work on armaments. Call it rebellion or simply common sense, but since politicians the world over seem bent on killing us all, it is the only way to avoid collective suicide.
ORCHESTRAL SOUND, HALLS AND TIMBRE

or - 'why does it sound so beautiful?'

This article examines aspects of the appreciation of orchestral sound, with particular reference to the transfer characteristics of the outer ear and its influence on timbre in various directions and on changes of orientation. New subjective criteria are proposed. The Kingsway Hall is used as a model in the discussion.

by Denis Vaughan*

Fig. 1. Filtering effect of the outer ear canal, showing peaks near 5 and 10kHz, common to all that we hear. All frequencies above 1kHz are much weaker.

Fig. 2. Filtering effect of the outer ear on sounds arriving through the horizontal plane. + corresponds to a point straight in front.

For several decades the most sought-after venue for recording orchestral music in England has been the Kingsway Hall in London; legend has it that Sir Thomas Beecham was the first to identify this hall as particularly suited for the purpose. Are there some identifiable reasons for its superior warmth and clarity? Could they be applied elsewhere?

My interest in acoustics was stimulated by a request from the Australian Broadcasting Commission. The quest to find a common denominator for warm, ringing sound has haunted us for years. But indeed it has led me to study many halls, and to analyze musical qualities and our hearing capacities. These analyses have brought several surprises. First of all come our hearing capacities.

Timbre

Our localization of sound is based on three main complementary systems: only two of these have been used so far in stereo recording techniques. The first is based on the exact timing of impulses to each ear. A difference of 0.63 milliseconds we interpret as a change of angle of 30° in the direction of the earlier impulse. So we can, miraculously, recognize a timing difference as small as 0.007ms, the time necessary to move an inch across one degree to the side. The second is based on loudness and intensity; a softer sound we seem farther away. We apply this in localization: just a small change in volume on one channel will shift a stereo picture to the left or right and a general rise in level brings an instrument nearer to us. But the third system, timbre, has yet to be explored.

We hear a different timbre from every angel. Move a small clock around close to your ear, and you will notice that you can always tell where it is, and that the sound is never identical. If the clock is near your ear but always equidistant from it, this test excludes the possibility of the impulse or intensity methods contributing to the effect; we recognize each and every direction partly by its own particular timbre. If you change the timbre, the apparent direction changes. The filtering effect of our external ear, illustrated by Fig. 1 and Fig. 2, causes us to hear a very odd balance in sound reaching us face-on. The left-hand column of Fig. 3 shows that, with 400Hz as ODB, three is a strong peak at 3kHz of 12dB and a deep trough at 10kHz of -10.5dB. So we hear certain upper-high frequencies (except 14 and 16kHz) fantastically very much weaker than those at 3kHz.

Horseshoe balcony in the Kingsway Hall is only 17m wide, giving early reflections back at the orchestra.

Horizontally to the side at 90° the balance is more even. The upper frequencies become as much as 15dB stronger than the frontal spectrum and the various peaks at lower pitches are smoother, thus reducing the range between the extremes to only 15dB as opposed to the 22.5dB range of the frontal spectrum. But the sensitivity which we have at 90° for 12 and 13kHz starts to disappear already at 54° and 144°. Figures 4 and 5 summarize the table of Fig. 1 graphically.

You may have noticed another audio characteristic. We tend to identify bass notes as coming from below our ears; also, the higher we sit in a hall, the warmer it sounds. I believe that we react similarly to loudspeaker placing. Surprisingly, above our heads we can hear a strong peak at 8 and 9kHz, as shown by Fig. 6. In fact we can only hear 8kHz as coming from that direction, no matter where the sound source. But further up the spectrum, above 10.5kHz, we hear very little from over our heads. There is a low room or a hall, where the most pleasant early reflections come from the ceiling, we can perceive very little refinement, delicacy or texture in the sound. Figure 7 is the graphical representation of Fig. 6.

Musical qualities

It is no easy task to prepare a preferential list of musical qualities in sound. Gelb in particular is to be praised for his pioneering work - his "aural impression" is called 'aural dissimilarity'. In a concert hall, it is the extent of the initial delay time between the original sound and the first reflection - often about 40ms in a medium-sized hall - which gives much of the character to the acoustic. (Distance - but only to a certain point, has been associated with this gap, but my list suggests other requisites.) Our ears appreciate these reflections most when they arrive close to horizontally from the side. My timbre list shows that the timbre of a hall is influenced for us first by the angle at which we hear the strongest first reflection, and then by the shape and materials of the hall, or room, and the reverberation spaces beneath it.

When we receive a lot of early reflections, one shortly after another, these impulses come in an impetuous form in slow motion rather like the rumbling of a train on a harp. This sequence of impulses we perceived as being warmer than an instantaneous reflection. A digital delay unit demonstrates this quickly, by making two or three string instruments sound like a rich chorus. Halls are preferred where the sequence of impulses, whether first or later reflections, die away smoothly. It is called a 'smooth decay curve'.

Home simulation

These two keys to richness, namely timbre and impulses, are demonstrable in the home with a system which I hope will be developed in the phonograph industry, as soon as the field of the external ear is completely measured. The system would need at least ten loudspeakers: one large one on the floor to represent the orchestra, and the smaller ones set around the room above and below the ear level, with the appropriate timbre applied to each speaker.
Long reverberation

Until such a time as a 'decaphonic' system in stereo currency, it is obvious why very reverberant halls will be favored for recording. Present systems use multiple microphones which pick up frontostside frequencies that we can never hear there (with our 33kHz cut-off), through, and general cut-off in the ear canal above 11kHz). Also the loudspeakers are usually placed at angles which we perceive several other frequencies very well, adding a 20dB range between the 3kHz and 11kHz readings. The simplest way of covering these two aural mismatches is to add reverberation to diffuse and thus beautify the sound.

This has the unfortunate effect of robbing the interpreter of a bit of the breathtaking dramatic effects, because he or she has to achieve a quick silence, until the common 2.5% of reverberation has died away. That would never have done for Verdi, Toscanini or Callas.

Instead we should seek out a true and satisfying way to give us global (3000 Hz) reflections in the reproduction. Natural, full-frequency spectrum, concentrating on our most sensitive area, between 40° and 140°. Even most headphones are unnatural (have those with integrated electroacoustics) in that the audience in whole of our own aural frequency filter system. The great advances in 'decaphonation' seem to be either poor (narrowband) and falling back at this point.

Architectural prequisites

The quest for the physical conditions necessary to produce performance of artistic tone in a concert hall was sparked off by the decision of my home town, Melbourne, Australia which spend 33.5 million dollars (A) to build a 35 metre square, virtually all-concert hall for that purpose. Of the many indications given to me, two of the most revealing were from Viljo Ilmari and Derek Jordan. Jordan could not obtain 'lateral efficiency' in a hall wider than 27 metres, and observed that all the famous halls had smaller widths.

Sugden stated: A hall must have 'presence' so that you not only perceive clarity in a reverberant field but the music will have 'weight'. A powerful sound in the hall at the 100 milliseconds in necessary. This can be achieved preferably with a width of 35 metres, and if this is not possible then deep balconies must be used, or the technique of putting the audience in terraces and providing large surfaces for lateral reflections. There must be rapidly following early reflections to really achieve intimacy or presence. A

A third useful piece of wisdom came from Denis de Caro's former chief, Kees van der Groen, of the Netherlands.

Kentish: 'I have recorded in many halls thought high in Europe and America and have found that halls built of mainly brick, which we have found in the old halls, always produce a good, natural, warm sound. Halls built with concrete and hard plaster seem to produce a thin, hard sound and always lack a warmth of tone and bass. Consequently, when looking for halls to record in, I always avoid modern concrete structures.' This statement has been endorsed by most of the other large recording companies.

First reflections

In all the famous orchestral halls, the first lateral reflections come from the side balcony fronts. The timing is nearly controlled by the width (1 foot = 1). So a central seat in the Leipzig Gewandhaus, with only 12.5 between the balcony faces, had an initial time delay of around 4ms. Vienna Musikverein, with a 15m had 49ms, Boston Symphony Hall (7199.5m) 56/66ms, and the Amsterdam Concertgebouw (19.8m) 66ms. These figures give a very good idea of the relative clarity of perception, in terms of delay and density of sound in each of the above halls. At upper-high frequencies fall off suddenly through atmospheric absorption after about 15 metres, Leipzig and Vienna must have the best quality.

Looking at the Kingsway Hall, it is easy to see where it satisfies the main requirements: Stage front line, 27 metres, with inner walls set on pillars at 19 metre width. But the distance between the reflected and direct sounds, a very useful curved reflecting surface beneath them, is only 17 metres at its widest (9m). microscope's position at 30m, the orchestra at a height of 3.5 metres. To be honest, I think that such a horseshoe would bring any large symphony orchestra good acoustic quality. It gives all the players a functioning position, except at the right angle, to allow them to obtain good ensemble. The unbroken surface helps to ensure that no reflections can reach back to the microphone (not too strong, mind you) because the long bass waves are effectively removed by the curve of the room. I might be worth copying this reflecting shape in Abbey Re- in, Watlington, Breton, or Watlington, London recording halls. The shape is very adaptable to those marvellous small Italian theatres.

In recent years, the Kingsway has been shared by EMI and Decca, also subletting it to RCA and other companies. I am surprised that downstages and many upstairs covered with wood. At the moment the reverberation time in orchestra present is about 2.5 seconds.

Hall background noise

Poor Wagner cannot have guessed that in Tristan and Isolde, by giving his listeners the limiting of the rock face (unavoidable) and solo which lasted more than four minutes, he was condemning one of his greatest interpreters - Furtwangler to recording a duet for English Horn and Piano Line. Unfortunately, collaboration between EMI and London Underground is not yet such that the echo of the 'very limited' extent to such other regions. The rumble of the noise of traffic, the rumble of the hall, was Kingsway not such a good hall. Moreover the cavernous staircases and adjacent behind the rock face, which undoubtedly contributes to the warmth of the sound there, develop the tube rumble with a more general and general reverberation is cruelly revealed by digital recording systems. The hall is very much alive at all frequencies, even in the strong sound range 3000 to 5000 Hz. The presence of 80 musicians is something with a certain 'sprininess', which gives the indispensible and audible human element to the music, with myriad small high-frequency extra echoes always in. The echo of tone and spaciousness achieved in Spoleto, Bologna 'Sinfonietta' and Furtwangler's Tristan have to my ear sample to be bettered on disc. Both recordings managed to reduce the reverberation of the hall and was present during the sessions, and which is an integral part of the greatness of the instrumental interpretation. A hold alone behind the music is the antithesis of this spell-binding breath of breath, and unfortunately I fear that Dolby techniques so far, in their valiant battle to eliminate this and that, have only eliminated some of this integral part of the music. Digital recording is proving to be of no help at the better. What we need is a way to reduce the human element in a performance, and the comment of the acoustic to human element.

'Singing' decay curve

It is fascinating to know just why the string sound at the beginning of the third movement of the Beethoven 'Sinfonietta' is accentuated, but which in the article, I went down on my hands and knees, and with the generous help of the Kingsway caretaker, measured the various distances, counter-checking them against the frequency readings of the hall. So please do not expect total accuracy. 'Singing' great halls have a certain 'singing' genre, being of a different form of crescendo in the decay curve. Just as we can all sing better in the bathroom, because the acoustic supports us, so the 'singing' curve gives a lift to the performers, and a live and genuine performance, without need for forcing. (I think that adding a short peak of this nature to a recording would give more informative results than the general confusion caused by the small long reverberation.) No. one has the formula for its production in a hall. Guildhall thinks that it needs a large area of parallel surfaces above the highest seat, as in Vienna, Boston, Amsterdam, etc. Ioan Sutherland (and I) think that it needs also a set of hard surfaces around the hall at the level of the performers. Schueller that it needs a filtering of smaller surfaces for the very first reflections. It is probably a combination of all.

For the Beecham sessions, with the orchestra facing the microphone, the electronic microphones were about 2 metres in front of the stage. For an instrument just under the microphone the following性格的声线在的反射分在各种部分的耳后的原始声音:

Front, 15ms; upper stage front, 30ms; side balconies, 48ms; back balcony, 54ms (first frontal reflection); ceiling, 75ms (large); walls, 75ms (large); side walls down stairs, 8ms (larger); attics between side pillars and gallery, 10ms (larger); stage back, 100ms (larger); back wall downstairs, 11ms; side walls upstairs, 13ms (larger); back wall upstairs, 147ms (larger).

Such a layering of sound, higher, where the reflection can only come back to the microphone with the help of a secondary surface, such as tile wall upstairs/lower ceiling. As the microphone is a man-made object, the ear memory suggests that the stereo microphones were hung upside down for 'singing' ways, which do not effectively larger reflections start about 15ms after the original sound. Boston's singing tone is based on growth up to a peak in the decay curve, the peak reaching from 15ms to 100ms and upwards very even later. By Sugden's standards of 'weight' Kingsway has quite a bit of low readings offering within the first 150ms, because the larger reflections continue to return up to 14ms, the substantial and lengthy support of the musicians is assured, before the riostus ping-pong of the subsequent reverberation.
in every direction sets in. All later reflections are naturally weaker.

Curves

Robert Lloyd, the bass, has observed that wherever there are a lot of curved surfaces, the acoustic tends to be very good. When the curves are concave, they may mark the stage in the front, reach them, and thus reflect well. When the curves are convex, they distort the sound waves even more widely. Kingsway is rich in both types of curve. Nearly all the stage-end surfaces are curved one way or the other, with many interim small reflections, such as curves over doors, etc. It can be sincerely that this article may stimulate others to copy them, above all because of the full-frequency-range efficiency of the linear long horncone of the balcony face and its undercurvature. For a full kick, it comes as a two moment to break up the sound, and is as worthy of respect as the exact measurements of the original shell in the Boston Symphony Hall. If you wish to copy a Stradivarian, all details are relevant.

Langmuir thin-film trough for molecular electronics

Collaboration between scientific instrument makers Joyce Loeb and a number of research establishments, especially Durham University, RSRE Malvern and ICI, has resulted in what is believed to be the world’s first commercial ultra-thin film “growing” equipment. The troughs are monolayer molecules of a layer of material floated on a liquid surface, usually water transferable to a solid surface by passing it through the liquid. The material originally used by the pioneer of this technique – Irving Langmuir of General Electric back in 1927 – was the soap-like fatty acid sodium stearate, but other materials and their deposition on solid surfaces were subsequently investigated by Langmuir and Bilodeau, resulting in the development of glass anti-reflection coatings. Chief property of the materials used is a rod-like molecule, one end of which is attracted to water and the other end repelled so they stand end-on (assuming the material is completely compressed). But the trough is aimed at the possible new applications of L-B films that arise largely out of microelectronics technology. Such layers, one molecule thick, are becoming important in what is called molecular electronics – the “science of clever chemistry and electronics”. Applications include insulating layers as thin as 10⁻⁷ metre in gallium arsenide devices and as a resist in electron-beam lithography. Organic layers may have application for gas detection, while biological molecules such as antibodies and enzymes may make field-effect devices feasible for in vivo monitoring. In integrated optics they offer a route to the precise building of multilayer films to one tenth of an Angstrom, unit, perhaps with the molecular addition of metallic atoms to tailor response to radiation.

“Molecular Lego”, as it has been dubbed, also has potential application to energy conversion devices, photosynthetic, magneto-optics, three-dimensional memory devices, and to display devices, where high electric fields may allow a high-speed alternative to current technology. Molecules are compressed in the Langmuir trough with a constant-perimeter boundary which encloses the monolayer and prevents film contamination. A sensitive microbalance with sensor in the liquid surface monitors directional surface tension, and links through a control system to the barrier drive. A motor-driven microscrew automatically drives a substrate in and out of the liquid. Constant surface pressure is provided by a differential feedback system to maintain film integrity. A pre-determined number of monolayers can be programmed by a control unit using a range of dipping speeds, and a two-axis recorder charts surface pressure and sites during deposition.

The trough is made by Joyce-Loeb, a subsidiary of Vickers Instruments, of Team Valley, Gateshead.

Enter W500 on reply card for further details.

WIRELESS WORLD MAY 1982

NETWORKING SMALL COMPUTERS

Simply transferring a program or data from one computer to another by telephone is not too great a problem, but if a number of remote computers are to work together regularly in an interactive situation, complex software is required to organize received information efficiently. This article describes such software designed for Pat microcomputers and outlines networking generally.

by Philip G. Barker*

As personal computers become more popular, the need for simple methods of exchanging programs and data between them increases. Eventually, it may be possible to exchange information through some form of recordable software on a global communications network, but at present, we have to make the best possible use of the facilities available. Some of the more important information dissemination techniques currently being explored are:

Further reading


Theatre. The sound has a characteristically varied sound spectrum, with both upper and lower frequencies well developed. The sound quality is generally good, but may be improved by some careful manipulation of the acoustics. The acoustical properties of the hall are such that reflections and reverberations are minimal, and the sound quality is unaffected by seating arrangements.

The central feature of the theatre is the stage, which is well equipped for all types of performance. The stage is raised above the floor level, and is divided into two sections by a wide central aisle. The upper section of the stage is used for acting, while the lower section is used for lighting and technical operations. The stage is surrounded by a number of boxes, which provide excellent views of the performance and are equipped with comfortable seating.

The auditorium is well equipped with lighting, sound, and technical facilities. The lighting system is designed to provide a wide range of effects, and is controlled by a computer. The sound system is also computer-controlled, and allows precise control over the audio levels and quality of the performance. The technical facilities include a large number of microphones and speakers, which are used to amplify the sound and ensure that it is heard clearly throughout the hall.

In conclusion, the Opera House is a fine example of modern theatre design, with excellent acoustics, lighting, sound, and technical facilities. It is a pleasure to see such a high standard of performance in such a fine setting.
to be transmitted in machine-code or source-language form. Factors influencing the ease with which programs may be communicated are:

- the level of language used
- the availability of internationally accepted language standards and the ability of programmers to keep within limitations imposed by these standards
- compatibility of the computers used.

These factors alone are probably sufficient to justify transmitting program files in source language form rather than as machine-code memory images. In this context we have been examining the problems associated with transmitting both Pascal and Basic programs over the p.u.n. between microcomputers and mainframes. Some interesting results have been obtained—a few of which are described here.

Files transmitted between the two computers consist of a contiguous set of characters. Certain special characters interspersed in the sequence, for example end-of-line $0D* or newline $0A, impose a simple record structure on these files. That the files may not be physically stored in this way in either the source or destination computer is of little consequence as far as this article is concerned.

Loading Basic from secondary storage

Once a Basic program has been transmitted from a remote computer and stored locally on a secondary storage medium such as a tape or disc drive, it is a simple matter to load the program into memory for subsequent execution. How the program is loaded will depend on the type of microcomputer used.

The function of a loading program is to recognize Basic programs contained in a secondary storage file, convert them to the appropriate format, and store them at the correct location in the memory space available. Functional requirements of such a program for the PET are summarized in Fig. 2(a), where it can be seen that the storage area for Basic programs starts at $400 and ends at $7FF where $12F of memory is available. Obviously, the loading program at the top end of the memory will slightly reduce the amount of space available for other programs.

One of the loading program’s main tasks is to convert the incoming source code to a code which can be stored in the computer’s memory, the two forms of which are represented in Fig. 2(b). When the source code is stored, each statement consists of a two-byte pointer, a two-byte encoding of the statement number, a sequence of bytes representing the original source line and a byte containing the ‘end-of-line’ marker. Further details on how Basic programs are stored in memory can usually be found in the computer’s manuals.

Once a statement has been converted, it has to be placed in the correct memory location. Both conversion and insertion are usually carried out by routines built into the computer’s operating system, which in the case of the PET are locations $0B48 to $0C84, and there is no reason why these routines may not be used in the programs concerned. But for most readers, copying the relevant r.o.m. information into r.o.m. will be more practical than altering the system’s r.o.m. A simple assembly language program will serve this purpose. The loading program’s basic structure is as follows:

Step 0: borrow code from the operating system
Step 1: initialize Basic (usually using "NEW")
Step 2: read input file (get next source character)
Step 3: if ‘end-of-line’, go to step 6
Step 4: if ‘end-of-file’, go to step 8
Step 5: store source character in Basic buffer then go to step 2
Step 6: prepare for operating-system entry, e.g., locate Basic
Step 7: convert source statement held in buffer, enter into Basic memory area, then go to step 2
Step 8: pass control back to Basic command mode with a ‘READY’ message.

As was suggested earlier, step 7 will probably be carried out by a ‘borrowed code’, and the remaining steps will be implemented by the operator, see Fig. 2(a).

An assembly-language program for the above algorithm— for Basic source files on cassette—is shown in Fig. 3, and a complementary flow diagram is shown in Fig. 4. When invoked, the initialization code copies $4B bytes, starting from $C348, in the slot reserved for it through manipulation of the assembler location counter. When this is completed, the loading operation starts. The program uses a subroutine called TREAD to transfer a block of data from cassette into the relevant buffer area. In turn, this routine makes use of the operating utility code commencing at $F855. Characters are then
copied one at a time from the tape buffer, $027A, across to the Basic input buffer, $0200 – $0250, using the Y and X registers respectively as pointers in the indexed load and store operations. Each time an end-of-the-line character, SDS, is encountered, or in the data stream (INCHAR) an end-of-statement marker, $0F, is set to the output stream (OUTCHAR) for placement in the Basic buffer. Subsequently, at step 6, the pointers at $77 and $78 are set to point to the memory area containing the new statement. A subroutine call to the operating system utility CHRGIT in the Basic is made. This is essentially a line-fetch routine that sets up the next Basic statement for processing. More details on how the routine operates are given elsewhere. If the first character of the data stream in question is CHRGIT, the code for converting/inserting the new line into the BASIC program area can commence. Further source statements are then processed one at a time until an end-of-file code, $00, for tape files, detected on INCHAR terminates the loading process and passes control back to Basic direct command mode with the prompt "READY".

A major disadvantage of the loader shown in Fig. 3 is its lack of identity checking. Inherent in the program is the assumption that the tape will be positioned at the point from which loading is to commence; the first character or block of the Basic program (its identity) is then skipped over. If necessary, it would be a simple matter to replace the first match in the UTRAP (line 21) by a call to subroutine that allows the operator to interrogate this tape buffer to check for the correct file before loading. Loading an incorrect program is harmful to the Basic system and the computer.

Comparison of load times

Given that there are now several ways of loading Basic programs into memory some consideration of load times would be appropriate. There are two important comparisons to be made:

- The relative speed of load routines as compared to memory image loading.
- The relative speed of tape loads compared with those from disc.

Fig. 4. Data flow diagram for the source code loading program shown in Fig. 3.
Teledon videotex in UK

The first private viewdata system based on the PET microcomputer, run by Teledon Computer, a new company in the Poulter advertising and marketing group. Developed by the Cable Research and Development Department of Communications, Teledon is an easy-to-use system to enable text and high-quality animated images to be transmitted to tvs. It was chosen for auditory scanners because it is about 35 times faster than tape loading where memory images are concerned but only about four times faster in the case of source-code loading. In the latter case, it would take 11 seconds to read the program into memory from disc. This would suggest that about 96% of the program loading time is devoted to converting source statements into a form suitable for storage, and storing them. Similarly, in the case of tape loading, it takes about six seconds to read a block from tape into memory. The test program contained 131 blocks, i.e., 192 × 131 characters, and so its input/output time would be about 786 seconds. This means that only 24% of the program loading time is spent on conversion operations. It is interesting to note that the time spent converting and inserting programs in memory is the same for both programs — 24% for the disc loading program and 251 seconds for the tape version. This means that the modifications converting the tape loading program into its disc equivalent do not influence the program’s performance characteristics. These results illustrate the advantages of memory-image loading over source-code loading, but most readers will probably prefer to sacrifice some efficiency to make their programs more compatible with computers of a different type.

References
1 Hamlyn, N., Bright project sets out on the micro road, Practical Computing, Aug. 1981, pp. 75-76.
10 Hampson, N., The PET Revealed, Computel Ltd., pp. 77-78.

DIGITAL TELEVISION STANDARDS

Towards a worldwide compatibility for broadcasting studio equipment at recent meetings of the CCIR in Geneva, decisions were taken which will have an important bearing on the introduction of digital systems into television studios throughout the world.

by A. Howard Jones

BBC Research Department

and high-definition television at the other. But the most urgent requirement, to be specified is the standard that will be used within all the main studio equipment processes that is the recording and transmission equipment used for international programme exchange. It was agreed at Geneva that the main studio standard would use sampling rates of 13.5 MHz for luminance and 6.75 MHz for each of the two colour-difference signals. This corresponds to 644 and 452 samples per line respectively in 625-line countries and 858 and 429 samples per line respectively in 525-line countries.

8-bit linear p.c.m. coding will be used and it was agreed by meet delegations that the coding schemes be as indicated in Fig. 1. There is a good chance that these figures will be formally written into the Recommendation by the time of the Plenary Assembly next year, together with the project that in both 625- and 525-line areas the circuits process only the active part of the television signal. The sampling frequency of 13.5 MHz, 720 samples occupy somewhat more than either of the nominal active line periods. The intention is that the latter will be defined by a blanking operation to be carried out when the signal eventually emerges into the analogue composite world. Meanwhile, an appropriate position for samples (Fig. 2 shows the EBU proposal for 625-line signals and digital and nominal sampling (and line timing for reference) will ensure that the system will accept the whole of an analogue active line at its input regardless of the actual timing within permitted tolerances.

The adoption of this specification will ensure maximum compatibility of equipment, and will lay the foundation upon which further specifications, covering studio interfaces, digital video tape formats, and the multiplex structure to be used on international digital links, can be built.

Corrections

Required for a b-line system. Unmarked components in Steve Kirby’s article in the March issue, page 54, pre-p-p transistor in Fig. 1 should be 1N34. Microwave switch diodes are high-power types — RC Component No. 512 or equivalent. Labeled “standby” and “normalise” should be transposed on the keyboard. Notes on selecting one link, a simplified one control switching circuit, and p.c.m. listing will be published at a later date in the mean time they can be obtained by sending a stamped, addressed envelope to Steve Kirby at the Department of Electronics, University of York, Heslington, York YO1 5DD.

Heating-fuel saver. The introductory paragraph states that in some appliances the gas sensor is not essential but in fact, the scheme would work without it. The non-essential part can even indicate the reading of the gas sensor. If this is not required, the milliammeter and dials can be omitted. In the first paragraph of the main text a d-t-o converter has been misspelled “converter”.

Digital, multi-track tape recorder. Contrary to the impression by April part of this article, it was not the final section. A further part of the playback facility will be published in the next issue.

BBCC micro. See News of the month.
Tracking vehicles

Disclosure of hitherto secret Home Office guidelines on the police use of "bugging" and other electronic equipment is to be followed by an official examination into a series of complaints by private motorists that police have tracked their vehicles by the attachment of a miniature transmitter which can then be located by use of sophisticated mobile Doppler-type v.h.f. and u.h.f. direction-finding equipment. The police are well aware of the problems of accurate df in built-up areas. Equipment of this type is made available to American firms which cannot, however, market it in the UK. Richard Rohde & Schwartz specifically described their PA002 and PA005 systems as capable of "tracking" in the field of personal protection or even in tracking "practising" vehicles. From fixed bases such equipment can locate an urban transmission to within about 100 metres. At least one manufacturer of mobile equipment that would have little difficulty in following a vehicle at a discrete distance.

Mobile radio and s.s.b.

The outlook for the v.h.f. single-sideband with 5 kHz channelising in the private-mobile radio or in the public-service band for mobile services cannot be as bright — and seems to depend on whether the fast-acting, compacting-type a.g.c. developed by Dr. George F. Neilson at Bath University proves suitable for incorporation into a mobile set.

The intensive work in the UK over the past few years on the Wolston project for mobile s.s.b. has failed to produce the clear-cut results needed to convince users. Completely independent user-trials by British Telecom Research and by the Home Office, and related trials by manufacturers, all seem to have shown that on frequencies of the order of 160 MHz, s.s.b. equipment (without compacting) does not provide fully equivalent performance to that of 12.5 kHz channelising f.m. systems and is significantly degraded in performance with 25 kHz channelising. The British Telecom results suggest that s.s.b. equipment requires a much higher channel interference protection ratio (about 20 dB) which would mean that there could be much more interference under the same level of demand. The same would be true under the same level of demand for mobile services.

While static was not too high, the badly-needed professional radio officials and coast station technicians worked overtime to ensure that the interested public heard on the other frequencies.

Topic of the week: the 1981 C.W. contest season. With a large number of pre-arranged and ad-hoc s.s.b. contacters, the weekend contest has become a popular event with many high scores and exciting contacts. Many operators have used mobile equipment for these contests, and the results show that mobile s.s.b. is becoming increasingly popular among the amateur radio community.

Broadcast relays

For several years, some of the European external broadcasting services have been using satellite circuits to carry programmes to their areas of operation, with stations in the UK, mainland Europe, and the Middle East having made use of interlink earth stations built primarily for telecommunications use.

However, Marconi Communication Systems have recently announced a series of C-band earth stations, the Foreign and Commonwealth Office for a 10-minute, re-organised service, which will be operated from a new site located on Mastshear Island, off the east coast of Oman, to be completed this year. The station will be used for relay services for British Overseas Service programmes for retransmission on the high-power F.M. television service of the British Broadcasting Corporation.

The users of extremely high-power f.h. over-the-horizon radar and broadcasting equipment may have cause to concern a recent report of recent joint-work of the Max-Planck-Institut for Aeronomy and the University of California, Los Alamos (February 1982). This shows that the ionosphere has non-linear characteristics such that above a certain optimum power, signals received at remote sites decrease with additional power. The optimum power is usually 25% of the maximum power which can be transmitted. For March 1982, 6.5 MW e.g.r. — a power less than that currently used by some broadcast and radar stations.

Marine communications

The long-awaited new Marine Safety Regulations (S.R.92) to come into force on 1 April 1982, are now in force. The regulations cover the use of radiocommunications in the marine environment. The regulations aim to provide a framework for the use of radiocommunications in the marine environment, and to ensure that communications are used in a safe and effective manner.

Licence snafu

Following meetings between the R.S.G.B. and the Home Office, the Home Office confirmed officially that the new amateur radio licence schedule, as published in the The London Gazette on February 12, contained errors and a revised schedule would be published with a minimum delay. The Home Office also issued a statement that they had "no intention of changing the basic amateur radio operation in the UK."

In brief

The 10.1 MHz band has still not been released for amateur use, although there is opposition from other users...

M. Hanssen and J. P. Loughlin of the American C.B. License Office, published an article in The London Gazette on February 12, containing new rules and amendments to the current amateur radio regulations. The amendments were designed to improve the efficiency of the amateur radio service, and to ensure that it remains accessible to all interested amateurs.
The input portion of the lighting system — the control desk — transforms the position of the numerous faders into data in the processor memory. To maintain processing speed and hence the interactive nature of the system input and output operations are designed so that no processor WAIT states are required. This is readily achievable in the output to the dimmers by ensuring that the access time to each dimmer is less than 410 ns (the maximum data bus access time permitted by the processor) and the use of a mapped-memory input technique was chosen. However, the analogue-to-digital conversion of the fader positions is inherently slow, and so some method of increasing their apparent conversion speed is required. Three possible methods can be considered:

- Allocate a slow a-d converter to each fader which continuously tracks the analogue level of the fader and then the processor addresses each converter in turn to obtain data. The large number of faders in a lighting desk makes this approach probably the most expensive solution.

- Use an a-d converter which is fast enough to perform a conversion in the maximum access time of 410 ns. The practical conversion time must be much shorter than this to allow for the multiplexing of the faders and the sampling of the analogue levels. The cost of high-speed converters and multiplexers means this solution is also expensive.

- Rather than set the conversion speed by the processor requirements, set the speed by the desk operator's requirements. For instance, the maximum useful "response time" of the system should be about 20 ms. Hence use a converter which is fast enough to perform all the conversions required in this maximum response time.

The faders can then be scanned by an analogue multiplexer, converted to digital data and stored in a block of memory locations. The processor is then able to access this block of memory. The major advantage of this method is that it obviates access to a block of memory by both the processor and the converter.

The final method was chosen for use in the control desk because of its lower cost. The fader units in this prototype system were designed on a modular basis. Each multiplexer connects one of 16 faders to a common analogue bus and the faders addressed via a 4-to-16 line decoder by a 4-bit digital address bus. One a-d converter was allocated to each of these 16 fader modules; however, the converter and sample-and-hold circuit used have a total conversion time of 26 ms at a 500 KHz clock frequency so one converter can access over 600 faders within a response time of 410 ms.

The input circuits can be split into three parts — an analogue multiplexer which connects the faders to the a-d converter, the converter itself and associated sample-and-hold and timing circuits, and the shared memory with access control logic.

**Analogue multiplexer module**

The fader connected to the common analogue bus is determined by a four-bit code, and address decoding is performed by a 4- to-16 line demultiplexer (74154). Fig. 11. Analogous to the control inputs are buffered by level-shifting inverters. Fader potentiometers are connected to a bipolar reference bus derived from the a-d converter internal reference voltage, Fig. 12.

As the lighting system scales the channel presents by a master preset control, as mentioned in the first article, this requires the multiplication of stored data. For any reasonable interaction time between fader position and light output, software multiplication by the processor is out of the question. As described in the final article, fader levels are stored in log form; multiplication and division become simple addition and subtraction. The processor generates a look-up table r.o.m. is used to provide the correct code for each output dimmer. Unusually, log-law potentiometers are used for the faders.

The potentiometers can be considered as a voltage source with an internal impedance which varies with slider position. The highest internal impedance is (nach resistance/4), that is 25 kΩ in this case. As the output capacitance of each c.m.o.s. switch is about 5 pF, the worst-case switching time constant for 16 switches on a common analogue bus is 2 ps. With a sample-and-hold for the a-d conversion of 6 ps, this gives a significant sampling error. The solution is to introduce a capacitor C0 to the input side of each switch. The percentage error in the final output voltage is 100% X C0(C0 + C0) for C0 = 100 nF the error is only 0.08%. The switching time constant is now about 25 ps; t is of this flip-flop is used as the start conversion pulse of the a-d converter. The end of conversion signal (EOC) goes low, and is used to hold the counter in its reset state. The positive-going edge of EOC clocks a 4-bit counter (74161A) which addresses the shared block of memory and the analogue multiplexer. The data outputs are always enabled, by holding OE (pin 2) low. The LF398 sample-and-hold circuit has more than adequate specifications for 8-bit accuracy at 6 µs sample time.

The sample-and-hold converter reference voltage is used to bias the fader potentiometers. To reduce processing time, the fader control codes are first checked to determine if they are zero (i.e. channel not in use); only if they are non-zero will further processing be performed. Contact and end-resistance in the potentiometers gives a small d.c. offset, even when the channel is not being used. Hence a bipolar voltage reference is supplied to the faders to give a small "deadband" for which the output code is zero. These references are obtained by buffering and inverting the converter reference voltage by a 744 dual op-amp.

**Shared memory and access control**

The memory can be formed either by the microprocessor or the a-d converter, and hence the data and address bus must be multiplexed between the microprocessor and converter. It differs from conventional direct memory access techniques in that the converter and processor have separate buses and operate independently, Fig. 15. The data bus in each module is a 16-bit word (8-bit Schottky r.m.s.). The devices have separate data inputs and outputs and the a-d converter only writes to this memory while the processor only reads from it, so no data bus multiplexing is required. Data outputs are tri-state which allows direct connection to the processor data bus. Address bus multiplexing is performed by two 74125 tri-state buffers, the appropriate one is enabled for read or write operations. For large systems standard 250 ms memory chips are used instead of the AM27507, but they will require additional data bus multiplexing.

The eight high-order bits of the processor address bus are compared with a bit pattern set by eight wire links to determine the page location in the memory map of the input data addresses, Fig. 14. This is achieved in the same manner as the output addressing decoding described in Part 1. When the processor needs to read from the shared memory, a read request signal is generated before the system enable signal is given low, achieved by AND-ing the address decoder output, M/O and W/R signals. The output is latched by the 8085.
address latch enable signal ALE to ensure that the read request signal is low before E goes low. Timing diagram: Fig. 15. The read request signal enables the appropriate address buffer and sets the memory to read mode.

The absence of a read request signal sets the memory to write mode and enables the A→D converter address buffer. A write request signal from the converter timing control enables the memory and data is clocked into the memory by the system enable, E. The duration of the write request is long enough to ensure that any data is always stored in the memory. Since the processor controls access to the memory at all times, no conflict of simultaneous access requests occurs.

Continued

The authors ask us to point out that E1 and E2 in Fig. 9 should be inverted, for which the two space 7400 gates may be used.

Figure 8 is the timing diagram for the listening sequence. On power-up, the Reset line is brought low for approximately 150 ms via R3 and C2 to reset the address latch IC2 and the addresses enable flip-flop IC1.

To select a channel and start an A→D conversion, the Basic statement below is executed:

PRINT a DN, "*"

where DN is the device number (0-80) * is the ASCII character "*" n is the ASCII equivalent of the required channel "0" to "F".

When the system receives a device number (DN) corresponding to that asserted on the address switches (S1 to S5 in Fig. 7), the 961-S48B will initiate a timing sequence, as shown in Fig. 8 (not to scale). The r.o.m. (IC4) decodes ASCII information to binary data, as shown in Table 1. Four outputs of the r.o.m. give the binary data obtained by converting ASCII "0" to "F" to binary 0000 to 1111, and the additional outputs are used to detect a "*" character and a carriage return (CR) — data output 06 and 65 are used for this purpose.

When the first "*" character is sent (2 in Fig. 8) the * line goes low (3) and the RXST and RXXRDY are pulsed (4) and (5) in accordance with Fig. 5. As the data is removed (6), * detect goes high and sets the address enable FF — Q goes high (8). The next data byte is presented (9), representing one of 16 address channels, and as RXST goes high (10), CLK goes high (11) and latchs the address latch (12), RXST and CLK than go low (13) and (14), and data is removed (15). A Carriage Return is now presented at the data bus (16) and the CR detect (or GO signal) goes low (17), and starts conversation in the AD5755 (to be discussed later). This signal also resets the address enable FF (18), while RXST pulses (19) and (20), CRD is removed (21) and GO is returned high.

The result of all this activity is that one of 16 channels is enabled in the AD7506 (16 channel multiplier) and a conversion cycle of the appropriate channel is started.

Talking sequence

The AD5755 in a 4/55-digit A→D conversion subsystem. A free-running clock (DMC) strobes out the b.c.d. data from the AD5755 in a 4-bit-wide bus. In this application, the AD5755 is the most significant digit; TRXD is high, indicating that data is ready; and SRQ has been brought low (12) telling the controller that a conversion has been completed and the new data is ready.

The article concludes with a continuation of the circuit description, its operation and a sample program for scanning through sixteen channels.

by Pat Hickey*

this application, the DMC signal is controlled by the 961-S48B handshake signals to transmit the information to the GPB. Each b.c.d. data byte is signalled by a digit line which goes low when that byte is being outputted, D0 going low for the most significant digit (sign and first digit), D1 for the next significant digit, etc., and D5 for the least-significant digit. In this application, D5 going low is used to send a carriage return code on the IEEE-488 bus. Although this loses one digit of resolution, it considerably eases the interface circuitry.

Figure 9 highlights the conversion timing sequence. Upon receipt of a GO signal (2) from the listening sequence in Fig. 8 (HOLD remains high (3) which instructs the AD5755 to start conversion; the free-running DMC clock is also enabled (4). Upon comparator crossing at the end of phase 0, (the beginning of the quasiloop A→D conversion procedure) SCC goes low (5), enabling the 1.024MHz clock to pin 12.

At the end of the conversion, SCC returns high (6) and on the next DMC rising edge (7), DAV goes high and remains high for two DMC pulses (9). During this period, the internal buffers are updated with the latest data. After this, DAV returns low (10) and brings HOLD Low (11). This is known as the master reset and enables the free-flowing DMC clock. From this point control of DMC is taken over by the TXST handshake during read-back.

At this stage, the data presented by the AD5755 is the most significant digit; TRXD is high, indicating that data is ready; and SRQ has been brought low (12) telling the controller that a conversion has been completed and the new data is ready.

Fig. 8. Timing diagram for the listening sequence.

16-CHANNEL DATA ACQUISITION SYSTEM

The article concludes with a continuation of the circuit description, its operation and a sample program for scanning through sixteen channels.

by Pat Hickey*

this application, the DMC signal is controlled by the 961-S48B handshake signals to transmit the information to the GPB. Each b.c.d. data byte is signalled by a digit line which goes low when that byte is being outputted, D0 going low for the most significant digit (sign and first digit), D1 for the next significant digit, etc., and D5 for the least-significant digit. In this application, D5 going low is used to send a carriage return code on the IEEE-488 bus. Although this loses one digit of resolution, it considerably eases the interface circuitry.

Figure 9 highlights the conversion timing sequence. Upon receipt of a GO signal (2) from the listening sequence in Fig. 8 (HOLD remains high (3) which instructs the AD5755 to start conversion; the free-running DMC clock is also enabled (4). Upon comparator crossing at the end of phase 0, (the beginning of the quasiloop A→D conversion procedure) SCC goes low (5), enabling the 1.024MHz clock to pin 12.

At the end of the conversion, SCC returns high (6) and on the next DMC rising edge (7), DAV goes high and remains high for two DMC pulses (9). During this period, the internal buffers are updated with the latest data. After this, DAV returns low (10) and brings HOLD Low (11). This is known as the master reset and enables the free-flowing DMC clock. From this point control of DMC is taken over by the TXST handshake during read-back.

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The sequence is repeated for D1, D2, D3 and D4 (10-23). TXRDY goes low (32), acknowledging that D4 has been received, and TXST goes low (24) to complete the handshake. This clocks DMC low (25) and brings D5 low (26). The output from the AD7555 is DS at this stage (the last unused digit of the 5-digit). However, a carriage return is transmitted to the controller instead, indicating the end of the string, via the data selector (IC5). As DS goes low, a carriage return (ASCII 13) is generated to the 96L3988 (27) and TXRDY goes high (28), indicating that it has a byte (CR) to send. DS going low also resets the SRQ flag (29). The CR is loaded during the rising edge of TXST (30) and the usual handshake follows.

The data string received by the controller is a 5-character string encoding a 4½-digit word. The first character is an encoded version of the sign and the most significant digit as outlined in the table. The program shows a simple method of converting the input string RS to a number R. A positive or negative over-range (caused by a voltage greater than +1.999 volts) is transmitted as "0<><><" and "2<><><" respectively.

**Fig. 10. Timing of the handshake sequence.**

### System performance
As discussed, the 5-digit converter is operated as a ½-digit system, but only 4½ digits are used. The 5-digit conversion time varies from 1.3 seconds for full-scale negative input, to 1.7 seconds for full-scale positive input. The conversion time can be reduced by a factor of ten by operating the 5-digit converter in the 4½-digit mode. Some minor changes in input voltages and pin-straps are necessary. As discussed, the a-to-d converter is negative input, to 1.7 seconds for full-scale operation. The operational amplifier and reference (IC5, IC6) are kept as close to the AD7555 as possible, and as far away from the digital circuitry. The AD7555 receives setup gives information on appropriate p.c.b.

### Fig. 11. Service request and data byte.

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## Change channels

```
00 NO SERVICE REQUEST
01 FINISHED CONVERTING 100 MICROSECONDS
02 BEGIN MESSAGE
03 ADDRESS
04 COMMAND
05 DATA
06 RESPONSE
07 OVER RANGE
08 END
```

Two programs, for Commodore PET and Floke 1720A, are included in this comprehensive listing of books.

### Books

<table>
<thead>
<tr>
<th>Title</th>
<th>Author(s)</th>
<th>Notes</th>
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<tr>
<td>European f.m. radio and television transmitters are included in this comprehensive listing of</td>
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<td>books. The first book published in Holland,</td>
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<td>presents the relevant information to enable a</td>
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<td>listener to identify or locate stations in the</td>
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<td>stations and DX clubs and there is a five-language</td>
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<td>key combining a frequency, wavelength</td>
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<tr>
<td>conversion table and a table giving the characteristics of rf transmitters.</td>
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**WIRELESS WORLD MAY 1982**
Waveform synthesizer
Here, an X/Y matrix is used to plot a given waveform. The waveform to be synthesized is divided into a number of time domains and the voltage at the end of each domain is set on a diode-chain potentiometer. If the length of the time domain is less than half the period of the maximum frequency present in the waveform and the number of discrete levels is large, accurate reproduction of the original can be achieved. This circuit lends itself to computer control and expansion.

By varying the 555-clock frequency, the output waveform frequency may be adjusted proportionally. A 7493 counter converts the clock signal into 4-bit binary to drive a 4-to-16-line decoder, which in turn drives 16 output transistors through t.t.l. buffers. Each transistor output is fed to a common point through a resistor. For certain waveforms, an integrating capacitor may be connected across the output to filter out steps and switching pulses.

P. D. Somerville
Crawley
Sussex

NiCd battery protection
Essentially a fold-back current limiter with a low-voltage detection capability, this circuit draws less than 300 mA and drops less than 0.35 V on full transmit load.

The low loss on load, important in many battery applications, is due to the use of germanium as the control element. Only one control transistor is shown in the simplified diagram although two in parallel are used. The germanium control transistor T1 is held on by a silicon transistor, T2, whose base current flows through resistor D1 and R6. With a 12 V battery D1 is 9.1 V. In the event of an overload or short circuit the p.d. across T1 rises and on reaching 0.6 V is detected by silicon transistor T2 which is emitter-base connected across the emitter-collector of the germanium control transistor. T2 turns on, raising the junction of D1 and R6 to battery voltage. This action turns off T1, and they remain off while any load is connected.

A similar action occurs if the voltage on or off load falls below 1 V, i.e. below 10 V. In this case the battery voltage fails to support a current through T1, requiring 0.6 V) and D1 (requiring 9.1 V) and T1 starts to turn off, initiating the same fold-back action. C1 is included to damp the fold-back loop. A low-value resistor R8 is used to control thermal runaway of T1.

J. B. H. Sted
Salisbury
Zimbabwe

Glitch detector
Using two fast monostable multivibrators, such as e.g. MC1019's, it is possible to detect extremely short glitches. These devices provide a very short pulse, but although the pulse is short, it is at least twice as long as anticipated glitches. As the timing diagram shows, normal pulses are rejected using an AND gate.

D. Vialletto
Carletana
Italy

Wideband f.m. demodulator
Operation of the demodulator relies on the linear relationship between power consumption (ID where VDD is fixed) and operating frequency of c.m.o.s. logic circuits. A 4013B D-type flip-flop is used because the internal clock elements have a high clock rise capability which extends beyond the normal range of usage. Measurements indicate that the demodulator will work satisfactorily from d.c. up to and beyond 20 MHz.

The flip-flop is clocked by logic level transitions and the resultant current flow converted to an output voltage by the current mirror and output components. The current mirror ensures a minimal interaction between supply voltage and current in the flip-flop - a higher performance mirror could be constructed using spare devices in the 3046 array if required.

The resistor is chosen to suit the maximum input frequency (the output can swing the supply full voltage, limited only by quiescent power consumption and VDD saturation) and the capacitor provides low-pass filtering to remove input frequency noise. Values shown have been used in a 10.7 MHz f.m demodulator prior to "noisy" filtering and stereo decoding.

G. C. Hammond
Whitstone
Nun Norton

Constant-current supply
This circuit is extremely simple, uses no special components, yet has a very wide range of output currents, 20 mA to 100 mA in six ranges. The only limitation to output in component ratings. It also has a performance that is comparable to more expensive equipment.

T1 and T2 comprise a constant-current source that can be varied from 0 to 100 V by varying VDD. When testing this section, no change in output voltage could be detected on both analogue and 3½-digit voltmeters with change of supply voltage from 150 V to 250 V and with sudden application of a 100 mA load.

T3 and IC2 comprise the constant-current section. R8 is the current sensing resistor. By choosing the appropriate range of R8 or switching different values, the required current range is obtained.

The voltage drop across R8 which equals VDD was chosen to be about 0.7 V so that the error in voltage measurement will not exceed this value plus the drop in the amplifier circuit, a total of less than 1 V. A multi-turn potentiometer to obtain VDD enables accurate current adjustment.

Capacitors C1 and C2 suppress oscillations that would otherwise occur. D1 and D2 protect T2 and T3 from possible negative voltages that may occur due to switching transistors. Switching T5 during operation proved to be of no harm, but IC5 may need extra protection if intermittent loading with outputs greater than 30 V is used frequently (a diode between pins 3 and 7 might help. Ed.).

Hussain A. Eissa
 Cairo University
Egypt

WIRELESS WORLD MAY 1982
DIGITAL FILTER DESIGN

In the next few years digital filters will be increasingly used in place of their analogue counterparts, not only on account of their accuracy and versatility but also their rapidly declining cost. Authors Cheetham and Hughes introduce the basic theory in this article, giving designs for a useful class of filters in the next, and describe their implementation by special-purpose microprocessor in a third article.

The conversion of an analogue signal into digital form requires a process of sampling at successive points in time separated by equal intervals, say T. Each sample is then converted to a binary number corresponding to the sampled voltage. The sampling process requires that the analogue signal be bandlimited to a Nyquist frequency fNYQ, where f = 1/T. This may be achieved by using an anti-aliasing pre- filter before the quantizing error. The sampling process may be a piece of special-purpose hardware consisting of some digital integrated circuits and a microprocessor. With such a dedicated hardware the process may be carried out in real time so that an output signal is generated as an uninterrupted stream of bytes with a single fixed delay between each input sample and its corresponding output sample. In this case the digital system, with associated analogue to digital converters, may act as a direct replacement for an analogue system such as a filter or a modulator.

Digital systems can be designed to carry out a wide range of operations on digital signals. A digital filter is a processing system which generates an output sequence from an input sequence. The importance of digital filters as devices for processing digital signals is rapidly increasing with the introduction of special-purpose analogue and digital microprocessors and integrated circuits specifically designed for signal processing. Using the natural processing power of such circuits, digital filters are able to perform operations corresponding to those of analogue filters. For example, the InTel 2820 analogue signal processor with its analogue/digital converters acts as a one-chip replacement for an analogue filter.

In addition to their uses in emulating the frequency responses of filter, digital filters have a wide range of other applications which take advantage of the much greater power and flexibility of numerical processing as compared with analogue methods, and may not easily be described as having a particular type of frequency response. Digital filters input are not limited by the dynamic range of analogue filters. But before doing this, this article briefly considers the elementary process often used to produce digital signals and introduces notation for representing such signals.

The input signal x(n) occurring at sampling 2πf allows for a z transform to be defined as:

\[ X(z) = \sum_{n=-\infty}^{\infty} x(n) z^{-n} \]

where z is a complex number with \(|z| > 1\). The z transform is a powerful tool for analysing digital filters and simplifying the analysis of related systems. The z transform also provides a method of representing and solving difference equations that govern the behaviour of digital filters.

The z transform is derived from the Laplace transform by replacing s = jω with z = e^jωT. The Laplace transform is the Fourier transform of the signal x(t) when the independent variable t is replaced by the discrete-time variable n, where n = 0, 1, 2, ... . The z transform is therefore the discrete-time version of the Laplace transform.

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The z-transform of the sequence \( x(n) \) is defined as the infinite sum

\[
X(z) = \sum_{n=-\infty}^{\infty} x(n)z^{-n}
\]

for a complex variable \( z \). Notice the similarity between this expression and equation \( 1 \), setting \( z = e^{j\omega} \) gives \( X(e^{j\omega}) \) as the Fourier transform of \( x(n) \). The z-transform of the impulse response \( h(n) \) is \( H(z) \) and hence the setting of \( z = e^{j\omega} \) in this case gives the frequency response already defined as \( H(e^{j\omega}) \). The equation above may therefore be thought of as a generalization of the Fourier transform. Also, the z-transform of the delayed sequence \( x(n-1) \) is \( z^{-1}X(z) \) as each coefficient of \( z^{-1} \) is shifted along by one place. In general the z-transform of \( x(n-k) \) is \( z^{-k}X(z) \). Also notice that the z-transform of the impulse \( (n\delta(n)) \) is \( z^{-1} \).

Applying the z-transform to the output of a digital filter as defined by equation 1 gives

\[
Y(z) = \sum_{n=0}^{\infty} x(n)z^{-n}Y(z)
\]

which may be rearranged and expressed in the form

\[
Y(z) = \sum_{n=0}^{\infty} \left( \sum_{j=0}^{N} a_j z^{-j} \right) x(n)z^{-n}
\]

The expression in square brackets above is equal to \( H(z) \) as if the input sequence \( \{n\delta(n)\} = \{b(n)\} \) then \( Y(z) \) becomes equal to the z-transform of the impulse response. Hence \( H(z) \) may be expressed directly in terms of the multiplier coefficients, and the frequency response may be obtained directly from this expression by setting \( z = e^{j\omega} \). This may be verified for the simple filter defined by equation 2 where \( H(z) = (1 + z^{-1})^{-1} \) and hence an expression for \( H(e^{j\omega}) \) identical to equation 7.

The transfer function of a filter, \( H(z) \), has now been expressed as the ratio of two polynomials in \( z^{-1} \), the roots of which are the poles and zeros of \( H(z) \). Hence

\[
H(z) = \frac{\sum_{j=0}^{M} h_j z^{-j}}{1 + \sum_{j=1}^{N} b_j z^{-j}}
\]

assuming \( a_n = b_0 \), where the poles are \( p \) and the zeros by \( z \). Expanding by partial fractions assuming there are no repeated roots other than \( z = 0 \),

\[
H(z) = \sum_{i=0}^{M} \frac{N}{\prod_{j=1}^{N} (1 - p_j z^{-1})}
\]

which expresses \( H(z) \) as the weighted sum of sequences whose z-transforms are \( z^{-1} \) and \( (1 - p_j z^{-1})^{-1} \). Clearly \( z^{-1} \) corresponds to a delayed impulse \( (\delta(n) - 1) \). By referring back to the example of a first-order filter whose transfer function is \( 1/(1 - z^{-1}) \), it may be deduced that \( 1/(1 - p_j z^{-1}) \) is the z-transform of an exponential sequence of the form

\[
\cdots 0, \cdots 0, p, p, \cdots, 1, \cdots
\]

The roots of a polynomial may of course be complex numbers and therefore the sequences above may be complex. As complex roots occur in conjugate pairs, the sequence obtained for \( h(n) \) is always real. A non-recursi ve filter, i.e. one with \( N = 0 \), will have an impulse response with \( h_0 = b_0 \) for \( 0 < \omega < \pi \) and zero otherwise. Such an impulse response is termed finite as only a finite number of elements are non-zero. The impulse response of a recursive filter \( \{x(n)\} \) will include at least one sequence of the form in equation 9 and can therefore be of infinite duration. For such a filter to be stable, the above sequence 9 corresponding to each of its \( N \) poles \( p \) must be a decaying exponential. Hence a stable filter must have \( |p| < 1 \) for all its poles.

Considerable insight into the behaviour of digital filters may be gained by plotting Argand diagrams showing the positions of poles and zeros as values \( z \). Such a diagram is shown in Fig. 5 for the transfer function \( H(z) \) which has a pole at \( z = 0.7 \), and a zero at \( z = 0 \). The points for which \( z = e^{j\omega} \) on this plane correspond to the unit circle with centre \( z = 0 \) and radius 1. The frequency response \( H(e^{j\omega}) \) is obtained by an evaluation of \( H(z) \) for values of \( \omega \) on this unit circle, where \( \omega \) is the angle subtended from the real axis to the point corresponding to \( z = e^{j\omega} \). Frequencies zero and the Nyquist appear at opposite sides of the unit circle on the real axis. A stable filter will have all its poles inside the unit circle \( |p| < 1 \). From equation 8 the value of \( H(e^{j\omega}) \) at any point on the unit circle is equal to the product of the distances from that point to each of the zeros, divided by the product of distances to the poles. The phase of \( H(e^{j\omega}) \) may also be readily calculated. Consequently zeros close to the unit circle correspond to frequencies for which \( H(e^{j\omega}) \) is close to zero. Poles close to the unit circle produce large values of \( H(e^{j\omega}) \), the closer the pole, the larger the modulus. Such poles can also affect \( \phi(\omega) \) resulting in severe phase non-linearity.

The design of digital filters with specified frequency responses is often carried out by locating zeros and poles at appropriate points on the Argand diagram. Aspects of techniques exist for both recursive and non-recursive filters: refer for details to any of the standard references, some of which are listed below. Non-recursive filters have certain advantages of guaranteed stability and easily specifiable phase characteristics, but tend to involve a large number of arithmetical operations which could make them more difficult to implement. Recursive filters are perhaps still more commonly used, and therefore the next article will introduce a design procedure for this class of filters.

**Further reading**


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**Fig. 4.** Frequency response of a digital filter (in this case Fig. 1) with \( b_0 = 0.7 \) characterizes its response to sampled sinusoidal inputs of the form \( \cos(n\omega) \). Amplitude response at top, phase response bottom.

**Fig. 5.** Argand diagram shows pole and zero positions for \( H(z) \) obtained from Fig. 1 which determines the frequency response \( H(e^{j\omega}) \).
A CHARTER FOR ISOLATION

I wish to quote from your editorial "A Charter for Isolation" in the December issue: "It leaves us, says Hartley, with a 'conception of the engineer as no more than a high-grade technician, a functionary not fully professional'."

"This conforms to a view held in this country in a previous age - 1920-50. But it surprises me that you did not correlate the holding of this view with the photo on page 37 of that issue, where 'engineers practice climbing on these short poles'. By our definitions, if British engineers will spend time climbing poles then we would have to say they are technicians."

"The engineering profession downgraded itself for too long in accepting such jobs, even in training; besides who can afford such at present starting salaries of US $22,000 or thereabouts?" J. D. Ryder, formerly Dean of Engineering, Michigan State University.

THE DEATH OF ELECTRICAL CURRENT

Ive Can't's letter in the February issue only serves to illustrate the deficiencies in his knowledge of mathematics and conventional EM theory and the confusion of his own theory. Can he not see that E=V/0 is wrong and H=0/0 is right for mathematical reasons? There is indeed a small change that the latter does not describe correctly the true physics of magnetic phenomena. Models are in fact nothing more than simplified sound.

His difficulty with step waveforms on transmission lines becomes clearer. Of course the conduction and displacement currents are both present in the line together, but only the wave advances. The displacement current dQ/dt is associated with the wave front only (O is constant elsewhere). If the wave reaches a 'correct' exponential termination dQ/dt ceases, the step is terminated and the resistor begins to absorb the energy in the wave. It is precisely because the displacement current flows across the transmission line that the wave is called a transverse EM wave and the displacement current is distinct from the conduction current. The energy associated with the displacement current is stored and can be recovered later (cf. radar pulse generators). It can be seen from Mr. Can't's own illustration (Fig. 5, p. 63, March 1979) that the E vector (dH/dt) and the displacement current vector (dQ/dt) are at right angles, therefore E x H is purely reactive. This is analogous with reactive power (VA), where current and voltage are 90° out of phase. The H vector associated with the conduction current is also 90° to the E field and again no energy is dissipated; the power associated with the conduction current is the displacement current. In a third case, the transmission line is resistive and there is a component of the E field along the line in a direction opposite to the current flow. Here some of the power is dissipated.

Mr. Can't is further confused with regard to electric charge. The existence of electric charge is not a theory; it is a fact like the sun and coal in South Wales. Since one of the manifestations of electric charge is electric potential, any theory of electric waves that dispenses with electric charge must be rubbish. E is the objective of EM theory to explain the various manifestations of electric charge.

Mr. Can't's mathematics is wrong; he does not understand the application of the 'third of Maxwell's wave' and he does not distinguish fact from theory. I'm sorry if he believes his version of Maxwell's theory is correct, it isn't. If he was not satisfied with some changes it would indeed be needed and radio would not work.

Dear Mr. Can't,

Albany, Belgium.

RECHARGING DRY CELLS

With reference to the letter from Mr. D. F. Caudrey (Letter, August 1981) I should like to offer my findings on the subject, and also to quote much of the information from the author.

I have been using the same four SP2 cells for about 11 weeks, five days a week, approximately 1 hour per day. At first I would recharge them (using the circuit and method due to Mr. Caudrey) for about five minutes, twice a week, but now I need to re-charge every day for about 2-3 hours to get an hour's use from the cells. Although I am convinced that the method is feasible in practice, I do not seem to have had the same success as Mr. Caudrey, and so I would like to hear from Mr. Caudrey his recommendations about charging, i.e. for how long, etc.

S. F. Narey, Bradford.

MILLIMETRE-WAVE LENS AERIALS

I have read Dr. K. L. Smith's article on millimetre-wave lens aerials with interest (and some nostalgia as I was in the lens business in the early 1950s) and congratulate him on an excellent introduction to an almost forgotten topic.

Has it occurred to Dr. Smith that his method of fabrication would be equally applicable to another of Wimpern Koch's inventions, the separation lens? This form of lens can be assembled from a set of plates which have been crimped into sinuous propagating guides in the TEM mode and the quasi-optical index is simply the ratio between the widths of crimped and uncrimped sheets. Dr. Smith has thereupon a stack of crimped sheets and a machine to produce a set of path-length lenses.

The separation lens has two advantages over the H0, wave-guide lens. It is unaffected by the spacing between plates, no tolerances are easy, and by arranging for the surfaces of the sinuadial sheets to be normal to the wave surface of the lens where they meet such surface, the beamwidth will be expanded to the flux density without the alternating 1/4 and 1/2 transformers which degrade the side-lobe performance of a waveguide lens in which the refractive index has been pushed too far from unity.

The push-length lens may have disadvantages as well, but since in the best of my knowledge one has never been produced for operational use, perhaps Dr. Smith will identify them by investigating the first thirteen models.

S. D. Jones

Malvern

Worcestershire
CLANDESTINE RADIO

Pat Hawker's review in the January and February, 1982 issues ably covers an area of interest for which much is written in the newspapers and issues of the ISRB (i.e. SOE) factory at Stonbridg, employing mainly services hamleys at St. Albans, which was only one of a large number of similar depots. Although some of the technical people to positively buoyant, and entirely powered by a pedestrian generator. The station was in two main sections, with the main part, which was intended for medium to long range in Balkan, Middle East and Africa countries as well as from Southern Africa. A small number of vehicles was also produced, but not developed, and B MK3 was produced primarily for the use of short range, low altitude.
In a receiver for a binary digital system, the aim is to process the signal in such a way that it is possible to be distinct between two hypotheses, which we label zero and one, with a minimum number of erasures. For this, we seek the best estimate of the original message from the attenuated, distorted and noisy signal in the receiver. Commonly the signal is detected, amplified and filtered and then to a decision gate which is opened for a short interval at the centre of each bit period by a pulse from a clock signal. This interval is known as the decision time. Assume that, for a received zero bit, the receiver output voltage at the decision time has a mean value of $m_0$, variance of $v_0$, while for a received one, the mean is $m_1$, and the variance $v_1$. Figure 1. The quantum noise is signal-dependent, $v_0$ and $v_1$ are different, in contrast to noise-transparent systems. Assume also for simplicity that $v_0 = 0$, has a Gaussian distribution, and the mean, $m_0$, of the signal, equals $Q$, $Q > 0$, measured in units of the thermal noise. The theory of optical receivers enables calculation of $m_0$, $m_1$ and $v_1$, in terms of the received optical waveform and the component values of the receiver. One can then predict the sensitivity of the receiver and model how it is affected by changes in receiver or system parameters. Details of theoretical analysis are listed in the bibliography, and, in the most simple case, is considered here. If the received optical power is measured by a photo-detector and directly, without further processing, the pulse energy for a one-pulse is $P_1$ and for a zero-pulse is $P_0$ in zero. The photocurrent $(i)$ is then $P_0i$ for a one-pulse and zero during a zero-pulse. The current is $I$ for the receiver front-end. A typical circuit is shown in Fig. 9 with the avalanche photodetector and avalanche diode for noise analysis. The photocurrent is then amplified and converted to a voltage by limiting filter $(H)$ resulting in an output voltage $V_{out}$, which corresponds to $m_0$. The noise sources which contribute to $m_0$, and $m_1$ are the amplifier thermal noise, the multiplier noise, the amplifier noise and excess above the shot noise, and the shot noise on the oscillator. The shot noise has been subtracted. In the receiver, determining the response to one photoelectron. Typical values are $10^{-10}$ at a few MHz to $10^{-12}$ at a few hundred MHz. This equation also assumes that the received signal has been normalized to be $b_1$, the optical energy for one pulse.

Shortly before this article was presented, three British Telecom Research Laboratories at Martlesham Heath announced the transmission in the laboratory of an optical signal capable of carrying nearly 2000 simultaneous telephone calls over 100 km of optical fibre, without the need for intermediate repeaters. Operating at 1600nm, this is the longest distance any fibre system has ever demonstrated. Many of the critical components were made in British Telecom Research Laboratories at Martlesham, including the very low-loss optical fibre, which is the most sensitive in the world at wavelengths between 13 and 16 km. The output repeater/amplifier included a single mode diode, of the sort described in this article, with a Pleasan GAT4 M.s.e.f. used for the critical first-stage amplifier.
More detailed treatments listed in the bibliography take into account the shape of the received pulse, noise spreading into neighbouring bit-times because of dispersion, and other system imperfections, and give detailed expressions for $Z$ in terms of the receiver components. Here consider a simple case first and then look at some of the results of the detailed theories. Consider a p-i-n photodiode which has unity gain only. The quantum noise is insignificant, so from equation 2:

$$\sigma_{d} = \sqrt{\frac{m_{p}}{2}}$$

From equation 1:

$$\sigma_{d} = \sqrt{\frac{m_{p}}{2}}$$

With typical component values, $Z$ might be $10^4$. So with $\beta = 6$, we need 12,000 photodetected electrons per one-pulse, in agreement with the earlier rough calculation. Using discrete components, a unity-gain photodiode has a receiver sensitivity typically 10 to 15 dB worse than an avalanche diode. However, by hybrid integrating the p-i-n photodiode with the first amplifier stage using a gallium arsenide m.e.t.f., the input capacitances of the receiver can be reduced so that it falls to 10,000 or less. The receiver noise parameter $Z$ is proportional to $C_{eq}$, at high data rates where $C$ is the total input capacitance (photodiode, gate-source and stray capacitances) and $g_{m}$ is the transconductance. In state-of-the-art receivers, $Z$ is around 0.5 $\text{pS}^2$ and $g_{m}$ is 20 mS. Such receivers have a sensitivity of $-44.2$ dBm at 160 MHz and $-40$ dBm at 294 Mbaud at 13.6um wavelength, and similar sensitivity at 15.5um, better than that of a p-i-n. Reciprocally, it might be possible to design a receiver using discrete components at a few hundred Mbaud, and with zero optical power on zero-pulses and no pulse spreading.

It can be seen that when the dark current is negligible, we need about 300 to 1500 photons per bit-time, depending on the noise properties of the photodiode. When the dark current is large, the number of photons per bit-time which is needed is roughly proportional to the square of the number of dark current electrons. The noise properties of the diode become far less important. The noise from the dark is hardly surprising as the dominant noise is the shot noise on the dark current, and both are subject to the excess noise of the photodiode. The optimum gain decreases markedly once the dark current has become a significant noise source.

Clearly it is important to minimize $N_{d}$ and to a lesser extent to reduce $V_{m}$.

Note that a leakage current of 160 $\text{nA}$ gives $N_{d}$ of 100 at 1Gbaud, which is large enough to dominate the receiver sensitivity. At lower data rates the effect would be less important.

Fig. 13 shows how $\sigma_{d}$ and $\sigma_{p}$ vary with extinction ratio $e$ and pulse spreading (extinction ratio is the mean power on zero-pulse divided by the mean power on one-pulse; if it is not zero the optical power on the zero level contributes to the noise).

The r.m.s. width of the impulse response of the fibre normalized to the bit-time $T$, and assumed to be Gaussian in configuration, is a measure of the bandwidth of the fibre.

Further developments

The above considerations relate to the situation in which the optical receiver is used in a free space communication system. In the case of a fibre optic system, the situation is somewhat different. The major factors which affect the performance of an optical fibre system are the optical fibre itself, the optical source, the optical detector, and the electronic circuitry used to amplify and process the received optical signal. The major factors which affect the performance of an optical fibre system are the optical fibre itself, the optical source, the optical detector, and the electronic circuitry used to amplify and process the received optical signal.

In brief

Optical fibre communications technology has made significant progress in recent years. This progress has been driven by the increasing demand for high-speed data transmission over fibre optic cables. Optical fibre cables offer several advantages over traditional copper wire, such as higher bandwidth, lower signal attenuation, and lower interference. These advantages have made optical fibre cables an attractive option for data transmission applications, particularly in the long-haul and wide-area network markets. As a result, optical fibre communications technology has become an essential component of modern communication networks.

In the past few decades, optical fibre communications technology has undergone rapid advancements, with the development of new materials, devices, and systems. These advancements have led to the deployment of optical fibre communication systems in a wide range of applications, including telecommunications, signal processing, computing, medicine, and military. Optical fibre communications technology has become an increasingly important area of research and development, with ongoing efforts to improve system performance, reduce costs, and expand the range of applications.

Regarding the state of the art in optical fibre communications technology, there are several key areas that have been the focus of recent research and development efforts. These include advances in optical fibre materials, improvement of optical fibre devices, development of new optical fibre systems, and the integration of optical fibre technology with other communication technologies. As these areas continue to evolve, optical fibre communications technology is expected to play an increasingly important role in modern communication networks.
Cables and politics

A broadband cable system connected to all houses in urban areas and covering about half the population is the recommendation of the Government's IT Advisory Panel. Although all the services to be provided are not yet known, it is suggested that the system should include video transmission facilities for, say, television, and it also recommends that the system should have a two-colour system for colour television, in addition to a black-and-white signal. The panel stresses that a single reference signal be fed through a cable, probably coastal, with colour selection provided at the distribution point, therefore providing the full broadband services and would be able to serve up to 100 houses. The panel also states that the colour system should be separated from the black-and-white system, and that existing cable distribution networks are coming to a high telephone value when they are provided with broadcasting transmitters. The panel states that the system would be a way of distributing the direct broadcasts from satellite, the PAL system comes out of patent restrictions at the end of 1983 and could lead to a flooding in the large-screen TV market of cheap black-and-white sets for Far East, leading to the cost of our domestic television manufacturing. If a set takes a great deal of money to implement, but with additional equipment, others can be provided, to add a return on their investment.

Satellite TV gets go-ahead

On the fourth of March, the Home Secretary, William Whitelaw, announced in the House of Commons that the country should make an early start with direct broadcasting by satellite (DBS), with the aim of having a service in operation by 1986. Because of the importance of making this early start, the Government had decided that the best course would be to start with two channels, and the plan is to allow an increased interest in the domestic market and to take advantage of satellite signals and cable distribution. The system is to be operated privately, and there were indications that there were interested participants in the aerospace and electronics industries who were ready to pay a start-up fee.

As far as the programmes were concerned it had been decided to award both DBS channels to the BBC as they had already formalised proposals to provide the channels. One channel would be a subscription service including a substantial element of feature films, and the other channel would be one that would provide educational services. There was an indication that the BBC may have a view of subscribers to the education channel to increase at the same time the number of subscribers for educational purposes. The system would probably have the capacity for two TV channels and three or four communication channels. There could be sufficient bandwidth to transmit high-definition TV and digital TV channels and also the primary channel for transmitting a Private Service type of service would be available for any kind of service which would draw on the best programmes from around the world, and would probably be financed by a supplementary levy.

The Home Secretary said that although the IBA and commercial television companies had not shown much interest in providing DBS services, "their plans were less advanced. Additional services are to be provided through the system." The government intends to make a decision about the right framework, which would be likely to involve the IBA. But the IBA say that their proposals for satellite broadcasting are as well prepared as any from the outside. It is believed that the government's study document on DBS last year, the IBA has argued that it may be too early both for the colour standard and the quality of the service. The government's intentions are still in the round about the green plan and there is a possibility that there could be a market for this service.

The Home Secretary is likely to be more than a little disturbed by the fact that the British Satellite Broadcasting (BSB) is to be allowed to launch a second channel and with the second as a standby and a third in the field for early launching. Additional services will aid satellite networks around the world and there is a possibility that a market for up to 100 of them.

The IBA is participating in the experimental satellite service, organized within the EBU. The five-week TV experiment, at the end of the fifth week, including the BBC, have each with a different language and the IBA's satellite service. The experiments were switched on, but there is no further replacement for these components. A spokesman said that a number of people were wondering whether the redundancy so far from experiment was adequate and they were confident that the British Satellite Broadcasting (BSB) is to be allowed to launch a second channel and with a third market for the satellite of seven years and more. They were pleased that the Federal German IBA has been launch in 1986 and the IBA has suggested that the all-British satellite should carry that service.

Maritime satellite gets sunshine

What was to have been a blaze of publicity when the Minister for Information Technology, Mr Peter Zhao, announced the beginning of a satellite-to-ship telephone call by way of the new European Space Agency (ESA) satellite appeared to have been damped when it was announced that the new satellite, which was one of the criteria, had been delayed until the astronauts had been successfully launched on the space shuttle.

The news had been over-anounced on the broadcast of the satellite in television in the important market of the United States, but the new satellite is expected to be available in Europe and to be launched by ESA to an international television audience. In all 300 television programmes, four times the capacity of the Maritime satelite will replace. It is also 11 degrees further west than Martian and so can cover the western part of the Gulf of Mexico and some of the eastern Pacific. In addition to telephone service the satellite can be used to receive and transmit fax, facsimile and digital data links. There is also a special signal link which can receive in the UK, and in the United States, the satellite communications station has been inaugurated at Ely, west of the Gulf of Mexico. The satellite to be launched on the 28th July, will be the first successful commercial satellite in the UK, and will be used for television, and to enhance customer choice within the UK.

IBA consent was required because the analogue system is not compatible. 3-D can only be seen by viewers using special black-and-white sets and to be seen on black-and-white sets will merely see a pair of flat images. Viewer's who don't have the analogue sets will see merely a pair of flat images.

Colour scenes cannot be transmitted, since the colour-coding is already being used for 3-D separation. The left-eye image is put out on the red channel and the red and blue phosphors replace the right-eye image. In fact, the colour scene is coded in this way, a certain sensation of the colours of the scene is retained even through the red-green glasses. As the brain attempts to add together the differing information received from each eye. But ambition and some discretion is caused by a pair of colour scenes, but none are expected to be inserted in the first programme. The research behind the German programme has been carried out in the Ely broadcasting Laboratories of Philips Ltd. Analogue image separation on TV is at best imperfect, since the green phosphor on the tube have a high red-green contrast, and the red phosphor should be doped the left eye sees some of the green image, which could be good news for viewers. In addition, colour coding within the PAL transmission system is accepted with some spread of colour information to the wrong place. Philips have developed a method of coding the matrix phase which remains secret, to eliminate this overlap and ensure only one of a pair of images that can be obtained within the PAL system. The greatest problem remains the provision of the colour-aided magnetic spectacles. TVs has obtained half of the audience with colour systems, and are distributing on one in every four TV sets. It seems there will be at best one viewing device to each set, so the programme is being scripted to allow time for it to pass from hand to hand. The programme cannot be cabled outside the South region, because of the lack of sufficient spectacles. Lucky viewers outside the region who are able to pick up the signal will have to make their own arrangements to get hold of a pair of spectacles.

Marinus A maritime communications satellite suffers from annoying causes by an overactive brain.

Eurpean Space Agency's communications satellite system. The three European space agencies had already investigated potential markets, and the technical and operational issues involved both in the short and long term. The system would probably have the capacity for two TV channels and three or four communication channels. There could be sufficient bandwidth to transmit high-definition TV and digital TV channels and also the primary channel for transmitting a Private Service type of service would be available for any kind of service which would draw on the best programmes from around the world, and would probably be financed by a supplementary levy.

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is to introduce a new Telecommunications Bill towards the end of the year. The Bill will propose the setting of about half the share of BT in the public and to establish a new telecommunications authority to oversee the provision of cable tv, telephone, data and electronic mail links. The so-called Barry Bonds, announced by the Chancellor in the Budget with which it was planned to direct public investment into BT, are now likely to be replaced by the much wider de-nationalisation. BT say the report is "your specialisation".

Bildschrifttext
At the heart of Prestel in the GEC 4800 computer which uses its own language, Babbage. With a five-year lead over any rival, GEC must have felt that they had a very good chance in the world's markets and particularly in Europe. That confidence received a severe blow, however, when the West German Bundespost placed an order worth several million with IBM. What was even more galling was that IBM have not demonstrated any system in public.

The GEC equipment has undergone a field trial in Germany, and the Bundespost has selected a Prestel-based system as, recommended by the CEP, but the selection of an IBM system means that IBM will have to write all the software for the contract deadline in 1983.

Sweden in space by 1984
Sweden's Space Corporation is in fact to be given the go-ahead for its space research program, more than double the 1978-80 figure. About half of this will be contributed to the European Space Agency where Sweden collaborates actively in the programmes of research. But in national programmes includes its own space research where the largest project is the Viking satellite, to be launched by Astrium in 1984 for North Pole magnetosphere studies, as well as the industrial Tele-X project. Due for launch in 1986 from Guyany Space Centre, South America, Tele-X is an experimental telecommunication satellite that will have pre-operational direct broadcast applications. And it will provide high-speed digital communication for inter-office links, a teleplayer service to mobile stations in vehicles, and propagation measurements in the 20-50GHz band for high-speed digital data communication, as well as widespread services.

Monitoring oil spills is the chief application of the Corporation's other main programme - in remote sensing. Marine surveillance from aircraft determines oil volumes and thickness, a microwave radiometer while a laser fluorosensor classifies oil type, this information being transmitted to oil combat vessels. Remote sensors also monitor ocean ice distribution and thickness, atmospheric pollution and map vegetation, deserts and lake water to study seasonal changes.

The Corporation manages the Europe station which receives, processes, stores and distributes images from ESA satellites in the Earth echo, and has already collected data from Landsat. The station operates incoherent sounding of Earth targets by use of a coherent radar system (see PW February 12, page 37).

Where is Chernobyl?
The position of the Russian electronics engineer Boris Chernobylsky who, as we reported in October 1981, we understood had been released by the KGB, is giving his wife Elena great cause for alarm. According to latest reports and on a relatively trivial charge (biting a policeman), Chernobylsky was sentenced to one year's imprisonment in a labour camp, much against the wishes of the court, who came under a great deal of pressure from the prosecution. He has the extended five-year sentence.

The court sentence was that Chernobylsky be taken to the labour camp immediately, but instead was held in prison for two months, whereabouts are unknown. According to our informants, he started his journey to the camp many weeks ago, but neither his destination nor present whereabouts are known, in spite of a telegram from his wife, L. Brezhnev, to the Soviet ambassador to which she has had no reply. His wife and friends fear that his disappearance is the result of summoning Chernobylsky for a "light" sentence, and that his health will be damaged by the extremely severe conditions on the journey and in the labour camp.

BCC micro
The BCC micro program listings at the Paisley Microelectronics Educational Development Centre, John Gordon tells us. Routing the instruction prompt should be

WIRELESS WORLD MAY 1982

Also in this issue

Book notes 49
Communication news 42
Competition

In our next issue 77
Langmuir thin film trough for "molecular electronics" at Teledon videotex in the UK 40

Scratchpad data defined. Location of the scratchpad is at the option of the programmer.

WIRELESS WORLD MAY 1982

by H. S. Lynes

Most commercially available e.p.r.o.m. programmers are expensive as they include software and other facilities to enable them to be used on their own. The cost of a programmer can be significantly reduced if it is designed for use with an existing microprocessor system as shown in this second of two articles. The design presented is for 2708, 2716 and 2532 e.p.r.o.m.s, but relatively simple modifications other devices may be programmed.

On entering the program one is given the system options and prompted to reply either Y (yes) or N. Next the addresses are requested, in read mode, starting from 0000. If the e.p.r.o.m. already has data in the first 256 locations the system asks if this is to be erased. If so, even though it is intended to reside at, say, DCBO. Options and addresses are displayed after each entry, and if sufficient information has been given the program requests that if it has the intended five-year sentence. The court sentence was that Chernobylsky be taken to the labour camp immediately, but instead was held in prison for two months, whereabouts are unknown. According to our informants, he started his journey to the camp many weeks ago, but neither his destination nor present whereabouts are known, in spite of a telegram from his wife, L. Brezhnev, to the Soviet ambassador to which she has had no reply. His wife and friends fear that his disappearance is the result of summoning Chernobylsky for a "light" sentence, and that his health will be damaged by the extremely severe conditions on the journey and in the labour camp.

It is useful to use lower-case characters for data names he points out: this can even the program round the problem which is keywords appearing at the beginning of a statement.

Also in this issue

Book notes 49
Communication news 42
Competition

In our next issue 77
Langmuir thin film trough for "molecular electronics" at Teledon videotex in the UK 40

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Also in this issue

Book notes 49
Communication news 42
Competition

In our next issue 77
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Also in this issue

Book notes 49
Communication news 42
Competition

In our next issue 77
Langmuir thin film trough for "molecular electronics" at Teledon videotex in the UK 40

WIRELESS WORLD MAY 1982
using the small d.i. switch next to the socket, and enter the necessary information to fill the scratchpad. After pressing G set-up the R55 ports by sending 82 (hex) to the control register at X501. The starting address of the e.p.r.o.m. is placed in the address ports A and C. The control pin-profile is OR-ed with the address in port C and the data read out from the e.p.r.o.m. from the address of port B. This is stored in the area of r.a.m. pointed to by C.A.D using the indexed mode of addressing. CAD and CAP are checked to make sure they are not outside limits and only then will be incremented until the needed data is placed in system r.a.m.

The time this takes is quite short, but it is possible to run a program from an e.p.r.o.m., in the programmer without considerable delay and a dedicated program to do it. In my system a facility exists to move some of the system r.a.m., beginning of which is in the pin-profile d.i.1 switches. Thus by using a toggle switch the r.a.m. can be made to behave though it was a programmed e.p.r.o.m., residing at the same address as the e.p.r.o.m. will in the finished system. This may be write-protected if desired. Ensure that only one device is enabled when shifting.

Programming. This is more difficult, since the e.p.r.o.m. needs to be given a program pulse for a defined time. An external voltage is required, about 240v (max) to allow for losses, and on my system a circuit measures this voltage and turns on an i.e.d. if it is correct. Thus the light indicates that the e.p.r.o.m. can be programmed. The use of a built-in program voltage is left to you; if the ports are likely to be used for general use I think it is safer to bring it in separately. Pin selection d.i.1. switch, address entry, etc. is as explained for reading. After pressing G the e.p.r.o.m. is placed in the write condition instead of the pin-profile described. A program pulse is applied to OR-ing CAP with the pin-profile and placing it at the port. This is timed using the delay routine, after which the address OR-ed with the write pulse-off pin-profile and stored at the port. Thus the port is in the write mode all the time, some of which is in the pin-profile mode; the e.p.r.o.m. address is only changed when the port is in plain write mode.

The choice of software timing for the pulse or the use of a monostable is not important; if you choose monostable timing the clock frequency is not important; but a monostable is another i.e.d. to wire and could be susceptible to interference. Software timing has its critics too, but when other e.p.r.o.m.s as well as 2760s are to be corrected for it is justified in my view. Programming does take time — typically one minute for every 1024 x 8 bits. Thus for the processor is tied-up for at least four minutes. If any interference occurs during this time it could cause trouble, so there may be some advantage to be gained by switching off any well-known generators of interference. In the home this can include anything with a thermostat control inductive load, etc.

Take care in the design of a close-fitting lid on the board to prevent the incidence of u.v. burns to eyes or skin. It is a neat quan to include an interlock which breaks the programming circuit (in the programme) whenever a separate interlock may be used during the erase period. The addition of a timer is a useful refinement to the programme. Clean the l.c. window before erase — after it may be covered to guard against possible loss of data when it has been programmed. And keep the e.p.r.o.m.s in conductive foam whenever possible to prevent electrostatic charge damage to the die.

Whilst this programmer satisfies the initial design requirements there is no reason why you cannot improve it. For instance, the on-chip circuits, the computer based programmer, can be developed in a separate header which may be used in a patch-board, in the same way that the d.i.1 switch was necessary in Fig 6. The 26V transistor interface, Fig 7, is tolerant of the value of output capacitance indicated although the recommended waveform is in the chart. The chart indicates which output is at high potential, which should be typically 26V to ensure that the minimum swing of 26V is maintained. Reset logic prevent unpowered voltage appearing on the e.p.r.o.m. when an output port is arranged so that logic 0 — 0V, 0 — 6V, etc. is the output showing the programming switches are set for the d.i.1. switches. You may find it useful to consider the possibility of setting up a separate facility for a separate header which may be used as a patch-board, in the same way that the d.i.1 switch was necessary in Fig 6. The 26V transistor interface, Fig 7, is tolerant of the value of output capacitance indicated although the recommended waveform is chart. The chart indicates which output is at high potential, which should be typically 26V to ensure that the minimum swing of 26V is maintained. Reset logic prevent unpowered voltage appearing on the e.p.r.o.m. when an output port is arranged so that logic 0 — 0V, 0 — 6V, etc. is the output showing the programming switches are set for the d.i.1. switches. You may find it useful to consider the possibility of setting up a separate facility for a separate header which may be used as a patch-board, in the same way that the d.i.1 switch was necessary in Fig 6. The 26V transistor interface, Fig 7, is tolerant of the value of output capacitance.
Within 80ms a mass of 1/4kg can be moved a distance of four inches and stopped to within a quarter micron of a specified point — this article shows how.

**Fig. 1.** Four methods used for mounting disc-drive positioner carriages. Common purpose of these is to allow only one degree of freedom, ideally along radius of the disc.

**Fig. 2.** Mounting read/write heads side-by-side in multi-platter drives reduces height of the disc pack and hence weight moved by the positioner, but alignment between carriage centre line and disc radius becomes more critical. Here, the heads are aligned at track A and the error caused by carriage-track radius misalignment becomes apparent at B.

In any positioning system the most crucial components are the prime mover and the transducer used to describe the position and velocity of the element under control. Here, the main features of disc-drive positioners, including feedback loops and control circuits, are described.

With the exception of fixed head and Winchester type disc drives, the read/write heads are mounted on a rigid platform called the carriage. This carriage has one degree of freedom (radial) to the drive spindle and is restricted by guideways, usually in the form of rails or bars; in most cases, the carriage runs on ball bearings, one or more of which is spring loaded to take up play and ensure that the bearings roll instead of skidding. Not all carriages run on ball bearings — some run directly on the guideway — but in either case, four types of those that do are constructed is shown in Fig. 1. Rotary positioners, such as those used in Winchester disc drives, will be described in a subsequent article.

In multi-platter drives, the heads are usually mounted side-by-side between the platters to reduce the overall height of the pack and minimize the weight of the carriage. The part of the carriage to which the heads are attached is often called the T-block because more often than not it is T-shaped. For convenience, the two sides of the T-block are designated A and B, and each side will have upward and downward facing heads. So in this case there are four read/write head labels, A-up, A-down, B-up and B-down. A and B heads designed for opposite directions are similar in appearance but if they are mistakenly interchanged, slipper sereodynamics will be affected, so the head type is usually clearly marked. Slots in the T-block allow radial adjustment of the heads.

As the heads are in two rows, it is vital that the centre line along which the carriage travels is precisely on the disc radius. Figure 2 shows why. Alignment fixtures provided with the drives allow the heads to be accurately aligned and, equally important, keep the head adjustment standard between drives using interchangeable discs.

**Motive power**

There are three main methods of driving the carriage — hydraulically, by moving coil or by electric motor.

**Hydraulics**

The first moving-head disc drives stored data at very low density by modern standards, so if large amounts of data had to be stored, large discs had to be used. Some of these discs measured several feet in diameter. The carriage was equally large, and the only practical way of moving it was by hydraulics. Much research into hydraulic systems for applications such as power-operated gun turrets on military aircraft had already been carried out so the design of a system for driving the carriage of a disc drive was simplified.

Figure 3(a) shows the essentials of an hydraulically powered positioner, in which the pump may be driven either by the spindle motor or by a separate motor. The accumulator is required for rapid stalls, when the peak-flow requirement is greater than the pump can deliver; the analogy with a power supply capacitor is clear. Fluid pressure is regulated by a bypass valve, the fluid equivalent of a zener diode and the selection of solenoid-operated valves with calibrated orifices are used to move the carriage at different speeds. Some drives with hydraulic positioners would move from their position in the control room, because of the reaction from fast carriage acceleration, and had to be moved back into place from time to time. Behemoth drives had two parallel spindles with opposed positioners between them to cancel out this effect, Fig. 3(b).

**Moving coil.** As head and medium design improved the storage density increased, allowing the platters to be made smaller. This made the carriage smaller and lighter so less power was required to move it. At the same time, advances in semiconductors technology brought down the price of power transistors. It thus became feasible to use a moving coil to drive the carriage, with the further weight reduction of the carriage that the principle allows being added to reduce access time.

A typical coil has a diameter of three inches and works in the radial flux from a permanent magnet weighing about 30 pounds. Smaller drives use a copper wire coil on a glass fibre former, but larger units may use self-supporting coils wound from rectangular-section aluminium strip. Aluminium has a higher strength-to-weight ratio than copper, and this consideration outweighs the disadvantage of higher resistance. The coil frequently requires forced air cooling in large units. The assembly is usually described as an e.m.a. (electromagnetic actuator), Fig. 4.

**Electric motor drive**

There are two main types — one is as shown in Fig. 5. In the first, the motor drives a leadscrew which moves the carriage as it turns. In some cases a stepping motor is used, where the stable positions of the motor correspond to the positions of disc cylinders.

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*B.Sc., M.Sc., Digital Equipment Co.*

"Digital Equipment Co."
The motor in the second type drives a drum which imparts linear motion to the carriage through flexible steel wires. These two types are normally used only in small drives.

**Detenting**

When the carriage is held at rest with the heads correctly aligned above the disk tracks, it is said to be detented. Early drives used mechanical detenting where paws on a detent actuator move to engage a rack on the carriage. Figure 6 shows a two-phase detent mechanism, where the spacing between cylinders is one half the rack pitch. Mechanical detenting can be found on both hydraulic and moving coil positioners, and the pawl will be operated by a ram in the former case, or by a solenoid in the latter. The teeth on the rack are symmetrical so that after the detent has engaged, some forward drive can be applied to take up any backlash without fear of the pawl jumping out of engagement. The detent actuator is a fine piece of precision engineering, and as such is expensive. Recent drives take advantage of the falling cost of electronic circuitry and employ electronic detenting where the carriage is held by a feedback loop using a position transducer. Should for any reason the positioner fail itself off track, the position transducer generates an error voltage which will drive the carriage until the error is cancelled. When operating in this way the carriage servo system is said to be in detent mode, track following mode, fine mode or linear mode, depending on the specific documentation consulted. During a seek, the servo system changes to velocity mode, also known as coarse mode. There are the two major operating modes of the servo.

**Transducers**

The purpose of a transducer will be one or more of the following:

- to count the number of cylinders crossed during a seek,
- to generate a signal proportional to carriage velocity, or
d-to generate a position error proportional to the distance from the centre of the desired track.

The third type is illustrated in Fig. 7. The first path of the transducer is completed by a rack on the carriage, often the same one as is used by the detent actuator. As the rack moves, the reluctance of the two limbs will rise and fall, and as the secondary coils are wound in opposition to each other, the output will be alternately in and out of phase with the input. A phase-sensitive rectifier gives a binary output which can be used to count cylinder crossings during a seek. As no accurate position error or velocity information can be extracted, this type of transducer is restricted to use in mechanical detent drives, in conjunction with a magnetic-velocity transducer. Adjustment of carrier-wave transducers is critical, as the signal becomes rapidly attenuated if the distance from the rack is too great, but the transducer may be damaged by the rack teeth if the clearance is too small.

**Optical transducers.**

These devices consist of gratings, one fixed and one movable. The relative positions of the two will control the amount of light from an I.D. or both which can pass through to one or more photo-transistors. Referring to Fig. 9, it can be seen that this class of transducer falls into two categories:

- Moiré-fringe
- parallel-grating.

In a Moiré-fringe transducer the bars on the moving grating are not parallel with the bars on the fixed grating. Relative movement causes a fringe pattern which travels at a right angle to the direction of motion. This results in sinusoidal modulation of the light beam.

In the second type, all the bars are parallel so the sensor's output is a triangle wave. In both types of optical transducer, the spacing between the two gratings is critical.

Whether the waveform used for counting cylinder crossings is sinusoidal or triangular is not important, so the choice between the two transducers is governed by whether a position error or a velocity signal is required. The slope of a sine wave is steeper in the zero region than an equivalent triangle wave so it is more useful for detecting position. Conversely, the constant slope of a triangle wave is easily differentiated to produce a velocity signal. Because the differential of a triangle wave changes sign twice per cycle, a two-phase optical transducer can be used to produce a continuous velocity-output signal. The stationary grating has two sets of bars with a 90° phase relationship and the resultant

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**Fig. 4.** Parallel bar and Moiré type gratings used to modulate a light beam produce triangle and sine-wave outputs, respectively. These gratings are used to detect position and velocity.

**Fig. 5.** Mechanical detenting. Detent pawl is split and has two sets of teeth at 180° to each other. At (a), the carriage is detented to an odd numbered cylinder and the upper pawl teeth are engaged. The lower pawl, represented by the broken lines, acts against the tops of the rack teeth. In (b), the carriage is detented at an even cylinder and the lower pawl is engaged. Tooth pitch on the rack is twice the carriage spacing.

**Fig. 6.** Carrier wave cylinder transducer. Oscillator feeds the transducer primary coil and the two secondaries are connected in opposite phase. Output signal phase, determined by the relative reluctance of the magnetic circuit's two limbs, is a function of the rack position. These examples are given with associated waveforms.
wavelengths are referred to as sin and cos, even if they are triangle waves. The two waveforms and their complements, known as sin and -cos, are differentiated and the four differentials in turn at times when there is no sign change. This process of commutation is achieved by f.e.t. analogue switches controlled by comparators looking for points where the input waveform crosses. The result is a clean output signal proportional to velocity.

Where one transducer has to generate all three of the required parameters, Moiré type gratings are preferable because of their better position-error detecting performance. A certain amount of ripple on the velocity output derived from a sin wave has to be accepted.

Optical transducers often contain additional light paths to aid carriage-travel limit detection. The resulting signals may be used during the head-loading sequence to position the heads at cylinder zero, as the sine or triangle outputs are cyclic and do not give an absolute cylinder address. Mechanical dent drives pose the problem of finding an absolute reference to the cyclic output from the rack transducer. One solution is to drive the carriage forward slowly until it contacts the forward stop, and then to preset the cylinder count to two or three cylinders more than the maximum.

Seeking

A seek is a process where the positioner moves from one cylinder to another. The speed with which a seek can be completed is a major factor in determining the access time of the drive. The main parameter controlling the carriage during a seek is the cylinder difference:

cylinder difference = desired address - current address.

The cylinder difference is a signed binary number representing the number of cylinders to be crossed to reach the target cylinder, direction being indicated by the sign. The cylinder difference is loaded into a counter which is decremented each time a cylinder is crossed. The counter drives a d-to-a converter which generates an analog voltage proportional to the cylinder difference. As shown in Fig. 10 this voltage, known as the scheduled velocity, is compared with the output of the carriage-velocity transducer. Hence any difference between the two results in a velocity-error voltage, which is then used to reposition the carriage before cancelling the error. As the carriage approaches the target cylinder, the cylinder difference becomes smaller with the result that the run-in to the target is critically damped (velocity = distance) to eliminate overshoot. Figure 11(a) shows graphs of scheduled velocity, actual velocity and actuator current with respect to cylinder difference during a seek. In the first half of the seek the actual velocity is less than the scheduled velocity causing a large velocity error. This saturates the servo amplifier, providing maximum current to the actuator which in turn accelerates the carriage to reduce the error. In the second half of the seek, the scheduled velocity falls below the actual velocity generating a negative velocity error, and the servo amplifier is now driving a reverse current through the actuator to decelerate the carriage in accordance with the schedule. The schedule deceleration slope can never be steeper than the saturated acceleration slope. Areas A and B. The current graph will be almost equal, as the kinetic energy put into the carriage has to be taken out. Any difference will be due to friction and other losses. The current through the coil is continuous which would result in a heating problem, so to counter this the d-to-a converter is made non-linear so that above a certain cylinder difference no increase in the scheduled velocity occurs. This results in the graph of Fig. 11(b). The actual-velocity graph is called a velocity profile, and consists of three regions: acceleration, where the system is saturated; a constant-velocity plateau, where only enough current is required to overcome friction, and the scheduled run-in to the desired cylinder. Deceleration is only significant in the first and last regions. The effect of carriage velocity on dissipation is as follows.

Carriage acceleration, \( a = \frac{d^2v}{dt^2} \)

where \( t \) is the seek time. Dissipation is \( I^2R \), which is proportional to \( a^2R \)

\[
I^2R = \frac{1}{2} \int (\frac{dv}{dt})^2 dt
\]

Average carriage velocity \( v = \frac{1}{t} \int v dt \), therefore, dissipation:

As a result, it is necessary to limit the maximum velocity of the positioner very accurately or severe overheating of the coil or amplifier may result.

A consequence of the critically damped run-in to the target cylinder is that short seeks are slow. Sometimes further non-linearity is introduced into the velocity schedule to speed up short seeks. The velocity profile becomes piecewise linear approximation to a curve by using non-linear feedback. Figure 12 shows the effect of using a shaper or profile generator, as this device is known.

Servo amplifiers

In small disk drives the amplifier is usually linear in all modes of operation, resembling nothing more than an audio output stage. As the scheduled velocity signal comes from a d-to-a converter, the deceleration ramp is detected by a staircase waveform. When the staircase is compared with the actual velocity signal, the resulting velocity-error signal contains an a.c. component due to the steps. This increases e.m.a. dissipation and can cause an audible output from the coil - a problem that is sometimes solved by adding a saw-tooth waveform, at the same rate as the steps, to the shaper output. This approach is shown in Fig. 13.

Larger units employ pulse-width modulation to reduce dissipation in the servo amplifier. The duty cycle is established typically by comparing the velocity error with a sawtooth waveform. A simplified example of this process is shown in Fig. 14. Appropriate electromagnetic radiation is caused by p.w.m. servo systems, but this is generally of no consequence as no data transfer takes place during a seek. In track following mode, p.w.m. servos revert to a linear amplifier configuration, which is why the term linear mode is often used to describe the detented state of the positioner.

The input of the servo amplifier normally has a number of analogue switches which select the appropriate signal according to the mode of the servo. As the output of the position transducer is a triangle or sine function, the sense of the position feedback loop has to be inverted on odd numbered cylinders, to allow detenting on the negative slope. In some cases a different velocity transducer is used when the heads are being retracted from the pack. Figure 15 shows a typical servo-amplifier input-selection circuit.

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Head alignment

On drives where interchangeable discs are used, the distance between the read/write heads and the spindle axis is critical. So to set the heads, an alignment disc (sometimes called a 'custom engineer') containing premarked flux patterns at a reference cylinder is used. Figure 16 shows a typical alignment-disc pattern and resulting oscilloscope waveforms for correct and incorrect head alignments.

Disc rotation, cooling, filtration, power supplies and safety will be discussed in the next chapter.
DESIGNING WITH MICROPROCESSORS

Linking a microprocessor with a printer directly is wasteful: much time can be saved by sending data to a buffer for reading at a slower rate. Professor Zissos concludes his series with two articles on programmable I/O chips, this first on basic concepts, and the second on design procedure and implementation.

by D. Zissos and Janne Fleus

Every new item of data before it accepts it: the pulse on handshake line h2 can be used directly for this.

In summary, the step-by-step operation of the handshake system in Fig. 2 is as follows. The source monitors status line h1 to determine whether the port is full or empty. If empty, it outputs the next item of data and pulses line h2, which strobes the data into the port and sets the status flip-flop (h1 = 1) by pulsing its clock terminal. This constitutes the write operation; the read operation is initiated by the acceptor when line h1 is high. When the data is read it resets the status flip-flop by pulsing its clear terminal.

Fig. 1. Fast device feeding a slow device needs buffer stage to avoid microprocessor wasting time.

Fig. 2. Handshake signals are exchanged before data is transferred from source to buffer and buffer to acceptor. Source monitors status line h1, as it sees the port empty. Line h2 then strobes data into port. Read operation is initiated by the acceptor when h1 is high.

Fig. 3. Status flip-flop generates signal h1. With h high and K low, pulses on line h2 set circuit and on h3 resets it.

Fig. 4. A handshake system requires two interfaces, one to coordinate source/buffer activity and the other acceptor/buffer activity.

Fig. 5. Microprocessor-based system with input port and source (paper tape reader), top, output port and acceptor (printer), bottom.

To implement a handshake system requires two interfaces, one to coordinate the activity of the source with the activity of the buffer, and the second to coordinate the activity of the acceptor with that of the buffer, Fig. 4.

Because most commercially-available microprocessor systems are normally provided with ports which are already interfaced to them, one needs only consider interfacing peripheral devices to the ports. Therefore microprocessor-based systems with 10 ports can be represented by the block diagrams in Fig. 5. A paper tape reader and printer act as source and acceptor because their action is easy to visualize— they can be clearly replaced by any other device, equipment or process.

Next article—Design steps and implementation.
The applications of the cepstrum to speech analysis are mainly connected with its ability to separate source and transmission path effects, provided they have different frequency contents. This is usually the case with speech where the source spectrum is very flat, containing a large number of harmonics of the voice pitch, but is modified by the resonance characteristics of the vocal tract, the so-called formants, which determine which vowel is being uttered. Fig. 13 shows spectra and cepstra for the vowels "ah", "o" and "ee" and illustrates how the differences mainly lie in the low frequency part of the cepstrum, which is dominated by the formant characteristic. Non-vocoded sounds, such as many consonants and whispered speech, do not give peaks in the cepstrum corresponding to the voice pitch, and one of the earliest applications of the cepstrum was to separate voiced and non-vocoded sounds and to measure voice pitch.

It is also possible by editing in the cepstrum to remove one effect completely, for example the voice, and thus simplify the tracking of the formants. Fig. 14 from ref. 11 shows a typical situation, a three-dimensional representation of the section "ee" from the word "Montreal". The picture is confused but by short-pass liftering each of the spectra to remove voice components, as shown in Figs 15 and 16, only the formants are left and the picture becomes much clearer.

The cepstrum can be used for efficient vocoding and transmission of speech. Most of the intelligence is contained in the low frequency part of the cepstrum so only this is transmitted, along with information as to whether the voice is voiced and if so its voice pitch. As the receiver end the speech is reconstructed using the low frequency information to generate a filter character.

Fig. 15 shows spectra and cepstra for the vowels "ee" of "Mona" 

In gearbox vibrations deviations from exact uniformity of each toothmesh show up partly as harmonics of the shaft speed and also as sidebands around the toothmesh harmonics caused by modulation of the toothmesh signal by the lower rotational frequencies. The sideband spacing thus contains valuable information as to the source of the modulation and can be extracted using the cepstrum. The cepstrum has the two advantages of being able to detect periodicity not immediately apparent to the eye, and of being able to measure it very accurately because it gives the average sideband spacing over the whole spectrum.

The first advantage is illustrated in Fig. 17 where the rotational speed of the second gear, even though this was idling being first gear was engaged.

It was traced to the rotational speed of the second gear, even though this was idling because first gear was engaged.

References

3. Thrane, N. Application of a long memory FFT analyzer in speech analysis. BAK application note 43.
Appendix A
Calculation using FFT analyzer and calculator.

Even though the analyzer basically performs a forward transformation of 1024 real data points, the result may be modified in the calculator so as to obtain the inverse transform of up to 1024 real or complex values thus giving the possibility of calculating both power spectra and complex spectra. The actual algorithms used are more generally applicable and so are detailed in Appendix B.

The digital version of eq 3 for the power cepstrum is

\[ C_R(n) = F^{-1}(\log R(k)) \]

where \( x(n) \) is a stride for \( n = 0 \) to \( N - 1 \) (the sampling interval) and then indicates the time, a run from 0 to 1023. Likewise \( R(k) \) represents the frequency \( k/N \) (in the linear space of the frequency spectrum) and in principle also runs from 0 to 1023 even though only the values from 0 to 512 are calculated. Because of the implicit periodicity of all functions calculated by the FFT process the values of \( k \) from 512 to 1024 also represent the negative frequency components (from -512 to 0) and can usually be derived from the positive frequency values. As \( F_R(k) \) is a real even function, the inverse transform can be replaced by a forward transform (Appendix B). In general only the one-sided power spectrum is given, and the simpler calculation method of Appendix B will be advantageous. With this method, only the one-sided spectrum is calculated, and the real part of the transform gives the desired cepstrum. Another advantage of this method is that the envelope spectrum (amplitude spectrum of the one-sided spectrum) of Fig. 4 may be obtained at the same time. In fact few values automatically calculate this and display it as the instantaneous spectrum, which can be viewed on a real-time basis. The envelope spectrum is

\[ F^{-1}(\log G(k)) \]

where \( G(k) \) is the one-sided power spectrum. The formula for the complex cepstrum is

\[ C_{R1}(n) = F^{-1}(\log R(k)) \cdot R(k) \]

Because the logarithmic cepstrum is a conjugate even function, the calculation method of Appendix B may be used. Note that the phase function \( \phi(k) \) must be unaltered to maintain continuity of function of frequency in place of the principal values modulo \( \pi \) which are calculated from the real and imaginary parts of the complex spectrum. Moreover the log magnitude must be scaled in neps (natural log of the amplitude) to correspond to the neps of the phase spectrum.

The analysts in general are a.e.c. coupled, so the phase frequency value in the one-sided spectrum is not calculated. It is therefore necessary to insert a value before calculating the cepstrum. The results are best obtained by selecting the zero frequency component equal to the value of the neighbouring line.

As the FFT algorithm used in the Analyzers types 2033 and 2031 is optimised for signals with no d.c. component, it is advantageous to subtract the mean log magnitude as well as the mean phase. This increases the sensitivity of the FFT algorithm, and is particularly valuable when editing and transformation in both directions is to be performed. In calculation of the complex cepstrum it is advisable before attempting to use the phase spectrum to subtract the mean of the phase spectrum which gives a linear slope to the phase spectrum. This should be done no more than the extent possible in the time signal before transformation, and then in the phase spectrum itself by varying the linear component until the number of "umps" over 2x is minimized.

Appendix B
Calculation of inverse Fourier transform

Consider the complex Fourier transform, as calculated by the FFT analyzers, are defined as

\[ X(k) = \sum_{n=0}^{N-1} x(n) \exp(-j2\pi kn/N) \]

and \( x(n) = \sum_{k=0}^{N-1} X(k) \exp(j2\pi kn/N) \)

where \( X(k) \) is the discrete complex spectrum (s) the sampled time function and \( N \) number of samples in the time record.

The Fourier transform implemented in the analyzers types 2033 and 2031 is designed to be used forward transformation of real-valued time signals, but by using some of the properties of the Fourier transform, as listed tables, it can also be used for forward and inverse transformation of any complex signals.

Based on the inverse transformation of the three types of signals: real-valued, real and even, and constant even are described in the following. The components of the original spectrum are given in any case, this saves forming the symmetrical spectrum for negative frequencies. It follows that

\[ F^{-1}(X(k)) = \text{Real}(F^T(X(k))) \]

where \( X(k) = \begin{cases} \text{Real}(X(k)), & k \leq 512 \\ 0, & k > 512 \end{cases} \)

The calculation procedure, Fig. 2, is thus

1. Forward transform
2. Extract and scale the real part.

B. Complex even spectrum

Any complex spectrum can be inverse-transformed by transforming the real and imaginary components separately by the procedure B1. However, this requires two Fourier transform calculations as an extra storage capacity for the intermediate results. In the situation where the spectrum is conjugate even, i.e. corresponding to a real time signal, the following procedure can be used. This requires only one transform and a minimum of storage space.

\[ F^{-1}(X(k)) = F^{-1}(X(k)) \cdot F^{-1}(X(-k)) \]

Also \( F^{-1}(X(k)) = X(k) \) or \( X(k) \) is given by

\[ X(k) = x(k) \]
12-BIT D-TO-A Linearisation of a 12-bit microprocessor compatible digital-to-analog converter is achieved. The 185318 has in-itself organized as three independent 4-bit elements each with its own register-loading enable input. Output voltage is programmable in ranges from 0 to 5V to ±10V and an internal reference is available, output-setting time is less than 1s. A 24-pin DIL package is used and the device operates on 5V to ±15V and 1mA operating current. CHIPS UK, 12a Park Street, Camberly, Surrey, WARK473.

FLUX-DENSITY METER
A small meter for checking magnetic fields up to 19.9 milligauss (19.9 x 10^-3 T) in three separate ranges is manufactured by Redcliffe. Readings are down to 0.01% on the most sensitive range, and are given in a 3 1/2-digit LCD. The meter has a peak measurement function for checking and locating maximum flux areas in pulse-magnetised coils. Two probes are available, one for horizontal fields and the other for axial fields, and a battery charger is supplied. Reference magnets are also available. Redcliffe Magnetronics Ltd, 24 Tritton Road, Bletchley, Milton Keynes, Buckinghamshire BS4 5PQ.

NEW PRODUCTS
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ACRYLIC FILTERS
Expansions in the current range of acrylic filters for light-emitting devices have been made. Red, green and blue filters are available in four shades, amber and blue filters in two. There are also yellow and purple filters. In addition, designers can obtain a sample palette containing four shades or colours of filter. Each sample has a section treated with Glarech – a coating for reducing glare and reflection. Quoors UK Ltd, 1-4 Cheltenham Street, London E1C 4PA.

CALIBRATED STROBOSCOPE
This type of instrument is used in every field of engineering and has medical applications, yet we see surprisingly few new designs. Firmin Mison has introduced a strobeoscope which it claims has, "Features usually associated with units costing twice as much." Resulting at £19.50 excluding v.a.t., the WM10 has three ranges covering rates from 0 (off) to 16000 flashes per second. When used without external triggering, the flash rate can be set to within 1% at certain points on the continuously variable scale using a main frequency-dependent calibration method; a t.r.t. compatible output is provided. Maximum light output of the unit is 10W and mains inputs from 110V to 240V a.c. can be used. Firmin Mison, Unit 49, The Malthings, Swanston, Abernethy, Herts.

ATOM SOURCE FOR VACUUM DEPOSITION
Researchers at UMIST's chemistry department developed a fast-atom bombardment (F.A.B.) source for mass spectrometry now available from Inn Tech Ltd. The sputter-field gas gun provides an intense neutral beam of fast atoms and does not require the use of a charge exchange cell to neutralise the gas ions produced with an evacuated sputter-field cell elsewhere. The cold cathode ion gun also has application in thin-film vacuum deposition and in substrate cleaning. Much better adhesion between a surface and, say, copper is obtained in the F.A.B. bombarded with the atom gun, the makers say. Known as the FAB-GG, the gun is available from Inn Tech Ltd, 2 Park Street, Teddington, Middle TW11 0LT.

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<tr>
<td>Power</td>
<td>60W</td>
<td>60W</td>
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### Semiconductors

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### Diodes

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<td>1610</td>
<td>4V</td>
<td>0.5A</td>
</tr>
<tr>
<td>1620</td>
<td>5V</td>
<td>0.2A</td>
</tr>
<tr>
<td>1630</td>
<td>6V</td>
<td>0.1A</td>
</tr>
</tbody>
</table>

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We manufacture a wide range of professional audio noise reduction systems which are used throughout the world in the broadcasting, recording, and film industries. The quality and reliability of our products is of prime importance.

An engineer is required who will be responsible to the QA Manager for all aspects of quality control in our products. This involves setting up and maintaining procedures and initiating improvements to existing procedures, and the supervision of the quality control team.

The successful applicant will probably be a graduate with experience of quality control in the electronics industry. A background in audio engineering would be an advantage.

The attractive salary is supplemented by competitive benefits including a non-contributory pension scheme and relocation assistance if needed.

For more information and an application form contact: Kevin Cross, Dolby Laboratories Inc., 364 Clapham Road, London SW9 9AP, Tel: 01-720 9111.

Dolby System

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Having introduced an extended new product range, many of which are microprocessor based, Marconi Instruments has now decided to expand its engineering staff with the appointment of an Engineer with experience in any of the following areas:

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Rediffusion Consumer Manufacturing Limited, a leading manufacturer of test equipment for the broadcast industry, is looking for an Engineer who has had experience of practical work, to be responsible to the Engineering Manager for all aspects of test equipment and in particular test equipment production.

The successful candidate will control a team of engineers and technicians who will supervise the design and production of the company's products. Some experience in the broadcast equipment field would be an advantage.

An attractive salary will be offered with 23 days' holiday per year and after a qualifying period, free life assurance and the benefits of a big company pension scheme.

If you are interested in this challenging position and would like more details, please write or telephone in complete confidence.

Engineering Product Manager

Engineering Consumer Manufacturing Limited,
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Drumchurch, Co. Meath, Ireland.
Telephone: 01-627 5451

REDIFFUSION

(D1236)

(D1247)
**Electronics Technicians and Engineers**

Marconi Communication Systems Limited are involved in the installation, commissioning, and maintenance of communication equipment worldwide. If you have formal qualifications in an electronic engineering discipline or H.M. Forces equivalent commissioning and maintenance electronic equipment and hold a current U.K. driving licence, you could be one of the people we are looking for to fill one of the following positions:

**Maintenance**

**Middle East – Fixed Term**

Successful applicants would have a minimum of three years experience working on Terrestrial Satcom, Radio Relay, Line of Site or Line of Communication Systems and be offered a two year contract with an attractive salary and excellent allowances.

**Installation and Commissioning**

**Worldwide – Permanent**

Successful applicants would have a minimum of three years practical experience working on Satellite Earth Stations. Salaries will be based on previous experience and qualifications. Excellent allowances.

Send a full C.V. or telephone for application form to Mandy Atinas, Marconi Communication Systems Limited, New Street, Chesham, Bucks. Telephone: Chesham (0244) 350221 Ext. 592

**Electronic Engineers for Q.A. Department**

Wembley Middlesex.

Racal BCC is a member of the highly successful Racal Electronics Group and are world leaders in the design and manufacture of tactical radio communications equipment.

We require two experienced electronic engineers to fill positions at Intermediate grade within the Quality Assurance department.

Preference will be given to engineers who are familiar with the requirements of Def—Start 0-21 and who have experience in a number of Q.A. functions including defect analysis, quality costs, and the monitoring and control of Company systems.

Applicants aged 25-30 must be educated to HNC/HTC Level or above in electronics. A working knowledge of communications equipment would be an advantage.

We offer excellent conditions of service including a good basic salary and Group Pankivity Scheme, 27 days annual holiday, a contributory pension scheme and a free life assurance.

**Racal BCC**

World leaders in electronics.

**Radio Operator Technicians for British Antarctic Survey**

The British Antarctic Survey requires Radio Operator Technicians to man single handed wireless stations at their permanent Antarctic bases. The appointments will cover two consecutive Antarctic winters which involves an absence from the United Kingdom of about 32 months.

Applicants must be able to maintain SSB transmitting and receiving equipment as well as aerial arrays. Communication between the Antarctic Stations and the United Kingdom is by radio teleprinter through a cable and wire station. Telegraphy, morse and voice communication is also maintained between foreign Antarctic stations, ships and aircraft.

Qualifications: MRG or better and a capability of sending and receiving morse at a minimum of 20 wpm.

Experience in maintaining communication equipment is essential. A knowledge of telegraphy and morse typing an advantage.

Applications from amateurs and armed service trained personnel will be considered provided that the necessary expertise can be demonstrated.

Candidates to work overseas should be single, aged between 22-35, physically fit and male.

Salary: From £6,462 to £10,431 per annum inclusive

An Electronics Technician with considerable experience of maintenance of electronic and biomedical equipment is required to supervise the day-to-day work of nine technicians engaged in the repair, calibration and safety checking of a wide range of medical and laboratory equipment.

Applicants should have previous experience of personnel supervision and an extensive knowledge of the electrical safety aspects of medical equipment.

Opportunities will exist for the development of electronic instrumentation and a knowledge of microprocessing would be desirable. The successful candidate will be expected to participate in the activities of the medical electronics section of the department of medical physics.

Ideally, the successful candidate will have an HNC or HND in electronic engineering.

For an application form and job description, please contact Mrs J. Cardyn, District Personnel Department, Charing Cross Hospital, Fullham Palace Road, London W6, Telephone 01-748 2040 ext. 2992.
Transmitter Engineer

Up to £11,500 p.a. plus benefits

A challenging post in this beautiful and mountainous Kingdom in Southern Africa. Applicants must possess an engineering degree and have at least five years experience in transmitter engineering and maintenance.

Duties will include operation and maintenance of two 100kW shortwave transmitters, identifying operational needs, and staff supervision and training.

Appointment will be on contract for two years.

Salary includes a substantial tax-free allowance paid under Britain's overseas aid programme.

Benefits include:
• Free passage
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Good salary, sea-going allowances, leave arrangements and company pension scheme benefits. Promotion prospects available. This is an opportunity to join a dynamic, fast-growing company involved in all aspects of shallow marine geophysical surveying.

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This is a new two-year degree scheme, launched in 1982, which involves participation by each of the participating universities, who are committed to the development of new educational and research programmes. This unique degree is a requirement for the European Space Science and Technology Centre (ESTEC) who need to recruit engineers for a project to construct a space station.

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For SW houses with contracts in fast-turn around positions, experience must be obtained with microprocessors and microcomputers. Limited experience on a degree level is required. A small number of places are available for graduates. Applicants must have good technical skills, and be able to work under pressure. A first or upper-second class degree in Electrical Engineering is required. The scheme is recognised by E.S.A. for award of advanced course allowances for the two-year period.

**CONSULTANT PROGRAMMERS**

For SW houses with contracts in fast-turn around positions, experience must be obtained with microprocessors and microcomputers. Limited experience on a degree level is required. A small number of places are available for graduates. Applicants must have good technical skills, and be able to work under pressure. A first or upper-second class degree in Electrical Engineering is required. The scheme is recognised by E.S.A. for award of advanced course allowances for the two-year period.

**HV & SW ENGINEERS**

For TV and video equipment engineers involved in developing new components and real-time picture processing. Experience should be obtained in P01 and several socrates in this field. Applicants should have a degree in Electronic Engineering or a relevant degree. A first or upper-second class degree in Electrical Engineering is required. The scheme is recognised by E.S.A. for award of advanced course allowances for the two-year period.

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For under-graduates with recent relevant experience. Assistance from P01 and some socrates in this field. Applicants should have a degree in Electronic Engineering or a relevant degree. A first or upper-second class degree in Electrical Engineering is required. The scheme is recognised by E.S.A. for award of advanced course allowances for the two-year period.

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BACS is a wholly owned subsidiary of the main Clearing Bank. The main activity of the Company is to provide an electronic funds transfer service to the banks and other customers.

To complement the current services and meet the plans for the expansion of the communications business to be undertaken by the Company, a Senior Network Technician is required. The candidate must have had previous experience of data communications and can demonstrate a working knowledge of:

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Salary circa £10,000 tax free

Must be able to work independently to promote the company's products. We are main distributors for Stornor UK Inc and need first-class engineer to push sales and assist customers' enquiries. Bachelors only or married children.

Send CV plus photo to:

Mr George Foss, General Manager
AL MASHAL UNITED CO. BOX 296.
AHBUL HAIL A.A.
Telex 27223 Phone 326917

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**TELEVISION SERVICE ENGINEER**

We are an expanding Television Services company with a requirement for an additional Television Engineer.

Suitable applicant will preferably have worked in a similar environment in TV or film.

A good driving licence is essential.

A spacious flat is available if required.

Address: Enquiries to Box X, Sales/TV Engineering, LONDON SW11 2PH.

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A vacancy exists for a Television Camera Operator to work principally in the studio but also to assist if required in a monopod training studio, in location video recording, and in the mobile unit. When not required to work with cameras, the operator would be expected to be attached to other technical sections so as a general Licenceman in the technical side of the studio is helpful. The successful candidate will be involved in some formal training together with practical experience, though the overall position will be given greater emphasis as the formation of the network continues.

**FILM SOUND RECORDIST (ST2)**

**SALARY RANGE £9,685 - £12,507 plus £1,104 London Weighting Allowance**

The work is largely film recording using the Nagra, but with periods of studio duty (viewing, boom operating, radio, and film making), and more audio work as may be required. Some night work is necessary. Any previous film recording experience would be an advantage, particularly where travel to locations is involved. Travel arrangements are required. Although applicants should have thorough knowledge of sound techniques in a film television environment, consideration will be given to those who are willing to learn, have appropriate technical qualifications, and experience elsewhere in the sound recording field.

**MAINTENANCE ENGINEER (ST3)**

**SALARY RANGE £9,261 - £12,507 plus £1,104 London Weighting Allowance**

The maintenance section has four members and is responsible for all the equipment at the studio centre, both vision and sound. Applicants must have relevant technical qualifications (knowledge of digital techniques would be an advantage), and should have good experience in the field, though some training would be given to experienced applicants. Although not essential, a certain amount of mechanical aptitude is advantageous. Experience in a similar technical environment is desirable. Although the section is small, the technical environment is wide, and travel arrangements are required. The Authority will pay for attendance at specialised manufacturers’ courses, whereas these are currently not financed.

Further information and application forms are available from the Education Office (EC/Estab 189) Room 388, County Hall, London, SE1. Please enclose an SAE. Completed forms should be returned 14 days from appearance of advertisement.

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### INDEX TO ADVERTISERS MAY

Appointments Vacant Advertisements appear on pages 108-119

<table>
<thead>
<tr>
<th>PAGE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>4</td>
</tr>
<tr>
<td>16</td>
<td>103</td>
</tr>
<tr>
<td>18</td>
<td>105</td>
</tr>
<tr>
<td>20</td>
<td>106</td>
</tr>
<tr>
<td>22</td>
<td>107</td>
</tr>
<tr>
<td>24</td>
<td>108</td>
</tr>
<tr>
<td>26</td>
<td>109</td>
</tr>
<tr>
<td>28</td>
<td>110</td>
</tr>
<tr>
<td>30</td>
<td>111</td>
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<td>32</td>
<td>112</td>
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<td>34</td>
<td>113</td>
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<td>36</td>
<td>114</td>
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<tr>
<td>38</td>
<td>115</td>
</tr>
<tr>
<td>40</td>
<td>116</td>
</tr>
<tr>
<td>42</td>
<td>117</td>
</tr>
<tr>
<td>44</td>
<td>118</td>
</tr>
<tr>
<td>46</td>
<td>119</td>
</tr>
</tbody>
</table>

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**INDEX TO ADVERTISERS MAY**

Appointments Vacant Advertisements appear on pages 108-119

<table>
<thead>
<tr>
<th>PAGE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>4</td>
</tr>
<tr>
<td>16</td>
<td>103</td>
</tr>
<tr>
<td>18</td>
<td>105</td>
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<td>106</td>
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<td>119</td>
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Interested? Then why not telephone your nearest Tektronix office or circle the enquiry number for further information.

Performance Specifications
Bandwidth
Two channels, DC-60 MHz to 20 mV/div, 50 MHz to 2 mV/div.
Light Weight
6.1 kg (13½ lbs). 6.8 kg (15 lbs) with cover and pouch.
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Sweeps from 0.5s to 0.05 µs (to 5 ns/div with ×10 magnification).
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Scale factors from 100 V/div (10X probe) to 2 mV/div (1X probe). Accurate to ± 3%. AC or DC coupling.

Also available from Electroplan.
* Prices subject to change without notice.